CHAPTER III
RESULTS

Following is a summary of the results of the monitoring program conducted in 2004. The general reservoir conditions during this period are described, and the water quality data obtained are summarized.

RESERVOIR CONDITION

There was frequent rainfall in 2004, and reservoir levels were relatively high throughout that year. In fact, reservoir levels were significantly higher during the 2004 monitoring period than they were during the 2002 monitoring period. The reservoir elevations for years 2001, 2002, 2003, and 2004 are presented on Figure III-1. The periods during which monitoring was conducted in 2001, 2002, and 2004 are also shown on Figure III-1. A comparison of elevations during 2002 and 2004 is as follows:

Year	Elevation (ft msl)	
	Begin Monitoring	End Monitoring
2002	314.9	312.8
2004	315.0	314.3

A more detailed representation of the lake elevations during the 2004 monitoring period is presented on Figure III-2. In general, the reservoir level was falling during the sampling period of August 10, 2004, through September 29, 2004. However, there were sufficient rains in the August 19-August 29 period to increase the overall lake level from 314.9 ft msl to 315.2 ft msl.

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Figure III-1
Water Quality Standards Evaluation
Richland-Chambers Reservoir

Reservoir Elevation
2001 - 2004

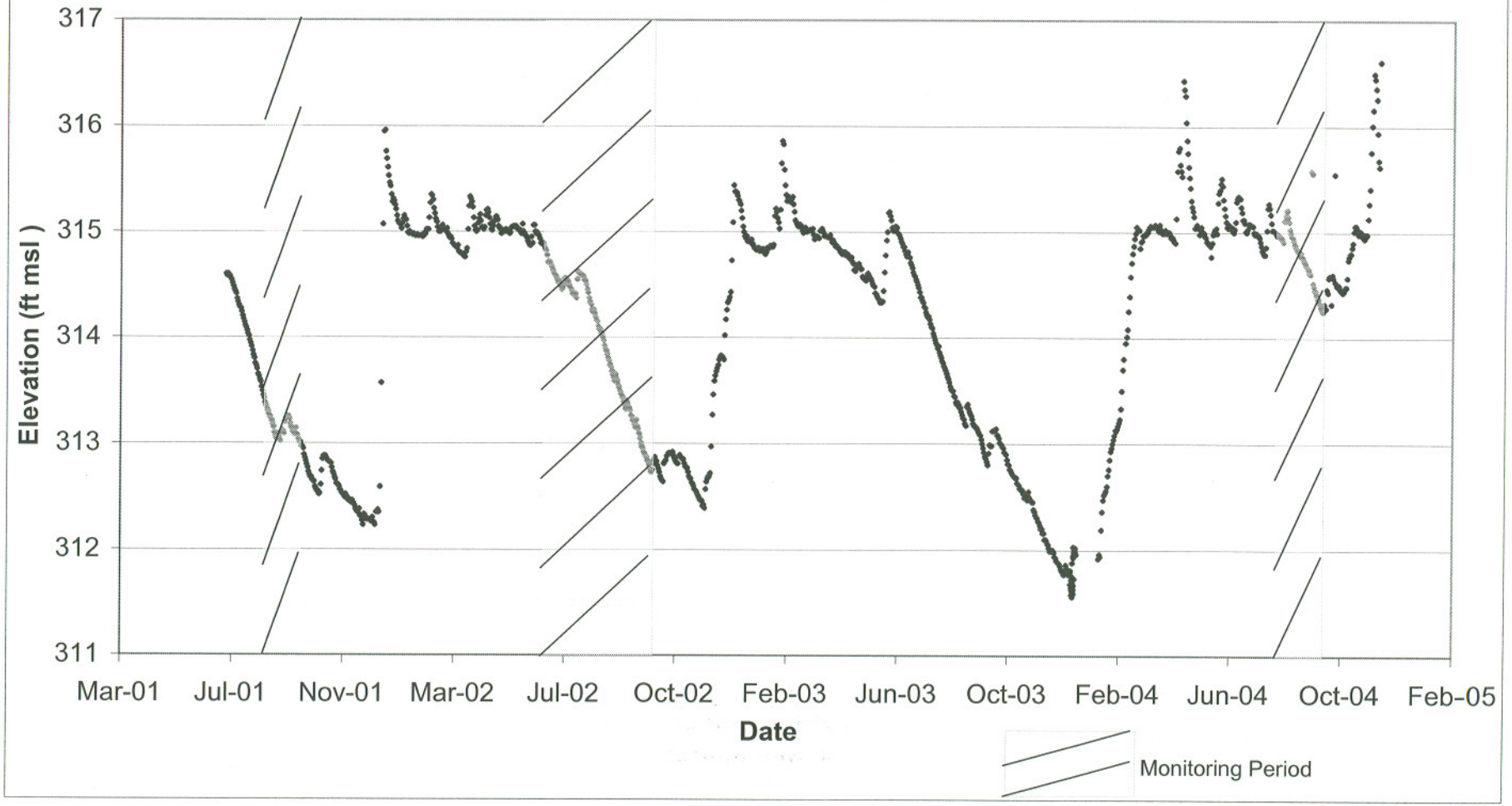

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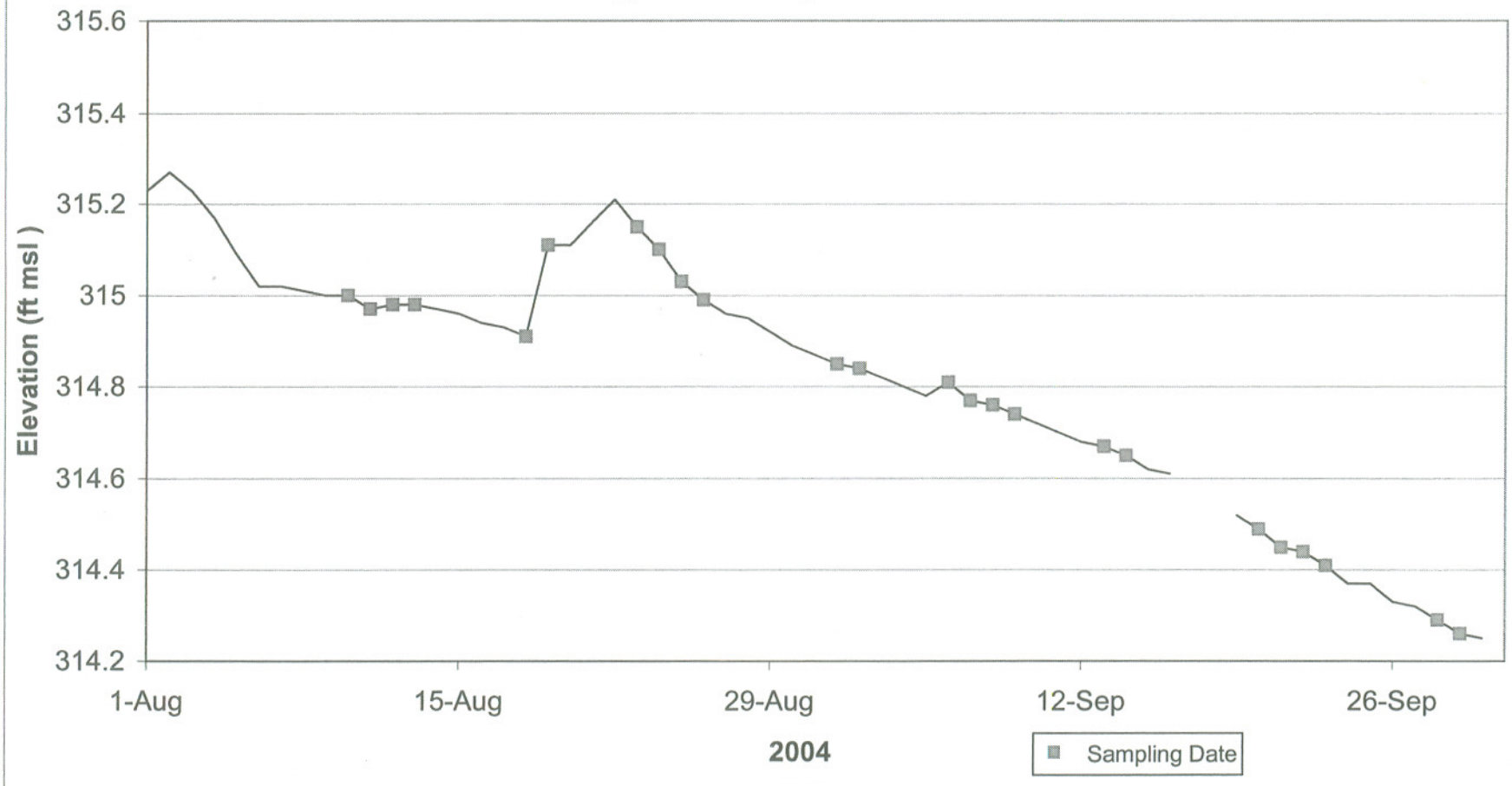
Figure III-2
Water Quality Standards Evaluation
Richland-Chambers Reservoir

Reservoir Elevation
August 2004 - September 2004



WATER QUALITY

A complete summary of the water quality data collected in 2004 is presented in Appendix A. The sampling dates for each monitoring event are summarized in Table III-1. On August 18, 2004, sampling of Post Oak Creek had to be canceled due to rainfall.

The early summer period of 2004 was very rainy, and it was not possible to obtain samples in June or July. In addition, heavy rainfalls occurred in early October; so, conditions were not suitable for sampling during that month, either. Rainfall records for June through October 2004 are shown on Table III-2. Table III-2 presents data for the rain gage operated by the U.S. Army Corps of Engineers at Navarro Mills Lake on Richland Creek and data for the rain gage operated by the National Oceanic and Atmospheric Administration (NOAA) at the Corsicana Campbell Airport. As previously noted, because of the frequent rainfall, the reservoir elevation was at, or above, the conservation pool elevation of 315 ft msl for most of the spring and summer of 2004.

Since it was not possible to conduct surveys in June or July of 2004, monitoring events were conducted more frequently in August and September. A minimum of five monitoring events was conducted at each monitoring station. More than five monitoring events were conducted for all of the tributary areas except Cedar Creek. The work plan states that, if a sample event was not conducted during each of the five summer months in 2004, the monitoring program would be continued into 2005. However, since more than five events were conducted for most tributary areas during the critical period in 2004 and data were available for the months of June, July, and October from the 2002 study, it is believed a sufficient body of data has been obtained. Our understanding is that TCEQ agreed with this conclusion.

An audit of the sampling program was conducted by the Trinity River Authority. The audit report is presented in Appendix B.

Water Quality Criterion

The objective of this study is to determine the appropriate DO water quality standard for the Post Oak Creek arm of Richland-Chambers Reservoir. The Texas Surface Water Quality Standards [Title 30 Texas Administrative Code (TAC) Chapter 307] establish that standards for DO are applied as follows:

Table III-1

Water Quality Standards Evaluation
Richland-Chambers Reservoir

Sampling Events - 2004

Tributary	Station	Sampling Dates							
		Event 1	Event 2	Event 3	Event 4	Event 5	Event 6	Event 7	Event 8
Cedar Creek	CC1	8/12	8/23	9/6	9/23	9/28	C	C	C
	CC4	8/12	8/23	9/6	9/23	9/28	C	C	C
	CC Bridge	8/12	8/23	9/6	9/23	9/28	C	C	C
	CC6	8/12	8/23	9/6	9/23	9/28	C	C	C
	CC7	8/12	8/23	9/6	9/23	9/28	C	C	C
Grape Creek	GC Bridge	8/10	8/18	8/24	9/2	9/7	9/14	9/20	C
Post Oak Creek	PO-AC	8/13	8/19[1]	8/26	9/1	9/9	9/13	9/22	9/29
	PO5	8/13	8/19[1]	8/26	9/1	9/9	9/13	9/22	9/29
	PO8	8/13	8/19[1]	8/26	9/1	9/9	9/13	9/22	9/29
Richland Creek	RC Love Bridge	8/11	8/18	8/25	9/2	9/8	9/14	9/21	C
	RC1	8/11	8/18	8/25	9/2	9/8	9/14	9/21	C
	RC2	8/11	8/18	8/25	9/2	9/8	9/14	9/21	C
	RC IH-45	8/11	8/18	8/25	9/2	9/8	9/14	9/21	C
	RC3	8/10	8/18	8/24	9/2	9/7	9/14	9/20	C

1 -Terminated due to rain.

Table III-2
Water Quality Standards Evaluation
Richland-Chambers Reservoir

Precipitation
(inches)

June 2004			July 2004			August 2004			September 2004			October 2004		
Day	Airport*	Richland Creek**	Day	Airport*	Richland Creek**	Day	Airport*	Richland Creek**	Day	Airport*	Richland Creek	Day	Airport*	Richland Creek**
1	0.71	-	1	-	0.12	1	-	0.04	1	-	-	1	1.36	-
2	0.65	0.16	2	-	-	2	-	-	2	-	-	2	0.05	0.14
3	0.24	0.51	3	T	-	3	-	-	3	-	-	3	-	1.24
4	-	0.64	4	-	-	4	-	-	4	-	-	4	1.80	-
5	-	-	5	-	-	5	-	-	5	T	-	5	T	2.36
6	-	-	6	-	-	6	-	-	6	0.01	-	6	0.38	-
7	0.36	-	7	-	-	7	-	-	7	-	0.24	7	0.18	0.91
8	2.95	-	8	-	-	8	-	-	8	-	-	8	-	0.32
9	0.58	3.05	9	-	-	9	-	-	9	-	-	9	0.15	-
10	0.09	0.11	10	-	0.16	10	-	-	10	-	-	10	0.04	0.23
11	0.03	0.18	11	-	-	11	T	-	11	-	-	11	-	0.05
12	-	-	12	-	-	12	-	-	12	-	-	12	-	-
13	-	-	13	-	-	13	-	-	13	-	-	13	-	-
14	-	-	14	-	-	14	-	-	14	0.35	-	14	-	-
15	0.01	-	15	-	-	15	-	-	15	-	-	15	-	-
16	-	-	16	-	-	16	-	-	16	-	-	16	-	-
17	-	-	17	-	-	17	-	-	17	-	-	17	-	-
18	-	-	18	-	-	18	-	-	18	-	-	18	-	-
19	0.63	-	19	-	-	19	2.90	-	19	-	-	19	-	-
20	-	-	20	-	-	20	0.30	1.64	20	-	-	20	-	-
21	-	-	21	-	0.02	21	0.38	0.08	21	-	-	21	-	-
22	0.98	-	22	T	-	22	0.72	0.01	22	-	-	22	0.40	-
23	-	0.70	23	-	-	23	T	0.52	23	-	-	23	0.44	0.03
24	-	-	24	-	-	24	-	-	24	-	-	24	0.28	0.55
25	0.04	-	25	-	-	25	-	-	25	T	-	25	0.01	0.39
26	0.53	-	26	-	-	26	T	-	26	-	-	26	3.15	-
27	0.44	0.24	27	-	-	27	0.01	-	27	-	-	27	0.01	0.17
28	0.51	0.22	28	-	-	28	0.48	-	28	-	-	28	-	-
29	0.01	0.30	29	0.45	-	29	-	0.01	29	-	-	29	-	-
30	0.29	0.04	30	0.18	-	30	-	-	30	-	-	30	0.08	0.23
			31	0.02	-	31	-	-						

*The airport weather station is located at the Corsicana Campbell Airport and maintained by the NOAA.
** Richland Creek station is located near Richland Creek and is maintained by the USACE.
T= Trace

- In non-tidal flowing streams, the DO criterion is applicable to the mixed surface layer, but a single sample taken near the surface is normally considered to provide an adequate representation.

- In impoundments, when stratification is present, the criterion applies to the epilimnion.

Dissolved Oxygen Concentrations

A summary of the average diurnal DO concentration, the minimum DO concentration, and the maximum DO concentration for each station for each monitoring event is presented on Table III-3. DO measurements were made four times each day at each station. The late morning measurement at each station included a depth profile. The other three measurements were surface measurements. In order to appropriately incorporate the depth profile data in the calculation of the daily average concentration, an average epilimnion concentration was calculated first. The average epilimnion concentration was then included in the calculation of the daily average, maximum, and minimum as one of four measurements. The epilimnion is defined as the part of the water column in which the water temperature is within 0.50°C (degrees Celsius) of the surface water temperature. The percentages of the diurnal average values that are less than 5.0 mg/L, 4.0 mg/L, and 3.0 mg/L, respectively, at each station are also presented in Table III-3.

Table III-3
Water Quality Standards Evaluation
Richland-Chambers Reservoir

Dissolved Oxygen Concentrations
Diurnal Average, Daily Minimum, and Daily Maximum*

Tributary	Station	Sampling Date	DO (mg/L)			% of Avg DO Values Less Than		
			Average	Minimum	Maximum	5.0 mg/L	4.0 mg/L	3.0 mg/L
Cedar Creek	CC1	8/12/04	4.8	3.3	6.1			
		8/23/04	5.0	4.9	5.1			
		9/6/04	5.2	5.0	5.5			
		9/23/04	4.7	4.2	5.3			
		9/28/04	4.7	4.2	5.0			
						60	0	0
	CC4	8/12/04	5.0	4.2	6.3			
		8/23/04	4.4	3.4	5.7			
		9/6/04	5.3	4.6	5.8			
		9/23/04	5.3	4.6	6.5			
		9/28/04	4.8	3.6	6.2			
						40	0	0
	CC Bridge	8/12/04	5.6	4.3	7.1			
		8/23/04	5.2	3.6	6.6			
		9/6/04	5.1	4.0	6.5			
		9/23/04	6.1	5.4	7.1			
		9/28/04	5.4	4.8	5.9			
						0	0	0
	CC6	8/12/04	5.9	4.5	7.2			
		8/23/04	5.0	4.2	5.9			
		9/6/04	5.7	4.4	7.1			
		9/23/04	6.4	5.7	7.1			
		9/28/04	5.6	5.2	5.9			
						0	0	0

*All values in this table are based on the average of four concentrations. When depth profiles were measured, the average epilimnion concentration is one of four concentrations included in the average.

Table III-3 (Cont'd)
Water Quality Standards Evaluation
Richland-Chambers Reservoir

Dissolved Oxygen Concentrations
Diurnal Average, Daily Minimum, and Daily Maximum*

Tributary	Station	Sampling Date	DO (mg/L)			% of Avg DO Values Less Than		
			Average	Minimum	Maximum	5.0 mg/L	4.0 mg/L	3.0 mg/L
Cedar Creek (Cont'd)	CC7	8/12/04	7.0	4.8	8.9			
		8/23/04	6.3	4.7	7.5			
		9/6/04	6.5	5.8	7.7			
		9/23/04	7.4	6.6	8.7			
		9/28/04	7.1	6.4	8.0			
						0	0	0
Grape Creek	GC Bridge	8/10/04	2.6	1.9	3.8			
		8/18/04	4.9	3.2	6.3			
		8/24/04	2.6	1.9	3.4			
		9/2/04	4.6	3.1	6.5			
		9/7/04	3.7	2.3	4.8			
		9/14/04	4.9	3.9	6.1			
		9/20/04	3.1	2.7	3.7			
						100	57	29
Post Oak Creek	PO-AC	8/13/04	5.1	4.5	5.8			
		8/26/04	4.9	4.2	5.5			
		9/1/04	5.4	4.6	6.3			
		9/9/04	6.3	5.6	7.2			
		9/13/04	6.3	6.0	6.6			
		9/22/04	9.5	6.1	14.5			
		9/29/04	6.6	5.4	7.9			
						14	0	0
	PO5	8/13/04	7.7	4.3	13.4			
		8/26/04	8.6	6.0	14.0			
		9/1/04	11.1	7.5	14.9			

*All values in this table are based on the average of four concentrations. When depth profiles were measured, the average epilimnion concentration is one of four concentrations included in the average.

Table III-3 (Cont'd)
Water Quality Standards Evaluation
Richland-Chambers Reservoir

Dissolved Oxygen Concentrations
Diurnal Average, Daily Minimum, and Daily Maximum*

Tributary	Station	Sampling Date	DO (mg/L)			% of Avg DO Values Less Than		
			Average	Minimum	Maximum	5.0 mg/L	4.0 mg/L	3.0 mg/L
Post Oak Creek (Cont'd	PO5	9/9/04	8.5	5.9	10.9			
		9/13/04	10.6	8.4	13.4			
		9/22/04	8.0	5.8	11.3			
		9/29/04	10.9	7.3	14.7			
						0	0	0
	PO8	8/13/04	7.6	5.5	9.9			
		8/26/04	8.6	7.2	11.0			
		9/1/04	8.6	6.3	10.2			
		9/9/04	7.9	6.0	8.9			
		9/13/04	8.8	7.7	10.1			
		9/22/04	8.2	6.7	10.0			
		9/29/04	9.1	6.6	10.4			
						0	0	0
Richland Creek	RC Love Br.	8/11/04	3.0	2.6	3.4			
		8/18/04	3.8	2.9	4.7			
		8/25/04	2.8	1.5	3.3			
		9/2/04	4.2	3.3	5.1			
		9/8/04	2.8	2.4	3.3			
		9/14/04	3.8	3.5	4.3			
		9/21/04	3.0	2.4	3.5			
						100	86	29

*All values in this table are based on the average of four concentrations. When depth profiles were measured, the average epilimnion concentration is one of four concentrations included in the average.

Table III-3 (Cont'd)
Water Quality Standards Evaluation
Richland-Chambers Reservoir

Dissolved Oxygen Concentrations
Diurnal Average, Daily Minimum, and Daily Maximum*

Tributary	Station	Sampling Date	DO (mg/L)			% of Avg DO Values Less Than		
			Average	Minimum	Maximum	5.0 mg/L	4.0 mg/L	3.0 mg/L
Richland Creek	RC1	8/11/04	5.5	4.2	6.3			
		8/18/04	4.5	3.2	5.8			
		8/25/04	7.8	5.8	10.4			
		9/2/04	5.0	3.7	6.3			
		9/8/04	3.9	2.6	5.2			
		9/14/04	5.6	5.0	6.2			
		9/21/04	4.7	3.1	5.7			
						43	14	0
	RC2	8/11/04	5.5	4.6	6.5			
		8/18/04	4.0	2.6	5.2			
		8/25/04	7.3	5.8	8.8			
		9/2/04	4.8	3.4	6.0			
		9/8/04	4.1	2.7	5.8			
		9/14/04	5.3	5.0	5.6			
		9/21/04	4.8	3.9	5.6			
						57	0	0
	RC IH-45	8/11/04	4.6	3.1	5.7			
		8/18/04	3.5	2.2	5.1			
		8/25/04	6.3	4.8	7.9			
		9/2/04	4.3	3.1	5.8			
		9/8/04	3.8	2.5	5.3			
		9/14/04	4.7	4.3	4.9			
		9/21/04	4.5	3.6	5.6			
						86	29	0

*All values in this table are based on the average of four concentrations. When depth profiles were measured, the average epilimnion concentration is one of four concentrations included in the average.

Table III-3 (Cont'd)
Water Quality Standards Evaluation
Richland-Chambers Reservoir

Dissolved Oxygen Concentrations
Diurnal Average, Daily Minimum, and Daily Maximum*

Tributary	Station	Sampling Date	DO (mg/L)			% of Avg DO Values Less Than		
			Average	Minimum	Maximum	5.0 mg/L	4.0 mg/L	3.0 mg/L
Richland Creek (cont'd)	RC3	8/10/04	6.5	4.9	7.7			
		8/18/04	7.4	6.0	8.3			
		8/24/04	7.4	6.5	8.5			
		9/2/04	7.9	6.5	9.9			
		9/7/04	7.0	4.7	8.8			
		9/14/04	7.4	6.8	8.1			
		9/20/04	7.8	6.1	9.2			
						0	0	0

*All values in this table are based on the average of four concentrations. When depth profiles were measured, the average epilimnion concentration is one of four concentrations included in the average.

CHAPTER IV
CONCLUSIONS

As clearly shown in Table III-3, the backwater areas of coves on Richland-Chambers Reservoir do not maintain a DO concentration of 5.0 mg/L, even if they do not receive point source discharges. Therefore, the data were reviewed to determine if a relationship could be developed that could be used to establish an appropriate water quality standard for DO in the Post Oak Creek arm. The actual data for the Post Oak Creek arm cannot be used for this purpose.

Visual inspection of the data suggests that naturally occurring DO concentrations are influenced by the ratio of width to depth, as well as climatic factors. Following are summaries of evaluations of these two factors and a recommended water quality standard for DO for the Post Oak Creek arm of Richland-Chambers Reservoir, based on those evaluations.

INVESTIGATION OF EFFECTS OF WIDTH AND DEPTH

For the investigation of the effects of the width-to-depth ratio, the data collected in 2001 and 2002 were used, as well as the 2004 data. The 2001 and 2002 data were collected in a somewhat different manner than the 2004 data. Following is a description of how data were collected in each of those years and how the daily average DO concentrations were calculated.

The 2001 data for each day are comprised of two instantaneous surface measurements. The measurements were made at approximately 9 AM and 3 PM. These two measurements were averaged for each monitoring day to identify a daily average DO concentration.

Data from the 2002 dataset were included in this investigation if there were two measurements in a single day or if there was one measurement that was taken after 11 AM. All of the measurements in 2002 were depth profiles. When there were two measurements in one day, the first profile was typically measured at 8 or 9 AM, and the second profile was typically measured at approximately 3 PM.

In order to compute daily averages for these samples, first, the depth of the epilimnion was determined for each profile. The epilimnion was defined as the water layer in which the temperature did not vary by more than 0.50^{o}C from the surface water temperature. Then, a depth-averaged DO concentration for the epilimnion was calculated. If two measurements were made in one day, the two depth-averaged values were averaged to determine the daily average.

All of the data used in this investigation are tabulated in Appendix C. Appendix C lists the daily average DO concentration for each monitoring event included in this evaluation. Appendix C also lists, for each station included in this evaluation, the approximate width and depth, the width-to-depth ratio, the percentage of daily average DO measurements that were less than 5.0 mg/L, and the percentage of daily average DO measurements that were less than 4.0 mg/L.

While this study was being conducted, the potential importance of width and depth to the study results was not known. Measurements of width were not made, and the only depth measurement made was a single measurement at the point where the DO profile was measured. The estimates of width in Appendix C are based on aerial photographs, U.S. Geological Survey (USGS) maps, and the recollections of the sampling staff. Aerial photographs suggest that the 315.0 ft contour on USGS maps does not accurately delineate the boundaries of the reservoir. In addition, USGS staff stated there may be some inaccuracies in the mapping in this area.

The depth measurements are based on the profile data. The depths reported are approximately the maximum depth of the stream at the monitoring station.

In general, during this study, when the width-to-depth ratio was less than 20, a significant number of the DO measurements were less than 4.0 mg/L. At the stations where the width-to-depth ratio was greater than 100, DO concentrations were almost always above 5.0 mg/L. Table IV-1 is a summary of the relationship between the width-to-depth ratio and the DO concentration that was observed in this study.

From a regulatory standpoint, the width-to-depth ratio may not be a practical criterion for defining where transitions in naturally occurring DO concentrations occur. Frequently, suitable depth data may not be available. In these cases, it may be that width alone can be used to delineate different zones in reservoirs for the establishment of DO standards. Therefore, Table IV-2 also includes the estimated width of each station.

Table IV-1
Water Quality Standards Evaluation
Richland-Chambers Reservoir

Relationship of Width-to-Depth Ratio and Width to Dissolved Oxygen Concentration

Station	Estimated Approx. Width (feet)	Appprox. Maximum Depth (feet)	Number of Measure-ments	Percent less than 5 mg/L DO	Percent less than 4 mg/L DO	Width / Depth
Width-to-Depth Ratio Less Than 20 or Width Less Than 100 Feet						
CC1	20	4	6	50%	0%	5
CC4	35	9	5	40%	0%	4
CC Bridge	40	7	9	44%	11%	6
GC Bridge	60	5	9	100%	56%	10
RC Love Bridge	40	3	7	100%	86%	10
RC1	60	8	7	43%	14%	7
RC2	60	8	7	57%	0%	7
RC IH-45	60	8	12	92%	17%	7
Cha H31	60	7	4	100%	50%	9
Cha 1	50	7	1	100%	100%	7
Cha Roane Rd	20	1	2	100%	100%	20
Cha IH-45	40	0.5	2	100%	100%	80
Width-to-Depth Ratio Greater Than 20 or Width Greater Than 100 Feet						
CC6	200	6	5	0%	0%	30
CC7	800	3	5	0%	0%	300
RC3	8000	3	7	0%	0%	2000

Table IV-2
Water Quality Standards Evaluation
Richland-Chambers Reservoir

Monthly Rainfalls - Summers of 2001, 2002, and 2004

Month	2001	2002	2004	Long-Term Average
June	1.64	1.33	7.61	3.12
July	0.9	5.91	1.24	2.14
August	0.99	0.6	4.96	2.24
September	3.07	2.94	0.18	2.95
October	3.16	5.83	7.82	3.61

This study does not provide data for a sufficient range of width-to-depth ratios, or widths, to support the development of a well-defined criterion. However, this study does indicate that when the width-to-depth ratio is less than 20, or the width is less than 100 feet, the concentration of DO, typically, will be less than 4.0 mg/L a significant portion of the time due to natural conditions. A width-to-depth ratio of 20 or a stream width of less than 100 feet may be unnecessarily stringent criteria for widespread application in delineating zones of reservoirs where site-specific DO standards apply. However, they may be functional criteria for the Post Oak Creek arm of Richland-Chambers Reservoir.

CLIMATIC FACTORS

As discussed in Chapter III, the study area experienced significant rainfall in the summer of 2004. The year 2002 was much drier than 2004. A comparison of monthly average rainfalls for the summers of 2001, 2002, and 2004, and the historical average is presented in Table IV-2. The dry conditions in 2002 affected reservoir levels, as previously shown on Figure III-1. As a result of the increased rainfall in 2004, in most instances, DO concentrations were significantly higher in 2004 than they were in 2002. This difference is summarized in Table IV-3. (There were only four stations where data were collected in two or more years). Since most of the data in Table IV-1 was collected in 2004, it can be expected that the percentage of DO readings that are less than 4.0 mg/L would be significantly greater in a drier summer than the percentages shown in Table IV-1.

APPLICATION TO POST OAK CREEK

A location in Post Oak Creek downstream of which the width is believed to be, typically, greater than 100 feet is Station PO6. This station is approximately 0.2 mile below the pipeline crossing (See Figure II-4). The approximate maximum depth at this location is 9 feet. It is recommended that a site-specific DO water quality standard be established for the Post Oak Creek arm of Richland-Chambers Reservoir, as follows:

- The daily average DO standard for waters upstream of a point 0.2 mile below the pipeline crossing is 3.0 mg/L.

- The daily average DO standard for waters downstream of a point 0.2 mile below the pipeline crossing is 5.0 mg/L.

Table IV-3
Water Quality Standards Evaluation
Richland-Chambers Reservoir

Annual Variation in Dissolved Oxygen Concentrations

Station	Year		
	2001	2002	2004
CC1	-	5.2	4.9
CC Bridge	-	3.4	5.5
GC Bridge	-	2.4	3.8
RC IH-45	4.2	2.5	4.5