APPENDIX C

WATER QUALITY AND SOILS

Wister Lake was the focus of a intensive Phase I Diagnostic/Feasibility study conducted by the Oklahoma Water Resource Board from June 1993 through June 1994 (OWRB 1996). Water quality data were collected both in Wister Lake and the surrounding watershed. An evaluation of the data identified problems in Wister Lake associated with accelerated eutrophication. High total phosphorus, high turbidity, low Secchi depth, and hypolimnetic anoxia classified Wister Lake as a hypereutrophic system. Data suggest nutrients and turbidity from both point and nonpoint sources within the lake watershed are the primary causes of the poor water quality in Wister Lake. The following table (C-1) is a summary of the parameters analyzed, as well as a description of each and how it relates to the water quality in the lake.

Table C-1 Water Quality Parameters Analyzed for Wister Lake. Values include all sampling sites, dates, and water depths and are expressed in mg/l unless otherwise noted.

Parameters	*Mean*	*Min.*	*Max*	*Number of Observations*
Temperature	26.2	22.5	32.4	221
Dissolved Oxygen	2.9	0.04	8.3	199
pH		5.8	8.4	233
Conductivity (µS/cm)	7.4	35.0	149.0	233
Secchi Disk (m)	0.4	0.1	1.0	15
Turbidity (NTU)	65	2.5	452	76
Total Alkalinity (AS $CACO_3$)	22	8	79	69
Total Hardness (AS $CACO_3$)	24	12	79	69
Chlorides	5	1	10	53
Sulfates	8	73	18	44
Nitrates	0.503	0.100	2.0	44
Total Kjeldal Nitrogen	0.579	0.040	2.1	38
Total Phosphorous (as P)	0.261	0.007	2.725	69
Total Iron (µg/l)	4571	710	26300	38
Total Manganese (µg/l)	1023	90	7560	38

Water Temperature

Temporal and spatial patterns of surface water temperature for Wister Lake are typical of Midwestern impoundments in the summer. Thermal stratification occurs when surface water is heated more rapidly than the heat can distribute, by mixing, through the water column. Such conditions usually occur during calm, warm periods of several days. As surface water heats and become less dense, resistance to mixing increases and the lake becomes stratified into a warm upper zone (epilimnion) and a cold lower zone (hypolimnion). Temperatures at Wister Lake increase throughout the summer and peak in late August. The maximum surface temperature was 32.4^{o} C recorded at Buzzards Roost in late August 1990. Weak thermal stratification exists during the summer months with differences of about 6^{o} C between the highest surface temperature and the lowest bottom temperature.

Normally, the epilimnion and hypolimnion do not mix until a cold front moves through the area and causes significant changes to surface water temperature. However, Wister Lake has two characteristics that make it an exception to normal dynamics. First, the effective fetch at Wister Lake runs north-south, and second, the lake is shallow. These characteristics allow for mixing during periods of high wind. Strong southwest winds are common during the summer in this part of the state. The lake then restratifies during calm periods. By mid September the lake has destratified.

Dissolved Oxygen

Surface dissolved oxygen (DO) levels range from a high of 8.2 mg/l at Buzzards Roost in late August to a low of 3.5 mg/l at Pocahontas Slough in early August. During periods of thermal stratification, DO concentrations in the hypolimnion dropped to less that 2 mg/l at all locations.

During periods of thermal stratification, the lake exhibits a clinograde oxygen profile. This profile occurs when the hypolimnion is depleted of oxygen by oxidative processes such as decomposition of organic material or respiration of organisms. After the lake is destratified in the fall, DO concentrations become similar throughout and normally remain that way until the following late spring or early summer.

pH

The pH is a measure of the hydrogen ion activity. A pH of 7 is neutral, less that 7 acidic, and greater than 7 basic. The range of pH in most area lakes is between 6 and 9. The pH values in Wister Lake fall between 5.83 to 8.35. The maximum value was a surface recording at the dam site, and the minimum was a surface reading at Quarry Isle. Little horizontal variation was observed, however, some changes do occur during periods of thermal stratification.

Conductivity

Conductivity is a measure of the capacity of water to conduct electrical current. Resistance to electrical current is reduced with increasing concentrations of ionized salts. Conductivity levels at Wister Lake were indicative of low concentrations of ionized salts. Recorded values ranged from 35 to 149 μS/cm, with a mean of 74. Mean values varied little among sites. Slight increases in conductivity were measured at lower depths during periods of stratification.

Secchi Disk

Transparency is measured using the Secchi disk. The depth at which the disk is no longer visible has been calculated at approximately five percent sunlight, or approximately the lowest amount of light necessary to complete photosynthesis. Wister Lake measurements varied from 0.06 to 1.0, with a mean of 0.38m. Sample locations near the Fourche Maline had the lowest mean (0.10), while the Quarry Isle location had the greatest mean (.58).

Turbidity

Turbidity describes the degree of cloudiness in water, produced by the suspended particulate matter. It is measured in Nephelometric Turbidity Units (NTU). The higher the value, the more turbid the water. Turbidity values at Wister Lake ranged for 2.5 to 452 NTU, with an overall mean of 65 NTU. However, means for the surface samples were much lower than the means for the bottom samples. Turbidity samples and visual observations show the primary source of suspended particulate matter to be the Fourche Maline River. At times, a visible turbidity plume is observed in the Fourche Maline River arm.

Alkalinity

Alkalinity is the capacity of water to neutralize acids. Alkalinity is important for aquatic life because it buffers pH changes that occur as a result of natural photosynthetic activity. Water at or below 20 mg/l is considered poorly buffered. Alkalinity values at Wister Lake range from 8 to 70 mg/l (as $CACO_3$) and averaged 22 mg/l (as $CACO_3$). Concentrations varied little among sites. Total alkalinity values for Wister Lake are indicative of a system poorly buffered against drastic pH changes.

Hardness

Hardness in water is caused primarily by calcium and magnesium. Other ions contribute to hardness, but are usually present in relatively insignificant amounts. A natural source of hardness is limestone. Fresh water with less than 75 mg/l as $CACO_3$ is considered soft.

Wister Lake is classified as extremely soft. Hardness levels ranged from 12 to 79 mg/l (as $CACO_3$) and averaged 24 mg/l (as $CACO_3$). Highest levels were measured in samples from the hypolimnion. Concentrations varied little among sites and sampling times.

Chloride

Chloride levels in Wister Lake were low and varied little with date, site, or stratum. Concentrations ranged from 1 to 10 mg/l.

Sulfates

Sulfate concentrations ranged from less than 3 to 18 mg/l. Little variation with date, site, or depth was observed.

Nitrate-Nitrogen

Nitrate-nitrogen (NO_3) usually occurs in fairly small concentrations in unpolluted fresh water systems. Concentrations vary from 0 to nearly 10 mg/l in unpolluted fresh waters, with variations both seasonally and spatially. Under normal conditions, the amount of NO_3 in solution at a given time is determined by metabolic processes in the body of water (such as production and decomposition of organic matter). It is in this form that nitrogen is taken up by green plants, including algae. NO_3 is extremely important as a nutrient as it promotes protein synthesis.

Nitrate values at Wister Lake range from below detection limits to 2 mg/l. The overall mean is approximately 0.45 mg/l. Concentrations less than detection limits were recorded at all sites and on more than one occasion.

Ammonia and Nitrite

Ammonia and nitrite, two forms of nitrogen, provide a picture of the total nitrogen content in the lake. Ammonia in water is primarily present as NH4+ when the pH is less than 9. Ammonia nitrogen can range from 0 to 5 mg/l in unpolluted surface waters, although levels are usually much lower than 51 mg/l. However, in anoxic hypolimnions, ammonia concentrations increase greatly and can exceed 10 mg/l. Ammonia values at Wister Lake ranged from 0.010 to 1.73 mg/l, with an overall mean of 0.44 mg/l. The highest value was recorded in the hypolimnion, near Quarry Isle, in mid September. Concentrations less than detection limits occurred on several occasions.

Nitrite is unstable in aerated waters and quickly converts to nitrate. Nitrite levels in lake waters are usually low, in the range of 0 to 0.01 mg/l. The presence of nitrite is generally considered to be an indicator of pollution from sewage or organic waste. Nitrite concentrations ranged from 0.055 to 0.273 mg/l, with a mean of 0.173 mg/l. The highest value was recorded in the hypolimnion at Potts Mountain in late July 1990.

Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is the sum of the inorganic ammonia plus the organic nitrogen present in the water sample. This parameter estimates the amount of nitrogen tied up in organic matter, which could be made available for use by aquatic plants. This information, along with phosphorus data, can then be related to biological productivity of the aquatic system.

Concentrations for TKN ranged from 0.040 to 2.10 mg/l, with an overall mean of 0.58 mg/l. The highest value was measured in the hypolimnion at Potts Mountain in midsummer. In terms of mean concentrations per site, Buzzards Roost had the lowest, at 0.41 mg/l, and Pocahontas Slough the highest, at 0.73 mg/l.

Phosphorus

Phosphorus has a major role in the metabolism of plants and animals. Because it is less abundant than carbon, nitrogen, oxygen, or sulfur (other nutritional and structural biota components), it commonly limits the biological productivity of aquatic ecosystems. Phosphate phosphorus is a key nutrient stimulating plant growth in lakes, and is the only significant form of inorganic phosphorus. The phosphorus values discussed here are an estimate of phosphorus available for metabolic use in plants.

Total phosphorus generally increases with lake productivity. General relationships of lake productivity to average concentrations of epilimnetic total phosphorus is shown in Table C-2. Total phosphorus concentrations of most uncontaminated surface waters are between 10 and 50 mg/l.

Table C-2 Classifications of Phosphorus

	Phosphorus
Ultra-oligotrophic	<5 µg/l
Oligo-mesotrophic	5-10 µg/l
Meso-eutrophic	10-30 µg/l
Eutrophic	30-100 µg/l
Hypereutrophic	>100 µg/l

Total mean phosphorus concentrations are much higher in the arms of the lake than they are in the main body. The mean concentrations at Pocahontas Slough were sometimes two to three times higher than the means for the two sites located in the main body of the lake near Buzzards Roost and Quarry Isle. The overall mean concentrations of total phosphorus in surface samples were 0.145 mg/l, which indicates that the lake is hypereutrophic. However for the main body of the lake the mean is 86 µg/1, which would classify it as eutrophic.

Chlorophyll a

Chlorophyll *a* concentrations can be used to indicate the trophic status of a lake (Table C-3). Chlorophyll *a* values at Wister Lake ranged from 8.3 to 39.5 µg/l, with a mean of 16.8 µg/l. Chlorophyll concentrations were highest during July and the lowest during September, with the arms of the lake have higher concentrations then the body of the lake. Based on its values, Wister Lake would fall in to the eutrophic category.

Table C-3 Classifications of Chlorophyll *a*

Oligotrophic	<4 µg/l
Mesotrophic	4-10 µg/l
Eutrophic	10-25 µg/l
Hyper-eutrophic	>25 µg/l

(Reckhow and Chapra 1983).

Total Iron

Iron is an essential micro-nutrient of freshwater plants and animals. The typical range of iron found in oxygenated surface waters is about 50 to 200 µg/l. Total iron concentrations in Wister Lake ranged from 540 to 26,300 µg/l, with a mean of 2,110 µg/l for surface samples and a mean of 7,000 µg/l for bottom samples. During thermal stratification, concentrations of iron near the bottom were five times higher than those in surface water. This is common in lakes with anoxic hypolimnia. Iron is released from sediment and goes into solution, then much of the iron precipitates out during a fall turnover, and the concentrations are similar from top to bottom. The criterion for freshwater aquatic life is 1,000 µg/l. Wister Lake samples consistently exceeded this amount. High concentrations of iron do not pose a human health threat, but may cause problems in domestic water supplies. The EPA criterion for domestic water supply is 0.300 µg/l - based on the staining of porcelain and laundry items.

Manganese

Manganese is also an essential micro-nutrient for plants and animals. It is used for photosynthesis and as a catalyst for enzyme systems in animals. A typical range of manganese in lake surface water is 10 to 850 μg/l, with an average of 35 μg/l. Levels for Wister Lake ranged for 90 to 7,560 μg/l, with an overall mean of 1,490 μg/l. Surface sample means were 680 μg/l, with bottom samples having a mean of 2,310 μg/l. The high concentrations in the bottom indicate release from sediments during anoxic conditions.

The EPA criterion for manganese is 50 μg/l. Concentrations above this level do not provide health risks, but they can cause problems in domestic water supply such as staining and poor taste.

SOILS

The following section provides detailed information about soil types in the project area (refer to section 3.2.1). The watershed of Wister Lake contains eight soil associations comprised of numerous soils. Detailed discussions of these soils can be found in the Scott County, AK, Latimer County, OK, and LeFlore County, OK soil surveys (USDA 1975, 1981, 1983).

The *Bengal-Clebit-Pirum* association is made up of moderately deep and shallow, very gently sloping to steep, well drained, stony soils that have a clayey or loamy subsoil over shale or sandstone. Bengal soils have a surface layer of dark brown stony fine sandy loam that is very friable. The middle layer, a yellowish red clay with a few shale fragments, is strongly acidic. The bottom layer is a yellowish red shale clay with light brownish-gray mottles. It too is very acidic and overlies gray and yellowish-brown soft shale. Clebit soils have a surface layer of dark brown stony fine loam that is very friable and strongly acidic. The middle layer is cobbly fine loam, which is also friable and strongly acidic. The lower layer is massive sandstone bedrock. Pirum soils have a surface layer that is stony fine sandy loam of medium acidity; a middle layer that is yellowish-red sandy, friable clay loam and very strongly acidic; and a strong brown cobbly clay loam middle layer, which is massive and friable, and has medium acidity. The lower portion is cobbly clay loam that is also friable, massive, and slightly acidic.

The *Neff-Kenn-Ceda* association is nearly level to very gentle sloping, moderately well drained, and composed of loamy soils that have a loamy subsoil or cobbly and loamy underlying layers. Neff soils have a dark brown, friable, neutral surface layer. The middle part is a dark yellowish slit loam with a few light brownish-gray and medium faint brown mottles present; it is strongly acidic. The lower part is a dark yellowish-brown silty clay, friable loam with many medium light brownish-gray and pale brown mottles; it is friable and highly acidic. The Kenn soils have a surface layer that is very dark grayish-brown, friable, neutral silty clay loam. The lower part is a dark brown silty clay overlying a reddish-brown, friable, mildly alkaline clay neutral loam. Ceda soils have a cobbly loam surface layer that is slightly acidic and a strong brown cobbly clay loam middle layer that is massive and friable, and has medium acidity. The lower portion is a brown cobbly clay loam that is also friable, massive, and slightly acidic.

The *Kamie-McKamie* associations are deep, gently sloping to strongly sloping, well drained, sandy and loamy soils that have a loamy or clayey subsoil. Kamie soils have a surface layer that is brown, very friable, and slightly acidic loamy fine sand. The middle layer is a yellowish-red sandy clay loam of medium acidity with a few fine distinct red mottles. The lower level is a massive, very friable yellowish-red sandy loam of medium acidity. The McKamie soils are comprised of a brown, friable, medium acidic loam surface layer with a red medium acidity clay middle layer, and a massive, friable, moderately alkaline silty clay loam lower level.

The *Istigler-Shermore-Wister* associations are deep, nearly level to sloping, moderately well drained, loamy soils that have a loamy or clayey subsoil over colluvium or shale. These associations are generally located on broad valley floors. Stigler soils are comprised of a dark grayish-brown silt loam surface layer of strong acidity. A middle layer of yellowish-brown silty clay is strongly acidic with fine distinct red mottles. The lower portion is a mottled yellowish brown and gray silty clay of medium acidity. Shermore soils have a friable, medium acidic brown fine sandy loam surface layer. The middle layers are strongly acidic, strong brown loams, and the lower level is a yellowish-brown clay loam with a few fine distinct red mottles and common grey vertical streaks; it is strongly acidic. Surficial Wister soils have a brown appearance are strongly acidic silt loams. The middle layer is a dark yellowish-brown silt clay with a few prominent red and common grey medium distinct mottles and is strongly acidic. Mottled yellowish-brown and gray silty clay of medium acidity comprises the lower part and overlies gray shale of medium acidity.

The *Carnasaw-Octavia-Pirum* association is deep and shallow, gently sloping to steep, stony, and well drained to excessively drained loamy soils with a very dark grayish-brown surface layer. The upper portion of the subsoil is a yellowish-red silty clay, and the lower part is yellowish-red mottled silty clay. The predominant underlying materials are tilted and fractured shale and sandstone or tilted and fractured shale bedrock. This association is generally located on mountains and ridges.

The *Sobol-Tuskahoma-Wister* association is shallow to deep, very gently sloping to moderately steep, and moderately well drained loamy soils. It is located mainly on low ridges and broad valleys. This soil association comprises a very small portion of the lake watershed.

The *Leadvale-Taft* association is deep, moderately well drained, somewhat poorly drained, and moderately permeable. It is comprised of level to gently sloping loamy soils on old stream terraces.

Leadvale soils have a brown silt loam surface layer with the upper portion of the subsoil a yellowish brown silt loam and the lower part a yellowish-brown mottled, firm and brittle, silty clay loam fragipan overlying acid shale bedrock. The Taft soils are somewhat poorly drained and have a dark grayish-brown silt loam surface layer. The upper portion of the subsoil is light yellowish brown, mottled silt loam. The middle part is a light yellowish-brown, mottled, firm and brittle, silt loam fragipan. The lower portion is yellowish-brown, mottled, silty clay loam.

The *Enders-Mountainburg* association is deep and shallow, well drained, and very slowly and moderately rapidly permeable. It is gently sloping to steep, loamy and stony soils on hills, mountains, and ridges. The deep Enders soils have a very dark grayish-brown gravelly silt loam surface layer. The upper portion of the subsoils is a yellowish-red silty clay material, and the lower portion is a red mottled clay overlying horizontally bedded shale bedrock. The Mountainburg soils are shallow with a very dark grayish-brown gravelly or stony fine sandy loam surface layer, and a strong brown, very gravelly or stony sandy clay loam subsoil overlying horizontally bedded sandstone bedrock.