APPENDIX C

WATER DEMANDS

To: Doug Murphy *cc:*
From: Thomas Dumm / George Rest
Re: Water Supply Shortfall

Date: February 13, 2011

INTRODUCTION

The Tennessee Duck River Development Agency (DRA) is developing a Comprehensive Regional Water Supply Plan for Bedford, Coffee, Marshall, Maury, and southern Williamson Counties to meet future water needs and address concerns with possible water shortages brought on by drought conditions. The drought of 2007 highlighted the issue that in extended dry weather conditions, the citizens of the Duck River region primarily depend on the water stored in Normandy Reservoir to meet multiple uses, including drinking water, wastewater assimilation, recreation, and natural resource protection. The dramatic decrease in rainfall, combined with the designated uses of the reservoir and river, caused record low water levels in Normandy Reservoir that resulted in temporary changes in dam operation to protect water uses. Weather patterns and growth projections, combined with the obligation to manage resources responsibly for future generations, have created the need for a comprehensive regional water supply plan for the Duck River region. The goal of the Comprehensive Regional Water Supply Plan is to address water needs through a 50-year planning period with a 100-year vision and provide direction to the DRA for the management of available water resources, including the implementation of specific water supply infrastructure projects.

Normandy Reservoir is located in the upper portion of the Duck River watershed and was constructed in 1976. Normandy Reservoir was designed to provide a variety of recreation, flood protection, water supply, and water quality benefits both upstream and downstream from the dam. Water users upstream from Normandy Dam (primarily Tullahoma and Manchester) are served from a water intake located in Normandy Reservoir. For downstream water users, water is released from Normandy to provide an instantaneous minimum flow of up to 165 cfs at Shelbyville (up to 10 cfs for water supply and 155 cfs for water quality control). The water quality control volume to be provided at Shelbyville has also historically met the water quality control needs at Columbia (i.e., 100 cfs).

TVA operates Normandy Reservoir using the following priorities to decide how to release water under normal rainfall conditions:

- Minimize downstream flooding (especially in winter and early spring).
- 40 cfs minimum instantaneous flow just downstream from the dam.
- 120 cfs minimum instantaneous flow at Shelbyville (December - May).
- 155 cfs minimum instantaneous flow at Shelbyville (June - November).
- Up to 10 cfs additional instantaneous flow at Shelbyville for water supply.

In 1996, the TDEC Division of Water Pollution Control evaluated the minimum instream flow required to maintain recreation and fish/aquatic life uses in the Duck River at Columbia in response to questions about the ability of the Duck River to meet additional water supply needs. The analysis resulted in a requirement that the streamflow should not fall below 100 cfs at Duck River Mile 132.8, immediately downstream from the Columbia water supply intake. This minimum flow requirement is included in Columbia's water permit (ARAP) and establishes a state-identified limit below which no additional water can be withdrawn from the Duck River

by Columbia. This 100 cfs requirement at River Mile 132.8 is recognized as a key constraint in the Comprehensive Regional Water Supply Plan.

The purpose of this memorandum is to present the methodology used to develop the shortfall in supply identified in the Comprehensive Regional Water Supply Plan.

NEED FOR ADDITIONAL WATER SUPPLY

The first step in the Comprehensive Regional Water Supply Plan was the assessment of the need for additional water supply through the year 2060. This assessment included an evaluation of the available supply from Normandy Reservoir and the Duck River and a projection of water demands for domestic, commercial, and industrial purposes. The OASIS computer model developed by HydroLogics, Inc. was used to examine the operation of Normandy Reservoir and the hydrology of the Duck River. This information assisted in developing a strategy to satisfy the future water needs for not only public water supply but for all designated Duck River uses. Water users upstream from Normandy Dam (primarily Tullahoma and Manchester) are served from a water intake located in Normandy Reservoir while downstream uses are met by withdrawals from the Duck River. In periods of extended dry weather, the flow in the Duck River is primarily composed of water released from Normandy Reservoir. To estimate future water needs in the region, the OASIS model used current and projected water demands as well as the following reservoir and river constraints defined by the Tennessee Department of Environment and Conservation (TDEC):

- **Normandy Reservoir**
  - Release water from Normandy Reservoir to maintain 25.8 mgd (40 cfs) minimum instantaneous flow just downstream of the dam.
- **Shelbyville**
  - 77.5 mgd (120 cfs) minimum instantaneous flow at Shelbyville (December through May).
  - 100.2 mgd (155 cfs) minimum instantaneous flow at Shelbyville (June through November).
  - 6.5 mgd (10 cfs) allocation for Shelbyville's water supply intake.
- **Columbia**

  Columbia Power and Water System's Aquatic Resource Alteration Permit (ARAP) identifies the following permit conditions:
  - Columbia Power and Water System's maximum instantaneous withdrawal rate shall be limited to 19.4 mgd (30 cfs).
  - Columbia Power and Water System's withdrawal shall not result in a reduction of flow in the Duck River of less than 64.6 mgd (100 cfs) as measured downstream of the intake.



Demands for municipal, industrial, and other needs were calculated based on the amount of water that

would be needed during a drought of record to assure that ample supplies would be available during a repeat of such a drought. Several sources of information were reviewed (i.e., US Geological Survey, Tennessee Valley Authority, and University of Tennessee) and ultimately water demands were projected using population projections from the University of Tennessee's Center for Business and Economic Research (CBER). Unrestricted water demands were projected to approximately double over the next 50 years (30 mgd in 2010 to 57 mgd in 2060). The OASIS modeling was performed over a period of hydrologic record extending from 1921 through 2008. The modeling results indicated that there is adequate supply for the users of Normandy Reservoir through 2060, but a potential deficit of up to 32 mgd for users of the Duck River between Shelbyville and Columbia. Currently, drought conditions such as those experienced in 2007 could result in a 4 mgd deficit at Columbia, straining the river's ability to maintain water supply for all uses. The drought and population growth challenges faced by the region indicate that water supply plans must be reliable, flexible, and collaborative to meet both current and future demands.

The attached Excel spreadsheet provides a basis for calculation of a deficit of up to 32 mgd at Columbia in year 2060. The OASIS computer model was used to evaluate the adequacy of Normandy Reservoir and the Duck River to meet current and future demands over a period of hydrologic record extending from 1921 through 2008. Because of streamflow data limitations (i.e., changes in the operation / flow through the Shelbyville, Lillards Mill and Columbia dams on the Duck River during the 87-year period of record in the model), the OASIS model cannot accurately calculate the daily gains and losses in the river which are needed to compute the daily river flow and deficit at Columbia. Consequently, it is necessary to convert the deficit calculated in the OASIS model at Columbia (which includes a monthly peaking factor) to a daily peak value (as shown in the attached spreadsheet).

Calculation of Water Demands and Deficit in Duck River at Columbia

Table 1. USGS Historic and Projected Average Water Use for the Upper Duck River Watershed Area							
Typical Climatological Conditions (2003 Base-Year)	**Historic and Projected Average Daily Water Use (MGD)**						
Water Service Area	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**
Bedford	5.7		6.7		8.1		9.9
Coffee	5		6.1		13		16
Marshall	3		3		4.2		4.8
Maury/Southern Williamson	11		13		17		21
Total	25		30		42		51

Notes for Table 1:

1. Table 7. "Estimated Use of Water in the Upper Duck River Watershed, Central Tennessee, and Water Demand Projections through 2030", USGS, 2008.

Table 2. Center for Business and Economic Research Historic and Projected Population							
	Historic and Projected Population						
Water Service Area	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**
Bedford	37,586	41,963	45,891	52,552	57,529	62,364	67,456
Coffee	48,014	50,690	53,078	57,201	60,017	62,288	64,520
Marshall	26,767	28,053	29,231	31,014	32,323	34,590	36,822
Maury/Southern Williamson	74,633	86,053	93,943	107,160	116,691	125,583	134,862
Total	187,000	206,759	222,143	247,927	266,560	284,825	303,660

Notes for Table 2:

1. "Population Projections for the State of Tennessee, Aggregate Projections for Municipalities Arrayed by County", University of Tennessee CBER, June 2009.

2. Population data based on populations for each municipality within the County plus the unincorporated portion of the County.

3. Population data for Maury County and Southern Williamson WSA is based on Maury County plus Spring Hill.

Table 3. Gross Water Use Based on USGS Average Water Use and CBER Population for Year 200(		
Water Service Area	**Average Water Use (gpd/person)**	
Bedford	152	gpd/person
Coffee	104	gpd/person
Marshall	112	gpd/person
Maury/Southern Williamson	147	gpd/person

Notes for Table 3:

1. Convert CBER population data to water demand data using surrogate average water use value computed for each County in WSA.
   Ratios of population in the incorporated and unincorporated area remain essentially equal for each County in the WSA's through 2030 based on CBER data.
   Assumes that population in the incorporated area will be served with public water and the unincorporated area will not be served.

Table 4. Calculated, Projected and Extrapolated Average Daily Water Use Based on CBER Population and Per Capita Water Use													
	Calculated (2000-2010), Projected (2015-2030) and Extrapolated (2035 - 2060) Average Daily Water Use (MGD)												
Water Service Area	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**2055**	**2060**
Bedford	5.7	6.4	7.0	8.0	8.7	9.5	10.2	11.0	11.7	12.5	13.2	14.0	14.8
Coffee	5.0	5.3	5.5	6.0	6.2	6.5	6.7	7.0	7.3	7.6	7.9	8.2	8.4
Marshall	3.0	3.1	3.3	3.5	3.6	3.9	4.1	4.3	4.5	4.7	4.9	5.1	5.3
Maury/Southern Williamson	11.0	12.7	13.8	15.8	17.2	18.5	19.9	21.4	22.8	24.3	25.8	27.3	28.8
Total	24.7	27.5	29.6	33.2	35.8	38.3	41.0	43.7	46.4	49.1	51.8	54.5	57.2

Table 5. Average Water Demands Used in OASIS Model Based on CBER Population and Per Capita Water Use

	Average Water Demands in OASIS Model (MGD)												
Water Service Area by Utility			**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**2055**	**2060**
Coffee County													
Tullahoma			2.9		3.3	3.4	3.5	3.7	3.8	4.0	4.1	4.3	4.4
Manchester			2.6		3.0	3.1	3.2	3.3	3.4	3.6	3.7	3.9	4.0
Bedford County													
Shelbyville			4.7		6.1	6.6	7.2	7.7	8.2	8.8	9.3	9.8	10.4
BCUD			2		2.6	2.8	3.1	3.3	3.5	3.7	4.0	4.2	4.4
Marshall County													
Lewisburg			3		3.6	3.9	4.1	4.3	4.5	4.7	4.9	5.1	5.3
Maury/Southern Williamson													
Spring Hill			2.5		3.1	3.3	3.5	3.8	4.1	4.3	4.6	4.9	5.1
Columbia			11.5		14.1	15.2	16.3	17.5	18.8	20.0	21.2	22.4	23.6
Total			29.2		35.8	38.3	41.0	43.7	46.4	49.1	51.8	54.5	57.2

Notes for Table 5:

1. Average water demands used in OASIS model for hydrologic analyses in September 2009 and presented to Water Resources Council in October 2009.

2. Highlighted columns represent data input to OASIS model.

Table 6. Average Water Demands Developed by DRUC in November 2009 (subsequent to OASIS modeling analyses and therefore not accounted for in reservoir modeling analyses)													
	Average Daily Water Demands (MGD)												
DRUC Average Water Demands for Reservoir Users			**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**2055**	**2060**
Coffee County													
Tullahoma			3.7		4.3	4.6	4.9	5.2	5.5	5.7	6.0	6.2	6.4
Manchester			2.7		3.1	3.3	3.6	3.8	4.0	4.2	4.3	4.5	4.6

Table 7. Average Water Demands Used in OASIS Model for Duck River Users Based on CBER Population and Per Capita Water Use													
	Average Daily Water Demands in OASIS Model for Duck River Users (MGD)												
OASIS Model Inputs for Duck River Users			**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**2055**	**2060**
Bedford County													
Shelbyville			4.7		6.1	6.6	7.2	7.7	8.2	8.8	9.3	9.8	10.4
BCUD			2.0		2.6	2.8	3.1	3.3	3.5	3.7	4.0	4.2	4.4
Marshall County													
Lewisburg			3.0		3.6	3.9	4.1	4.3	4.5	4.7	4.9	5.1	5.3
Maury/Southern Williamson													
Spring Hill			2.5		3.1	3.3	3.5	3.8	4.1	4.3	4.6	4.9	5.1
Columbia			11.5		14.1	15.2	16.3	17.5	18.8	20.0	21.2	22.4	23.6
Total			23.7		29.5	31.8	34.2	36.7	39.1	41.5	43.9	46.3	48.8

Notes for Table 7:

1. Average water demands used in OASIS model for hydrologic analyses and presented to Water Resources Council in October 2009.

Table 8. Average Daily and Peak Daily Water Demands for Duck River Users													
Water Demands for River Users	**Water Demands for River Users (MGD)**												
			2010	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**2055**	**2060**
Average Daily Demand for River Users			24	27	30	32	34	37	39	42	44	46	49
Peak Daily Demand for River Users			36	41	44	48	51	55	59	62	66	70	73

Notes for Table 8:

1. Ratio of peak day:average day demand = 1.5 based on historic water use for river users from 2003 -2007 as presented in Workshop No. 2.

Table 9. Calculation of Net Peak Monthly Water Use (Consumptive Use) and Net Peak Daily Water Use (Consumptive Use) at Columbia for Year 2010										
	Net Peak Monthly Water Use (Consumptive Use) for Year 2010 (MGD)					**Net Peak Daily Water Use (Consumptive Use) for Year 2010 (MGD)**				
Consumptive Use for River Users (2010)	Average Water Demand in OASIS Model for River Users (MGD)	Peak Monthly Demand Factor in OASIS Model	Average Water Demand in Peak Month in OASIS Model for River Users (MGD)	Wastewater Return Flow Ratio in OASIS Model for River Users	Net Peak Monthly Water Use or Consumptive Use (MGD)	Average Water Demand in OASIS Model for River Users (MGD)	Peak Daily Demand Factor	Peak Daily Water Demand for River Users (MGD)	Wastewater Return Flow Ratio in OASIS Model for River Users	Net Peak Daily Water Use or Consumptive Use (MGD)
Bedford County										
Shelbyville	4.7	1.106	5.2	0.721	1.5	4.7	1.5	7.1	0.721	2.0
BCUD	2.0	1.154	2.3	0.500	1.2	2.0	1.5	3.0	0.500	1.5
Marshall County										
Lewisburg	3.0	1.073	3.2	0.604	1.3	3.0	1.5	4.5	0.604	1.8
Maury/Southern Williamson										
Spring Hill	3.0	1.214	3.6	0.000	3.6	2.5	1.5	3.8	0.000	3.8
Columbia	11.0	1.126	12.4	0.000	12.4	11.5	1.5	17.3	0.000	17.3
Total	24		27		20	24		36		26

Notes for Table 9:

1. OASIS model results based on average demands multiplied by a monthly peaking factor due to data limitations. Water needs for river users based on peak daily demand so need to convert monthly results to peak daily.

2. Consumptive use represents the flow that is withdrawn from the river by the water utility and not returned (i.e., water withdrawal - wastewater return flow).

3. Wastewater return flow ratio = 0 and consumptive use = 100% for Spring Hill and Columbia because wastewater return flows to the Duck River are downstream of Columbia gage which is the location of the 100 cfs river constraint.

4. Peak Daily Demand Factor is ratio of peak day:average day demand = 1.5 based on review of historic water use for river users from 2003 -2007 and presented at Workshop No. 2.

Table 10. Calculation of Net Peak Monthly Water Use (Consumptive Use) and Net Peak Daily Water Use (Consumptive Use) at Columbia for Year 2060

	Net Peak Monthly Water Use (Consumptive Use) for Year 2060 (MGD)					Net Peak Daily Water Use (Consumptive Use) for Year 2060 (MGD)				
Consumptive Use for River Users (2060)	Average Water Demand in OASIS Model for River Users (MGD)	Peak Monthly Demand Factor in OASIS Model	Peak Monthly Water Demand in OASIS Model for River Users (MGD)	Wastewater Return Flow Ratio in OASIS Model for River Users	Net Peak Monthly Water Use or Consumptive Use (MGD)	Average Daily Water Demand in OASIS Model for River Users (MGD)	Peak Daily Demand Factor	Peak Daily Water Demand for River Users (MGD)	Wastewater Return Flow Ratio in OASIS Model for River Users	Net Peak Daily Water Use or Consumptive Use (MGD)
Bedford County										
Shelbyville	10.4	1.1	11.5	0.721	3.2	10.4	1.5	15.5	0.721	4.3
BCUD	4.4	1.2	5.1	0.500	2.5	4.4	1.5	6.6	0.500	3.3
Marshall County										
Lewisburg	5.3	1.1	5.6	0.604	2.2	5.3	1.5	7.9	0.604	3.1
Maury/Southern Williamson										
Spring Hill	5.1	1.2	6.2	0.000	6.2	5.1	1.5	7.7	0.000	7.7
Columbia	23.6	1.1	26.6	0.000	26.6	23.6	1.5	35.4	0.000	35.4
Total	49		55		41	49		73		54

Notes for Table 10:

1. OASIS model results based on average demands multiplied by a monthly peaking factor due to data limitations. Water needs for river users based on peak daily demand so need to convert monthly results to peak daily.

2. Consumptive use represents the flow that is withdrawn from the river by the water utility and not returned (i.e., water withdrawal - wastewater return flow).

3. Wastewater return flow ratio = 0 and consumptive use = 100% for Spring Hill and Columbia because wastewater return flows to the Duck River are downstream of Columbia gage which is the location of the 100 cfs river constraint.

4. Peak Daily Demand Factor is ratio of peak day:average day demand = 1.5 based on review of historic water use for river users from 2003 -2007 and presented at Workshop No. 2.

Table 11. Calculation of River Deficit Based on 100 cfs River Constraint at Columbia

Calculation of River Deficit			Calculation of Current and Projected River Deficit (MGD)										
			2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
Minimum Unimpaired Flow at Columbia (MGD)			88	88	88	88	88	88	88	88	88	88	88
100 cfs River Constraint at Columbia (MGD)			66	66	66	66	66	66	66	66	66	66	66
Net Peak Daily Water Use or Consumptive Use (MGD)			26	29	32	35	37	40	43	46	48	51	54
River flow at Columbia for 1 in 87 yr Event (MGD)			62	59	56	53	51	48	45	42	40	37	34
Projected Deficit for 1 in 87 yr Event (MGD)			**4**	**7**	**10**	**13**	**15**	**18**	**21**	**24**	**26**	**29**	**32**

Notes for Table 11:

1. Minimum unimpaired flow represents the minimum flow computed by OASIS (September 2009) at Columbia for the 87 years of record that would occur absent any utility river withdrawals.
The unimpaired flow (88 mgd) is equal to the 2010 OASIS minimum flow result at Columbia (105 cfs or 68 mgd) plus the 2010 consumptive use by river users (20 mgd).