Appendix D-1

2011 PK-Granbury-Whitney Water Management Study

BRAZOS RIVER AUTHORITY PK-GRANBURY-WHITNEY WATER MANAGEMENT STUDY

Prepared by

Brazos River Authority **and** **Halff Associates**

Texas Firm Registration No. F-312

May 2011
AVO 27440

Table of Contents

List of Tables

List of Figures

List of Appendices

Acronyms

BEPC – Brazos Electric Power Cooperative
BRA – Brazos River Authority
CPNPP – Comanche Peak Nuclear Power Plant
DOQQ – Digital Orthophoto Quarter Quads
ESRI – Environmental Systems Research Institute
FERC – Federal Energy Regulatory Commission
GIS – Geographic Information Systems
GPS – Global Positioning System
HEC – Hydrologic Engineering Center
PK – Possum Kingdom Lake
SWPA – Southwestern Power Administration
TIN – Triangulated Irregular Network
TNRIS – Texas Natural Resources Information System
TWDB – Texas Water Development Board
USACE – United States Army Corps of Engineers
USGS – United States Geological Survey

Executive Summary

In late 2007 the Brazos River Authority (BRA) discontinued hydropower generation at Possum Kingdom (PK) Lake. In the absence of hydropower releases from Possum Kingdom, an interim Water Management protocol was established by BRA in early 2008 based on operating Lakes PK and Granbury on a 1:1 elevation drawdown basis (*Equal Drawdown*). In other words, releases are made from PK as needed so that Lake Granbury is never lower in terms of depth below full than PK. While this method of operation has been simple, easily explainable, and justifiable in the short-term and absence of a detailed study, it has received scrutiny from various interest groups, particularly those around Lake Granbury, that have been accustomed to the historical flows provided by PK hydropower generation. The drought conditions of 2008-2009 contributed heavily to this scrutiny, as well as concerns related to the proposed addition of two new nuclear generating units at Luminant's Comanche Peak Nuclear Power Plant that would divert additional water from Lake Granbury for cooling.

In the spring of 2010, BRA, in conjunction with Halff Associates, began a water supply Water Management study of the PK – Granbury - Whitney portion of BRA's reservoir system. Lake Whitney is included in the study because it is physically located downstream of the other two reservoirs. However, due to the relatively small amount of storage space controlled by BRA in Lake Whitney, the focus of the study effort is on PK and Granbury. The goal of the study is to formally evaluate and develop a Water Management procedure for the PK-Granbury-Whitney portion of the BRA reservoir system that meets water supply needs and considers major items and issues affected by lake levels and water supply management.

The study was divided into four main components: (1) development of critical metrics and constraints of features in the reservoir system affected by lake level variations and lake level management; (2) development of historical period-of-record input data and simulation of alternative lake level management procedures/guidelines; (3) comparison of critical metric impacts to simulation output and refinement of alternative management procedures; and, (4) public involvement and stakeholder communication process.

Extensive field work, inventorying, and data collection were used to determine lake bottom elevations at over 1,600 features (docks, ramps, marinas, etc..) on Possum Kingdom Lake and nearly 3,500 features on Lake Granbury. This analysis indicated that the *Equal Drawdown* plan (currently in use by BRA for the upper Brazos River system) does not produce "equal" impacts to water features at Possum Kingdom Lake and Lake Granbury as shown in Figure ES-1. A higher percentage of features are out-of-service at Lake Granbury than at Possum Kingdom Lake for an equal drawdown level.

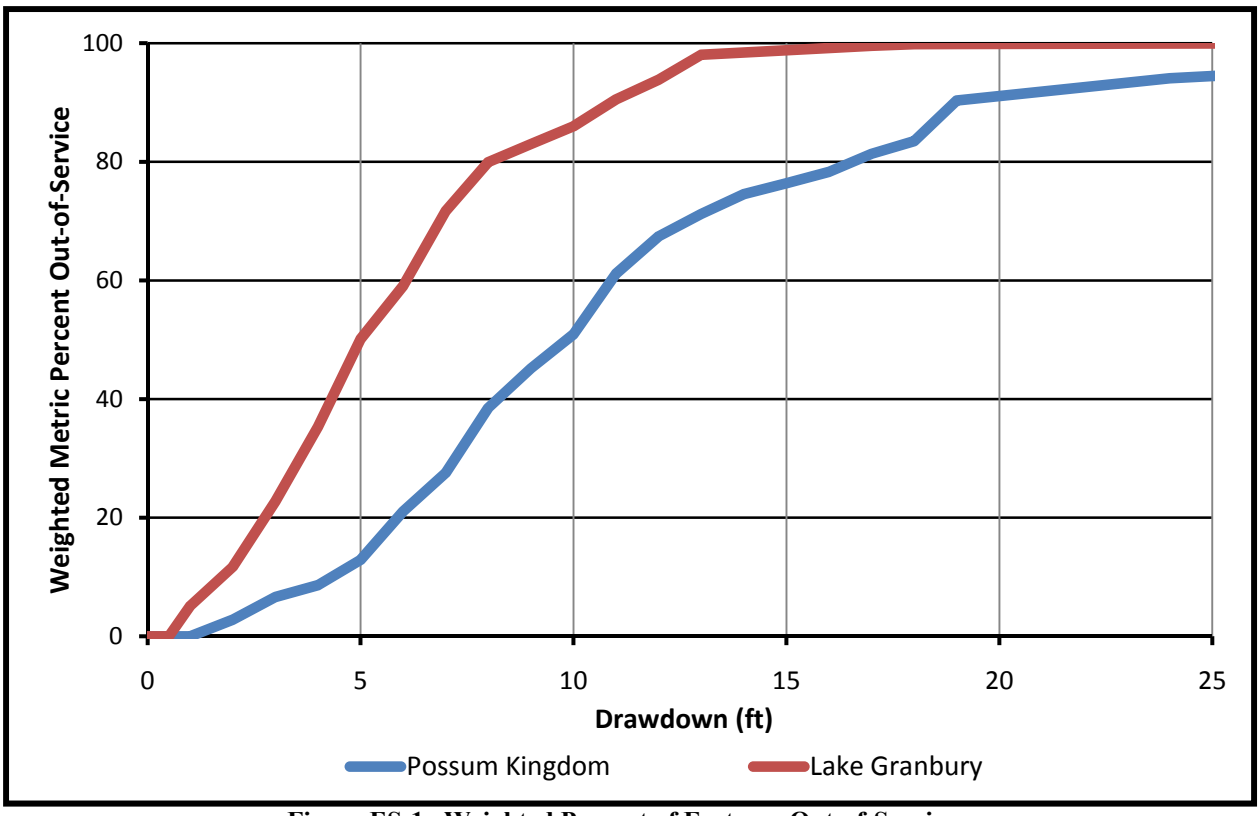

Figure ES-1. Weighted Percent of Features Out-of-Service

The critical metrics/features data at each lake were combined with reservoir system simulations spanning from 1939-2009 with various water supply demand scenarios and alternative Water Management strategies. Based on these results, a *Zonal Drawdown* plan was developed with a goal of balancing the percent of features out-of-service at each lake for a range of elevations (drawdowns). Conclusions from the study suggest operating the system dependent upon "lake depth zones" (*Zonal Drawdown*) can produce a more equitable balance of impacts at both PK and Granbury without sacrificing the water supply yield of the upper Brazos River system. Based on near-term projected demands before Units 3 and 4 are added at Comanche Peak, a 1.75:1 (PK:Granbury) drawdown ratio is recommended when PK's lake elevation is above 992.0 ft-msl. In this scenario, releases would be made as needed from PK so that for every 1 foot of drawdown experienced at Lake Granbury, a corresponding 1.75 feet of drawdown would be experienced at PK. Based on the metric analysis and model output, this scenario provides a "balanced" impact (percent of time facilities out-of-service) between PK and Granbury. When PK's lake elevation falls below 992.0 ft-msl, the drawdown ratio would change to 1:1. Conclusions for future demand conditions, including the addition of Units 3 and 4 at Comanche Peak, indicate that the 1.75:1 drawdown ratio is still appropriate for balancing impacts between the two lakes when PK's lake elevation is above 992.0 ft-msl. However, when PK's lake elevation falls below 992.0 ft-msl, a drawdown ratio between 1.5:1 and 1.75:1 will be required to balance impacts.

A series of presentations were made to elected officials and the public beginning in February 2011. Presentations were made to the state legislative staffs (Senator Birdwell, Senator Estes,

and Representative Keffer) and local leadership in Granbury, Hood County, and Palo Pinto County. A public meeting was held on March 28, 2011 in Granbury and on March 29, 2011 in Graford to discuss the study results with local stakeholders. The recommended operational procedure (*Zonal Drawdown*) was presented to the BRA board at the April 18, 2011 board meeting, and a resolution was passed to adopt the *Zonal Drawdown* procedure. The *Zonal Drawdown* plan will serve as a basis for BRA reservoir operations from PK, Granbury, and Whitney in the PK post hydroelectric power generation era. The proposed operational procedure will enable BRA to meet contractual water supply obligations while balancing adverse impacts that may be experienced at the lakes during dry times.

1.0 Introduction

In April 2010, Halff Associates was authorized by the Brazos River Authority (BRA) to begin work on a Water Management Procedure study for the Possum Kingdom (PK) Lake, Lake Granbury, and Lake Whitney system along the upper Brazos River. The goal of the study is to formally evaluate and develop a Water Management procedure for the PK – Granbury – Whitney portion of the BRA reservoir system that meets water supply needs and considers major items and issues affected by lake levels and water supply management (boat docks, boat ramps, lakeside properties, etc.). Lake Whitney is included in the study because it is physically located downstream of the other two reservoirs. However, due to the relatively small amount of storage space controlled by BRA in Lake Whitney, the focus of the study effort is on PK and Granbury.

1.1 Study Background

The Brazos River Authority operates a mainstem reservoir series sub-system in the upper and central Brazos River basin that includes BRA owned and operated Lake Possum Kingdom and Lake Granbury. BRA also holds a permit to store approximately 50,000 acre-feet of water in the federally-owned (U.S. Army Corps of Engineers) Lake Whitney. Lake Possum Kingdom is the most upstream reservoir in the system located in Palo Pinto, Young, and Stephens County. Lake Possum Kingdom has a relatively large storage capacity of approximately 540,000 acre-feet and a contributing drainage area from west Texas of approximately 14,030 square miles. Lake Possum Kingdom has been utilized in the past primarily to meet downstream demands and generate hydropower electricity. Lake Granbury is located approximately 145 river miles below Possum Kingdom Lake in Hood County. Lake Granbury has a substantially smaller storage capacity of approximately 129,000 acre-feet, but has a significant lakeside demand including cooling water for Comanche Peak Nuclear Power Plant (CPNPP) Units 1 & 2 near Glen Rose, Texas. Total intervening drainage area between Possum Kingdom Lake and Lake Granbury is approximately 2,085 square miles. Lake Whitney is a large multi-purpose reservoir owned by the federal government located in Hill and Bosque Counties approximately 100 river miles downstream of Lake Granbury. Figure 1 provides a general location map of the BRA reservoirs and system.

In late 2007 BRA discontinued hydropower generation at Possum Kingdom. In the absence of hydropower releases from Possum Kingdom, an interim Water Management protocol was established by BRA in early 2008 based on operating Lakes PK and Granbury on a 1:1 elevation drawdown basis. In other words, releases are made from PK as needed so that Lake Granbury is never lower in terms of depth below full than PK. While this method of operation has been simple, easily explainable, and justifiable in the short-term and absence of a detailed study, it has received scrutiny from various interest groups, particularly those around Lake Granbury, that have been accustomed to the historical flows provided by PK hydropower generation. The drought conditions of 2008-2009 contributed heavily to this scrutiny.

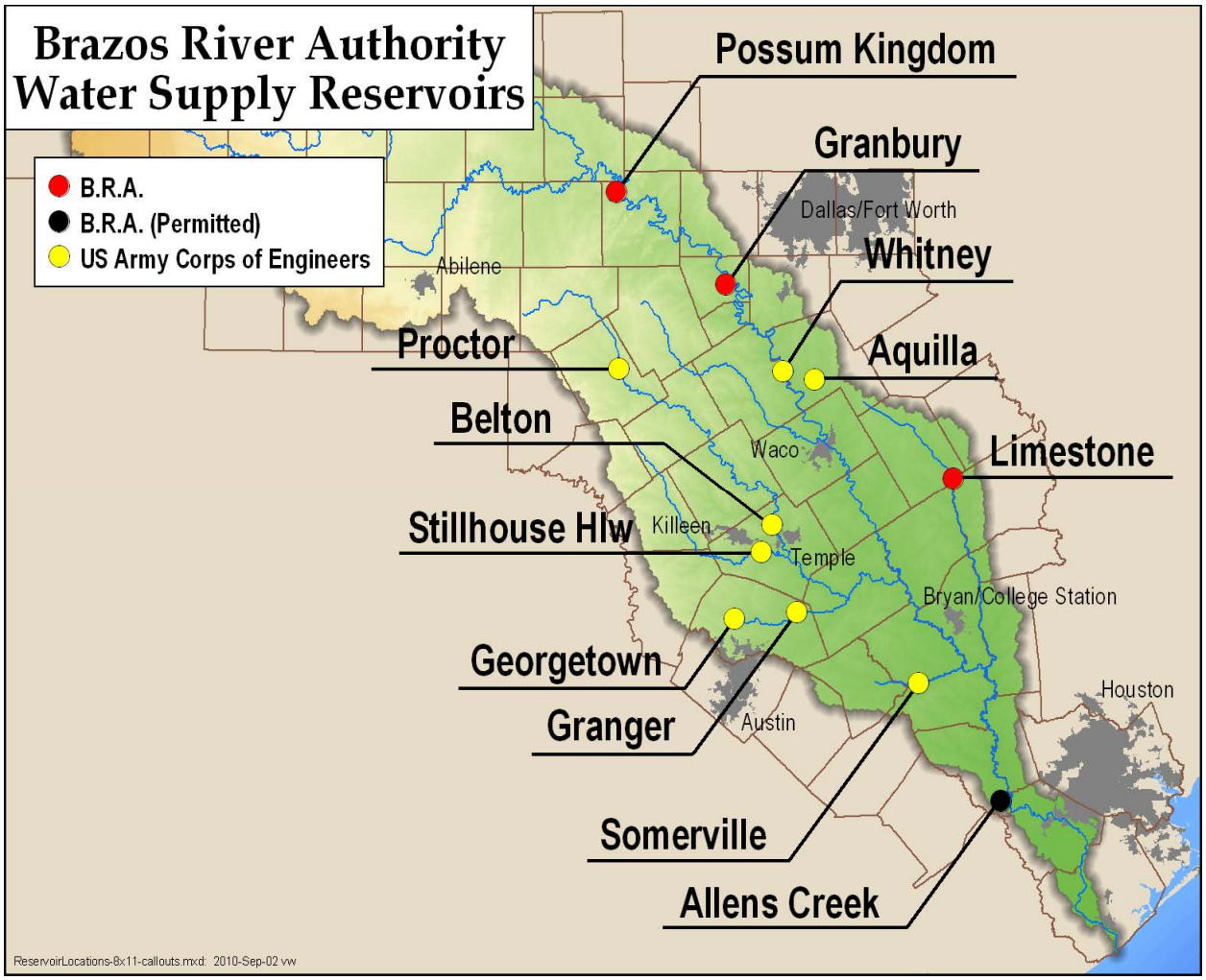

Figure 1. BRA General Location Map

Consequently, in the spring of 2010, BRA began a water supply Water Management study of the PK – Granbury - Whitney portion of BRA's reservoir system. Main drivers creating a need for the study were the discontinuance of hydropower generation from PK and the proposed addition of two new nuclear generating units at Comanche Peak that would potentially divert additional water from Lake Granbury for cooling.

1.2 Study Approach

Recreation activities and lakeside business and property owners are impacted by changes in lake levels (both during floods and droughts). In order to assess the relative impacts of alternative Water Management strategies, elevations and locations of key lakeside and downstream features (critical metrics) impacted by variations in water levels were needed along with an inflow dataset and simulation model of various alternatives. The study was divided into four main components: (1) development of critical metrics and constraints of features in the reservoir system affected by lake level variations and lake level management; (2) development of historical period-of-record input data and simulation of alternative lake level management procedures/guidelines; (3) comparison of critical metric impacts to simulation output and refinement of alternative

management procedures; and, (4) public involvement and stakeholder communication process. The study, analysis, and evaluation were a collaboration between the BRA (water services) and Halff Associates staff.

The study involved a significant amount of field work, data collection, and Geographic Information System (GIS) mapping. A detailed inventory of boat docks, boat ramps, lakeside properties and other features ("metrics") was developed around the lakes. Lake depth information was obtained for the features to approximate reservoir elevations at which these facilities and features would become unusable at each of the lakes. Reservoir operations models were developed and calibrated to historical data and simulated over the 1939-2009 period-of-record. The models were then used to evaluate different operational scenarios for a range of current and future water supply demand conditions. BRA's mission states that "The Brazos River Authority exists to develop, manage, and protect the water resources of the Brazos River Basin to meet the needs of Texas". Operating plans to appease recreational interests cannot come at the expense of reduced water supply. Water supply impacts were also evaluated for the operational scenarios and demand conditions. Output from the models was compared to the metrics at each lake to determine impacts. The goal was to balance impacts (percent of time facilities out-of-service) at each of the lakes while not compromising water supply.

Elevations reported throughout this report are based on the NGVD 29 datum at Possum Kingdom Lake and the BRA datum at Lake Granbury. Conservation (full) pool levels are assumed to be 999.0 ft-msl and 692.7 ft-msl at PK and Granbury, respectively.

2.0 Critical Metric Development

In order to assess relative impacts to lakeside features for various alternative operating scenarios and lake levels, the location, number, and "critical" depth of these lakeside features were inventoried and assembled in a GIS database. The "critical" depth was assumed two feet above the lake bottom elevation at a given feature. Although actual out-of-service elevation is dependent on a range of factors, including: boat draft, type of feature, pitch of feature, and pitch of lake bottom, it was assumed that a minimum of two feet of water above the lake bottom would be required for functionality of a given feature for this study. For example, if the lake bottom elevation under a given boat dock was determined to be 994.0 feet-msl, this feature was assumed "out-of-service" when the lake elevation dropped below 996.0 feet-msl.

It is understood that some docks, ramps, and marinas will require more than two feet of water, while some features may be accessed with less than two feet of water. Based on comments received at the public meetings related to this depth of water assumption, fixed and floating dock requirements were revisited, as well as the boating capacity studies completed in 2006. If one foot or five feet of minimum water depth for a feature to be in service was selected, the proposed operating protocol as outlined in this report would be relatively unchanged since the same minimum water depth would have been applied at both Possum Kingdom Lake and Lake Granbury as arguments can be made for deeper water requirements at both fixed and floating docks. The percent of features in service would have decreased (or increased) at each lake proportionally with a different minimum water depth selection, but the "balance" of impacts with the proposed operating protocol would have been maintained. Although the two-foot assumption is not perfect for all lake features, it is a reasonable assumption for the purposes of this study.

A list of several features, including: water supply intake locations, boat launches/ramps, boat docks, canals, lakeside and downstream businesses, lakefront properties, and lakeside/downstream recreational areas, were developed by BRA and Halff Associates. Considerable time and effort were spent during the scoping and planning phase of this study to identify quantifiable and objective key metrics for the lakes and downstream river reaches. Appendix A provides a summary of the metrics, quantification methods, and assumptions utilized for this study. These were developed based on sensitivity to variable lake and river levels, measurable/quantifiable features, and budget/time constraints.

The locations and critical metrics of these features were then mapped and quantified using GIS applications by Halff Associates. The primary purpose of this exercise was to develop measurable metrics for each of these features to assess the relative impacts of various alternative Water Management procedures. Information used to develop these critical metrics included: BRA records, field work, Internet searches, aerial photography, Texas Water Development Board (TWDB) volumetric surveys, and other available data sources. Economic impacts to the features resulting from varying lake levels were not considered directly as part of this study due to the complexity and subjectivity associated with this parameter. The metrics are intended to be used for assessing relative impacts to features on each reservoir and along the Brazos River between the reservoirs for various Water Management plans.

2.1 GIS Geodatabase

ESRI GIS tools were utilized to develop a database of the critical metrics. The File Geodatabase was used as the data storage method for this project since it provides a mechanism to maintain a uniform, central repository of data. File Geodatabases allow for domains to be created, data standards and types to be set and enforced, and projection information to be standardized as part of the storage mechanism. This ensured that the resulting work and critical metric development was standardized and consistent between users and lakes.

State Plane North Central Texas FIPS 4202 with a datum of North American Datum 1983 was selected as the projections for the central repository. This standardization allowed for the use of data from many disparate sources while ensuring that they would be compatible with each other, regardless of the data source's original projection. The File Geodatabases also allowed for the use of aerial photography (Texas Orthoimagery Program 2008-2009 Digital Orthophoto Quarter Quads (DOQQs) from TNRIS) and the creation of a Raster Catalog which seamlessly stitches together many aerial photos to create a single aerial photo for each lake. Raster Catalogs enabled the user to choose which DOQQs to incorporate so that the aerial photo dataset loaded faster while panning in GIS.

For the critical metric development project, one File Geodatabase was created for each lake for the base map data such as: roads, aerial photography, county boundaries, stream centerlines, etc. A separate File Geodatabase was developed for each lake for the critical metrics production data such as: boat docks, boat ramps, water supply intakes, lakefront property, lakeside businesses, lakeside recreation, and other miscellaneous lake specific data such as BRA Dock Survey data on Possum Kingdom Lake and canal information for Lake Granbury. Appendix B provides a list of the fields and attributes for each critical metric feature class in the GIS Geodatabase.

2.2 Water Supply Intakes

BRA supplies raw and treated water to numerous customers (municipal, industrial, commercial, agricultural, etc..) throughout the Brazos River basin, including water from Possum Kingdom Lake, Lake Granbury, and Lake Whitney. In order to supply this water, there are several intake structures located within the upper basin reservoir system. The intake structures ability to reliably provide water are dependent on maintaining sufficient lake levels at or above the intake elevations. The intakes included in the critical metric development are wholesale water customers with long-term BRA contracts. BRA provided Halff with a copy of its *Long-term Lakeside Contracts* spreadsheet which included the latitude and longitude and other relevant data for each intake structure on the three lakes. Individual property owner irrigation pumping contracts and intakes were not included with this metric. Halff created a point file based on these coordinates, and then projected the points into the State Plane Texas North Central FIPS 4202 projection in GIS. Based on the latitude and longitude provided in the BRA database, some of these points in GIS are not located within the lake conservation pool levels. After further investigation, it was determined that the latitude and longitude in the database is the actual diversion point, and not necessarily the physical location of the intake structure within the lake. No further adjustment was made to the points in the GIS geodatabase. In total seven, twenty-one, and five water supply intakes at Possum Kingdom Lake, Lake Granbury, and Lake Whitney, respectively, were digitized in GIS.

2.3 Boat Ramps/Launches

Halff Associates initially digitized boat ramps on both Possum Kingdom Lake and Lake Granbury using the aerial photography. BRA Lake Rangers were then provided maps for review and contributed their local knowledge of boat ramp locations and features. Both public and group private (homeowner's association, condominiums, campgrounds, etc…) ramps were included. Individual property boat ramps were not included in the metric development. The location and elevation at the end of each boat ramp were determined through field work undertaken by two Halff Associates employees accompanied by at least one BRA lake officer. BRA boats were utilized for the boat ramp field work which was completed in May 2010. The process involved the BRA officer maneuvering the boat to the approximate end of each ramp. A Halff employee would then use a survey range pole to locate the bottom edge of the ramp. The range pole was used to determine a depth below the water surface at the end of the boat ramp. These depths measurements were not taken with field survey tolerances and equipment. The depth measurements were converted to an elevation using the nearest USGS lake stage gauge reading for the date/time of the field work. The elevations at the ramps are approximate (within 0.5') based on the range pole and USGS gauge readings. A GPS point was obtained (Northing and Easting coordinates) and recorded along with the depth and a digital photograph at each ramp. These field data were assembled into the GIS geodatabase.

At Possum Kingdom Lake, twenty-six public ramps and eighteen private ramps were measured. This does not include the BRA Emergency Boat Launch ramp near the Public Ramp by Sam's Dock that is used only when the lake is extremely low. This ramp would not be impacted by minor fluctuations in water surface elevations, and is not used except during extreme drought periods. The BRA Private Ramp near the dam was also not included since it is in a restricted area and only used by BRA staff. An elevation for the Camp Constantine ramp was developed manually from the TWDB data. In total, ten public and forty-five group private boat ramps were measured at Lake Granbury. Table 1 provides a list of the ramps that were identified along with the measured elevation at the end of each ramp. These elevations reflect lake bottom elevations (end of ramp) and do not include the "2-foot buffer" as discussed in Section 2.0. The "2-foot buffer" was incorporated as part of the model simulation analysis.

Table 1. Boat Ramp Elevations

Possum Kingdom Lake		Lake Granbury	
Boat Ramp	**Elevation (ft-msl)**	**Boat Ramp**	**Elevation (BRA Datum)**
Barge Yard	997.4	Comanche Cove Owners Association	690.5
Boy Scouts - Camp Constantine	996.0*	Jackson Heights	690.5
Long Hollow	995.4	Alta Vista	690.3
YMCA Frontier Unit Camp	994.9	The Peninsula	690.3
Sandy Beach Park	994.4	Brazos Harbor	689.8
Bug Beach	994.4	Hideaway Bay	689.8
Costello Island	994.3	Silverado on the Brazos	689.8
Gaines Bend #1	992.4	Purple K	689.5
Bob White Bluffs	992.4	Sandy Beach	689.7
Pat and Herman's Camp	992.3	Laguna Vista	689.3
Breaker's	991.9	Mesa Grande	689.3
Long's Camp	991.8	Holiday Estates	689.2

Possum Kingdom Lake		Lake Granbury	
Boat Ramp	**Elevation (ft-msl)**	**Boat Ramp**	**Elevation (BRA Datum)**
The Ranch	991.4	Spanish Trail Property Owners Association	689.0
PK Lodge	991.3	Whippoorwill Bay	689.0
North Shore RV Park	991.3	Indian Harbor	688.9
North D & D	991.3	Indian Harbor - 2 Lanes	688.9
Hills Over PK	990.8	Canyon Creek	688.9
YMCA Main Camp	990.4	Lakeside Hills	688.9
Fox Hollow	990.4	Rio Brazos	688.8
South D & D	990.4	Rolling Hills Shores	688.8
Scenic Point Cove	990.4	Water's Edge	688.3
Possum Hollow Ramp #1	989.9	The Shores	688.3
Willow Beach Marina	989.8	Rio Brazos North	688.3
Bass Hollow	989.4	Arrowhead Shores	688.3
Shaker's Camp	989.4	De Cordova Bend Estates - PWC only ramp	688.0
Lakeview	989.4	Timber Haven	687.5
Ponderosa Condos	989.3	Timber Cove	687.5
Rock Creek Camp	989.3	Montego Bay	687.5
Rainbow Lodge	989.3	Sky Harbor	687.3
Public ramp by Sam's Dock	989.3	Oak Trail Shores	687.3
Lefty's Camp	989.3	Mallard Pointe	687.3
Possum Kingdom State Park	988.9	Timber Cove	687.1
Possum Hollow Ramp #2	988.4	Rough Creek Park	686.9
Bailey's Camp	988.4	Harbor Lakes	686.9
Landing Condos	988.3	City Boat Ramp - 3 lanes	686.8
West Side Public Use Area	987.8	Water Mark	686.8
Commercial ramp behind Mr. C's Store	987.8	Pecan Plantation	686.5
YMCA Ray Bean	986.4	De Cordova Bend Estates	686.5
The Cliffs	986.4	Port Ridglea East	686.5
Sky Camp	986.3	Indian Harbor	686.4
Gaines Bend #2 Neely's Slough	984.4	Western Hills Harbor	686.4
Villa Marina	984.4	Hunter Park	686.3
Sportsman's World	983.4	Tin Top	686.3
Golden Cove	982.4	Bentwater	686.3
		Lake Country Shores	686.3
BRA - Dam repair boat ramp	---	Canyon Creek	686.3
BRA - Emergency Boat Launch	---	Blue Water Shores	685.5
		Ki Kaga	685.5
		Rock Harbor	685.4
		Comanche Creek	684.9
		Thorpe Springs Park	684.8
		De Cordova Park	684.5
		The Ridge	684.5
		Ports O' Call	683.4
		Conference Center	683.3

* Depth not field verified.

Public Ramp

Group Private Ramp

2.4 Canals – Lake Granbury

Lake Granbury has an extensive system of man-made canals along its main body shoreline. Canal depths were determined through field measurements in May 2010 by Halff Associates staff and BRA Lake Rangers. Two Halff Associates employees accompanied at least one BRA officer in a BRA patrol boat. Using a survey range pole, point measurements were taken at multiple locations along a canal. Generally, the measurements were taken at the canal mouth, middle, and terminus, with intervening points if the canal was particularly long or if the depth changed substantially. Each time a depth measurement was taken, a GPS point was created to mark its location. These points were incorporated into the GIS, and converted to a lake bottom elevation based on the USGS lake level readings at the time of the data collection. In total, 177 Lake Granbury canal measurements were made in the field. Table 2 provides a summary of the canal field measurements taken by Halff Associates in May 2010.

In addition to these field measurements, Brown and Gay completed a *Canal Specification Project* for BRA and Lake Granbury in 2007. Average water depths were recorded for several of the canal systems and developments as part of the 2007 study based on 92 measurements. Actual locations and measurements for each canal point obtained by Brown and Gay were not available. The 2007 report states that the depths of canals surveyed ranged from 1.5 to 12 feet with an average depth of 7 feet for the canals. As shown in Table 2, field measurements in 2010 were not made for all the canals. The 2007 Brown and Gay study measurements and TWDB volumetric survey data were used for these other canal systems. For canal systems with measurements from both Halff Associates in 2010 and Brown and Gay in 2007, Halff Associates values were utilized since the exact location and method of the Brown and Gay data collection are unknown. Also shown in Table 2 are the approximate number of dock and ramp structures located within each canal system (See Section 2.5 for more details related to the dock structures). Approximately 45 percent of the total dock structures at Lake Granbury are located on a canal system.

Table 2. Lake Granbury Canal Measurements (Elevations are based on BRA Datum)

Development/Canal System	Number of 2010 Halff Field Measurements	Average 2010 Halff Canal Bottom (ft-msl)	Average 2007 Brown and Gay Canal Bottom (ft-msl)	No. of Dock Structures	No. of Ramps*
Alta Vista	0	N/A	686.9	3	0
Arrowhead Shores	3	687.1	688.0	17	0
Blue Water Shores	14	687.8	688.7	95	0
Catalina Bay	22	685.8	N/A	12	0
Comanche Harbor	0	N/A	685.2	32	0
DeCordova Bend Estates	5	685.7	686.0	66	2
Groggy Dawg Marina	3	683.5	N/A	2	0
Harbor Lakes	12	683.1	N/A	84	0
Hideaway Bay	0	N/A	687.1	9	1
Holiday Estates	9	685.6	682.7	74	1
Indian Harbor	29	686.4	686.4	258	3
Jackson Heights	2	688.8	685.5	12	0
Laguna Tres	0	N/A	682.8	55	0
Lakewood Hills	0	N/A	689.6	19	0
Long Creek	0	N/A	689.8	12	0

Development/Canal System	Number of 2010 Halff Field Measurements	Average 2010 Halff Canal Bottom (ft-msl)	Average 2007 Brown and Gay Canal Bottom (ft-msl)	No. of Dock Structures	No. of Ramps*
Montego Bay	3	689.1	N/A	6	0
Nassau Bay	3	686.6	686.9	63	0
Oak Trail Shores	4	688.8	689.9	41	0
Port Ridglea East	16	685.8	685.8	132	0
Port Ridglea West	5	685.4	685	30	0
Ports O'Call	18	683.2	683.8	88	0
Rock Harbor	0	N/A	687.4	9	0
Rolling Hills Shores	0	N/A	690.0	19	0
Rough Creek	0	N/A	690.8	7	0
Sky Harbour	6	687.4	685.5	89	1
South Harbor	0	N/A	685.9	16	0
Sunrise Bay	0	N/A	686.9	7	0
The Shores	4	685.6	685.9	48	0
Timber Cove	5	686.5	N/A	2	2
Water's Edge	14	681.9	682.5	123	1
Western Hills Harbor	0	N/A	683.3	12	0
TOTAL	177	N/A	N/A	1,442	11

*Does not include private individual lot ramps.

2.5 Boat Docks, Marinas, Fuel Stations, and Group Residential Docks

Water features such as boat docks, marinas, on-water boat fuel stations, and group residential docks were identified and classified based on available aerial photography in GIS. *Microsoft Bing's Bird's Eye View* (where available) was also utilized for the dock classification. The individual boat docks were further classified as fixed-residential, fixed-commercial, floating-residential, and floating-commercial. Commercial docks are associated with restaurants and other lakeside businesses (non-marina) that provide slips for boating patrons. Marinas are defined as public use boat storage areas on the water, and the watercraft fuel station locations were also digitized in the GIS. Group residential docks are multiple dock/slip structures that are owned by homeowner's associations, condominiums, and cabins/lodges for use by residents or guests. Only one point was digitized in the GIS per independent feature. A single Marina business may have multiple independent banks of boat slips. Each of these individual structures was digitized in the GIS database. The digitization (elevation) point was typically placed on the most landward slip for multi-slip facilities and marinas. Walkways and piers associated with docks, boat ramps, and marinas were not digitized independently. Table 3 shows a summary of digitized water features by class at each lake.

Although fixed and floating docks were digitized separately in the GIS database, there was no distinction made for the detailed analysis. A dock was assumed out-of-service when less than two feet of water depth was available at the feature. Most of the fixed docks at Granbury are equipped with boat hoists that can raise/lower watercraft from the water surface to the dock platform if the lake is down.

Initially, lake bottom elevations below docks and the other water features were to be determined with the latest Texas Water Development Board (TWDB) bathymetric survey. Possum Kingdom Lake was surveyed in 2005 and Lake Granbury was last surveyed by the TWDB in 2003. The initial plan was to utilize the triangular irregular network (TINs) developed as part of the TWDB bathymetric surveys and intersect these lake bottom elevations with the water feature points that were digitized in GIS. However, the primary purpose of the TWDB bathymetric surveys is to develop the storage capacity of the reservoir. The TWDB survey paths and mass points transect the main deeper portions of the lake well, but are not as dense or non-existent in areas along the shore and other shallow areas. The TWDB TINs are created based on an interpolation from the shoreline to the survey mass points, so many times the elevations reported under the docks and other water features in shallower areas are straight interpolations with no actual survey points in the vicinity.

Table 3. Water Feature Counts

Feature	Possum Kingdom Lake	Lake Granbury
Fixed Residential	87	2,948
Fixed Commercial	3	31
Floating Residential	1,383	253
Floating Commercial	28	2
Marina	41	19
Fuel Stations (on-water)	10	6
Group Residential	10	6
Total	**1,562**	**3,265**

Since the boat ramps were field measured by Halff and BRA, a comparison was made between the measured elevations and the TWDB TIN elevations at these common points. Based on the 43 boat ramp field measurements at Possum Kingdom Lake, twenty (20) had TWDB TIN elevations that were lower than the field measurements and twenty-three (23) TWDB TIN elevations were higher. The range was -6.75 to +5.2 feet with an absolute value of the mean of 2.1 feet. Given this wide variability, a "correction" factor could not be globally applied to the TWDB elevations for non-field measured features such as the docks. At Lake Granbury, the comparison between the TWDB elevations and field measurements resulted in generally the same variability as Possum Kingdom Lake. The TWDB elevations had even less coverage at Lake Granbury than Possum Kingdom Lake due to the shallow cove and canal systems, areas upstream of the low profile SH 144 bridge that were inaccessible by the TWDB boat, and older survey technology (2003 vs. 2005).

Several conference calls were made with BRA staff to discuss alternatives and options for determining lake bottom elevations other than using the TWDB bathymetric survey data. A decision was made to obtain additional field measurements at selected boat docks and other water features. Given time and budget constraints, additional field measurements of all boat docks were not possible. The additional field work focused on the most critical areas and locations with limited available data from other sources. Ultimately, several methods for determining lake bottom elevations at boat docks and other water features were utilized for the study. Each of these methods is summarized below.

2.5.1 Field Work (Individual Docks)

Two Halff Associates employees accompanied at least one BRA officer in a BRA patrol boat. The on-board BRA sonar was used to obtain a depth reading near the feature. Where possible, a depth reading was taken at the landward edge of the dock or at the dock's boat slip. The location of the sonar transducer (18" below the water line at the back of the boat) and the USGS lake levels at the time of field work were taken into consideration and used to adjust the depth readings to obtain the approximate lake bottom elevation beneath selected water features.

2.5.2 Canal Method (Lake Granbury Only)

A large number of boat docks and other water features at Lake Granbury are located on the canal systems (See Section 2.4). The 177 canal measurements collected by Halff Associates at Lake Granbury in 2010 were converted into GIS routes calibrated based on their elevation. For instance, if a route consists of two points with elevations of 688 ft-msl and 690 ft-msl at each end, then the middle of the route would have a value of 689 ft-msl. These routes were utilized to assign lake bottom (canal bottom) elevations to the docks and other features in the canal systems. Each dock was assigned the elevation of the route closest to it at the shortest Euclidean distance away from the dock. For instance, using the previously mentioned example, a dock located at the middle of the route would be given an elevation of 689 ft-msl. Figure 2 illustrates the *Canal Method*.

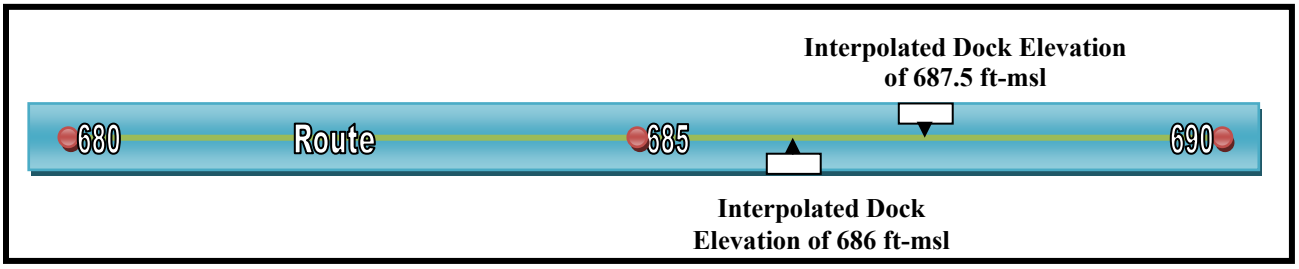

Figure 2. Canal Method

A couple of key assumptions were made when using this method (1) Canals are generally man-made and therefore were dredged or excavated to some extent when they were constructed, leaving them uniformly deep perpendicular to their centerline (docks on either side of the canal are likely to have the same depth). (2) The depth does not vary in a non-linear fashion between canal depth points. This was checked in the field by watching the on-board sonar as the boat moved through the canals. Measurements were taken at observed inflection points.

2.5.3 TWDB Mass Points Interpolation (Lake Granbury Only)

The *TWDB Mass Points Interpolation Method* was used only on Lake Granbury. Using the mass points from the Texas Water Development Board's (TWDB) lake volumetric survey, Halff assigned depths to docks using the following method. First, all mass points within 200 feet of the shoreline were selected using a buffer. For each TWDB mass point within the 200 foot buffer, the perpendicular distance to the shoreline was determined. The lake bottom slope along this perpendicular alignment was then calculated using the shoreline elevation, the mass point elevation, and the perpendicular distance. Then for each dock, the closest TWDB mass point

was determined and its calculated slope was transferred to the dock. The lake bottom elevation at each dock was then back-calculated based on the perpendicular distance from the dock to the shoreline, the shoreline elevation, and the closest TWDB mass point slope.

2.5.4 TWDB Mass Points TIN (Possum Kingdom Lake Only)

As discussed previously, the TWDB bathymetric survey TIN was not always reliable in shallow areas along the shoreline. However, at Possum Kingdom Lake, the 2005 volumetric survey had better coverage than the Lake Granbury 2003 survey. Using the lake outline and mass point data from the Texas Water Development Board (TWDB), a triangular irregular network (TIN) was created. The TIN's elevations were based on the mass points' elevations and the lake outline was set to an elevation of 1,000 ft-msl for Possum Kingdom Lake. This TIN was used to assign a lake bottom elevation to each of the dock and other water feature locations.

2.5.5 BRA Dock Inventory (Possum Kingdom Lake Only)

BRA staff has collected latitude and longitude data as well as an approximate depth to the lake bottom for over three hundred docks at Possum Kingdom Lake as part of routine dock inventories and inspections. BRA provided Halff Associates with these dock data via a spreadsheet. The depth measurements were obtained over the last several years using the on-board boat sonar by BRA staff. Halff incorporated these measurements into the GIS geodatabase by creating a shapefile based on the latitude and longitude information, and then the depth values were assigned to a new field in the existing dock feature class using a spatial join.

2.5.6 Manual

Field measurements could not be made for all the docks and other water features. Other features were located so far away from the TWDB data that simply assigning the feature a depth based on the mass points TIN or using the *Mass Points Interpolation Method* would be relying too heavily on an interpolation. In some locations, using available data, such as water color on the aerial photography, mass points in surrounding areas, local knowledge from BRA officers, or alternate aerial photography such as *Bing Bird's Eye View*, a probable depth could be manually determined. This manual method of assigning depth measurements was only utilized if other means were not available or deemed not accurate.

For Possum Kingdom Lake, the *Manual Method* was utilized for approximately 581 of the docks and other water features. Over 65% of the *Manual Method* determinations were used for features in over ten feet of water at normal pool levels. The additional field work at Possum Kingdom Lake was focused on the shallower areas, so the *Manual Method* was used more frequently for the deeper locations. The features in deeper water would not be impacted as frequently as other features in shallower water. The remaining *Manual Methods* were generally used at Possum Kingdom Lake to make minor corrections to values computed with the *TWDB Mass Points TIN Method*. The example in Figure 3 shows a typical example where the Mass Points TIN from the shoreline (1000 ft-msl) to the TWDB mass points assumed a constant slope and generated a dock elevation of 968.4 ft-msl. However, a manual check of nearby TWDB mass points to the left of the dock indicates that the dock is most likely in deeper water and the slope is steeper closer to the shoreline. In this case, the dock was assigned a lake bottom elevation of 945.8 ft-msl via the *Manual Method*.

Figure 3. Manual Adjustment Example

At Lake Granbury, the *Manual Method* was utilized to estimate lake bottom elevations in areas where the water was too shallow to be accessed by boat in the field or in locations where the *TWDB Mass Points Interpolation* had limited coverage. Only 5% of the 3,265 docks, marinas, and fuel stations at Lake Granbury were assigned a lake bottom elevation with the *Manual Method*.

2.5.7 Feature Measurements Priority Order

Lake bottom elevations for features at selected locations were determined with multiple methods. For example, the TWDB Mass Points TIN could be used to generate an elevation for the majority of the features. However, more confidence would be placed on actual field measurements at these locations. In the GIS geodatabase, lake bottom elevations for each feature are shown for any and all measurement methods employed. In order to assign a "final" lake bottom elevation (also shown in the GIS geodatabase) to be utilized for determining impacts related to various alternative lake operating plans, a priority order of measurement methods was created. Field measurements for a feature had the highest priority. BRA dock inventory survey data at Possum Kingdom Lake was considered a field measurement but was subsidiary to Halff field measurements since it is older. At Granbury, the *Canal Method* of determining dock elevations on the canal systems had the next highest priority since this method is indirectly based on field measurements. Next, the *TWDB Mass Points Interpolation* and *Mass Points TIN Methods* were used for assigning lake bottom elevations. Finally, the *Manual Method* was used if no other methods were available, or if a minor adjustment to an *Interpolation Method* was justified. Table 4 shows a summary of the method utilized to determine the "final" lake bottom elevations for the docks and other features at both Lake Granbury and Possum Kingdom Lake. Figure 4 and Figure 5 show the approximate number of water features (docks, marinas, and on-water fuel stations) that are out-of-service for various lake elevations at both Possum Kingdom

Lake and Lake Granbury. These elevations are approximate and were determined using the methods described in this report. These out-of-service elevations in Figure 4 and Figure 5 include the "two-foot buffer" over the lake bottom elevation.

Table 4. Lake Bottom Elevation Determination Selected Methods

Method	Possum Kingdom Lake	Lake Granbury
Field Work (Individual Dock)	484	1,120
Canal Method	0	1,542
TWDB Mass Points Interpolation	0	433
TWDB Mass Points TIN	174	0
BRA Dock Inventory	323	0
Manual	581	170
Total:	**1,562**	**3,265**

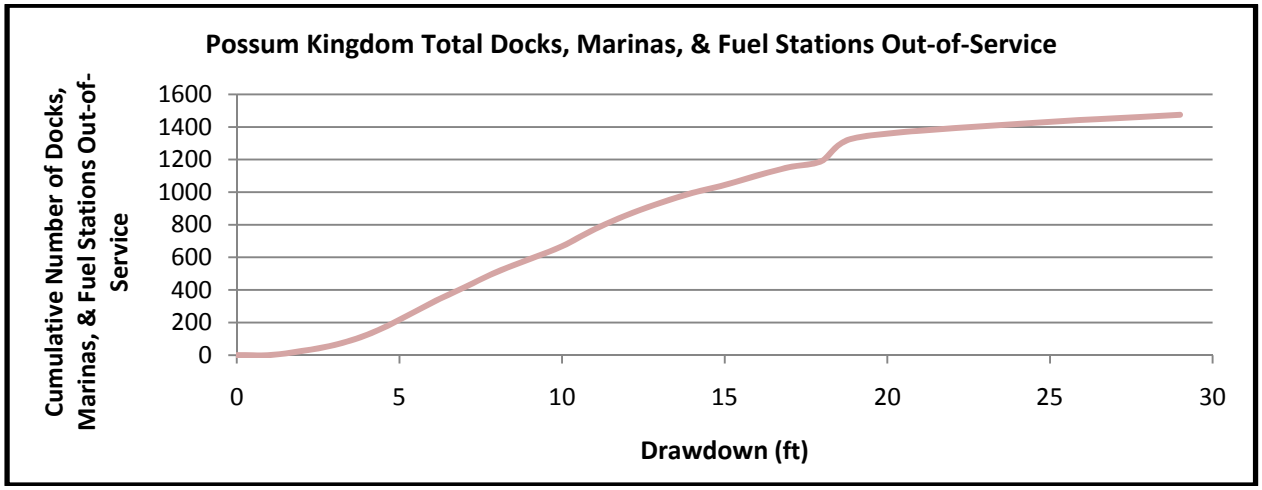

Figure 4. Possum Kingdom Lake Cumulative Number of Features Out-of-Service

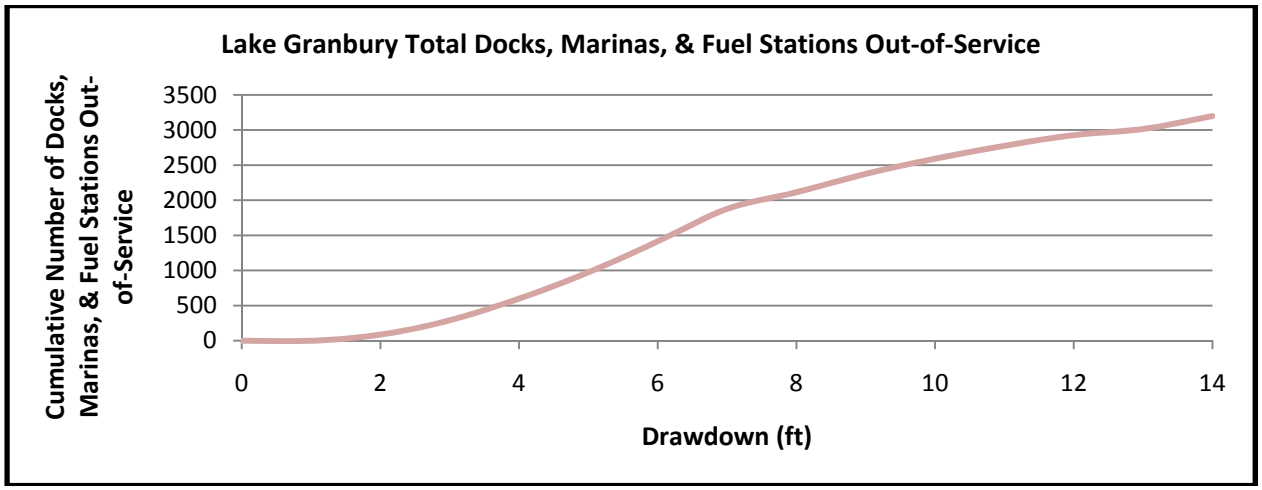

Figure 5. Lake Granbury Cumulative Number of Features Out-of-Service

2.6 Lakeside Recreational Areas

Swimming areas, parks, and campgrounds along the shores of both Lake Granbury and Possum Kingdom Lake were identified through aerial photography and digitized in the GIS geodatabase. Many of these lakeside recreational areas include both swimming and camping areas, but were only digitized once in the GIS. For features with multiple amenities, the priority order for classification was (1) swimming area, (2) camping area, and (3) park area. Notes were added in the GIS geodatabase to identify amenities provided at each recreational location. Golf courses were also digitized in the GIS. No lake bottom elevations were associated with these lakeside recreational areas. Eleven (11) public swimming and/or camping areas were digitized along the shores of Possum Kingdom Lake, and twenty-five (25) swimming, camping, golf courses, and/or park areas were digitized on Lake Granbury.

2.7 Lakeside Businesses

Business properties located directly on the lake shore or in the immediate vicinity of the lake that would be impacted by lower water surface elevations were digitized in the GIS geodatabase. These features include: lodging facilities, restaurants, convenience stores, boat rentals, etc. The locations were identified via aerial photography and the Chamber of Commerce websites at each lake. The addresses obtained from the Chamber of Commerce websites were geocoded to establish their geographic positions and their locations were further refined using parcel data, aerial photography, *Microsoft Bing's Bird's Eye View* photography, and knowledge gained following the field work. Information obtained from the business' website was also utilized. The "Marina" category in the "Lakeside Business" Class represents the actual business location on the land, whereas the "Marina" category in the "Boat Docks, Marinas, Fuel Stations, and Group Residential Docks" class represents the physical boat slips on the water. Many of these businesses could be classified in more than one category. For example, many marinas also rent boats. No lake bottom elevations were associated with these lakeside business properties. Table 5 provides a summary of the lakeside businesses at both Possum Kingdom Lake and Lake Granbury. This is not an exhaustive list, but was based primarily on Chamber of Commerce websites and aerial photography.

Table 5. Lakeside Businesses

Lakeside Business	Possum Kingdom Lake	Lake Granbury
Conventions	0	2
Fishing Outfits	2	0
Lodging	18	38
Marina	7	3
Boat Rental	1	0
Boat Repair	3	0
Restaurants	2	65
Retail	7	0
Dry Boat Storage	8	0
Dock Building and Repair	6	0
Other	5	4
Total	**59**	**112**

2.8 Lakeside Properties

The latest available parcel polygon data were used to digitize a point file in the Geodatabases containing a point for each parcel adjacent to the reservoir. Palo Pinto and Hood County digital parcel data were the only available counties at the time of the study. While Lake Granbury had full coverage from Hood County's parcel data, Palo Pinto covered most, but not all of Possum Kingdom Lake. The western most arm of Possum Kingdom Lake did not have parcel data available from Stephens County, and this left approximately 8.5 miles of shoreline, out of 186 miles total, without parcel data. No classification was made of Lakeside Property in Stephens and Young Counties. All points were attributed with the property's probable type (commercial, residential, BRA, City of Granbury, or unknown), a note field containing additional information about the property if applicable or available, and a field containing the owner's name from the parcel data if available. A distinction was made between commercial and residential properties by checking against the Lakeside Business' information as well as information obtained from aerial photography. For instance, multiple residential structures on a single parcel would indicate that it is most likely a commercial property that rents out houses or condos. Similarly, empty lots adjacent to the lake were considered commercial properties, since it was likely that they were being held for real estate investment reasons. While completed houses on the market would be considered commercial properties for the same reason as the empty lots, their "commercial" status would be more transient than the undeveloped lots, since they were simply transitioning between residential users. No lake bottom elevations were associated with these lakefront properties. Table 6 provides a summary of the lakefront property type counts at each lake.

Table 6. Lakefront Properties

Lakefront Property	Possum Kingdom Lake*	Lake Granbury
BRA	47	7
City of Granbury	0	11
Commercial	532	274
Residential	1,917	4,396
Unknown	16	6
Total	**2,512**	**4,694**

*Palo Pinto County Only

2.9 Downstream Businesses

Business properties related to, but downstream of, the respective lakes were only considered when listed on the lakes' respective Chamber of Commerce websites or visible via a pan with the aerial photography. The addresses obtained were geocoded and added to the Downstream Businesses' feature class. No river bottom elevations were associated with these downstream business properties. Although no elevations were associated with these properties, releases from both Possum Kingdom Lake and Lake Granbury were compared between the various alternatives and historic releases to note relative impacts on downstream flows below the dams (See Section 5.4).

2.10 Lake Whitney Data

Although most of the critical metric development was focused on Possum Kingdom Lake and Lake Granbury, data related to Lake Whitney were also included in the GIS geodatabase. No field work was completed at Lake Whitney as part of this project. Critical metrics for Lake

Whitney were developed using aerial photography, the U.S. Army Corps of Engineers (USACE) website, and the Internet. Digitization of features at Lake Whitney includes: 184 docks, 60 marina points (7 unique marinas), thirty-five boat ramps with probable public/private distinction, five water supply intakes, and lakeside recreation showing thirteen USACE parks and a couple of public parks.

2.11 Critical Metric Development Summary

A wide range of data sources and methods were utilized to develop and quantify critical metric features at Possum Kingdom Lake, Lake Granbury, and Lake Whitney. The data and metrics were organized in a GIS geodatabase developed by Halff Associates. Data sources and methodologies have been documented for each metric. The features and metrics should not be viewed as comprehensive and the lake bottom elevations are approximate. The purpose of the metric development is to provide a tool to analyze relative impacts for varying lake level elevations for alternative Water Management plans, and not to focus on the impacts at a single feature.

To simplify the number of features to be analyzed and evaluated as part of the model simulations, several features were combined into broader categories. Only features in the water were considered as part of the "balancing" of impacts as discussed in Section 4.0 and 5.0. The fixed/floating, residential/commercial, and group residential dock features were combined into a single "Dock" class. This is appropriate since only the lake bottom elevation plus a two-foot buffer was utilized to determine when a feature went out-of-service. The marinas and fuel stations were combined into a single "Marina" class. The private and public boat ramps were maintained in two independent categories. A detailed breakdown of these four feature classes and elevation out-of-service can be found in Appendix C. Although lakeside recreation, lakeside business, and lakeside property were not directly considered in the "balancing" evaluation, impacts to these features will be evaluated indirectly through the on-water facilities. Impacts to reservoir releases were analyzed which will have a direct impact on downstream river businesses and recreational interests.

3.0 Water Management Study Simulations

The second major task of the study included the development of the historical period-of-record input data set and development and simulation of the Water Management scenarios. It was important to evaluate any Water Management scenario over a range of wet and dry cycles of variable intensity and duration. Historical simulations using the period-of-record (1939-2009) were utilized for the evaluation of the Water Management scenarios. The simulations were executed in a HEC-ResSim reservoir simulation program for a range of alternative management scenarios with varying water supply demands. The period-of-record allows the entire lake system to be simulated with each alternative management scenario and demand data set as if these conditions had been in place since 1939 (prior to construction of Lake Granbury and Lake Whitney). Period-of-record analysis is a widely accepted and utilized methodology for reservoir and water supply planning projects on the state and national level.

3.1 Input Dataset Development

The required input dataset for the HEC-ResSim model simulations include: daily reservoir inflows, daily reservoir evaporation rates, and daily lakeside water demands/diversions over the period-of-record. Each of these input datasets were developed with specific methods as described in the following sections.

3.1.1 Reservoir Inflows

A seventy-one year period-of-record (1939-2009) simulation was utilized to analyze various Water Management alternatives. The historical inflows throughout this period were developed and used throughout the entire study for all Water Management and water supply demand scenarios. Although the hydrologic record will not repeat itself exactly over the next seventy-one years, it provides a historical set of wet and dry cycles for the Brazos River basin to assess the relative impacts of various Water Management scenarios and demands using a common baseline inflow dataset.

For this study, the United States Army Corps of Engineers (USACE) Brazos River Basin period-of-record inflow dataset (1939-2007) was used as a starting point for the development of the final inflow data set. The United States Army Corps of Engineers (Southwestern Division) have developed period-of-record inflow datasets for river basins throughout Texas, Oklahoma, and Arkansas using USGS streamflow records, river authority records, reservoir stage records, reservoir release records, and other hydrologic data sources. The inflow dataset is a daily time-step and includes local reservoir inflows (i.e., the influence of upstream dams and reservoir releases are removed). By using the historical local inflows, reservoirs (even those that may not have been constructed at the start of the period-of-record) and alternative reservoir operations can be evaluated as if they had been in place over the full period-of-record. Lake Granbury was constructed in 1969, so historical observations of the reservoir during the 1950s drought are non-existent. The period-of-record analysis and inflow dataset used for this study allow impacts at Lake Granbury to be evaluated under alternative reservoir operations and demands if the 1950s drought was to repeat itself. For the 1939-2009 period-of-record, the total computed inflow volume to Possum Kingdom Lake is 47.5 million acre-feet, 30.6 million acre-feet between Morris Sheppard Dam (Possum Kingdom) and Lake Granbury, and 18.3 million acre-feet

between DeCordova Bend Dam (Lake Granbury) and Lake Whitney. Figure 6 shows the daily historical inflow developed for this study for Possum Kingdom Lake, Lake Granbury (local inflow below PK), and Lake Whitney (local inflow below Granbury), respectively. The negative inflows are adjustments to the computed inflows to keep the mass balance (total available volume of water) in check. The negative inflow spikes are typically associated with flood events and are related to the timing of observed inflows and releases. The total volume of water is maintained and this is more critical than individual daily peak flow rates. This same inflow data set was utilized for each Water Management alternative scenario and demand data set so the impacts could be evaluated relative to one another with common base data.

3.1.2 Evaporation

Daily evaporation rates were developed by the USACE for Possum Kingdom Lake, Lake Granbury, and Lake Whitney, using historical pan evaporation data. The monthly rates were distributed uniformly for each day of the month. For the period following reservoir construction, the gross lake evaporation value was utilized. For the pre-reservoir construction period, the net evaporation rates were utilized. The impoundment dates are 1941 for Possum Kingdom Lake, 1969 for Lake Granbury, and 1952 for Lake Whitney. These daily evaporation rates are used in conjunction with the HEC-ResSim model elevation-storage-area relationships to compute the daily volume of water lost to evaporation for each Water Management scenario and demand data set.

3.1.3 Lakeside Demands/Diversions

Several lakeside water supply demands and diversions were analyzed for Possum Kingdom Lake, Lake Granbury, and Lake Whitney. Current demand conditions, 2020 demand conditions without Comanche Peak Nuclear Power Plant (CPNPP) Units 3 and 4, 2020 demand conditions with CPNPP Units 3 and 4, 2060 demand conditions with CPNPP Units 3 and 4, and 2060 demand conditions with CPNPP Units 3 and 4 demand applied downstream of Lake Whitney, were simulated in HEC-ResSim.

For current demands, the 2007, 2008, and 2009 historical water use and monthly diversions based on BRA records were compared. The highest monthly diversions were in 2008, so these 12 monthly values were assumed for the entire period-of-record to represent current demands. Both current demands and future demands include the Lake Granbury make-up water for Squaw Creek Reservoir (CPNPP Units 1&2). This demand accounts for approximately 48,300 acre-feet per year from Lake Granbury with no return flow assumed.

The 2020 demands at Possum Kingdom and Lake Granbury were based on the *2008 Lake Granbury Dissolved Minerals Study* performed by Freese and Nichols for Luminant Energy. CPNPP Units 3&4 are assumed to utilize 90,152 acre-feet per year from Lake Granbury with approximately forty percent of this diversion returned as blowdown to Lake Granbury, for a net demand (loss of water from Lake Granbury) of 54,091 acre-feet per year. The 2020 lakeside demand at Lake Whitney is based on a doubling of the current demands.

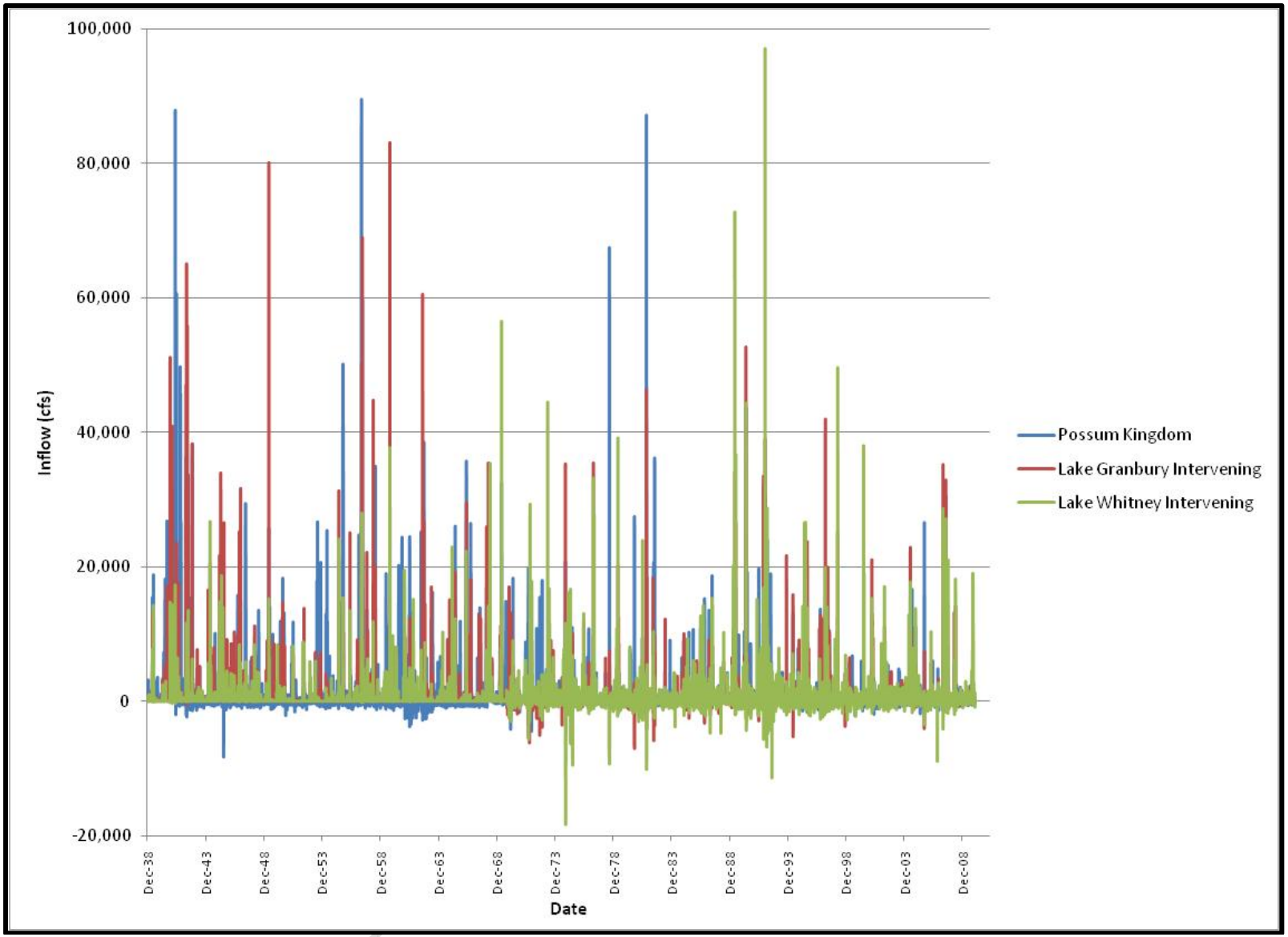

Figure 6. Daily Inflows

The 2060 demands at Possum Kingdom and Lake Granbury were also based on the *2008 Lake Granbury Dissolved Minerals Study* performed by Freese and Nichols for Luminant Energy. CPNPP Units 3&4 are assumed to utilize 90,152 acre-feet per year from Lake Granbury with approximately forty percent of this diversion returned as blowdown to Lake Granbury, for a net demand (loss of water from Lake Granbury) of 54,091 acre-feet per year for 2060 conditions as well. If CPNPP Units 3&4 do not come on-line, it is anticipated that by 2060 this water will be sold to customers in the central and lower Brazos River basin. Therefore, for 2060 conditions, a scenario was also modeled with the CPNPP Units 3&4 demand (54,091 acre-feet/year) located downstream of Lake Whitney. The 2060 lakeside demand at Lake Whitney is based on a future City of Cleburne and Johnson County demand, and a general increase from 2020 to 2060 demands in-line with Possum Kingdom Lake. Table 7, Table 8, and Table 9 show a monthly summary of the lakeside demands/diversions for the various water supply scenarios and conditions.

During the summer months, BRA may make releases from Lake Granbury for environmental and/or downstream purposes if storage space exists in Lake Whitney or a downstream need exists. Historic daily releases from May through September were evaluated. Typically a larger sustained release (500 cfs) will be made one day each week with the standard 25 cfs low flow release maintained for the remainder of the week. An average daily flow was computed and utilized for each day of the month for the purpose of the Water Management Study. Lake Granbury environmental and/or downstream releases are shown in Table 10.

Table 7. Possum Kingdom Reservoir Lakeside Annual Demands/Diversions (acre-feet)

Month	Current Demand	2020 w/ CPNPP 3 &4	2020 w/o CPNPP 3 &4	2060 w/ CPNPP 3 & 4	2060 w/ CPNPP 3 & 4 Downstream
January	369	818	818	1,103	1,103
February	402	755	755	1,030	1,030
March	224	861	861	1,159	1,159
April	221	894	894	1,211	1,211
May	270	1,115	1,115	1,491	1,491
June	374	1,319	1,319	1,733	1,733
July	527	1,693	1,693	2,220	2,220
August	302	1,590	1,590	2,099	2,099
September	493	1,184	1,184	1,604	1,604
October	477	973	973	1,355	1,355
November	262	835	835	1,146	1,146
December	352	832	832	1,133	1,133
Total	**4,273**	**12,869**	**12,869**	**17,285**	**17,285**

Table 8. Lake Granbury Lakeside Annual Demands/Diversions (acre-feet)

Month	Current Demand	2020 w/ CPNPP 3 &4	2020 w/o CPNPP 3 &4	2060 w/ CPNPP 3 & 4	2060 w/ CPNPP 3 & 4 Downstream
January	2,465	10,605	6,013	12,017	7,425
February	4,738	9,882	5,701	11,272	7,091
March	4,194	10,946	6,354	12,460	7,868
April	2,518	10,996	6,555	12,621	8,180
May	3,832	11,989	7,398	13,900	9,308
June	7,063	12,394	7,954	14,489	10,048

Month	Current Demand	2020 w/ CPNPP 3 &4	2020 w/o CPNPP 3 &4	2060 w/ CPNPP 3 & 4	2060 w/ CPNPP 3 & 4 Downstream
July	8,286	13,800	9,208	16,404	11,812
August	7,182	13,452	8,860	15,958	11,367
September	6,512	12,034	7,593	14,143	9,702
October	5,801	11,589	6,998	13,508	8,916
November	5,067	10,716	6,275	12,292	7,851
December	5,000	10,792	6,200	12,304	7,712
Total	**62,658**	**139,194**	**85,109**	**161,366**	**107,280**

Table 9. Lake Whitney Lakeside Annual Demands/Diversions (acre-feet)

Month	Current Demand	2020 w/ CPNPP 3 &4	2020 w/o CPNPP 3 &4	2060 w/ CPNPP 3 & 4	2060 w/ CPNPP 3 & 4 Downstream
January	33	66	66	199	199
February	47	94	94	284	284
March	26	52	52	156	156
April	36	72	72	217	217
May	69	140	140	419	419
June	79	158	158	476	476
July	92	186	186	557	557
August	60	121	121	364	364
September	163	328	328	987	987
October	51	103	103	307	307
November	42	84	84	252	252
December	23	47	47	143	143
Total	**721**	**1,452**	**1,452**	**4,361**	**4,361**

Table 10. Lake Granbury Environmental and/or Downstream Releases

Month	Lake Granbury Average Environmental and/or Downstream Release (cfs)
May	102
June	88
July	117
August	86
September	120

3.1.4 Downstream Demands/Diversions

In addition to the lakeside demands/diversions at Possum Kingdom Lake, Lake Granbury, and Lake Whitney, BRA must also make releases from Lake Whitney to meet water supply contracts in the central and lower Brazos River basin. The current downstream releases from Lake Whitney were based on 2008 records. The 2020 downstream demands were based on a ten percent increase over current demands which is the same increase in the Texas Region H Water Plan. The 2020 downstream demands were doubled to account for 2060 conditions based on combined water needs for Fort Bend and Brazoria Counties. Table 11 provides a summary of the downstream demands to be met from Lake Whitney and the upper Brazos River watershed.

Table 11. Downstream Annual Demands (Below Lake Whitney) (acre-feet)

Month	Current Demand	2020 w/ CPNPP 3 &4	2020 w/o CPNPP 3 &4	2060 w/ CPNPP 3 & 4	2060 w/ CPNPP 3 & 4 Demand Downstream
January	1,390	1,998	1,998	3,997	8,588
February	133	1,938	1,938	3,876	8,057
March	2,023	2,091	2,091	4,181	8,773
April	1,256	2,214	2,214	4,427	8,868
May	61	2,613	2,613	5,226	9,818
June	2,178	2,862	2,862	5,718	10,159
July	9,094	3,628	3,628	7,256	11,847
August	5,005	3,505	3,505	7,010	11,601
September	2,309	2,922	2,922	5,843	10,284
October	2,705	2,675	2,675	5,349	9,941
November	1,267	2,184	2,184	4,368	8,808
December	529	2,121	2,121	4,243	8,834
Total	**27,950**	**30,750**	**30,750**	**61,494**	**115,580**

In summary, the total current water demands for the Possum Kingdom/Granbury/Whitney system are approximately 95,600 acre-feet per year. The demand increases to approximately 184,265 acre-feet per year in 2020 with CPNPP Units 3&4 and 130,180 acre-feet per year in 2020 without CPNPP Units 3&4. In 2060, the total annual demand for the upper Brazos River system is estimated to be 244,500 acre-feet.

3.2 HEC-ResSim Physical Model Development

HEC-ResSim is a reservoir simulation program developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center (HEC). HEC-ResSim was selected as the reservoir modeling software for the Water Management Study given its ease of use, performance on previous BRA projects, and ability to simulate a period-of-record on a daily time step.

The HEC-ResSim model developed for the Water Management Study includes Possum Kingdom Lake, Lake Granbury, and Lake Whitney. The latest TWDB and BRA elevation-area-capacity data were used for Possum Kingdom (2006 report) and Lake Granbury (2005 report) current conditions. BRA does not own Lake Whitney (USACE), but is contracted for 22% of the storage capacity (approximately 50,000 acre-feet) between elevations 520.0 ft-msl and 533.0 ft-msl (top of conservation). Southwestern Power Administration (SWPA) operates as the agency to market available surplus electric power and energy at Lake Whitney. Brazos Electric Power Cooperative (BEPC) currently holds an electric service agreement to purchase the power and energy generated for the remaining 78% of the storage capacity between elevations 520.0-ft msl and 533.0-ft msl. For the Water Management Study, twenty-two percent of the total Lake Whitney storage capacities and surface areas from the 2005 TWDB volumetric survey were input to the HEC-ResSim model to account for the BRA water within the reservoir.

Sedimentation impacts were considered for future conditions at all three reservoirs by extrapolation of the latest TWDB and BRA elevation-area-capacity data. Figure 7, Figure 8, and Figure 9 show the elevation-area-capacity curves utilized in the analysis for current, 2020, and 2060 conditions.

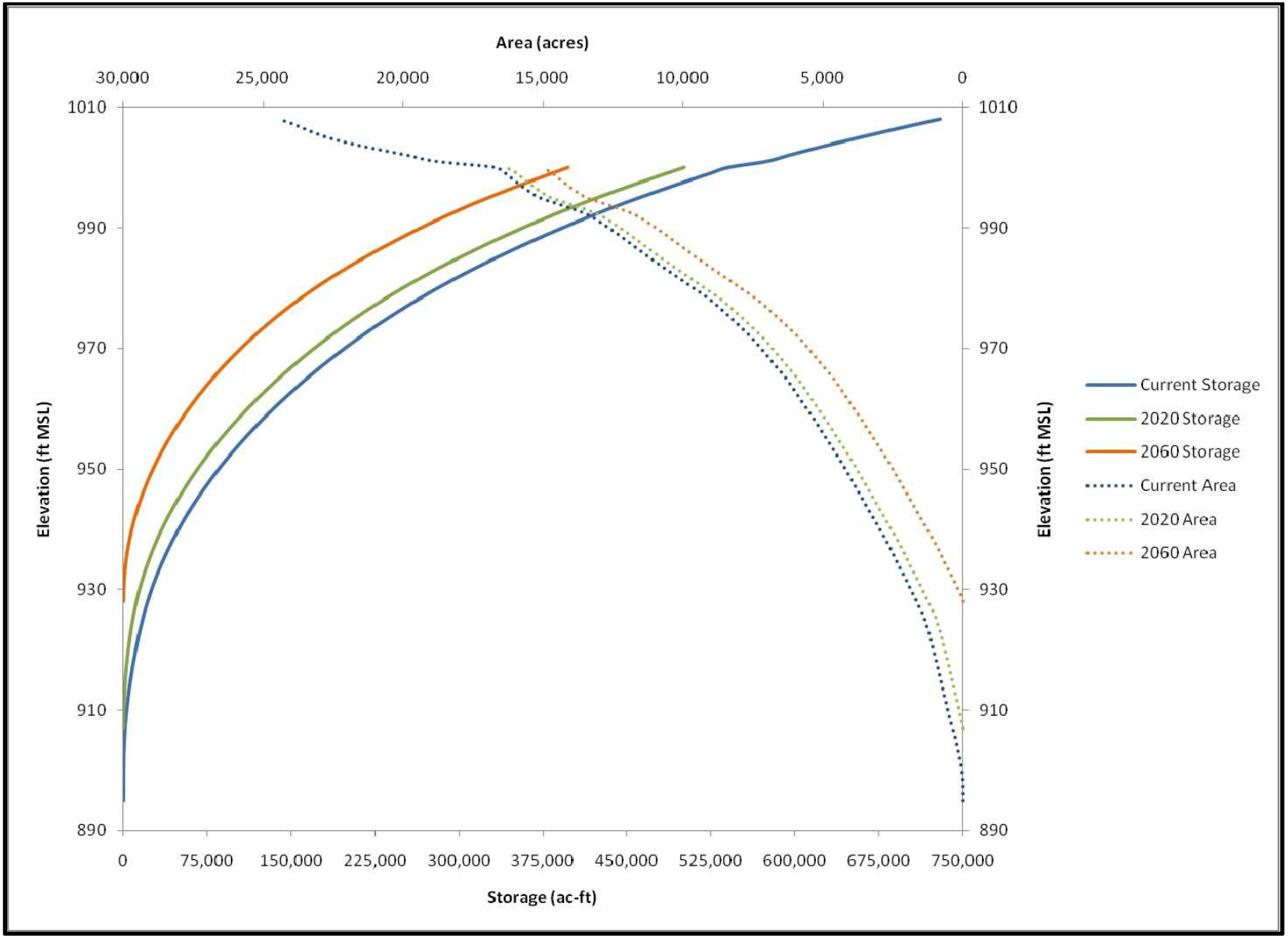

Figure 7. Possum Kingdom Lake E-A-C Data

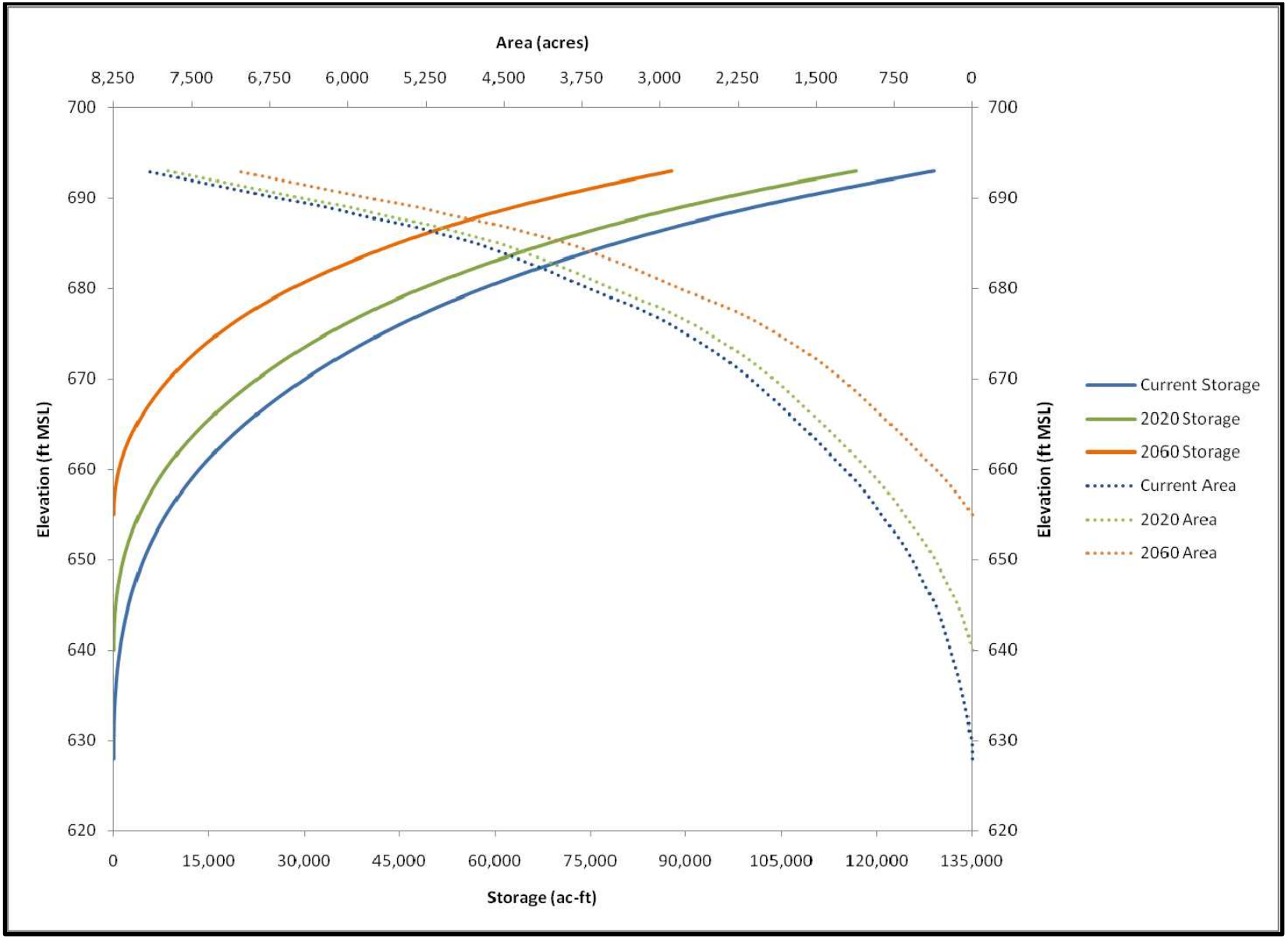

Figure 8. Lake Granbury E-A-C Data

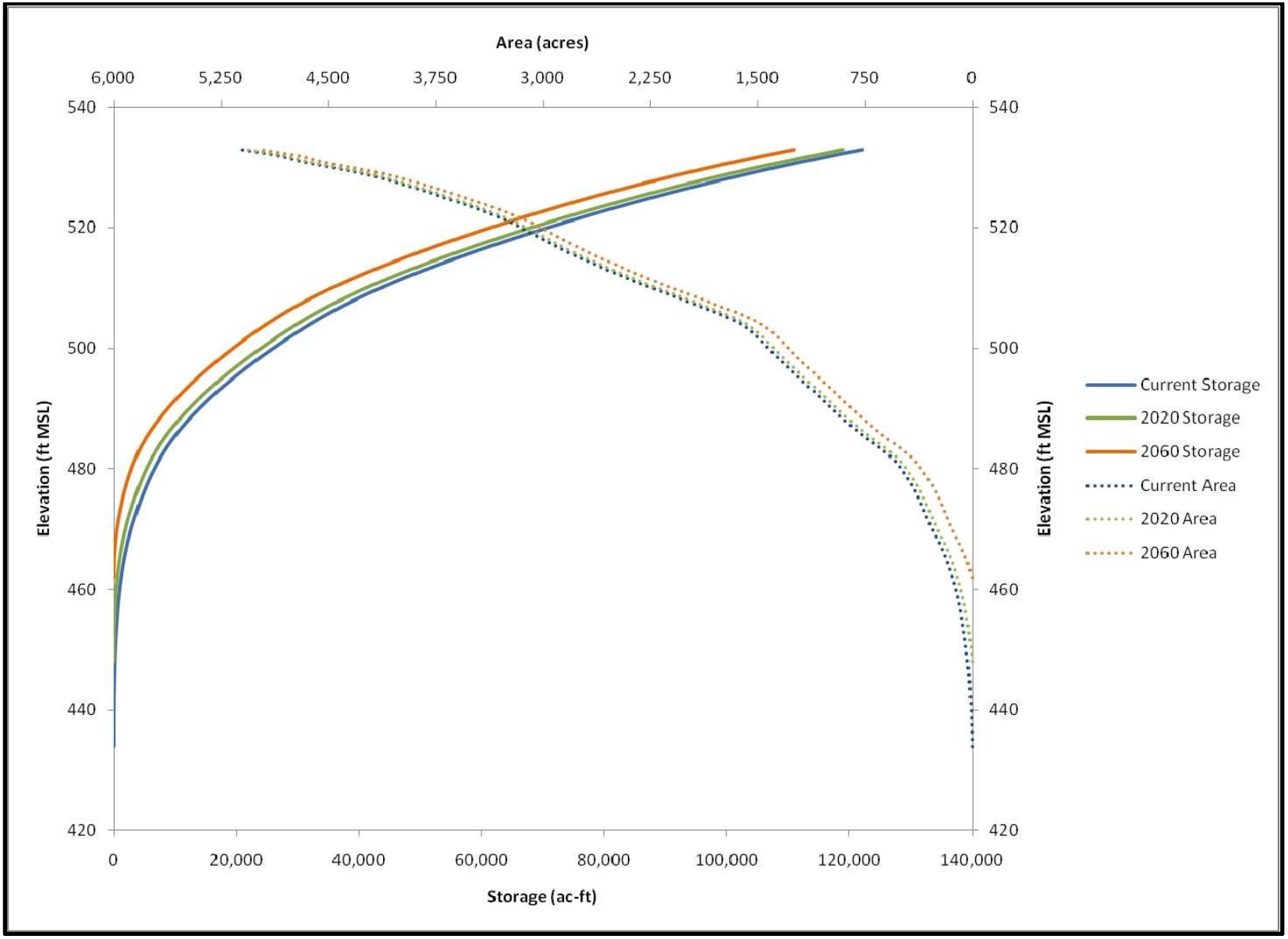

Figure 9. Lake Whitney E-A-C Data

Existing physical features of each dam and associated outlet rating curves were also entered into the HEC-ResSim model. At Possum Kingdom Lake, the nine bear trap gates (crest spillway elevation of 987.0 ft-msl), the emergency spillway (crest spillway elevation of 1000.0 ft-msl), and the three low flow outlets (bottom elevation of 976.0 ft-msl) were included in the model. The two turbines and hydropower generation were not considered at Possum Kingdom Lake. With the decommissioning of hydropower generation at PK, a modified outlet was assumed to be constructed at Morris Sheppard Dam for 2020 and 2060 conditions to allow releases down to elevation 920 ft-msl. BRA is currently planning to begin construction of the modified PK outlet in 2013. At Lake Granbury, the sixteen tainter gates (crest spillway elevation of 658.0 ft-msl), and one sluice gate (#4) were included in the model. Leakage from the dam was also entered as a function of headwater elevation and ranged from 0 cfs to 3 cfs. As previously noted, the Lake Whitney storage capacity was adjusted to model the BRA water. The total leakage from the dam is approximately 25 cfs, but only half of this amount is accounted for as BRA water, so a 12.5 cfs leakage was included in the model for elevations above elevation 520.0 ft-msl. The seventeen tainter gates and one controlled outlet were included in the model for downstream releases.

Diversions were also included at each reservoir to account for the lakeside demands and water supply contracts as discussed in Section 3.1.3 for the various demand scenarios. The evaporation rates (Section 3.1.2) were included in the period-of-record simulations to account for the loss of stored water due to evaporation.

Routing reaches and parameters were included to approximate the travel time and attenuation of releases from both Possum Kingdom and Lake Granbury. The Working R&D method was utilized and the parameters were developed by the USACE as part of the inflow dataset development. Routing reaches were included from Morris Sheppard Dam (Possum Kingdom) to the Palo Pinto USGS gauge, from the Palo Pinto USGS gauge to the Dennis USGS gauge, and from DeCordova Bend Dam (Lake Granbury) to the Glen Rose USGS gauge.

Daily period-of-record inflows (Section 3.1.1) were input to the HEC-ResSim model at Possum Kingdom Lake, Lake Granbury, and Lake Whitney. Minimum low flow (environmental) release requirements were also included for each reservoir. At Possum Kingdom Lake, the Federal Energy Regulatory Commission (FERC) minimum flow releases range from 10 to 100 cfs dependent upon the time of the year and pool elevation. At Lake Granbury sluice gate #4 was utilized to maintain a 25 cfs minimum flow release from DeCordova Bend Dam. Figure 10 provides a general schematic of the reservoir simulation inputs and outputs.

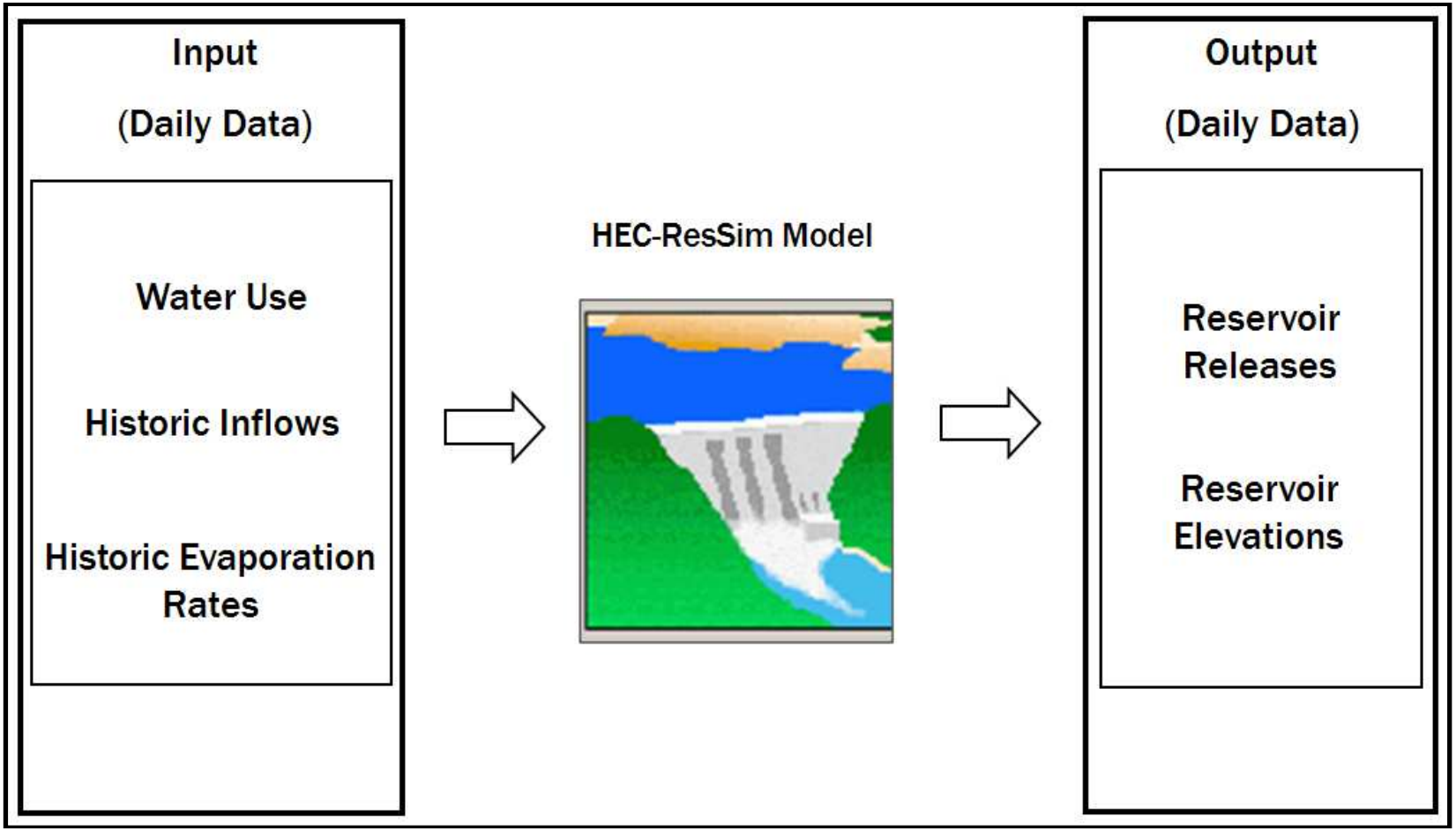

Figure 10. Reservoir Simulation Inputs and Output

3.3 HEC-ResSim Model Validation

Prior to commencing period-of-record simulations for various Water Management scenarios and demands, the HEC-ResSim model, daily inflow data set, and evaporation data set needed to be validated. The daily inflow data set, evaporation data set, historic reservoir releases, and observed lakeside pumpage/diversions were input to the model. A period from January 1993 through December 2009 was selected for the validation simulation. This period was selected as electronic release, diversion, and pumpage records were available. The validation period includes several cycles of wet and dry watershed conditions. The baseline HEC-ResSim model was simulated and the computed reservoir elevations were compared to historical elevations. The computed elevations tracked very well with historical elevations over the simulation period as shown in Figure 11 and Figure 12 for Possum Kingdom Lake and Lake Granbury, respectively. The results of this validation simulation provided confidence that the inflow data set, routing reach parameters, evaporation data, and general model performance were accurate for the purposes of evaluating flow and elevation differences through the upper Brazos River reservoir system for alternative Water Management scenarios.

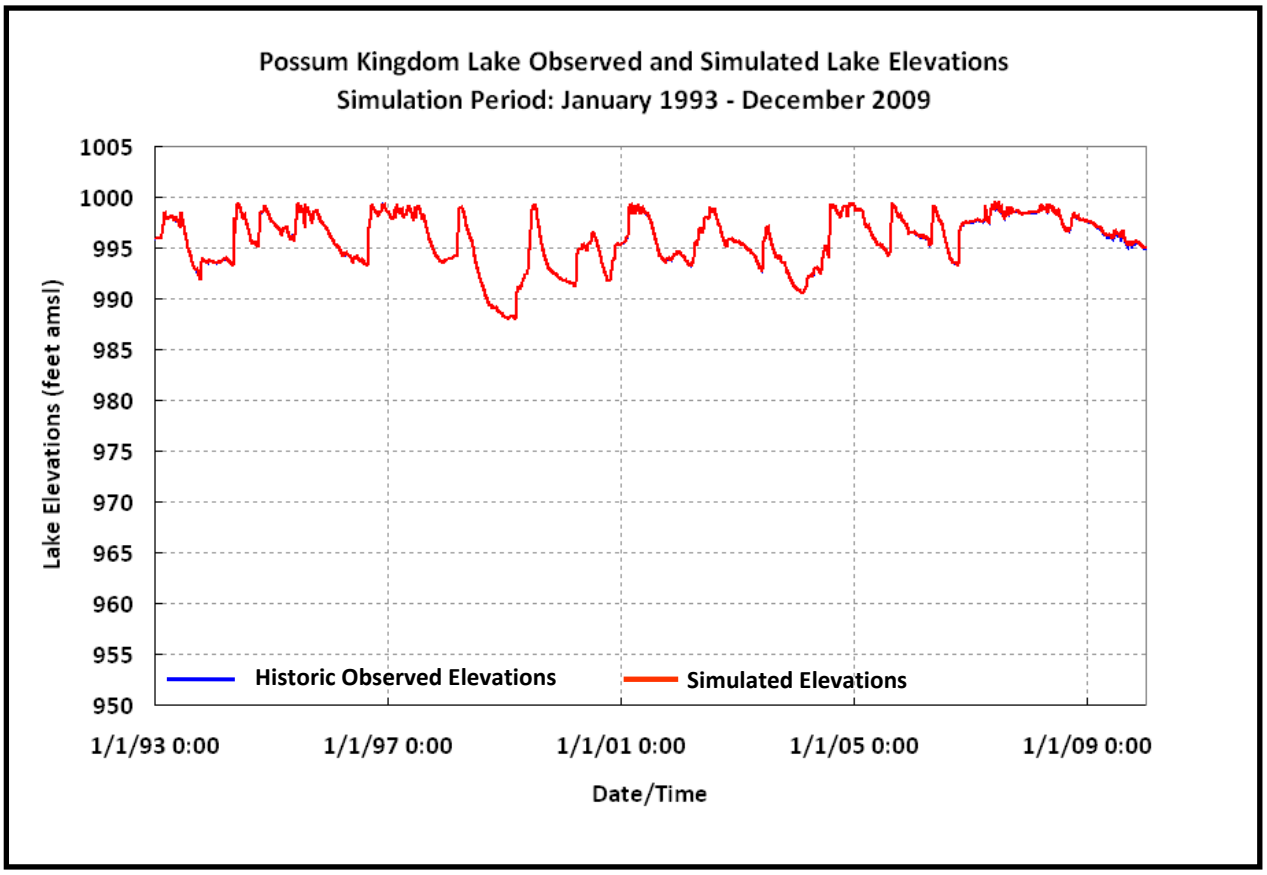

Figure 11. Possum Kingdom Reservoir Simulation Validation

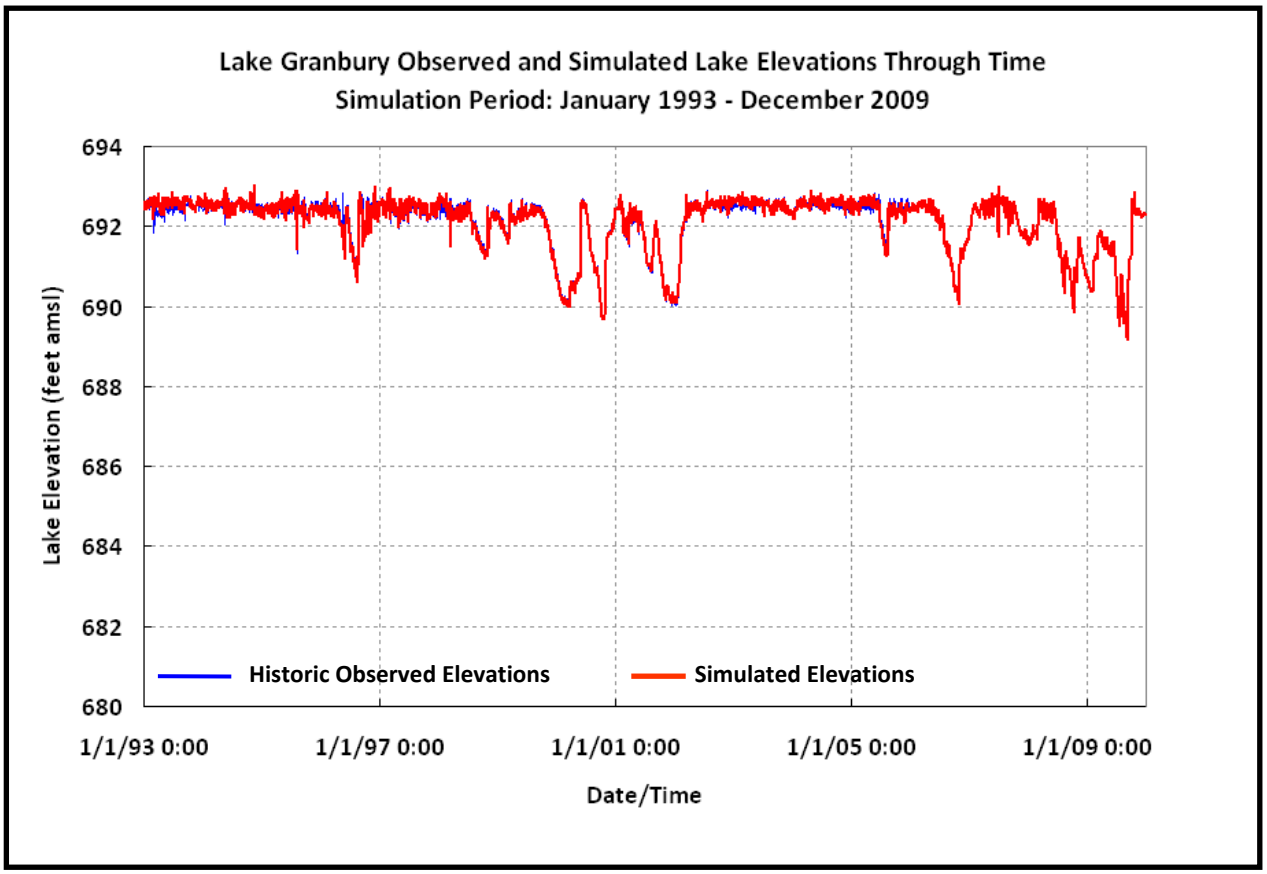

Figure 12. Lake Granbury Reservoir Simulation Validation

3.4 HEC-ResSim Alternative Operating Plans

Alternative operating plans for each reservoir were simulated for the various demand scenarios to assess the impacts on lake features over the period-of-record. The first two operating plans were extreme ("bookend") conditions used to bound the other plans. The first of these bookend plans was the *PK 1st* operating plan. Under this plan, Possum Kingdom releases are made to maintain Lake Granbury at the top of conservation pool level (692.7 ft-msl), and Lake Granbury is used to keep BRA storage in Lake Whitney full. In effect, Possum Kingdom water is used to maintain both Lake Granbury and Lake Whitney at full pool levels to the extent possible. The other extreme operating plan is the *GB 1st* alternative. Possum Kingdom releases are not made to keep Lake Granbury full, but are only used to keep Lake Granbury above elevation 675.0 ft-msl. Lake Granbury releases are made to keep BRA storage in Lake Whitney full.

An additional operating plan was simulated called *No Demand*. Under this scenario, the only demands on the reservoirs are the minimum low flow release requirements (FERC at Possum Kingdom and 25 cfs at Lake Granbury). Contracted lakeside demands and downstream demands are not included for this simulation. This includes no municipal, industrial, mining, or irrigation demands from the system, including no water for CPNPP Units 1&2. The purpose of this simulation is to show the impacts on lake levels due strictly to cyclical wet/dry periods and evaporation cycles over the period-of-record. As discussed in the results Section 5.0, Possum

Kingdom Lake and Lake Granbury cannot be kept full at all times, even without any water demands, due to the natural variable weather cycles.

Two additional "balancing" operating plan alternatives were also simulated for each demand scenario. The first is an *Equal Drawdown* (1:1) plan based on lake elevations. This plan attempts to keep both Possum Kingdom Lake and Lake Granbury at the same level (feet down) below top of conservation pool level. In other words, if Lake Granbury is two feet down (690.7 ft-msl) and Possum Kingdom is one foot down (998.0 ft-msl), releases will be made from Possum Kingdom until the two reservoirs are at equal levels (based on elevation). This is the operating plan that BRA has utilized since 2007 when Possum Kingdom hydropower generation was terminated. Lake Granbury releases (when above 675.0 ft-msl) are made to keep Lake Whitney above 520.0 ft-msl, but not full to the top of conservation level.

The second "balancing" alternative was a *Zonal Drawdown*. With this alternative, both Possum Kingdom Lake and Lake Granbury are divided into two zones based on pool elevation (depth from full). Rather than using a 1:1 *Equal Drawdown* plan, the drawdown ratios are varied within each zone. These ratios vary by demand scenario and were established in an iterative process in an attempt to "balance" impacts to critical metrics at both Possum Kingdom Lake and Lake Granbury as discussed in Section 4.0. The zone divide (established in an iterative manner) at Possum Kingdom Lake was set to 992.0 ft-msl and at Lake Granbury it was set to 688.7 ft-msl based on an optimized drawdown ratio of 1.75:1 (PK:Granbury) to balance the percent of features out of service at each lake over a range of elevations. Lake Granbury releases (when above 675.0 ft-msl) are made to keep Lake Whitney above 520.0 ft-msl, but not full to the top of conservation level. More details related to the *Zonal Drawdown* are provided in Sections 4.0 and 5.0

4.0 HEC-ResSim Simulations and Critical Metric Incorporation

The various demand scenarios and operating plans were combined into alternatives in HEC-ResSim and simulated over the 1939-2009 period-of-record. A *Microsoft Office Excel* spreadsheet was developed to take the simulation results (daily lake elevations) and incorporate with the critical metric/feature data and elevations at each lake. The goal of the spreadsheet was to quantify the relative impacts to the metrics and recreational features at each lake. The spreadsheet went through numerous iterations and refinements before the final version was developed. The spreadsheet was utilized for each alternative and demand scenario and was used in an iterative manner with the HEC-ResSim model to develop the optimal *Zonal Drawdown* plan for "balancing" impacts at both Possum Kingdom Lake and Lake Granbury.

The percent of time in service values presented in Sections 4.0 and 5.0 of this report are based on the historic period-of-record inflows and evaporation records (1939-2009) and are not a guarantee of future conditions due to variable hydrologic cycles. The percent of time in service values are also based on lake bottom elevations determined with various methods and two feet of required water depth as discussed in Section 2.0.

4.1 Metric Analysis Spreadsheet Tool

The *Microsoft Office Excel* spreadsheet analysis tool developed for this study combines the HEC-ResSim daily lake elevation results with the critical metric out-of-service elevations to evaluate impacts at both Possum Kingdom Lake and Lake Granbury. For the *GB 1st*, *PK 1st*, *No Demand*, and *Equal Drawdown* operations, the spreadsheet was used to quantify the impacts at each lake and highlight relative differences in percent of features out-of-service at each lake. For the *Zonal Drawdown* plan, the spreadsheet was executed in an iterative fashion with the HEC-ResSim model to optimize the zonal elevations and drawdown ratios at both Possum Kingdom Lake and Lake Granbury to "balance" impacts.

The following provides a summary of the spreadsheet inputs and outputs:

1. The "Out-of-Service" tab includes the critical metric counts/elevations developed previously (Section 2.0) and tabulates the total (cumulative) number of features out-of-service for a given elevation at each lake. The out-of-service count includes a two-foot buffer above the actual lake bottom elevation. The "Out-of-Service" tab includes both an actual count and percent of total out-of-service for a given elevation. Since these data are all based on physical lake bottom elevations, this tab of the spreadsheet is not changed from alternative to alternative.

   The four feature classes (docks, marinas, public ramps, and private ramps) are assigned a weighting criteria. The weights were set equal between docks, marinas, and ramps, with the public ramps weighted slightly more than the private ramps as shown in Figure 13.

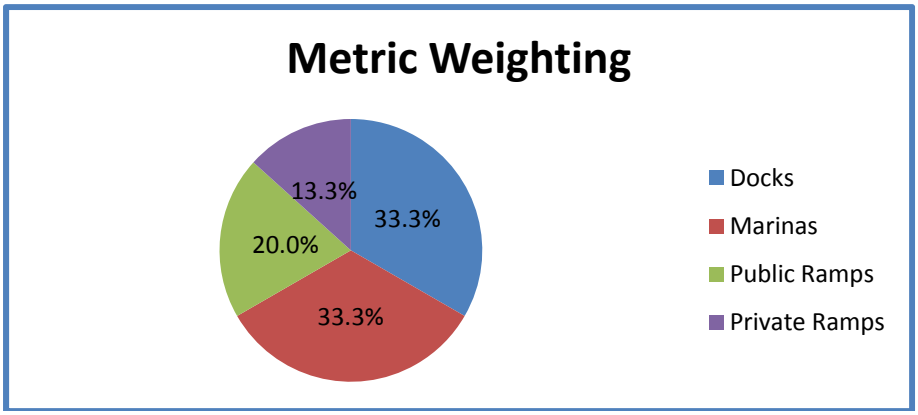

Figure 13. Feature Weighting

These weights are subjective, so a sensitivity analysis was performed as discussed in Section 4.2. Since the numbers of features at each lake are not equal, percentages of totals and weights are needed to normalize the results and compute a single "out-of-service" value for a given elevation. If the actual number of features out-of-service is the only consideration, the docks will control and there would be no need to even consider marinas, fuel stations, or ramp impacts since the total number of these features is such a small percentage of the total number of docks. With the weighted feature classes, a single weighted percent of total features out-of-service at each lake can be computed for a given elevation or drawdown.

Figure 14 shows the weighted total compared to the four individual feature classes at both Possum Kingdom Lake and Lake Granbury. Figure 15 shows the weighted percent of features out-of-service for each lake on the same plot. As shown here, drawdown levels do not produce equal weighted metric percent out-of-service features at each lake. Features at Lake Granbury are impacted by drawdowns much sooner than Possum Kingdom Lake. This information was used in an iterative fashion to help determine the *Zonal Drawdown* threshold levels and ratios to better "balance" impacts between the two reservoirs.

2. Once a simulation in HEC-ResSim is executed, the daily computed lake elevations at both Possum Kingdom Lake and Lake Granbury are copied into the "Days Analysis" tab of the spreadsheet. For each day, the spreadsheet counts (and interpolates) the number of docks, marinas, public ramps, and private ramps out-of-service at each lake by querying the "Out-of-Service" tab. The "Docks" feature includes both residential, commercial, and group residential docks (floating and fixed). The "Marinas" feature includes the marinas and fuel stations.

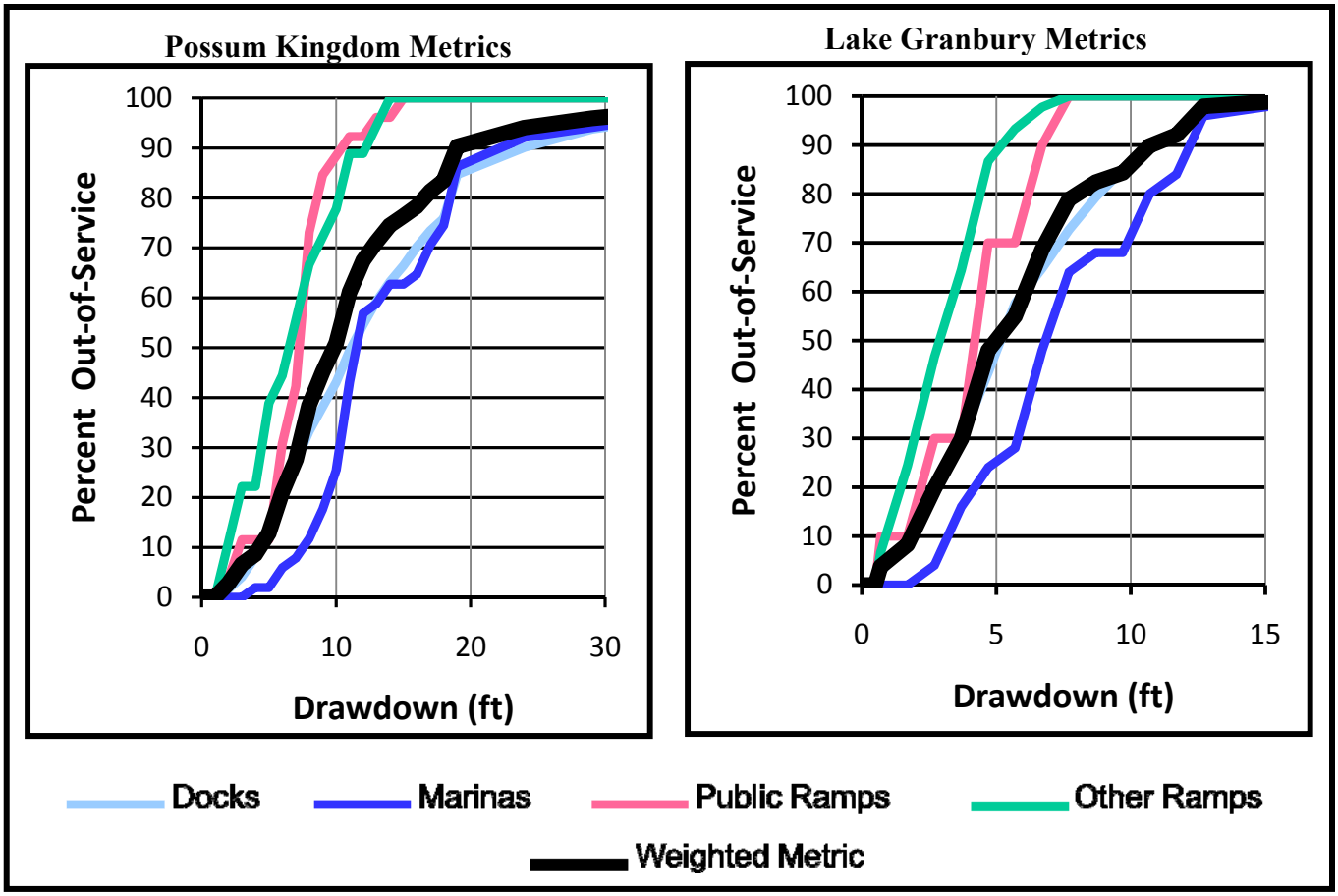

Figure 14. Percent of Features Out-of-Service

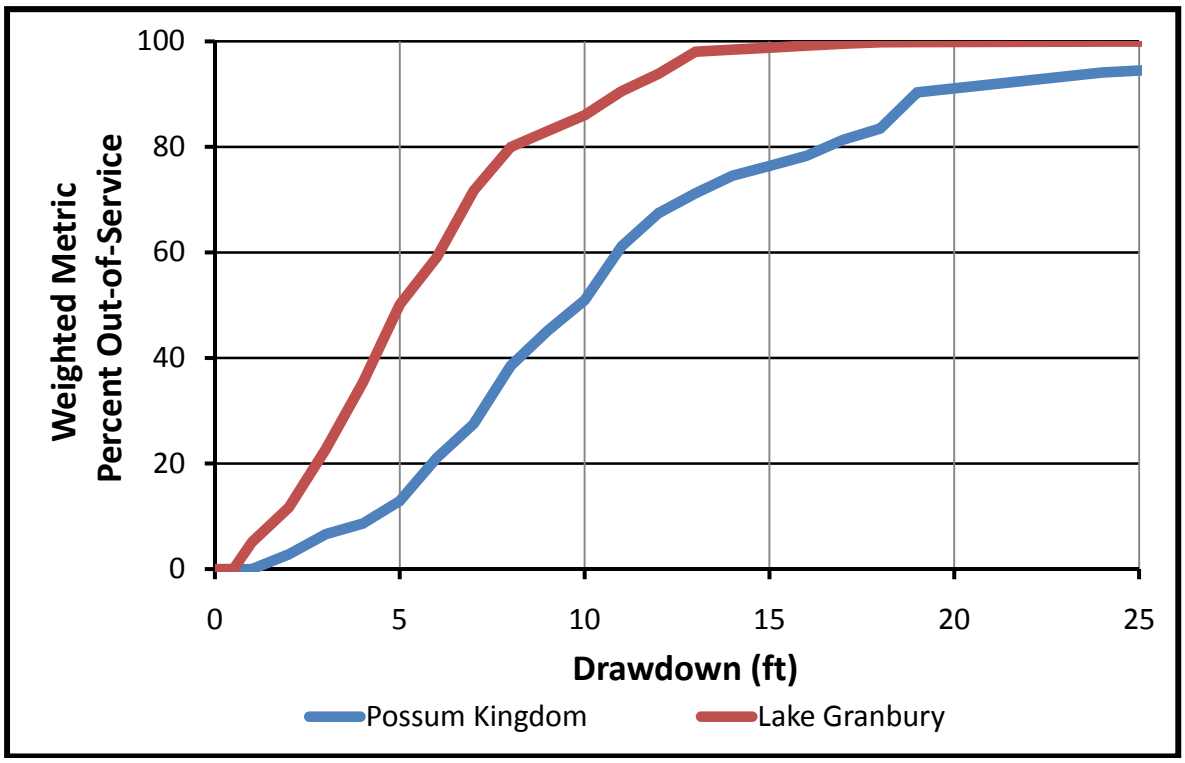

Figure 15. Weighted Percent of Features Out-of-Service

3. The "Days Summary" tab in the spreadsheet computes the total out-of-service (OOS) days and percentage of potential OOS for the docks, marinas, public ramps, and private ramps. One feature out-of-service for one day is one OOS day. For example, there are 3,240 docks at Lake Granbury and 25,932 days over the 71-year period-of-record. Therefore, if every dock was out-of-service every day, there are 84,019,680 potential OOS dock-days. The "Days Summary" tab computes the weighted metric percent of potential OOS at each lake for both year-round and also the summer months (May-September) only. A ratio is computed based on the weighted metric percent of potential OOS between Lake Granbury and Possum Kingdom Lake. A ratio of 1 would indicate that the weighted metric percent of potential OOS are equal at both lakes.

4. The "Days Summary" data is then graphed showing a comparison of the percent of potential OOS for each feature, as well as the weighted metric total at each lake for both year-round and summer months.

5. The "Percentiles" tab in the spreadsheet computes a range of percentile elevations (0.1% to 90%) for each lake based on the simulation elevation results. For these percentile elevations, the percent of each feature out-of-service at each lake is tabulated. A weighted metric total percent out-of-service is then computed for each percentile elevation and the difference for each lake is computed. For example, if the 10^{th} percentile elevation (elevations lower than this value occur 10% of the time over the period-of-record) for a given simulation at Lake Granbury has a weighted percent of features out-of-service value of 21.5% and the 10^{th} percentile elevation at Possum Kingdom Lake has a weighted percent of features out-of-service of 22.7%, the difference for the 10^{th} percentile elevation is -1.2%. These values are computed for both year-round and summer only times.

6. The difference in weighted percentile elevations are then plotted in terms of both the Granbury percentile elevations and Possum Kingdom percentile elevations. As noted in Section 3.4, the *Zonal Drawdown* plan ratios were established in an iterative process using this spreadsheet. The goal was to vary the ratio in the operating plan in order for the plotted weighted percent of features out-of-service differences to be within five percent of one another at both lakes for the range of percentile elevations. This would indicate “balanced” impacts at both reservoirs over a range of lake elevations.

   Key results from the spreadsheet analysis tool are presented in Section 5.0.

4.2 Weighting Sensitivity Analysis

The goal of this spreadsheet analysis tool was to be as objective as possible in assessing impacts to lake features using field elevations and computed period-of-record simulation elevations. In order to help normalize the results between features and lakes, a weighting criteria was introduced which is subjective. Initial weighting was set to 33.3% for docks, 33.3% for marinas, 20% for public ramps, and 13.3% for private ramps. A sensitivity analysis was performed on the weighting criteria. Rather than equal weighting, a 2/3 to 1/3 weighting criteria was analyzed. For example, docks were weighted 2/3 while marinas and ramps were each weighted 1/6, and

then marinas were weighted 2/3 while docks and ramps were each weighted 1/6, and finally, ramps were weighted 2/3 and docks and marinas were each weighted 1/6. The spreadsheet tool was re-executed with these varying weights and it was found that the difference in weighted percent of features out-of-service were still within five percent except for the extreme drought (low percentile elevations) conditions. Therefore, equal weighting between docks, marinas, and ramps were maintained for the final analysis. As shown in Figure 14, the weighted metric line tracks very closely to the "Docks" feature class.

5.0 Simulation Results Overview

Section 5.0 provides results of the period-of-record simulations in HEC-ResSim for various combinations of demand conditions and alternative operating plans. For each simulation, a table is provided showing key percentile elevations at each lake over the period-of-record. These percentile elevations represent the percent of time the lake will be at or below the given level over the entire period-of-record. For example, a 10^{th} percentile elevation of 690.9 ft-msl for Lake Granbury indicates that Lake Granbury will be at or below 690.9 ft-msl ten percent of the time over the seventy-one year period-of-record. Another way of looking at this 10^{th} percentile elevation is that 90 percent of the time, Lake Granbury will be no more than 1.8 feet below full (692.7 ft-msl – 690.9 ft-msl).

Also provided for each simulation is a "Weighted Percent of Potential Out-of-Service" value as computed by the spreadsheet analysis tool (Section 4.1). For example, each day that a single feature is out-of-service constitutes one out-of-service day. If fifty docks are out of service on a given day, that would equal 50 out-of-service days. The "Percent of Potential Out-of-Service" is computed over the entire period-of-record for each of the four major feature classes (Docks, Marinas, Public Ramps, and Private Ramps) and the weighted values are used to compute a total "Weighted Percent of Potential Out of Service". The tables provided with each simulation also show the delta between the PK and Granbury "Weighted Percent of Potential Out-of-Service". A delta value of 0 would indicate equal percents out-of-service at each lake. Some of the simulations show results for multiple operating plan alternatives, where others only show the *Zonal Drawdown*. All of the bookend alternatives were not simulated for every demand condition.

In addition to the table for each simulation, two figures are also shown for the *Zonal Drawdown*. The first figure shows the percentile drawdowns (levels below full) at each lake and the total weighted metric percent of features out-of-service at each lake for each of the percentile drawdowns for all months of the year over the period-of-record. The second figure focuses only on the peak recreational (summer) times of the year (May-September) over the period-of-record. The *Zonal Drawdown* schemes were determined in an iterative process with the *Microsoft Office Excel* spreadsheet and HEC-ResSim simulations. The goal was to define a *Zonal Drawdown* that would result in equal (within 5%) weighted percent of features out-of-service at each lake for each percentile elevation (drawdown). A figure that shows the Possum Kingdom and Granbury plots directly on top of one another would indicate equal impacts in terms of percent of features out-of-service over the range of elevations. All that is presented in the following sections are the final "optimized" *Zonal Drawdown* simulations. If a 1.75:1 (PK:Granbury) ratio above Possum Kingdom elevation 992.0 ft-msl is shown, it generated the best "balance" of impacts between each reservoir. Several other combinations of drawdown ratios and breakpoint elevations were simulated but did not provide as equal a "balance" of impacts as those shown in the following sections. A more detailed comparison of the simulations can be found in Appendix D.

5.1 Current Demands

The first set of simulations included the current demand data set with the existing Morris Sheppard Dam outlets without hydropower. When the Possum Kingdom Lake elevation drops below 987.0 ft-msl, only the three low flow outlets can be used to release water downstream.

Once the lake drops below elevation 976.0 ft-msl, water can no longer be released downstream from Morris Sheppard Dam.

5.1.1 Simulation 1: Current Demands

The *Zonal Drawdown* scenario details were determined in an iterative fashion with the critical metric analysis spreadsheet in an attempt to balance impacts between Possum Kingdom Lake and Lake Granbury. For the current demands, a 1.75:1 (PK:Granbury) balancing drawdown when Possum Kingdom Lake is above elevation 992.0 ft-msl and 1:1 balancing when Possum Kingdom Lake falls below 992.0 ft-msl provided the best balance of impacts. In other words, Possum Kingdom will provide water to Lake Granbury to maintain a 1.75:1 (PK:Granbury) elevation drawdown ratio until Possum Kingdom is seven feet below top of conservation level (Granbury would be four feet below top-of-conservation level), and then the reservoirs will be operated on an equal drawdown basis.

Figure 16 shows the corresponding lake levels for the selected *Zonal Drawdown*. Table 12 shows summaries of the simulated results and critical metric impacts for the current demand scenarios. Figure 17 and Figure 18 show the weighted metric percent out-of-service at each lake for the various percentile drawdowns under the *Zonal Drawdown* for year-round and summer only, respectively. For the current demands, Figure 19 shows the *Equal Drawdown* simulation results since this is the operating plan that has been in place since hydropower operations were terminated at Possum Kingdom Lake in 2007. As shown in Figure 19, the *Equal Drawdown* simulation produces more impacts at Lake Granbury than a more "balanced" *Zonal Drawdown Plan*.

Possum Kingdom Elevation	Granbury Elevation
999	692.7
995.5	690.7
992	688.7
988	684.7
984	680.7

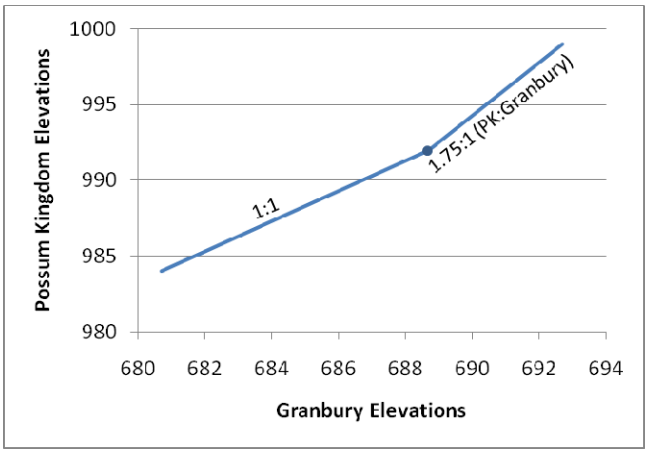

Figure 16. Optimized *Zonal Drawdown* Plan for Current Demand Conditions

Table 12. Current Demands Results

	Possum Kingdom				Granbury				
Alternative	**90% Elev.**	**50% Elev.**	**10% Elev.**	**Weighted % of Potential OOS**	**90% Elev.**	**50% Elev.**	**10% Elev.**	**Weighted % of Potential OOS**	**Δ PK-GB Weighted % of Potential OOS**
PK 1st	999.00	997.54	989.34	12.92	692.70	692.70	692.55	0.39	12.53
GB 1st	999.00	998.84	995.83	2.07	692.70	692.65	687.21	12.90	-10.83
No Demand	999.00	998.86	995.97	1.94	692.70	692.70	692.38	0.35	1.59
Equal Drawdown	998.99	998.58	995.14	2.79	692.70	692.69	690.30	4.85	-2.06
Zonal Drawdown*	998.99	998.50	994.67	3.39	692.70	692.70	691.06	2.72	0.67

* Zonal Drawdown: 1.75:1 when PK above 992.0 ft-msl. 1:1 balancing when PK below 992.0 ft-msl.
* OOS – Out-of-Service

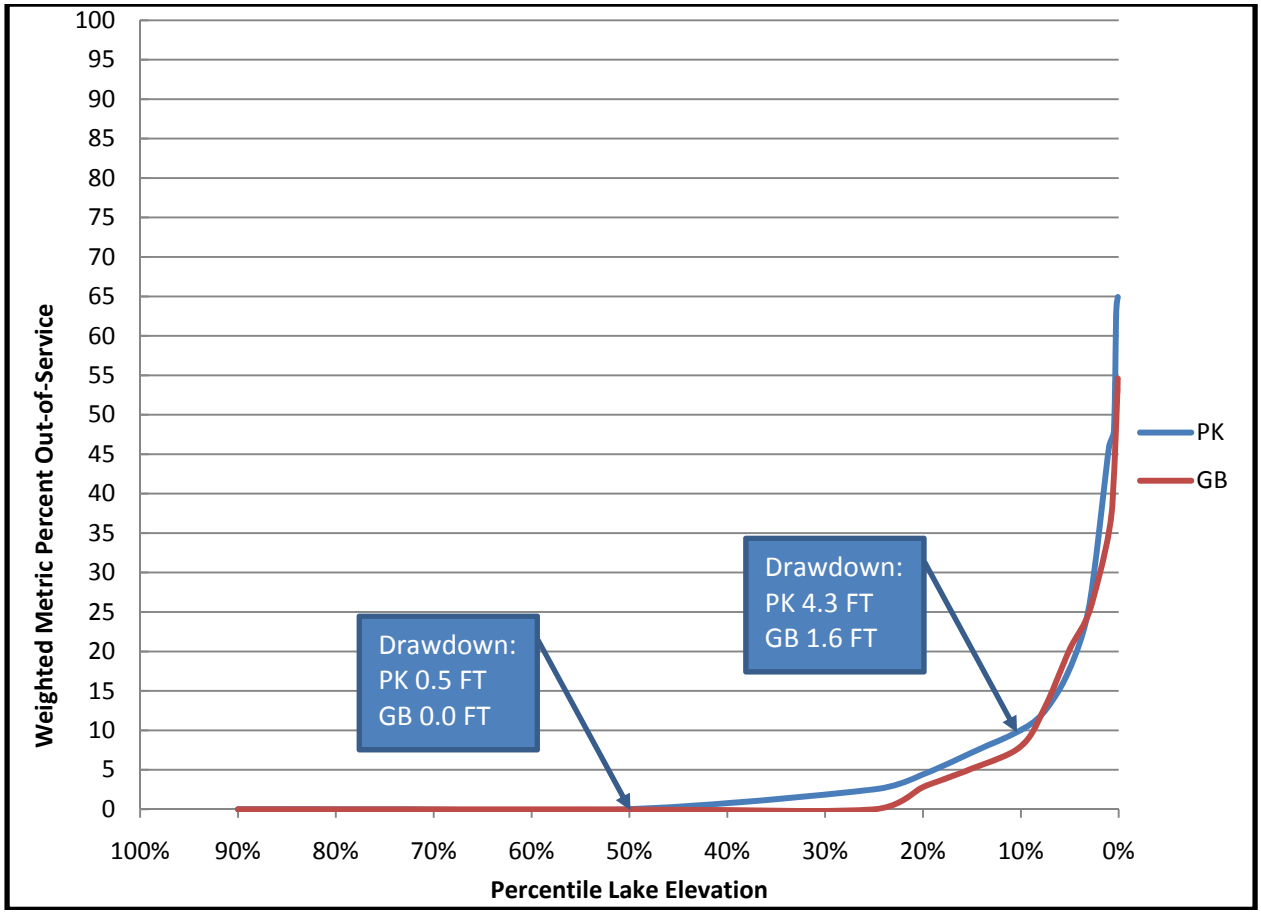

Figure 17. *Zonal Drawdown* Current Demands – Year Round

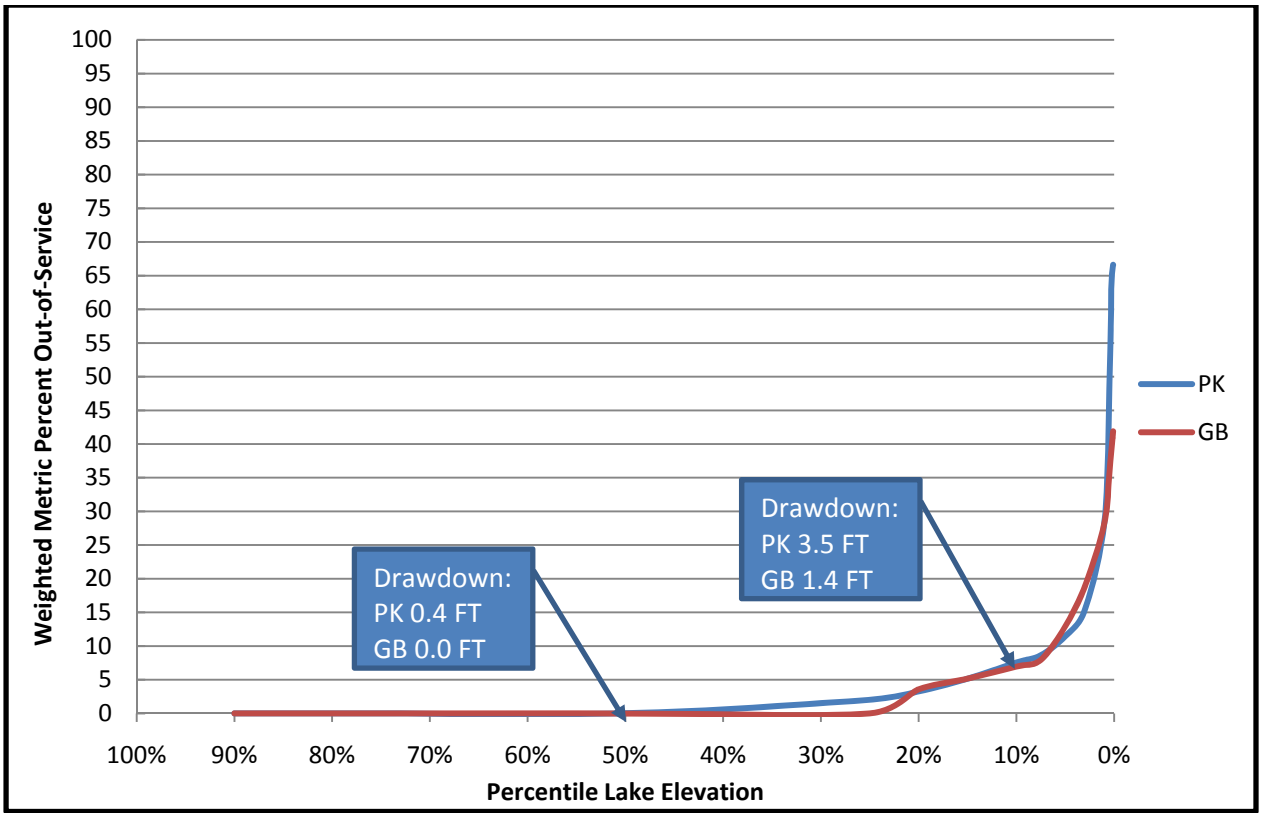

Figure 18. ***Zonal Drawdown*** **Current Demands – Summer Months**

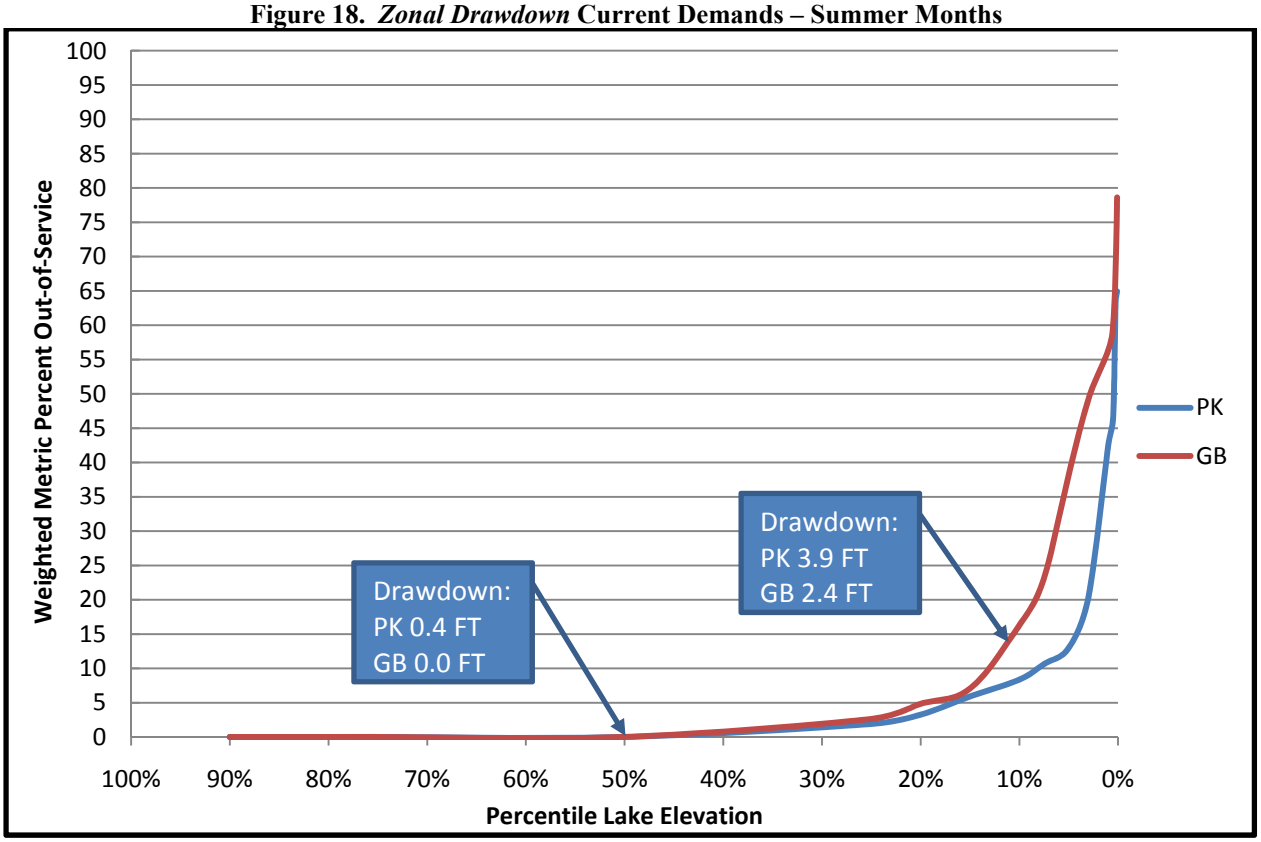

Figure 19. ***Equal Drawdown*** **Current Demands – Year Round**

The *No Demand* alternative shows that the variable weather cycles and evaporation rates make it impossible to maintain both reservoirs at a full level at all times. The *PK 1st* and *GB 1st* produce the most dramatic impacts at each reservoir and represent extremes in terms of operation and balancing of impacts. The *Zonal Drawdown* produces a better balance of impacts than the *Equal Drawdown* operation currently employed by BRA. The *Zonal Drawdown* will result in higher lake levels at Lake Granbury on average than the *Equal Drawdown* as shown in Figure 20. The *Zonal Drawdown* will result in higher average lake elevations at Possum Kingdom Lake than have been seen historically when hydropower generation was in service as shown in Figure 21.

Under current demands and the *Zonal Drawdown*, Lake Granbury will remain within 1.6 feet of full and Possum Kingdom Lake will remain within 4.3 feet of full approximately 90 percent of the time based on the historical period-of-record. During the summer months, the drawdown is actually even less. As expected, the *Zonal Drawdown* produces slightly lower elevations at Possum Kingdom Lake and slightly higher elevations at Lake Granbury than the *Equal Drawdown* plan. As seen in Figure 17 and Figure 18 the *Zonal Drawdown* "balanced" the weighted metric percent of features out-of-service at each lake very well, especially for the summer months. Over 90 percent of the time over the period-of-record, less than 10 percent of the weighted features at each lake will be out-of-service with the *Zonal Drawdown*.

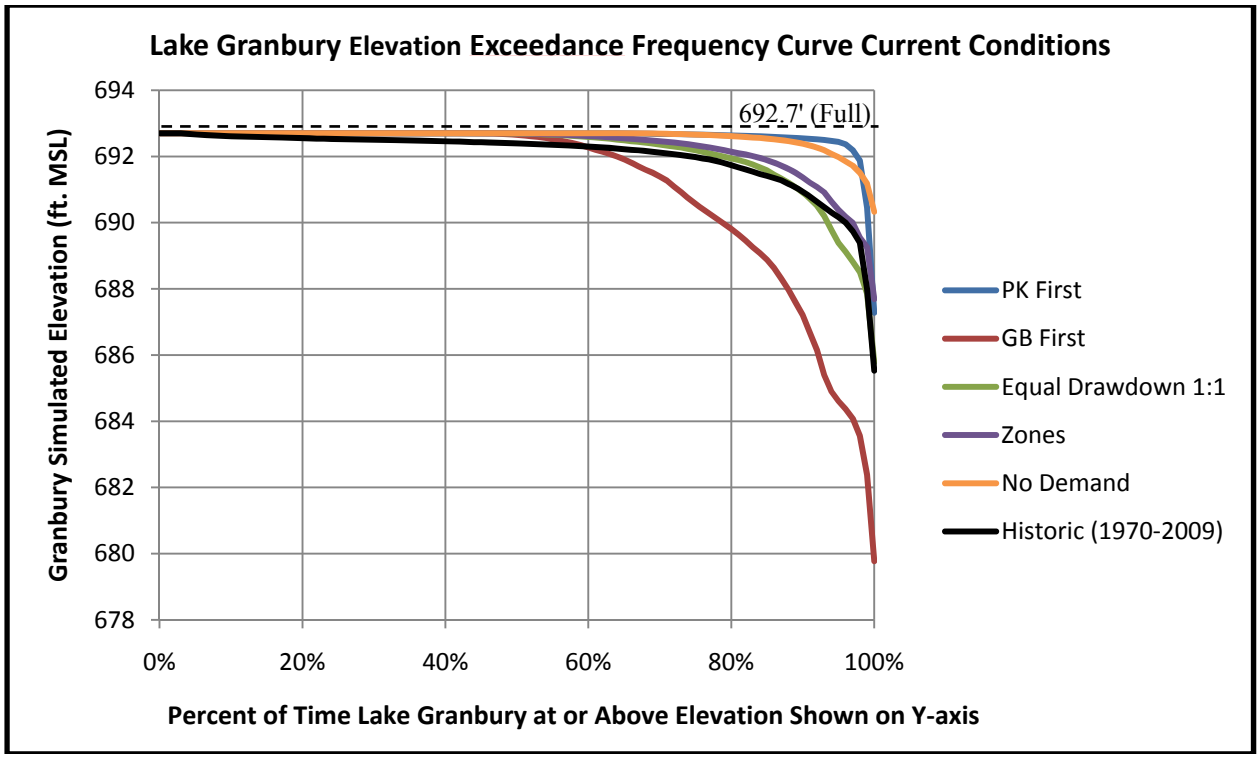

Figure 20. Lake Granbury Elevation Exceedance Frequency Curve – Current Conditions

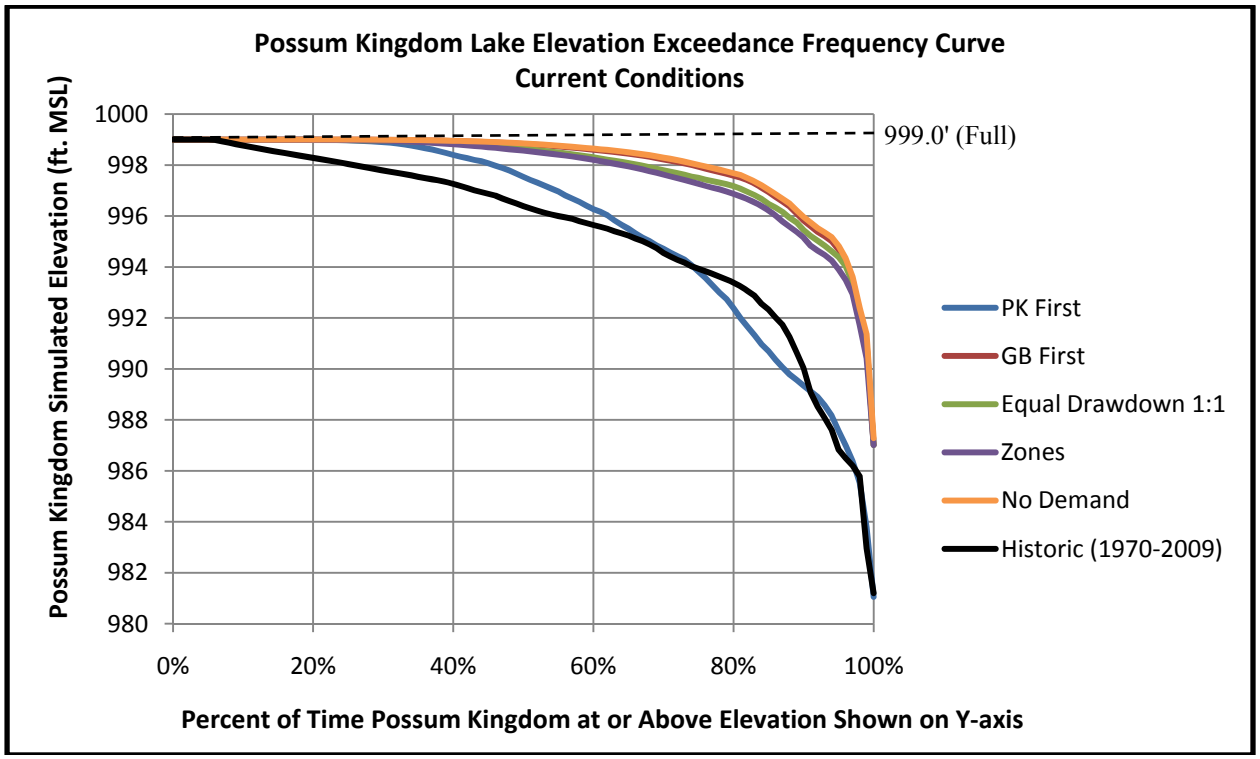

Figure 21. Possum Kingdom Lake Elevation Exceedance Frequency Curve – Current Conditions

5.2 2020 Demands

Several variations of the 2020 demand data set were simulated with the operating plan alternatives. All of the 2020 demand simulations include the modified Possum Kingdom low flow outlets that enable releases to be made down to elevation 920.0 ft-msl. The 2020 demand simulations included combinations of with and without CPNPP Units 3&4.

5.2.1 Simulation 2: 2020 Demands with CPNPP Units 3&4

The first 2020 demands simulation assumed that CPNPP Units 3&4 are in service (in addition to Units 1&2). The *Zonal Drawdown* scenario details were determined in an iterative fashion with the critical metric analysis spreadsheet in an attempt to balance impacts between Possum Kingdom Lake and Lake Granbury. For the 2020 demands with CPNPP Units 3&4, a 1.75:1 (PK:Granbury) balancing drawdown when Possum Kingdom Lake is above elevation 992.0 ft-msl and a 1.5:1 (PK:Granbury) balancing when Possum Kingdom Lake falls below 992.0 ft-msl provided the best balance of impacts. In other words, Possum Kingdom will provide water to Lake Granbury to maintain a 1.75:1 elevation drawdown ratio until Possum Kingdom is seven feet below the top of conservation level (Granbury would be four feet below top-of-conservation level) and then shift to a 1.5:1 ratio below that elevation. This is slightly different than the current demands optimized *Zonal Drawdown* in which there is 1:1 balancing when Possum Kingdom Lake elevation drops below 992.0 ft-msl. Figure 22 shows the corresponding lake levels for the selected *Zonal Drawdown*. Table 13 shows summaries of the simulated results and critical metrics for the 2020 demand scenario with CPNPP Units 3&4. Figure 23 and Figure 24 show the weighted metric percent out-of-service at each lake for the various percentile drawdowns under the *Zonal Drawdown* for year round and summer months only, respectively.

Possum Kingdom Elevation	Granbury Elevation
999	692.7
995.5	690.7
992	688.7
989	686.7
986	684.7

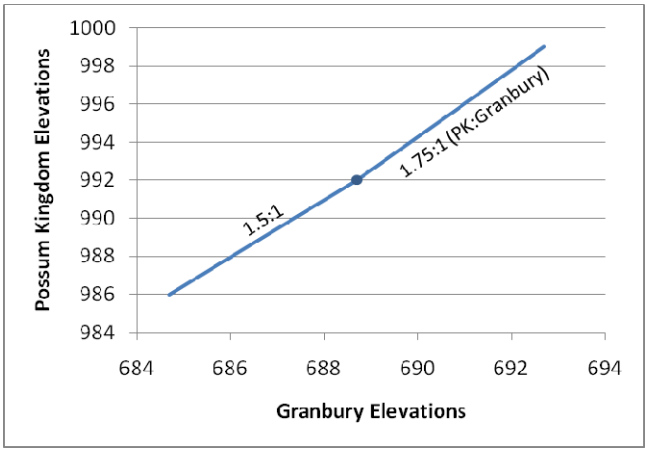

Figure 22. Optimized *Zonal Drawdown* Plan for 2020 Demands with CPNPP Units 3&4

Table 13. 2020 Demands with Comanche Peak Units 3&4 Results

	Possum Kingdom				Granbury				
Alternative	90% Elev.	50% Elev.	10% Elev.	Weighted % of Potential OOS*	90% Elev.	50% Elev.	10% Elev.	Weighted % of Potential OOS	Δ PK-GB Weighted % of Potential OOS
PK 1st	993.57	987.44	973.45	60.52	692.70	692.70	692.48	0.03	60.49
GB 1st	999.00	998.75	994.46	3.69	692.70	691.78	679.75	29.49	-25.8
No Demand	999.00	998.86	995.98	1.95	692.70	692.70	692.44	0.29	1.66
Equal Drawdown	998.99	998.22	993.64	5.03	692.70	692.41	688.35	10.59	-5.56
Zonal Drawdown*	998.99	998.04	992.74	6.52	692.70	692.49	689.82	6.24	0.28

* Zonal Drawdown: 1.75:1 when PK above 992.0 ft-msl. 1.5:1 balancing when PK below 992.0 ft-msl.
* OOS – Out-of-Service

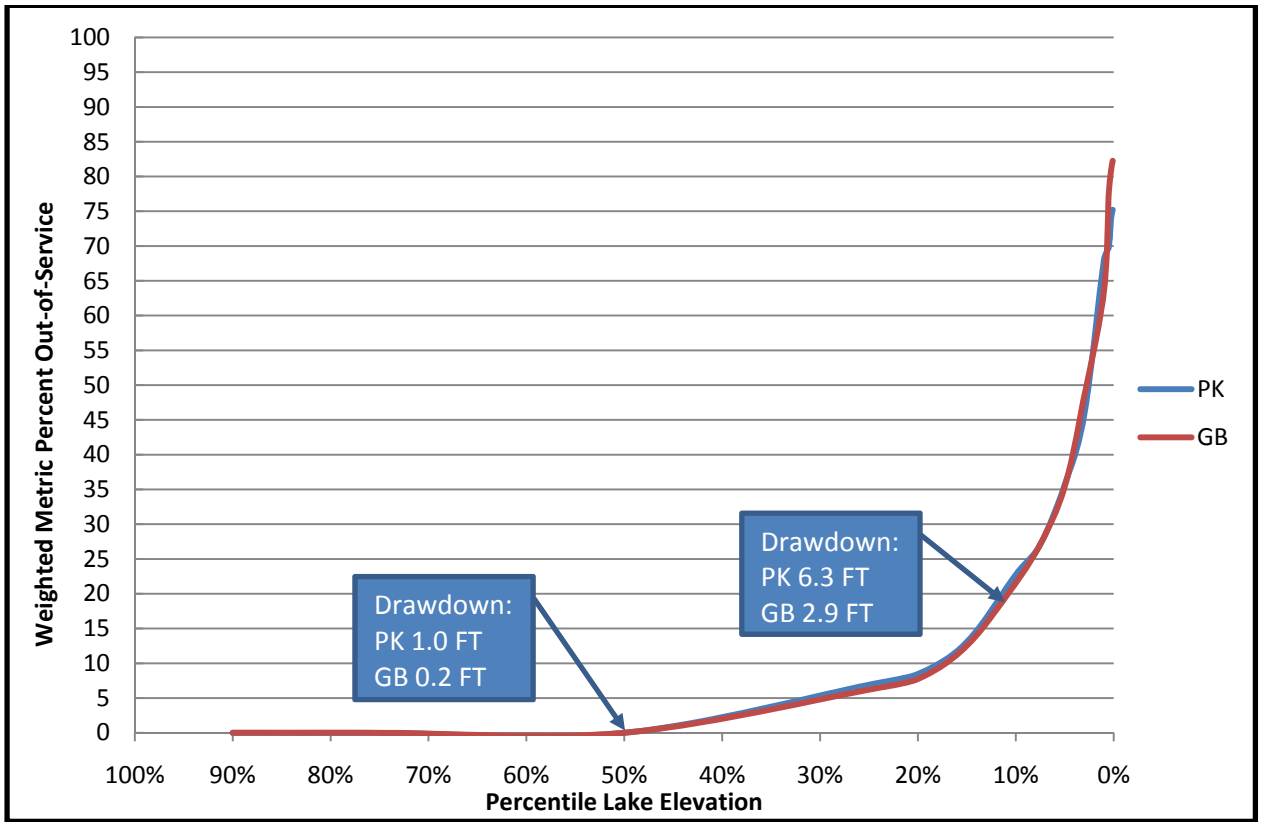

Figure 23. *Zonal Drawdown* 2020 Demands with CPNPP Units 3&4 – Year Round

The *No Demand* scenario for Simulation 2 produces slightly different results than the *No Demand* scenario for Simulation 1. Although both simulations contain only the minimum low flow releases with no demands, the variation in the elevation-capacity relationships between current conditions and 2020 conditions changes the storage which impacts the surface area, which impacts the evaporation loss. The *PK 1st* alternative produces a higher minimum Lake Granbury elevation compared to *PK 1st* with Simulation 1 with less demands. The reason for this change is that under 2020 conditions with the modified PK outlet, PK can continue to supply

water to keep Granbury near full even during drought periods. With Simulation 1 and the current outlet capacity at Possum Kingdom, releases are greatly reduced as the Possum Kingdom pool elevation falls. For example, when Lake Granbury reaches its minimum elevation of 687.6 ft-msl in October 1984 (with the PK 1st plan), Possum Kingdom is too low to be able to release enough water to keep Lake Granbury full without the modified outlet.

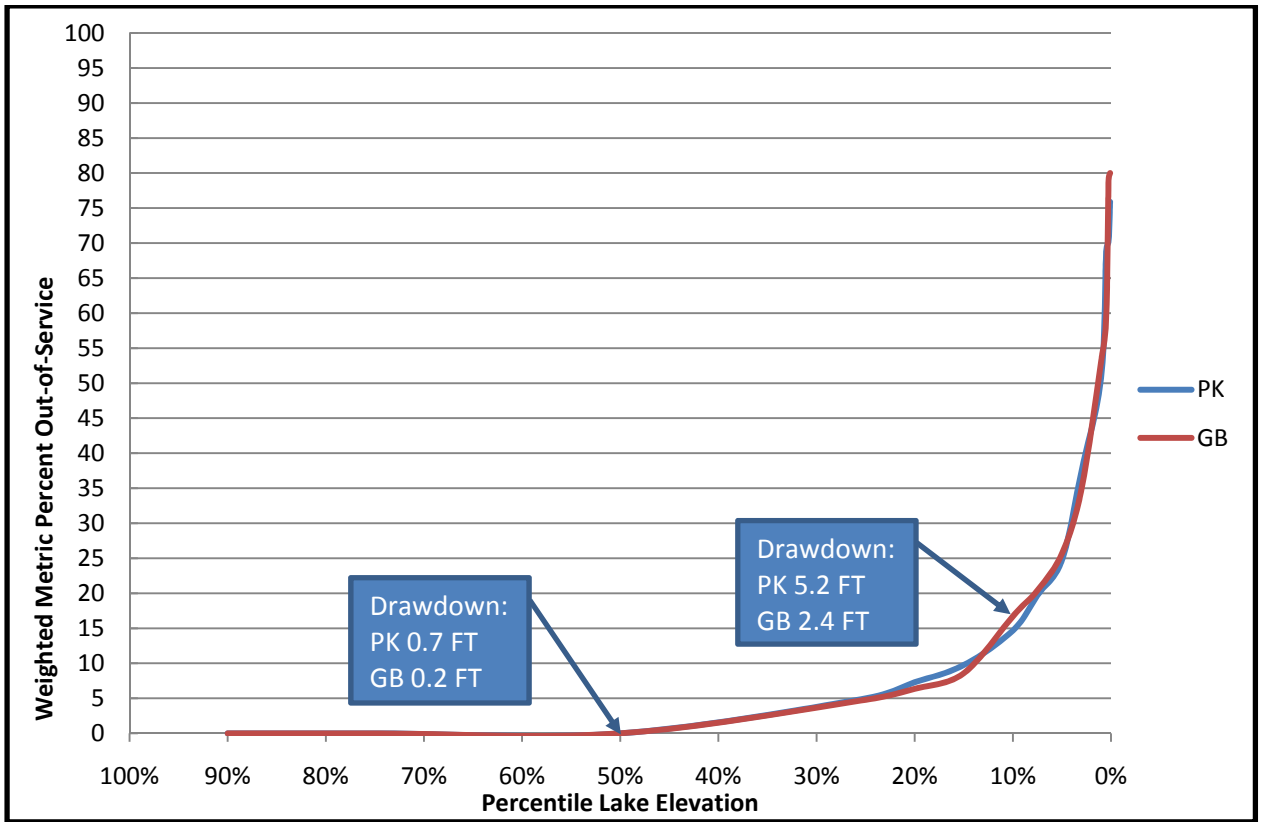

Figure 24. *Zonal Drawdown* 2020 Demands with CPNPP Units 3&4 – Summer Months

The *Zonal Drawdown* produces a better balance of impacts than the *Equal Drawdown* operation currently employed by BRA. The *Zonal Drawdown* will result in higher lake levels at Lake Granbury on average than the *Equal Drawdown* (nearly 1.5' at the 10th percentile elevation). The *Zonal Drawdown* will result in higher average lake elevations at Possum Kingdom Lake than have been seen historically when hydropower generation was in service.

Under 2020 demands with CPNPP Units 3&4 and the *Zonal Drawdown*, Lake Granbury will remain within 2.0 feet of full and Possum Kingdom Lake will remain within 5.0 feet of full approximately 85 percent of the time over the period-of-record. As seen in Figure 23 and Figure 24 the *Zonal Drawdown* "balanced" the weighted metric percent out-of-service at each lake. Over 80 percent of the time, less than 10 percent of the weighted features at each lake will be out-of-service with the *Zonal Drawdown*.

5.2.2 Simulation 3: 2020 Demands without CPNPP Units 3&4

The third simulation assumed that CPNPP Units 3&4 were not in service. The *Zonal Drawdown* scenario details were determined in an iterative fashion with the critical metric analysis spreadsheet in an attempt to balance impacts between Possum Kingdom Lake and Lake Granbury. For the 2020 demands without CPNPP Units 3&4, a 1.75:1 (PK:Granbury) balancing drawdown when Possum Kingdom Lake is above elevation 992.0 ft-msl and no balancing when Possum Kingdom Lake falls below 992.0 ft-msl provided the best balance of impacts. Table 14 shows summaries of the simulated results and critical metric impacts for the 2020 demand scenarios without CPNPP Units 3&4. Figure 25 and Figure 26 show the weighted metric percent of features out-of-service at each lake for the various percentile drawdowns under the *Zonal Drawdown*. Only the *Equal Drawdown* and *Zonal Drawdown* were simulated for this 2020 demand scenario.

Table 14. 2020 Demands without CPNPP Units 3&4 Results

	Possum Kingdom				Granbury				
Alternative	**90% Elev.**	**50% Elev.**	**10% Elev.**	**Weighted % of Potential OOS***	**90% Elev.**	**50% Elev.**	**10% Elev.**	**Weighted % of Potential OOS**	**Δ PK-GB Weighted % of Potential OOS**
Equal Drawdown	998.99	998.51	995.02	3.07	692.70	692.64	690.22	5.48	-2.41
Zonal Drawdown*	998.99	998.41	994.49	3.67	692.70	692.66	690.89	3.37	0.30

* Zonal Drawdown: 1.75:1 when PK above 992.0 ft-msl. No balancing when PK below 992.0 ft-msl.
* OOS – Out-of-Service

Comparison of Table 14 with Table 12 shows that the 2020 demands without CPNPP Units 3&4 result in slightly lower pool elevations at both reservoirs than current conditions. This is related to the increase in current lakeside and downstream municipal, industrial, mining, and irrigation demands not associated with CPNPP. Figure 27 and Figure 28 show the frequency plots for 2020 demands both with and without CPNPP Units 3&4 at Lake Granbury and Possum Kingdom Lake, respectively. These figures show that CPNPP Units 3&4 will only have a few tenths of a foot impact on the lake levels the majority of the time. Only during the most severe droughts do the impacts of CPNPP Units 3&4 on lake levels become more pronounced.

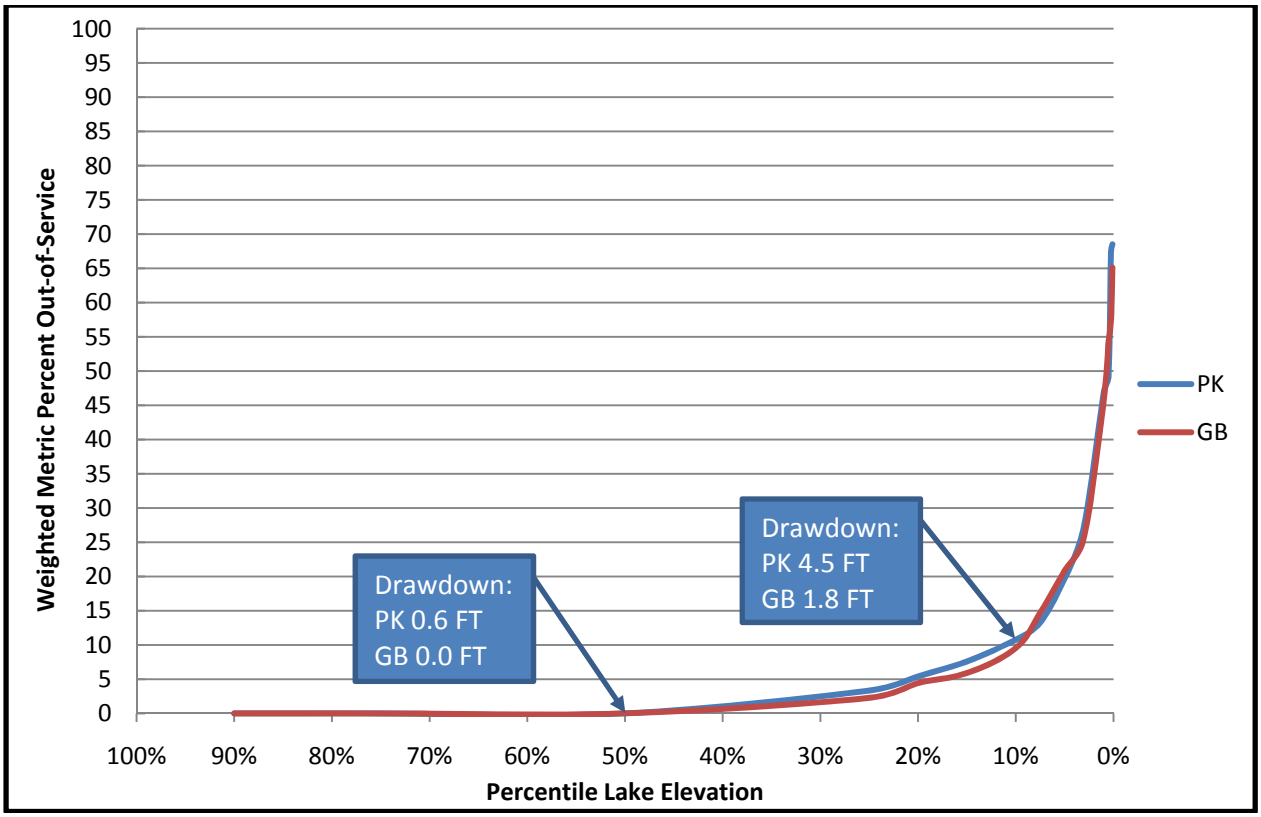

Figure 25. *Zonal Drawdown* 2020 Demands without CPNPP Units 3&4 – Year Round

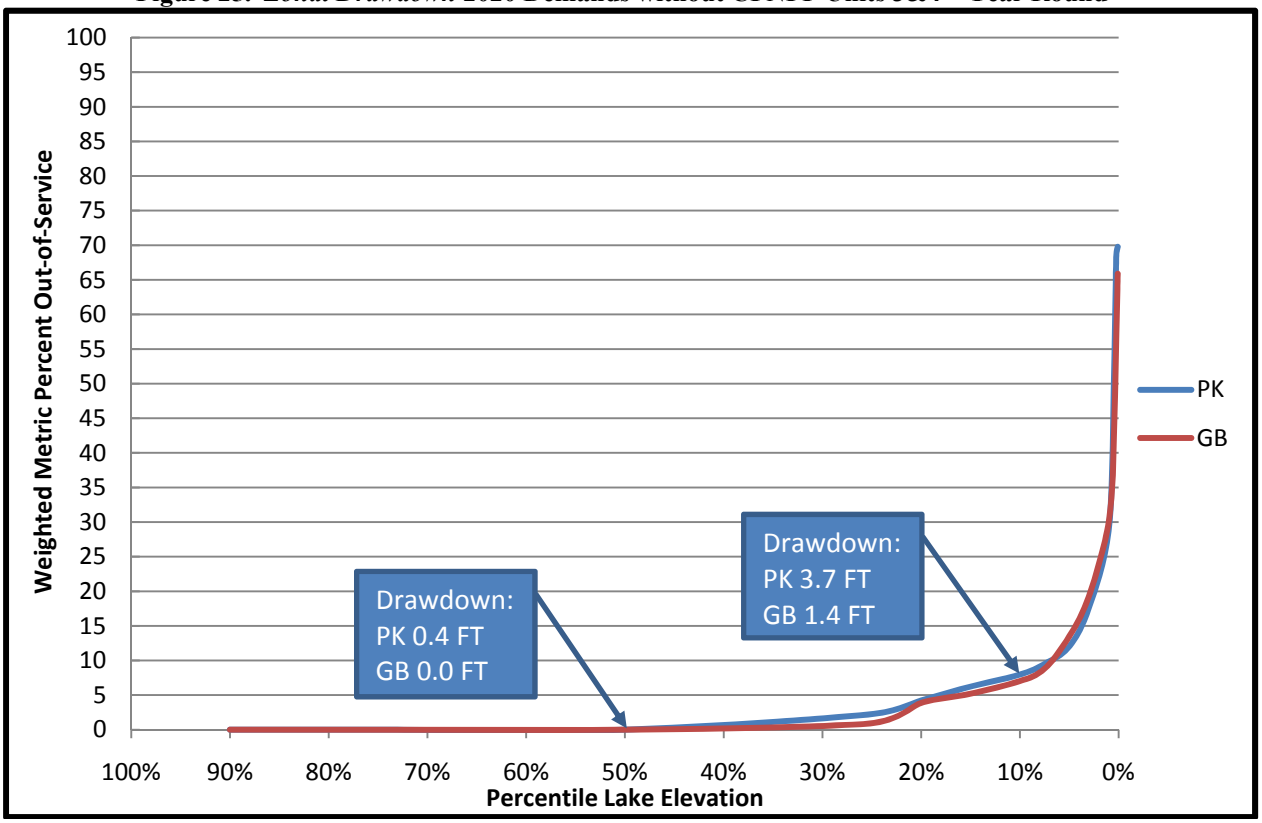

Figure 26. *Zonal Drawdown* 2020 Demands without CPNPP Units 3&4 – Summer Months

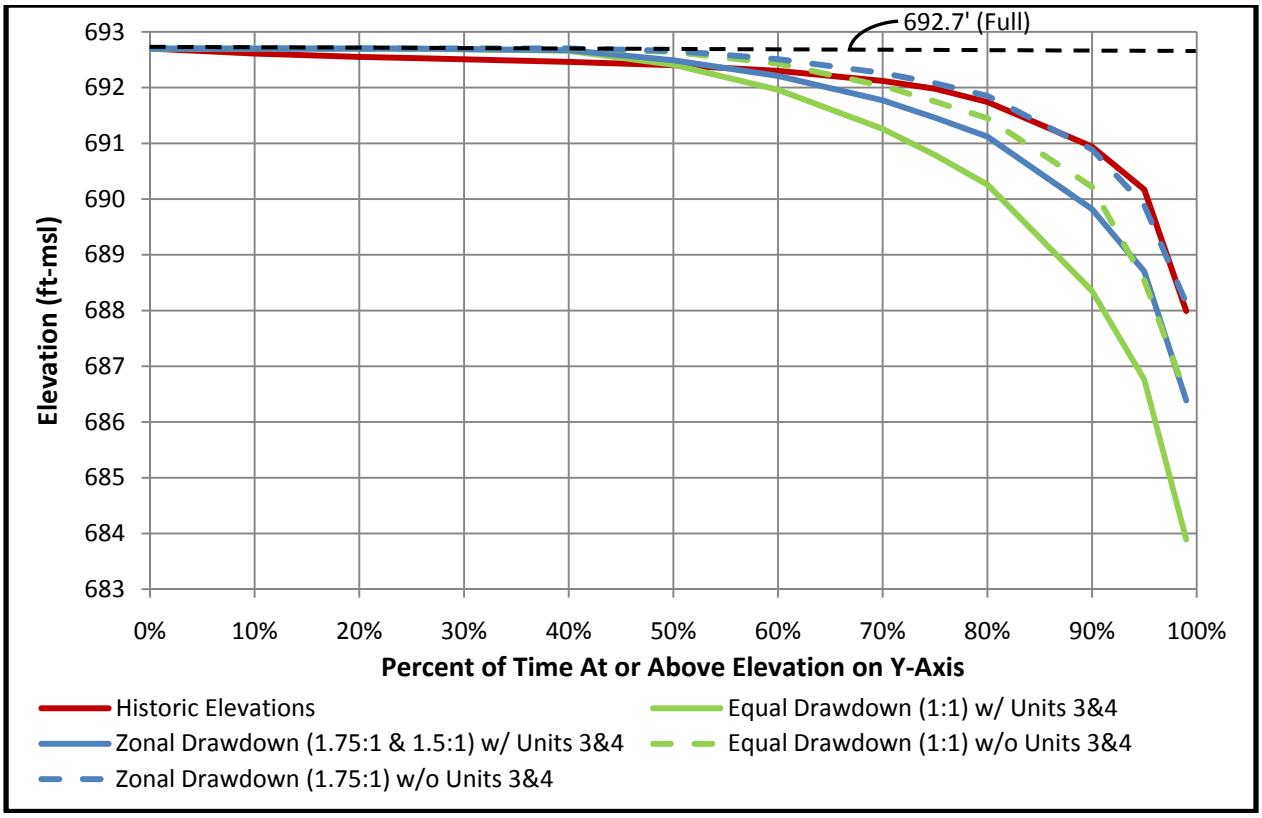

Figure 27. Lake Granbury Frequency Plot 2020 Demands

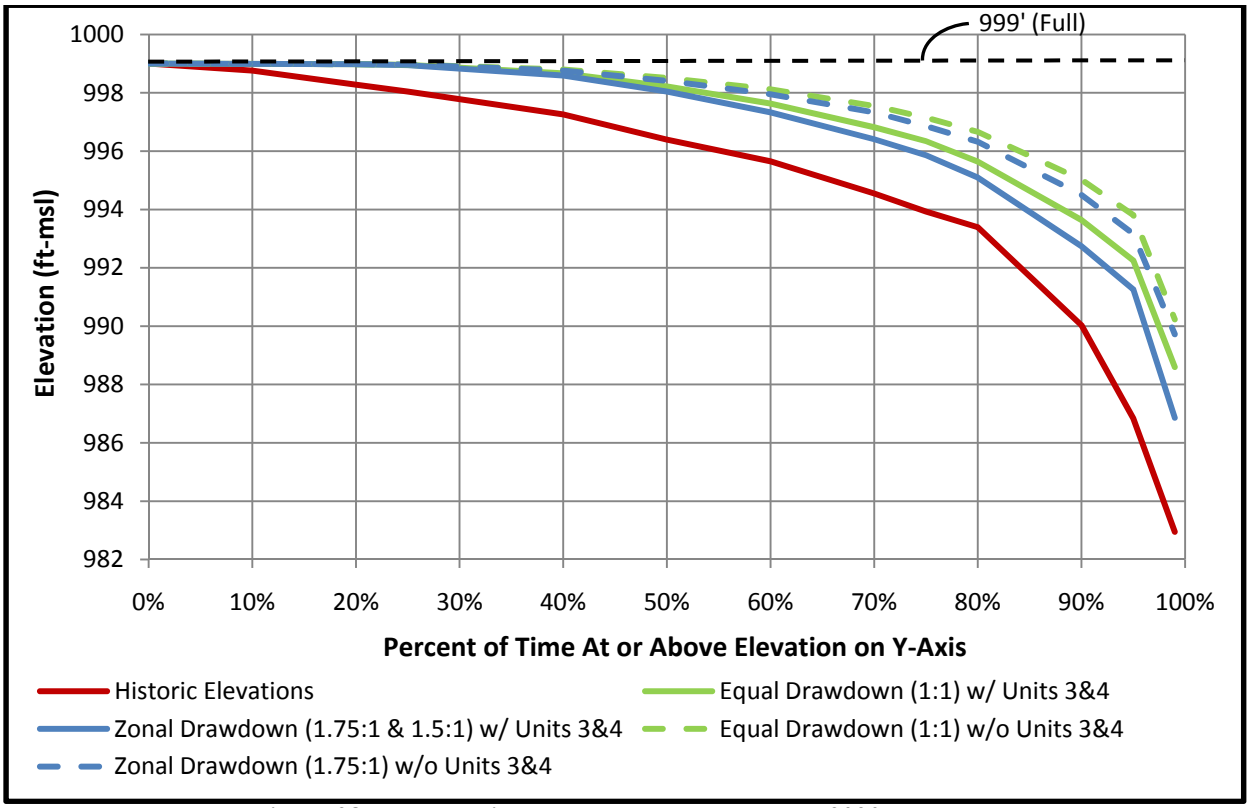

Figure 28. Possum Kingdom Lake Frequency Plot 2020 Demands

5.3 2060 Demands

Simulations were also made for a longer planning horizon out to 2060 demands. By 2060, it was assumed that even if CPNPP Units 3&4 were not in service, that demand would be located in the lower basin below Lake Whitney. Therefore, 2060 demand simulations included combinations with Comanche Peak Units 3&4 (demand at Lake Granbury) and with the Units 3&4 demand located in the central or lower basin (below Lake Whitney). The 2060 demand simulations include the modified Possum Kingdom low flow outlets that enable releases to be made down to elevation 920.0 ft-msl.

5.3.1 Simulation 4: 2060 Demands with Comanche Peak Units 3&4

The first 2060 demands simulation assumed that Comanche Peak Units 3&4 are in service (in addition to Units 1&2). The *Zonal Drawdown* scenario details were determined in an iterative fashion with the critical metric analysis spreadsheet in an attempt to balance impacts between Possum Kingdom Lake and Lake Granbury. For the 2060 demands with CPNPP Units 3&4, a 1.75:1 (PK:Granbury) balancing drawdown at all levels provided the best balance of impacts. Figure 29 shows the corresponding lake levels for the selected *Zonal Drawdown*. Table 15 shows summaries of the simulated results and critical metric impacts for the 2060 demand scenarios with CPNPP Units 3&4. Figure 30 and Figure 31 show the weighted metric percent out-of-service at each lake for the various percentile drawdowns under the *Zonal Drawdown*.

Possum Kingdom Elevation	Granbury Elevation
999	692.7
995.5	690.7
992	688.7
988.5	686.7
985	684.7

Figure 29. Optimized *Zonal Drawdown* Plan for 2060 Demands with CPNPP Units 3&4

Table 15. 2060 Demands with CPNPP Units 3&4 Results

	Possum Kingdom				Granbury				
Alternative	90% Elev.	50% Elev.	10% Elev.	Weighted % of Potential OOS*	90% Elev.	50% Elev.	10% Elev.	Weighted % of Potential OOS	Δ PK-GB Weighted % of Potential OOS
PK 1st	993.32	986.31	964.32	64.37	692.70	692.70	692.37	0.10	64.27
GB 1st	999.00	998.63	990.75	9.13	692.70	690.88	678.51	37.74	-28.61
No Demand	999.00	998.87	996.00	2.03	692.70	692.70	692.42	0.30	1.73
Equal Drawdown	998.98	997.99	992.30	7.20	692.70	692.28	687.28	13.77	-6.57
Zonal Drawdown*	998.98	997.76	991.21	9.20	692.70	692.41	689.14	8.36	0.84

* Zonal Drawdown: 1.75:1 at all elevations
* OOS – Out-of-Service

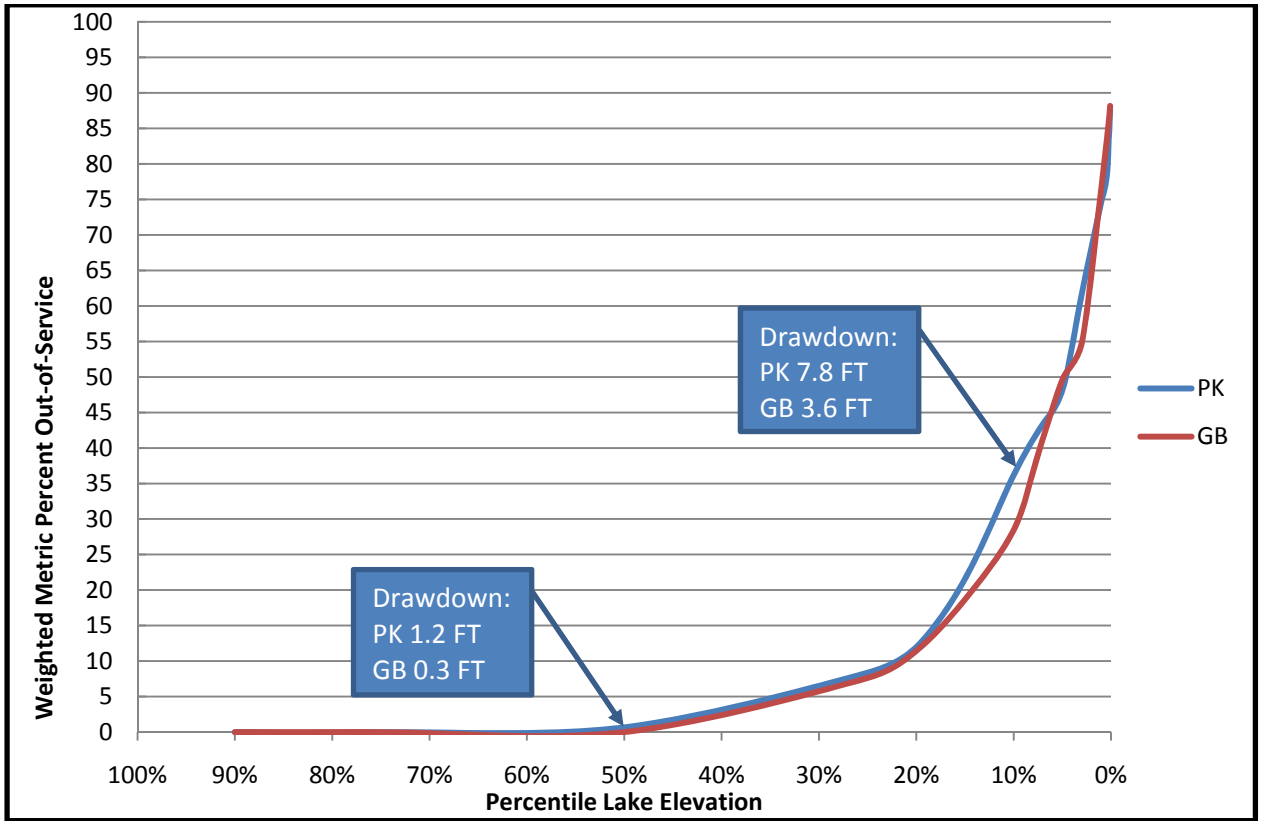

Figure 30. *Zonal Drawdown* 2060 Demands with CPNPP Units 3&4 – Year Round

The *No Demand* scenario for Simulation 4 produces slightly different results than the *No Demand* scenario for Simulations 1 and 2. Although all three simulations contain only the minimum low flow releases with no demands, the variations in the elevation-capacity relationships between current conditions, 2020 conditions, and 2060 conditions changes the storage which impacts the surface area, which impacts the evaporation loss. Under the extreme

PK 1st plan, Possum Kingdom Lake goes dry (elevation 928.0 ft-msl assuming 2060 sedimentation conditions) and cannot meet 2060 demands.

The *Zonal Drawdown* produces a better balance of impacts than the *Equal Drawdown* operation currently employed by BRA. The *Zonal Drawdown* will result in higher lake levels at Lake Granbury on average than the *Equal Drawdown* (nearly 1.9' at the 10th percentile elevation).

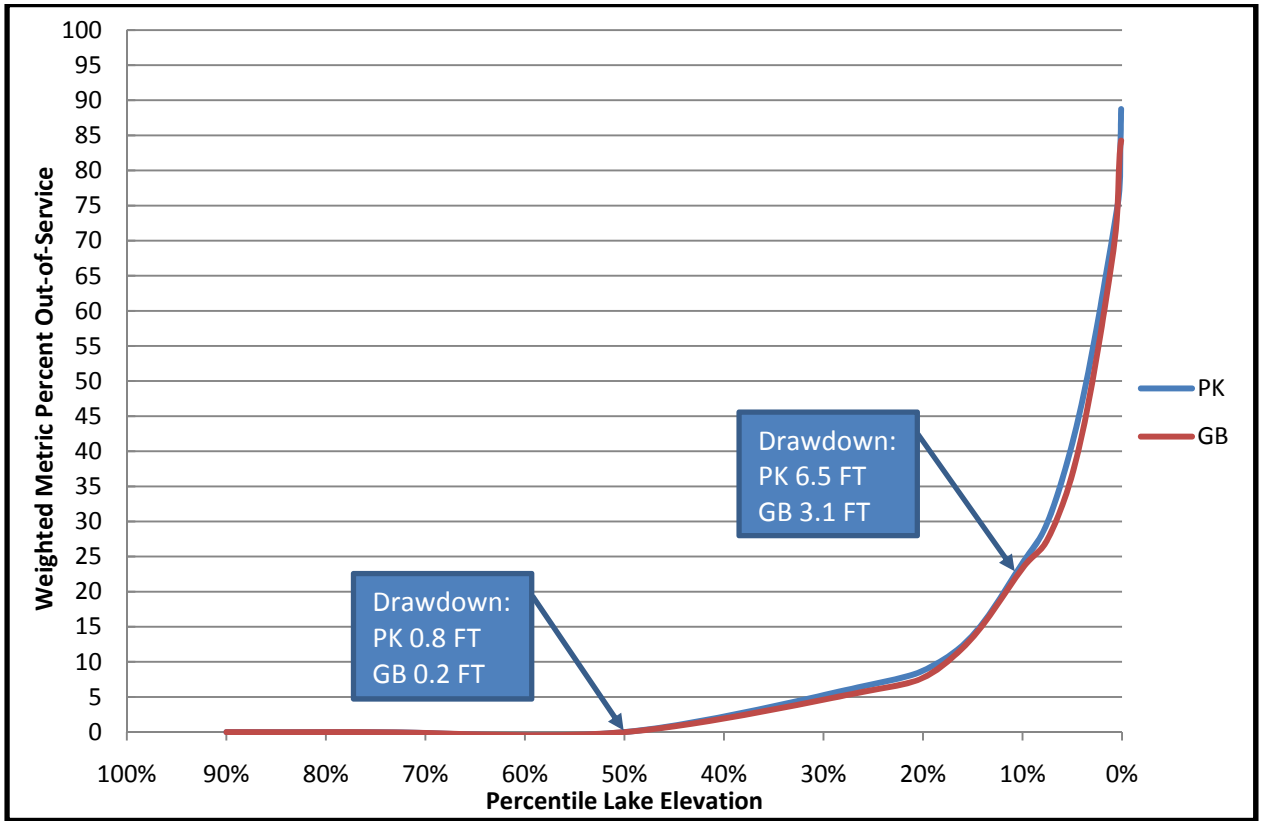

Figure 31. *Zonal Drawdown* 2060 Demands with CPNPP Units 3&4 – Summer Months

Under 2060 demands with Comanche Peak Units 3&4 and the *Zonal Drawdown*, Lake Granbury will remain within 2.0 feet of full and Possum Kingdom Lake will remain within 5.0 feet of full approximately 80 percent of the time over the period-of-record (versus 85 percent of the time for 2020 demands). As seen in Figure 30 and Figure 31 the *Zonal Drawdown* "balanced" the weighted metric percent out-of-service at each lake. Over 80 percent of the time over the period-of-record, less than 12 percent of the weighted features at each lake will be out-of-service with the *Zonal Drawdown*.

5.3.2 Simulation 5: 2060 Demands with CPNPP Units 3&4 Demand Located Downstream of Lake Whitney

The fifth simulation assumed that CPNPP Units 3&4 demand (54,086 acre-feet/year) was located downstream of Lake Whitney and not on Lake Granbury. The *Zonal Drawdown* scenario details were determined in an iterative fashion with the critical metric analysis spreadsheet in an attempt to balance impacts between Possum Kingdom Lake and Lake Granbury. For the 2060 demands

with CPNPP Units 3&4 demand located downstream of Lake Whitney, a 1.75:1 (PK:Granbury) balancing drawdown when Possum Kingdom Lake is above elevation 992.0 ft-msl and 1.5:1 (PK:Granbury) drawdown when Possum Kingdom Lake falls below 992.0 ft-msl provided the best balance of impacts. This is the same drawdown ratio as the 2020 demands with CPNPP Units 3&4. Table 16 shows a summary of the simulated results for the 2060 demand scenarios with CPNPP Units 3&4 demands downstream of Lake Whitney. Figure 32 and Figure 33 show the weighted metric percent of features out-of-service at each lake for the various percentile drawdowns under the *Zonal Drawdown*. Only the *Equal Drawdown* and *Zonal Drawdown* were simulated for this 2060 demand scenario.

Table 16. 2060 Demands with CPNPP Units 3&4 Downstream Results

	Possum Kingdom				Granbury				
Alternative	**90% Elev.**	**50% Elev.**	**10% Elev.**	**Weighted % of Potential OOS***	**90% Elev.**	**50% Elev.**	**10% Elev.**	**Weighted % of Potential OOS**	**Δ PK-GB Weighted % of Potential OOS**
Equal Drawdown	998.98	998.34	992.82	5.92	692.70	692.54	688.09	10.57	-4.65
Zonal Drawdown*	998.98	998.11	991.75	7.81	692.70	692.57	689.48	7.01	0.80

* Zonal Drawdown: 1.75:1 when PK above 992.0 ft-msl. 1.5:1 when PK below 992.0 ft-msl.
* OOS – Out-of-Service

Comparison of Table 16 with Table 15 shows that the 2060 demands with CPNPP Units 3&4 demand downstream results in higher pool elevations at both reservoirs than with the CPNPP Units 3&4 demand applied to Lake Granbury. This is related to moving the demand downstream and having additional local inflows (Lake Granbury to Lake Whitney) available to meet the downstream demand. With the *Zonal Drawdown* for the 2060 Units 3&4 demand downstream of Lake Whitney, both Possum Kingdom Lake and Lake Granbury will have less than 10 percent of weighted metric features out-of-service for over 80 percent of the time over the period-of-record.

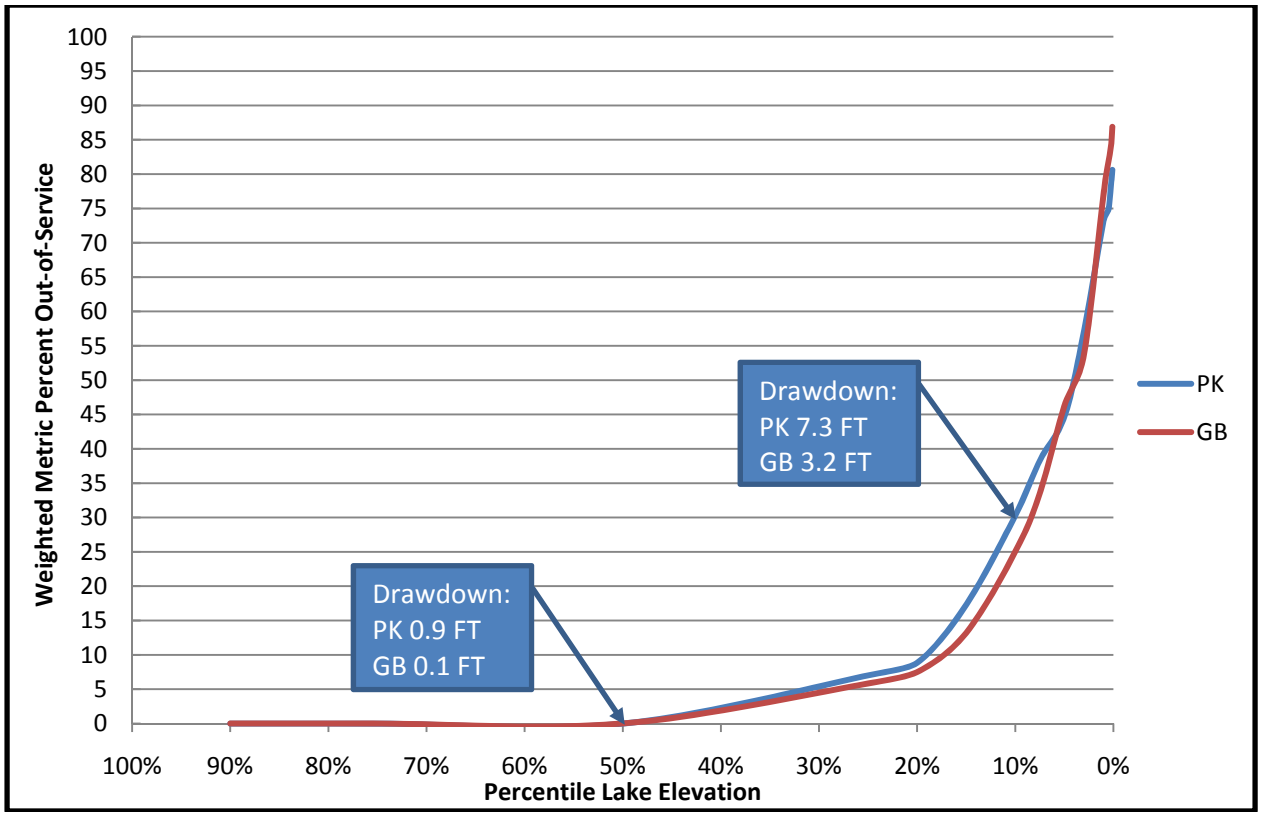

Figure 32. *Zonal Drawdown* 2060 Demands with CPNPP Units 3&4 Downstream – Year Round

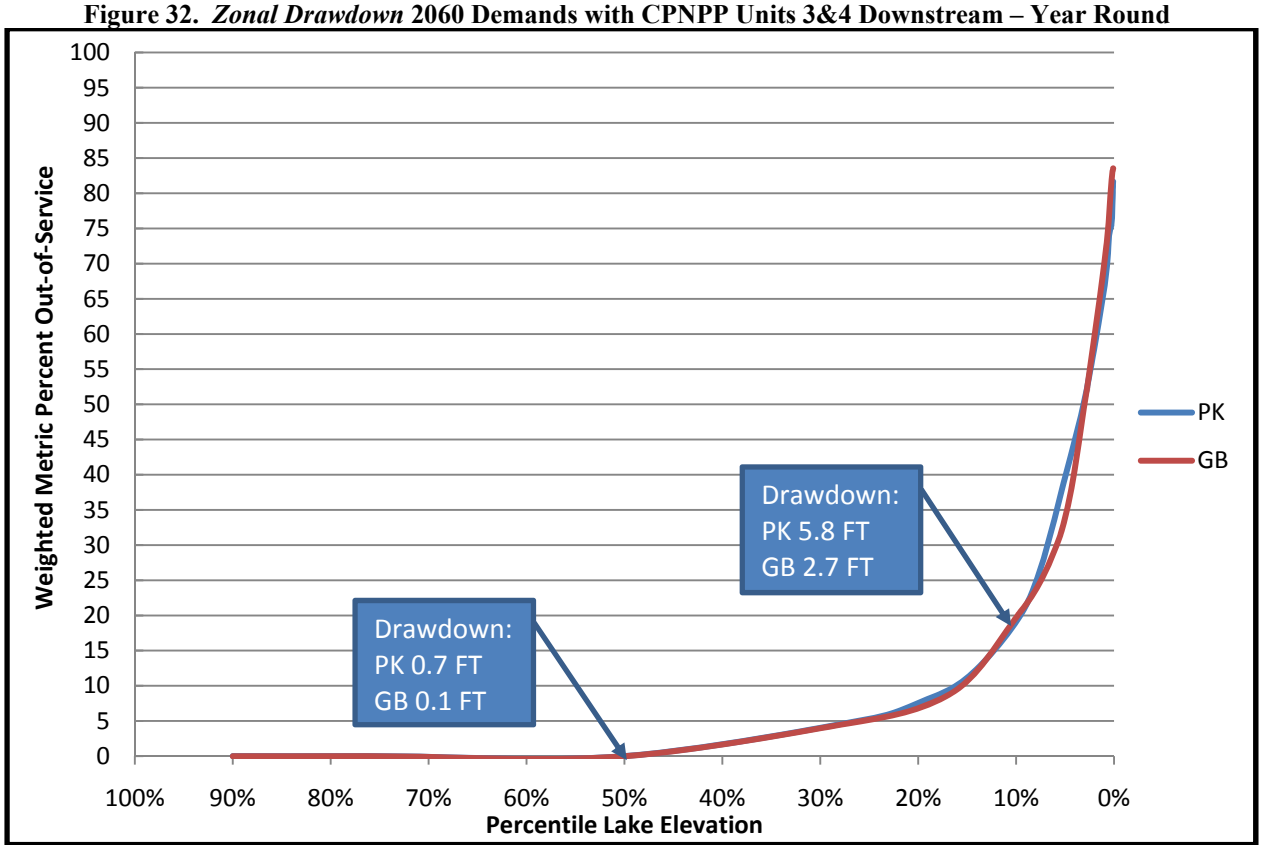

Figure 33. *Zonal Drawdown* 2060 Demands with CPNPP Units 3&4 Downstream – Summer Months

5.4 Impacts Below Reservoirs

In addition to recreational and business interests located along the shoreline of both Possum Kingdom Lake and Lake Granbury, there are recreational interests along the Brazos River between Possum Kingdom and Lake Granbury and Lake Granbury and Lake Whitney. These interests include canoe rentals, tube rentals, campgrounds, and RV parks. The primary purpose of the Water Management Study was to analyze macro balancing of impacts (lake levels) at both Possum Kingdom and Lake Granbury.

The model simulations for this study were executed on a daily time step. Future work (beyond the scope of this current study) may be needed to evaluate when and how these balancing releases from Possum Kingdom and Lake Granbury will be made. Typical questions to be answered as part of future work include:

- Will the release balancing volume be made with a slug or a more gradual, sustained flow?
- How often will the balancing releases be made?
- What day(s) of the week will the release be made?

The *Zonal Drawdown* will release more water from Possum Kingdom Lake (more water in the river) than has occurred since 2007 under the *Equal Drawdown* plan, but will be considerably less than historic hydropower generation for current demand conditions. As an initial look, the annual hydropower releases from Possum Kingdom Lake were compared to the *Zonal Drawdown* simulated daily releases from the HEC-ResSim model as shown in Table 17. In 1990, the hydropower generation at Morris Sheppard Dam was altered due to the FERC license activation and this resulted in an average decrease in the amount of water released from Possum Kingdom Lake compared to years prior to 1990 which are included in the hydropower statistics. With the addition of downstream demand increases in 2020, *Zonal Drawdown* releases will increase as shown in Table 17.

Table 17. Possum Kingdom Average Annual Releases (acre-ft/year)

	Hydropower[1]	Zonal – Current Demands[2]	Zonal – 2020 w/CPNPP Units 3&4 Demands[3]
Minimum	39,999	9,763	8,601
Maximum	713,882	458,737	459,571
Average	333,646	158,505	178,362
Median	304,110	146,684	172,327

[1]Hydropower Historic Releases (1942-2007)
[2]Current Demands with Granbury Releases (Zonal Drawdown 1.75:1 and 1:1) (1939-2009)
[3]2020 Demands with CPNPP Units 3&4 with Granbury Releases (Zonal Drawdown 1.75:1) (1939-2009)

5.5 Recreational Impacts Summary

The goal of the *Zonal Drawdown* was to determine pool level zones and ratio drawdowns at Possum Kingdom and Lake Granbury to "balance" the weighted percent of features out-of-service at both lakes for a range of elevations. These optimized ratios varied dependent on water supply demand conditions. Below is a summary of the recreational impacts as determined by this analysis:

Current Demands

1. The current *Equal Drawdown* plan that has been used by BRA since 2007 when PK hydropower operations were terminated does not provide an equitable impact to features at both lakes. Lake Granbury is impacted more severely than Possum Kingdom Lake in terms of weighted percent of features out-of-service.
2. The *Zonal Drawdown* plan for current demands (1.75:1 above 992.0 ft-msl and 1:1 below 992.0 ft-msl) provides a better "balance" of recreational impacts between the two lakes.
3. The *Zonal Drawdown* plan produces higher elevations at Lake Granbury than the *Equal Drawdown* plan, yet still maintains elevations at Possum Kingdom Lake that are higher than historic elevations with hydropower generation.
4. The *Zonal Drawdown* plan produces slightly higher elevations during the summer months and peak recreational times than year-round averages.
5. The *Zonal Drawdown* plan will keep Lake Granbury within 1.6 feet of full and Possum Kingdom Lake within 4.3 feet of full approximately 90 percent of the time over the period-of-record, and this equates to approximately ten percent of the features at each lake being out-of-service. The *Zonal Drawdown* plan will keep Lake Granbury higher than historic levels over 80 percent of the time, and Possum Kingdom Lake higher than historic levels nearly 100 percent of the time.
6. On average, Possum Kingdom Lake will be over 2.2 feet higher with the *Zonal Drawdown* plan compared to historic levels. The Lake Granbury average elevation with the *Zonal Drawdown* plan will be approximately equal to the historic average from 1970-2009 (692.1 ft-msl).
7. The *Zonal Drawdown* plan will result in less dramatic water level drops (1-2') at Lake Granbury during drought periods compared to the *Equal Drawdown* plan for current demands.
8. The *Zonal Drawdown* plan will keep Possum Kingdom Lake a few inches lower on average than the current *Equal Drawdown* plan, but several feet higher than historic levels during droughts.

2020 Demands

9. In 2020, with CPNPP Units 3&4, the total Upper Brazos River system demand will nearly double from 96,000 acre-feet per year currently to 185,000 acre-feet per year. However, with the *Zonal Drawdown* plan (1.75:1 above 992.0 ft-msl and 1.5:1 below 992.0 ft-msl), elevations at Possum Kingdom Lake will still remain higher than historically with hydropower generation, and Lake Granbury will still remain within 2.0 feet of full approximately 85 percent of the time with less than 15 percent of the features out-of-service.
10. At Lake Granbury, the *Zonal Drawdown* plan with CPNPP Units 3&4 will keep average elevations over the period-of-record (691.8 ft-msl) less than 0.4 feet lower than the *Zonal Drawdown* plan without CPNPP Units 3&4 (692.17 ft-msl). In comparison, if the *Equal Drawdown* plan is maintained in 2020, the average elevation with CPNPP Units 3&4 (691.37 ft-msl) will be 0.6 feet lower than without CPNPP Units 3&4 (691.94 ft-msl).
11. The *Zonal Drawdown* plan will keep Lake Granbury on average 0.44 feet higher over the period-of-record with CPNPP Units 3&4 compared to maintaining the *Equal Drawdown* plan.
12. The *Zonal Drawdown* plan will keep Possum Kingdom Lake approximately 1.5 feet higher on average than historic levels even with increased 2020 demands and CPNPP Units 3&4.
13. If the *Equal Drawdown* plan were continued in 2020 with CPNPP Units 3&4, nearly 10 percent more features would be out-of-service at Lake Granbury as compared to Possum Kingdom Lake over twenty percent of the time. At the 10^{th} percentile elevation, over 25 percent more features would be out-of-service at Lake Granbury than Possum Kingdom Lake. The 10^{th} percentile elevation at Lake Granbury is also 1.5 feet lower under the *Equal Drawdown* plan compared to the *Zonal Drawdown* plan.
14. The *Zonal Drawdown* plan will result in less dramatic water level drops (1.5-2.5') at Lake Granbury during drought periods compared to the *Equal Drawdown* plan for 2020 demands with CPNPP Units 3&4.

5.6 Water Supply Impacts

The methodology and results presented thus far in the report were focused primarily on impacts to lakeside recreational interests and features based on simulated lake elevations. Potential impacts to water supply need to be evaluated as well for the various alternative operating plans and demand scenarios. BRA's mission states that "The Brazos River Authority exists to develop, manage, and protect the water resources of the Brazos River Basin to meet the needs of Texas". Operating plans to appease recreational interests cannot come at the expense of reduced water supply.

In order to evaluate the water supply impacts, the demand scenarios for each simulation were maintained and then an additional constant daily diversion was added at Lake Whitney ("Whitney Max Diversion") to simulate additional water that would potentially be available above and beyond the current, 2020, and 2060 demand scenarios. This diversion was determined in an iterative fashion with the goal of increasing the diversion until the system could no longer meet the demands. In other words, Possum Kingdom went dry and/or Lake Granbury fell below elevation 675.0 ft-msl and could not meet CPNPP demand requirements. This analysis is not an

official system yield simulation but is intended to look at the relative impacts to water supply between the various alternative operating plans and demand conditions.

Table 18 shows the additional Lake Whitney diversion above the given demand conditions that could be met with each operating plan alternative. The yield value includes the given demand scenario (lakeside and downstream) plus the "Whitney Max Diversion" value. For example, the 2020 Demands with CPNPP Units 3&4 simulation includes the 2020 lakeside demands at Possum Kingdom, Lake Granbury (including CPNPP Units 3 and 4), and Lake Whitney; downstream 2020 demands below Lake Whitney, and an additional 297 cfs release from Lake Whitney (215,018 acre-feet/year).

Table 18. Yield Simulations

Alternative	Whitney Max Diversion (cfs)	Yield (ac-ft/year)*
Current Demands Max System Yield		
Max Yield	227.5	260,422
Current Demands		
PK 1st	154.0	207,173
GB 1st	181.5	227,096
Equal Drawdown	219.9	254,916
Zone Scenario (1.75:1>992 and 1:1<992)	227.5	260,422
2020 Demands Max System Yield		
Max Yield	381.3	406,416
2020 Demands with CPNPP Units 3&4		
PK 1st	122.0	272,650
GB 1st	242.0	359,587
Equal Drawdown	299.0	400,883
Zone Scenario (1.75:1>992 and 1.5:1<992)	297.0	399,434
2020 Demands without CPNPP Units 3&4		
Zone Scenario (1.75:1>992)	374.0	401,127
2060 Demands Max System Yield		
Max Yield	266.75	383,670
2060 Demands with CPNPP Units 3&4		
PK 1st	0 (cannot meet current demand scenario)	132,539
GB 1st	52	282,178
Equal Drawdown	188	380,707
Zone Scenario (1.75:1 all zones)	189.55	381,830
2060 Demands with CPNPP Units 3&4 Downstream		
Zone Scenario (1.75:1>992 and 1.5:1<992)	190.1	382,228

* Yield is the given demands (lakeside and downstream) plus the "Whitney Max Diversion."

Below is a summary of the yield simulations:

1. The *PK 1st* operating scenario produces the lowest yield for current, 2020, and 2060 conditions indicating that this operation has a major impact on water supply for the upper Brazos River system. In fact, 2060 demand projections (without additional theoretical demand placed on Lake Whitney) cannot be met with the *PK 1st* operating plan.

2. For 2020 conditions, the yield is not sensitive to the *Equal Drawdown* versus *Zonal Drawdown* plans.
3. For current and 2060 conditions, the *Zonal Drawdown* does generate a slightly higher yield than the *Equal Drawdown* operating plan.
4. The "Whitney Max Diversion" is much lower for the current demands *Equal Drawdown* and *Zonal Drawdown* plans compared to the 2020 demands. At first glance this does not seem logical since the current demands are lower than the 2020 demands, and additional water should be available for the "Whitney Max Diversion" demand. However, this is related to the limited Possum Kingdom outlet capacity for current conditions. Although additional water is in storage at Possum Kingdom, it cannot be released downstream during the drier periods. The 2020 demand simulations utilized a modified Possum Kingdom outlet works configuration to enable water to be released from much lower pool elevations than currently exist.
5. The *Max Yield* simulations utilize Lake Granbury to keep Lake Whitney above 520.0 ft-msl and use Possum Kingdom to keep Lake Granbury above 675.0 ft-msl. These simulations do not include CPNPP Units 3&4. For current demands with the limited Possum Kingdom outlet capacity, Possum Kingdom water is not called on until Lake Granbury is near 675.0 ft-msl for the *Max Yield* simulation. For the *Equal Drawdown* and *Zonal Drawdown*, Possum Kingdom water is used earlier before capacity is limited to supplement Granbury (and Whitney). A plot of Lake Granbury elevations for current demands with *Max Yield*, *Equal Drawdown*, and *Zonal Drawdown*, shows that Lake Granbury approaches 675.0 ft-msl many more times for the *Max Yield* scenario as opposed to the *Equal Drawdown* or *Zonal Drawdown* plan yield alternatives.

5.7 2009 Simulations

In 2009 a severe drought impacted the Brazos River basin. During this same time period, Possum Kingdom Lake hydropower releases had been terminated and BRA was operating PK and Lake Granbury under the *Equal Drawdown* plan. Figure 34 and Figure 35 show what the elevations would have been at each reservoir during 2009 if the *Zonal Drawdown* plan had been in place compared to the historic (observed) elevations. Possum Kingdom would have been approximately 0.75 feet lower on average and Lake Granbury would have been approximately 1.0 feet higher on average with the *Zonal Drawdown* plan.

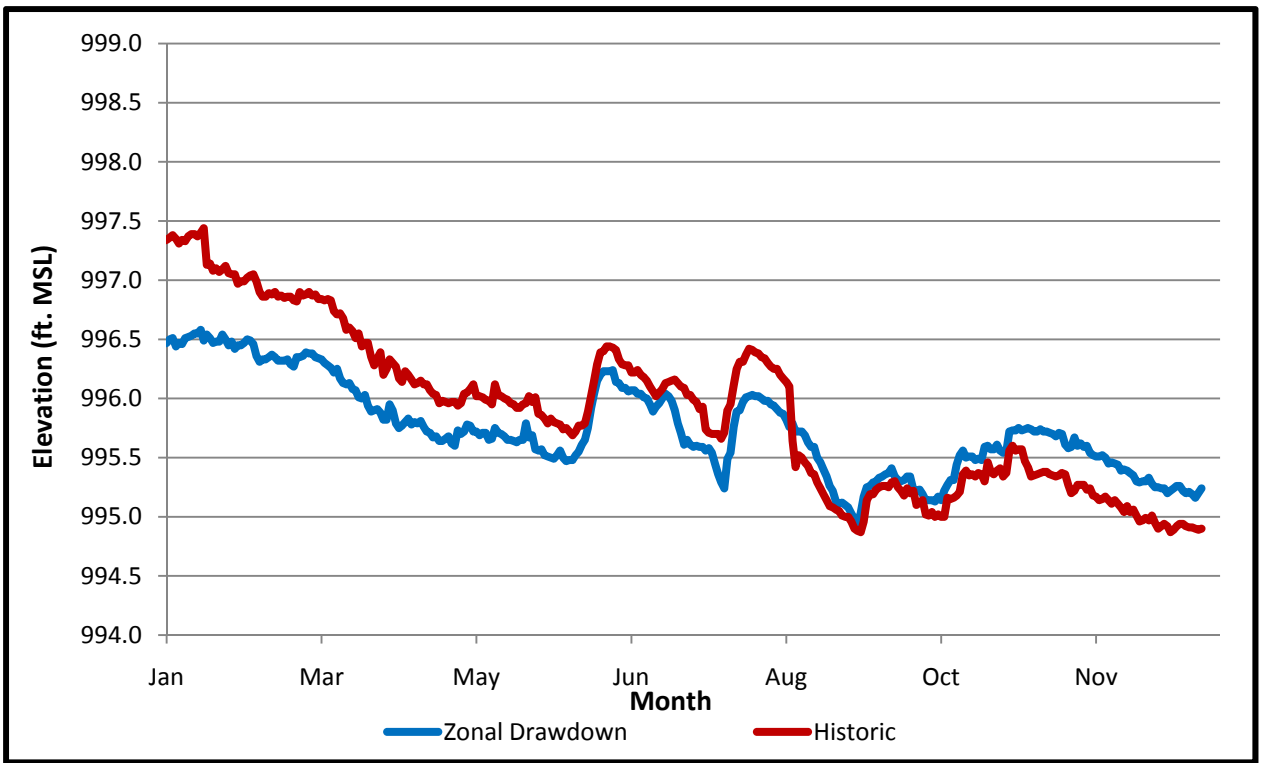

Figure 34. 2009 Simulations at Possum Kingdom Lake

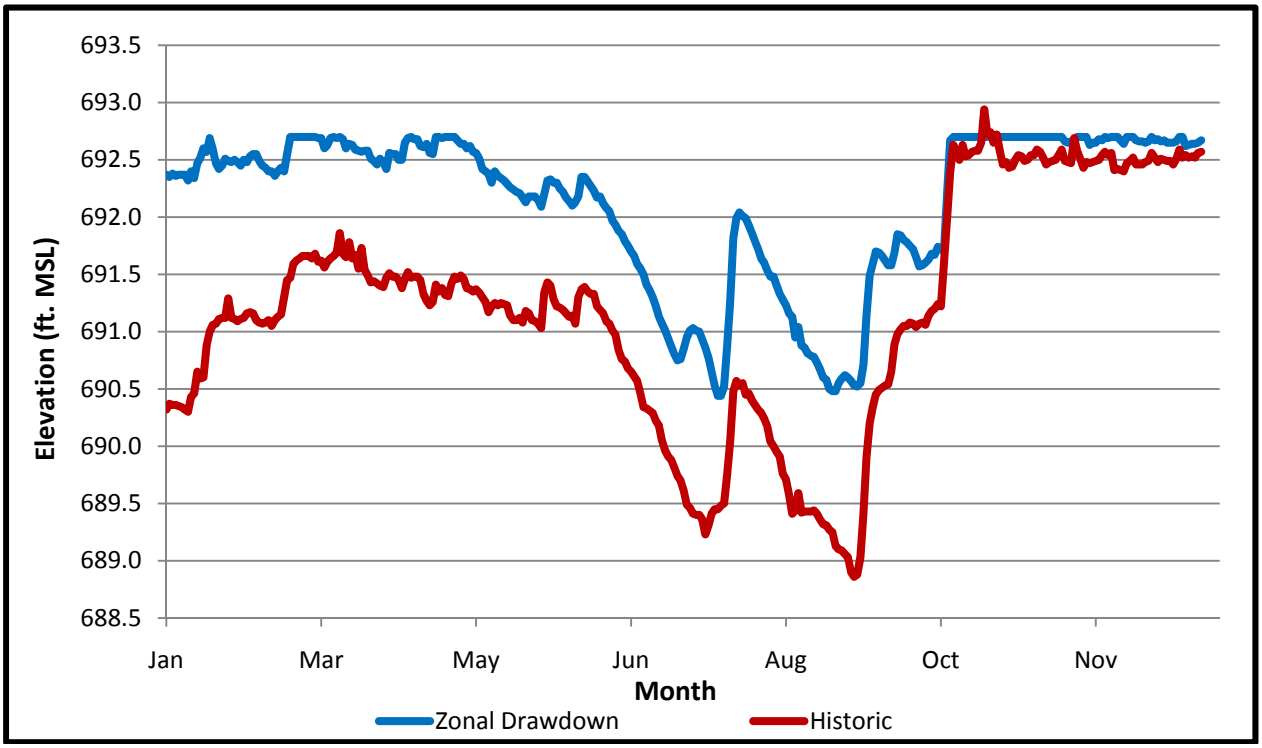

Figure 35. 2009 Simulations at Lake Granbury

5.8 CPNPP Units 3&4 Annual Demand Comparison

The Comanche Peak Nuclear Power Plant (CPNPP), Units 3 & 4, COL Application, Part 3 – Environmental Report (November 2009) references two annual demands for CPNPP Units 3&4. The first is 90,152 acre-feet per year for CPNPP Units 3 & 4 (Section 3.1.3), with 36,325 acre-feet per year returned to Lake Granbury as blowdown, for a consumptive demand of 53,827 acre-feet per year. This demand was utilized for the analyses as part of the Water Management Study as supplied by Luminant in previous studies and reports. The demand is based on a statistical analysis of historical air temperature conditions at the site. The second demand referenced in the *COL Application* is based on other studies, such as the amendment to the Brazos G Regional Water Plan, and states a demand of 103,717 acre-feet per year with a consumptive demand of 61,617 acre-feet per year (42,100 acre-feet per year returned as blowdown) for CPNPP Units 3&4.

The HEC-ResSim model (inflows, evaporation, physical parameters, etc…) developed for the Water Management Study was modified to utilize the 103,717 acre-feet per year demand for CPNPP Units 3&4 rather than the 90,152 acre-feet per year demand. Figure 36 shows the results of that simulation for 2020 conditions with the *Zonal Drawdown* (1.75:1 and 1.5:1) plan. The increased demand results in less than two-tenths of a foot difference in Lake Granbury elevations 90 percent of the time.

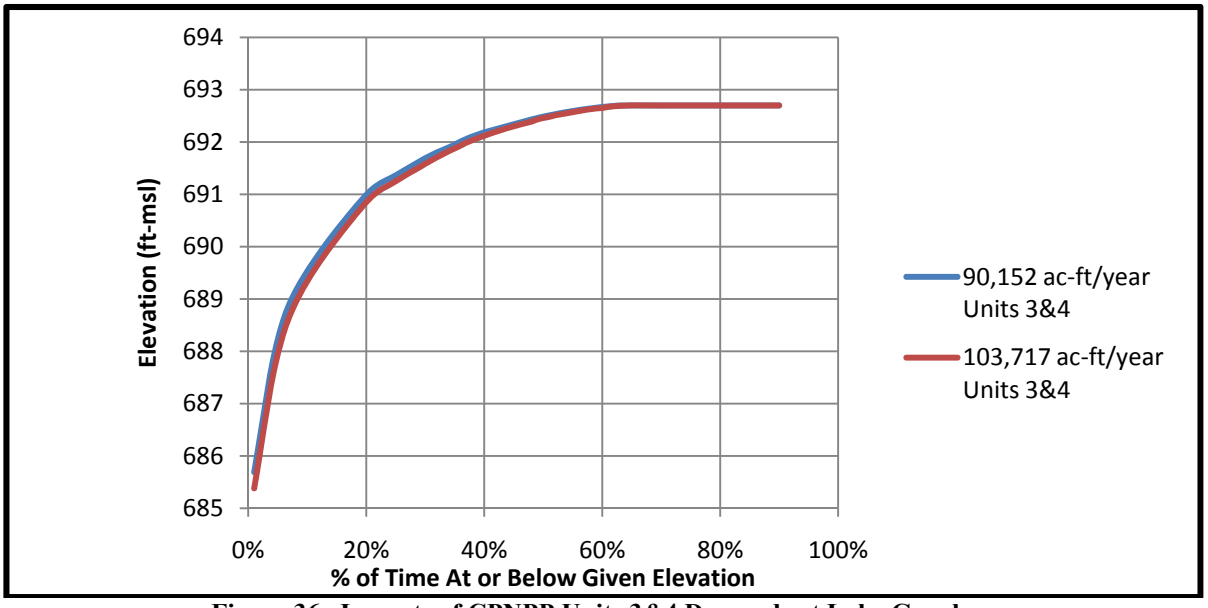

Figure 36. Impacts of CPNPP Units 3&4 Demands at Lake Granbury

6.0 Conclusions and Recommendations

The goal of the Water Management Study is to formally evaluate and develop a Water Management procedure for the PK-Granbury-Whitney portion of the BRA reservoir system that meets water supply needs and considers major items and issues affected by lake levels and water supply management. The study was divided into four main components: (1) development of critical metrics and constraints of features in the reservoir system affected by lake level variations and lake level management; (2) development of historical period-of-record input data and simulation of alternative lake level management procedures/guidelines; (3) comparison of critical metric impacts to simulation output and refinement of alternative management procedures; and, (4) public involvement and stakeholder communication process.

Extensive field work, inventorying, and data collection were used to determine lake bottom elevations at over 1,600 features (docks, ramps, marinas, etc.) on Possum Kingdom Lake and nearly 3,500 features on Lake Granbury. This analysis indicated that the *Equal Drawdown* plan (currently in use by BRA for the upper Brazos River system since 2008) does not produce "equal" impacts to water features at Possum Kingdom Lake and Lake Granbury as shown in Figure 37. A higher percentage of features are out-of-service at Lake Granbury for an equal drawdown level than at Possum Kingdom Lake.

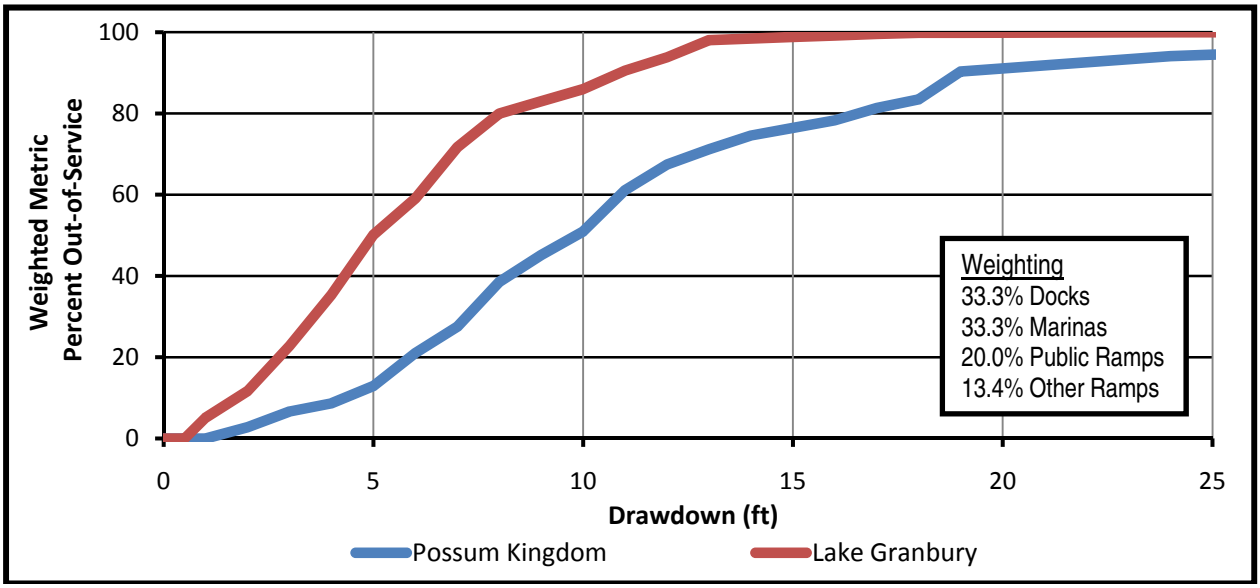

Figure 37. Weighted Percent of Features Out-of-Service

The critical metrics/features data at each lake were combined with reservoir system simulations spanning from 1939-2009 with various water supply demand scenarios and alternative Water Management strategies. Based on these results, a *Zonal Drawdown* plan was developed with a goal of balancing the percent of features out-of-service at each lake for a range of elevations (drawdowns). Conclusions from the study suggest operating the system dependent upon "lake depth zones" (*Zonal Drawdown*) can produce a more equitable balance of impacts at both PK and Granbury without sacrificing the water supply yield of the upper Brazos River system. Based on near-term projected demands before Units 3 and 4 are added at Comanche Peak, a

1.75:1 (PK:Granbury) drawdown ratio is recommended when PK's lake elevation is above 992.0 ft-msl. In this scenario, releases would be made as needed from PK so that for every 1 foot of drawdown experienced at Lake Granbury, a corresponding 1.75 feet of drawdown would be experienced at PK. Based on the metric analysis and model output, this scenario provides a "balanced" impact (percent of time facilities out-of-service) between PK and Granbury. When PK's lake elevation falls below 992.0 ft-msl, the drawdown ratio would change to 1:1.

Based on this *Zonal Drawdown* plan and current demand conditions, Lake Granbury will be on average approximately equal to historic levels and "higher" 50 percent more of the time than if the *Equal Drawdown* plan were maintained. Possum Kingdom Lake with the *Zonal Drawdown* plan will be on average over 2.2 feet higher than historic levels with hydropower generations.

Conclusions for future demand conditions, including the addition of Units 3 and 4 at Comanche Peak, indicate that the 1.75:1 drawdown ratio is still appropriate for balancing impacts between the two lakes when PK's lake elevation is above 992.0 ft-msl. However, when PK's lake elevation falls below 992.0 ft-msl a drawdown ratio between 1.5:1 (PK:Granbury) and 1.75:1 (PK:Granbury) will be required to balance impacts.

For 2020 demands with CPNPP Units 3 and 4, the *Zonal Drawdown* plan will result in Lake Granbury being "lower" than historic levels approximately 40 percent of the time and on average approximately 0.25 feet "lower" than historic levels. However, the *Zonal Drawdown* will keep Lake Granbury on average 0.44 feet "higher" in 2020 with CPNPP Units 3 and 4 than if the *Equal Drawdown* plan were maintained. The *Zonal Drawdown* plan will also lessen the impacts during dry periods by 1.5 to 2.5 feet compared to the *Equal Drawdown* plan. At Possum Kingdom Lake, the *Zonal Drawdown* plan will still keep average elevations over 1.4 feet higher with the increased downstream demands compared to historic averages with hydropower generation.

A series of presentations were made to elected officials and the public beginning in February 2011. Presentations were made to the state legislative staffs (Senator Birdwell, Senator Estes, and Representative Keffer) and local leadership in Granbury, Hood County, and Palo Pinto County. A public meeting was held on March 28, 2011 in Granbury and on March 29, 2011 in Graford to discuss the study results with local stakeholders. Transcripts from these public meetings can be found in Appendix E. The recommended operational procedure (*Zonal Drawdown*) was presented to the BRA board at the April 18, 2011 board meeting, and a resolution was passed to adopt the *Zonal Drawdown* procedure as shown in Appendix F and G. The *Zonal Drawdown* plan will serve as a basis for BRA reservoir operations from PK, Granbury, and Whitney in the PK post hydroelectric power generation era. The proposed operational procedure will enable BRA to meet contractual water supply obligations while balancing adverse impacts that may be experienced at the lakes during dry times.

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Appendix A

APPENDIX A
CRITICAL METRICS AND CONSTRAINTS
List of Items with Associated Metrics that are Potentially Affected by Lake Level Management

Description	**Metric/Deliverable**			**Metric Determination Method**	Metric Needed at these lakes:			**Assumptions**
					PK	**Gby**	**Wh**	
Items for Consultant to Measure and Report:								
Municipal intakes - Determine the number of municipal intakes and their relative location on the lake.	**Number of intakes:_____**	**Relative Location**	**GIS feature w/ approximate intake location**	Utilize BRA provided permits/records	X	X	X	Halff will plot and document the municipal intakes as provided by BRA permit records. No additional research/data collection will be required.
Industrial intakes - Determine the number of industrial intakes and their relative location on the lake.	**Number of intakes:_____**	**Relative Location**	**GIS feature w/ approximate intake location**	Utilize BRA provided permits/records	X	X	X	Halff will plot and document the industrial intakes as provided by BRA permit records. No additional research/data collection will be required.
Irrigation intakes - Determine the number of irrigation intakes and their relative location on the lake.	**Number of intakes:_____**	**Relative Location**	**GIS feature w/ approximate intake location**	Utilize BRA provided permits/records	X	X	X	Halff will plot and document the irrigation intakes as provided by BRA permit records. No additional research/data collection will be required. These are large irrigation contracts/intakes, and this does not include individual private lawn irrigation intakes/pumps.
Hydraulic Capacity - Determine hydraulic capacity of the low flow outlets both at PK and Granbury. What are the critical elevations in which hydraulic capacity is compromised?	**Critical/invert elevations** (ft-msl)	**Hydraulic capacity** (cfs)		Research has already been conducted at PK in determining this information. Develop similar information for Granbury. BRA will provide results from FNI De Cordova Bend Low Flow Contract.	X	X		Halff will take available data/information provided by BRA and document. No additional calculations, research, or analysis will be required.
Boat docks - Determine the number of both fixed and floatable docks as well as whether they are residential or commercial. Determine at what elevation where the fixed docks become inoperable.	**Number of fixed (res./com.) docks: _____ Number of floatable docks (res./com.): _____**	**Lake elevation in which fixed (and possibly floating) docks (res./com.) become inoperable: _____**	**GIS feature w/ location**	GIS tools, aerial imagery, TWDB volumetric survey, and BRA dock permits database. Limited field measurements.	X	X		Halff Associates will classify docks as private/public and fixed/floating using the latest available GIS imagery. Bottom elevations of the lake at the docks will be estimated using the TWDB volumetric survey data and GIS tools. Based on the initial office work, a few selected areas (not individual docks) may be measured in the field for further verification as part of the launch/ramp data collection efforts within the 5-day time window at each lake.

Description	Metric/Deliverable		Metric Determination Method		Metric Needed at these lakes:			Assumptions
					PK	Gby	Wh	
Items for Consultant to Measure and Report:								
Boat launch/ramp access - Determine the numbers of public and private boat launches/ramps and the elevation at which each becomes inoperable.	**Number of public boat launches:** _____ **Number of private boat launches:** _____	**Bottom depth of launches and ramps:** _____ **Approximate location of end of ramp/launch**	**GIS feature w/ location and elevation**	Field measurements required for launch/ramp bottom depths using range pole and GPS equipment. BRA lake rangers will also provide some information.	X	X	X	Private ramps do not include individual homeowners' ramps/launches. Private refers to HOAs and other larger private ramps. Assumes 40-50 ramps/launches at Granbury and 50-60 ramps/launches at PK. Assumes Halff Associates will spend 5 days (up to 8 hours per day) riding with BRA lake rangers at both Lake Granbury and Possum Kingdom Lake. BRA will provide boat and driver. Halff Associates will measure elevation (depth) and extents of ramps/boat launches using range pole and GPS equipment provided by Halff. Boat launch and ramp access at Lake Whitney will be based on USACE website information and call to USACE. No field work associated with Lake Whitney.
Canals - Determine the numbers of residential and commercial canals, the bottom depth of the canals, and how many docks/lots are located on the canals.	**Number of docks on canals (Res./Com.):** _____	**Bottom depth of canals:** _____	**Number of lots (businesses) located on the canals:** _____	Aerial imagery, 2007 Brown and Gay Canal study, TWDB volumetric survey, City of Granbury plans, and county parcel data. Limited field measurements.	X	X		Halff Associates will count the number of canals and classify as public/private. Halff will count the number of properties and boat docks along each canal. Halff will utilize TWDB volumetric surveys and 2007 Brown and Gay study to determine average canal depths. Limited field measurements may be made for further verification as part of the launch/ramp data collection efforts within the 5-day time window at each lake. Halff will prepare a map showing the location and data source (field measurement, TWDB volumetric survey, 2007 Brown and Gay study) of canal measurements.
Downstream Businesses - Determine the number of businesses between PK and Granbury and Granbury and Whitney that rely on the river flows for business (canoe rentals, tube rentals, etc...).	**Number** of businesses below each lake. _____		**GIS feature**	Aerial photography, BRA rangers info, Chamber of Commerce	X	X		Halff Associates will determine the approximate number/type of downstream businesses that rely on the river flows.

Description		Metric/Deliverable		Metric Determination Method	Metric Needed at these lakes:			Assumptions
Items for Consultant to Measure and Report:					**PK**	**Gby**	**Wh**	
Lakefront Properties - Determine the number of both residential and commercial properties that front each lake.	**Number** of total residential and commercial lakefront properties/lots at each lake. _____				X	X		Halff Associates will determine the approximate number of lakefront properties (commercial/residential) around each lake.
Lakeside Businesses - Determine the number of fuel stations, restaurants, conventions, marinas, ski boat rental, fishing outfits, etc. located on each lake.	**Number of businesses and type of business:** _____		**GIS feature**	County parcel maps, aerial photography, Chamber of Commerce, and BRA lake ranger information. BRA will provide available marina information (size, number of slips, etc…)	X	X		Halff Associates will determine the approximate number/type of lake side businesses that rely on lake traffic around each lake.
Lakeside/downstream beaches, swimming areas, parks/camping - Determine the number of recreational areas both lakeside and downstream of each reservoir	**Number** of recreational areas (lakeside and downstream). _____		**GIS feature**	Aerial imagery, Chamber of Commerce, and BRA lake ranger information	X	X	X	Halff Associates will determine the approximate number/type of recreational areas on and downstream of each lake.
Water Supply - Determine firm yield of the system of reservoirs (PK-Granbury-Whitney), evaporative losses and spills under differing lake level management strategies.	Given a management strategy and known constraints what is the yield of the system (acft/yr), what are the evaporative losses (acft), and what is the volume of spills (acft) over the period of record.			This will involve a sensitivity analysis on the different operating policies with varying constraints (i.e. max. yield, drawdown target, zones or index).	X	X		Halff Associates will not quantify water supply related metrics.

Appendix B

APPENDIX B: GIS FEATURE CLASS ATTRIBUTE FIELDS

Feature: Water Supply Intakes

Field Name	Description
TWC_CON_NO	Unique identifier
NAME_ID	Name of Intake
NAME_MAIL	Name of Company / Mailing Name
ADDRESS_1	Address Part 1
ADDRESS_2	Address Part 2
TYPE_USE	Type of Intake: Municipal, Irrigation, Industrial, Mining
ANN_AMOUNT	Annual Amount Used
LON_DEC	Longitude of Diversion Point
LAT_DEC	Latitude of Diversion Point
UP_SHEF	Gage Data
DN_SHEF	Gage Data
RESERVOIR	Reservoir Name
CONTACT	Contact person
PHONE	Contact Phone Number
NUM_INTAKES	Number of intakes
INTAKE_ELEVATION	Elevation of intake(s)

Feature: Boat Ramps/Launches

Field Name	Description
EASTING	Easting of Boat Ramp
NORTHING	Northing of Boat Ramp
PHOTO	Name of photo of boat ramp
COMMENT	Name of ramp; generally subdivision related
GPS_DATE	Date GPS point was taken / field work was performed
GPS_TIME	Time GPS point was taken / field work was performed
RAMP_ELEV	Adjusted boat ramp elevation
BOAT_LAUNCH	Public / Private boat ramp
GAGE	USGS Gage used to convert water depth to lake bottom elevation

Feature: Lakeside Recreational Areas

Field Name	Description
REC_TYPE	Type of recreation, swimming, camping, etc
NOTES	Notes about recreation points, including name and amenities when available

Feature: Lakeside Properties

Field Name	Description
PROP_TYPE	Type of property: Residential, Commercial, BRA, Lake Granbury, etc
NOTES	General notes about property if needed
OWNER	Owner as specified in available parcel data

Feature: Canals – Lake Granbury

Field Name	Description
BG_AV_DEPTH	Brown and Gay Average Depths, obtained from *2007 Canal Specification Project*
COMMENT	Comment from field work or digitized from Brown and Gay study
GPS_DATE	Date GPS point was taken, N/A to Brown and Gay points
GPS_TIME	Time of day GPS point was taken
EASTING	Easting of the point.
NORTHING	Northing of the point.
SUBDIVISION	Name of Canal System or Subdivision
TYPE	Type of Canal point, Residential or Commercial. Only Commercial is a Marina.
PHOTO	Network path to photo of canal taken in the field
GAGE_SITE	Lake level USGS Gage used to develop lake bottom elevation
MEASURED_CANAL_ELEV	Canal bottom elevation

Feature: Lakeside Businesses and Downstream Businesses

Field Name	Description
CATEGORY	Listing of all services/categories associated with the business
BUSINESS_NAME	Name of business
ADDRESS	Street Address of Business
CITY__STATE__ZIP	City, State and Zip Code of Business
WEBSITE	Website of business
LAKE_ACCESS	Business service related to the lake
ONLAKE	Is the business on the lake?
BUSINESS_TYPE	General category of business used for classification: Marina, Retail, Boat Repair, Storage, etc

Feature: Boat Docks, Marinas, and Fuel Stations – Lake Granbury

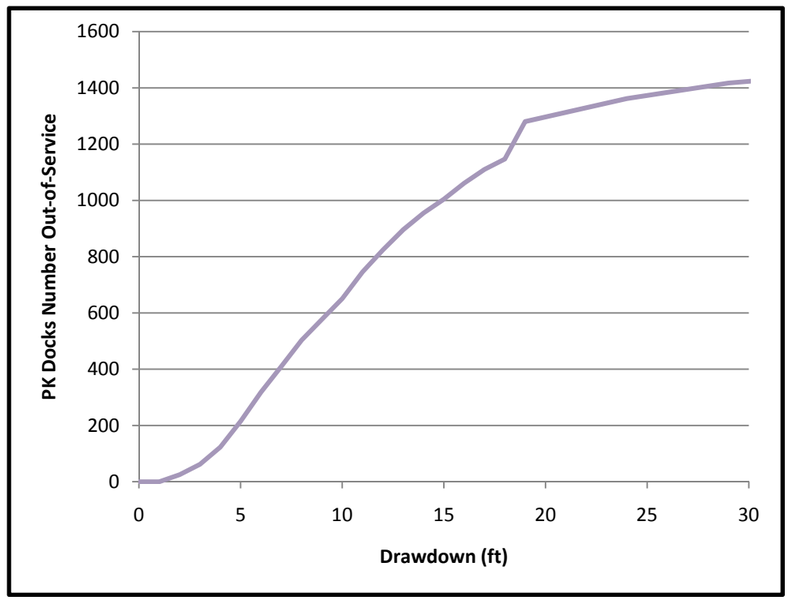
Field Name	Description
DOCK TYPE	Type of Feature: Floating / Fixed, Commercial / Residential, Marina, Fuel Stations
NOTES	Miscellaneous Notes regarding dock, default is owner information
SUBDIVISION	Subdivision for the Canal based features
FIELDWORK_TIMESTAMP	Date and time of field work completed on this feature
GAGE	USGS Gage used to develop lake bottom elevation
DEPTH_FIELDWORK	Depth of dock as obtained with field work
DEPTH_CANAL	Depth of dock as obtained using the Canal Method
DEPTH_MP_INTERP	Depth of dock as obtained using the Mass Points Interpolation Method
DEPTH_MANUAL	Depth of dock as obtained by manually assigning a depth
DEPTH_FINAL	Final depth to perform analysis with, chosen from other "depth_" fields
DEPTH_FROM	Which field "Depth_Final" is from (Method used to develop "Depth_Final")

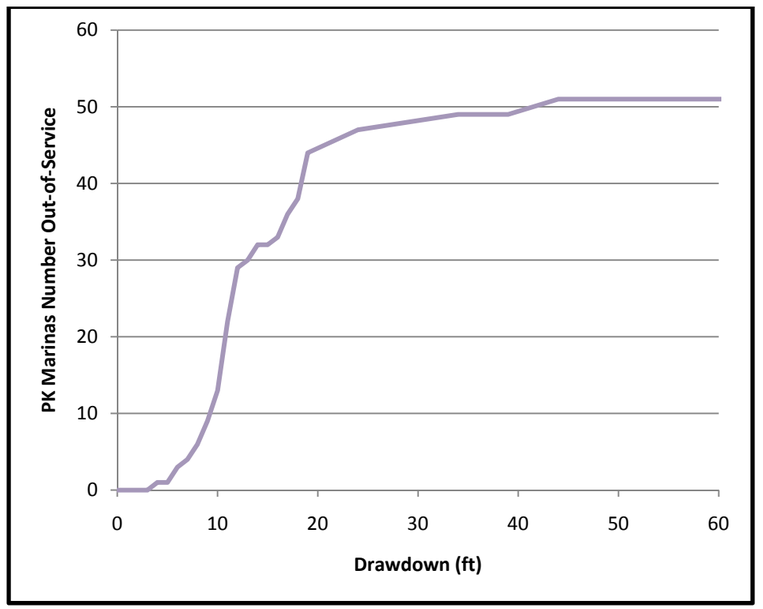
Feature: Boat Docks, Marinas, and Fuel Stations –Possum Kingdom Lake

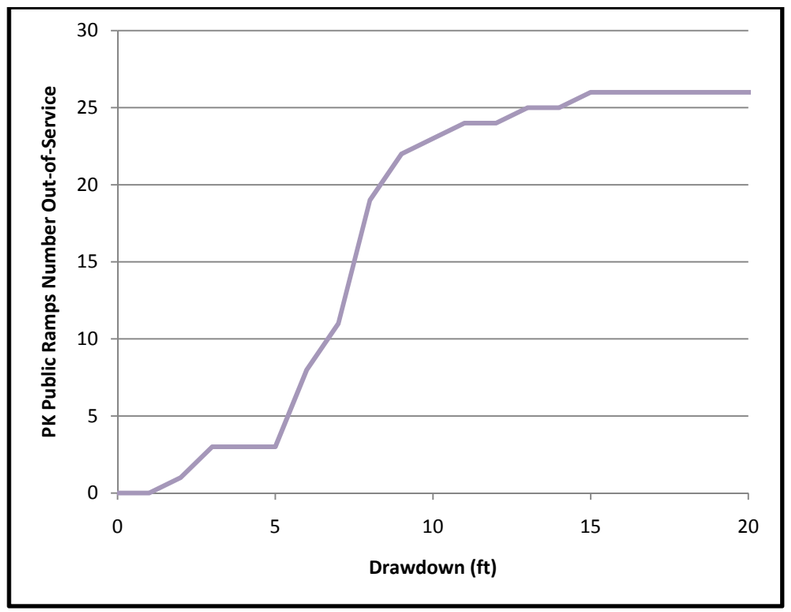
Field Name	Description
DOCK TYPE	Type of Feature: Floating / Fixed, Commercial / Residential, Marina, Fuel Stations
NOTES	Miscellaneous Notes regarding dock, default is owner information
BRA_SURVEY	BRA Dock Inventory survey measurement
FIELDWORK_TIMESTAMP	Date and time of field work completed on this feature
GAGE	USGS Gage used to develop lake bottom elevation
DEPTH_FIELDWORK	Depth of dock as obtained with field work
DEPTH_TIN	Depth of dock as obtained using the TWDB TIN
DEPTH_MANUAL	Depth of dock as obtained by manually assigning a depth
DEPTH_FINAL	Final depth to perform analysis with, chosen from other "depth_" fields
DEPTH_FROM	Which field "Depth_Final" is from (Method used to develop "Depth_Final")

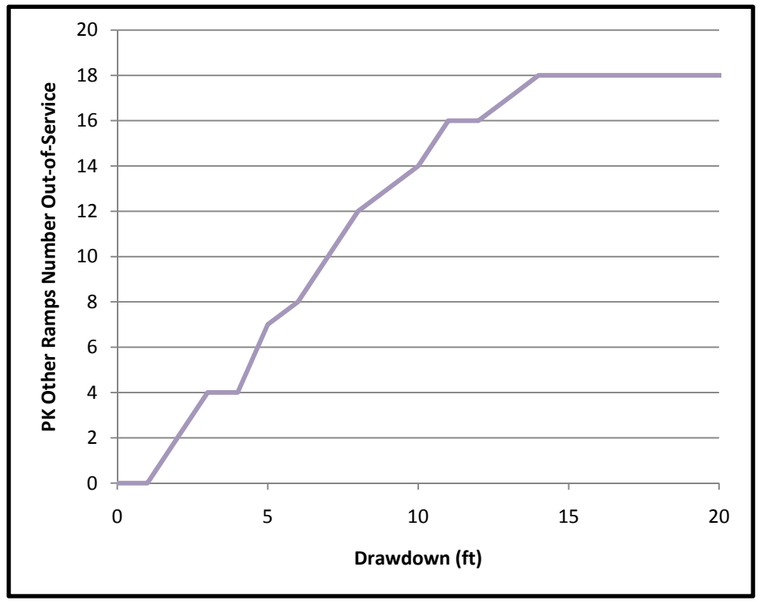
Appendix C

Possum Kingdom Out of Service Charts (2' Minimum Water Depth)

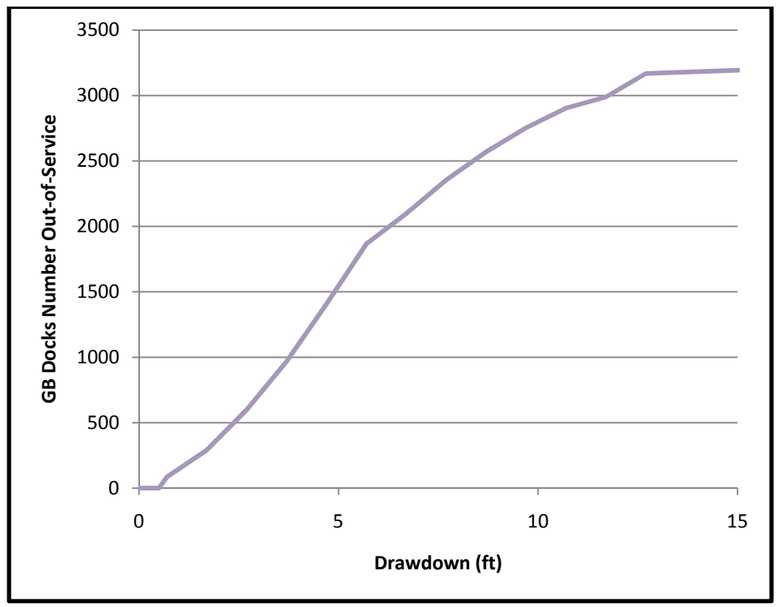


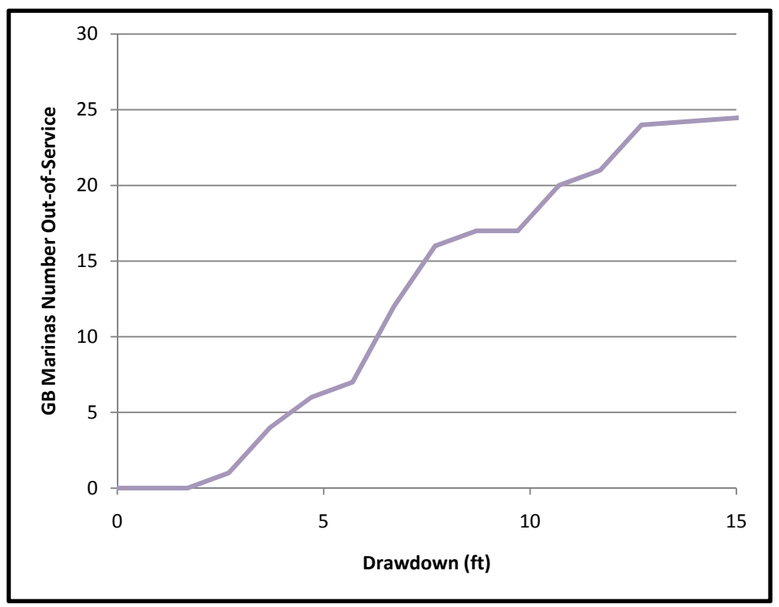


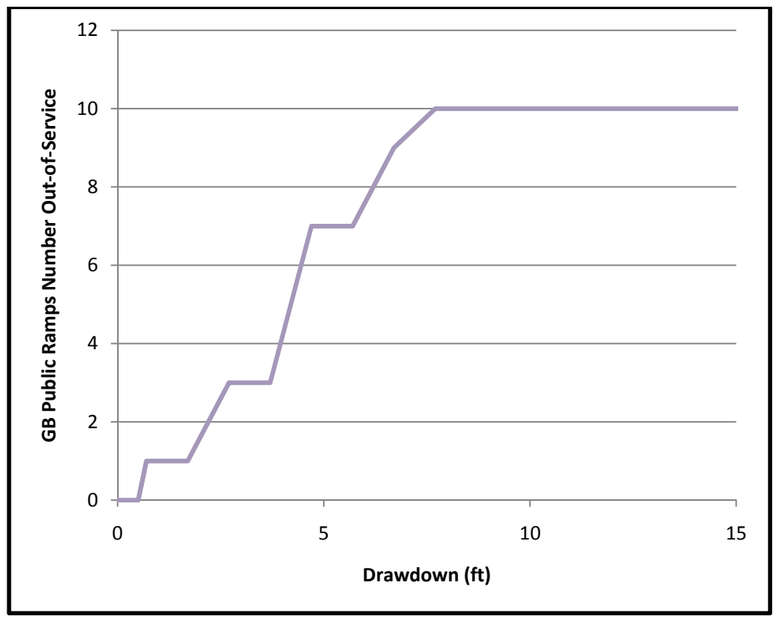


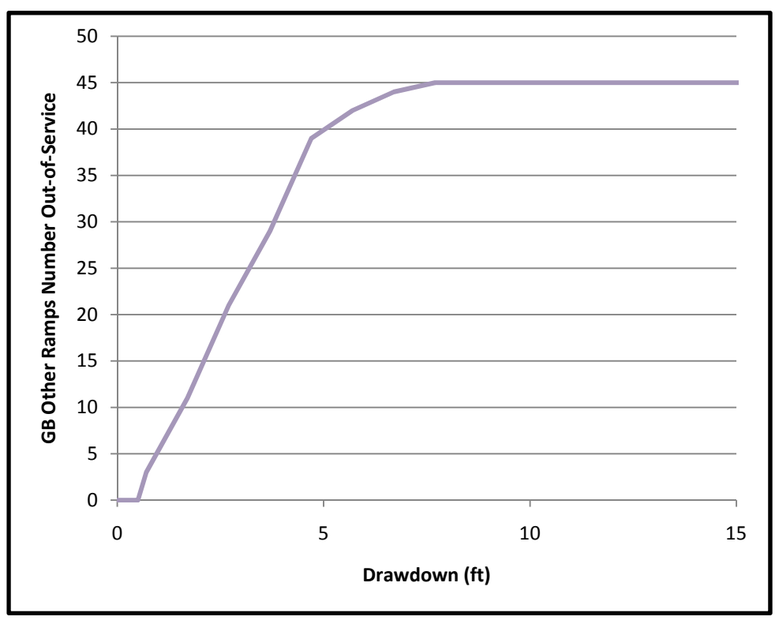


Granbury Out of Service Charts (2' Minimum Water Depth)









Appendix D

APPENDIX D
SIMULATION SUMMARIES

Granbury																											
1970-2009		(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)		(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
		Historic		Current EDD	Current Zonal	2020 EDD w/ 3&4	2020 Zonal w/ 3&4	2020 EDD w/o 3&4	2020 Zonal w/o 3&4	2060 EDD w/ 3&4	2060 Zonal w/ 3&4	2060 EDD w/DS 3&4	2060 Zonal w/DS 3&4	2020 Zonal w/3&4 w/Granbury Q	2020 Zonal w/o 3&4 w/Granbury Q	2020 EDD w/o 3&4 w/Granbury Q		Current	Current	2020 w/3&4	2020 w/3&4	2020 w/o Zonal	2060 w/3&4	2060 w/Zonal-	2020 Zonal w/o Granbury Q-	2020 Zonal w/ Granbury Q w/ Units 3&4-	2020 Zonal w/ Granbuy Q w/o 3&4-
					1.75:1 and 1:1		1.75:1 and 1.5:1		1.75:1 and No		1.75:1		1.75:1 and 1.5:1	1.75:1 and 1.5:1	1.75:1 and 1:1		Zonal-EDD	Zonal - Historic	Zonal-EDD	Zonal-Historic	- 2020 w/ Zonal	Zonal-EDD	2060w/DS Zonal	2020 Zonal w/ Granbury Q	Historic	2020 EDD w/ Granbuy Q w/o 3&4
Average		692.05		691.90	692.16	691.14	691.66	691.78	692.07	690.72	691.40	691.12	691.59	691.56	691.99	691.64		0.26	0.11	0.52	-0.38	0.41	0.68	-0.19	0.10	-0.48	0.35
Minimum		685.53		686.42	688.34	681.13	684.57	684.75	686.02	678.51	683.33	679.17	683.26	684.28	685.48	683.38		1.92	2.81	3.44	-0.96	1.45	4.82	0.07	0.29	-1.25	2.10
100%	0%	692.70		692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90%	10%	692.61		692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70		0.00	0.09	0.00	0.09	0.00	0.00	0.00	0.00	0.09	0.00
80%	20%	692.55		692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70		0.00	0.15	0.00	0.15	0.00	0.00	0.00	0.00	0.15	0.00
75%	25%	692.53		692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70		0.00	0.17	0.00	0.17	0.00	0.00	0.00	0.00	0.17	0.00
60%	40%	692.46		692.70	692.70	692.53	692.58	692.67	692.68	692.44	692.52	692.61	692.62	692.58	692.68	692.66		0.00	0.24	0.05	0.12	0.10	0.08	-0.10	0.00	0.12	0.02
50%	50%	692.40		692.60	692.63	692.13	692.32	692.50	692.56	691.90	692.19	692.34	692.40	692.31	692.55	692.49		0.03	0.23	0.19	-0.08	0.24	0.29	-0.21	0.01	-0.09	0.06
40%	60%	692.30		692.42	692.51	691.58	691.97	692.20	692.38	691.18	691.71	691.89	692.10	691.91	692.36	692.17		0.09	0.21	0.39	-0.33	0.41	0.53	-0.39	0.06	-0.39	0.19
30%	70%	692.12		692.08	692.30	690.84	691.51	691.77	692.12	690.33	691.17	691.16	691.56	691.40	692.04	691.61		0.22	0.18	0.67	-0.61	0.61	0.84	-0.39	0.11	-0.72	0.43
25%	75%	691.98		691.84	692.13	690.38	691.24	691.51	691.94	689.78	690.82	690.65	691.26	691.09	691.85	691.33		0.29	0.15	0.86	-0.74	0.70	1.04	-0.44	0.15	-0.89	0.52
20%	80%	691.74		691.43	691.85	689.92	690.90	691.19	691.72	689.17	690.39	690.00	690.85	690.73	691.59	690.98		0.42	0.11	0.98	-0.84	0.82	1.22	-0.46	0.17	-1.01	0.61
10%	90%	690.94		689.71	690.65	687.66	689.28	689.53	690.46	686.34	688.49	687.01	688.74	688.95	690.10	688.95		0.94	-0.29	1.62	-1.66	1.18	2.15	-0.25	0.33	-1.99	1.15
5%	95%	690.17		688.23	689.75	686.21	688.34	688.12	689.66	684.66	687.41	685.30	687.65	687.90	689.30	687.51		1.52	-0.42	2.13	-1.83	1.32	2.75	-0.24	0.44	-2.27	1.79
1%	99%	687.99		686.92	688.84	684.26	686.81	686.58	688.41	682.05	685.67	682.53	685.37	686.22	687.66	685.70		1.92	0.85	2.55	-1.18	1.60	3.62	0.30	0.59	-1.77	1.96
Granbury																											
1970-2007																											
Average		692.08		691.88	692.15	691.16	691.67	691.77	692.06	690.75	691.42	691.15	691.60	691.58	691.98	691.63		0.27	0.07	0.51	-0.41	0.39	0.67	-0.18	0.10	-0.50	0.35
Minimum		685.53		686.42	688.34	681.13	684.57	684.75	686.02	678.51	683.33	679.17	683.26	684.28	685.48	683.38		1.92	2.81	3.44	-0.96	1.45	4.82	0.07	0.29	-1.25	2.10
100%	0%	692.70		692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90%	10%	692.62		692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70		0.00	0.08	0.00	0.08	0.00	0.00	0.00	0.00	0.08	0.00
80%	20%	692.55		692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70		0.00	0.15	0.00	0.15	0.00	0.00	0.00	0.00	0.15	0.00
75%	25%	692.53		692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70		0.00	0.17	0.00	0.17	0.00	0.00	0.00	0.00	0.17	0.00
60%	40%	692.46		692.70	692.70	692.56	692.60	692.68	692.69	692.48	692.55	692.64	692.64	692.60	692.69	692.68		0.00	0.24	0.04	0.14	0.09	0.07	-0.09	0.00	0.14	0.01
50%	50%	692.41		692.62	692.64	692.20	692.36	692.53	692.57	692.00	692.25	692.38	692.44	692.35	692.56	692.52		0.02	0.23	0.16	-0.05	0.21	0.25	-0.19	0.01	-0.06	0.04
40%	60%	692.32		692.44	692.52	691.66	692.02	692.25	692.41	691.29	691.78	691.98	692.16	691.96	692.39	692.22		0.08	0.20	0.36	-0.30	0.39	0.49	-0.38	0.06	-0.36	0.17
30%	70%	692.17		692.10	692.30	690.93	691.56	691.80	692.13	690.40	691.23	691.25	691.62	691.46	692.07	691.66		0.20	0.13	0.63	-0.61	0.57	0.83	-0.39	0.10	-0.71	0.41
25%	75%	692.05		691.84	692.12	690.45	691.28	691.51	691.94	689.85	690.89	690.72	691.31	691.13	691.86	691.34		0.28	0.07	0.83	-0.77	0.66	1.04	-0.42	0.15	-0.92	0.52
20%	80%	691.88		691.39	691.81	689.99	690.93	691.15	691.68	689.27	690.46	690.17	690.91	690.78	691.56	690.94		0.42	-0.07	0.94	-0.95	0.75	1.19	-0.45	0.15	-1.10	0.62
10%	90%	691.11		689.57	690.55	687.53	689.21	689.41	690.39	686.29	688.42	687.01	688.68	688.84	690.03	688.79		0.98	-0.56	1.68	-1.90	1.18	2.13	-0.26	0.37	-2.27	1.24
5%	95%	690.19		688.19	689.73	686.13	688.29	688.06	689.61	684.58	687.36	685.24	687.58	687.83	689.26	687.46		1.54	-0.46	2.16	-1.90	1.32	2.78	-0.22	0.46	-2.36	1.80
1%	99%	687.89		686.92	688.82	684.23	686.78	686.57	688.37	682.00	685.61	682.49	685.34	686.18	687.62	685.66		1.90	0.93	2.55	-1.11	1.59	3.61	0.27	0.60	-1.71	1.96
Granbury																											
1939-2009*																											
Average		692.05		692.03	692.24	691.37	691.81	691.94	692.17	691.01	691.58	691.38	691.76	691.72	692.09	691.81		0.21	0.20	0.44	-0.24	0.36	0.58	-0.17	0.09	-0.32	0.28
Minimum		685.53		684.60	686.75	680.02	683.46	684.56	686.02	676.31	681.86	677.39	681.73	682.61	685.20	683.00		2.15	1.22	3.44	-2.07	2.56	5.55	0.13	0.85	-2.92	2.20
100%	0%	692.70		692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
90%	10%	692.61		692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70		0.00	0.09	0.00	0.09	0.00	0.00	0.00	0.00	0.09	0.00
80%	20%	692.55		692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70		0.00	0.15	0.00	0.15	0.00	0.00	0.00	0.00	0.15	0.00
75%	25%	692.53		692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70	692.70		0.00	0.17	0.00	0.17	0.00	0.00	0.00	0.00	0.17	0.00
60%	40%	692.46		692.70	692.70	692.66	692.67	692.70	692.70	692.61	692.64	692.70	692.67	692.70	692.70	692.70		0.00	0.24	0.01	0.21	0.03	0.03	-0.06	0.00	0.21	0.00
50%	50%	692.40		692.69	692.70	692.41	692.49	692.64	692.66	692.28	692.41	692.54	692.57	692.49	692.65	692.63		0.01	0.30	0.08	0.09	0.17	0.13	-0.16	0.00	0.09	0.02
40%	60%	692.30		692.56	692.60	691.96	692.21	692.43	692.51	691.69	692.05	692.22	692.40	692.30	692.49	692.40		0.04	0.30	0.25	-0.09	0.30	0.36	-0.25	0.03	-0.12	0.09
30%	70%	692.12		692.29	692.42	691.26	691.77	692.03	692.26	690.82	691.49	691.55	691.85	691.69	692.20	691.93		0.13	0.30	0.51	-0.35	0.49	0.67	-0.36	0.08	-0.43	0.27
25%	75%	691.98		692.06	692.26	690.79	691.46	691.75	692.08	690.27	691.14	691.14	691.54	691.37	692.00	691.59		0.20	0.28	0.67	-0.52	0.62	0.88	-0.40	0.10	-0.62	0.41
20%	80%	691.74		691.76	692.05	690.26	691.12	691.45	691.85	689.63	690.72	690.55	691.17	690.99	691.75	691.27		0.29	0.31	0.86	-0.62	0.73	1.09	-0.45	0.13	-0.75	0.48
10%	90%	690.94		690.30	691.06	688.35	689.82	690.22	690.89	687.29	689.14	688.09	689.48	689.53	690.57	689.72		0.76	0.12	1.47	-1.12	1.07	1.85	-0.34	0.29	-1.41	0.85
5%	95%	690.17		688.54	689.95	686.76	688.70	688.54	689.89	685.31	687.77	686.03	688.10	688.23	689.53	687.90		1.41	-0.22	1.94	-1.47	1.19	2.46	-0.33	0.47	-1.94	1.63
1%	99%	687.99		686.90	688.71	683.89	686.39	686.48	688.13	681.47	685.21	682.19	685.18	685.69	687.40	685.50		1.81	0.72	2.50	-1.60	1.74	3.74	0.03	0.70	-2.30	1.90

These cells were manually set to the conservation elevation of the respective lake in order to prevent confusion from the 100th percentile elevation being greater than "full".

* Historic Values are 1970-2009

Current Demand Statistics include Lake Granbury Summer Releases

2020 and 2060 Demand Statistics do not include Lake Granbury Summer Releases except for 12,13,and 14

(1) Historic Elevations
(2) Elevations with Current Demands and Equal Drawdown Plan
(3) Elevations with Current Demands and Zonal Drawdown Plan
(4) Elevations with 2020 Demands w/ CPNPP Units 3&4 and Equal Drawdown Plan
(5) Elevations with 2020 Demands w/ CPNPP Units 3&4 and Zonal Drawdown Plan
(6) Elevations with 2020 Demands w/o CPNPP Units 3&4 and Equal Drawdown Plan
(7) Elevations with 2020 Demands w/o CPNPP Units 3&4 and Zonal Drawdown Plan
(8) Elevations with 2060 Demands w/ CPNPP Units 3&4 and Equal Drawdown Plan
(9) Elevations with 2060 Demands w/ CPNPP Units 3&4 and Zonal Drawdown Plan
(10) Elevations with 2060 Demands w/CPNPP Units 3&4 D/S of Whitney and Equal Drawdown Plan
(11) Elevations with 2060 Demands w/CPNPP Units 3&4 D/S of Whitney and Zonal Drawdown Plan
(12) Elevations with 2020 Demands w/CPNPP Units 3&4 and Zonal Drawdown Plan and Granbury Summer Release
(13) Elevations with 2020 Demands w/oCPNPP Units 3&4 and Zonal Drawdown Plan and Granbury Summer Release
(14) Elevations with 2020 Demands w/oCPNPP Units 3&4 and Equal Drawdown Plan and Granbury Summer Release
(15) Difference in Zonal Drawdown and Equal Drawdown Elevations with Current Demands
(16) Difference in Zonal Drawdown with Current Demands and Historic Elevations
(17) Difference in Zonal Drawdown and Equal Drawdown Elevations with 2020 Demands w/ CPNPP Units 3&4
(18) Difference in Zonal Drawdown with 2020 Demands w/ CPNPP Units 3&4 and Historic Elevations
(19) Difference in Zonal Drawdown with 2020 Demands w/o CPNPP Units 3&4 and Zonal Drawdown with 2020 Demands w/ CPNPP Units 3&4
(20) Difference in Zonal Drawdown and Equal Drawdown with 2060 Demands w/ CPNPP Units 3&4
(21) Difference in Zonal Drawdown with 2060 Demands w/ CPNPP Units 3&4 and Zonal Drawdown with 2060 Demands w/ CPNPP Units 3&4 D/S of Whitney
(22) Difference in Zonal Drawdown with 2020 Demands w/ CPNPP Units 3&4 and no Granbury Summer Releases and Zonal Drawdown with 2020 Demands w/ CPNPP Units 3&4 and Granbury Summer Releases
(23) Difference in Zonal Drawdown with 2020 Demands w/ CPNPP Units 3&4 and with Granbury Summer Releases and Historic Elevations
(24) Difference in Zonal Drawdown with 2020 Demands w/o CPNPP Units 3&4 and with Granbury Summer Releases and Equal Drawdown with 2020 Demands w/o CPNPP Units 3&4 and with Granbury Summer Releases

PK																											
1970-2009		(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)		(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
		Historic		Current EDD	Current Zonal	2020 EDD w/ 3&4	2020 Zonal w/ 3&4	2020 EDD w/o 3&4	2020 Zonal w/o 3&4	2060 EDD w/ 3&4	2060 Zonal w/ 3&4	2060 EDD w/DS 3&4	2060 Zonal w/DS 3&4	2020 Zonal w/3&4 w/Granbury Q	2020 Zonal w/o 3&4 w/Granbury Q	2020 EDD w/o 3&4 w/Granbury Q		Current	Current	2020 w/3&4	2020 w/3&4	2020 w/o Zonal	2060 w/3&4	2060 w/Zonal-	2020 Zonal w/o Granbury Q-	2020 Zonal w/ Granbury Q w/ Units 3&4-	2020 Zonal w/ Granbury Q w/o 3&4-
					1.75:1 and 1:1		1.75:1 and 1.5:1		1.75:1 and No		1.75:1		1.75:1 and 1.5:1	1.75:1 and 1.5:1	1.75:1 and 1:1		Zonal-EDD	Zonal - Historic	Zonal-EDD	Zonal-Historic	- 2020 w/ Zonal	Zonal-EDD	2060w/DS Zonal	2020 Zonal w/ Granbury Q	Historic	2020 EDD w/ Granbury Q w/o 3&4
Average		995.41		997.85	997.63	997.13	996.76	997.73	997.50	996.65	996.20	997.04	996.58	996.56	997.36	997.61		-0.21	2.22	-0.36	1.35	0.74	-0.46	-0.38	0.20	1.15	-0.25
Minimum		981.20		990.52	989.62	987.45	985.87	989.89	989.18	984.81	982.68	985.26	983.68	985.08	988.69	989.57		-0.90	8.42	-1.58	4.67	3.31	-2.13	-1.00	0.79	3.88	-0.88
100%	0%	999.00		999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.39	999.39	999.39		0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.39	0.39	0.00
90%	10%	998.76		998.99	998.99	998.99	998.98	998.99	998.99	998.98	998.98	998.98	998.98	998.98	998.99	998.99		0.00	0.23	-0.03	0.22	0.01	0.00	0.00	0.00	0.22	0.00
80%	20%	998.28		998.98	998.98	998.98	998.98	998.98	998.98	998.97	998.97	998.98	998.98	998.98	998.98	998.98		0.00	0.70	0.00	0.70	0.00	0.00	-0.01	0.00	0.70	0.00
75%	25%	998.04		998.98	998.98	998.96	998.95	998.97	998.97	998.95	998.93	998.97	998.96	998.95	998.97	998.97		0.00	0.94	-0.01	0.91	0.02	-0.02	-0.03	0.00	0.91	0.00
60%	40%	997.26		998.83	998.77	998.61	998.49	998.77	998.69	998.50	998.35	998.68	998.54	998.47	998.68	998.76		-0.06	1.51	-0.12	1.23	0.20	-0.15	-0.19	0.02	1.21	-0.08
50%	50%	996.39		998.56	998.43	997.99	997.72	998.43	998.28	997.72	997.40	998.24	997.87	997.66	998.23	998.38		-0.13	2.04	-0.27	1.33	0.56	-0.32	-0.47	0.06	1.27	-0.15
40%	60%	995.65		998.20	997.99	997.41	996.97	998.07	997.84	996.99	996.45	997.67	997.12	996.80	997.69	997.94		-0.21	2.34	-0.44	1.32	0.87	-0.54	-0.67	0.17	1.15	-0.25
30%	70%	994.55		997.66	997.42	996.60	996.11	997.48	997.20	996.04	995.44	996.91	996.21	995.87	997.07	997.38		-0.24	2.87	-0.49	1.56	1.09	-0.60	-0.77	0.24	1.32	-0.31
25%	75%	993.93		997.32	997.05	996.19	995.63	997.09	996.75	995.48	994.79	996.41	995.63	995.38	996.62	997.00		-0.27	3.12	-0.56	1.70	1.12	-0.69	-0.84	0.25	1.45	-0.38
20%	80%	993.39		996.93	996.53	995.28	994.63	996.83	996.20	994.46	993.57	995.20	994.25	994.26	995.90	996.35		-0.40	3.14	-0.65	1.24	1.57	-0.89	-0.68	0.37	0.87	-0.45
10%	90%	990.03		995.28	994.71	993.43	992.38	995.09	994.48	991.91	990.65	992.47	991.21	991.78	994.01	994.70		-0.57	4.68	-1.05	2.35	2.10	-1.26	-0.56	0.60	1.75	-0.69
5%	95%	986.83		994.29	993.58	992.34	991.26	994.05	993.34	990.77	989.42	991.28	990.05	990.61	992.79	993.61		-0.71	6.75	-1.08	4.43	2.08	-1.35	-0.63	0.65	3.78	-0.82
1%	99%	982.95		992.86	991.83	990.46	989.16	992.48	991.64	988.35	986.52	988.58	987.03	988.18	990.95	991.93		-1.03	8.88	-1.30	6.21	2.48	-1.83	-0.51	0.98	5.23	-0.98
PK																											
1970-2007																											
Average		995.32		997.84	997.63	997.16	996.80	997.73	997.51	996.71	996.26	997.09	996.64	996.61	997.37	997.61		-0.21	2.31	-0.36	1.48	0.70	-0.45	-0.38	0.19	1.29	-0.25
Minimum		981.20		990.52	989.62	987.45	985.87	989.89	989.18	984.81	982.68	985.26	983.68	985.08	988.69	989.57		-0.90	8.42	-1.58	4.67	3.31	-2.13	-1.00	0.79	3.88	-0.88
100%	0%	999.00		999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.39	999.39	999.39		0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.39	0.39	0.00
90%	10%	998.77		998.99	998.99	998.99	998.99	998.99	998.99	998.98	998.98	998.98	998.98	998.99	998.99	998.99		0.00	0.22	0.00	0.22	0.00	0.00	0.00	0.00	0.22	0.00
80%	20%	998.26		998.98	998.98	998.98	998.98	998.98	998.98	998.98	998.98	998.98	998.98	998.98	998.98	998.98		0.00	0.72	0.00	0.72	0.00	0.00	0.00	0.00	0.72	0.00
75%	25%	998.03		998.98	998.98	998.97	998.96	998.98	998.97	998.96	998.95	998.97	998.97	998.96	998.97	998.98		0.00	0.95	-0.01	0.93	0.01	-0.01	-0.02	0.00	0.93	-0.01
60%	40%	997.22		998.85	998.81	998.67	998.56	998.81	998.74	998.57	998.44	998.73	998.61	998.54	998.74	998.80		-0.04	1.59	-0.11	1.34	0.18	-0.13	-0.17	0.02	1.32	-0.06
50%	50%	996.32		998.59	998.46	998.11	997.87	998.48	998.33	997.86	997.60	998.31	998.00	997.82	998.31	998.44		-0.13	2.14	-0.24	1.55	0.46	-0.26	-0.40	0.05	1.50	-0.13
40%	60%	995.57		998.24	998.04	997.48	997.07	998.11	997.88	997.08	996.58	997.76	997.24	996.89	997.76	998.00		-0.20	2.47	-0.41	1.50	0.81	-0.50	-0.66	0.18	1.32	-0.24
30%	70%	994.33		997.72	997.47	996.68	996.21	997.53	997.26	996.13	995.53	996.98	996.32	995.97	997.15	997.44		-0.25	3.14	-0.47	1.88	1.05	-0.60	-0.79	0.24	1.64	-0.29
25%	75%	993.80		997.34	997.07	996.27	995.75	997.14	996.81	995.60	994.95	996.54	995.74	995.48	996.70	997.04		-0.27	3.27	-0.52	1.95	1.06	-0.65	-0.79	0.27	1.68	-0.34
20%	80%	993.24		996.87	996.44	995.49	994.85	996.60	996.18	994.70	993.87	995.43	994.48	994.49	995.90	996.35		-0.43	3.20	-0.64	1.61	1.33	-0.83	-0.61	0.36	1.25	-0.45
10%	90%	989.47		995.16	994.61	993.35	992.25	995.01	994.39	991.86	990.60	992.59	991.31	991.66	993.94	994.60		-0.55	5.14	-1.10	2.78	2.14	-1.26	-0.71	0.59	2.19	-0.66
5%	95%	986.77		994.23	993.53	992.27	991.18	994.00	993.28	990.67	989.33	991.21	989.96	990.55	992.71	993.56		-0.70	6.76	-1.09	4.41	2.10	-1.34	-0.63	0.63	3.78	-0.85
1%	99%	982.82		992.84	991.81	990.45	989.14	992.41	991.63	988.24	986.40	988.52	986.92	988.13	990.92	991.87		-1.03	8.99	-1.31	6.32	2.49	-1.84	-0.52	1.01	5.31	-0.95
PK																											
1939-2009*																											
Average		995.41		997.77	997.61	997.19	996.89	997.68	997.51	996.77	996.38	997.12	996.72	996.71	997.38	997.57		-0.16	2.20	-0.31	1.48	0.62	-0.39	-0.34	0.18	1.30	-0.19
Minimum		981.20		987.01	987.01	986.08	983.97	986.25	986.25	982.50	979.83	983.65	981.47	982.71	986.25	986.25		0.00	5.81	-2.11	2.77	2.28	-2.67	-1.64	1.26	1.51	0.00
100%	0%	999.00		999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.00	999.53	999.53	999.53		0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.53	0.53	0.00
90%	10%	998.76		998.99	998.99	998.99	998.99	998.99	998.99	998.98	998.98	998.98	998.98	998.98	998.99	998.99		0.00	0.23	0.00	0.23	0.00	0.00	0.00	0.01	0.22	0.00
80%	20%	998.28		998.98	998.98	998.98	998.98	998.98	998.98	998.97	998.97	998.98	998.98	998.98	998.98	998.98		0.00	0.70	0.00	0.70	0.00	0.00	-0.01	0.00	0.70	0.00
75%	25%	998.04		998.98	998.98	998.96	998.95	998.97	998.97	998.95	998.93	998.97	998.96	998.95	998.97	998.97		0.00	0.94	-0.01	0.91	0.02	-0.02	-0.03	0.00	0.91	0.00
60%	40%	997.26		998.84	998.81	998.67	998.59	998.80	998.76	998.58	998.47	998.73	998.64	998.57	998.75	998.79		-0.03	1.55	-0.08	1.33	0.17	-0.11	-0.17	0.02	1.31	-0.04
50%	50%	996.39		998.58	998.50	998.22	998.04	998.51	998.41	997.99	997.76	998.34	998.11	997.97	998.39	998.47		-0.08	2.11	-0.18	1.65	0.37	-0.23	-0.35	0.07	1.58	-0.08
40%	60%	995.65		998.22	998.08	997.63	997.33	998.12	997.95	997.27	996.90	997.83	997.38	997.14	997.85	998.04		-0.14	2.43	-0.30	1.68	0.62	-0.37	-0.48	0.19	1.49	-0.19
30%	70%	994.55		997.69	997.49	996.82	996.41	997.55	997.33	996.29	995.76	997.04	996.44	996.17	997.21	997.45		-0.20	2.94	-0.41	1.86	0.92	-0.53	-0.68	0.24	1.62	-0.24
25%	75%	993.93		997.32	997.10	996.34	995.86	997.15	996.86	995.73	995.13	996.56	995.81	995.60	996.73	997.05		-0.22	3.17	-0.48	1.93	1.00	-0.60	-0.68	0.26	1.67	-0.32
20%	80%	993.39		996.88	996.58	995.64	995.09	996.66	996.32	994.87	994.21	995.71	994.95	994.81	996.10	996.44		-0.30	3.19	-0.55	1.70	1.23	-0.66	-0.74	0.28	1.42	-0.34
10%	90%	990.03		995.14	994.67	993.64	992.74	995.02	994.50	992.30	991.21	992.82	991.75	992.11	994.07	994.65		-0.47	4.64	-0.90	2.71	1.76	-1.09	-0.54	0.63	2.08	-0.58
5%	95%	986.83		993.99	993.39	992.25	991.26	993.81	993.17	990.81	989.48	991.28	990.08	990.61	992.53	993.35		-0.60	6.56	-0.99	4.43	1.90	-1.33	-0.60	0.65	3.78	-0.82
1%	99%	982.95		990.41	989.88	988.60	986.86	990.23	989.72	986.22	984.90	987.18	985.41	986.50	989.24	989.71		-0.53	6.93	-1.74	3.91	2.86	-1.32	-0.51	0.36	3.55	-0.47

These cells were manually set to the conservation elevation of the respective lake in order to prevent confusion from the 100th percentile elevation being greater than "full"

* Historic Values are 1970-2009

Current Demand Statistics include Lake Granbury Summer Releases

2020 and 2060 Demand Statistics do not include Lake Granbury Summer Releases except for 12,13,and 14

(1) Historic Elevations
(2) Elevations with Current Demands and Equal Drawdown Plan
(3) Elevations with Current Demands and Zonal Drawdown Plan
(4) Elevations with 2020 Demands w/ CPNPP Units 3&4 and Equal Drawdown Plan
(5) Elevations with 2020 Demands w/ CPNPP Units 3&4 and Zonal Drawdown Plan
(6) Elevations with 2020 Demands w/o CPNPP Units 3&4 and Equal Drawdown Plan
(7) Elevations with 2020 Demands w/o CPNPP Units 3&4 and Zonal Drawdown Plan
(8) Elevations with 2060 Demands w/ CPNPP Units 3&4 and Equal Drawdown Plan
(9) Elevations with 2060 Demands w/ CPNPP Units 3&4 and Zonal Drawdown Plan
(10) Elevations with 2060 Demands w/CPNPP Units 3&4 D/S of Whitney and Equal Drawdown Plan
(11) Elevations with 2060 Demands w/CPNPP Units 3&4 D/S of Whitney and Zonal Drawdown Plan
(12) Elevations with 2020 Demands w/CPNPP Units 3&4 and Zonal Drawdown Plan and Granbury Summer Release
(13) Elevations with 2020 Demands w/oCPNPP Units 3&4 and Zonal Drawdown Plan and Granbury Summer Release
(14) Elevations with 2020 Demands w/oCPNPP Units 3&4 and Equal Drawdown Plan and Granbury Summer Release
(15) Difference in Zonal Drawdown and Equal Drawdown Elevations with Current Demands
(16) Difference in Zonal Drawdown with Current Demands and Historic Elevations
(17) Difference in Zonal Drawdown and Equal Drawdown Elevations with 2020 Demands w/ CPNPP Units 3&4
(18) Difference in Zonal Drawdown with 2020 Demands w/ CPNPP Units 3&4 and Historic Elevations
(19) Difference in Zonal Drawdown with 2020 Demands w/o CPNPP Units 3&4 and Zonal Drawdown with 2020 Demands w/ CPNPP Units 3&4
(20) Difference in Zonal Drawdown and Equal Drawdown with 2060 Demands w/ CPNPP Units 3&4
(21) Difference in Zonal Drawdown with 2060 Demands w/ CPNPP Units 3&4 and Zonal Drawdown with 2060 Demands w/ CPNPP Units 3&4 D/S of Whitney
(22) Difference in Zonal Drawdown with 2020 Demands w/ CPNPP Units 3&4 and no Granbury Summer Releases and Zonal Drawdown with 2020 Demands w/ CPNPP Units 3&4 and Granbury Summer Releases
(23) Difference in Zonal Drawdown with 2020 Demands w/ CPNPP Units 3&4 and with Granbury Summer Releases and Historic Elevations
(24) Difference in Zonal Drawdown with 2020 Demands w/o CPNPP Units 3&4 and with Granbury Summer Releases and Equal Drawdown with 2020 Demands w/o CPNPP Units 3&4 and with Granbury Summer Releases

Appendix E

Brazos River Authority - Water Management Study Open House and Public Presentation

Granbury Resort Conference Center: March 28, 2011

Transcript of Questions, Statements, Comments, and Answers

Question/Comment 1: Unknown – A gentleman stated that he lived in California and explained how Lake Mead's reservoir elevation has been drawn down due to increased use. He stated that a similar scenario would happen here at Lake Granbury. He asked the following question: "Do you have any numbers that show the lowest levels that the lake is going to be once the Comanche Peak Nuclear Power Plant Reactors 3 and 4 go into use?"

Answer 1: *Brad Brunett, BRA - Water Services Manager/Andrew Ickert, Halff Project Manager – Mr. Brunett explained that the models were based on a repeat of the last 70 years of record, so this elevation is coming from the 1950's drought simulated as if Lake Granbury was in operation through this critical drought period. Mr. Ickert provided the following information related to lake levels. He explained that in 2020 with the proposed zonal drawdown plan the minimum elevation is 683.5-ft. versus the minimum elevation of 680 with the equal drawdown (1:1) plan. Mr. Ickert explained further that with current demands, the minimum elevation is 686.7-ft.*

Question/Comment 2: Robert Williams – "Give us more information so we can seriously sit down and look at the Study. We can only absorb so much from the presentation."

Answer 2: *Brad Brunett, BRA - Water Services Manager – Mr. Brunett explained that the BRA is going to have copies of this presentation posted on the website and we also have hard copies of the presentation at the lake offices for those that do not have internet access.*

Question/Comment 3: Robert Williams – "Why are you in such a hurry to implement the management plan?"

Answer 3: *Brad Brunett, BRA - Water Services Manager – Mr. Brunett stated that the BRA is not necessarily in a rush to implement this plan other than the fact that a change to the zonal method will benefit the reservoir. He explained that the BRA's suggested change would allow more water to flow to Lake Granbury.*

Question/Comment 4: Judy McHugh – Ms. McHugh commented that she was appreciative that the BRA completed the study and that they involved the public. She expressed concern that industrial water use had priority over municipal water use and had the following question: "I have a concern that currently Comanche Peak has senior water rights over the City of Granbury. With the Comanche Peak expansion will it be necessary to possibly develop the legislation to put Granbury's drinking water ahead of water for industries such as Comanche Peak?"

Answer 4: *Brad Brunett, BRA - Water Services Manager – Mr. Brunett explained that the BRA contracts for water with industries, irrigators, municipalities and so forth. He stated that all contracts are equal. Should we experience a new drought of record, Comanche Peak would not have priority over the City. He*

noted that all contracts stipulate that the method BRA would utilize to ration water is on a pro rata basis and it is in accordance with the Texas Water Code. Mr. Brunett explained that it was his thinking that the Texas Water Code puts municipal use ahead of industrial use. As a result, if we were literally running out of water the State Law would dictate that municipalities receive water ahead of industries.

Question/Comment 5: Tony Allen – Mr. Allen asked if the presentation that will be posted on the website would be the same one that was provided to Sen. Birdwell and Rep. Keffer. He explained that the presentation given tonight was much different than the presentations given to the Senator and Representative and that those presentations had different language than the public version. Mr. Allen went on to ask if the "booklet" would be given to everyone.

***Answer 5**: Brad Brunett, BRA - Water Services Manager – Mr. Brunett stated that the presentation that will be posted on the website would be the version that was given tonight. He explained that the slides given to Sen. Birdwell and Rep. Keffer varied little to the slides presented this evening. Mr. Brunett explained that a two page written summary of the study was distributed to the staffs of Sen. Birdwell and Rep. Keffer. He asked if the two-page summary was the "booklet" that Mr. Allen referred to.*

Question/Comment 6: Tony Allen – Stated that the BRA did a "good job" in the study and thanked the BRA for coming. Mr. Allen explained that he was for the nuclear plant for area businesses. He explained that the BRA was good enough to coordinate bills with Sen. Birdwell and Rep. Keffer for dock permit reimbursement. Mr. Allen went on to ask why the BRA doesn't go a step further and provide a break on taxes if the lake levels drop. He explained that lakefront properties pay more in taxes than anyone else in the City. Mr. Allen stated that he lives next to Sen. Birdwell and said that the BRA was behind those bills.

***Answer 6:** Brad Brunett, BRA - Water Services Manager – Mr. Brunett stated that he was familiar with the "dock bills." He explained that the BRA has no input regarding property taxes. He explained that BRA had been in contact with the staffs of Sen. Birdwell and Rep. Keffer since those bills were filed, but stated that the BRA was not the impetus behind those bills.*

Question/Comment 7: Unknown – A lady explained that she has concerns regarding the demand numbers in the study. She stated that the present water demands show 95,600 acre-feet per year. She explained that the contracts that the BRA has for providing water out of the lake often do not utilize the full contracted amount. She went on to ask when we state a demand number what percentage of the contracts is the BRA estimating that are drawn at and what happens when the BRA customers start drawing more water against those contracts. She went on to ask if our demand numbers account for increased demand through the years. She explained that she was very concerned at the over allocation of water in the future.

***Answer 7:** Brad Brunett, BRA - Water Services Manager – Mr. Brunett explained that currently the BRA has contracts in place for all of the water that the system can provide. He explained that depending on whether it is a "wet" year or a "dry" year, the BRA uses anywhere from one-third to one-half of this water. Mr. Brunett explained that the demands in the study are the actual demands that we project to be drawn on those contracts in 2020.*

He pointed out that the BRA is currently not in a position to supply water to Luminant for the new units. The BRA has a permit application that has been filed with the Texas Commission on Environmental Quality (TCEQ) to provide the BRA with the ability to sell additional water. He explained that the permit is not in place and that the BRA does not have any contract with Luminant at this time. He said Luminant has gone through the Regional Water Planning process and approached the Brazos G Regional Water Planning Group to include the needs for the new units in the Regional Water Plan. Mr. Brunett explained that the BRA would entertain entering a contract with Luminant once the new water permit is in place and BRA has the ability to provide them with that water.

Mr. Brunett explained that the BRA is planning for increased use and that is why its contract totals exceed current levels of use. He explained that over contracting would jeopardize the BRA's ability to deliver water in the instances when demand exceeds supplies. Mr. Brunett explained that individually, Lake Granbury is one of the BRA's highest use lakes and that in this past year Lake Granbury about 55,000 acre-feet of water has been drawn by local customers. Mr. Brunett explained that BRA's permitted authorized use from Lake Granbury is between 64,000 and 65,000 acre-feet per year. He explained that in some years BRA can exceed that amount, but must then reduce sales from other lakes within the system. Mr. Brunett explained that the 95,600 acre-feet per year value is the water use from Possum Kingdom, Granbury and Whitney in 2009. He explained that the water use in 2010 was much less due to a relatively wet year and decreased water use. Mr. Brunett explained that this past year (2010) the water use was much less than that because it was a relatively "wet year" and water use was down.

Question/Comment 8: (Q&A for comment 8 represents a condensed summary of a very lengthy conversation between Joe Williams and Brad Brunett, BRA Water Services Manager) – Mr. Williams asked a series of questions related to BRA water rights and the amounts of water that BRA has contracted. He asked additional questions related to how the BRA system of reservoirs operates to provide water to customers. Mr. Williams then asked a series of questions related to the BRA System Operation Permit and the current proceedings and administrative process related to the permit. He went on to ask how the System Operations Permit would be used. He commented on the financial revenue the BRA would gain due to the proposed expansion at Comanche Peak and stated that Lake Granbury residents are at risk. Mr. Williams asked if the BRA would be willing to agree to any legislation that would require the BRA to pay fines to the City of Granbury if the lake levels at Lake Granbury drop below historic levels. He explained that the BRA does not need to take the water from Lake Granbury and that the residents of Lake Granbury are the ones at risk.

Answer 8: *Brad Brunett, BRA - Water Services Manager – Mr. Brunett explained that the BRA system currently has the ability to provide approximately 700,000 acre-feet of water per year to its customers across the basin. He explained that the BRA has studied the maximum amount of water the system of reservoirs can provide for water supply and that as demand increases, more water will be needed from the system and the lakes will fluctuate more frequently. Mr. Brunett explained that the impact will be felt in all areas of the basin.*

Mr. Brunett explained that the BRA's new permit application is for an amount of around 423,000 acre-feet. He explained how the System Operation permit would be implemented. He explained that System Operations is a basin-wide concept, and that the more water the BRA provides in the upper portion of the basin, the less the Authority would be able to supply downstream. He explained that the reason the BRA sought the new permit application was that in the future we don't know where water would be needed throughout the basin. Mr. Brunett explained the reason for the current hearing over the new permit application.

He further explained that the current Water Management Study was completed under the assumption of historical data (inflows and evaporation) and that no one can predict the weather. He explained that at some point in the future there will be droughts that are worse than we've experienced in the past, and cannot be controlled.

Question/Comment 9: Gary Newman – Mr. Newman asked if there were plans for any upstream, off-channel reservoirs that might mitigate the large fluctuations in the lake level in the future.

Answer 9: *Brad Brunett, BRA - Water Services Manager – Mr. Brunett explained that there are a number of reservoir projects proposed upstream of Lake Granbury. He explained that the most recent project was the on-channel Cedar Ridge Reservoir located upstream of Possum Kingdom. Mr. Brunett explained that he was not aware of any off-channel reservoir projects upstream of Granbury.*

He explained that water supply reservoirs constructed in the 1950's and 1960's were designed to provide water to the growing population. If those reservoirs are taken out of service and not used to supply water, a large water shortage would be realized and additional projects would need to be developed and constructed.

Mr. Brunett summarized the difficulties that are apparent when developing and constructing new water supply sources including new reservoir or groundwater projects. He mentioned examples of other potential reservoir projects where landowners fear that their land would be taken from them. He explained that as we go forward, the process to balance competing interests will become more and more important. Mr. Brunett stated that there may be sites upstream for off-channel reservoirs that are feasible, but to design and construct such reservoirs would cost about $200 to $500 million dollars, and that bill would be paid by the water customers.

Question/Comment 10: Ken Hackett – Mr. Hackett explained that he understood that there are 1,600 features at Possum Kingdom and 3,300 at Lake Granbury. He went on to say that he understood that the weighting process weighted each category at one-third. Mr. Hackett explained that to be fair in the allocation of water management, the Study should weight the residential docks at a higher percentage than the commercial and public facilities which he explained are normally located in deeper water. He stated that weighting the residential docks up to possibly 50 percent of the formula would be more realistic. Mr. Hackett also explained that since more fixed docks are located at Lake Granbury than Possum Kingdom, not differentiating fixed from floating docks would damage Lake Granbury greater since fixed docks don't move. He explained that the first 4 or 5 feet of drawdown at Granbury will result in much more impact than at Possum Kingdom.

Answer 10: *Andrew Ickert, Halff Associates – Project Manager/Brad Brunett, BRA - Water Services Manager – Mr. Ickert explained that the weighting for the docks was increased up to two-thirds with the remaining categories weighted at one-sixth, and the results were not sensitive to that weighting. He explained that the weighted metric line tracks very closely to the docks percent out-of-service line, so if we would have ignored the marinas and ramps and just focused on docks we would have obtained the same results. Mr. Ickert did state that the fixed docks were not categorized differently from the floating docks. He explained that if fixed docks were categorized differently and more weighting was placed on fixed docks it was his estimation that the results would not be that different. Mr. Ickert explained that changing the weighting value did not result in very different answers. He stated that the current equal drawdown plan obviously does not balance the impacts between the two lakes, but that the goal of this study was to balance the impacts between the two lakes.*

Mr. Brunett went on to explain how the criteria of an out-of-service facility are the same whether it is a fixed dock or a floating dock. He explained that over the first 4 feet of drawdown at Granbury approximately 50 percent of the facilities are out-of-service versus less than 20 percent out-of-service at Possum Kingdom.

Question/Comment 11: Mel Robinson – Mr. Robinson was concerned about the ecology of the system. He explained that he was appalled at the state of the ecology due to our needs. Mr. Robinson explained that something has happened in this system to cause this golden algae problem. He explained that there has not been enough money spent to study the problem. Mr. Robinson requested that the BRA make a commitment to fund more in terms of golden algae research, stocking fish and working with the Texas Parks and Wildlife.

Answer 11: *Brad Brunett, BRA - Water Services Manager – Mr. Brunett explained that the BRA does care about the ecology. He explained that other areas in the basin, such as Lake Whitney, have been impacted by golden algae over the last several years. He explained that there are many that live along the river and enjoy the benefits. He explained that other areas in the basin, particularly Lake Whitney, have been impacted by golden algae over the last several years. Mr. Brunett explained that the causes of golden algae are complex and unknown. Mr. Brunett stated that the BRA has scientists that conduct sampling activities and coordinate with the Texas Parks and Wildlife Department. He explained that the BRA is committed to addressing the problem and is putting money and staff time toward doing so. Mr. Brunett stated that this problem is not unique to Texas. Other areas such as Colorado and Oklahoma have also had golden algae outbreaks.*

Question/Comment 12: Unknown – The gentleman had a clarification question related to lake levels. He wanted confirmation that once it rains significantly, both Possum Kingdom and Lake Granbury will fill to 999-ft. and 692.7-ft, respectively. He explained that any additional water would be released through the floodgates and once it stops raining then Luminant would keep pumping at 20 million gallons per day and the lake would go down.

Answer 12: *Brad Brunett, BRA - Water Services Manager – Mr. Brunett confirmed that any additional water above 999-ft. and 692.7-ft. would be released through the flood gates.*

Question/Comment 13: Jack Rosenfeld – Mr. Rosenfeld asked the status of the Possum Kingdom Hydroelectric Plant and how that will affect water management. He questioned what part of the facility had safety concerns.

Answer 13: *Michael McClendon, BRA – Upper Basin Regional Manager – Mr. McClendon stated that since 2007 the hydroelectric facility at Possum Kingdom has been out-of-service primarily due to safety concerns. He reported that after reviewing an extensive cost-benefit analysis, the Board of Directors voted to decommission the facility. BRA recently submitted a Surrender Application for review to certain state and federal agencies. Once we hear back from them, we'll submit the document(s) to FERC.*

Mr. McClendon explained that the safety concern pertained to the penstocks and he could not explain any further due to litigation pending at the Texas Supreme Court. He stated there is no projected use of the hydroelectric facility at this time.

Question/Comment 14: Buddy Almay – Mr. Almay explained that he was a longtime resident of Granbury and has worked in real estate for 52 years. He explained that there was undeveloped land around the lake due to the inability to build additional docks in those areas. Mr. Almay went on to explain that there were a number of individuals that were impacted financially due to the inability to develop certain lakeside lots.

Answer 14: *Michael McClendon, BRA – Upper Basin Regional Manager – Mr. McClendon stated that Mr. Almay was probably referring to a boating capacity study conducted in 2006. He explained that the goal of that study was to prevent certain areas of the lake from becoming overcrowded. Mr. McClendon did state that there are still areas on the lake were docks can be constructed. He explained that it was decided that the boating capacity study at Lake Granbury would be updated once every 5 to 6 years.*

Mr. McClendon stated the BRA coordinated with the City of Granbury last year to investigate updating the boating capacity study that was conducted in 2006. He explained that there were some difficulties with that, but stated that updating the study is a possibility.

Question/Comment 15: Joe Williams – Mr. Williams explained that there are discrepancies in the wording between a presentation given previously to elected officials and the presentation given tonight. He said the discrepancies are related to the amount of impact to Lake Granbury associated with the new units at Comanche Peak.

Answer 15: *Brad Brunett, BRA – Water Services Manager – Mr. Brunett explained that there is some miscommunication or misinterpretation of the two different presentations. He went on to explain the impacts related to the new units.*

Question/Comment 16: Lee Benson – Mr. Benson asked what the historical drawdown ratio between Possum Kingdom and Granbury was and why the BRA did not come up with that ratio as its management protocol.

Answer 16: *Brad Brunett, BRA – Water Services Manager – Mr. Brunett explained that he did not have the historical drawdown ratio numbers readily available but that he would send them to Mr. Benson. He would send the historical drawdown ratio between Possum Kingdom and Granbury to Mr. Benson.*

Question/Comment 17: Barry Ackerly – Mr. Ackerly explained that the BRA's sale of water is a clear benefit to corporate revenue for BRA and other taxing authorities, but poses a risk to the property values here at Lake Granbury. He asked what risk is imposed by BRA to sell the additional rights. Mr. Ackerly asked whether it would be feasible to set up a fund specifying that as the BRA sold additional water, that the lakefront owners would be compensated to offset the risks of lower lake levels. He asked additional questions related to the financial aspects of the BRA and if there was a prioritized list of capital projects.

Answer 17: *Brad Brunett, BRA – Water Services Manager – Mr. Brunett explained that the BRA does not receive any tax revenue. The BRA is not a tax agency and the BRA does not receive any federal or state tax dollars. Mr. Brunett explained the BRA System Water Rate structure and that selling additional water could actually reduce the System Water Rate. He explained that the revenue that the BRA gains allows for the development and construction of new water supply projects. Mr. Brunett explained that those are not really risks, but that is the purpose of the BRA. He summarized and explained the budget process at the BRA and how excess revenue remains on reserve to be used for capital projects. Mr. Brunett stated that a prioritized list of capital projects is explained annually at customer meetings and that the next Upper Basin customer meeting would be coming up in late June. The list of capital improvement projects goes before the Board of Directors at the BRA in July.*

Question/Comment 18: Ron Peterson – Mr. Peterson stated that he understood that there would be some additional construction at Possum Kingdom dam to allow for improved flow downstream. He questioned whether that type of construction to improve the low water flow at Possum Kingdom was included in the Study. Mr. Peterson asked what the timeline for the construction would be. He asked if the decommissioning process had already been approved by the BRA Board.

Answer 18: *Brad Brunett, BRA – Water Services Manager – Mr. Brunett explained that the hydropower facilities at Possum Kingdom were historically used to pass water downstream for water supply purposes. He explained that after decommissioning the hydropower facilities, another outlet structure will be constructed that will provide the ability to release water downstream. Mr. Brunett explained that the construction of this new outlet structure is expected in the 2012 to 2013 timeframe. He explained that BRA currently has the capability to release water down to around elevation 976-ft. He explained that the elevation at Possum Kingdom has not been below 976-ft. since probably the drought of the 1950's.*

Question/Comment 19: Unknown – A man asked what the process is for a waterfront owner if they want to develop their mineral rights into the middle of the lake since some properties extend out into the lake.

Answer 19: *Michael McClendon, BRA – Upper Basin Regional Manager – Mr. McClendon explained that he would have to contact the BRA property administrator, but in previous scenarios property owners*

would have to utilize directional or horizontal drilling from the shoreline to access minerals into the lake. He explained that most of the lake is actually owned by the BRA.

An unknown gentleman familiar in the oil and gas business attempted to answer the question. He explained that one would need to look at your deed at the County Courthouse to determine if you are the owner of any mineral rights on your property. He also went on to explain some of the details pertaining to mineral rights.

Brazos River Authority - Water Management Study Open House and Public Presentation

Possum Kingdom Chamber of Commerce: March 29, 2011

Transcript of Questions, Statements, Comments, and Answers

Question/Comment 1: (Q&A for comment 1 represents a condensed summary of a lengthy back and forth conversation between a lady that didn't provide her name and Brad Brunett, BRA Water Services Manager.) Unknown – You are making the results sound better than they are. If I need up to five feet of water to use my dock, then the BRA definition for "out-of-use" equating to 2 feet of water or less isn't sufficient and your report distorts this fact to make the impact of your new management plan look more positive than it actually is. My dock may be out-of-service 40 percent of the time when your report shows it to be out-of-service only 20 percent of the time.

Further, using "historical" as a baseline comparison isn't fair for Possum Kingdom. Historically, Granbury has been seen as a constant level lake due to the high volumes of water that were released through the hydro-power facility. Electric generation had a negative impact on lake levels at PK and they fluctuated considerably in the past—we would have loved to have been more like Granbury historically.

Answer 1: *Brad Brunett, BRA Water Services Manager, provided that her assessment is valid and that she brought up a good point. "If you have a more precise estimate of what "out-of-service" means in your specific case, you can refer to the charts which we have just described to get a more accurate accounting of what you might expect in terms of how often your dock won't perform as you would like. The presentation materials will be available online and at the Lake office."*

For the purpose of developing an estimate of what dock owners at both lakes could expect, Mr. Brunett provided that we had to pick a reasonable number. In some cases at Lake Granbury, some people have built docks where the water is only 2 feet deep. We understand there are differences in the variables of each lake—there are differences not only in depth at the docks, but in the types of docks. We were tasked with finding a solution that best suited everyone—we believe this to be the most reasonable solution. He added that regardless of the number that was chosen to reflect "out-of-service," the management ratio of 1.75:1 would likely not have changed.

As to the comment on historic fluctuations of the lake levels, Mr. Brunett provided that those were reflected "not as a target that we were trying to hit, but as an indicator only for comparison to the anticipated results from the proposed zonal drawdown plan."

Question/Comment 2: Rick Lasky asked "is hyrdo really dead and gone—history?"

Answer 2: *Mike McClendon, Upper Basin Manager, reported that the Board of Directors, upon reviewing an extensive cost-benefit analysis, voted to decommission the facility. BRA recently submitted a "Surrender Application" for review to certain state and federal agencies. He provided that "once we hear back from them, we'll submit the document(s) to FERC."*

Mr. McClendon went on to provide that this question was in line with one he had just been handed in which he was asked whether the BRA Board of Directors would be taking further action in regard to decommissioning or if it is all up to FERC.

Mr. McClendon provided that when the Board made the decision to decommission, they gave the BRA General Manager/CEO authority to take any and all action necessary to complete the process. "No further Board action is required that we are aware of. After FERC reports their findings, we'll know where we stand in the process."

Question/Comment 3: Rick Lasky went on to suggest that the relative improvement in the level of the (PK) lake was the result of discontinuing hydro-electric production.

Answer 3: *Mike McClendon provided that Mr. Lasky was correct in his understanding. Brad Brunett provided a slide that compared the volume of historical releases from the lake for hydro-power verses anticipated release volumes under the proposed zonal drawdown plan. This to further drive home the point that Mr. Lasky correctly understood that PK Lake would be better off under the new management plan than it had been historically.*

Question/Comment 4: (Unknown) Am I understanding that Granbury built their docks to better accommodate lower lake levels than PK and that they did so based on BRA's operations? Therefore, isn't PK more adversely impacted by the new plan than Granbury since Granbury is better prepared for lake fluctuations?

Answer 4: *Mike McClendon and Brad Brunett explained that the reverse was true. In some instances at Granbury, fixed docks were built in shallow canals and tend to go "out-of-service" more quickly when lake levels drop. At PK, floating docks were built to accommodate fluctuations in lake levels that residents had been accustomed to with hydro-power production. The zonal drawdown that is proposed is designed to provide a more equitable impact on both lakes as lake levels fluctuate.*

Question/Comment 5: (Unknown) How much water will Units 3 & 4 at Comanche Peak require? Why is BRA requesting from TCEQ an additional 500,000 acre feet to sell?

Answer 5: *Brad Brunett explained that the new units are projected to use an additional 90,000 to 100,000 acre feet of water, but that design work is not complete and the number will be better known when it is. He further noted that Comanche Peak would recycle some of the water that they use—in effect, the units would put back 40 percent of the water that they take and have a net impact of 50,000 to 60,000 acre feet per year. For the purposes of the BRA study that had been presented, BRA assumed a future use of 53,000 acre feet.*

Brad Brunett followed by explaining that our request for additional water rights from TCEQ was based on state water planning projections for future needs of the basin. He stated that the BRA permit application is for 423,000 acre feet. The water would be used to meet future demand as the population grows and additional water and utility needs materialize. He further provided that in addition to maximizing water that is currently available in our basin, BRA considers prospects for new reservoirs and the potential

acquisition of groundwater. These are the tools available in the BRA toolbox for developing water supply to meet current and future needs of our constituents.

Question/Comment 6: (Unknown) Am I correctly understanding that this new drawdown ratio is meant to help meet downstream demands? Are Abilene's future needs factored into this?

Answer 6: *Brad Brunett provided that the assumed demand for water from PK and Granbury is based on the local needs of PK, Granbury and Whitney and a percentage of the demand from further downstream. Referring to an earlier slide from the presentation, Mr. Brunett provided that BRA has customers throughout the basin all the way down to the coast. "We aren't going to supply all the water out of PK and Granbury. We have 11 reservoirs in our system."*

Mr. Brunett added that the future demand of Abilene was factored into the 1.75:1 ratio. He noted that Abilene is currently exploring a couple of options to meet their future demand and that regardless of which option they choose, we did factor them into our management ratio based on their actual needs.

Abilene is in the process of determining whether they'll build a new reservoir, or based on the outcome of BRA's application with TCEQ, they may be able to exercise an option contract with BRA for 20,000 acre feet. It is likely that they wouldn't do both.

Appendix F

Brazos River Authority

BOARD OF DIRECTORS
Possum Kingdom – Granbury – Whitney Water Management Plan
Agenda Item No. 7

ACTION:
The following resolution is presented for consideration to the Board of Directors of the Brazos River Authority for adoption at its April 18, 2011 meeting.

> **"BE IT RESOLVED** that the Board of Directors of the Brazos River Authority hereby approves the zonal drawdown methodology for operating Possum Kingdom Lake and Lake Granbury in accordance with results of the Possum Kingdom – Granbury – Whitney Water Management draft Study report dated April 2011; and
>
> **BE IT FURTHER RESOLVED** that the Board of Directors of the Brazos River Authority authorize the General Manager/CEO to use a drawdown ratio of 1.75:1 (Possum Kingdom:Granbury) when the elevation of Possum Kingdom is above 992.0 feet mean sea level (ft msl), and a drawdown ratio of 1:1 when the elevation of Possum Kingdom drops below 992.0 ft msl; and
>
> **BE IT FURTHER RESOLVED** that based on the study results, it is understood that the 1:1 drawdown ratio used when the elevation of Possum Kingdom Lake is below elevation 992.0 ft msl may be adjusted by the General Manager/CEO **with Board approval** in the future if demands on this portion of the Brazos River Authority's System increase significantly."

SUMMARY:
The Brazos River Authority (Authority) Board of Directors (Board) was briefed on the draft results of a study at the January 31, 2011 Board meeting. The purpose of the study was to develop a water management procedure for the Possum Kingdom – Granbury – Whitney portion of the Authority's Water Supply System following the discontinuance of hydropower generation at Possum Kingdom Lake. The objective of the study was to develop a management protocol that meets the Authority's water supply needs from this portion of the System while

balancing adverse impacts experienced at each of the lakes during dry times. A "zonal drawdown" procedure was developed that accomplishes the objective.

Under the proposed procedure, releases would be made from Possum Kingdom Lake as necessary to maintain a 1.75:1 foot drawdown ratio between the elevation of Possum Kingdom Lake and Lake Granbury when Possum Kingdom Lake's elevation is above 992.0 feet mean sea level (ft msl). When Possum Kingdom Lake's elevation drops below 992.0 ft msl, the drawdown ratio would change to 1:1. As water demands increase in the future, the drawdown ratio will need to be adjusted in this lower zone (below 992.0 ft msl) at Possum Kingdom Lake.

Following the Board meeting in January, a series of presentations were made about the study. Legislative staff representing State Senator Brian Birdwell, State Senator Craig Estes, and State Representative Jim Keffer were briefed at the State Capitol on February 11. On February 28, local leadership including Granbury Mayor Ricky Pratt, Hood County Judge Darrell Cockerham, Hood County Commissioner Leonard Heathington, and Interim Granbury City Manager Ron Berryman were briefed in Granbury. Palo Pinto County Judge David Nicklas was briefed on March 3. The City of Granbury Chamber of Commerce Executive Committee was briefed on March 23. Positive feedback and constructive comments were received at all of these briefings. All were impressed with the study effort, methodology, and comprehensiveness.

Public meetings were conducted on Monday evening, March 28, in Granbury and Tuesday evening, March 29, in Graford. The presentations and the question and answer sessions were recorded. Written transcripts summarizing the question and answer sessions at both meetings were prepared. Most public comments and questions were critical in nature, particularly at the Granbury meeting. In general, comments received at Granbury were that more water should be released from Possum Kingdom Lake than what is proposed. Conversely, general comments at Graford were the opposite.

FINANCIAL IMPACT:
The study effort was conducted by in-house staff with assistance from Halff Associates, Inc. Halff Associates' fee for its portion of the study effort was $198,048. No major financial impacts are anticipated upon adoption of a formal operational protocol.

STAFF VIEW:
Staff believes that the zonal drawdown methodology developed in the study is a reasonable, fair, and equitable means for operating this portion of the Authority's water supply system.

Appendix G

Brazos River Authority

RESOLUTION OF THE BOARD OF DIRECTORS OF THE BRAZOS RIVER AUTHORITY APRIL 18, 2011

Agenda Item No. 7
Possum Kingdom – Granbury – Whitney Water Management Plan

"**BE IT RESOLVED** that the Board of Directors of the Brazos River Authority hereby approves the zonal drawdown methodology for operating Possum Kingdom Lake and Lake Granbury in accordance with results of the Possum Kingdom – Granbury – Whitney Water Management draft Study report dated April 2011; and

BE IT FURTHER RESOLVED that the Board of Directors of the Brazos River Authority authorize the General Manager/CEO to use a drawdown ratio of 1.75:1 (Possum Kingdom:Granbury) when the elevation of Possum Kingdom is above 992.0 feet mean sea level (ft msl), and a drawdown ratio of 1:1 when the elevation of Possum Kingdom drops below 992.0 ft msl; and

BE IT FURTHER RESOLVED that based on the study results, it is understood that the 1:1 drawdown ratio used when the elevation of Possum Kingdom Lake is below elevation 992.0 ft msl may be adjusted by the General Manager/CEO with Board approval in the future if demands on this portion of the Brazos River Authority's System increase significantly."

The aforementioned resolution was approved by the Board of Directors of the Brazos River Authority on April 18, 2011, to certify which witness my hand and seal.

Christopher D. DeCluitt
Presiding Officer

SUBSCRIBED AND SWORN TO BEFORE ME on this the 18 day of April, 2011, to certify which witness my hand and official seal.

Jennifer J White
Notary Public
State of Texas
Commission expires:
05/21/13

Notary Public in and for the
State of Texas