CITY OF MOORE
LAKE THUNDERBIRD TMDL
COMPLIANCE PLAN

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LIST OF ACRONYMS

ACOG	Association of Central Oklahoma Governments
BMP	Best Management Practice(s)
CBOD	Carbonaceous Oxygen Demand
CFR	Code of Federal Regulations
CWA	Clean Water Act
EFDC	Environmental Fluid Dynamics Code Model
EPA	Environmental Protection Agency
FWP	Fish and Wildlife Propagation
GIS	Geographic Information Systems
HSPF	Hydrological Simulation Program – FORTRAN Model
IDDE	Illicit Discharge Detection and Elimination
LA	Load Allocations
LID	Low Impact Development
MCM	Minimum Control Measure
MEP	Maximum Extent Practicable
MOS	Margin of Safety
MS4	Municipal Separate Storm Sewer System
MSA	Metropolitan Statistical Area
MSGP	Multi-Sector General Permit
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NTU	Nephelometric Turbidity Units
ODEQ	Oklahoma Department of Environmental Quality
OPDES	Oklahoma Pollutant Discharge Elimination System
SWMP	Stormwater Management Plan
SWPPP	Stormwater Pollution Prevention Plan
SWS	Sensitive Water Supply
TAC	Technical Advisory Committee
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
USC	United States Code
USGS	Unites Stated Geological Survey
WLA	Waste Load Allocations
WWAC	Warm Water Aquatic Community

EXECUTIVE SUMMARY

The City of Moore (the City) is subject to the requirements of the Oklahoma Department of Environmental Quality (ODEQ) Phase II Small Municipal Separate Storm Sewer System (MS4) Discharges within the State of Oklahoma General Permit No. OKR04, issued June 1, 2021, which sets the requirements and conditions for stormwater discharges from a small MS4 to surface waters in the State.

Lake Thunderbird is listed on Oklahoma's 2020 303(d) list for impaired beneficial uses of public/private water supply and warm water aquatic community life. Causes of impairment were identified in the Final Lake Thunderbird Report for Nutrient, Turbidity, and Dissolved Oxygen Total Maximum Daily Loads, approved by the EPA on November 13, 2013, as low oxygen levels, high levels of chlorophyll-a, and high turbidity (ODEQ, 2013). Lake Thunderbird is designated by the Oklahoma Water Quality Standards (ODEQ, 2020) as a Sensitive Water Supply (SWS) since the lake serves as the primary public water supply source for the Cities of Norman, Midwest City, and Del City. The City and its MS4 Program is one of three municipalities within the Lake Thunderbird watershed, along with the Cities of Norman and Oklahoma City.

Section 303(d) of the federal Clean Water Act (CWA) and U.S. Environmental Protection Agency (EPA) Water Quality Planning and Management Regulations (40 Code of Federal Regulations [CFR] Part 130) requires development of total maximum daily loads (TMDLs) for waterbodies not meeting designated uses where technology-based controls are in place. TMDLs establish the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream water quality conditions to implement water quality-based controls to reduce pollution from point and nonpoint sources and restore and maintain water quality (EPA, 1991). In November 2013, the ODEQ established a TMDL for Lake Thunderbird, which established waste load allocations within the watershed to each of three contributing cities and required the City to develop and implement TMDL Compliance and Monitoring Plans for total suspended solids (TSS), total nitrogen, total phosphorus, and carbonaceous biological oxygen demand (CBOD) in discharges to the Lake Thunderbird watershed.

The Compliance Plan outlines the processes and procedures adopted by the City to reduce stormwater pollution in the watershed and meet the load reduction requirements in the TMDL. The Monitoring Plan outlines the processes and procedures adopted by the City to quantify the amount of pollutants in stormwater runoff and evaluate the effectiveness of Best Management Practices (BMPs) deployed to reach its compliance goals. The TMDL Compliance and Monitoring Plans were initially approved and adopted in 2015.

The City of Moore Lake Thunderbird TMDL Compliance Plan is a plan for achieving the 35% waste load reduction of TSS, total nitrogen, total phosphorous, and CBOD established in the TMDL. The waste load reduction activities are also included as minimum control measures in the City of Moore Oklahoma Pollutant Discharge Elimination System (OPDES) Phase II Small MS4 permit required Storm Water Management Plan (SWMP).

The Compliance Plan presents the strategies to meet the waste load reductions and TMDL goals as specified in the TMDL and current MS4 permit. Specifically, the Compliance Plan will provide the basis for the City to:

1. Provide BMPs to achieve an equivalent of 35% waste load reductions of its contributing watershed which stormwater runoff is managed to the maximum extent practicable (MEP).
2. Meet TMDL Waste load Allocations (WLAs) approved by the ODEQ and EPA.
3. Educate and involve residents, businesses, and stakeholder groups in achieving measurable water quality improvements.
4. Establish a reporting framework that will be used for annual reporting as required in the City's OPDES MS4 Permit.
5. Identify necessary maintenance, adaptive management, staffing, and financial strategies to implement the Compliance Plan.

Contributing Watersheds

The City's MS4 includes the land within the legal City boundary discharging to and associated with runoff to Little River and its tributaries. For the purposes of the waste load reduction and TMDL compliance conditions of the MS4 permit, the Compliance Plan will concentrate on the area within the City limits, which includes the following watersheds, as defined by the Department of Natural Resources:

1. Little River
2. North Fork of the Little River

Although neither of the above watersheds are listed as impaired, they contribute flow to Lake Thunderbird, which is subject to the TMDL for nutrients and sediments. The Lake Thunderbird TMDL available guidance documents were focused on the pollutant loadings based on construction, industrial, and MS4 permittee contributions and their correlation of BMPs to quantified reductions of nutrients and sediment. Illicit discharge detection and elimination (IDDE) programs will be used to reduce the loadings of the other potential contributors.

Meeting the TMDL Goals

To meet the 35% reduction goal, the City will utilize a diverse and comprehensive approach for meeting the TMDL requirements as needed. This includes:

- Implementing stormwater management projects, including traditional BMPs, Low Impact Development Design (LID) practices where applicable, and Educational BMP;
- Employing a variety of programs to improve water quality, including mechanical street sweeping, construction site inspections, and IDDE; and
- Fostering partnerships to encourage private development of stormwater management practices.

Finally, the City believes that by implementing stormwater management projects, employing a variety of programs, and fostering partnerships, we will be on track to meet the TMDL goals. Implementing these practices will provide a reduction of 35% of our current waste load to meet the TMDL requirement of 205.1 kilograms per day (kg/day) of total nitrogen, 44.5 kg/day of total phosphorus, 781.3 kg/day of CBOD, and 16,236.0 kg/day of TSS by the end of the third MS4 permit period. Education and enforcement programs focused on illicit discharges, in concert with water and sanitary sewer infrastructure improvements, will also result a reduction of nutrients.

A monitoring program focused on illicit discharges will address the TMDL for TSS and nutrients from construction and industrial permittees.

Public Outreach

In order for the Compliance Plan to be successful, it will need an informed public and engaged partners to review and provide advice on the Plan as well as identify needs and issues that will need to be addressed. The City recognizes and is committed to the role that public outreach and stewardship will play if improved water quality conditions are going to be achieved. This will require engaging diverse set of stakeholders who can serve as the leaders and champions for clean water in their communities, including greater participation from business groups, schools, and neighborhood associations.

Additionally, this approach requires working collaboratively with other City agencies to look for better and more efficient ways to communicate messages, cross-train, and create synergies that result in greater engagement, greater awareness, and sustained changes in behavior.

Maintenance

Having a successful TMDL program does not stop with the implementation of BMPs; in order to improve maintenance of current facilities, as well as meet the stormwater management practices that will be implemented to meet the Small MS4 Permit and TMDL requirements, the City will focus on BMP maintenance and implementation. The City has designated personnel, as identified in the City of Moore SWMP that will maintain all city-owned BMP, regardless of the agency that installed or is responsible for the BMP.

1.0 INTRODUCTION

The City of Moore (the City) is subject to the requirements of the Oklahoma Department of Environmental Quality (ODEQ) Phase II Small Municipal Separate Storm Sewer System (MS4) Discharges within the State of Oklahoma General Permit No. OKR04, issued June 1, 2021, which sets the requirements and conditions for stormwater discharges from a small MS4 to surface waters in the State.

Lake Thunderbird is listed on Oklahoma's 2020 303(d) list for impaired beneficial uses of public/private water supply and warm water aquatic community life. Causes of impairment were identified in the Final Lake Thunderbird Report for Nutrient, Turbidity, and Dissolved Oxygen Total Maximum Daily Loads (TMDLs), approved by the EPA on November 13, 2013, as low oxygen levels, high levels of chlorophyll-a, and high turbidity (ODEQ, 2013). Lake Thunderbird is designated by the Oklahoma Water Quality Standards (ODEQ, 2020) as a Sensitive Water Supply (SWS) since the lake serves as the primary public water supply source for the Cities of Norman, Midwest City, and Del City. The City and its MS4 is one of three municipalities within the Lake Thunderbird watershed, along with the Cities of Norman and Oklahoma City.

Section 303(d) of the federal Clean Water Act (CWA) and U.S. Environmental Protection Agency (EPA) Water Quality Planning and Management Regulations (40 Code of Federal Regulations [CFR] Part 130) requires development of TMDLs for waterbodies not meeting designated uses where technology-based controls are in place. TMDLs establish the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream water quality conditions to implement water quality-based controls to reduce pollution from point and nonpoint sources and restore and maintain water quality (EPA, 1991). In November 2013, the ODEQ established a TMDL for Lake Thunderbird, which established waste load allocations within the watershed to each of three contributing cities and required the City to develop and implement TMDL Compliance and Monitoring Plans for total suspended solids (TSS), total nitrogen, total phosphorus, and carbonaceous biological oxygen demand (CBOD) in discharges to the Lake Thunderbird watershed.

The Compliance Plan outlines the processes and procedures adopted by the City to reduce stormwater pollution in the watershed and meet the load reduction requirements in the TMDL. The Monitoring Plan outlines the processes and procedures adopted by the City to quantify the amount of pollutants in stormwater runoff and evaluate the effectiveness of Best Management Practices (BMPs) deployed to reach its compliance goals. The TMDL Compliance and Monitoring Plans were initially approved and adopted in 2015.

The City of Moore Lake Thunderbird TMDL Compliance Plan is a plan for achieving the 35% waste load reduction of TSS, total nitrogen, total phosphorous, and CBOD established in the TMDL. The waste load reduction activities are also included as minimum control measures in the City of Moore Oklahoma Pollutant Discharge Elimination System (OPDES) Phase II Small MS4 permit required Storm Water Management Plan (SWMP). Thirty-five percent restoration represents a significant commitment by the City to reduce potential pollutants through educational activities, construction inspection, identification, review, and possible implementation of low impact development (LID) standards, and good housekeeping procedures and implementation.

The Compliance Plan presents the strategies to meet the waste load reductions and TMDL goals as specified in the TMDL and current MS4 permit. Specifically, the Compliance Plan will provide the basis for the City to:

1. Provide BMPs to achieve an equivalent of 35% waste load reductions of its contributing watershed which stormwater runoff is managed to the maximum extent practicable (MEP).
2. Meet TMDL Waste Load Allocations (WLAs) approved by the ODEQ and EPA.
3. Educate and involve residents, businesses, and stakeholder groups in achieving measurable water quality improvements.
4. Establish a reporting framework that will be used for annual reporting as required in the City's OPDES MS4 Permit.
5. Identify necessary maintenance, adaptive management, staffing, and financial strategies to implement the Compliance Plan.

The MS4 Permit requires that the City manage, implement, and enforce a SWMP in accordance with the CWA and corresponding stormwater OPDES regulations, 40 CFR Part 122, to meet the following requirements:

1. Effectively prohibit pollutants in stormwater discharges or other unauthorized discharges into the MS4 as necessary to comply with ODEQ's receiving water quality standards;
2. Attain applicable WLAs for each established or approved TMDL for each receiving water body, consistent with Title 33 of the U.S. Code (USC) §1342(p)(3)(B)(iii); 40 CFR §122.44(k)(2); and
3. Comply with all other provisions and requirements contained in the MS4 permit, and in plans and schedules developed in fulfillment of the MS4 permit such as the Lake Thunderbird TMDL.

One condition of the City's MS4 Permit is to make progress toward implementation of TMDL load reduction allocations in the City watersheds. Understanding the physical, economic, social, hydrologic, and organizational conditions of the City provides necessary guidance to craft a Compliance Plan that best achieves the established restoration goals.

2.0 REGULATORY FRAMEWORK

2.1 Lake Thunderbird TMDL

Lake Thunderbird is a 6,070-acre reservoir located 13 miles east of downtown Norman in Cleveland County, Oklahoma. The Lake is located within a 256 square mile drainage area of the upper Little River watershed (HUC, 11090203). The Lake, owned by the U.S. Bureau of Reclamation, was constructed to provide flood control, municipal water supply, recreation, and wildlife habitat. The Lake serves as the primary public water supply for the cities of Norman, Midwest City, and Del City with water usage governed by the Central Oklahoma Master Conservancy District (COMCD). Lake Thunderbird is on Oklahoma's 2010 303(d) list for impaired beneficial uses of public/private water supply and warm water aquatic community (WWAC).

The purpose of the TMDL is to establish WLA and load allocations determined to be necessary for reducing turbidity and chlorophyll-a levels and maintaining sufficient oxygen levels in the Lake to attain water quality targets to restore impaired beneficial uses and protect public health. TMDLs determine the pollutant loading that a waterbody, such as Lake Thunderbird, can assimilate without exceeding applicable water quality standards. TMDLs also establish the pollutant load allocation necessary to meet the water quality standards established for a waterbody based on the relationship between pollutant sources and water quality conditions in the waterbody. A TMDL consists of a WLA, load allocations (LA), and a margin of safety (MOS). The WLA is the fraction of the total pollutant load apportioned to point sources and includes stormwater discharges regulated under the National Pollutant Discharge Elimination System (NPDES) as point sources. Additional information can be found in the *Final Lake Thunderbird Report for Nutrient, Turbidity, and Dissolved Oxygen TMDLs* provided in Appendix A.

2.1.1 TMDL Identification and Water Quality Targets

Designated uses of Lake Thunderbird are flood control, municipal water supply, recreation, and fish and wildlife propagation. Lake Thunderbird is designated as a Category 5a lake on the Oklahoma 303(d) list with a Priority 1 ranking. Category 5 defines a waterbody where, since the water quality standard is not attained, the waterbody is impaired or threatened for one or more designated uses by a pollutant(s), and the water body requires a TMDL. ODEQ has determined that Lake Thunderbird, designated as a SWS lake, is not supporting its designated uses for (a) Fish & Wildlife Propagation (FWP) for a WWAC because of excessive levels of turbidity and low dissolved oxygen; and (b) Public Water Supply because of excessive chlorophyll-a levels. High levels of both turbidity and chlorophyll-a can have deleterious effects on the raw water quality, such as taste and odor complaints and treatment costs of drinking water. The water quality targets established for Lake Thunderbird, based on statistics of the most recent 10 years of record, are defined as the long-term average in-lake surface concentration of 10 micrograms per liter (µg/L) for chlorophyll-a and the 90th percentile of the in-lake surface concentration of 25 nephelometric turbidity units (NTU) for turbidity.

2.1.2 Watershed and Lake Modeling

A model framework was developed to establish the cause-effect linkage between pollutant loading from the watershed (the Hydrological Simulation Program - FORTRAN (HSPF) model) and water quality conditions in the lake (the Environmental Fluid Dynamics Code (EFDC) model). Flow and pollutant loading from the watershed to the Lake was simulated for a one-year period from April 2008 to April 2009 with the public domain HSPF watershed model. Watershed model results were used to estimate the relative contributions of point and nonpoint sources of pollutant loading. The three cities of Moore, Norman and Oklahoma City accounted for the dominant share of total pollutant loading from the watershed. The EFDC model was developed to simulate water quality conditions in Lake Thunderbird for sediments, nutrients, organic matter, dissolved oxygen, and chlorophyll-a.

The linked watershed (the HSPF model) and lake (the EFDC model) model framework was used to calculate average annual suspended solids, CBOD, nitrogen and phosphorus loads in kilograms per year (kg/yr) that, if achieved, should meet the water quality targets established for turbidity, chlorophyll-a, and dissolved oxygen. For reporting purposes, the final TMDLs, according to EPA guidelines, are expressed as daily loads in kilograms per day (kg/day). The WLA for the TMDL for Lake Thunderbird is assigned to regulated NPDES point source discharges under three MS4 stormwater permits for Moore, Norman, and Oklahoma City. The WLA, split among the three

MS4 permits, includes pollutant discharges regulated under NPDES stormwater permits for Construction Sites and Multi-Sector General Permit (MSGP) for various industrial facilities located within the MS4 areas of the watershed. The LA for the TMDL is assigned to the small land area of the watershed not included in the land area for the three MS4 permits and is set at the existing loading during the calibration period.

2.1.3 Waste Load Allocation, Load Allocation and Margin of Safety

The calibrated lake model (the EFDC model) was used to evaluate the water quality response to reductions in watershed loading of sediment and nutrients. Load reduction scenario model runs were performed to determine if water quality targets for turbidity and chlorophyll could be attained with watershed- based load reductions based on 35% removal of loading for sediment and nutrients. The long-term model results indicated that compliance with water quality criteria for turbidity, dissolved oxygen and chlorophyll could be achieved within a reasonable period. The calibrated model results thus supported the development of TMDLs for sediments, CBOD, total nitrogen and total phosphorus to achieve compliance with water quality standards for turbidity, chlorophyll, and dissolved oxygen.

The LA is computed as the difference from the TMDL and the total WLA load. The TMDL load is split between three WLAs for the three MS4 cities. The LA for the unincorporated area of the watershed and the implicit MOS as shown in Table 1.

2.2 MS4 Permit Coverage

On December 8, 1999, EPA published final regulations that address urban stormwater runoff from cities under 100,000 population and counties that lie within the Urbanized Area as defined by the latest US Bureau of Census designation. These Phase II cities and counties must develop a comprehensive Stormwater Management Program that addresses six Minimum Control Measures (MCMs). These are:

1. Public Education and Outreach
2. Public Participation and Involvement

Table 1. Load Allocations

Water Quality Constituent	TMDL	LA	WLA				MOS*
			Total	Moore	Norman	OKC	
	(kg/day)	(kg/day)	(kg/day)	(kg/day)	(kg/day)	(kg/day)	(kg/day)
Total Nitrogen	807.7	21.3	786.4	205.1	319.4	261.8	Implicit
Total Phosphorus	158.4	4.4	154.0	44.5	60.1	49.4	Implicit
CBOD	2,480.8	57.4	2,423.4	781.3	955.6	686.5	Implicit
Suspended solids (TSS)	76,950.8	2,068.7	74,882.1	16,236.0	31,596.1	27,049.9	Implicit

*Additional information regarding MOS can be found in the Final *"Lake Thunderbird Report for Nutrient, Turbidity, and Dissolved Oxygen TMDLs"* Appendix A.

3. Illicit Discharge Detection and Elimination
4. Construction Site Stormwater Runoff Control
5. Post Construction Management in New Development and Re-Development
6. Pollution Prevention and Good Housekeeping

The ODEQ presently has primary authority over permitting and enforcement of the Phase II Stormwater Program for Oklahoma. The ODEQ has developed a General Permit OKR04 for Phase II Municipal Separate Storm Sewer System Discharges for Small Cities Within the State of Oklahoma. The Phase II regulations require that the regulated community submit a Notice of Intent (NOI) to apply for coverage under the Oklahoma Stormwater General Permit OKR04 along with a SWMP that specifies, for each MCM, what activities/BMPs will be performed, along with schedules and measurable goals for each BMP.

The City is updating its existing SWMP document which provides descriptions of all activities that will be conducted on behalf of the City to meet its obligations under the ODEQ General Permit OKR04. All six MCMs are addressed in the SWMP. In addition, the City of Moore incorporates requirements of the Lake Thunderbird TMDL into the SWMP in which the City will have continuous coverage for all MS4 activities. Each MCM has a number of BMPs that constitute the core activities pertaining to each MCM. The SWMP Appendices will summarize the BMP and provide Measurable Goals for each BMP, along with descriptions, implementation schedules and estimated annual costs. Every reasonable effort has been, and will be, made to comply with all requirements in the State's OKR04 General Permit for Small MS4s.

2.3 Additional OPDES Permits

As authorized by the CWA, the OPDES permit program controls water pollution by regulating point sources that discharge pollutants into waters of the United States. Industrial, municipal, and other facilities must obtain permits if their discharges go directly to surface waters. The OPDES permit program is administered by ODEQ. In addition to the MS4 Permit, three NPDES permits regulate activities in the City:

- Stormwater Discharges from Construction Activities General Permit OKR10 - Stormwater discharges from construction activities (such as clearing, grading, excavating, and stockpiling) that disturb one or more acres, or smaller sites that are part of a larger common plan of development or sale, are regulated under the OPDES stormwater program. Prior to discharging stormwater, construction operators must obtain coverage under an NPDES permit. The General Construction Permit, with its increased regulations, will result in less sediment entering the City's waters. However, the burden of pollutant contribution from these permitted sites has been assigned to the City, and as such, the City must now assume the responsibility of reducing the impacts from the permitted sources.
- Multi-Sector General Permit for Industrial Activities OKR05 - ODEQ authorizes the discharge of stormwater associated with industrial activities to waters of the state under the OPDES General Permit Number OKR05. The permit contains provisions that require industrial facilities in 26 different industrial sectors to, among other things, implement control measures and develop site-specific stormwater pollution prevention plans (SWPPP) to comply with OPDES requirements. Again, the burden of pollutant contribution from these permitted sites has been assigned to the City, and as such, the City must now assume the responsibility of reducing the impacts from the permitted sources.
- Wastewater Treatment Plant Individual Discharge Permits - The operations of the City Wastewater Treatment Plant are permitted by ODEQ. The permit contains general operating restrictions as well as limitations on the contents of the plants' effluent. Compliance with these numeric effluent limits is determined by regular sampling and reporting to the ODEQ. There is no discharge from the treatment plant into the Lake Thunderbird watershed.

3.0 ENVIRONMENTAL SETTING

3.1 Land Use

The City is located to the south of Oklahoma City and to the north of Norman in central Oklahoma. The City has a total area of 22.35 square miles of which 21.95 square miles is land and 0.35 square miles is water as shown in Figure 1. Existing land use in the urbanized area is approximately 6,530 acres of residential, 1,445 acres of commercial, 321 acres of industrial, and 729 acres of parklands. Most of the land area in the City is developed in some form. Only 28% of land (3,464 acres) is undeveloped or used for agriculture.

The City consists of three Wards as shown in Figure 2. Each Ward has unique development characteristics:

- Ward 1 is a mix of light commercial, minor industrial, and single and multi-family residential land uses and maintains the largest amount of open space and agricultural activities. Ward 1 discharges mainly to the North Fork of the Little River as shown in Figure 3.
- Ward 2 is a mix of light commercial along Interstate Highway 35, minor industrial, and single and multi-family residential land uses. Ward 2 discharges to both the North Fork of the Little River in the east and Little River to the west as shown in Figure 4.
- Ward 3 is a mix of commercial, some minor industrial and single and multi-family residential. Ward three also has constructed water amenities that contain waterfowl populations as shown in Figure 5.

3.1.1 Demographic Analysis

The City's population grew from 55,081 in 2010 to 62,793 in 2020, over 14%, a slightly slower pace than Cleveland County, the Oklahoma City Metropolitan Statistical Area (MSA), and the State of Oklahoma. According to the Oklahoma Department of Commerce, the population of Cleveland County is projected to grow an additional 14.5% in the next ten years from 262,862 in 2012 to 303,105 in 2022 (RKG Associates, 2013).

Figure 1. City of Moore Legal Boundary

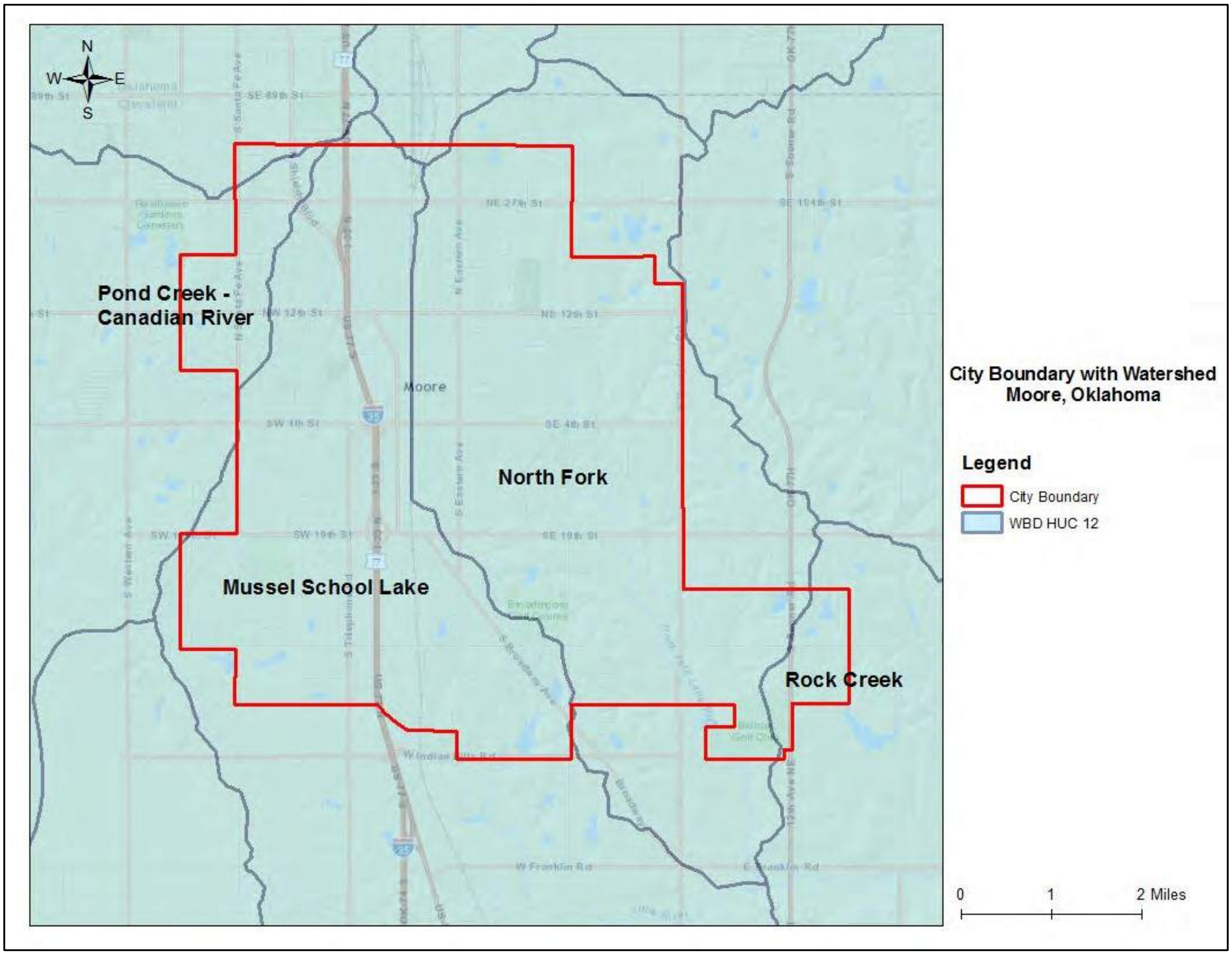


Figure 2. City Wards

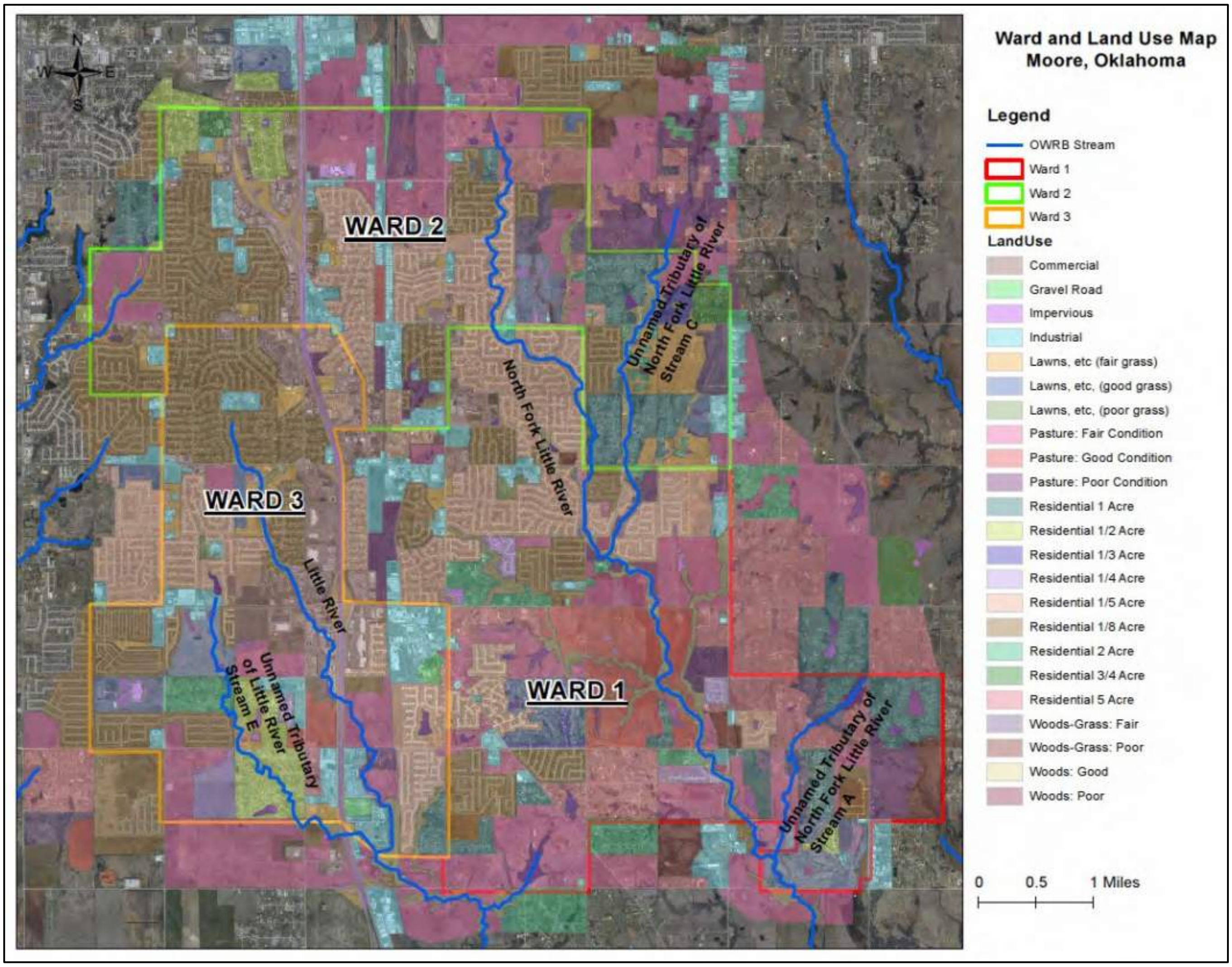


Figure 3. Ward 1 – Land Uses and Development

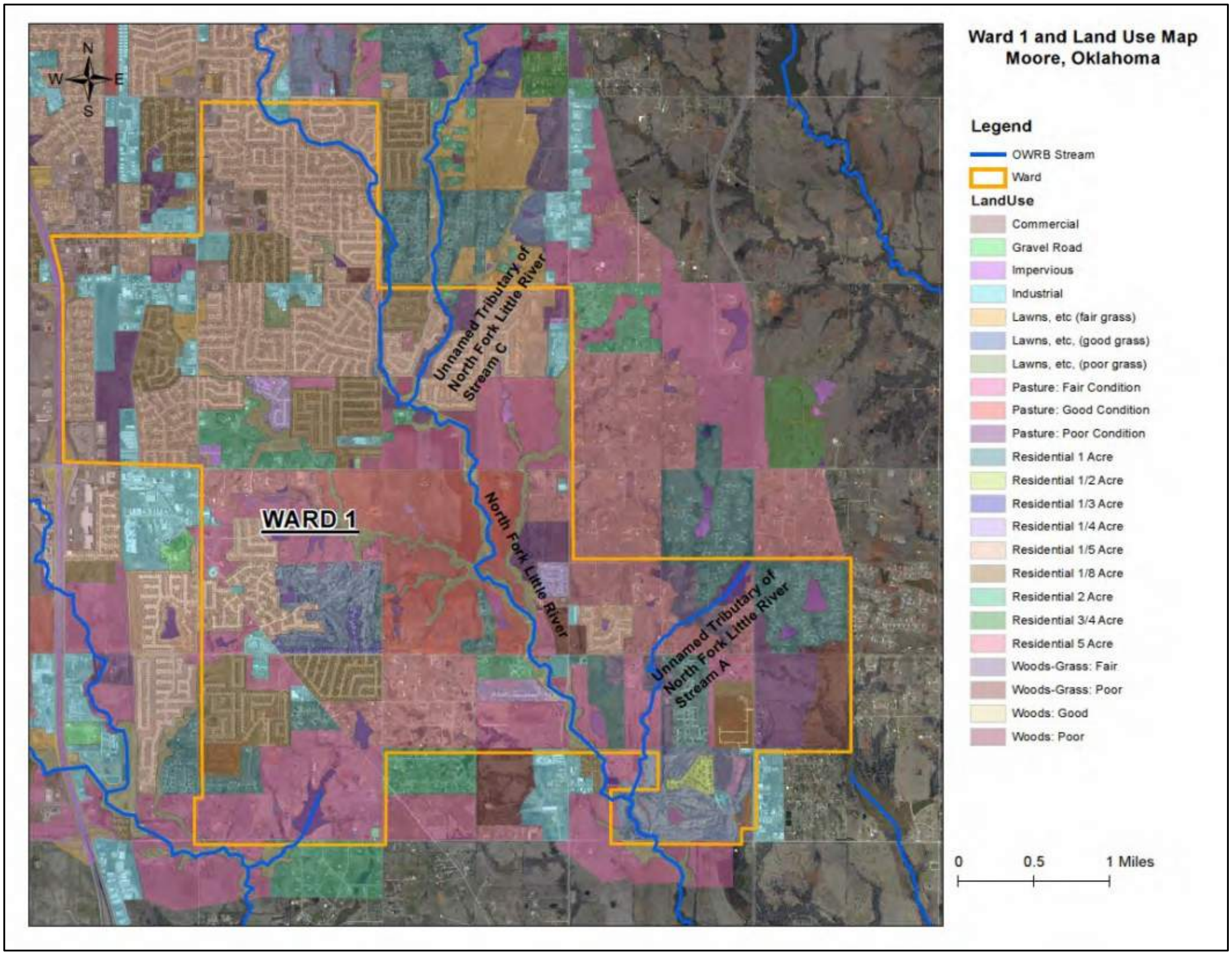


Figure 4. Ward 2 – Land Uses and Development

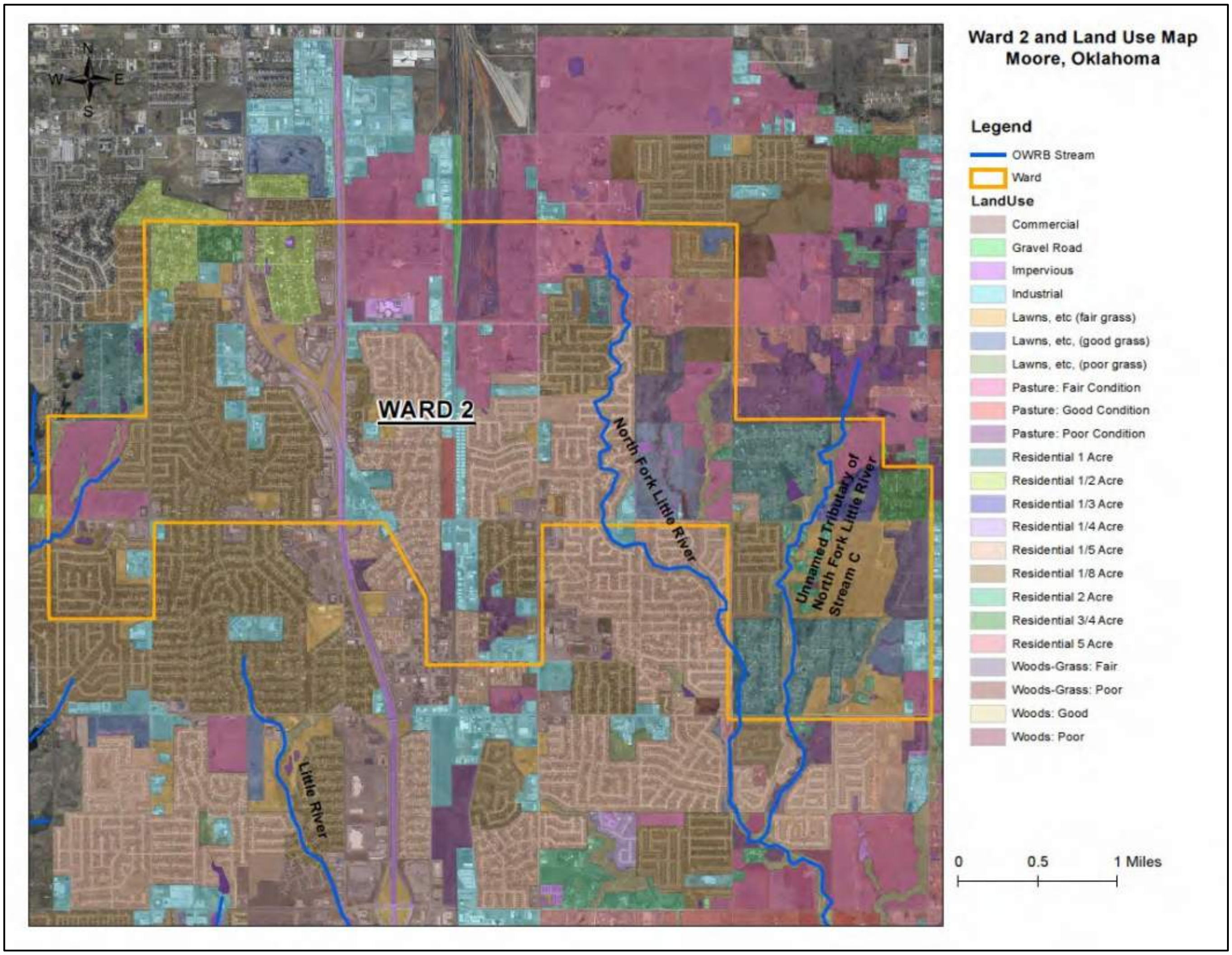
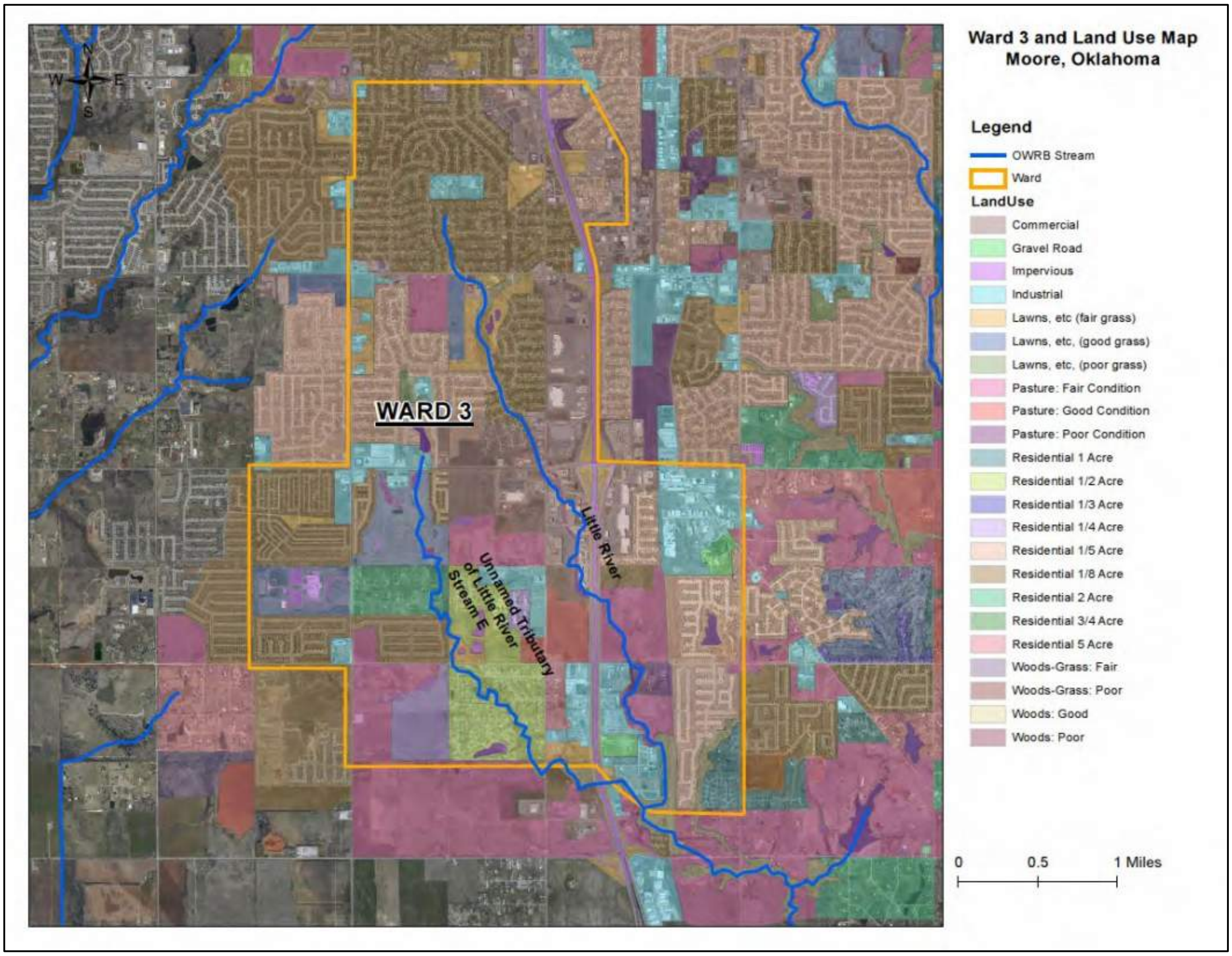


Figure 5. Ward 3 – Land Uses and Development



Households grew at an even faster rate than population, increasing almost 36% from 2000 to 2010. Non-family households make up 26.7% of the households in Moore, and nearly 80% are one-person households. The City's highly regarded school system has been credited for the attraction of family households to Moore (RKG Associates, 2013).

3.1.2 Housing Analysis

Based on data obtained from the Cleveland County real property tax assessment database, the City contains a total of 21,199 residential dwelling units comprising single family detached, mobile homes, duplexes, and garden apartments. In 2012, the City housing inventory comprised 69% owner occupied homes, compared to 59% of owner-occupied homes in the State of Oklahoma and 66% in the nation. The renter occupied inventory in the City was 26% in the same year, compared to 29% in the state and 34% in the nation. The percentage of rental occupied homes rose from 22% in 2000 to 26% in 2012, following a national trend. Based on an inventory of 1,899 apartments and 853 duplexes/triplexes of which 90%, or 768, are rentals, the balance of approximately 2,845 renter occupied dwellings comprise single family detached units.

Most of the remaining developable land in the City falls into the Rural Residential and Urban Residential/Low Density zoning designations, with only small amounts of acreage that could be developed to Medium Density or High Density Residential. In total, vacant, and underutilized land could support a range of 2,123 to 16,478 residential units at full build out, with a midpoint of 9,300 units. The minimum build out of 2,123 units is estimated at approximately four to seven years, the maximum build out of 16,478 units is estimated at 34-55 years, and the midpoint of 9,300 units is estimated at 19 to 31 years.

The May 2013 F5 tornado, nearly a mile wide, directly impacted almost 10% of the City's entire housing stock by either damaging or completely destructing housing units. Of a total of 1,776 single family homes impacted, 696 were damaged and 1,080 were destroyed. Approximately 247 apartment units were destroyed in the event. Approximately 700 single family residential building permits have been issued for rebuilds and 450 have been issued for remodels.

The City's future residential development is constrained by its relatively limited land area of 22 square miles, in stark contrast to the 621 square miles of Oklahoma City and 190 square miles of Norman. Given the finite and limited amount of land remaining for residential development the potential for construction impacts is limited. Most of the remaining developable land in the City falls into the Rural Residential and Urban Residential/Low Density land use designations, with only small amounts of acreage that could be developed to Medium Density of High Density Residential. The 1,082 acres slated for Rural Residential development could support a maximum of 811 residential units, assuming full build out at one unit per 0.75 acres. The 2,402 acres of Urban Residential/Low Density land could support in the range of 811 to 14,413 units at full build out, based on densities of one unit per 0.75 acres to six units per acre. Medium Density land is estimated to equal approximately 39 acres, allows 6 to 14 units per acre, and could support a range of 231 to 578 units. High Density land is estimated to equal approximately 45 acres, allows 6 to 14 units per acre as well, and could support a range of 270 to 675 units. In total, vacant, and underutilized land could support a range of 2,123 to 16,478 residential units at full build out, with a midpoint of 9,300 units (RKG Associates, 2013).

3.1.3 Impacts of Tornadoes

The City of Moore has seen ten tornadoes between 1998 and 2015, three of them big enough to claim lives and cause catastrophic damage. The City was damaged by significant tornadoes on October 4, 1998; May 3, 1999; May 8, 2003; May 10, 2010; and May 20, 2013, with weaker tornadoes striking at other times, notably May 31, 2013 and March 25, 2015. The most significant tornadoes to hit the City occurred in 1999 and 2013.

After the May 31, 2013 tornado, the City saw two schools, a school administration building, a regional hospital, 90-businesses, and over 2,400-housing units damaged or destroyed. The figure is important as it relates to disaster recovery in the City related to rebuilding significant structures. This disaster rebuilding may, in part, relate to abnormally higher instances of TSS contribution.

3.2 Geology and Lithology

The City lies in the Cross Timbers region of the Southern Plains. The geologic units associated with this area, according to the Natural Resources Conservation Service, include:

- HENNESSEY FORMATION (Phy) underlies approximately 45% of the City. This formation consists of shale and siltstone, poorly exposed, mostly moderate reddish brown to moderate reddish orange with conspicuous light greenish gray iron-reduction spots. The lower 20 to 30 feet is predominantly a blocky-weathering, silty shale and clayshale that exhibits good paleosol development; locally with lenticular beds of sandstone and siltstone-pebble conglomerate and fine- to very fine-grained sandstone. Shale typically unstratified and highly fractured; rarely with small-scale slickensides that are evidence of paleosol development. Above the lower part, thin bedded to laminated, stratified to well stratified siltstones and very fine-grained sandstones are more common. Siltstone moderately to well stratified. Sandstone locally cross-stratified on large and small scale, uncommonly trough-cross-stratified and/or ripple marked. Trace fossils and shale rip-up clasts very rare. Sandstone rarely forms channel form deposits. Shale outcrops locally weather to blocky, very fractured, or hackly appearance; form bare, rounded outcrops and/or badlands-type topography. In other places, shale weathers to muddy soil with abundant small calcareous nodules. Calcite veinlets uncommon. Interbedded siltstone and shale weather to bench-and-slope topography. Siltstone and sandstone exhibit platy to flaggy weathering. Siltstone and sandstone beds with small-scale cross-stratification and ripples. Moderately indurated, occur as resistant beds capping tops of hills and ridges. Overall, unit is expressed as highly weathered, muddy soil. Thickness: 0 to 220 feet, top not exposed.
- COVER SAND (Qcs) underlies approximately 25% of the City. This formation consists of very fine grained to coarse- grained silt and clay, moderately to poorly sorted. It consists mainly of rounded to subrounded quartz grains, with abundant silt and clay-size material. Forms extensive nearly flat topographic surfaces as much as 50 feet above modern alluvial valleys. Probably represents eolian reworking of older Pleistocene-aged terrace deposits. Thickness: from a thin veneer to as much as 10 feet, averages closer to three feet.
- REMNANTS OF OLDER TERRACE DEPOSITS (Qtr) underlie approximately 20% of the City. This formation consists of clay, silt, sand, and gravel adjacent to flood plain of Little River. Sand commonly is medium- to coarse-grained and very light colored; gravel locally consists of concentrations of distally derived pebbles and cobbles, mostly well rounded and sub-discoidal quartz and metaquartzites. Base of unit is about 30 feet to 60 feet above the modern flood plain and ranges in elevation from 1130 feet to 1190

feet above sea level. The top of the unit is as much as 70 feet above the modern flood plain and is as high as 1230 feet above sea level. The majority of these deposits occur along the north side of Little River. Thickness: 0 to 35 feet, averages about 10 feet.

- ALLUVIUM (Qal) underlies approximately 10% of the City. This formation consists of clay, silt, sand, and gravel in channels and on flood plains of modern streams and includes terrace deposits of similar composition located directly above and adjacent to modern channels and flood plains. Thickness: 0 to about 30 feet.

As indicated by the geologic units listed above, the City is located on geologic formations and weathered soils that are naturally predisposed to excessive soil runoff during storm events. This predisposition to natural erosion places a greater burden on the City to control the amount of total suspended solids from entering Little River and other unnamed tributaries discharging to Lake Thunderbird.

3.3 Watersheds and Lake Thunderbird

Lake Thunderbird was constructed by the U.S. Bureau of Reclamation in 1965 to provide flood control, municipal water supply, recreation, and wildlife habitat along the upper reaches of Little River to the east of Norman in Cleveland County, Oklahoma. Its watershed drains 256 square miles in Oklahoma and Cleveland Counties, including the Cities of Norman, Oklahoma City, and Moore. Lake Thunderbird serves as a primary public water supply reservoir for the Cities of Norman, Midwest City, and Del City.

Stormwater runoff from the urbanized area is contained in two drainage basins: the Little River watershed and the North Fork of Little River watershed. Only the Little River watershed contributes flow to Lake Thunderbird. Lake Thunderbird is on Oklahoma’s 303(d) list for impaired beneficial uses of public/private water supply and warm water aquatic community life. The City has two 8-digit watersheds as designated by the US Geological Service (USGS):

1. Little River - 11090203
2. Lower Canadian-Walnut - 11090202

Only the Little River Watershed contributes flow to Lake Thunderbird. The drainage area and features can be found in the *Final Lake Thunderbird Report for Nutrient, Turbidity, and Dissolved Oxygen TMDLs* provided in Appendix A.

3.4 Streams and Stormwater Infrastructure

The City has about 18.8 miles of streams and consist of the Little River and North Fork of Little River and their unnamed tributaries. However, the open network of the City MS4 (natural ditches, improved ditches, natural channels, improved channels, and constructed open conveyances is approximately 183 linear miles and are all part of the City's MS4.

In addition, the storm drain system includes:

- 15.3 miles of storm drain pipes
- 2,713 storm drain inlets
- 12,888 utility access holes
- 334 outfalls
- 192 outfalls (36 inches or greater)

3.5 Potential Sources of TSS, Nutrients, and CBOD

The following sources have the greatest potential to contribute TSS, nutrients, and CBOD to the City of Moore MS4 and Lake Thunderbird watershed:

- **Construction Sites:** Construction within the City will continue as the City grows at its current rate, but as indicated above; the City has seen increased construction activities due to tornado destruction. Construction activities can contribute TSS, which in the case of the Lake Thunderbird TMDL is used as a surrogate that has the potential to carry nutrients along with the potential TSS discharges.
- **Pet, Waterfowl, and Livestock Waste:** Pet waste continues to be a significant source of potential nutrients that can enter the Lake Thunderbird watershed, along with livestock mainly located in Ward 2. Waterfowl, located within Ward 3 at the constructed water amenities, can contribute significant levels of nutrients as the population grows and becomes domesticated. Waterfowl problems in urban and suburban areas are primarily caused by giant Canada geese, which are probably the

most adaptable of all waterfowl. If left undisturbed, these geese can readily establish nesting territories on constructed water amenities, in residential yards, golf courses, condominium complexes, city parks, or on agricultural areas. Waterfowl can soon turn from visual amenity to pest, however. A pair of geese can, in 5 to 7 years, easily become 50 to 100 birds that can then foul constructed water amenities and surrounding greenbelts and damage landscaping, gardens, and golf courses.

- **Fertilizer Application:** Fertilizer application in the spring can potentially contribute to nutrient loadings within the City.
- **Natural Soil Runoff:** As stated above in Section 3.2, the City lies on very sandy soil that very easily and naturally erodes through storm event runoff. Natural soil runoff includes streambank stabilization within the channels and streams of the City. Currently the City is conducting a study of potential streambank stabilization opportunities through hydro-geomorphology improvements. This may be the most difficult potential contribution to reduce but can be minimized through the use of LID and streambank stabilization techniques.
- **Sanitary Sewer Overflows:** Sanitary sewer overflows can potentially contribute to the nutrient loading within the Lake Thunderbird watershed.

4.0 TMDL COMPLIANCE PLAN DEVELOPMENT AND 5-YEAR UPDATE

As established in Section 3 of the *Final Lake Thunderbird Report for Nutrient, Turbidity, and Dissolved Oxygen TMDLs* provided in Appendix A, urban stormwater related discharges are the main sources of controllable pollutants to Lake Thunderbird. The three main municipalities in the watershed were therefore required to undertake certain pollutant reduction measures within the terms of their MS4 permits under the OPDES system. These measures are designed to achieve progress toward meeting the reduction goals established in the TMDL.

The TMDL Compliance and Monitoring Plans were initially approved and adopted in 2015. The TMDL Compliance Plan was developed in accordance with the following stormwater BMP-based requirements:

1. Perform an evaluation to identify potential significant sources of TSS, nutrients and organic matter entering the MS4. Such an evaluation should include an enhanced plan for illicit discharge screening and remediation. Develop (or modify an existing program as necessary) and implement a program to reduce the discharge of TSS, nutrients and organic matters in municipal stormwater contributed by all significant sources identified in the evaluation.

   Potentially significant sources of TSS, nutrients, and CBOD within the City of Moore MS4 and Lake Thunderbird watershed were identified as indicated in Section 3.5. The City continues to update and implement the MS4 SWMP, which includes BMPs and MCMs to reduce the discharge of TSS, nutrients, and organic matter into the municipal stormwater system as well as provide structural and non-structural controls to minimize or eliminate potential contributing sources of TSS, nutrients and organic matter within the MS4.

2. Demonstrate in the TMDL Compliance Plan an understanding of the TMDL requirements and the strategy for meeting the WLAs. There are several ways for an MS4 to meet a TMDL WLA using BMPs and other approaches, including but not limited to:

   - Retrofitting developed areas and other suitable sites with structural stormwater BMPs (e.g., infiltration BMPs in built out areas).
   - Implementing BMPs that prevent additional stormwater TSS, nutrients and organic matter pollution associated with new development and re-

development; (e.g., promoting LID and green infrastructure, installing infiltration BMPs in areas converting from one land use to another).

- Implementing non-structural BMPs designed for source control (e.g., fertilizer application restrictions or soil nutrient testing requirements, and riparian buffer protection requirements) by considering ordinances or other regulatory mechanisms to require TSS, nutrients and organic matter pollution control, as well as enforcement procedures for noncompliance.
- Implementing non-structural BMPs designed to treat existing loads (e.g., more frequent street sweeping).

The City's understanding and strategy for the implementation of the TMDL requirements is presented in Sections 6.0 and 7.0 of this Compliance Plan. In addition, the City continues to update and implement the MS4 SWMP, which includes BMPs to reduce the discharge of TSS, nutrients, and organic matter into the municipal stormwater system as well as provide structural and non-structural controls to minimize or eliminate potential contributing sources of TSS, nutrients and organic matter within the MS4.

3. Implement enhanced or more frequent construction site stormwater compliance inspections and considering adopting ordinance that allows "stop work" orders and other enhanced enforcement for construction permit violators.

   The City's strategy for the implementation of stormwater compliance inspections and ordinances as part of the TMDL is presented in Sections 7.0 of this Compliance Plan. In addition, the City continues to update and implement the MS4 SWMP, which includes BMPs for stormwater compliance inspections and ordinances for construction activities within the MS4.

4. Determine a schedule for achieving the WLA: This schedule can be general in nature, discussing groups of activities to be implemented within permit cycles or based on funding cycles. Specific activities need not be included in this section of the TMDL Compliance Plan.

   The City's schedule for the implementation of the TMDL requirements is presented in Section 8.0 of this Compliance Plan.

5. Implement and track BMPs. BMP Summary Sheets should be prepared for both structural and non-structural BMP. For BMPs for which pollutant reductions can be calculated or modeled, BMP sheets should include any information used to make the calculations, BMP efficiencies, and maintenance information for the BMP (e.g., to ensure the efficiency used in the calculation is valid into the future or determine if it

needs to be adjusted). Include references to support the calculations or modeling. BMP Sheets can be prepared for ordinances, resources, or other tools needed for implementation of BMP. Load reductions may be difficult to quantify with these BMP, but these tools may be needed to implement BMP that reduce loading.

The City's understanding and strategy for the implementation of the TMDL requirements is presented in Sections 6.0 and 7.0 of this Compliance Plan. In addition, the City continues to update and implement the MS4 SWMP, which includes BMPs and measurable goals to reduce the discharge of TSS, nutrients, and organic matter into the municipal stormwater system as well as provide structural and non-structural controls to minimize or eliminate potential contributing sources of TSS, nutrients and organic matter within the MS4.

6. Develop educational programs directed at reducing TSS, nutrients and organic matter pollution. Implement a public education program to reduce the discharge of TSS, nutrients and organic matter in municipal stormwater contributed (if applicable) by construction activities, recreational and agricultural activities, etc.

   The City's strategy for the implementation of educational programs as part of the TMDL is presented in Section 7.0 of this Compliance Plan. In addition, the City continues to update and implement the MS4 SWMP, which includes public education, outreach, and involvement BMPs to reduce the discharge of TSS, nutrients, and organic matter into the municipal stormwater system.

5.0 CITY OF MOORE STORMWATER/TMDL STAKEHOLDERS

Implementing the TMDL Compliance Plan and maintaining compliance with the City's MS4 permit requires a collaborative effort among city departments, local non-profit activities, such as recycling centers, community partners, and the private sector. This collaboration will focus on the planning, design, construction, implementation, and maintenance of projects and programs across all stakeholder groups.

The TMDL Compliance Plan is executed by stakeholders that comprise a Stormwater Management Team, which also serves as a Technical Working Group for the TMDL. The Stormwater Management Team is led by the Community Development Department. Representatives from several other City departments and divisions are included as members of the Stormwater Management Team. An organizational chart of the City's departments is presented in Figure 6.

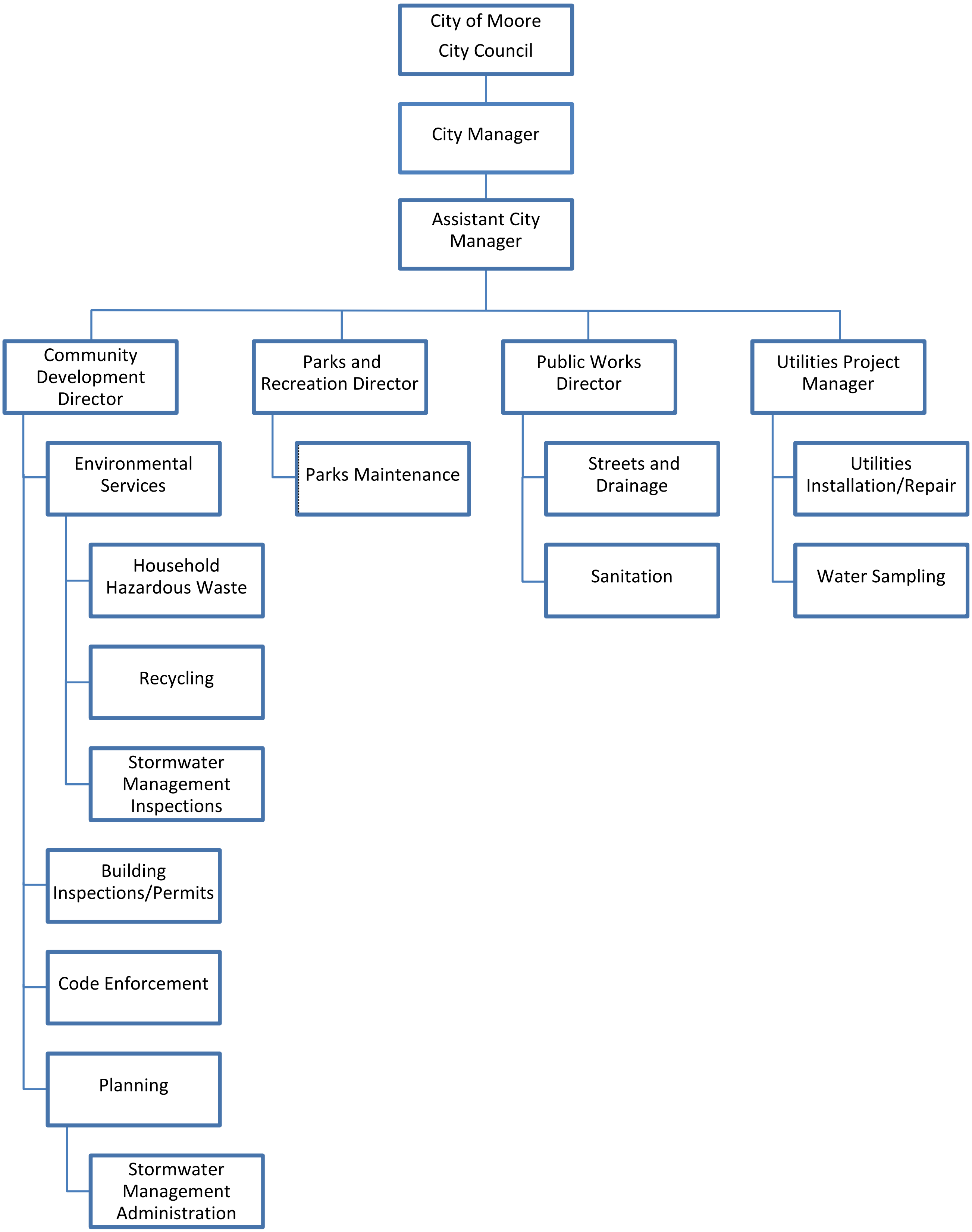
The following sections outline the stakeholder groups that are part of the implementation of the TMDL Compliance Plan as well as their respective responsibilities. In addition, the implementation strategies provided in Section 7.0 are organized by stakeholder groups for consistency and ease of tracking and implementation.

5.1 Community Development Department

The mission of the Community Development Department is to plan and guide the orderly growth and development of the City, to enforce compliance with applicable legislation in order to meet the quality of life, health, and safety needs of the community, and to deliver to its customers courteous, efficient, and competent services. The Community Development Department is made of the following separate but related divisions:

- **Environmental Services** – The Environmental Services Division serves as the main point of contact for the MS4 permit and TMDL Compliance Plan. In addition to Compliance Plan development and annual reporting for the MS4 permit, the Environmental Services division provides partnership coordination for grant funding, community engagement, and educational content, the stormwater management and erosion

Figure 6. City of Moore Organizational Chart



and sediment control program for development (plans reviews and inspections, and response and investigation for erosion and sediment control and polluted surface waters response. All aspects of the MS4 and TMDL programming are the responsibility of the Environmental Services Division even if performed by other City departments or divisions.

The City's Environmental Services Division is also dedicated to improving the environment by offering safe ways to dispose of hazardous waste, convenient options for recycling, and educating the public on the effects of wrongful disposal of liquids into our city sewer system. These values are important in promoting a healthy environment for all residents and visitors alike. The Environmental Services Division provides household hazardous waste collection, recycling, stormwater construction inspections, and inspections of the MS4 for IDDE.

- **Building Inspections and Permits** - The Inspections staff provides inspections and review of residential, commercial, and industrial building permits. They provide construction applications within the City and issue MS4 SWMP BMP information requirements such as required ODEQ construction permits, City building code standards, and any necessary LID requirements adopted.
- **Code Enforcement** - The Code Enforcement Division works to reduce neighborhood nuisances and residential deterioration within the city. Typical violations include overgrown grass and weeds, parking in the yard, junked vehicles, trash, and debris.
- **Planning** - Planning is an essential service provided by the City to promote the health, safety, and welfare of its residents. The following are the main functions of the planning division:
    - Development ordinances
    - Floodplain administration
    - Geographic Information Systems (GIS)
    - Comprehensive Plan Development
    - Subdivision Development
    - Traffic Impacts
    - Zoning

5.2 Parks and Recreation Department

The City Parks and Recreation Department works to provide quality recreational opportunities for all citizens of Moore. The Department strives to provide environmentally safe and beneficial areas for recreational purposes, and to coordinate efforts to maximize the use of existing parks utilizing approved methods for maintenance, such as fertilizer application, and use. While the Parks and Recreation Department is also responsible for their own good housekeeping procedures and management of fertilizer storage, application and disposal, the department also provides waterfowl dispersement measures at City-owned facilities and parks, tree plantings, and pet waste removal services in public parks and open spaces.

5.3 Public Utilities Department

The City of Moore has 390 miles of water line, 28 active water wells, four water towers, one ground storage pump station, 2,647 fire hydrants, and two new water booster stations. The Public Utilities Department is made of the following divisions:

- Water
- Sewer and Waste Treatment

The Public Utilities Department assists with stormwater outfall monitoring as part of the TMDL Monitoring Plan.

5.4 Public Works Department

The Public Works Department manages residential sanitation services, animal welfare, streets maintenance, fleet maintenance, trash collection and facilities maintenance. The Streets and Roads Division is responsible for mechanical street sweeping, inlet cleaning, and stream debris removal and disposal.

5.5 Information Technology Department

The Information Technology Department is responsible for the implementation of GIS resources within the City. The GIS Division supports the MS4 and TMDL programs through the maintenance of GIS information related to the public storm drain system and planned and completed stormwater management facilities.

5.6 City Manager's Office

The City Manager's Office oversees the work of all City Departments and Divisions and is responsible for the development of design standards and specifications for the stormwater management and erosion and sediment control used in the City's capital projects as well as compliance with MS4 and TMDL regulations on all capital projects.

5.7 Lake Thunderbird Watershed Alliance

The Lake Thunderbird Watershed Partnership was an ad hoc group of Moore, Oklahoma City, and Norman formed in response to the TMDL requirements in 2017. Since then, the group has evolved into the more formalized Lake Thunderbird Watershed Alliance in 2021. The Lake Thunderbird Watershed Alliance includes the original members of Oklahoma City, Moore, and Norman, but also features board members from Midwest City and residents surrounding Lake Thunderbird. The goal of the Lake Thunderbird Watershed Alliance is to educate the public about the Lake Thunderbird watershed and ways that they can help improve the lake's water quality through collaborative efforts, activities, and events.

5.8 Central Oklahoma Stormwater Alliance

COSWA is a central Oklahoma-based 501(c)(3) non-profit organization composed of MS4s, public agencies, and private businesses that collaborate and pool resources to satisfy OPDES permit obligations on a regional level. There are currently 25 members including the City of Moore. COSWA encourages local residents to conserve water and reduce pollution through the "Everyday Environmentalist" radio ad campaign, promoting the use of rain barrels and composters, and participating in events such as the Oklahoma City Home + Garden Show.

5.9 Technical Advisory Committee (TAC) and MS4 Public Meetings

The TAC meets to inform TMDL Stakeholders of technical issues, provide advice on technical issues, and to act as a bridge between ODEQ and TMDL Stakeholders. Meeting agendas, presentations, and attendee lists can be viewed on the ODEQ's website under the TMDL Program.

Public meetings are an opportunity to help educate the public and other stakeholders about the TMDL program, modeling, and the requirements for development and implementation of the TMDL Compliance Plan, TMDL Monitoring Plan, and updates to the Phase II Small MS4 SWMP. The Public Notices can be viewed on the ODEQ's website under the TMDL Program, which also contains presentations, reports, and comments.

6.0 TMDL STRATEGIES/PROCEDURES TO ACHIEVE WASTE LOAD ALLOCATION

Given that the City of Moore consists of urban development, a diverse and comprehensive approach for meeting the 35% waste load reduction and TMDL requirements was developed. In the 2015 TMDL Compliance Plan, the City developed an implementation strategy that allowed for the best identification, placement, and implementation of BMPs to achieve waste load reductions as an extension of their existing stormwater management program BMPs. As part of the 5-year update of the TMDL Compliance Plan, the identified BMPs were re-assessed or evaluated using the following process to determine each BMPs effectiveness at achieving waste load reduction goals.

6.1 BMP Selection Process

The City assessed existing program elements set forth in the previous permit, modified as necessary, and developed and implemented necessary new elements to continue reducing the discharge of pollutants from the MS4 to the MEP. As a result, BMPs described in the previous permit were kept, modified, or replaced, as necessary.

6.1.1 Assessment of Existing BMPs

The City has implemented various BMPs intended to protect stormwater quality through its MS4 and TMDL programs. An important aspect of developing an effective, compliant, and cost efficient MS4 and TMDL program is to account for the existing programs that are efficiently benefitting water quality. Likewise, a successful MS4 and TMDL program involves modifying or eliminating inefficient or ineffective existing BMPs. As such, one of the initial steps of the assessment process, which included meetings with staff from City departments, involved modifying or eliminating BMPs.

6.1.2 Identification of Additional BMPs

The second step identified additional BMPs that would meet requirements of the permit and protect water quality to the MEP. Additional BMPs were selected to supplement the City's existing programs and to satisfy unmet requirements of the Small MS4 General Permit. The additional BMPs were evaluated based on their ability to meet at least one, and preferably several, of the MCM requirements.

The evaluation process involved researching a variety of sources of BMPs, such as regulatory agencies, industry associations, and private enterprises. Some of the additional BMPs were selected directly from standard BMP toolboxes available from the EPA, while others were tailored to the specific needs of the City. Each BMP considered was evaluated based on the following criteria:

- Which of the minimum control measure requirements does the BMP meet?
- How does the BMP fit into the City's existing goals, operations, and activities?
- What is the anticipated effectiveness of the BMP?

6.1.3 Measurable Goals and Implementation Schedule

Specific measurable goals have been developed for each BMP. In accordance with the permit requirements, measurable goals have been developed to evaluate the success of the City 's TMDL Compliance Plan toward reaching the goal of protecting water quality and waste loads of nutrients, TSS and CBOD. Goals were selected with a consideration toward achieving steady implementation, assessing the ability to measure and track progress, and working within budgetary constraints. In general, measurable goals for existing BMPs monitor the effectiveness of the BMP, whereas measurable goals for new BMPs monitor their implementation progress.

The ODEQ allows for implementation of new BMPs over a multi-year period. For new BMPs, the first year of the permit program is dedicated to identifying the approach to implement each activity. The second through fifth years focus on implementation, evaluating the effectiveness of existing BMPs, and tracking the implementation of new BMPs. For existing BMPs, the first year of the permit term is dedicated to continuing and evaluating the existing activities.

6.1.4 Measurable Goal Evaluation Process

The selected measurable goals for each BMP will be evaluated on an annual basis. Implementation of each BMP will be tracked as appropriate during each permit year in order to provide documentation of the BMP activities. Relative success at achieving the measurable goals, as well as an assessment of the effectiveness of each BMP, will also be evaluated on an annual basis.

Multiple City departments are responsible for implementing portions of the TMDL Compliance Plan and its BMPs and for tracking and evaluating the City's success in meeting the program's measurable goals. Each City department with activities or responsibilities that may impact stormwater quality will maintain documentation showing progress towards meeting the annual measurable goals for each BMP and make this information available to the person designated for TMDL program coordination.

6.1.5 Prioritization and Benefits

Not all of the BMP identified will be implemented. The City has identified more BMP than what is needed to meet the current TMDL and MS4 permit conditions. As part of the adaptive management process, additional BMPs may be selected after they are prioritized based on several factors, including:

- Equitable distribution of implementation across City watersheds, neighborhoods, and demographics and potential to address environmental conditions.
- Cost effectiveness of practice compared to load reduction capability.
- Collaboration opportunity with other environmental initiatives within the City.
- Social and economic benefits to areas surrounding BMP location.
- Public outreach and stewardship opportunities to modify behaviors (increase secondary activity based BMPs for pollution prevention) and decrease maintenance needs.
- Stream restoration, beyond simple reductions of identified pollutants.

Additionally, while new neighborhoods may be targeted for the location of LID practices, other neighborhoods may be considered. These adjustments will be made as part of an adaptive management process.

6.2 Adaptive Management Process

Sound implementation strategies require ongoing assessment and effective adaptation to respond to changing conditions, new technologies, and lessons learned. This will be the basis that the Compliance Plan will use when WLA are not met, or projected funding is inadequate. Adaptive management requires monitoring of a variety of measures that can be used to determine whether progress is being made towards meeting the MS4 and TMDL water quality objectives.

It is the in-stream water quality and the loading limits with respect to the TMDL that determine the success of implementation; however, there are many interim measures that can also be correlated to success, which are worth pursuing.

Any discharges to the MS4 and TMDL watershed must meet the limitations, conditions, or other requirements of this Compliance Plan associated with the WLA, LA and/or TMDL within any timeframes established in the TMDL. Monitoring and reporting of the discharges may also be required as appropriate to ensure compliance with the TMDL. The City must adopt any WLAs assigned to its discharges specified in the TMDL as measurable goals in the SWMP. If the TMDL relies on a BMP-based approach, effective implementation of additional TMDL-related BMPs should be sufficient to implement applicable WLAs.

For many TMDL Compliance Plan strategies, it may be difficult to formulate individual effectiveness in terms of pollutant load reductions, but collectively, the monitoring and tracking that occurs should provide adequate insight into the overall effectiveness of the Compliance Plan strategy. In addition to the monitoring and assessment, the City will be reporting results on an annual basis as part of their OPDES MS4 Permit annual report.

The MS4 Permit requires annual reporting of the following:

- The status of the City's compliance with permit conditions, an assessment of the appropriateness of the identified best management practices, progress towards achieving the statutory goal of reducing the discharge of pollutants to the MEP, and progress toward achieving the measurable goals for each of the MCMs.

- Results of information collected and analyzed, if any, during the reporting period, including monitoring data used to assess the success of the SWMP at reducing the discharge of pollutants to the MEP.
- A summary of the stormwater activities the City plans to undertake during the next reporting cycle (including an implementation schedule).
- Proposed changes to the SWMP, including changes to any BMP or any identified measurable goals that apply to the SWMP elements.
- Description and schedule for implementation of any additional BMP or monitoring that may be necessary to reduce/eliminate the discharges of the pollutant of concern into impaired waters on the 303(d) list.
- Description and schedule for implementation of any additional BMP or monitoring that may be necessary to ensure compliance with any applicable TMDL or watershed plan in lieu of a TMDL.
- Notice that you are relying on another government entity to satisfy some of your permit obligations (if applicable) and a copy of the written agreement with that entity.

The City will build upon annual reporting that has historically occurred to meet permit requirements and will supplement this reporting with tracking table summaries that quantify implementation activities for the range of strategies pursued during that year so that the following can be incorporated and evaluated:

- Adherence to the TMDL Compliance Plan and schedule
- Meeting milestones
- New technology and innovative practices
- Changes to any stormwater laws, rules, and regulations
- Resource availability

If sufficient progress is not demonstrated in this evaluation, the City may be required to submit an updated Compliance Plan and implementation schedule within six months. Noncompliance may also be subject to enforcement action.

7.0 TMDL BEST MANAGEMENT PRACTICES

The BMPs available for evaluation and selection by the City are limited by City resources as well as their applicability to urban environments. The City has selected the followings BMPs to provide nutrient and sediment removal through traditional and non-traditional means. Each of the City's stakeholder departments have responsibility for regular implementation of many of the selected BMPs.

7.1 Community Development Department

7.1.1 Environmental Services

Educational (Non-Structural) BMPs	Description
Annual TMDL Public Meetings	The City will hold annual public meetings to present progress on the Compliance Plan, TMDL progress and MS4 Program requirements. The presentation will be a summary of the Annual Report, as well as a look at projects, programs, and partnerships for the coming year.
MS4 Public Education BMPs	The City recognizes that meeting the MS4 and TMDL requirements cannot be done solely by government – residents, organizations, schools, and businesses each play a role. The City will develop and provide educational materials and training in support of the Small Phase II MS4 permit, this Compliance Plan, and the City's stormwater management efforts, and assist in the promotion and dissemination of this information. When identifying public education for trash and litter reduction, pet and agricultural waste, and illegal dumping, the City will provide additional focus and training in target areas where monitoring information indicates higher than expected levels of pollutants and encouraging the reduction of stormwater runoff from private properties with activities upland of ambient monitoring locations.
MS4 Community Involvement BMPs	The City recognizes and is committed to the role that public outreach and stewardship will play if improved water quality conditions are going to be achieved. This will require engaging a broader and more diverse set of stakeholders who can serve as leaders and champions for clean water in their neighborhoods, including greater participation from minority and faith-based groups, business groups, schools, and neighborhood associations. Additionally, this approach requires working collaboratively with other City departments to look for better and more efficient ways to communicate messages, cross-train, and create teamwork that results in greater engagement, greater awareness, and sustained changes in behavior. The City maintains the website, which addresses and provides an overview of the City's stormwater program and initiatives.

<table>
<tr><th>Educational (Non-Structural) BMPs</th><th>Description</th></tr>
<tr><td>Fertilizer Application Education</td><td rowspan="5">In order to facilitate and expand public education and enforcement of stormwater BMP, the City will develop and provide educational material and training in support of the Small Phase II MS4 permit, this Compliance Plan, and the City’s stormwater management efforts, and assist in the promotion and dissemination of this information. Educating the public about what they can do to reduce polluted runoff, including:
o Illegal dumping;
o Pet waste;
o Waterfowl waste;
o Fertilizer application
o Septic System Discharge</td></tr>
<tr><td>Illegal Dumping Education</td></tr>
<tr><td>Duck Waste Education</td></tr>
<tr><td>Pet Waste Education</td></tr>
<tr><td>Septic System Discharge Education</td></tr>
<tr><th>Structural BMPs & Physical Controls</th><th>Description</th></tr>
<tr><td>Bioretention Projects (public/private)</td><td rowspan="4">Land disturbance activities are required to meet stormwater management regulations – including City departments, public and private institutions, and developers. Acceptable stormwater management projects include bio-retention, swales, pervious pavement where applicable and appropriate, and impervious surface removal if appropriate. For the purposes of the Compliance Plan, structural BMPs include practices that treat drainage areas of five acres or more, such as stormwater ponds, wetlands, detention basins, and infiltration swales. While the City has few stormwater management ponds and limited space to install new ponds or large practices, there may be some ponds that were developed prior to 2010 that will be evaluated as candidates for retrofitting. Opportunities for installing new ponds, wetlands, and large bio-retention facilities are typically in parks or major rights-of-way and will also be evaluated, if applicable.</td></tr>
<tr><td>Retrofitting Ponds or Wetlands</td></tr>
<tr><td>Vacant Land for Stormwater Management</td></tr>
<tr><td>Pervious Surface Placement</td></tr>
<tr><td>Construction Inspections</td><td>Inspections will be conducted in accordance with the Small Phase II MS4 General Permit for evaluating pollutant loading in stormwater discharges from construction and industrial sites, such as monitoring requirements for site operators or small drainage monitoring for multiple construction sites</td></tr>
<tr><td>Inspect MS4 for IDDEs</td><td>The City is responsible for monitoring the quality of the streams and MS4 in the City. Source tracking inspections for chronic sources consist of visual inspections performed by City crews and may include one or more field test kits for parameters that monitor the type of stormwater pollution that is indicated (e.g., chlorine residual, pH, dissolved oxygen, conductivity, etc.). The visual inspection will describe and/or quantify the extent of pollution (e.g., floatables, excess algae growth, dead or stressed stream vegetation and organisms, color of water, odors, sediments, etc.).
When episodic incidental pollution is reported to the City (e.g., motor oil dumped into a storm drains), the City’s stormwater staff will record the date, location, information source, and description of the event. If necessary, a public works crew member will be sent to investigate and determine if the site should be cleaned (e.g., removal of yard waste, containment of oil, etc.).</td></tr>
</table>

Ordinances and Policies	Description
LID Incentive Programs	Evaluating, establishing through ordinance, and installing LID stormwater management practices like stormwater retention in public rights-of-way, parking lots, and vacant lots, as well as construction LID practices. LID practices are small stormwater facilities that treat five acres or less, including bio-retention, bio- swales, permeable paving, and rain barrels. Given the small size of these practices, they fit well into the City's urban environment of streets, parking lots, small parks, and school grounds. Unfortunately, they can be expensive to install, limited by existing conduits, utilities, and soil conditions, and conflict with right-of-way needs like on-street parking or community acceptance. LID practices will be evaluated as a potential measure for stormwater quality protection. Potential projects may be evaluated for each of the three Wards and will be assigned a prioritization level as applicable and appropriate.
Erosion and Sediment Control Ordinance	The City will review and update as necessary the ordinance for erosion and sediment control (Moore City Code, Chapter 15 Article C). The ordinance outlines the City's erosion and sediment control restrictions, stream setbacks, provides clear guidance to developers and property owners, and provides additional authority to enforce violations. The City also provides continued education and training to developers, contractors and homeowners regarding erosion and sediment control through its website. Finally, the City has implemented Service Request system that allows citizens to report any erosion problems, whether construction sites, street work, or from properties by phone and email. Through implementation of ordinances, standards, and inspections the City will be able to quantify benefits related to TMDL pollutant reduction. Metrics for quantified benefits will be developed as baseline pollutant concentrations are established.
Fertilizer Application Ordinance	The City will consider and develop an ordinance for fertilizer application, as necessary.
Disaster Recovery and Funding	Disaster Recovery funding, as it may become available during the implementation of the TMDL may offer an opportunity for pervious surface placement, implementation of small stormwater management practices, and additional tree planting.
Water Quality Monitoring	**Description**
Ambient Background/Baseline Monitoring	The City intends to conduct an ambient background concentration study to better understand the pollutant concentrations that may discharge from the City. The City believes that this level of analysis will provide the necessary background levels to model pollutant reduction of the established TMDL constituents more effectively. Establishing baseline data requires a multi-year (typically a minimum of five (5) years, EPA841-R-97-006, May 1997) monitoring program that provides for variations in drought, above annual average rainfall, and natural disasters such as tornadoes. This Background Assessment is presented in the TMDL Monitoring Plan.

Water Quality Monitoring	**Description**
TMDL Monitoring Plan	The primary goal of the monitoring program is to supplement baseline data on receiving streams in the City for use in determining long-term water quality trends. The City seeks to continue documenting water quality improvements resulting from BMP effectiveness as they have over the past several years encompassing the previous Small MS4 permit term. The City intends to perform monitoring in order to provide: 1) more coordinated and comprehensive baseline water quality sampling; 2) more sound and reliable ambient data collection; 3) to ensure greater cost effectiveness for proposed BMP; and 4) to establish a truer assessment of the City's impact on stream and watershed water quality. This Monitoring Program is presented in the TMDL Monitoring Plan.
Community Stakeholders	**Description**
Lake Thunderbird Watershed Alliance	Partnerships are BMPs that are installed by the public, private and non-profit sectors, whether as a requirement for development, projects by environmental non-profits, or participation in local sub- state organizations such as ACOG. It is projected that these BMPs will reduce the waste load to the watershed.
Central Oklahoma Stormwater Alliance (COSWA)	COSWA is a central Oklahoma-based 501(c)(3) non-profit organization composed of MS4s, public agencies, and private businesses that collaborate and pool resources to satisfy OPDES permit obligations on a regional level. There are currently 25 members including the City of Moore. COSWA encourages local residents to conserve water and reduce pollution through the "Everyday Environmentalist" radio ad campaign, promoting the use of rain barrels and composters, and participating in events such as the Oklahoma City Home + Garden Show.

7.2 Parks and Recreation Department

Structural BMPs & Physical Controls	**Description**
Disperse Waterfowl	The Oklahoma Department of Wildlife Conservation is consulted when dispersing waterfowl. The Parks Department maintains one structural control at Central Park being a fake alligator in the lake to discourage waterfowl from nesting.
Pet Waste Removal	Pet waste management programs are maintained at all parks. Pet waste contributes to increased bacteria levels in stormwater runoff. Each park contains signage and free poop bags to encourage proper pet waste disposal.
Tree Planting	Aesthetic maintenance focuses on how the stormwater facility looks, making sure that it is litter and trash free and that the plants are healthy and attractive. This includes routine maintenance like removing litter and debris, weeding, and mulching. Aesthetic maintenance provides opportunities for collaboration with residents, businesses, and civic groups.

7.3 Public Utilities Department

Water Quality Monitoring	Description
Outfall Monitoring	The TMDL requires the collection of at least one representative sample of a stormwater discharge from at least 50% of the major discharge points discharging directly to surface waters of the state within the portion of the TMDL watershed in the MS4 area. A major discharge point is a pipe or open conveyance measuring 36 inches or more at its widest cross section. There are four outfalls that meet the criteria. This Outfall Monitoring is presented in the TMDL Monitoring Plan.

7.4 Public Works Department

Structural BMPs & Physical Controls	Description
Street Sweeping	The City maintains two street sweepers that operate in the central areas of the City and many of the main commuter routes and corridors on a daily schedule. Other streets in neighborhoods and commercial areas of the City are swept on an as-needed/as-requested basis. With increased public education and outreach, the City expects the amount of trash and debris collected by the mechanical street sweeping program to decrease over the course of the permit. Any decrease will be monitored and attributed to the education and outreach programs. Currently, the Public Works Department has no tracking system for how much debris is collected from street sweepers.
Inlet Cleaning	The City currently performs catch basin and inlet cleaning on as as-needed basis. The City will evaluate the need for additional scheduled cleaning and the possible need for catch basin/inlet filter placement during the first permit term of the Small MS4 permit, where the filters can be the most cost effective. If it is determined to be appropriate and successful, the City will look to expand the catch basin/inlet filter programs.
Restore Streams/Erosion Protection	The City's streams are moderately degraded, with eroding banks and shifting bottoms due to the nature of the soil within the City. Stream restoration may be an opportunity to reduce erosion and sedimentation, increase natural channel flow, and improve the health of the stream and adjacent riparian areas. Stream restoration projects will be evaluated and identified during the TMDL implementation period. A prioritization matrix will be developed as needed and appropriate.
Disperse Waterfowl	Animal Control receives training on how to remove eggs from Canadian Geese nests to control population and discourage nesting. Additionally, in emergency situations, the waterfowl themselves can be removed and placed in an approved habitat.
Animal Waste Removal	Animal waste management programs. Animal Control personnel regularly clean animal shelter yards and holding pens of animal waste. It is disposed of in the trash.

8.0 TMDL MILESTONE SCHEDULE

To promote continual progress, the City has established the milestone schedule presented in Table 2 to meet the TMDL waste load reduction requirements. These milestones include program enhancements to increase resources and improve the implementation process and implementation actions, which are on-the-ground activities that will directly result in nutrient and sediment load reductions.

8.1 Tracking Mechanisms

The City will track all BMPs (planned, implemented, and/or constructed) using an electronic database and/or GIS tracking tool. The tracked data will coincide with MS4 General Permit OKR04 reporting requirements. A majority of BMP implementation will be reported through the permitting process for construction activities. The BMP milestones will also be updated as per the TMDL Compliance and MS4 General Permit OKR04 requirements.

8.2 Staffing and Resources

The pace of implementation is expected to increase as new BMPs, and Compliance Plan elements are implemented. Meeting the MS4 and TMDL requirements may require an increase in the design and construction of stormwater capital projects, inspection of facilities, water quality testing and analysis, community outreach, and maintenance.

The most significant increase is anticipated to be related to stormwater inspections (in order to increase the number of construction and industrial site inspections as well as installed BMPs), BMP implementation (providing dedicated project management and in-house design and engineering), and education and outreach (build community capacity by targeting new partner groups that provide the necessary leadership, oversight, and sustained effort to change behaviors and foster stewardship).

Table 2. TMDL Milestone Schedule

Permit Term	Program Milestones	Milestone Completion
First Permit Cycle (2015-2020)	Complete the City of Moore Comprehensive Storm Water Management and Drainage Plan	✓ Completed. City will update, as necessary.
	Identify education needs and cost for and begin program issuance: • Pet waste. • Livestock waste. • Fertilizer application • Septic System Discharge	✓ Completed. City incorporated into MS4 public education BMPs.
	Perform Ambient Background Assessment monitoring program	☐ Started. City will continue under updates to TMDL Monitoring Plan.
	Establish and implement Lake Thunderbird specific IDDE protocols and procedures and begin increased performance as appropriate	✓ Completed. City incorporated into MS4 SWMP.
	Evaluate the need to restore streams (hydro-geomorphology) and establish design standards and requirements	☐ Postponed. City will reevaluate in future permit cycles.
	Evaluate and establish need to update ordinances for LID stormwater management practices and develop standards as appropriate	✓ Completed. City incorporated into stormwater management design criteria.
	Identify need for increased staff: • Establish staff qualification criteria • Develop budget requirements for additional staff	☐ Postponed. City stakeholders implement program.
	Evaluate the need to disperse waterfowl populations in water amenities (wildlife management) and develop standard procedures as necessary	✓ Completed. City animal control managed dispersement.
	Evaluate the need to retrofit and/or install ponds or wetlands and begin development of design standards as appropriate.	☐ Postponed. City will reevaluate in future permit cycles.
	Identify the need for increased preventative inlet cleaning in targeted neighborhoods of the City. The effort will be in collaboration with inlet screen installation and expanded street sweeping operations. • Develop costs for performance • Identify funding sources	✓ Completed. City completes, as needed. New street sweeper purchased.
	Establish and perform increased Construction site inspection schedules in coordination with ODEQ	✓ Completed. City has robust construction inspection program.

Permit Term	Program Milestones	Milestone Completion
First Permit Cycle (2015-2020)	Develop the protocols for the Technical Work Group. • Identify members of the Technical Work Group • Establish goals • Conduct development meetings with identified City departments	✓ Completed. City stakeholders implement program.
	Develop feasibility studies for private participation incentive programs	✓ Completed. City developed LID incentives program. No other studies are anticipated.
	Perform cost to benefit analysis of TMDL program to date	☐ Postponed. City will reevaluate in future permit cycles.
Second Permit Cycle (2020-2025)	Update Monitoring Plan and conduct monitoring in accordance with Plan and QAPP.	
	Assess performance of BMP implementation based on monitoring data collected in the City as well as monitoring data from sampling and analysis on Lake	
	Increase staff as appropriate by hiring or contracting for stormwater management programming	
	Review and update, as necessary, ordinances for: • LID • Erosion and sediment control • Pet waste	
	Consider and develop, as necessary, ordinances for: • Livestock management • Fertilizer application • Vehicle washing	
	Reassess BMP practices and continue BMP implementation, as appropriate.	
	Create a consistent set of informational sheets, messages, and signage for reducing stormwater pollutants.	
	Continue to incorporate trees and landscaping into stormwater BMP projects/City-owned projects	
	Perform cost to benefit analysis of TMDL program to date	
Third Permit Cycle (2025-2030)	Update Monitoring Plan and conduct monitoring in accordance with Plan and QAPP.	
	Reassess BMP practices and continue BMP implementation, as appropriate.	

Permit Term	Program Milestones	Milestone Completion
Third Permit Cycle (2025-2030)	Update stormwater ordinances, as necessary.	
	Perform cost to benefit analysis of TMDL program to date.	
	Complete an analysis of city-owned facilities for possible stormwater retrofits	
	Evaluate the need to restore streams (hydro-geomorphology) and establish design standards and requirements	
	Evaluate the need to retrofit and/or install ponds or wetlands and begin development of design standards as appropriate.	
	Update the Final Lake Thunderbird Report for Nutrient, Turbidity, and Dissolved Oxygen TMDLs	

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Appendix A
Final Lake Thunderbird Report for Nutrient, Turbidity, and Dissolved Oxygen TMDLs

FINAL

Lake Thunderbird Report for Nutrient, Turbidity, and Dissolved Oxygen TMDLs

Prepared for
Oklahoma Department of Environmental Quality
Water Quality Division

OKLAHOMA
DEPARTMENT OF ENVIRONMENTAL QUALITY

November 10, 2013

By

Dynamic Solutions, LLC

Dynamic Solutions LLC

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List of Acronyms and Abbreviations

3-D	Three-dimensional
ADCP	Acoustic Doppler Continuous Profiler
ARRA	American Recovery and Reinvestment Act of 2009
BMP	Best management practices
CBOD	Carbonaceous Biochemical oxygen demand
BUMP	Beneficial Uses Monitoring Program
CAFO	Concentrated Animal Feeding Operation
CASTNET	Clean Air Status and Trends Network
CFR	Code of Federal Regulations
cfs	cubic feet per second
Chl-*a*	Chlorophyll-*a*
COD	Chemical Oxygen Demand
COE	United States Army Corps of Engineers
COMCD	Central Oklahoma Master Conservancy District
CPP	Continuing Planning Process
CST	Central Standard Time Zone
CV	Coefficient of Variation
CWA	Clean Water Act
DEQ	Oklahoma Department of Environmental Quality
DIN	Dissolved inorganic nitrogen (DIN=nitrate + ammonia)
DMR	Discharge Monitoring Report
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DON	Dissolved Organic Nitrogen
DOP	Dissolved Organic Phosphorus
DSLLC	Dynamic Solutions, LLC
EFDC	Environmental Fluid Dynamics Code
EPA	Environmental Protection Agency
FWP	Fish & Wildlife Propagation
HSPF	Hydrologic Simulation Program FORTRAN
HUC	Hydrologic Unit Code
GIS	Geographic Information System
GUI	Graphical user interface
Kg	Kilograms

LA	Load Allocation
lb	pound
LTA	Long term average load
mg/L	milligram per liter
MDL	Maximum Daily Load
MOS	Margin of Safety
MS4	Municipal separate storm sewer system
MSGP	Multi-Sector General Permits
MSL	Mean Sea Level
NADP	National Atmospheric Deposition Program
NAD83	North American Datum of 1983
NAVD88	North American Vertical Datum of 1988
NCDC	National Climatic Data Center (NOAA)
NED	National Elevation Dataset
NGVD29	National Geodetic Vertical Datum of 1929
NH4	Ammonium-N
NHD	National Hydrography Dataset
NLCD	National Land Cover Database
NLW	Nutrient Limited Waterbody
NO2	Nitrite-N
NO3	Nitrate-N
NO23	Nitrite-N + Nitrate-N
NOAA	National Oceanic Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
N-S	Nash-Sutcliffe coefficient
NTU	Nephelometric turbidity units
O.S.	Oklahoma Statutes
OAC	Oklahoma Administrative Code
OCC	Oklahoma Conservation Commission
ODAFF	Oklahoma Department of Agriculture, Food, and Forestry
OWRB	Oklahoma Water Resources Board
POC	Particulate Organic Carbon
PON	Particulate Organic Nitrogen
POP	Particulate Organic Phosphorus
RMS	Root Mean Square

RMSE	Root Mean Square Error
r^2	Correlation coefficient
SDOX	Supersaturated Dissolved Oxygen
SIC	Standard Industrial Classification
SOD	Sediment Oxygen Demand
SSO	Sanitary Sewer Overflow
SWP3	Storm Water Pollution Prevention Plan
SWS	Sensitive Water Supply
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TOC	Total Organic Carbon
TON	Total Organic Nitrogen
TOP	Total Organic Phosphorus
TP	Total Phosphorus
TPO4	Total Phosphate
TSI	Trophic State Index
TSS	Total Suspended Solids
USDA	United States Dept. Agriculture
USGS	United States Geological Survey
UTM	Universal Transverse Mercator (map projection)
WLA	Wasteload allocation
WQM	Water quality monitoring
WQMP	Water Quality Management Plan
WQS	Water Quality Standard
WWAC	Warm Water Aquatic Community
WWTP	Wastewater treatment plant

EXECUTIVE SUMMARY

Lake Thunderbird is a 6,070-acre reservoir located 13 miles east of downtown Norman in Cleveland County, Oklahoma. The Lake is located within a 256 square mile drainage area of the upper Little River watershed (HUC, 11090203). The Lake, owned by the U.S. Bureau of Reclamation, was constructed to provide flood control, municipal water supply, recreation and wildlife habitat. Lake Thunderbird is a prime recreational lake for camping, fishing, swimming and boating for the growing population in and around the watershed. As of the 2010 census, the watershed population is estimated at 99,600. The Lake serves as the primary public water supply for the cities of Norman, Midwest City, and Del City with water usage governed by the Central Oklahoma Master Conservancy District (COMCD). Lake Thunderbird is on Oklahoma's 2010 303(d) list for impaired beneficial uses of public/private water supply and warm water aquatic community (WWAC).

This report documents the data and assessment methods used to establish total maximum daily loads (TMDL) for Lake Thunderbird (OK520810000020_00). Data assessment and TMDL calculations are conducted in accordance with requirements of Section 303(d) of the federal Clean Water Act (CWA), Water Quality Planning and Management Regulations (40 CFR Part 130), United States Environmental Protection Agency (EPA) guidance, and Oklahoma Department of Environmental Quality (DEQ) guidance and procedures. DEQ is required to submit all TMDLs to the EPA for review and approval. Once the Environmental Protection Agency (EPA) approves a TMDL, the waterbody may then be moved to Category 4 of a state's Integrated Water Quality Monitoring and Assessment Report, where it remains until compliance with water quality standards (WQS) is achieved (EPA, 2003).

The purpose of this TMDL report is to establish waste load allocations (WLA) and load allocations (LA) determined to be necessary for reducing turbidity and chlorophyll-*a* levels and maintaining sufficient oxygen levels in the Lake to attain water quality targets to restore impaired beneficial uses and protect public health. TMDLs determine the pollutant loading that a waterbody, such as Lake Thunderbird, can assimilate without exceeding applicable water quality standards. TMDLs also establish the pollutant load allocation necessary to meet the water quality standards established for a waterbody based on the relationship between pollutant sources and water quality conditions in the waterbody. A TMDL consists of a waste load allocation (WLA), load allocation (LA), and a margin of safety (MOS). The WLA is the fraction of the total pollutant load apportioned to point sources, and includes stormwater discharges regulated under the National Pollutant Discharge Elimination System (NPDES) as point sources. The LA is the fraction of the total pollutant load apportioned to nonpoint sources. The MOS is a percentage of the TMDL set aside to account for the lack of knowledge associated with natural processes in aquatic systems, model assumptions, and data limitations.

This report does not identify specific control actions (regulatory controls) or management measures (voluntary best management practices) necessary to reduce pollutant loading from the watershed. Watershed-specific control actions and management measures will be identified, selected, and implemented under a separate process involving stakeholders who live and work in the watershed, along with local, state, and federal government agencies.

ES.1 Problem Identification and Water Quality Targets

Designated uses of Lake Thunderbird are flood control, municipal water supply, recreation, and fish and wildlife propagation. Lake Thunderbird is designated as a Category 5a lake on the Oklahoma 303(d) list with a Priority 1 ranking. Category 5 defines a waterbody where, since the water quality standard is not attained, the waterbody is impaired or threatened for one or more designated uses by a pollutant(s), and the water body requires a TMDL. DEQ has determined that Lake Thunderbird, designated as a Sensitive Water Supply (SWS) lake, is not supporting its designated uses for (a) Fish & Wildlife Propagation (FWP) for a Warm Water Aquatic Community because of excessive levels of turbidity and low dissolved oxygen; and (b) Public Water Supply because of excessive chlorophyll-*a* levels. High levels of both turbidity and chlorophyll-*a* can have deleterious effects on the raw water quality, such as taste and odor complaints and treatment costs of drinking water. Low levels of dissolved oxygen below the thermocline reflect decay of organic matter in the sediment bed and restricted transfer of oxygen from the surface layer because of summer thermal stratification. The water quality targets established for Lake Thunderbird, based on statistics of the most recent 10 years of record, are defined as the long-term average in-lake surface concentration of 10 µg/L for chlorophyll-*a* and the 90th percentile of the in-lake surface concentration of 25 NTU for turbidity. Water quality criteria for DO are defined for: (a) the surface layer (epilimnion) during periods of thermal stratification and (b) the entire water column when the lake is not stratified. A Warm Water Aquatic Community (WWAC) lake is fully supporting its designated beneficial uses for the epilimnion and the entire water column if 10% or less of DO samples are less than 6 mg/L from April 1 through June 15 and less than 5 mg/L during the remainder of the year (June 16 through March 31). DO criteria for a WWAC lake are also defined on the basis of the anoxic volume of the lake that is less than a target cutoff level of DO. During the period of thermal stratification, the lake is fully supporting if 50% or less of the lake volume is less than the target cutoff of 2 mg/L.

ES.2 Pollutant Source Assessment

Water quality constituents that relate to impairments of Lake Thunderbird include suspended sediment, chlorophyll-*a*, phosphorus, nitrogen, and carbonaceous biochemical oxygen demand (CBOD). The major contribution of pollutant sources from the watershed are derived from urban stormwater runoff from Moore, Norman and Oklahoma City. A smaller contribution of pollutant loading is related to runoff from rural and unincorporated areas of the watershed. A waste load allocation (WLA) for point source discharges of urban stormwater from Moore, Norman and Oklahoma City, is determined for sediment, nutrients and CBOD. Urban stormwater discharges are regulated under the Clean Water Act by NPDES permits issued to the three cities as part of the MS4 Stormwater Program. A load allocation (LA) for nonpoint runoff of sediment, nutrients and ultimate CBOD is determined for the unincorporated area of the watershed not included within the boundaries of the three MS4 permits, along with the very small areas of the cities of Noble and Midwest City located in the watershed.

ES.3 Watershed and Lake Model

A model framework was developed to establish the cause-effect linkage between pollutant loading from the watershed (the HSPF model) and water quality conditions in the lake (the EFDC model). Flow and pollutant loading from the watershed to the Lake was simulated for a one year period from April 2008 to April 2009 with the public domain HSPF watershed model. Watershed model results were used to estimate the relative contributions of point and nonpoint sources of pollutant loading. As shown in Table ES-1, the three cities of Moore, Norman and Oklahoma City accounted for the dominant share of total pollutant loading from the watershed. The EFDC model was developed to simulate water quality conditions in Lake Thunderbird for sediments, nutrients, organic matter, dissolved oxygen and chlorophyll-*a*.

Table ES-1 Relative Contribution of Point and Nonpoint Source Loading of Pollutants from the Lake Thunderbird Watershed (April 2008-April 2009)

	TN	TP	CBOD	Sediment
City Name	**%**	**%**	**%**	**%**
Moore	25.4	28.1	31.5	21.1
Norman	39.5	38.0	38.5	41.0
Oklahoma City	32.4	31.1	27.7	35.1
Other areas	2.6	2.8	2.3	2.7
Total	100	100	100	100

Model results for suspended solids were transformed to turbidity for comparison to water quality criteria for turbidity. Simulated suspended solids were transformed with a site-specific regression relationship developed from Lake Thunderbird station records for TSS and turbidity. EFDC is a public domain surface water model that includes hydrodynamics, sediment transport, water quality, eutrophication and sediment diagenesis. The EFDC lake model was developed with water quality data collected at eight locations in the Lake during the one year period from April 2008 through April 2009. Model results were calibrated to observations for water level, water temperature, TSS, nitrogen, phosphorus, dissolved oxygen, organic carbon and algae biomass (chlorophyll-*a*). The Relative RMS Error performance targets of (a) 20% for water level and dissolved oxygen; (b) 50% for water temperature, nitrate and total organic phosphorus; and (c) 100% for chlorophyll-*a* were all attained with the model results for these constituents either much better than, or close to, the target criteria. The model results for TSS, total phosphorus, total phosphate, and total nitrogen were also good with the model performance statistics shown to be only 5-6% over the target criteria of 50%.

The calibrated lake model was used to evaluate the water quality response to reductions in watershed loading of sediment and nutrients. Load reduction scenario model runs were performed to determine if water quality targets for turbidity and chlorophyll could be attained with watershed-based load reductions based on 35% removal of loading for sediment and nutrients. The long-term model results indicated that compliance with water quality criteria for turbidity, dissolved oxygen and chlorophyll could be achieved within a reasonable time frame. The calibrated model results thus supported the development of TMDLs for sediments, CBOD, TN and TP to achieve compliance with water quality standards for turbidity, chlorophyll and dissolved oxygen.

ES.4 TMDL, Waste Load Allocation, Load Allocation and Margin of Safety

The linked watershed (HSPF) and lake (EFDC) model framework was used to calculate average annual suspended solids, CBOD, nitrogen and phosphorus loads (kg/yr) that, if achieved, should meet the water quality targets established for turbidity, chlorophyll-*a*, and dissolved oxygen. For reporting purposes, the final TMDLs, according to EPA guidelines, are expressed as daily loads (kg/day). The waste load allocation (WLA) for the TMDL for Lake Thunderbird is assigned to regulated NPDES point source discharges under three MS4 stormwater permits for Moore, Norman and Oklahoma City. The WLA, split among the three MS4 permits, includes pollutant discharges regulated under NPDES stormwater permits for Construction Sites and Multi-Sector General Permit (MSGP) for various industrial facilities located within the MS4 areas of the watershed. The load allocation (LA) for the TMDL is assigned to the small land area of the watershed not included in the land area for the three MS4 permits and is set at the existing loading during the calibration period.

Seasonal variation was accounted for in the TMDL determination for Lake Thunderbird in two ways: (1) water quality standards, and (2) the time period represented by the watershed and lake models. Oklahoma's water quality standards for dissolved oxygen for lakes are developed on a seasonal basis to be protective of fish and wildlife propagation for a warm water aquatic community at all life stages, including spawning. Within the surface layer, dissolved oxygen standards specify that DO levels shall be no less than 6 mg/L from April 1 to June 15 to be protective of early life stages and no less than 5 mg/L for the remainder of the year (June 16 to March 31). Under summer stratified conditions during the period from mid-May to October, the hypoxic volume of the lake, defined by a DO target of 2 mg/L, is not to be greater than 50% of the lake volume. Seasonality was also accounted for in the TMDL analysis by developing the models based on one full year of water quality data collected as part of a special study of Lake Thunderbird from April 2008-April 2009. The watershed and lake models were developed with hourly to sub-hourly time steps over a full year of simulation with meteorological data representative of typical average hydrologic conditions in the watershed. The TMDL determined for Lake Thunderbird accounts for an implicit Margin of Safety (MOS) by decreasing the water quality targets for chlorophyll-*a* and turbidity by a factor of 10%. The decrease resulted in the target for turbidity lowered from 25 to 22.5 NTU and the target for chlorophyll-*a* lowered from 10 to 9 µg/L.

The TMDL for Suspended Solids, TN and TP, determined from the lake model response to watershed load reductions, is based on the 35% reduction of the existing 2008 - 2009 watershed loads estimated with the HSPF model. Load reductions for these constituents are needed because the water quality criteria for turbidity and chlorophyll-a are not met under the existing loading conditions. For CBOD, however, the TMDL is based on the existing 2008 - 2009 ultimate CBOD loading from the HSPF watershed model since the water quality criterion for dissolved oxygen is met under existing loading conditions with reserved capacities. For example, the predicted volumetric anoxic volume for Lake Thunderbird is only about 30% (Figure 0-1) while the standards allows up to 50% anoxic volume. This reserved capacity will act as the implicit margin of safety. The total WLA for the three MS4 cities was computed from the Total Maximum Daily Load (TMDL) that was in turn derived from the long term average daily load (LTA) and the coefficient of variation (CV) estimated from HSPF loading data. The statistical methodology, documented in EPA (2007) “Options for Expressing Daily Loads in TMDLs”, for computing the maximum daily load (MDL) limit is based on a long-term average load (LTA), temporal variability of the pollutant loading dataset expressed by the coefficient of variation (CV), the Z-score statistic (1.645) for 95% probability of occurrence and the assumption that streamflow and pollutant loading from the watershed can be described as a lognormal distribution (Table ES-2).

Table ES- 2 Existing Loading and TMDL for Lake Thunderbird

	Units	TN	TP	CBOD	Suspended Solids
Existing 2008 - 2009 Load	kg/yr	117,537.9	23,086.7	236,186.6	11,492,695.8
Existing 2008 - 2009 Load	kg/day	322.0	63.3	647.1	31,486.8
Reduction Rate Required	Percent	35%	35%	0%	35%
Long Term Average Load	LTA, kg/day	209.3	41.1	647.1	20,466.4
Coefficient Variation	CV (N=365)	4.252	4.398	4.774	5.817
Total, Max Daily Load	TMDL, kg/day	807.7	158.4	2,480.8	76,950.8
Z-Score statistic =1.645 for 95% probability					

The load allocation (LA) is computed as the difference from the total maximum daily load (TMDL) and the total WLA load. The TMDL load is split between three WLAs for the three MS4 cities, the LA for the unincorporated area of the watershed and the implicit MOS as shown in Table ES-3.

Table ES- 3 TMDL for Lake Thunderbird

Water Quality Constituent	TMDL	LA	WLA				MOS
			Total	Moore	Norman	OKC	
	(Kg/day)	(Kg/day)	(Kg/day)	(Kg/day)	(Kg/day)	(Kg/day)	(Kg/day)
Total Nitrogen (TN)	807.7	21.3	786.4	205.1	319.4	261.8	Implicit
Total Phosphorus (TP)	158.4	4.4	154.0	44.5	60.1	49.4	Implicit
CBOD	2,480.8	57.4	2,423.4	781.3	955.6	686.5	Implicit
Suspended solids (TSS)	76,950.8	2,068.7	74,882.1	16,236.0	31,596.1	27,049.9	Implicit

ES.5 Public Participation

On May 4, 2012 there was an informational meeting for the public to discuss the Lake Thunderbird Watershed and the TMDL process. On May 16, 2013, EPA preliminarily approved of the draft TMDL report and gave permission to go forward with the Public Comment period. The public comment period was open from June 10, 2013 to August 1, 2013. A Public Meeting was held the evening of July 23, 2013. By the time the public comment period ended, DEQ had received 41 comments from 7 entities. The comments and responses can be found in Appendix G.

SECTION 1 INTRODUCTION

1.1 Clean Water Act and TMDL Program

Section 303(d) of the federal Clean Water Act (CWA) and U.S. Environmental Protection Agency (EPA) Water Quality Planning and Management Regulations (40 Code of Federal Regulations [CFR] Part 130) require states to develop total maximum daily loads (TMDL) for waterbodies not meeting designated uses where technology-based controls are in place. TMDLs establish the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream water quality conditions, so States can implement water quality-based controls to reduce pollution from point and nonpoint sources and restore and maintain water quality (EPA, 1991a).

This report documents the data and assessment used to establish TMDLs for turbidity, chlorophyll-a, and dissolved oxygen for Lake Thunderbird reservoir in Cleveland County, Oklahoma within the Little River drainage basin (Hydrologic Unit Code 11090203). High levels of turbidity reflect sediment loading from the watershed and elevated levels of chlorophyll-*a* in lakes reflect excessive algae growth. High levels of both turbidity and chlorophyll-a can have deleterious effects on the raw water quality and treatment costs of drinking water. Excessive algae growth can also negatively affect the aquatic biological communities of lakes. Elevated chlorophyll-*a* levels typically indicate eutrophication of the lake as a result of excessive loading of the primary growth-limiting algal nutrients nitrogen and phosphorus to the waterbody. Low levels of dissolved oxygen, particularly at depths deeper than the seasonal thermocline, reflect the effects of decomposition of organic matter below the thermocline and within the sediment bed and restricted mixing of dissolved oxygen from the surface layer of the lake to the lower layer of the lake during conditions of summer stratification.

The purpose of this TMDL report is to establish sediment, organic matter and nutrient load allocations necessary for improving turbidity, chlorophyll-a and dissolved oxygen levels in the lake as the first step toward restoring water quality and protecting public health in this waterbody. TMDLs determine the pollutant loading a waterbody can assimilate without exceeding applicable water quality standards (WQS). TMDLs also establish the pollutant load allocation necessary to meet the WQS established for a waterbody based on the cause-effect relationship between pollutant sources and water quality conditions in the waterbody. A TMDL consists of three components: (1) wasteload allocation (WLA), (2) load allocation (LA), and (3) margin of safety (MOS). The WLA is the fraction of the total pollutant load apportioned to point sources, and includes stormwater discharges regulated under the National Pollutant Discharge Elimination System (NPDES) as point sources. The LA is the fraction of the total pollutant load apportioned to nonpoint sources (NPS). The MOS is a percentage of the TMDL set aside to account for the lack of knowledge associated with natural process in aquatic systems, surface water model assumptions, and data limitations.

Data assessment and TMDL calculations are conducted in accordance with requirements of Section 303(d) of the CWA, Water Quality Planning and Management Regulations (40 CFR Part 130), EPA guidance, and Oklahoma Department of Environmental Quality (DEQ) guidance and procedures. DEQ is required to submit all TMDLs to EPA for review and approval. Once the EPA approves a TMDL, then the waterbody may be moved to Category 4a of a State's Integrated Water Quality Monitoring and Assessment Report, where it remains until compliance with water quality standards (WQS) is achieved (EPA 2003).

This report does not stipulate specific control actions (regulatory controls) or management measures (voluntary best management practices) necessary to reduce nutrients within the Lake watershed. Watershed-specific control actions and management measures will be identified, selected, and implemented under a separate process involving stakeholders who live and work in the watersheds, along with local, state, and federal government agencies.

Lake Thunderbird is on Oklahoma's 2010 303(d) list for impaired beneficial uses of public/private water supply and warm water aquatic community life. Causes of impairment have been identified as low oxygen levels, high levels of chlorophyll-*a*, and high turbidity (DEQ, 2010a). An important recreational lake for fishing and boating, Lake Thunderbird is designated by the Oklahoma Water Quality Standards (OWRB 2011) as a Sensitive Water Supply (SWS) since the Lake serves as the primary public water supply source for the cities of Norman, Midwest City and Del City. With the three major municipalities of Moore, Norman and Oklahoma City in the watershed, this area is one of the fastest growing regions in Oklahoma. Urban development has been rapid over the past decade and continued urban development is forecast by local governments. There is clearly the need for appropriate mitigation of the ecological impact of point source and nonpoint sources of pollutant loading from the watershed to Lake Thunderbird.

Figure 1-1 shows a location map of Lake Thunderbird and the contributing sub-watersheds of the drainage basin to the Lake. The map also displays the locations of the five (5) stream water quality monitoring (WQM) stations in the watershed and the eight (8) Lake water quality monitoring stations used for this TMDL determination. Data obtained from the Lake stations over the past 10 years were used as the basis for placement of Lake Thunderbird on the Oklahoma 303(d) list.

1.2 Watershed and Lake Thunderbird Description

Lake Thunderbird (OK Waterbody Identification Number OK520810000020_00) is a 6,070-acre reservoir located 13 miles east of downtown Norman in Cleveland County, Oklahoma at Longitude: 97° 13' 5" and Latitude: 35° 13' 15". The Lake is located within a 256 square mile drainage area of the upper reaches of the Little River basin. The Little River basin is designated by the USGS with an identification code (11090203) known as the 8-digit level Hydrologic Unit Code (HUC) or catalog unit code. The Lake, owned by the U.S. Bureau of Reclamation, was constructed in 1965 to provide flood control, municipal water supply, recreation and wildlife habitat by impounding the Little River and Hog Creek in northeast Cleveland County. Lake Thunderbird is an important recreational lake for camping, fishing and boating which is managed by the Oklahoma Tourism and Recreation Department (Lake Thunderbird State Park) (Bureau of Reclamation, 2009). The Lake serves as a public water supply for the cities of Norman, Midwest City and Del City with water usage governed by the Central Oklahoma Master Conservancy District (COMCD). Lake Thunderbird is bordered by 86 miles of shoreline which is comprised of clay, sand, and sandstone (OK Dept. Wildlife Conservation, 2008).

Figure 1-1 Lake Thunderbird Watershed

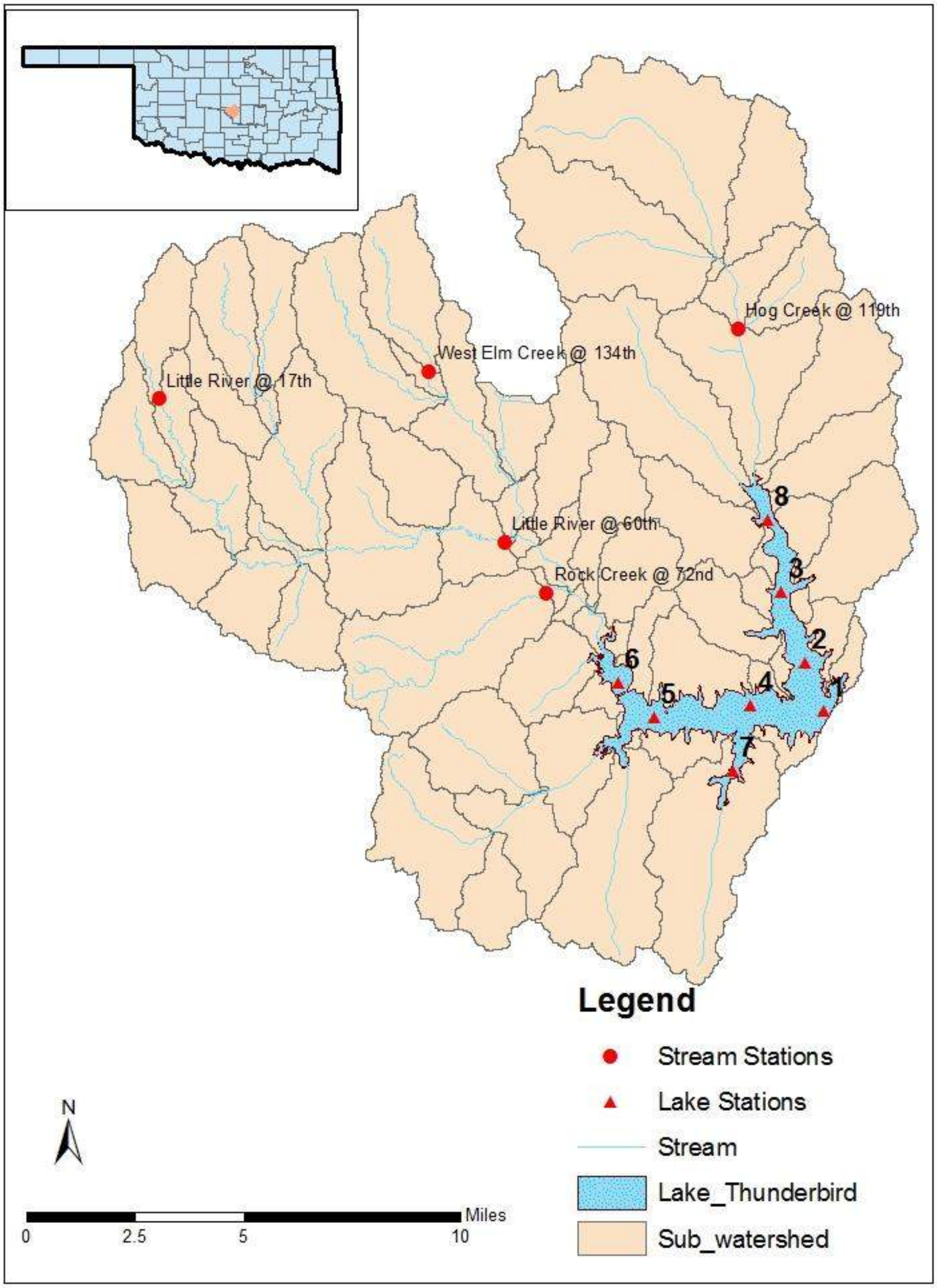


Table 1-1 presents general physical characteristics of Lake Thunderbird. Data sources include the U.S. Army Corps of Engineers, Tulsa District, Bureau of Reclamation, and the Oklahoma Department of Wildlife Conservation (2008).

Table 1-1 Physical Characteristics of Lake Thunderbird

Drainage Area	sq-miles	256
Surface Area @ Normal Pool Elevation[1]	acres	6,070
Normal Conservation Pool Elevation	ft, MSL[2]	1,039.0
Conservation Pool Storage Volume	acre-ft	119,600
Surface Area @ Flood Pool Elevation	acres	8,788
Flood Pool Elevation	ft, MSL	1,049.4
Flood Control Pool Storage Volume	acre-ft	196,260
Average Depth	ft	19.7
Maximum Depth	ft	57.6
Shoreline	miles	86.0

1. Elevation: vertical datum,NGVD29
2. MSL: mean sea level

Data Sources: *OK Dept Wildlife Conservation (2008)*
Bureau of Reclamation (2009)
http://www.swt-wc.usace.army.mil/THUN.lakepage.html

The watershed occupies 256 square miles of residential, commercial and agricultural lands. The surrounding woodland habitat is comprised of Post and Blackjack oak in the Cross Timbers ecotype region of the Southern Plains. Table 1-2 summarizes the percentages and acres of land use categories for the contributing watersheds of the basin. The land use/land cover data were derived from the 2006 National Land Cover Database (NLCD) database (Fry et al., 2011). This table shows the land use in the watershed draining to Lake Thunderbird. The most common land use category in the study area is Grassland/Herbaceous with 38% of the watershed area. In addition to Grassland/Herbaceous land use, a significant portion of the watershed is classified as Deciduous Forest with 35% of the watershed area. Urban developed land use categories account for 16% of the watershed area.

Table 1-2 Land Use Characteristics of the Watershed

Land Use	Acres	Percent
Open water	6,738	4.322%
Developed, open space	14,661	9.405%
Developed, low intensity	6,769	4.342%
Developed, medium intensity	3,102	1.990%
Developed, high intensity	661	0.424%
Barren Land	30	0.019%
Deciduous Forest	55,010	35.288%
Evergreen Forest	351	0.225%
Grassland/Herbaceous	59,765	38.338%
Pasture/Hay	5,452	3.498%
Cultivated Crops	3,341	2.143%
Emergent herbaceous wetlands	8	0.005%
Total Watershed	155,888	100%
Data Source: 2006 NLCD		

Prevailing winds are out of the south-southeast most of the year at 5 to 20 mph (OK Dept. Wildlife Conservation, 2008). Average annual precipitation, derived from NOAA's NCDC statistical summary of air temperature and precipitation from 1971-2000, is 37.65 inches at the station located in Norman (ID=346386). [http://climate.ok.gov/data/public/climate/ok/archive/normals/ncdc/1971-2000/oknorm.pdf] Annual rainfall for Lake Thunderbird measured during the simulation period from 2008 - 2009 (36.9 inches) is comparable to the long term (1971-2000) average rainfall of 37.65 inches. This indicates that the 2008 - 2009 time period used for development of the model and analysis of loads for the TMDL represents "typical" hydrologic conditions for the watershed. Based on 2010 census data (US Census Bureau, 2011), the population within this rapidly growing watershed is estimated at 99,600 based on an overlay of the watershed boundary and census tract data.

Figure 1-3 presents population density of the census tract areas located within the watershed boundary. As can be seen, the highest population density of 5000-6999 persons per square mile corresponds to Oklahoma City and Moore in the urbanized northwest area of the watershed. The lowest population density (<100 persons per square mile) is characteristic of the more rural eastern area of the watershed and corresponds to the dominant land use categories of Grassland and Deciduous Forest. Table 1-3 presents population based on 2010 census data for Cleveland and Oklahoma counties that are located within the watershed. The table presents the total population of the county and the population of the county located within the watershed based on compilation of census tract data presented in Figure 1-3.

Table 1-3 County Population within the Watershed

County	Total Population	Population in the Thunderbird Watershed
Cleveland	255,755	91,875
Oklahoma	718,633	7,725
Total	974,388	99,600
Data Source: 2010 US Census		

Based on 2010 census tract data and a GIS map of populated areas served by public sewer systems in the watershed (Figure 1-4) estimates of the population served by public sewers (49%) and those not served (51%) in 2010 are presented in Table 1- 4. The Census did not collect public sewer system data in its 2000 or 2010 census.

Table 1- 4 2010 Population Served by Public Sewer Systems

2010	Population Total	Percent of Total
Sewered	48,920	49%
Unsewered	50,680	51%
Total	99,600	100%
Data Sources: 2010 US Census and GIS maps of public sewer systems		

Figure 1-2 Land Use Distribution of the Watershed

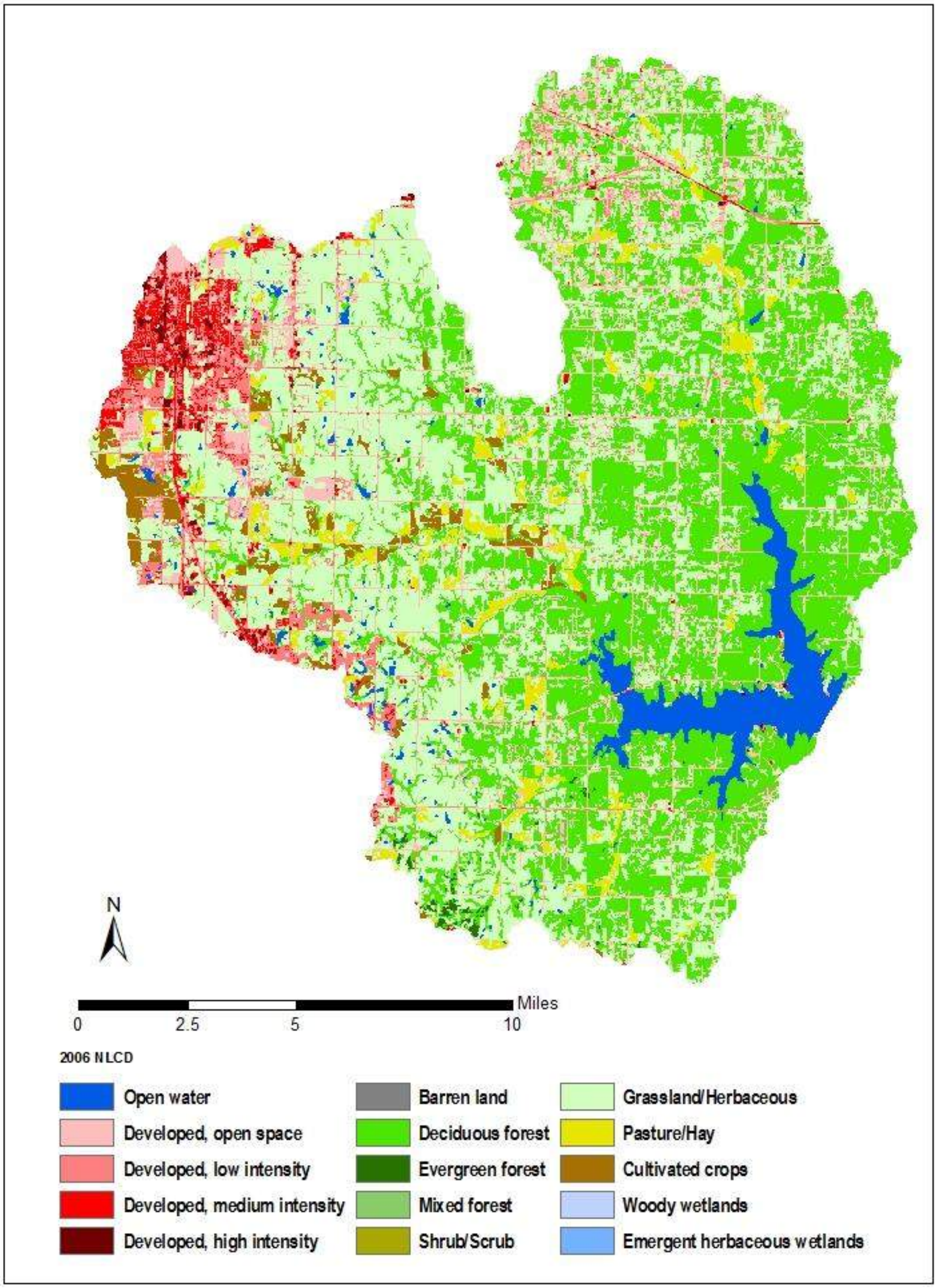


Figure 1-3 Population Density (persons per square mile) based on 2010 Census Tracts within the Lake Thunderbird Watershed

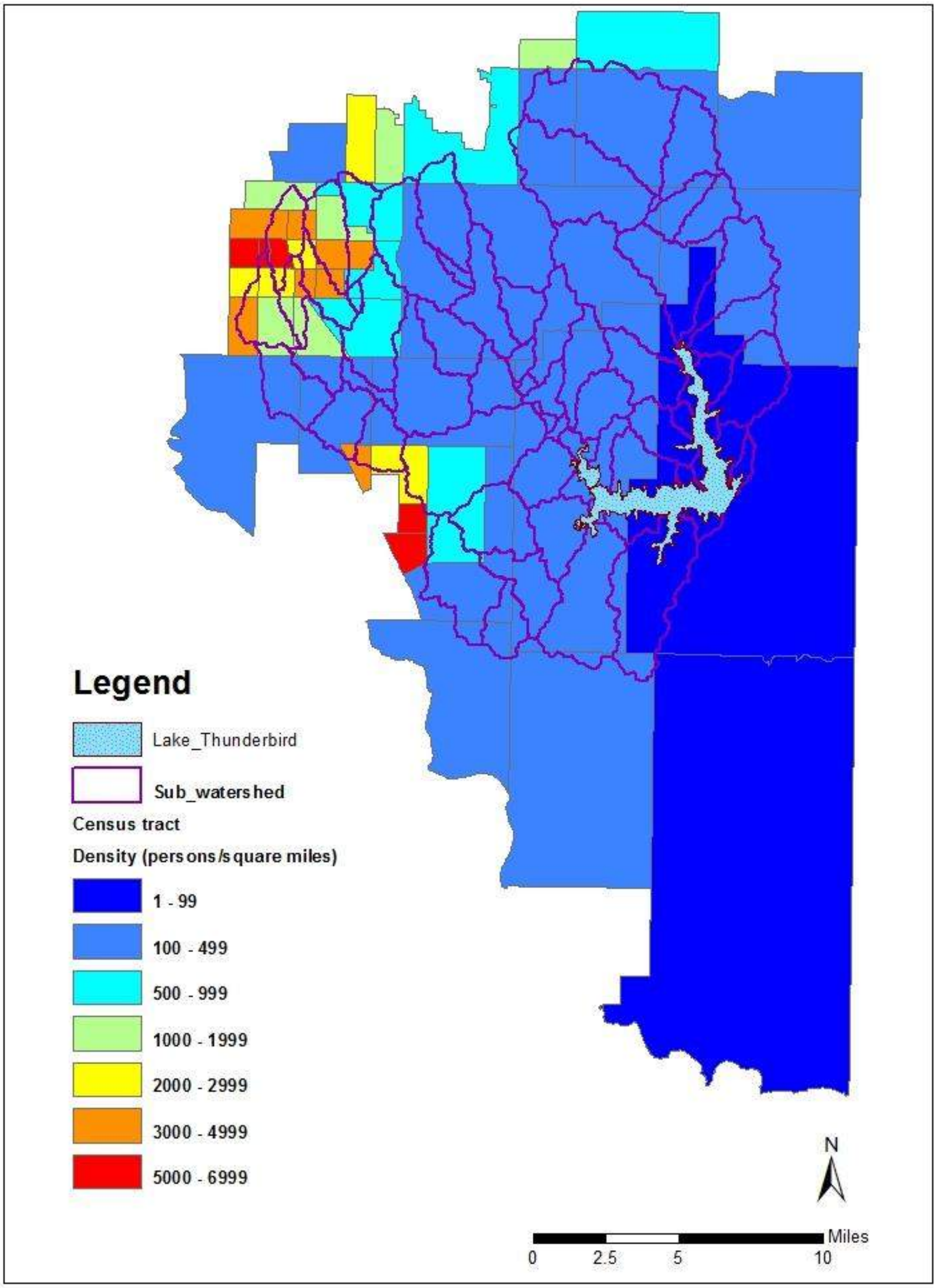
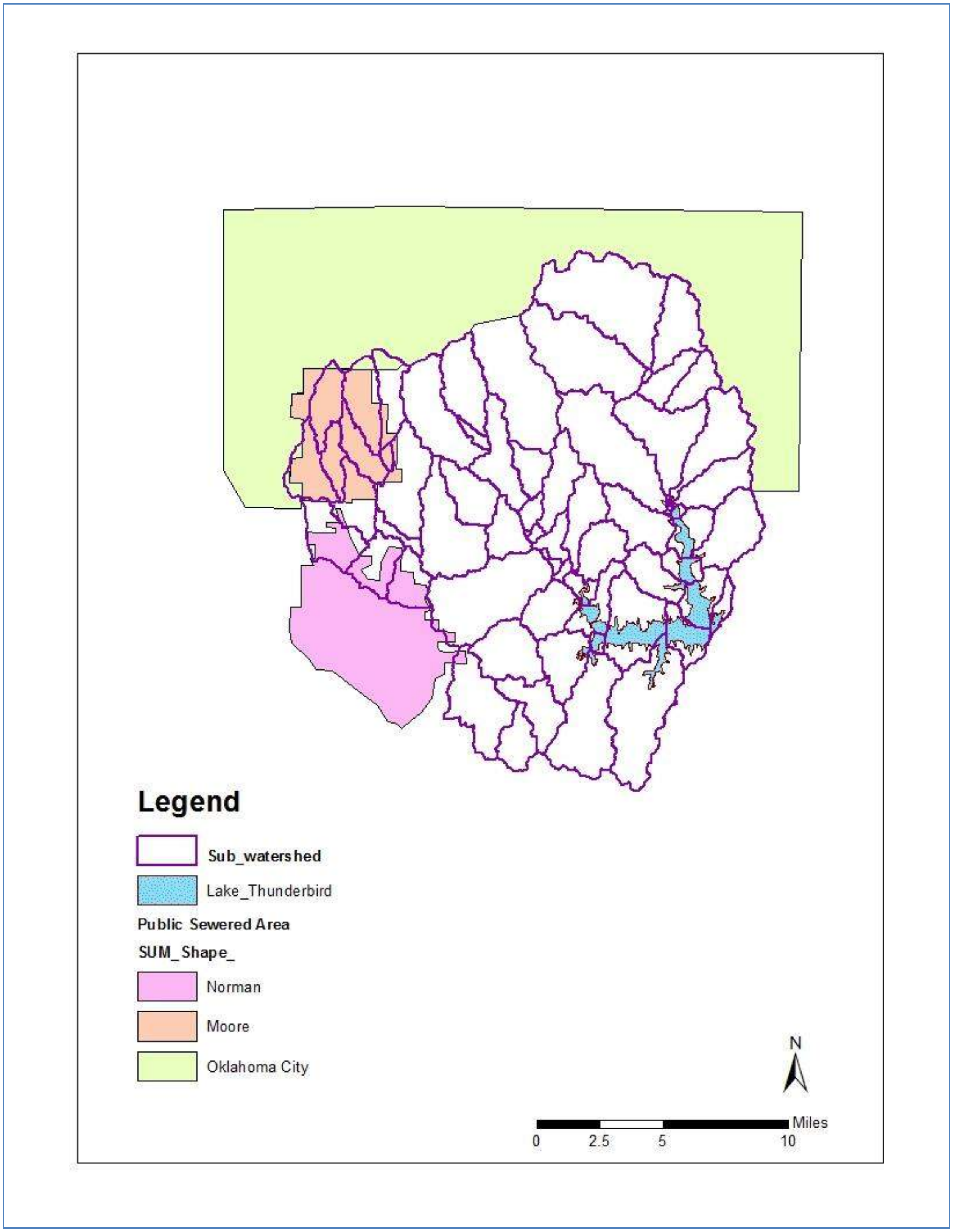


Figure 1-4 Public Sewer System Boundaries within the Lake Thunderbird Watershed



1.3 Streamflow Characteristics

The magnitudes of annual, seasonal and daily variability of streamflow from the major streams in the watershed are essential data to characterize water and load inflows to a waterbody for a water quality management study such as this TMDL assessment of Lake Thunderbird. Although a USGS stream gage was historically located on the Little River at the present location near its lake inlet, the streamflow gage ceased operation in 1955 before the reservoir was constructed. At present there are only two gages recently installed and maintained by the USGS on the Little River upstream of Lake Thunderbird. The gage near Franklin Road in Norman (07229480) had records for gage height from March 30, 2012 to June 12, 2012 and the gage at Twelfth Ave NW in Norman (07229451) has records of both gage height and streamflow up to date since March 30, 2012. Stanley Draper Lake is a reservoir located in the Oklahoma City portion of the watershed that is upstream of Lake Thunderbird. Since the outflow from Stanley Draper Lake is exported outside of the watershed area draining to Lake Thunderbird, the contributing drainage area of 11.8 square miles to Stanley Draper Lake does not contribute to stream inflow to Lake Thunderbird. In the absence of historical and/or current streamflow measurements for the Lake Thunderbird watershed study area, flow estimates for the Little River, Hog Creek, Dave Blue Creek, Jim Blue Creek, Clear Creek and other smaller tributaries to the Lake were developed using the HSPF watershed model. The development of the watershed model for the Lake Thunderbird study is summarized in Section 3.3 of this report and the complete technical report for the watershed model is presented in Appendix A.

SECTION 2 PROBLEM IDENTIFICATION AND WATER QUALITY TARGETS

2.1 Oklahoma Water Quality Standards/Criteria

Chapters 45 and 46 of Title 785 of the Oklahoma Administrative Code (OAC) contain Oklahoma's WQS and implementation procedures, respectively. The Oklahoma Water Resources Board (OWRB) has statutory authority and responsibility concerning establishment of state water quality standards, as provided under 82 Oklahoma Statute [O.S.], §1085.30. This statute authorizes the OWRB to promulgate rules …*which establish classifications of uses of waters of the state, criteria to maintain and protect such classifications, and other standards or policies pertaining to the quality of such waters*. [O.S. 82:1085:30(A)]. Beneficial uses are designated for all waters of the state. Such uses are protected through restrictions imposed by the anti-degradation policy statement, narrative water quality criteria, and numerical criteria (OWRB, 2011). An excerpt of the Oklahoma WQS (Chapter 45, Title 785) summarizing the State of Oklahoma Anti-degradation Policy is provided in Appendix C. Table 2-1, an excerpt from the 2010 Integrated Report (DEQ, 2010), lists beneficial uses designated for Lake Thunderbird. The beneficial uses include:

- AES – Aesthetics
- AG – Agriculture Water Supply
- FISH – Fish Consumption
- Fish and Wildlife Propagation
    - WWAC – Warm Water Aquatic Community
- PBCR – Primary Body Contact Recreation
- PPWS – Public & Private Water Supply
- SWS – Sensitive Public and Private Water Supply

Table 2-1 2010 Integrated Report – Oklahoma §303(d) List of Impaired Waters (Category 5a) for Lake Thunderbird

Waterbody ID	Waterbody Name	AES	AG	FISH	WWAC	PBCR	PPWS	SWS
Lake Thunderbird	OK520810000020_00	I	F	X	N	F	N	X

F – Fully supporting; N – Not supporting; I – Insufficient information; X – Not assessed
Source: 2010 Integrated Report, DEQ 2010

Table 2-2 summarizes the impairment status for Lake Thunderbird. Lake Thunderbird is designated as a Category 5a lake. Category 5 defines a waterbody where, since the water quality standard is not attained, the waterbody is impaired or threatened for one or more designated uses by a pollutant(s), and the water body requires a TMDL. This category constitutes the Section 303(d) list of waters impaired or threatened by a pollutant(s) for which one or more TMDL(s) are needed. Sub-Category 5a means that a TMDL is underway or will be scheduled. The TMDLs established in this report, which are a necessary step in the process of restoring water quality, address water quality issues related to nonattainment of the public and private water supply and warm water aquatic community beneficial uses.

Table 2-2 2010 Integrated Report – Oklahoma 303(d) List for Lake Thunderbird

Waterbody ID	Waterbody Name	Size (acres)	TMDL Date	Priority	Turbidity	DO	Chl-*a*
OK520810000020_00	Lake Thunderbird	6,070	2012	1	×	×	×

2.1.1 Turbidity Standards for Lakes

The following excerpt from the Oklahoma WQS (OAC 785:45-5-12(f)(7)) stipulates the turbidity numeric criterion to maintain and protect "Warm Water Aquatic Community" beneficial uses (OWRB, 2011).

(A) Turbidity from other than natural sources shall be restricted to not exceed the following numerical limits:

i. Cool Water Aquatic Community/Trout Fisheries: 10 NTUs;

ii. Lakes: 25 NTU; and

iii. Other surface waters: 50 NTUs.

(B) In waters where background turbidity exceeds these values, turbidity from point sources will be restricted to not exceed ambient levels.

(C) Numerical criteria listed in (A) of this paragraph apply only to seasonal base flow conditions.

(D) Elevated turbidity levels may be expected during, and for several days after, a runoff event

The abbreviated excerpt below from Chapter 46: 785:46-15-5, stipulates how water quality data will be assessed to determine support of fish and wildlife propagation as well as how the water quality target for TMDLs will be defined for turbidity.

Assessment of Fish and Wildlife Propagation support

(a) Scope. The provisions of this Section shall be used to determine whether the beneficial use of Fish and Wildlife Propagation or any subcategory thereof designated in OAC 785:45 for a waterbody is supported.

(e) Turbidity. The criteria for turbidity stated in 785:45-5-12(f)(7) shall constitute the screening levels for turbidity. The tests for use support shall follow the default protocol in 785:46-15-4(b).

785:46-15-4. Default protocols

(b) Short term average numerical parameters.

(1) Short term average numerical parameters are based upon exposure periods of less than seven days. Short term average parameters to which this Section applies include, but are not limited to, sample standards and turbidity.

(2) A beneficial use shall be deemed to be fully supported for a given parameter whose criterion is based upon a short term average if 10% or less of the samples for that parameter exceed the applicable screening level prescribed in this Subchapter.

Turbidity is a measure of water clarity and is caused by suspended particles in the water column. Because turbidity cannot be expressed as a mass load, total suspended solids (TSS) are used as a surrogate for the TMDLs in this report.

2.1.2 Dissolved Oxygen Standards for Lakes

The following excerpt from the Oklahoma WQS [OAC 785:45-5-12(f)(1)(D)] stipulates the dissolved oxygen numeric criterion for lakes to maintain and protect "Warm Water Aquatic Community" beneficial uses (OWRB, 2011):

(v) Support tests for WWAC lakes. The WWAC subcategory of the Fish and Wildlife Propagation beneficial use designated for a lake shall be deemed to be fully supported with respect to the DO criterion if both the Surface and Water Column criteria prescribed in (vi)(I) and (vii)(I) of this subparagraph (D) are satisfied. If either of the Surface or Water Column criteria prescribed in (vi)(II) or (vii)(II) produce a result of undetermined, then the WWAC subcategory of the Fish and Wildlife Propagation beneficial use designated for a lake shall be deemed to be undetermined with respect to the DO criterion; provided, if either of the Surface or Water Column criteria prescribed in (vi)(III) or (vii)(III) produce a result of not supported, then the WWAC subcategory of the Fish and Wildlife Propagation beneficial use designated for a lake shall be deemed to be not supported with respect to the DO criterion.

(vi) Surface criteria for WWAC lakes.

(I) The WWAC subcategory of the Fish and Wildlife Propagation beneficial use designated for a lake shall be deemed to be fully supported with respect to the DO criterion if 10% or less of the samples from the epilimnion during periods of thermal stratification, or the entire water column when no stratification is present, are less than 6.0 mg/L from April 1 through June 15 and less than 5.0 mg/L during the remainder of the year.

(II) The WWAC subcategory of the Fish and Wildlife Propagation beneficial use designated for a lake shall be deemed to be undetermined with respect to the DO criterion if more than 10% of the samples from the epilimnion during periods of thermal stratification, or the entire water column when no stratification is present, are less than 5.0 mg/L and 10% or less of the samples are less than 4 mg/L from June 16 through October 15, or more than 10% of the samples from the surface are less than 6.0 mg/L and 10% or less of the samples are less than 5.0 mg/L from April 1 through June 15.

(III) The WWAC subcategory of the Fish and Wildlife Propagation beneficial use designated for a lake shall be deemed to be not supported with respect to the DO criterion if more than 10% of the samples from the epilimnion during periods of thermal stratification, or the entire water column when no stratification is present, are less than 5.0 mg/L from April 1 through June 15 or less than 4.0 mg/L from June 16 through October 15, or less than 5.0 mg/L from October 16 through March 31, due to other than naturally occurring conditions.

(vii) Water Column criteria for WWAC lakes.

(I) The WWAC subcategory of the Fish and Wildlife Propagation beneficial use designated for a lake shall be deemed to be fully supported during periods of thermal stratification with respect to the DO criterion if less than 50% of the volume (if volumetric data is available) or 50% or less of the water column (if no volumetric data is available) of all sample sites in the lake are less than 2.0 mg/L.

(II) The WWAC subcategory of the Fish and Wildlife Propagation beneficial use designated for a lake shall be deemed to be undetermined during periods of thermal stratification with respect to the DO criterion if 50% or more, but not greater than 70%, of the water column at any given sample site in the lake is less than 2.0 mg/L due to other than naturally occurring conditions.

(III) The WWAC subcategory of the Fish and Wildlife Propagation beneficial use designated for a lake shall be deemed to be not supported during periods of thermal stratification with respect to the DO criterion if 50% or more of the water volume (if volumetric data is available) or more than 70% of the water column (if no volumetric data is available) at any given sample site is less than 2.0 mg/L.

(IV) If a lake specific study including historical analysis produces a support status which is contrary to an assessment obtained from the application of (I), (II) or (III) of (D)(vii) of this section, then that lake specific result will control.

2.1.3 Chlorophyll-*a* Standards for SWS Lakes

Lake Thunderbird is designated as a Sensitive Public and Private Water Supply (SWS) lake. The definition of SWS is summarized by the following excerpt from OAC 785:45-5-25(c)(4) of the Oklahoma WQS (OWRB 2011):

(A) Waters designated "SWS" are those waters of the state which constitute sensitive public and private water supplies as a result of their unique physical conditions and are listed in Appendix of this Chapter as "SWS" waters. These are waters (a) currently used as water supply lakes, (b) that generally possess a watershed of less than approximately 100 square miles or (c) as otherwise designated by the Board.

(B) New point source discharges of any pollutant after June 11, 1989, and increased load of any specified pollutant from any point source discharge existing as of June 11,1989, shall be prohibited in any waterbody or watershed designated in Appendix A of this Chapter with the limitation "SWS". Any discharge of any pollutant to a waterbody designated "SWS" which would, if it occurred, lower existing water quality shall be prohibited, provided however that new point source discharge(s) or increased load of specified pollutants described in 785:45-5-25(b) may be approved by the permitting authority in those circumstances where the discharger demonstrates to the satisfaction of the permitting authority that a new point source discharge or increased load from an existing point source discharge will result in maintaining or improving the water quality of both the direct receiving water and any downstream waterbodies designated SWS.

The following excerpt from the Oklahoma WQS (OAC 785:45-5-10) stipulates the numeric criterion set for SWS lakes, including Lake Thunderbird (OWRB, 2011).

785:45-5-10. Public and private water supplies

The following criteria apply to surface waters of the state having the designated beneficial use of Public and Private Water Supplies:

*(7) Chlorophyll-a numerical criterion for certain waters. The long term average concentration of chlorophyll-*a *at a depth of 0.5 meters below the surface shall not exceed 0.010 milligrams per liter in Wister Lake, Tenkiller Ferry Reservoir, nor any waterbody designated SWS in Appendix A of this Chapter. Wherever such criterion is exceeded, numerical phosphorus or nitrogen criteria or both may be promulgated.*

In addition to the SWS designation of Lake Thunderbird, the Lake watershed has also been assigned the designation of “Nutrient Limited Watershed” (NLW) in OAC 785:45-5-29. A NLW means a watershed of a waterbody with a designated beneficial use that is adversely affected by excess nutrients as determined by Carlson's (1977) Trophic State Index (TSI) (using chlorophyll-*a*) of 62 or greater, or is otherwise listed as “NLW” in Appendix A of Chapter 45 (OWRB 2010).

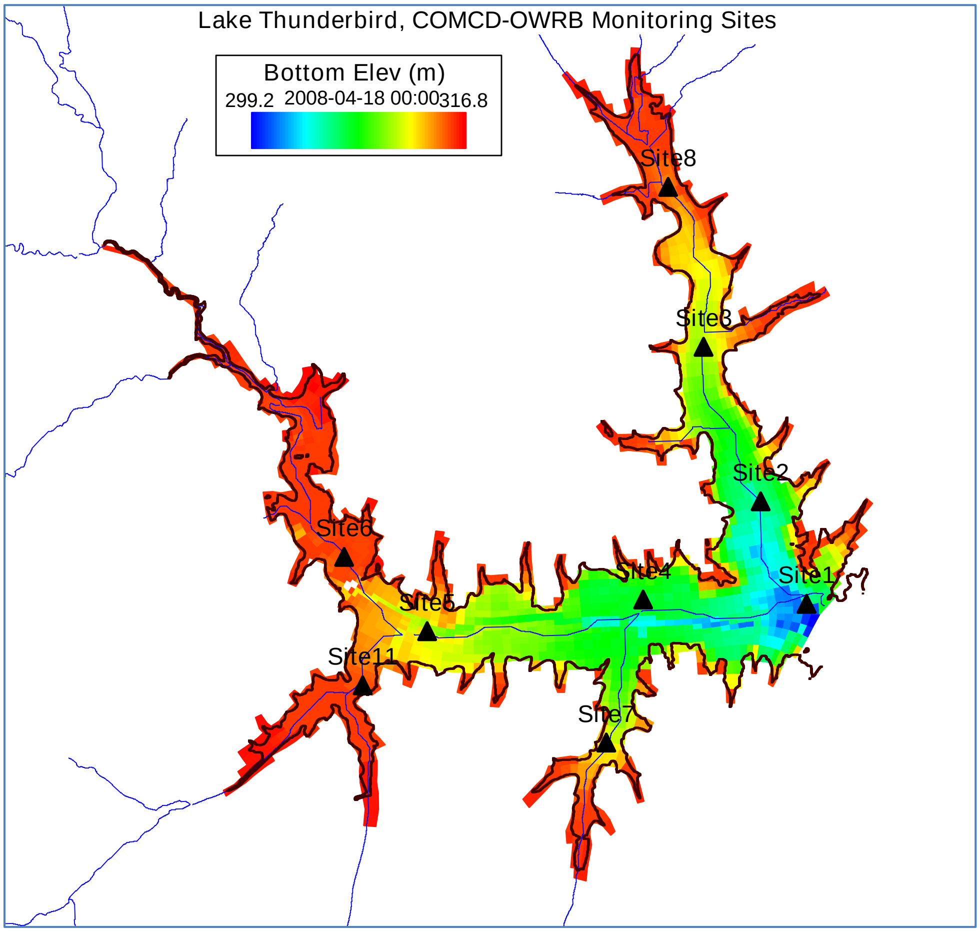
2.2 Overview of Water Quality Problems and Issues

Lake Thunderbird, located in central Oklahoma southeast of Oklahoma City, is a popular recreational lake in addition to its use as a water supply reservoir for the cities of Norman, Del City and Midwest City. Designated uses of the reservoir are flood control, municipal water supply, recreation, and fish and wildlife propagation. As a municipal water supply, Lake Thunderbird furnishes raw water for Del City, Midwest City, and the City of Norman under the authority of the Central Oklahoma Master Conservancy District (COMCD). Significant taste and odor problems, related to eutrophication, have led to numerous complaints from water supply customers (see OWRB, 2009 and OWRB, 2010). Based on an assessment of water quality monitoring data, DEQ has determined that Lake Thunderbird is not supporting its designated uses for (a) Fish & Wildlife Propagation (FWP) for a Warm Water Aquatic Community because of excessive levels of turbidity and low dissolved oxygen; and (b) Public Water Supply because of excessive chlorophyll-*a* levels. Excessive nutrient loading from the watershed, primarily from urban development, is thought to be causally related to the observed eutrophication of the Lake. The Central Oklahoma Master Conservancy District (COMCD), in cooperation with OWRB, has been monitoring chlorophyll-a, nutrients, sediment, water temperature, organic matter and dissolved oxygen in the Lake since 2000. In support of this TMDL study of Lake Thunderbird, OWRB and Oklahoma Conservation Commission (OCC) conducted a special monitoring program for the Lake and its tributaries from April 2008 through April 2009 to supplement the monitoring program conducted as part of the routine COMCD-OWRB surveys. Table 2-3 summarizes the site designation names, station numbers and locations of the water quality monitoring stations maintained by OWRB in Lake Thunderbird as a component of the Oklahoma Beneficial Use Monitoring Program (BUMP) network (OWRB, 2008). These stations are also used in the COMCD-OWRB surveys and the special monitoring for the TMDL study. Figure 2-1 shows the locations of the Lake monitoring sites.

Table 2-3 OWRB Water Quality Monitoring Stations for Lake Thunderbird

Site	Station Number	Latitude	Longitude	Represents
1	520810000020-1sX	35.223333	-97.220833	Dam Site; Lacustrine
	520810000020-1-4X			
	520810000020-1-8X			
	520810000020-1-12X			
	520810000020-1bX			
2	520810000020-2X	35.238889	-97.228889	Lacustrine
	520810000020-2bX			
3	520810000020-3X	35.262222	-97.238889	Transition
4	520810000020-4X	35.224444	-97.250833	Lacustrine
	520810000020-4bX			
5	520810000020-5X	35.220278	-97.290556	Transition
6	520810000020-6X	35.231667	-97.305556	Riverine
7	520810000020-7X	35.203056	-97.258056	Riverine
8	520810000020-8X	35.286409	-97.244887	Riverine
11	520810000020-11X	35.212292	-97.302545	Riverine

Figure 2-1 OWRB Water Quality Monitoring Stations for Lake Thunderbird



2.3 Water Quality Observations and Targets for Turbidity, Chlorophyll-*a* and Dissolved Oxygen

Oklahoma Water Quality Standards for Lake Thunderbird turbidity, chlorophyll-*a* and dissolved oxygen are as follows:

- Turbidity: no more than 10% of turbidity samples greater than 25 NTU based on long-term record of most recent 10 years
- Chlorophyll-*a*: Average value of surface chlorophyll-a no greater than 10 µg/L based on long-term record of most recent 10 years.
- Dissolved Oxygen, Stratified Conditions: Within the surface/epilimnion layer for protection of fish and wildlife propagation in warm water aquatic community (a) DO no less than 6 mg/L from April 1 to June 15 for early life stages; and (b) DO no less than 5 mg/L from June 16 to October 15 and October 16 to March 31 for protection of other life stages.
- Dissolved Oxygen, Non-Stratified Conditions: Within the entire water column for protection of fish and wildlife propagation in warm water aquatic community (a) DO no less than 6 mg/L from April 1 to June 15 for early life stages; and (b) DO no less than 5 mg/L from June 16 to October 15 and October 16 to March 31 for protection of other life stages.
- Dissolved Oxygen: Anoxic volume of the Lake, defined by a DO target level of 2 mg/L, shall not exceed 50% of the lake volume during the summer stratified season.

As stipulated in the Implementation Procedures for Oklahoma Water Quality Standards [785:46-15-3c], the most recent 10 years of water quality data is to be used as the basis for assessment of the water quality conditions and beneficial use support for a waterbody (OWRB, 2011a). Lake Thunderbird is listed as impaired based on an analysis of the most recent 10 years of records for chlorophyll-*a*, turbidity and DO.

Summary statistics presented in Table 2-4 are based on data collected by COMCD-OWRB from 2000 through 2009 used for the impaired listing of Lake Thunderbird. Observations for data collected from November 2000 through October 2009 for turbidity (Figure 2-2) and from July 2001 through October 2009 for chlorophyll-*a* (Figure 2-3) are used to compute the summary statistics for the monitoring sites listed in Table 2-3. The water quality data sets collected by COMCD-OWRB and OCC in 2008 - 2009 that was used to support the watershed and lake modeling studies developed for this TMDL are presented in Appendix D.

Table 2-4 Summary Statistics for Observed Turbidity and Chlorophyll-*a* in Lake Thunderbird, 2000-2009

Summary Statistic	Turbidity NTU	WQ Target NTU	Chlorophyll-a µg/L	WQ Target µg/L
Number of Records	307		770	
Start Date	11/2/2000		7/19/2001	
End Date	10/19/2009		10/19/2009	
Mean	22.8		**20.7**	**10**
10th Percentile	6.7		6.2	
25th Percentile	9.0		10.4	
50th Percentile	15.0		16.5	
75th Percentile	27.0		27.3	
90th Percentile	**53.2**	**25**	41.3	

As can be seen in the data presented in Table 2-4, the 90th percentile of 53.2 NTU for observed surface turbidity from 2000-2009 exceeds the water quality criteria target of 25 NTU. The 2001-2009 average for observed surface chlorophyll of 20.7 µg/L exceeds the water quality criteria target of 10 µg/L. The observed turbidity and chlorophyll-*a* data for 2000-2009 documents that conditions during this period did not support the Warm Water Aquatic Community use and the Public and Private Water Supply use of the lake as a SWS waterbody.

Based on an assessment of surface layer dissolved oxygen data, OWRB has determined that Lake Thunderbird is not fully supporting its beneficial uses for Fish and Wildlife Propagation as it relates to dissolved oxygen. As the result, Lake Thunderbird was listed for DO impairment in the 2010 303(d) list. Oklahoma Water Quality Standards for dissolved oxygen have been changed since the assessments for 2010 303(d) list were done. DEQ made a request to OWRB to perform a new DO assessment of Lake Thunderbird using the new surface and volumetric DO standards. It was determined that Lake Thunderbird is still impaired for dissolved oxygen. In 2003, for example, there were multiple instances recorded as early as May, where the dissolved oxygen was less than 5.0 mg/L throughout the entire water column. In addition to the evaluation of surface layer dissolved oxygen data, volumetric and water column analyses of dissolved oxygen station data showed that more than 50% of the lake volume was less than the 2 mg/L target for anoxia within the hypolimnion during summer stratified conditions.

Figure 2-2 Observed Turbidity in Lake Thunderbird, 2000-2009

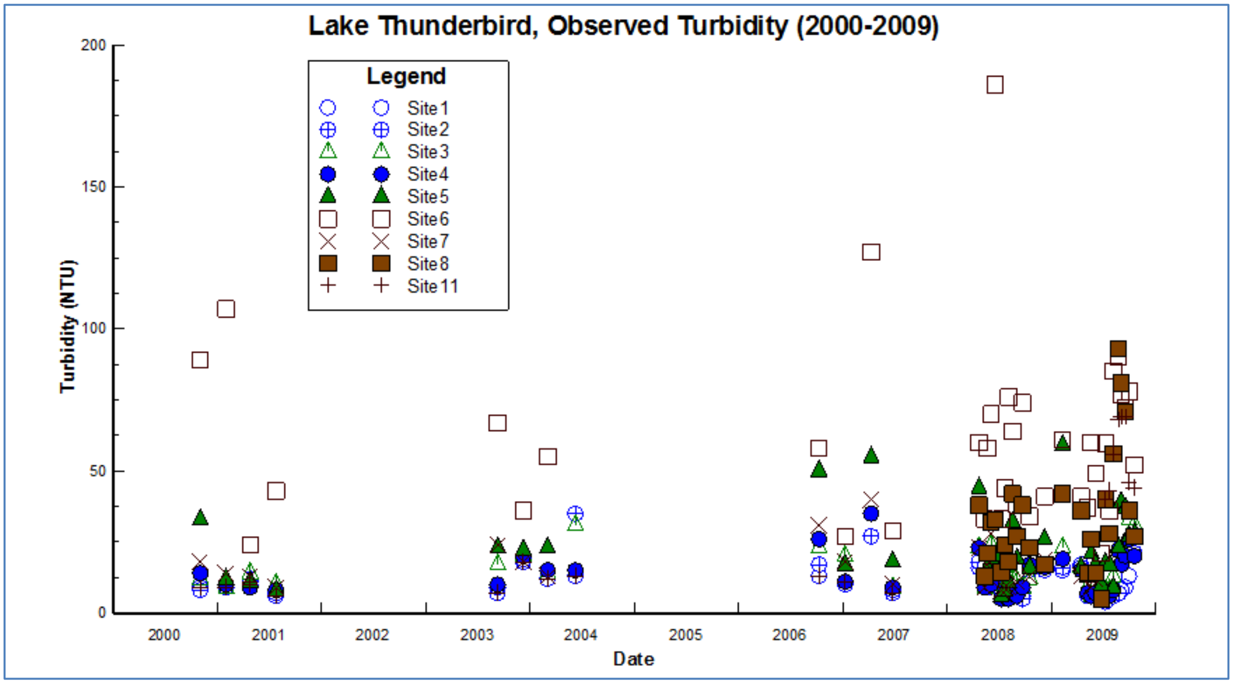
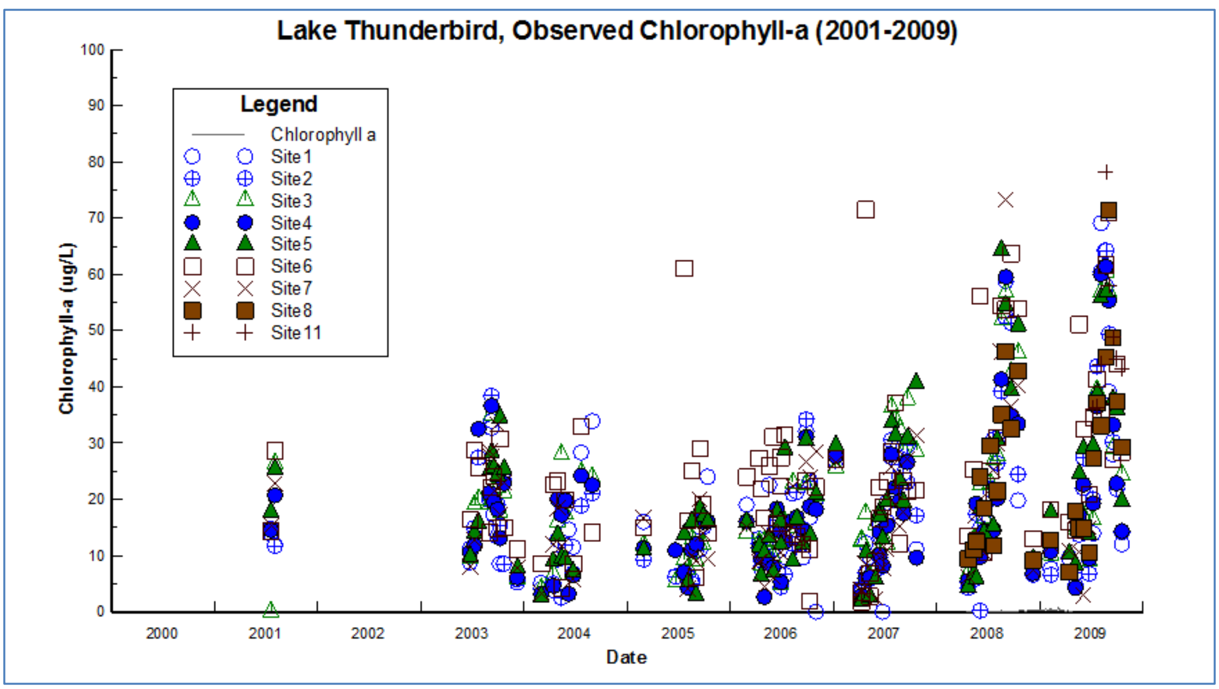


Figure 2-3 Observed Chlorophyll-a in Lake Thunderbird, 2001-2009



The Code of Federal Regulations [40 CFR §130.7(c)(1)] states that, "*TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards*." The water quality targets established for Lake Thunderbird must demonstrate compliance with the numeric criteria prescribed for SWS lakes in the Oklahoma WQS (OWRB, 2011).

Water quality variables that relate to impairments of Lake Thunderbird for water clarity and turbidity include suspended sediment and algae biomass as chlorophyll-a. Water quality constituents that relate to impairments for chlorophyll-*a* include algae biomass as chlorophyll-a, total nitrogen, total phosphorus, and suspended solids. Water quality constituents that relate to impairments for dissolved oxygen include algae biomass (chlorophyll-*a*), ultimate CBOD, and ammonia nitrogen. Although the water quality criteria for water clarity is based on turbidity, total suspended solids (TSS) is commonly used as a surrogate indicator of water clarity for development of the mass loading analysis required for the TMDL determination. A site-specific relationship must be developed therefore to transform TSS data to turbidity to be able to compare the effect of sediment loading of TSS from the watershed on compliance with the water quality criteria for turbidity in the Lake. The methodology used to develop the TSS-turbidity relationship is summarized in Section 4 with more details presented in Appendix B.

SECTION 3 POLLUTANT SOURCE ASSESSMENT

This section includes an assessment of the known and suspected sources of nutrients, organic matter and sediments contributing to the eutrophication and water quality impairments of Lake Thunderbird. Pollutant sources identified are categorized and quantified to the extent that reliable information is available. Generally, sediment and nutrient loadings causing impairment of lakes originate from point or nonpoint sources of pollution. Point source discharges are regulated under permits through the NPDES program. Nonpoint sources are diffuse sources that typically cannot be identified as entering a waterbody through a discrete conveyance, such as a pipe, at a single location. Nonpoint sources may originate from rainfall runoff and landscape dependent characteristics and processes that contribute sediment, organic matter and nutrient loads to surface waters. For the TMDLs presented in this report, all sources of pollutant loading not regulated under the NPDES permit system are considered nonpoint sources.

Under 40 CFR, §122.2, a point source is described as an identifiable, confined, and discrete conveyance from which pollutants are, or may be, discharged to surface waters. NPDES-permitted facilities classified as point sources that may contribute sediment, organic matter and nutrient loading include:

- NPDES municipal wastewater treatment plant (WWTP) discharges.
- NPDES industrial WWTP discharges.
- Municipal no-discharge WWTPs.
- NPDES municipal separate storm sewer system (MS4) discharges.
- NPDES Construction Site stormwater discharges.
- NPDES Multi-Sector General Permits (MSGP) stormwater discharges.
- NPDES concentrated animal feeding operations (CAFO)

There are no municipal and industrial wastewater facilities or concentrated animal feeding operations (CAFO) located within the Lake Thunderbird watershed. The watershed does include a number of no-discharge WWTP facilities that do not discharge wastewater effluent to surface waters. For the purposes of this TMDL, no-discharge facilities are not considered a source of sediment, organic matter or nutrient loading to the Lake.

Urban stormwater runoff from MS4 areas, which is now regulated under the EPA NPDES Program, can contribute significant loading of sediments, organic matter and nutrients to Lake Thunderbird. MS4 permits have been issued for Midwest City, Moore, Noble, Norman, and Oklahoma City. Stormwater runoff from MS4 areas, facilities under multi-sector general permits (MSGP), and NPDES permitted construction sites, which are regulated under the EPA NPDES Program, can all contribute sediment loading to the Lake. Within the Lake Thunderbird watershed there are a number of construction site permits and multi-sector general permits that have been issued and will be addressed in Section 3.1.4 and 3.1.5 of this report. 40 CFR §130.2(h) requires that NPDES-regulated stormwater discharges must be addressed by the wasteload allocation (WLA) component of a TMDL assessment.

3.1 Assessment of Point Sources

3.1.1 NPDES Municipal and Industrial Wastewater Dischargers

There are no municipal or industrial wastewater facilities located within the Lake Thunderbird watershed.

3.1.2 No-Discharge Wastewater Treatment Plants

A no-discharge WWTP facility does not discharge wastewater effluent to surface waters. For the purpose of this TMDL assessment, it is assumed that no-discharge wastewater facilities do not contribute TSS, organic matter or nutrient loading to watershed streams and Lake Thunderbird. It is possible, however, that the wastewater collection system associated with no-discharge facilities could be a source of pollutant loading to streams, or that discharges from the WWTP may occur during large rainfall events that exceed the storage capacity of the wastewater system. These types of unauthorized wastewater discharges are typically reported as sanitary sewer overflows (SSOs) or bypass overflows. As shown in Figure 3-1 and Table 3-1, there are 14 no-discharge facilities located within the watershed study area.

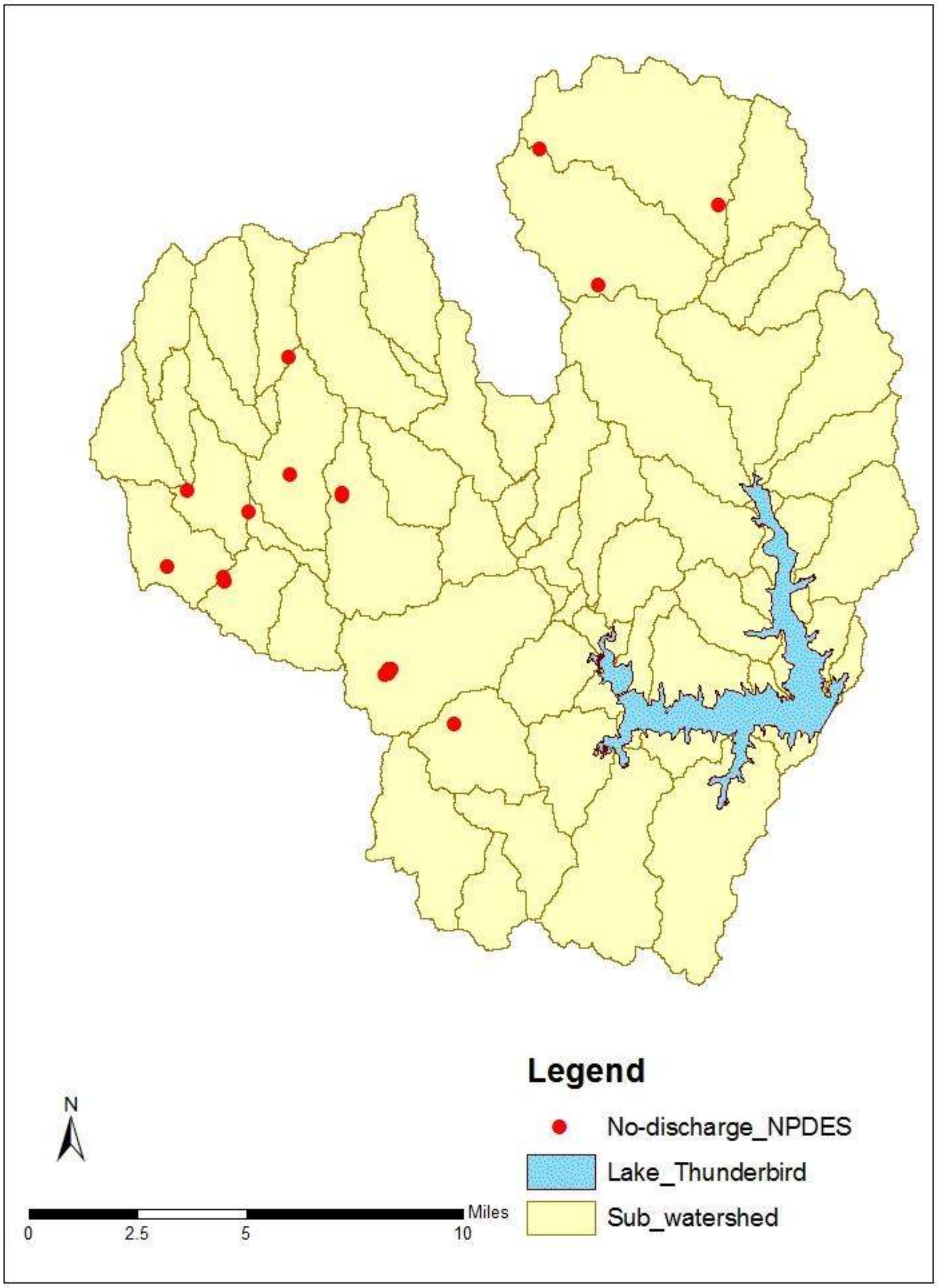
Table 3-1 NPDES No-Discharge Facilities in Lake Thunderbird Watershed

Facility Name	Facility Type	Facility No.	OWRB	County
All Saints Catholic School Lagoon	Lagoon (Total Retention)			Cleveland
BCM Oklahoma – Tecumseh Rd	Total Retention	OKG11T020	WD82-013	Cleveland
BCM Oklahoma – Norman North	Total Retention	OKG11T019		Cleveland
Control Flow	Total Retention		WD82-017	Cleveland
Dolese - North Norman	Total Retention	OKG11T031		Cleveland
Dolese - Moore	Total Retention	OKG11T082		Cleveland
Hall Park*	Lagoon (Total Retention)			Cleveland
Lakeside Church of God WWT	Lagoon (Total Retention)			Cleveland
Lucky Food Mart	Total Retention	OKG75T009		Cleveland
Miller's Acres WWT	Lagoon (Total Retention)			Cleveland
Ranch Estates MHP	Lagoon (Total Retention)			Cleveland
Barnes School	Lagoon (Total Retention)			Oklahoma
Schwartz School	Lagoon (Total Retention)			Oklahoma
Pro-Am	Lagoon (Total Retention)			Oklahoma

* No longer in use. Hall Park is connected to Norman sewer system.

Sanitary sewer overflows (SSO) from wastewater collection systems of discharging WWTP facilities, although infrequent, can also be a major source of pollutant loading to streams. SSOs have existed since the introduction of separate sanitary sewers, and most are caused by blockage of sewer pipes by grease, tree roots, and other debris that clog sewer lines, by sewer line breaks and leaks, cross connections with storm sewers, and inflow and infiltration of groundwater into sanitary sewers. SSOs are NPDES permit violations that must be addressed by the responsible NPDES permit holder. The reporting of SSOs has been strongly encouraged by EPA, primarily through enforcement and monetary fines. While not all sewer overflows are reported, DEQ maintains a database on reported SSOs. Within the City of Moore in the Lake Thunderbird watershed there were 374 overflows reported during the years from 2000 to 2012. Of these, 130 events spilled more than 1000 gallons with a maximum bypass volume of 374,000 gallons. Within the City of Norman in the Lake Thunderbird watershed there were 28 overflows reported during the years from 2000 to 2008 that spilled more than 1000 gallons with a maximum bypass volume of 20,000 gallons. Table 3-2 summarizes the SSO bypass occurrences in the Cities of Moore and Norman. Oklahoma City has a negligible publicly sewered area in the watershed. A detailed chronology of the bypass events for Moore and Norman is presented in Appendix F.

Figure 3-1 Location of NPDES No-Discharge WWTP Facilities in Lake Thunderbird Watershed



Sanitary sewer overflows (SSO) from wastewater collection systems of discharging WWTP facilities, although infrequent, can also be a major source of pollutant loading to streams. SSOs have existed since the introduction of separate sanitary sewers, and most are caused by blockage of sewer pipes by grease, tree roots, and other debris that clog sewer lines, by sewer line breaks and leaks, cross connections with storm sewers, and inflow and infiltration of groundwater into sanitary sewers. SSOs are NPDES permit violations that must be addressed by the responsible NPDES permit holder. The reporting of SSOs has been strongly encouraged by EPA, primarily through enforcement and monetary fines. While not all sewer overflows are reported, DEQ maintains a database on reported SSOs. Within the City of Moore in the Lake Thunderbird watershed there were 374 overflows reported during the years from 2000 to 2012. Of these, 130 events spilled more than 1000 gallons with a maximum bypass volume of 374,000 gallons. Within the City of Norman in the Lake Thunderbird watershed there were 28 overflows reported during the years from 2000 to 2008 that spilled more than 1000 gallons with a maximum bypass volume of 20,000 gallons. Table 3-2 summarizes the SSO bypass occurrences in the Cities of Moore and Norman. Oklahoma City has a negligible publicly sewered area in the watershed. A detailed chronology of the bypass events for Moore and Norman is presented in Appendix F.

Table 3-2 Summary of Sanitary Sewer Overflow (SSO) Bypass (> 1000 gallons) Occurrences in the Lake Thunderbird Watershed

City Name	Bypass Volume (gallons)	Number Events	Date Range		Max. Bypass Volume (gallons)
			From	To	
Moore	2,459,679	98	10/11/2000	3/20/2012	374,000
Norman	123,949	28	10/9/2000	11/6/2008	20,000

3.1.3 NPDES Municipal Separate Storm Sewer System (MS4)

In 1990 the EPA developed rules establishing Phase I of the NPDES Stormwater Program, designed to prevent pollutants from being washed off by stormwater runoff into municipal separate storm sewer systems (MS4s) or from being dumped directly into the stormwater system and then discharged into local receiving water bodies (EPA, 2005). Phase I of the program required operators of medium and large MS4s, defined as facilities serving populations of 100,000 or greater, to implement a stormwater management program as a means to control polluted urban runoff discharges to surface waters. Approved stormwater management programs for medium and large MS4s are required to address a variety of water quality-related issues, including roadway runoff management, municipal-owned operations, and hazardous waste treatment. Within the watershed area for Lake Thunderbird there is one Phase I MS4 permit for Oklahoma City.

Phase II of the rule extends coverage of the NPDES stormwater program to certain smaller urban areas with stormwater systems. Small MS4s are defined as any MS4 that is not defined as a medium or large MS4 covered by Phase I of the NPDES Stormwater Program. Phase II requires operators of regulated small MS4s to obtain NPDES permits and develop a stormwater management program. Programs are designed to reduce discharges of pollutants to the "maximum extent practicable," protect water quality, and satisfy appropriate water quality requirements of the CWA. Small MS4 stormwater programs must address the following minimum control measures:

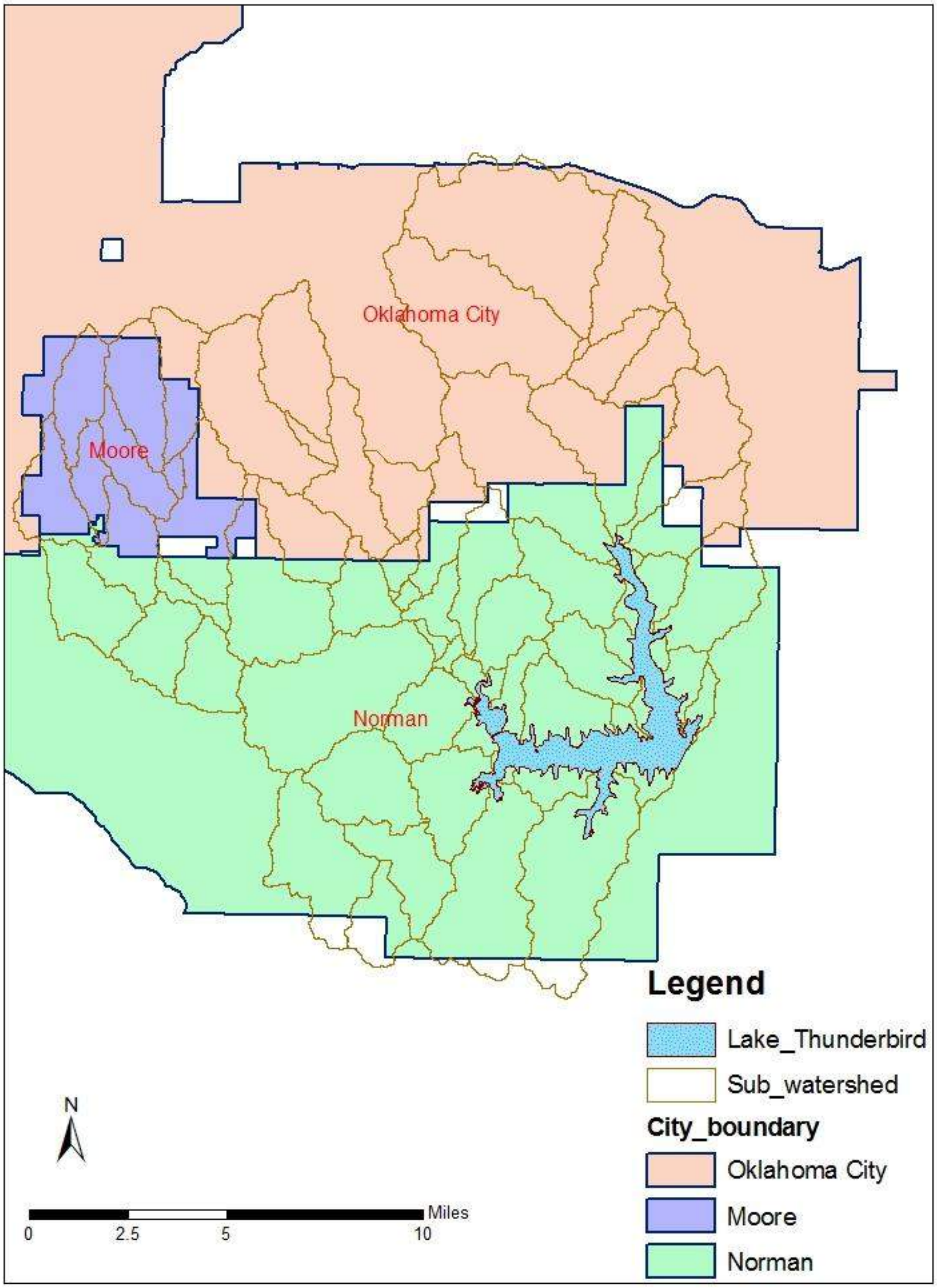
- Public Education and Outreach.
- Public Participation/Involvement.
- Illicit Discharge Detection and Elimination.
- Construction Site Runoff Control.
- Post- Construction Runoff Control.
- Pollution Prevention and Good Housekeeping.

The small MS4 General Permit for communities in Oklahoma became effective on February 8, 2005. DEQ provides information on the current status of the MS4 program at the DEQ webpage: http://www.deq.state.ok.us/WQDnew/stormwater/ms4/. The cities of Midwest City, Moore, Noble and Norman have Phase II MS4 permits for stormwater discharges and stormwater management (Figure 3-2). Because there are no numeric load limits for MS4 permits, Moore and Norman, along with Oklahoma City, will receive a separate WLA based on the proportional contribution of pollutant loading from each of the three cities relative to the total watershed load determined with the watershed model developed for this TMDL study. Noble comprises 0.26% of the watershed and Midwest City comprises 0.05%. Midwest City and Noble have a very small contribution to the total watershed area so they will not be included as part of the WLA determined for the MS4 permits for the three larger cities in the watershed. These two smaller MS4 areas will, however, be accounted for by the Load Allocation (LA) for the portion of the watershed that is not included in the three MS4 urban areas. Table 3-3 lists the urban areas with Phase I or Phase II MS4 permits in the Lake Thunderbird watershed area.

Table 3-3 Urban Areas with MS4 Permits in the Lake Thunderbird Watershed

City Name	Permit-ID	MS4 Phase	Date Issued
Oklahoma City	OKS000101	Phase I	03/15/2013
Moore	OKR040012	Phase II	12/1/2005
Norman	OKR040015	Phase II	11/29/2005
Noble	OKR040037	Phase II	1/5/2006
Midwest City	OKR040011	Phase II	11/7/2005

Figure 3-2 MS4 City Boundaries for Moore, Norman and Oklahoma City in the Lake Thunderbird Watershed



3.1.4 NPDES Construction Site Permits

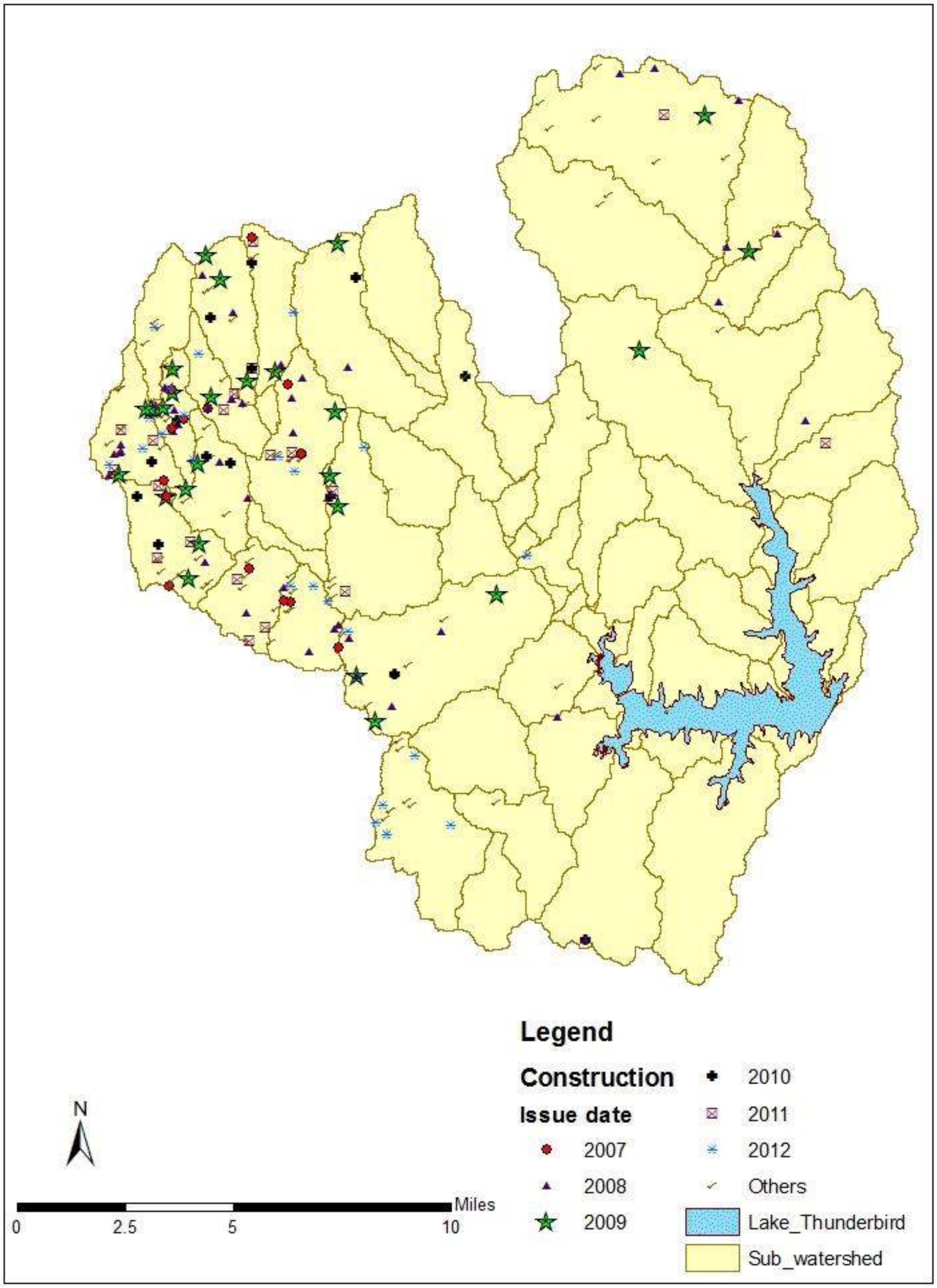
The Oklahoma Department of Environmental Quality (DEQ) has issued the "*General Permit OKR10 for Stormwater Discharges from Construction Activities within the State Of Oklahoma*". Permits are issued for a period of five years for the period from 2007-2012. Permit authorizations are required for construction activities that disturb more than one acre or less than one acre if the construction activity is part of a larger common plan of development that totals at least one acre. This includes the installation, or relocation, of water or sewer lines that have the potential to disturb more than one acre. Construction activities that are on Indian Country Lands or are at oil and gas exploration and production related industry and pipeline operations that are under the jurisdiction of the Oklahoma Corporation Commission are regulated by the US Environmental Protection Agency.

A permit authorization to discharge stormwater from activity at a construction site must be obtained prior to the commencement of any soil disturbing activities. The owner/operator must also develop and implement a Storm Water Pollution Prevention Plan (SWP3) for the construction site. The SWP3 shall provide information that pertains to the site description, stormwater controls, maintenance, inspections and non-stormwater discharges. Permit authorizations are terminated at the completion of the project or when there is a change of owner/operator for the entire project. Permit termination means that all of the temporary sediment control measures have been removed and that the site has had 70% vegetative cover established. The locations, and year, of the 243 construction site permits issued within the Lake Thunderbird watershed are shown in Figure 3-3. Table 3-4 summarizes the number of construction site permits issued for each year from 2007 through 2012 where the issue date of the permit was available.

Table 3-4 Construction Site Permits Issued in the Lake Thunderbird Watershed

Year	Number of Permits
2007	15
2008	52
2009	26
2010	15
2011	20
2012	26
Unknown	89
Total	**243**

Figure 3-3 Construction Site Permits Issued in the Lake Thunderbird Watershed (2007-2012)



3.1.5 NPDES Multi-Sector General Permits (MSGP) for Industrial Sites

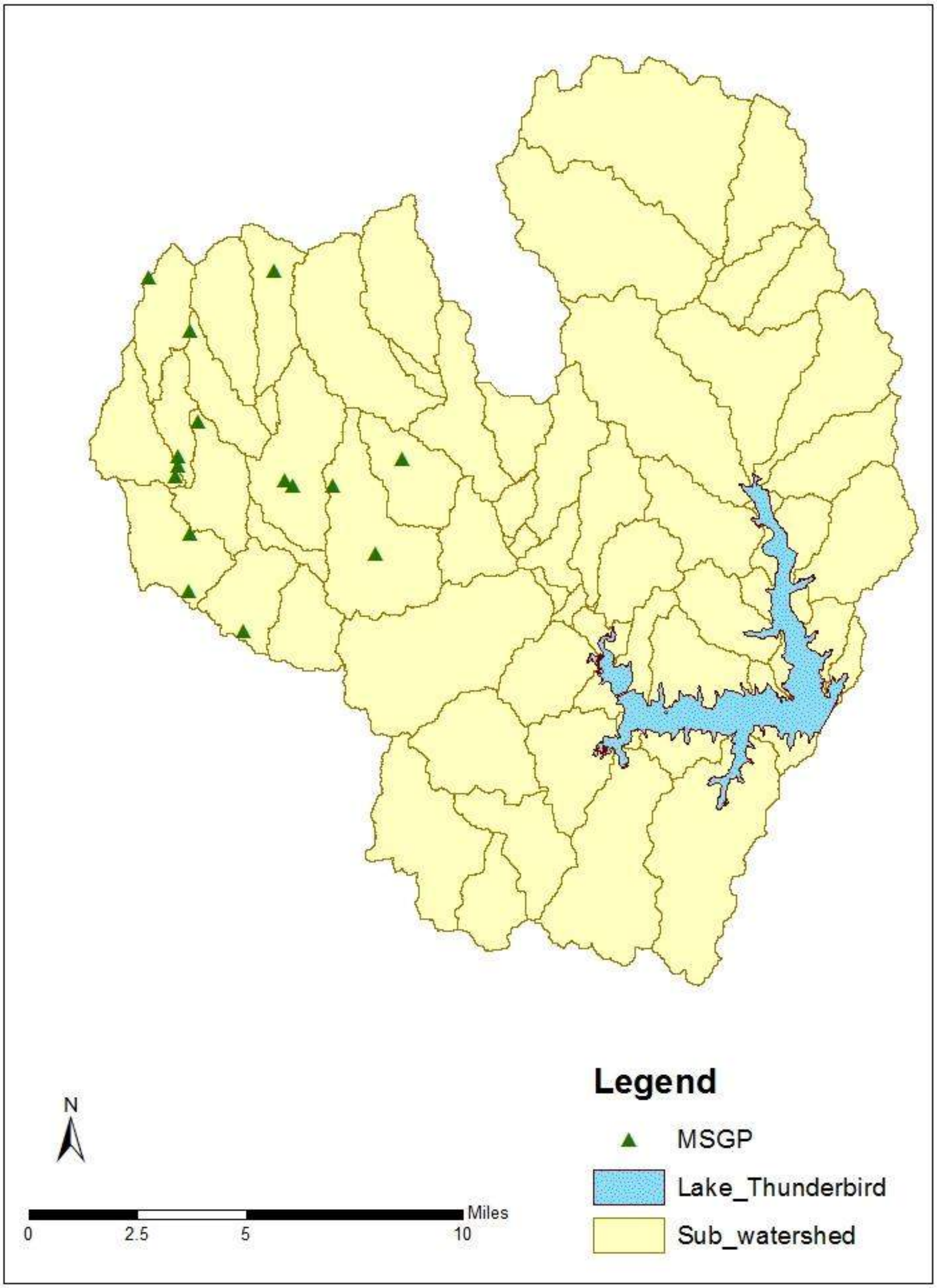
NPDES permit authorizations are required for stormwater discharges from 29 sectors of SIC-coded industrial activities listed in the OKR05 Multi-Sector General Permit (DEQ, 2011). Industrial activities that are on Indian Country Lands or are at oil and gas exploration and production related industry and pipeline operations that are under the jurisdiction of the Oklahoma Corporation Commission are regulated by the US Environmental Protection Agency.

An NPDES permit authorization to discharge stormwater from an industrial activity must be obtained prior to the start of any operations. The owner/operator permit holder must also develop and implement a Storm Water Pollution Prevention Plan (SWP3) for the industrial facility maintained at the site. The SWP3 provides information that pertains to the site description, stormwater controls, maintenance, inspections and non-stormwater discharges. Permit authorizations are terminated when operations have ceased and there no longer are discharges of stormwater associated with industrial activity from the facility. The locations of the 14 industrial site MSGP permits issued within the Lake Thunderbird watershed are shown in Figure 3-4. Table 3-5, organized by SIC type description and the permit identification numbers, summarizes the MSGP industrial site permits issued in the watershed.

Table 3-5 Industrial Site MSGP Permits Issued in Lake Thunderbird Watershed

Company Name	SIC Type	County	Permit-ID	Date Issued	Receiving Water
Silver Star	Asphalt Paving Mixtures And Blocks	Cleveland	OKR050570	2/23/2012	Little River
Vaughan Foods	Food Preparations	Cleveland	OKR051641	2/29/2012	Moore Creek
E & S Equipment, Inc.	Industrial Valves	Cleveland	OKR051761	3/15/2012	Little River, N Fork
Milligan Materials	Local Trucking, Without Storage	Cleveland	OKR052433		Little River
Southwestern Wire, Inc.	Miscellaneous Fabricated Wire Products	Cleveland	OKR051014	5/30/2012	Little River
Oklahoma Foreign Parts, Inc.	Motor Vehicle Parts, Used	Cleveland	OKR050246	3/12/2012	Little River
Ruppert Enterprises, Inc.	Motor Vehicle Parts, Used	Cleveland	OKR050252	3/28/2012	Little River
Frecks Truck Parts, Oklahoma Truck Parts, Inc.	Motor Vehicle Parts, Used	Cleveland	OKR051032	3/28/2012	Little River
Pat Spaulding	Motor Vehicle Parts, Used	Cleveland	OKR051422	3/1/2012	Little River
Windmill LLC	Motor Vehicle Parts, Used; Scrap And Waste Materials	Cleveland	OKR051320	2/14/2012	Little River
Sand Express Inc.	Nonmetallic Minerals Services	Cleveland	OKR051916	7/15/2009	Little River, N Fork
Sooner Redi Mix LLC	Ready-Mixed Concrete	Oklahoma	OKR051754	8/13/2008	Little River, N Fork
Van Eaton Ready Mix	Ready-Mixed Concrete	Cleveland	OKR051978	3/2/2012	Little River, N Fork
Johnson Controls, Inc.	Refrigeration And Heating Equipment	Cleveland	OKR050347	3/13/2012	Little River

Figure 3-4 Multi-Sector General Permits (MSGP) Issued in the Lake Thunderbird Watershed for Industrial Sites



3.1.6 NPDES Animal CAFOs

There are no concentrated animal feeding operations (CAFO) located within the Lake Thunderbird watershed.

3.2 Assessment of Pollutant Sources

3.2.1 Atmospheric Deposition of Nutrients

In many coastal and inland watersheds, atmospheric deposition of nitrogen, derived primarily from burning fossil fuels, can account for a significant fraction of the total nitrogen loading to a waterbody. Atmospheric deposition, for example, accounts for 10-40% of nitrogen loading to estuaries along the East coast of the USA and eastern Gulf of Mexico (Paerl et al., 2002) and 25-28% in Chesapeake Bay (EPA, 2010). Atmospheric deposition of nitrogen is therefore a potentially significant component of nitrogen loading to a waterbody.

This source is considered to be an uncontrollable source term for the TMDL determination. Nevertheless, lake water quality models that simulate the nutrient balance of the lake must account for sources of both nitrogen and phosphorus. Atmospheric deposition of nitrogen and phosphorus to a waterbody is contributed by both dry and wet deposition. Dry deposition is defined as a mass flux rate (as g/m^2-day) for a constituent that settles as dust or is deposited on a dry surface during a period of no precipitation. The mass flux of a constituent from wet deposition is defined by the concentration of the constituent in rainfall and the rate of precipitation. For Lake Thunderbird, wet and dry deposition data was estimated as the average of annual data from 2008 - 2009 for ammonia and nitrate from the National Atmospheric Deposition Program (NADP) for Station OK17 (Kessler Farm Field Laboratory, Lat 34.98; Lon -97.5214) and the Clean Air Status and Trends Network (CASTNET) Station CHE185 (Cherokee Nation, Lat 35.7507, Lon -94.67). Data was not available from the CASTNET or NADP sites for deposition of phosphorus. Dry deposition for phosphorus was estimated using the CASTNET and NADP data for nitrogen with annual average N/P ratios for atmospheric deposition of N and P reported for six sites located in Iowa (Anderson and Downing, 2006). Annual average wet phosphorus concentration was estimated in proportion to the Dry/Wet ratio for phosphate deposition fluxes reported by Anderson and Downing (2006). Appendix B details the data sources and parameter values used to assign atmospheric deposition of nitrogen and phosphorus for the lake model.

3.2.2 Watershed Loading of Nutrients and Sediment

External loading of nutrients and sediments from the watershed to the lake results from precipitation and hydrologic runoff processes over drainage area catchments that are dependent on characteristic properties of the landscape such as topography, land use, soil types and physical processes such as infiltration and erosion. Flow and pollutants, derived from watershed runoff, are transported through a network of streams and rivers with discharge into the lake at downstream outlets of the streams. Since watershed loading of nutrients usually is a significant component of the overall nutrient loading to a waterbody, loading from the watershed to the lake is considered as a controllable source term for a TMDL determination.

Streamflow, runoff, and pollutant loading of nutrients and sediments from the Little River drainage basin into Lake Thunderbird is estimated using a public domain and peer reviewed watershed model, Hydrologic Simulation Program-FORTRAN (HSPF). An overview description of the application of the HSPF watershed model for the Lake Thunderbird project is presented in Section 3.3 of this report with a complete description of the model given in Appendix A of this report.

3.2.3 Internal Lake Loading from Benthic Nutrient Release

In addition to the external loading of nutrients from watershed runoff and atmospheric deposition into the lake, decomposition processes in the sediment bed can also contribute a significant internal load of nutrients to the overall nutrient loading for the lake and stimulate algal production. Particulate organic matter in the water column and sediment bed of Lake Thunderbird is derived from both external watershed runoff loading (non-living detritus) and internal biological production of living organic matter. Particulate organic matter settles out of the water column, accumulates within the sediment bed, and undergoes decomposition processes. During the summer stratified months from mid-May through October, decay processes within the sediment bed deplete dissolved oxygen below the thermocline and release inorganic nutrients from the sediment bed back into the water column. The release of ammonia and phosphate from the bed to the water column, in particular, is controlled, in part, by bottom water dissolved oxygen levels with the largest release rates occurring during summer anoxic conditions. This internal source of nutrients is considered to be an uncontrollable source term for the TMDL determination in this study. Nevertheless, just like atmospheric deposition of nutrients, lake water quality models that simulate the nutrient balance of the lake must account for this internal source of nutrients.

Site-specific measurements of nutrient release from the sediment bed under aerobic and anoxic conditions in Lake Thunderbird are not presently available. Benthic nutrient release data is available, however, from some lakes and reservoirs in the region such as Lake Wister (Haggard and Scott, 2011); Lake Frances (Haggard and Soerens, 2006); Eucha Lake (Haggard et al., 2005) in Oklahoma; Beaver Lake in Arkansas (Sen et al., 2007; Hamdan et al., 2010), Acton Lake in Ohio (Nowlin et al., 2005) and a set of 17 lakes/reservoirs in the Central Plains (Dzialowski and Carter, 2011) that can be used to estimate internal loading rates of nutrients for Lake Thunderbird. Benthic phosphate release rates, characteristic of mesotrophic lakes and reservoirs, have also been estimated by OWRB (2011b) for Lake Thunderbird using an empirical methodology developed by Nurnberg (1984).

3.3 HSPF Watershed Model

3.3.1 Overview of HSPF model

The Hydrological Simulation Program FORTRAN (HSPF), supported by EPA and the USGS as a public domain model, is a lumped parameter watershed runoff model that simulates watershed hydrology and non-point source pollutant loadings for organic matter, nutrients, sediments, bacteria and toxic chemicals within a watershed network of delineated sub-watersheds (Bicknell et al., 2001). The internal stream model routes flow and water quality constituents through a network of river reaches for each sub-watershed of the watershed. The HSPF hydrologic sub-model provides for simulation of water balances in each sub-watershed based on precipitation, evaporation, water withdrawals, irrigation, diversions, wastewater discharges, infiltration, and active and deep groundwater reservoirs. Empirical model parameters are assigned for each sub-watershed land use through model calibration to simulate the water balance and pollutant loading from a sub-watershed. HSPF is designed as a time variable model with results generated on an hourly or daily basis. Hundreds of applications of HSPF over the past two decades have included short-term storm events and/or continuous simulations over annual and decadal cycles. BMP alternatives designed to reduce pollutant loads to receiving waters can be represented in HSPF by adjustments of land use-based yield coefficients for a pollutant. Windows-based user-friendly GUI software tools such as WinHSPF (Duda et al., 2001), GenScn (Kittle et al., 1998) and HSPFParm (Donigian et al., 1999) have been developed to facilitate pre- and post-processing tasks for HSPF. Time series results for streamflow and pollutant loads generated by HSPF have been linked for input to hydrodynamic (e.g., EFDC) and water quality models (e.g., EFDC, WASP7) in numerous applications over the past decade. HSPF is considered a Level 3 Complex or Advanced Model. The URL for HSPF is http://www.epa.gov/ceampubl/swater/hspf/index.htm

3.3.2 Model Setup and Data Sources

The HSPF model was initially setup using EPA's BASINS watershed modeling platform. The sub-watershed boundaries were delineated based on USGS's NHD flow line and the National Elevation Dataset (NED). The 2001 NLCD land use data were used in the Lake Thunderbird watershed model. An intensive one-year stream monitoring was conducted by the Oklahoma Conservation Commission (OCC) with support from DEQ from April 2008 to April 2009. Five monitoring stations were set up in the Lake watershed on major tributaries with programmable automatic samplers (autosamplers) and rain gages. The information of these stations is given in Table 3-6 and Figure 3-5. Five-minute rainfall data from these five stations and the MESONET station at the Max Westheimer Airport (Figure 3-5) were used as boundary forcing in the Thunderbird model. All the other meteorological data were obtained from the MESONET station at the Westheimer Airport.

Table 3-6 Information of the OCC observation stations

Station ID	Site Name	Description	Latitude	Longitude
OK520810-00-0080W	L17	Little River @ 17th St.	35.32350	-97.49630
OK520810-00-0140P	Elm	West Elm Creek @ 134th St.	35.33400	-97.38540
OK520810-00-0080H	L60	Little River @ 60th Ave.	35.27763	-97.35321
OK520810-00-0090C	Rock	Rock Creek @ 72nd Ave.	35.26100	-97.33550
OK520810-00-0030G	Hog	Hog Creek @ 119th Ave.	35.34957	-97.25816

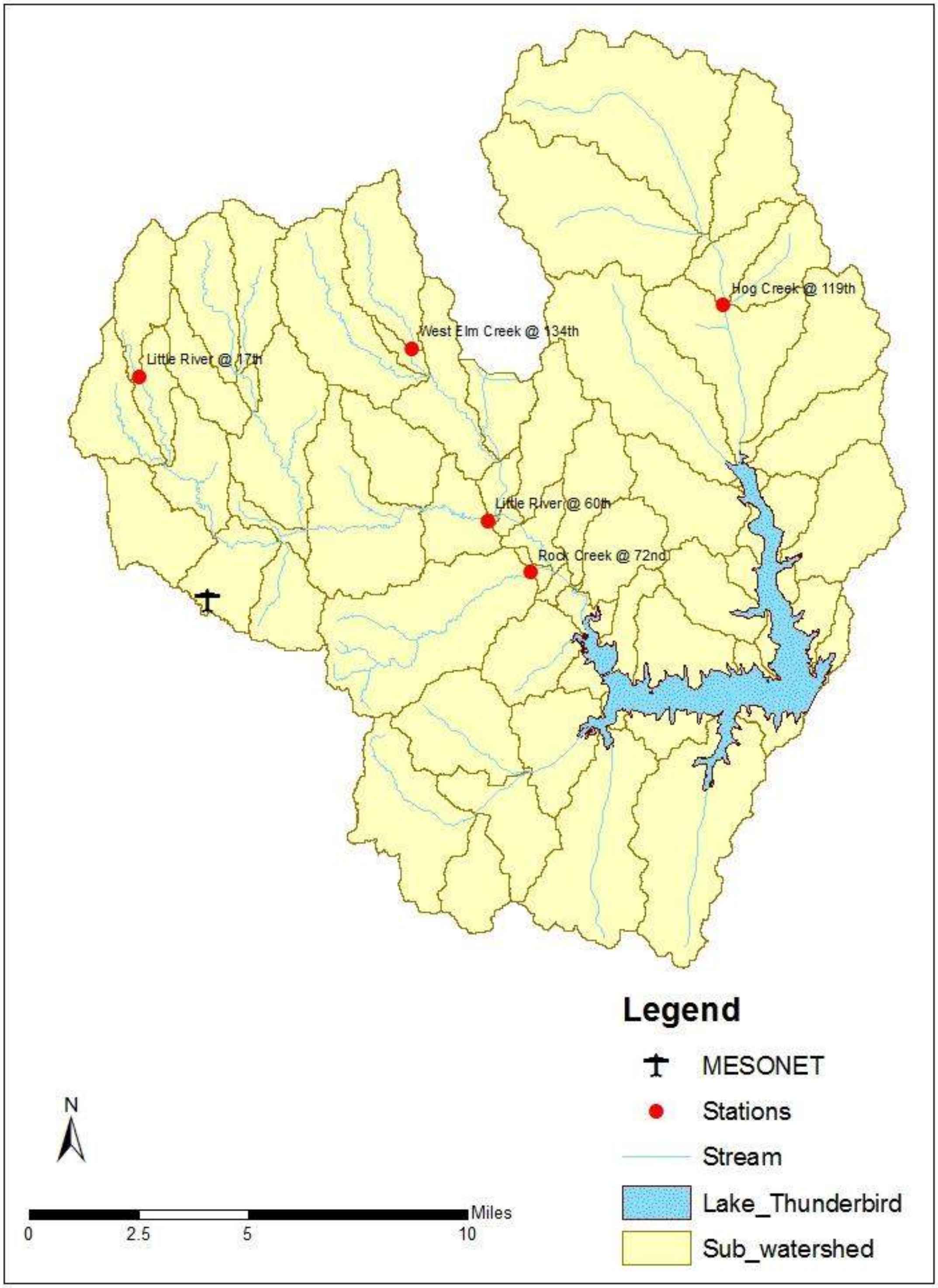
3.3.3 Model domain and discretization for sub-watershed representation

The model breaks the Lake Thunderbird watershed into 66 sub-watershed/stream reaches based on the stream network in the watershed as described by USGS's NHD database and flow path calculations based on the NED dataset (Figure 3-5). These sub-watersheds were further assigned to six groups based on the precipitation data used for each of these groups. All other meteorological data (e.g., air temperature and solar radiation) were shared by all sub-watersheds as reported by the MESONET station at the Westheimer Airport. The MESONET station is located just outside the watershed in Norman while the airport is partially in the watershed.

3.3.4 Observed OCC 2008 - 2009 stream data for model calibration

Stream discharge and water quality data from the five OCC stations were used for model calibration (Table 3-6 and Figure 3-5). Stream discharge rating curves based on water depth were initially developed for the monitoring stations using stream survey data, limited number of discharge measurements, and Manning's equation. As more stream discharge measurements with a wider range of discharge rates became available well into the monitoring period, the rating curves were refined and updated. They were finalized after the monitoring work was completed and the discharge record was revised retrospectively. This affected the flow-weighted sampling for total phosphorus (TP) and total Kjeldahl nitrogen (TKN) as they required accurate discharge rate for correct flow weighting. The model calibration process accounted for this inconsistency by simulating water depth at the monitoring sites and using the initial rating curves to simulate the concentrations of TP and TKN of the flow-weighted composite samples.

Figure 3-5 Sub-watershed delineation for the Lake Thunderbird watershed



3.3.5 HSPF Model Calibration

The HSPF model covered the period where stream discharge and water quality data were measured for the watershed: April 17, 2008 through April 26, 2009. The time step for the HSPF model simulation was set at one hour.

Computer water quality models are simplified representation of the physical world. In addition, observed data from monitoring have inherent errors from the sample collection process, equipment used, and lab analysis procedures. As a result, models, even after calibration, do not produce results that match exactly with observed data. To judge if a model performs as designed and simulates pollutant loads with a reasonable accuracy, graphic comparison and statistical analysis are conducted to evaluate model performance. For more details on the procedure used for HSPF model development and the results obtained for HSPF model calibration, please refer to Appendix A of this report.

In this study, observed stream discharge and water quality parameters were plotted on the same graphs with model simulated time series of these same parameters. Visual inspections were made to compare the observed and simulated data. Three statistics, percent difference of average values (% error), correlation coefficient (r^2), and Nash-Sutcliffe coefficient (N-S), were calculated to quantify how well model simulation matched observed data. Statistics for comparing the observed data and the model simulation were calculated as shown in Table 3-7. Figure 3-6 through Figure 3-9 showed the time series comparison plots at one of the five monitoring stations.

Table 3-7 Calculated statistics at calibration station L17 (Little River at 17th Street, Moore)

Parameter	Units	Observed Data average	HSPF Average	% Difference	r^2	Nash-Sutcliffe coefficient
Flow	cfs	7.6	6.2	-18%	0.92	0.66
Temperature	Degrees-C	16.3	16.3	0%	0.72	0.71
TSS	mg/L	19.0	20.7	8.9%	0.63	-0.56
TP	mg/L	0.215	0.25	5.5%	0.0	-1.54
TKN	mg/L	1.35	1.56	9.1%	0.09	-1.56
DO	mg/L	8.5	8.0	-6.2%	0.71	0.71

Figure 3-6 Comparison of observed and simulated stream flows (flow calibration plot) at L17 station (observed data are not continuous)

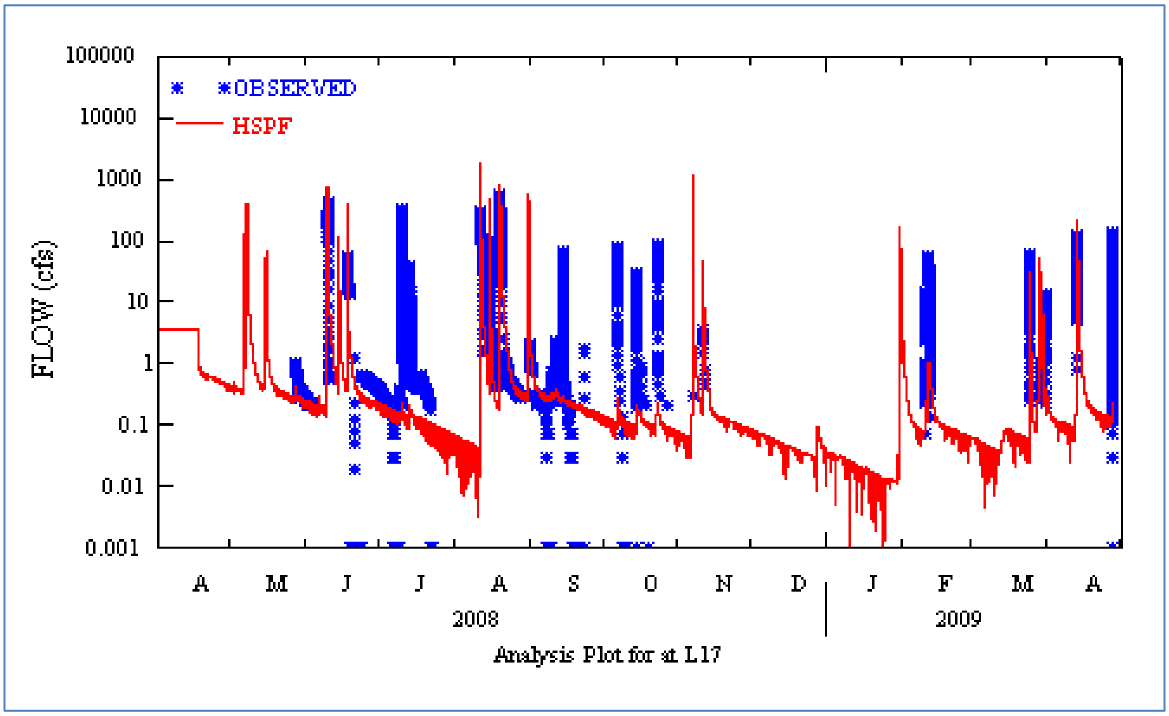


Figure 3-7 Little River at 17th St. (L17) site - Water temperature calibration plot

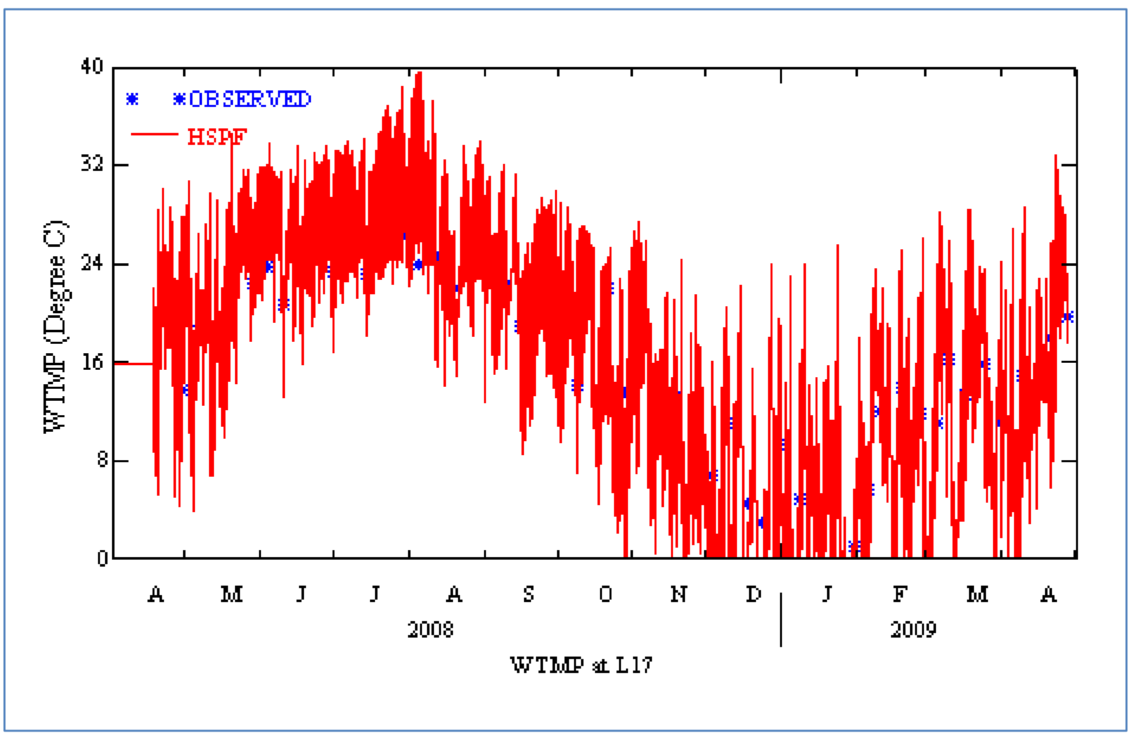


Figure 3-8 DO calibration plot at station L17

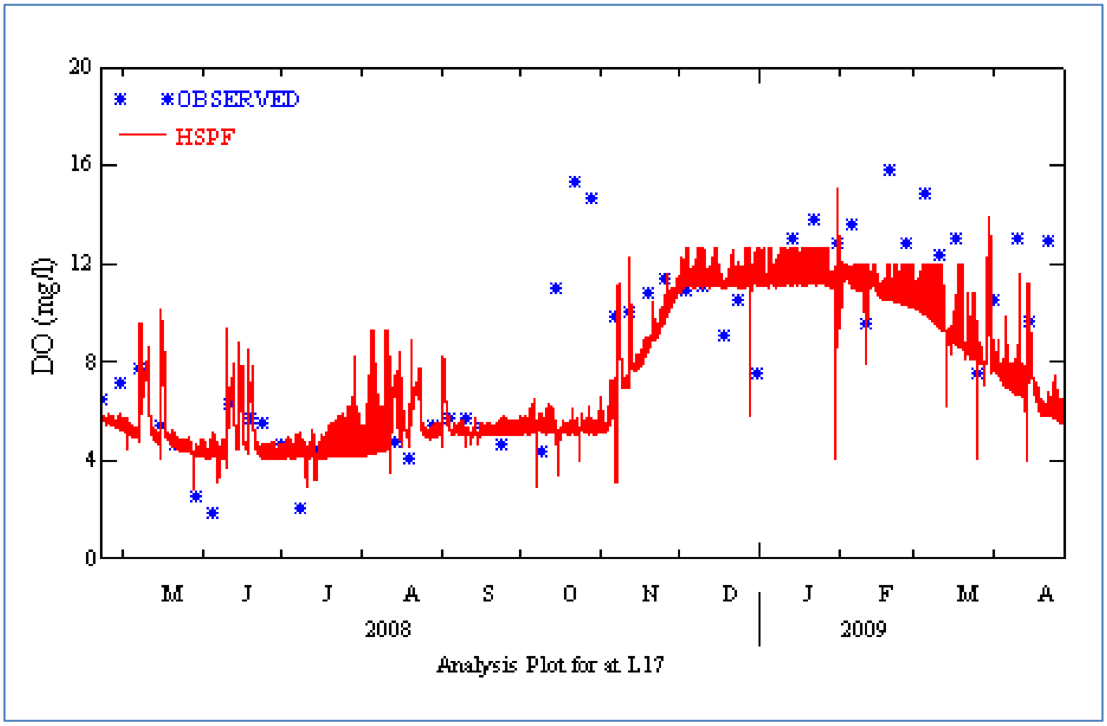
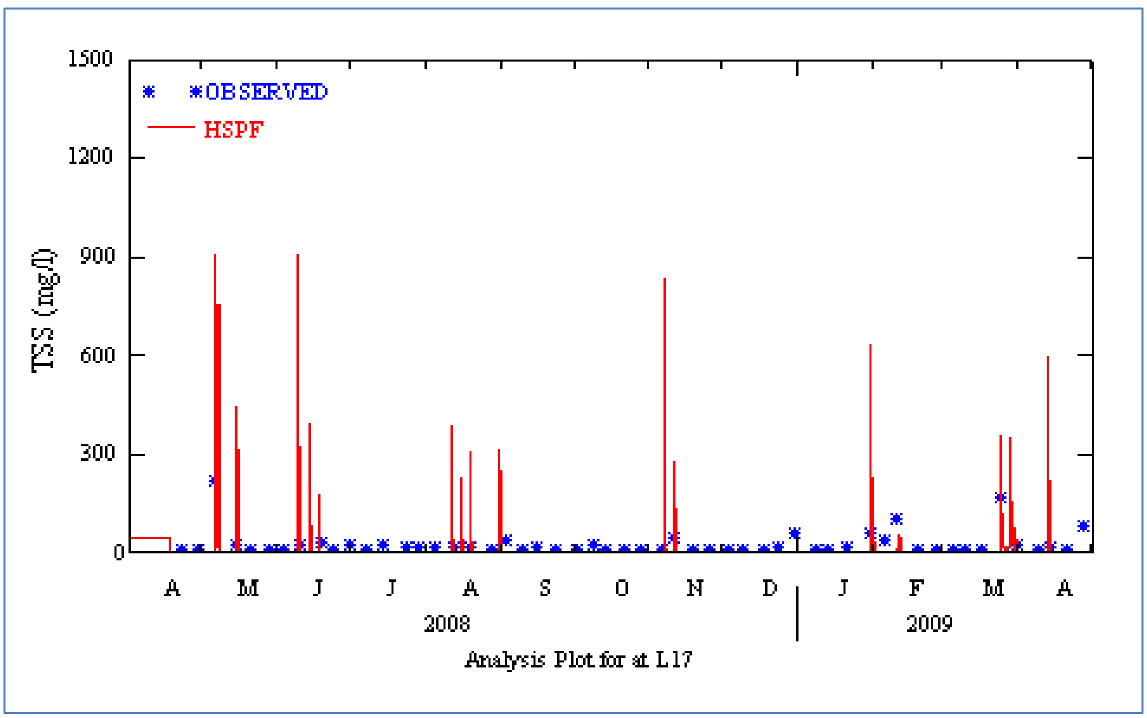


Figure 3-9 TSS calibration plot at station L17



3.3.6 HSPF Loads for TSS, TN, TP and CBOD for Existing Calibration Conditions

The HSPF model framework consists of a network of sub-watersheds that generate flow and pollutant loading from runoff over the land uses of sub-watersheds defined within a larger watershed domain for a project. Sub-watersheds are defined by an in-stream reach where flow and pollutant loads simulated as land use dependent runoff are input and routed through a reach that is defined by length, volume, surface area, depth and hydraulic residence time. In this study, sub-watersheds that drain into Lake Thunderbird via a tributary generate flow and water quality concentrations at specific downstream outlet locations at the Lake. Sub-watersheds that are adjacent to and drain directly into Lake Thunderbird generate water volume and loads from distributed runoff over the entire sub-watershed. By aggregating the pollutant loading from all the tributary and distributed runoff sub-watersheds, the annual pollutant loading derived from the HSPF model is given in Table 3-8.

There are ten land use categories used in the Lake Thunderbird watershed model. The land area in acres, the Total Phosphorus and Total Nitrogen unit loadings in pounds per acre per year and the total nutrient loading in pounds per year for each land use category are summarized in Table 3-9.

To further show the sources of pollutants, the pollutant loadings normalized on a per acre per year basis for each sub-watershed are given in Figure 3-10 through Figure 3-14.

Table 3-8 HSPF Loads for TN, TP, CBOD, Sediment and TOC

Total HSPF watershed Loads: 4/27/2008-4/26/2009					
Pollutants	**TN**	**TP**	**CBOD**	**Sediment**	**TOC**
Units	**1000 lb/yr**	**1000 lb/yr**	**1000 lb/yr**	**1000 lb/yr**	**1000 lb/yr**
Tributary	243.82	48.37	490.90	24086.71	1251.77
Distributed	15.30	2.52	29.80	1250.09	88.58
Total	259.12	50.90	520.70	25336.80	1340.34
OR					
Units	**kg/day**	**kg/day**	**kg/day**	**kg/day**	**kg/day**
Tributary	303.01	60.11	610.05	29933.32	1555.61
Distributed	19.01	3.14	37.04	1553.52	110.08
Total	322.02	63.25	647.09	31486.84	1665.69

Table 3-9. Nutrient Loading for Each Land Use Category

Land Use Category	Land Area (acres)	TN (lb/ac/yr)	TN (lbs/yr)	TP (lb/ac/yr)	TP (lbs/yr)
Forest Deciduous	55,010	0.189	10,397	0.009	495
Forest Evergreen	351	0.183	64	0.009	3
Total Forest		**10,461**		**498**	
Wetland	8	0.324	3	0.046	0
Rangeland	59,765	3.074	183,718	0.607	36,277

Land Use Category	Land Area (acres)	TN (lb/ac/yr)	TN (lbs/yr)	TP (lb/ac/yr)	TP (lbs/yr)
Pasture	5,452	4.043	22,042	0.611	3,331
Agriculture	3,341	3.413	11,403	0.913	3,050
Low Density Urban	6,769	9.019	61,050	1.886	12,766
Medium Density Urban	3,102	9.089	28,194	1.895	5,878
Commercial	14,661	9.906	145,232	2.024	29,674
High Density Urban	661	10.34	6,835	2.169	1,434
Total Urban		**241,311**		**49,762**	

Figure 3-10 Calculated sub-watershed sediment loadings by HSPF model

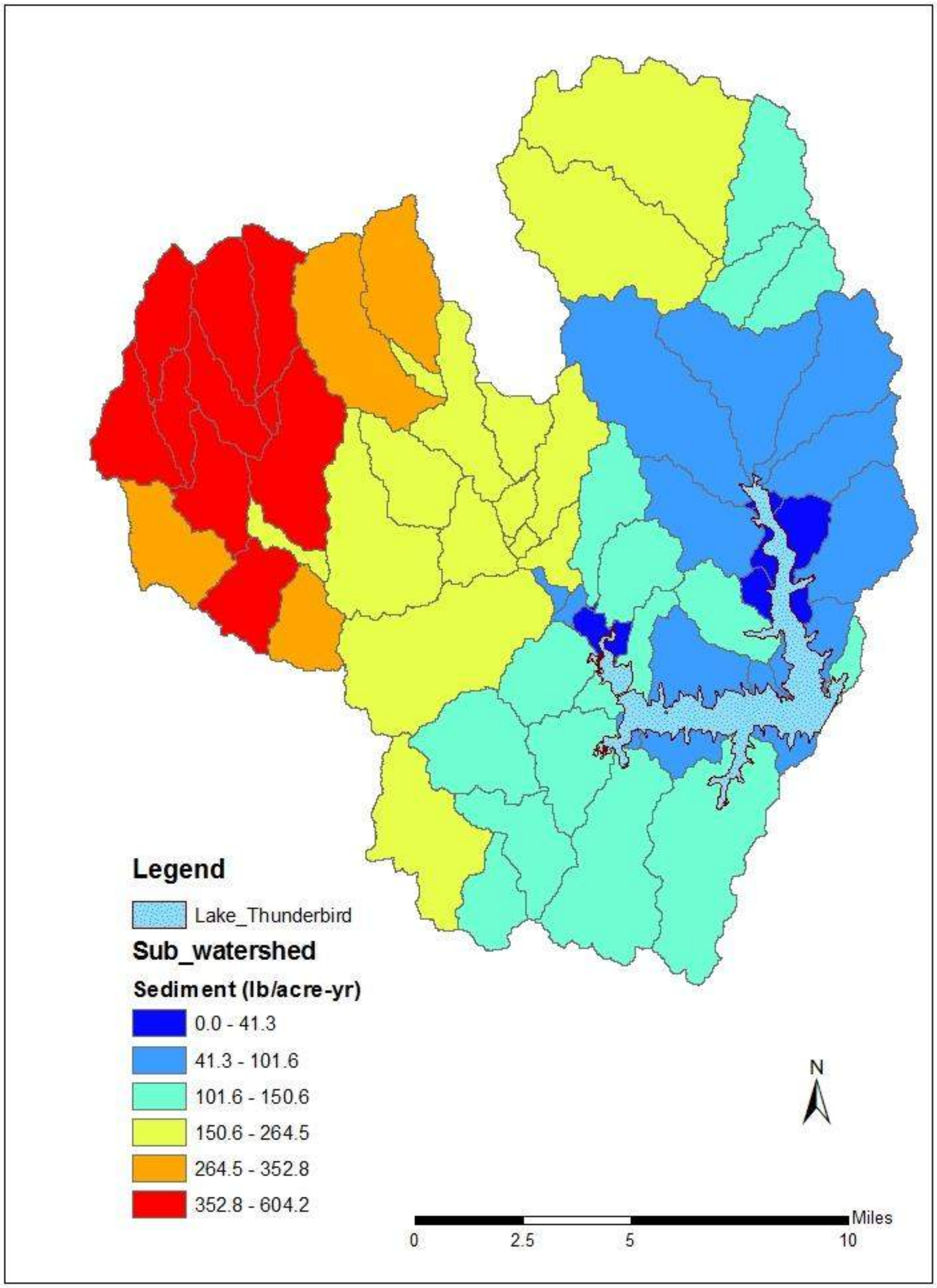


Figure 3-11 Calculated sub-watershed CBOD loadings by HSPF model

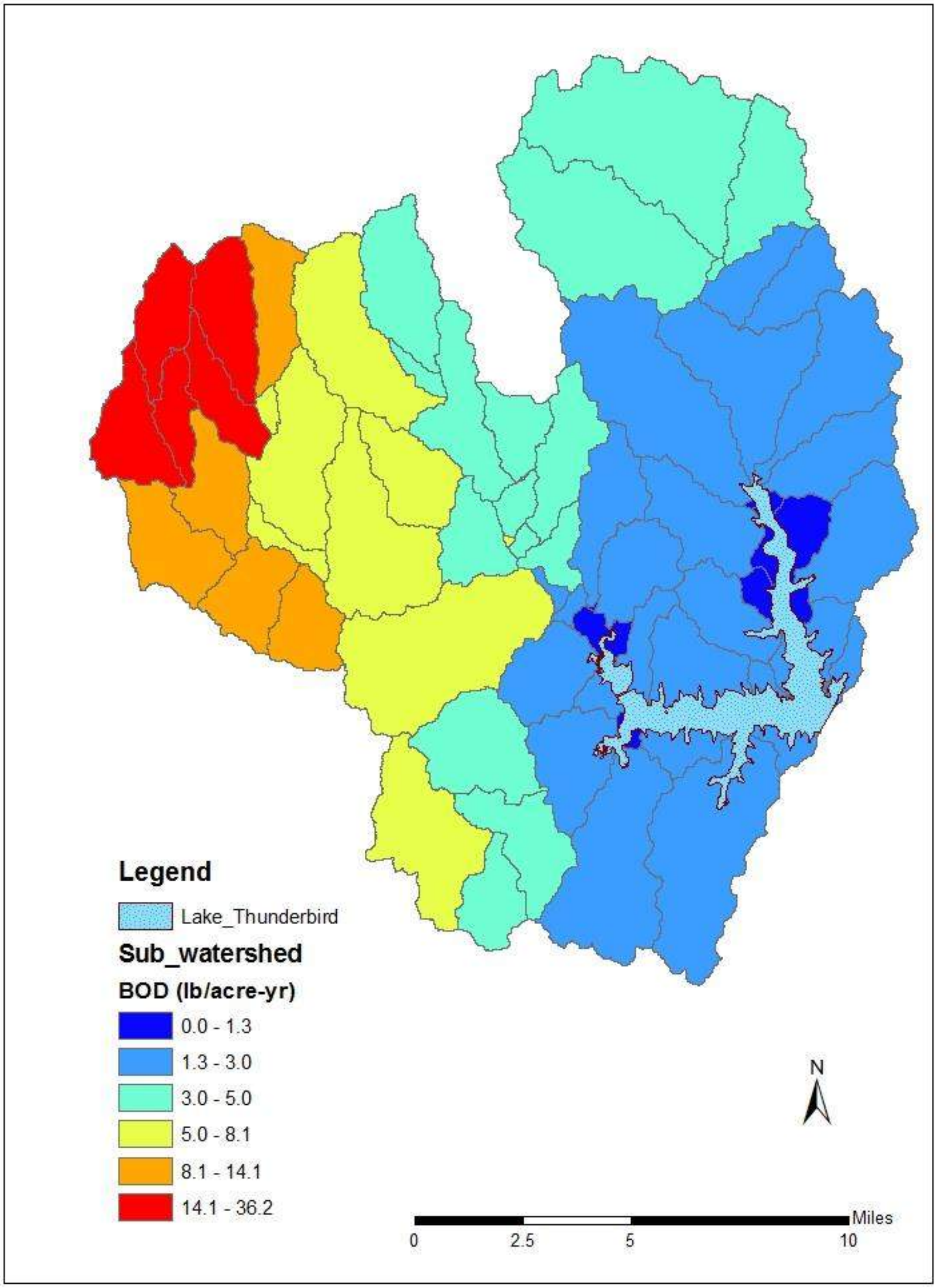


Figure 3-12 Calculated sub-watershed TOC loadings by HSPF model

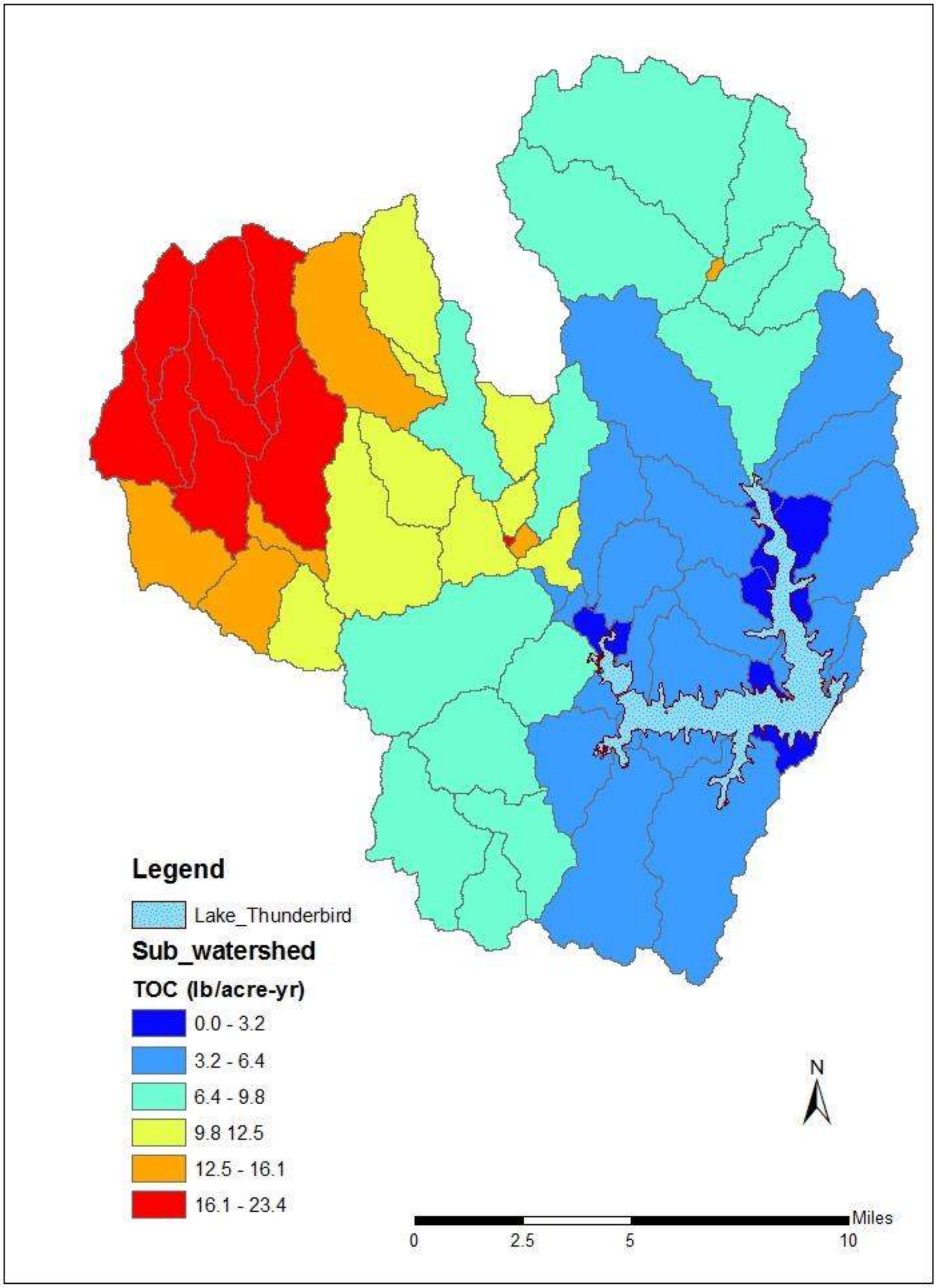


Figure 3-13 Calculated sub-watershed TN loadings by HSPF model

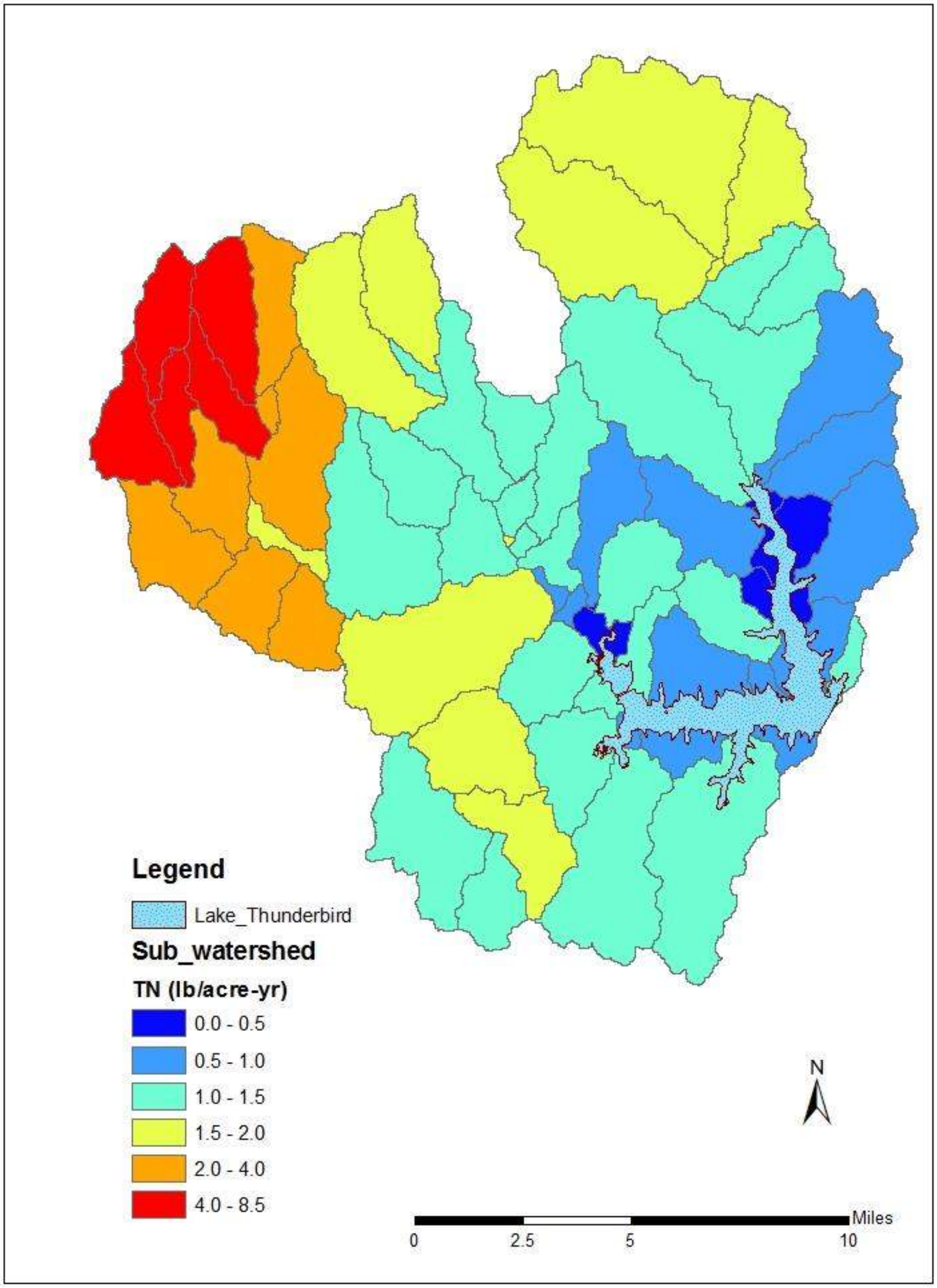
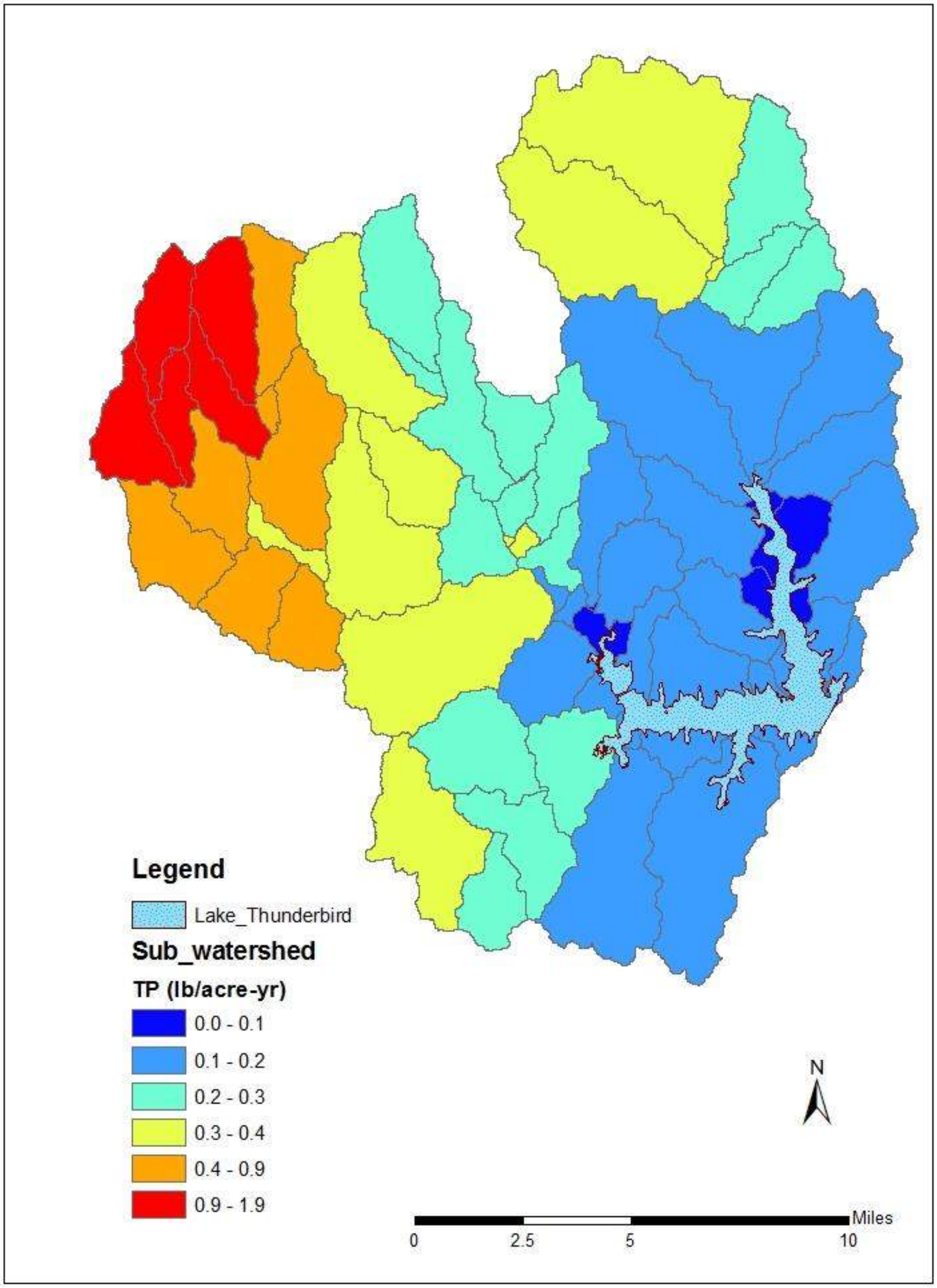


Figure 3-14 Calculated sub-watershed TP loadings by HSPF model



SECTION 4 LAKE MODEL AND WATERSHED- LAKE MODEL LINKAGE

The objective of a TMDL study is to estimate allowable pollutant loads expected to achieve compliance with water quality criteria. The allowable load is then allocated among the known pollutant sources in the watershed so that appropriate control measures can be implemented to reduce pollutant loading. To determine the effect of watershed management measures on in-lake water quality, it is necessary to establish a cause-effect linkage between the external loading of sediments, nutrients and organic matter from the watershed and the waterbody response in terms of lake water quality conditions for sediments, nutrients, organic matter, dissolved oxygen and chlorophyll-*a*. This section describes an overview of the water quality modeling analysis of the EFDC linkage between water quality conditions in Lake Thunderbird and HSPF watershed pollutant loading. Appendix B of this TMDL report presents a description of the EFDC model, setup of the model, data sources, model results for current conditions and analysis of the effect of watershed load reductions on lake water quality.

4.1 EFDC Model Description

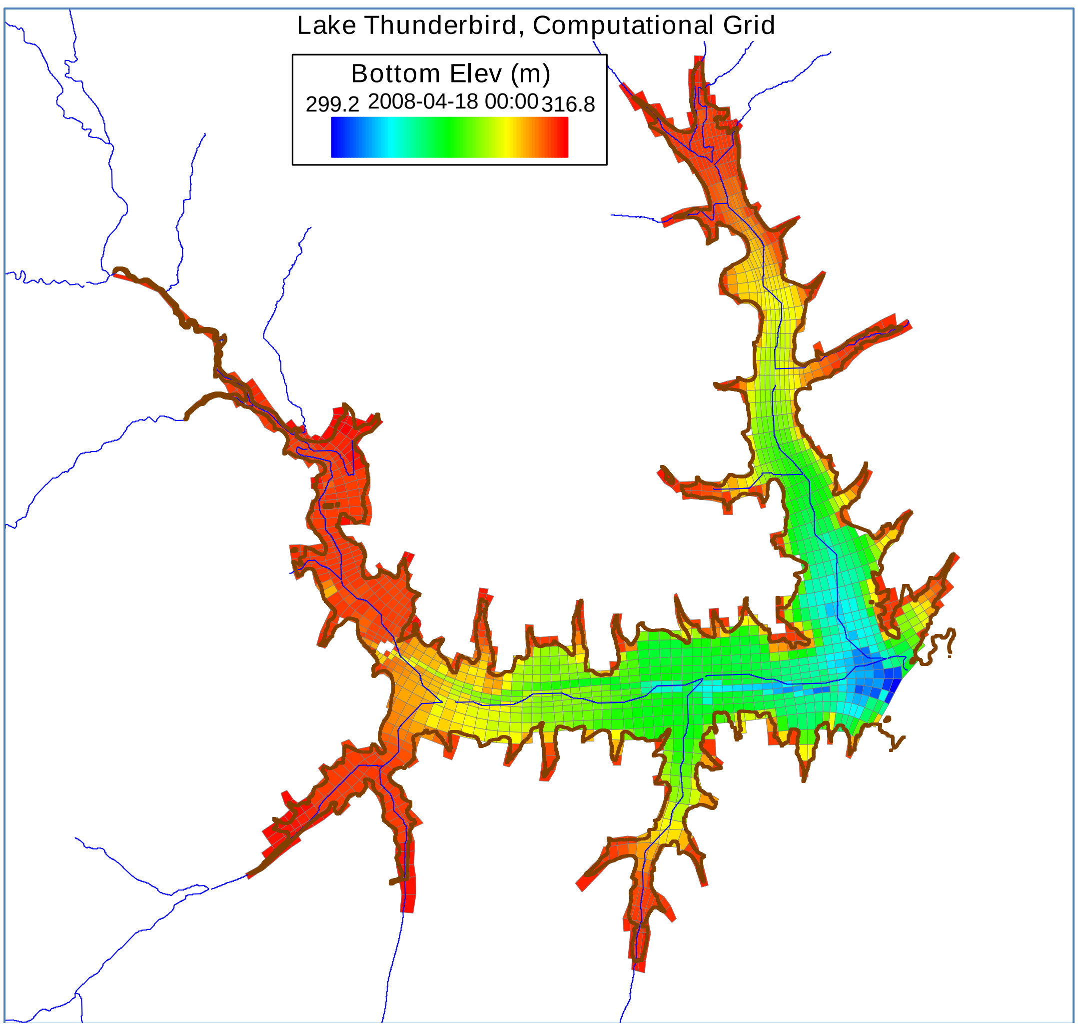
EFDC is an advanced surface water modeling package for simulating three-dimensional (3-D) circulation, salinity, water temperature, sediment transport and biogeochemical processes in surface waters including rivers, lakes, reservoirs, estuaries, and coastal systems. The EFDC model has been supported by EPA over the past decade as a public domain, peer reviewed model to support surface water quality investigations including numerous TMDL evaluations (Ji, 2008). EFDC directly couples the hydrodynamic model (Hamrick, 1992, 1996) with sediment transport (Tetra Tech, 2002), water quality (Park et al., 2000; Hamrick, 2007) and sediment diagenesis models (Di Toro, 2000). EFDC state variables include suspended solids, dissolved oxygen, nutrients (N, P), organic carbon, algae, sediment bed organic carbon and nutrients and benthic fluxes of nutrients and dissolved oxygen. The EFDC model is time variable with model results output at user-assigned hourly time intervals. The EFDC model requires input data to characterize lake geometry (shoreline, depth, surface area, and volume), time varying watershed inputs of flow and pollutant loads, time varying water supply withdrawals and release flows, and kinetic coefficients to describe water quality interactions such as nutrient uptake by algae. Observed water quality data collected at Lake monitoring sites is used for calibration of the model results to observations. Model setup, data input, and post-processing of model results is facilitated with the EFDC_Explorer graphical user interface (Craig, 2012).

4.2 Data Sources and EFDC Model Setup

Data Sources: Data sources used for development of the model included routine Lake and tributary monitoring by Oklahoma Water Resources Board (OWRB) and the Oklahoma Conservation Commission (OCC); Lake level and storage volume monitoring by the USGS and the U.S. Army Corps of Engineers (COE); and meteorological data from rain gages co-located with tributary sampling sites and the Oklahoma MESONET network. Data was collected by OWRB in 2001 with an Acoustic Doppler Continuous Profiler (ADCP) to map bathymetry of Lake Thunderbird. The Central Oklahoma Master Conservancy District (COMCD), in cooperation with OWRB, has been monitoring chlorophyll-*a*, nutrients, sediment, water temperature, organic matter and dissolved oxygen in the Lake since 2000. In support of this TMDL study of Lake Thunderbird, OWRB and OCC conducted a special monitoring program from April 2008 through April 2009 to collect samples in watershed tributaries and to supplement the monitoring program conducted as part of the routine COMCD-OWRB surveys of Lake Thunderbird. Sediment bed data was also collected by OWRB at five stations in the Lake in 2008 to provide sediment bed data needed for the sediment diagenesis model. The data collected by OWRB and OCC was used for development and calibration of the EFDC hydrodynamic, sediment transport, water quality, and sediment diagenesis models. Tables of observed water quality data used for lake model calibration are presented in Appendix D of this report.

EFDC Model Domain: The EFDC model allows for the physical representation of the lake with either coarse or fine resolution grid blocks. For this study, a fine resolution mesh of grid cells was developed to obtain a good representation of the effect of lake geometry, particularly the remnant river channels of the Little River and Hog Creek, and river inflow on circulation in the Lake (Figure 4-1). The computational grid developed to map the geometry of Lake Thunderbird consisted of 1,660 horizontal cells. Depth of the water column was represented with 6 layers to account for the effects of seasonal stratification. The shoreline of the Lake is defined by the normal pool elevation of 1039.0 ft (vertical datum, NGVD29). Bottom elevation of the lake model was interpolated to each grid cell using the high resolution bathymetry data collected by OWRB (Figure 4-1). The causeway across the southwestern area of the Little River arm of the Lake was represented in the model grid as a barrier to flow by removing selected model grid cells to force flow to be transported around the roadway.

Figure 4-1 Lake Thunderbird Computational Grid and Bottom Elevation



Boundary Conditions: The EFDC lake model requires the specification of external boundary data to describe: (1) flow and pollutant loading from the watershed; (2) withdrawals from water supply intakes and releases at the dam; (3) meteorological and wind forcing; and (4) atmospheric deposition of nutrients. As described in Section 3.3, flow and pollutant loading from the watershed was provided by the HSPF model as hourly time series data for 18 tributaries and 18 distributed flow areas. Tributary inflows included the Little River, Elm Creek, Rock Creek, Hog Creek, Dave Blue Creek, Jim Blue Creek, Clear Creek, Willow Branch and a number of unnamed streams. Although HSPF and EFDC both model sediments, nutrients, organic matter, algae and dissolved oxygen, the model results for some HSPF state variables require stoichiometric transformations, as described in Appendix B, for linkage to the EFDC state variables.

A flow boundary was assigned to represent water supply withdrawals at a common intake location from the reservoir for the municipalities of Norman, Midwest City and Del City. Water supply withdrawal data was provided by COMCD. A flow boundary was assigned to account for release flow at the dam (designated by the U.S. Army Corps of Engineers as Station NRM02) with flow data provided by the Army Corps of Engineers. The only sources of water inflow to the lake model are from the simulated HSPF flows and precipitation and the only withdrawals of water are assigned from water supply withdrawals, release flow at the dam and evaporation.

The EFDC model requires time series data to describe the effect of meteorological forcing and winds on lake circulation processes. Wind speed/direction and meteorological data was obtained from the Oklahoma MESONET database at Station NRMN. Meteorological data needed for the model includes wind, air temperature, air pressure, relative humidity, precipitation, evaporation, cloud cover and solar radiation.

The EFDC model requires specification of wet and dry atmospheric deposition of nitrogen and phosphorus over the entire surface area of the Lake. Atmospheric deposition of nutrients is represented using the same constant loading rate for both model calibration to existing conditions (2008 - 2009) and model evaluations of watershed load reduction scenarios. Since atmospheric deposition is uncontrollable on the local watershed scale, there is no load allocation for atmospheric deposition of nutrients for the TMDL. For Lake Thunderbird, wet and dry deposition data for nitrogen, presented in Appendix B, was estimated as the average of annual data from 2008 - 2009 for ammonia and nitrate from the National Atmospheric Deposition Program (NADP) for Station OK17 (Kessler Farm Field Laboratory) and the Clean Air Status and Trends Network (CASTNET) Station CHE185. Wet deposition loading of ammonia and nitrate was estimated from annual rainfall (36.9 inches) measured during the period from April 2008-April 2009. Since data was not available from the CASTNET or NADP sites for deposition of phosphorus, dry deposition for phosphorus was estimated using the CASTNET and NADP data for nitrogen with annual average N/P ratios for atmospheric deposition of N and P reported for 6 sites located in Iowa (Anderson and Downing, 2006). Annual average wet phosphate concentration was estimated in proportion to the Dry/Wet ratio for phosphate deposition fluxes reported by Anderson and Downing (2006).

Initial Conditions: As a time varying model, EFDC requires the specification of initial distributions of all the model state variables at the beginning of the model simulation period in mid-April 2008. The spatial distribution of initial conditions for the model is based on simulated conditions at the end of the 1-year model simulation period. Restart conditions, written for all state variables of the model at the end of a preliminary model run, were used to assign a simulated set of initial conditions that accounted for spatial variability of conditions in the water column and sediment bed.

4.3 EFDC Model Calibration to Existing Conditions

The EFDC lake model was setup for a 375 day period from April 17, 2008 through April 26, 2009. Model results were calibrated against observed data collected at eight water quality monitoring sites shown in Figure 2-1. Model results were calibrated to observations for water level, water temperature, TSS, nitrogen, phosphorus, dissolved oxygen, organic carbon and algae biomass (chlorophyll). The model-data performance statistics selected for calibration of the hydrodynamic and water quality model are the Root Mean Square Error (RMSE) and the Relative RMS Error. The Relative RMS error, computed as the ratio of the RMSE to the observed range of each water quality constituent, is expressed as a percentage. The Relative RMS Error thus provides a straightforward performance measure statistic to evaluate agreement between model results and observations in comparison to model performance targets. This section only provides a brief description of lake model calibration. For more details on the procedure used for EFDC model development and the results obtained for EFDC model calibration, please refer to Appendix B of this report.

TSS and Turbidity: Water clarity is an issue for impairment of Lake Thunderbird and turbidity is the water quality parameter used to determine if the lake fully supports designated uses. Oklahoma water quality criteria states that no more than 10% of samples collected over the most recent 10 year period shall be greater than 25 NTU. Turbidity is a measure of the optical properties of water that causes light to be scattered and absorbed by particles in the water sample. Turbidity, as measured with a Nepholometer and reported with units of Nepholometric Turbidity Units (NTU), however, accounts only for the scattering of light. Since turbidity is not a mass-based concentration, a surrogate indicator of water quality must be used to develop a TMDL that addresses compliance with water quality criteria for turbidity. Total suspended solids (TSS) is a common water quality measurement that can be used as a surrogate indicator for turbidity. Although turbidity and TSS measure very different properties of water samples, both measurements do provide information about water clarity. TSS vs. turbidity relationships can therefore be developed and applied for TMDL determinations. The TSS vs. turbidity relationship must, however, be developed using site-specific paired data since inconsistencies and interferences in the relationship can result from site-specific properties of a water sample including water color, size, shape and refractive index of sediment particles, the organic and inorganic composition of sediment particles, and the inconsistency of instruments used for the turbidity measurement itself (Thackston and Palermo, 2000; Bash, Berman and Bolton, 2001). For the Lake Thunderbird study, paired TSS and turbidity measurements from the eight Lake stations were used to develop a whole lake linear regression relationship. As described in Appendix B, the relationship was considered acceptable to apply a site-specific correlation to compute simulated turbidity from modeled TSS for Lake Thunderbird.

The TSS vs. turbidity relationship developed for Lake Thunderbird was used to transform EFDC model results for TSS to turbidity for comparison to the water quality criteria for turbidity of 25 NTU. Based on summary statistics computed for turbidity for all eight stations, the 90^{th} percentile for observed 2008 - 2009 turbidity (29.7 NTU) is seen to exceed the water quality target of 25 NTU. The 90^{th} percentile of the calibrated model results for turbidity (27.6 NTU) computed for the eight stations also shows non-compliance with the target of 25 NTU.

Chlorophyll-a: Water quality criteria targets for chlorophyll-*a* and dissolved oxygen are directly compared to model results for chlorophyll and dissolved oxygen. Model results for chlorophyll-*a*, in general, show good agreement with the observed seasonal trend of chlorophyll for most of the simulation period of 2008 - 2009. The observed seasonal progression of algae biomass is controlled by water temperature, the availability of phosphate and adequate light for growth. Observed TN:TP ratios and model results both indicate that phosphorus is the limiting factor for algal growth in Lake Thunderbird. Based on summary statistics computed for all eight stations, the 2008 - 2009 average for observed surface chlorophyll (24.8 µg/L) exceeds the target criteria for SWS lakes of 10 µg/L. The average value for the calibrated model results for chlorophyll of 21.5 µg/L also shows non-compliance with the SWS target criteria.

Dissolved Oxygen: Oklahoma water quality standards for dissolved oxygen for Lake Thunderbird are specified in relation to (a) the surface layer/epilimnion, (b) the entire water column and (c) the anoxic volume of the lake within the hypolimnion. Within the surface layer/epilimnion under stratified conditions, dissolved oxygen shall be no less than 6 mg/L from April 1 to June 15 for protection of early life stages and no less than 5 mg/L from June 16 to March 31 for protection of other life stages of a warm water aquatic community. Within the entire water column when the lake is well-mixed (i.e., non-stratified), dissolved oxygen shall be no less than 6 mg/L from April 1 to June 15 for protection of early life stages and no less than 5 mg/L from June 16 to March 31 for protection of other life stages of a warm water aquatic community. Within the hypolimnion, the anoxic volume of the lake, defined by a cutoff DO level of 2 mg/L, shall not exceed 50% of the lake volume during the period of seasonal stratification from mid-May through October 1. Model results for dissolved oxygen at the deep lacustrine sites (1, 2 and 4) show good agreement with the observed seasonal trend of both surface layer oxygen levels and bottom layer oxygen depletion where the observed anoxic conditions are controlled by the onset and erosion of lake stratification. Model results for dissolved oxygen for each grid cell are post-processed to derive a composite time series to compute the percentage of the whole lake volume defined as anoxic by the cutoff target DO level of 2 mg/L. On a whole lake basis, the maximum percentage of the lake volume defined by the target oxygen level of 2 mg/L for 2008 - 2009 is estimated at ~30% in early August just prior to the two large storm events of August 2008. Since the maximum anoxic volume estimated for the whole lake is ~30%, the water quality anoxic volume target of no more than 50% of the lake volume less than 2 mg/L during stratification is attained for the 2008 - 2009 calibration period.

Benthic Flux of Phosphate: Model results are also analyzed to evaluate benthic flux rates of phosphate and sediment oxygen demand simulated with the sediment diagenesis model since these coupled water column-sediment bed processes are critical for model results for chlorophyll-a and dissolved oxygen. Since observed measurements of the benthic flux of phosphate are not available for Lake Thunderbird, mean values of modeled benthic phosphate fluxes are computed for the summer stratified anoxic period from May 15 through October 1, 2008 for the lacustrine monitoring stations (Site 1, 2 and 4) for comparison to literature data for other lakes and reservoirs. The mean benthic flux rates for phosphate, computed as 4.8, 3.4, and 5.4 mg P/m^2-day for Sites 1, 2 and 4, respectively, are thus consistent with the 10th to 90th percentile range of anoxic phosphate fluxes of ~2 to 8 mg P/m^2-day measured by Dzialowski and Carter (2011).in mesotrophic reservoirs in Missouri and Kansas.

Model-Data Performance: The Relative RMS Error performance targets, defined as a composite statistic derived from pooled model-observed data pairs from all stations, are consistent with model performance targets recommended for surface water models (Donigian, 2000). As presented in Appendix B, the model performance targets for water level and dissolved oxygen (20%), water temperature, nitrate and total organic phosphorus (50%), and chlorophyll (100%) are all attained with the model results for these variables much better than, or close to, the target criteria. The model results for TSS, total phosphorus, total phosphate, and total nitrogen are also good with the model performance statistics shown to be only 5-6% over the target criteria of 50%. The exceptions to the overall good results achieved with the model are for Total Organic Carbon and Total Organic Nitrogen where the Relative RMS Errors exceed the target criteria of 50% by over 25%.

Given the lack of a general consensus for defining quantitative model performance criteria, the inherent errors in input and observed data, and the approximate nature of model formulations, *absolute* criteria for model acceptance or rejection are not appropriate for studies such as the development of the lake model for Lake Thunderbird. The Relative RMS Errors are used as targets for performance evaluation of the calibration of the model, but not as rigid absolute criteria for rejection or acceptance of model results. The "weight of evidence" approach used in this study recognizes that, as an approximation of a waterbody, perfect agreement between observed data and model results is not expected and is not specified as performance criteria for defining the success of model calibration. Model performance statistics are used as guidelines to supplement the visual evaluation of model-data plots for model calibration. The "weight of evidence" approach used for this study thus acknowledges the approximate nature of the model and the inherent uncertainty in both input data and observed data.

4.4 Pollutant Loads for Existing Model Calibration (2008 - 2009)

Using data developed for calibration of the watershed model and the lake model to 2008 - 2009 conditions, mass loads for sediment, nutrients and CBOD are compiled to identify the relative magnitude of the external and internal sources of pollutant loading to the lake. External sources include tributary inputs, wet and dry atmospheric deposition, and overland runoff from the watershed. Internal sources include the benthic fluxes of inorganic nutrients across the sediment-water interface of the lake. Loading rates (as kg/day) are compiled for the 375 day simulation period from April 2008-April 2009. In addition to documentation of the external and internal sources of pollutants in this section, a more detailed analysis of model data is presented in Appendix B to compare the inputs (external and internal sources) and outputs (sinks) of phosphorus. The input and output load data for the existing conditions model calibration is used to estimate total phosphorus retention in Lake Thunderbird from April 2008 through April 2009. Table 4-1 presents a summary of nutrients, CBOD and sediment loads for the existing 2008 - 2009 calibration conditions for HSPF watershed loads. The table presents a summary, and comparison, of the external sources from the watershed and atmospheric deposition and internal benthic flux loading rates for the existing 2008 - 2009 calibration conditions.

Table 4-1 Annual Loading of Nutrients, CBOD and Sediment for Existing Calibration Conditions (2008 - 2009) Delivered to Lake Thunderbird

Model Calibration Source Existing 2008 - 2009	Annual HSPF kg/day	Annual AtmDep kg/day	Annual SedFlux kg/day	Annual Total kg/day
Total Nitrogen (TN)	322.0	112.1	90.1	524.2
Nitrate (NO3)	31.0	79.5	59.5	170.0
Ammonia (NH4)	7.7	32.6	30.6	70.9
Total_OrgN	283.0	0.0	0.0	283.0
Algae_PON	0.23	0.00	0.00	0.23
DIN(NO3+NH4)	38.8	112.1	90.1	241.0
Total Phosphorus (TP)	63.3	0.5	66.5	130.3
Phosphate(PO4)	7.9	0.5	66.5	74.9
Total_OrgP	55.3	0.0	0.0	55.3
Algae_POP	0.03	0.00	0.00	0.03
CBOD	647.1	0.0	0.0	647.1
Suspended solids	31,486.8	0.0	0.0	31,486.8

Table 4-2 presents the percentage contributions of watershed, atmospheric deposition and benthic flux loading to the total loads. As shown in Table 4-2 , internal benthic flux of phosphate accounts for 89% of the phosphate loading and 51% of the total phosphorus to the Lake on an annual basis. Atmospheric deposition of the sum of nitrate and ammonia (DIN) accounts for 46% of the inorganic nitrogen input and 21% of the total nitrogen input to the Lake. The benthic flux of DIN accounts for 37% of the total DIN loading and 17% of the total nitrogen input. Accounting for about one-fifth of the total nitrogen loading, atmospheric deposition (21%) and benthic flux (17%) both represent a significant contribution to the total nitrogen load to the Lake.

Table 4-2 Percentage Contribution of Annual Watershed Loading, Atmospheric Deposition and Sediment Flux for Nutrients, CBOD and Sediment for Existing Calibration Conditions (2008 - 2009)

Model Calibration	Annual	Annual	Annual	Annual
Source	**HSPF**	**AtmDep**	**SedFlux**	**Total**
Existing 2008 - 2009	**%**	**%**	**%**	**%**
Total Nitrogen (TN)	61.4%	21.4%	17.2%	100%
Nitrate (NO3)	18.3%	46.8%	35.0%	100%
Ammonia (NH4)	10.9%	46.0%	43.1%	100%
Total_OrgN	100.0%	0.0%	0.0%	100%
Algae_PON	100.0%	0.0%	0.0%	100%
DIN(NO3+NH4)	16.1%	46.5%	37.4%	100%
Total Phosphorus (TP)	48.6%	0.4%	51.1%	100%
Phosphate(PO4)	10.6%	0.7%	88.8%	100%
Total_OrgP	100.0%	0.0%	0.0%	100%
Algae_POP	100.0%	0.0%	0.0%	100%
CBOD	100.0%	0.0%	0.0%	100%
Suspended solids	100.0%	0.0%	0.0%	100%

4.5 Water Quality Response to Modeled Load Reduction Scenarios

The calibrated lake model was used to evaluate the water quality response to reductions in watershed loading of sediment, nutrients and CBOD. Load reduction scenario simulation runs were performed to determine if water quality targets for turbidity, chlorophyll and dissolved oxygen could be attained with watershed-based load reductions of 25%, 35%, 50%, and 75%. Based on an evaluation of the load reduction scenario results the 35% removal alternative was selected for a detailed “spin-up” analysis of the long-term water quality response of the Lake to changes in watershed loads. The 35% removal scenario was used to simulate eight years of sequential “spin-up” runs to evaluate the long-term response of water quality conditions in the Lake to the 35% removal change in external loads from the watershed. For the set of spin-up runs, watershed flow and reduced pollutant loading from the HSPF model were repeated for each of the eight spin-up years. The results derived from the eight years of spin-up simulations did not, therefore, account for any projected, or future, conditions of hydrologic variability within the watershed.

The 35% pollutant removal scenario identified for the TMDL for Lake Thunderbird is based on a simple uniform reduction of all sediment, CBOD, TN and TP loads contributed by all tributaries, stormwater point sources and distributed runoff from the watershed to represent the reduction of pollutant loads to Lake Thunderbird. The methodology applied for developing the load reduction scenarios did not attempt to represent changes in external watershed loading based on implementation of specific BMPs or point source waste load allocations.

Results of the spin-up model runs for the 35% removal scenario are presented to show long-term trends in turbidity, chlorophyll, dissolved oxygen, benthic phosphate flux, and sediment oxygen demand. The spin-up results are also used to evaluate long-term changes in the relative contribution of internal phosphate loading from the sediment bed to external phosphate loads from the watershed and atmospheric deposition.

Turbidity and Chlorophyll-a: As discussed in Section 2 of this report, Oklahoma Water Quality Standards for Lake Thunderbird turbidity and chlorophyll-*a* are as follows:

- *Turbidity*: no more than 10% of turbidity samples greater than 25 NTU based on compilation of records of most recent 10 years
- *Chlorophyll-a*: Average value of surface chlorophyll-*a* no greater than 10 µg/L based on long-term historical record of most recent 10 years

Table 4-3 summarizes the annual statistics for turbidity and chlorophyll-*a* for (a) the observed data collected in 2008 - 2009 used for model calibration, (b) the calibrated model results and the results generated with (c) eight years of spin-up runs for the 35% removal scenario, respectively. Summary statistics are computed from model results for all eight sites for the annual simulation period from April 2008-April 2009. The chlorophyll-*a* statistic is computed as the average of the model results for all eight sites. The turbidity statistic is computed as the 90th percentile of the model results for all eight sites. The number of simulation records for the model statistics (N=17,856) are based on 2,232 records per site for eight sites.

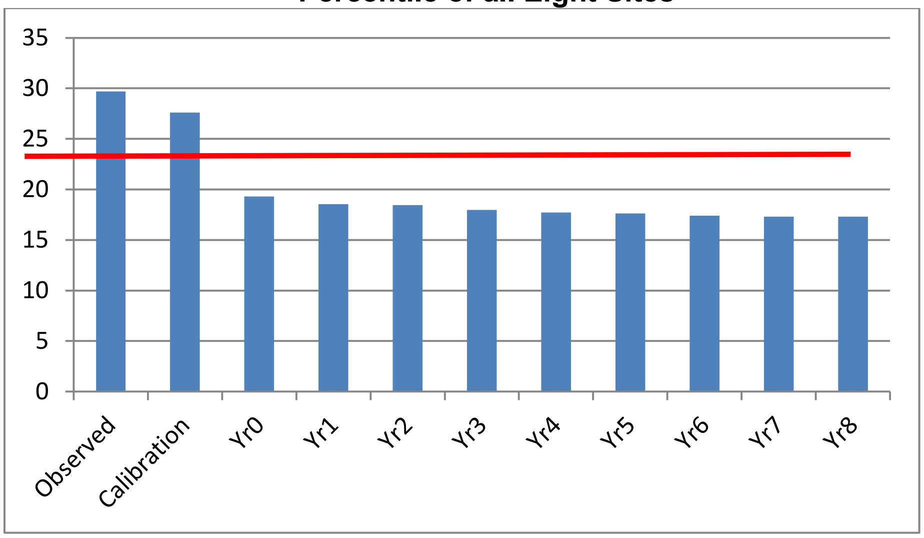
Table 4-3 Summary Statistics for Chlorophyll-*a* and Turbidity for Observed Data, Model Calibration and 8 Years (Year 1 – Year 8) of Spin-Up Runs of the 35% Removal Scenario

[Observed Data and Model Results are Aggregated Over the Whole Lake for the Simulation Period (2008 - 2009)]

35%R	8 SITES	8 SITES	8 SITES	8 SITES
	Chlorophyll-*a*	Turbidity	Chlorophyll-*a*	Turbidity
	(µg/L)	(NTU)	(µg/L)	(NTU)
Annual	Average	90th percentile	Percent Change	Percent Change
Target	10	25		
Observed	24.8	29.7		
Calibration	21.5	27.6		
Year 0	23.0	19.3		
Year 1	24.5	18.5	6.6%	-3.8%
Year 2	20.5	18.4	-16.4%	-0.6%
Year 3	15.6	18.0	-23.9%	-2.5%
Year 4	11.8	17.7	-24.3%	-1.4%
Year 5	10.0	17.6	-15.2%	-0.6%
Year 6	9.3	17.4	-7.6%	-1.1%
Year 7	8.9	17.3	-3.4%	-0.7%
Year 8	8.9	17.3	-0.9%	0.0%

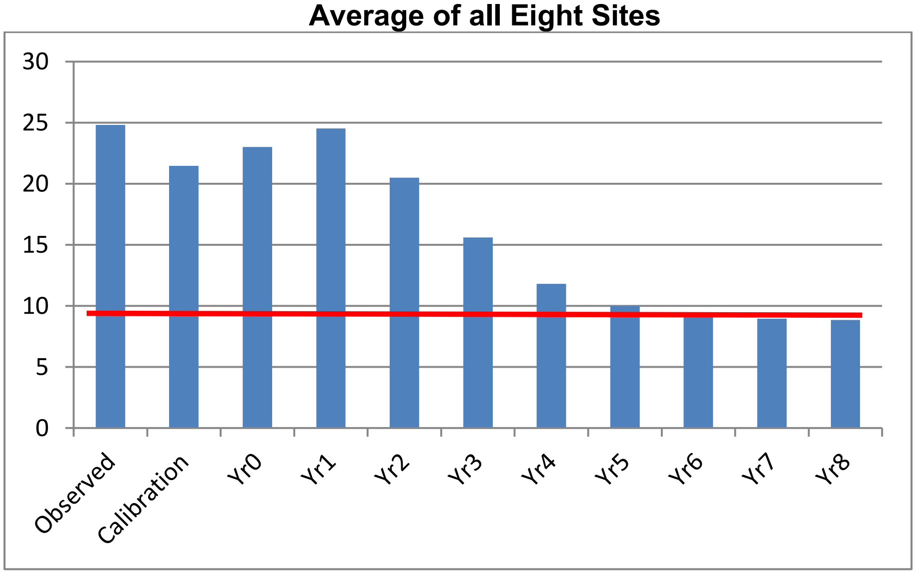
As can be seen in the data presented in Table 4-3, the 90th percentile for observed turbidity (29.7 NTU) exceeds the target of 25 NTU. The calibrated model results for surface turbidity (27.6 NTU) also show non-compliance with the target of 25 NTU. Each of the spin-up runs for the 35% management scenario show a gradual improvement in turbidity with respect to compliance with the target of 25 NTU.Figure 4-2 presents the long-term trends for the turbidity data presented in Table 4-3 for the 35% removal scenario.

Figure 4-2 Surface Turbidity (NTU): Spin-Up Model Results for 35% Removal, Annual 90th Percentile of all Eight Sites



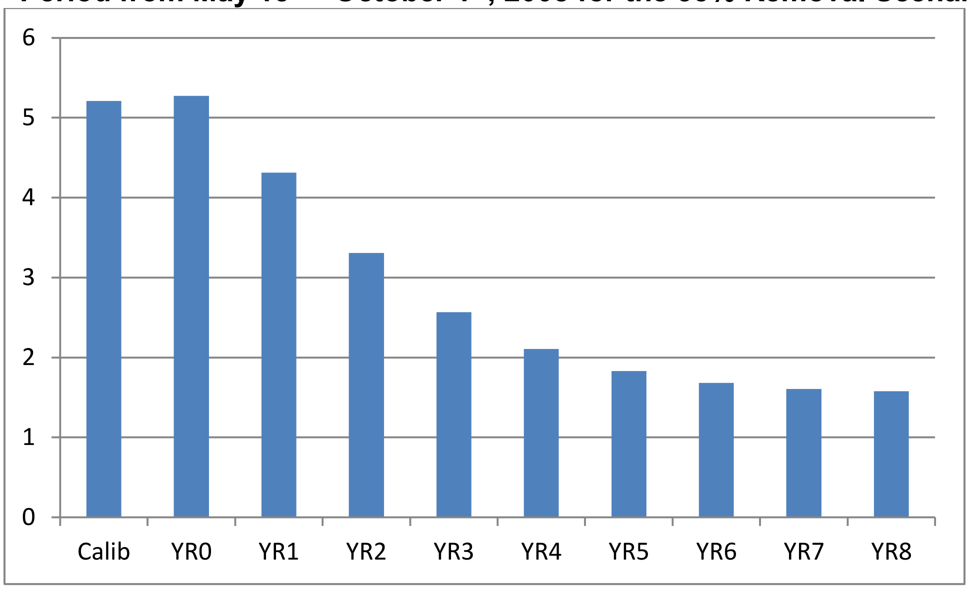
As shown in Table 4-3, the 2008 - 2009 average for observed surface chlorophyll-a (24.8 µg/L) exceeds the target criteria for SWS lakes of 10 µg/L. The calibrated model results for chlorophyll-*a* (21.5 µg/L) also show non-compliance with the SWS target criteria. Figure 4-3 shows the spin-up trend for the chlorophyll data presented in Table 4-3 for the 35% removal scenario. Algae biomass increases for Year 0 and Year 1 of the 35% removal scenario because turbidity is reduced, water clarity is improved and primary productivity increases with increased light availability for algae growth.

Figure 4-3 Surface chlorophyll-*a* (µg/L): Spin-Up Model Results for 35% Removal and Annual Average of all Eight Sites



After Year 1, chlorophyll-*a* progressively declines each year until the SWS water quality criteria of 10 µg/L is attained by Year 5 under the 35% removal scenario. Chlorophyll-*a* gradually declines after the first spin-up year because the supply of phosphorus available to support primary production in the euphotic zone diminishes as internal phosphorus loading from benthic phosphate flux is reduced (see Figure 4-4). The largest contribution of internal loading of phosphate to the Lake, controlled by hypoxic bottom water oxygen conditions, occurs during the summer stratified period from mid-May to early October. As can be seen in Figure 4-4 the whole lake seasonal benthic phosphate flux declines from 5.3 mg P/m^2-day for the initial year (Year 0) to 1.6 mg P/m^2-day after eight years of model spin-up as the coupled interaction of the sediment-water system attains a new equilibrium condition.

Figure 4-4 Sediment Flux PO4 (Mg P/M^2-Day), Whole Lake Average for Seasonal Stratified Period from May 15th - October 1st, 2008 for the 35% Removal Scenario



The spin-up simulation analysis of the coupled water column-sediment bed response to the 35% reduction in watershed loading of sediment and nutrients indicates that compliance with the SWS target for chlorophyll-*a* of 10 µg/L can be attained within a reasonable time frame. **It is important to emphasize that the model spin-up results are <u>not</u> a prediction of the number of years required for lake recovery because of the idealized spin-up conditions of a precisely maintained watershed load reduction level and repeated climatic and hydrologic conditions of 2008 - 2009.** The model results, do, however, provide technically credible evidence that future conditions can be in compliance with SWS water quality criteria for chlorophyll-*a* within a reasonable time frame if watershed loads are reduced as recommended and the reduction is sustained.

Dissolved Oxygen and Sediment Oxygen Demand: Oklahoma water quality standards for dissolved oxygen for Lake Thunderbird are specified in relation to (a) stratified conditions for the surface layer (epilimnion) and the anoxic volume of the Lake within the hypolimnion and (b) non-stratified conditions over the entire water column. Within the surface layer (epilimnion) during the period of thermal stratification, 10% or less of the dissolved oxygen samples shall be no less than 6 mg/L from April 1 to June 15 and no less than 5 mg/L during the remainder of the year (June 16 to March 31) based on long-term records of the most recent 10 years. Within the hypolimnion, the anoxic volume of the lake, defined by the 2 mg/L cutoff target for DO, shall not exceed 50% of the lake volume during the period of seasonal thermal stratification. Within the entire water column during the period when the lake is not stratified, 10% or less of the dissolved oxygen samples shall be no less than 6 mg/L from April 1 to June 15 and no less than 5 mg/L during the remainder of the year (June 16 to March 31) based on long-term records of the most recent 10 years.

The period of seasonal thermal stratification for Lake Thunderbird is determined using water temperature observations from Site 1, Site 2, and Site 4 in the lacustrine zone of the lake. Dates for the onset and erosion of thermal stratification were based on the vertical temperature gradient between surface layer and bottom layer observations. Figure 4-5 shows surface and bottom layer temperature observations for Site 1, Site 2 and Site 4 for April 2008 through October 2009.

Figure 4-5 Surface and Bottom Layer Water Temperature for Lacustrine Sites in Lake Thunderbird, 2008 - 2009.

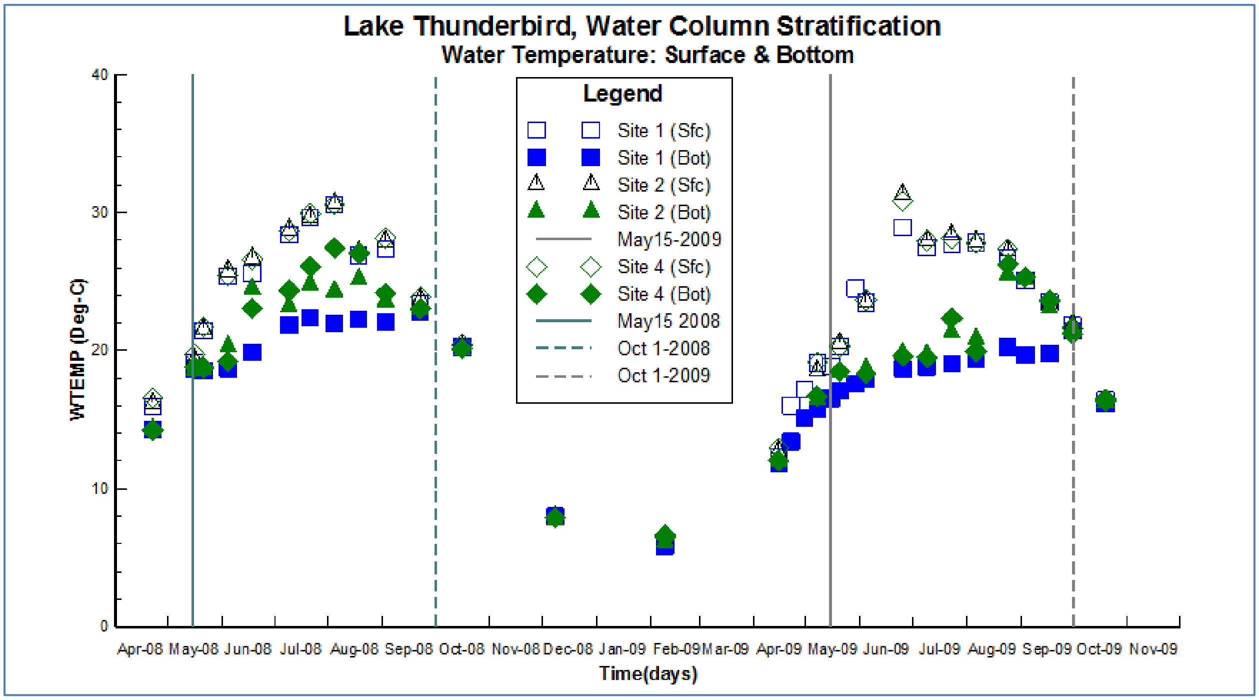
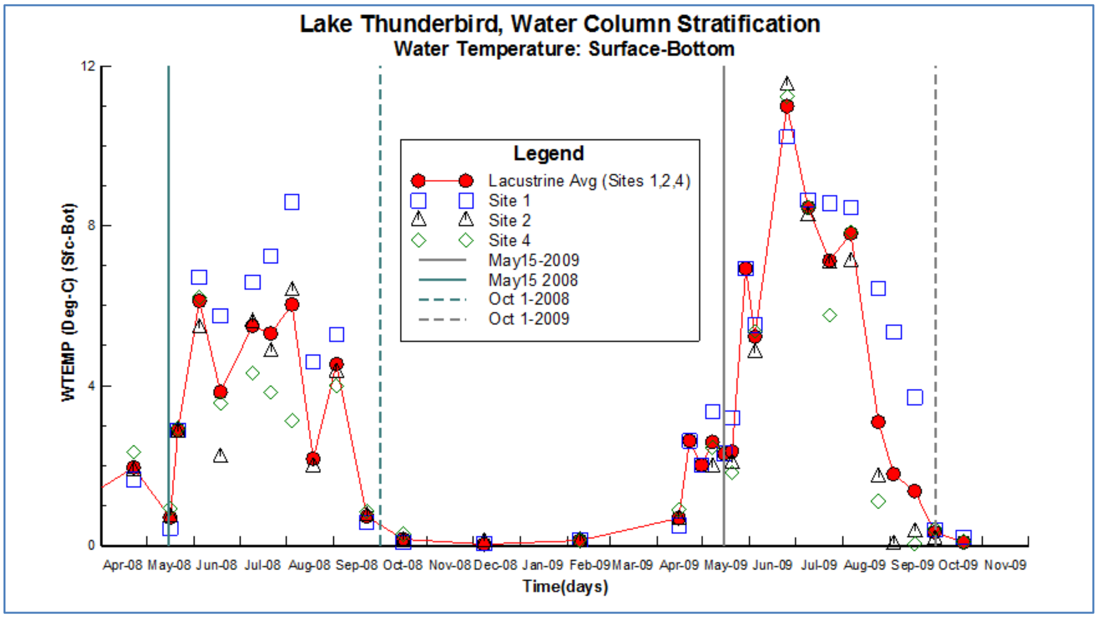


Figure 4-6 shows the difference between surface and bottom temperature for each site and the average of the three sites. May 15 is defined as the date for the onset of stratification when the vertical temperature gradient begins to increase. By October 1, the temperature gradient decreases and remains small through the well-mixed non-stratified winter-spring months until the onset of stratification begins again in May 2009. The time series plots show marker lines for May 15 and October 1 for 2008 and 2009.

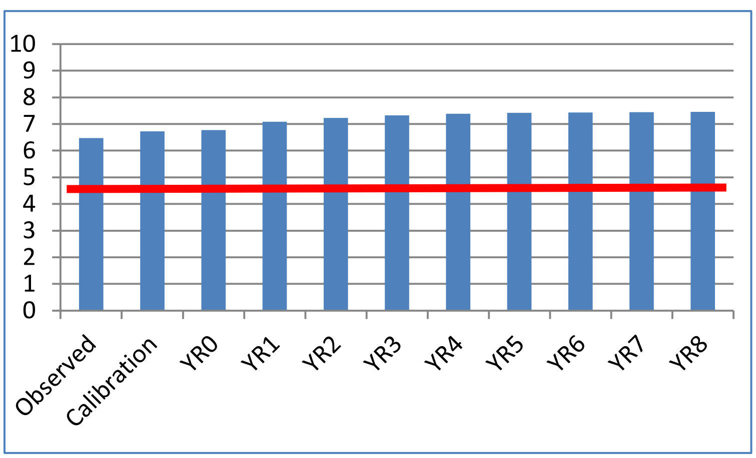
Under the 35% load reduction determined for the TMDL, compliance with the water quality criteria for dissolved oxygen is demonstrated for (a) stratified conditions for the surface layer (epilimnion) and the anoxic volume of lake and (b) the entire water column for the period when the lake is not stratified.

Figure 4-6 Temperature Stratification (Surface-Bottom) for Lacustrine Sites in Lake Thunderbird, 2008 - 2009



Stratified Period, Surface Layer (Epilimnion) : Water quality criteria require that DO levels be 6 mg/L or more during stratified conditions from April 1 through June 15. The criteria also requires that DO levels be 5 mg/L or more during stratified conditions from June 16 through the remainder of the year. For Lake Thunderbird observed water temperature data shows that stratification begins on May 15 and ends on October 1. Model results, extracted for the stratified period from May 15-October 1, for surface layer dissolved oxygen are seen to be in compliance with the water quality criteria for surface DO levels with the 10th percentile values of DO greater than the most stringent stratified season criteria of 5 mg/L (Figure 4-7).

Figure 4-7 Surface Layer (Epilimnion) Dissolved Oxygen (mg/L): Spin-Up Model Results for 35% Removal, Seasonal Stratified Period 10th Percentile of all Eight Sites

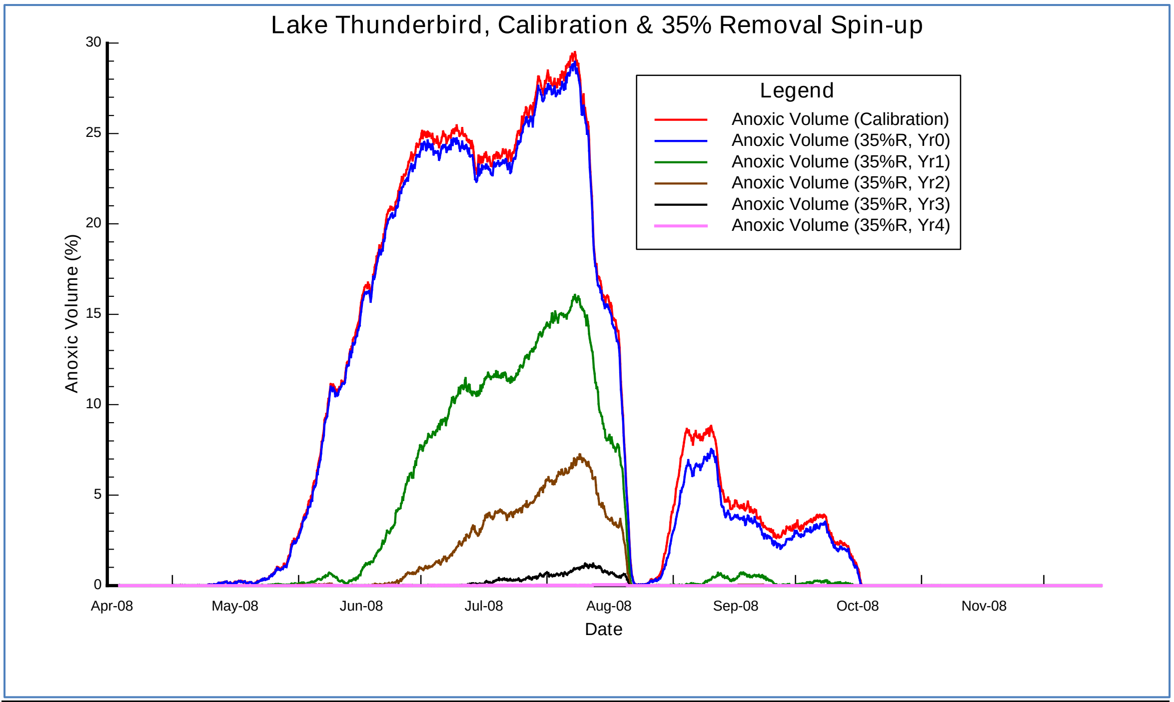


Stratified Period, Anoxic Lake Volume: Water quality criteria require that 50% or less of the lake volume be lower than a 2 mg/L cutoff level of DO during the period of seasonal thermal stratification The results of the computations of anoxic volume, based on a target oxygen level of 2 mg/L, are presented as time series of anoxic volume of the whole lake in Figure 4-8 for the 35%

removal scenario with a comparison shown to the anoxic volume results for the existing calibration conditions. As can be seen by comparison of the model calibration to the progression of spin-up years, the anoxic volume gradually decreases with each spin-up year as a result of the 35% reduction of watershed loading.

Figure 4-8 Time Series of Anoxic Volume of Whole Lake For 35% Removal Management Scenario.

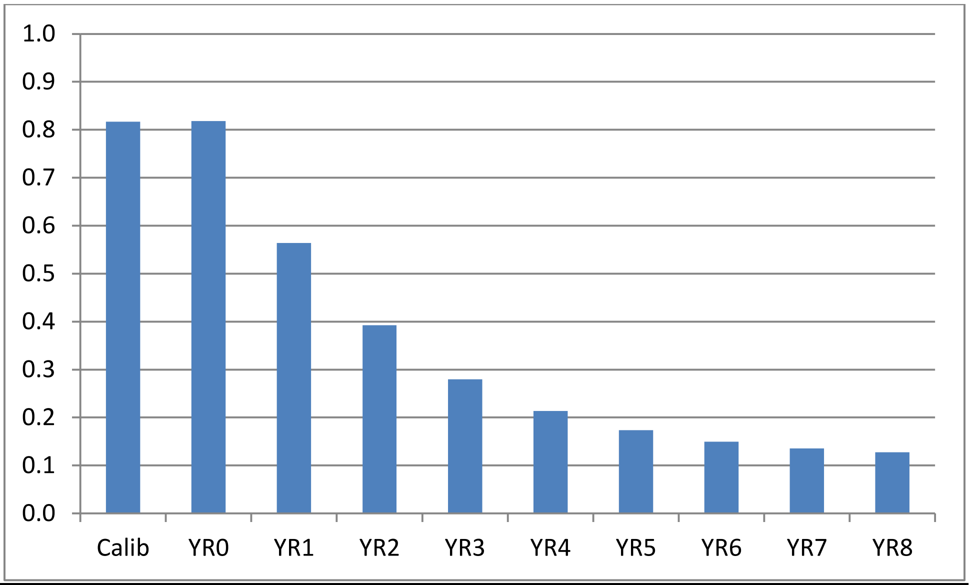
Model Calibration Results are Shown as Red Line. Percentage of Anoxic Volume is Based on Aggregation of All Grid Cells in the Lake. The DO Cutoff Target is 2 Mg/L



The anoxic volume of the lake gradually decreases because the whole lake sediment oxygen demand (SOD) is reduced with each spin-up year of the 35% removal scenario (Figure 4-9). SOD gradually declines from ~0.8 g O_2/m^2-day for the initial year (Year 0) to 0.2 g O_2/m^2-day after 4 years and ~0.12 g O_2/m^2-day after eight years of spin-up for the 35% removal scenario. The gradual decline in SOD reflects the response of the coupled water column and sediment bed of the lake to new equilibrium conditions for particulate organic matter deposition to the sediment bed based on the effectiveness of the load reduction scenario for 35% removal of sediments and nutrients from watershed loading.

As a management alternative in response to the repeated occurrence of hypolimnetic anoxia during summer stratified conditions, an oxygen injection system has been installed in Lake Thunderbird (Cadenhead, 2012). COMCD received an American Recovery and Reinvestment Act of 2009 grant (ARRA) to install and operate a Supersaturated Dissolved Oxygen (SDOX) system and in 2010, the COMCD partnered with the OWRB, to design, install, and monitor the SDOX pump at the Lake's deepest area near the dam. This energy-efficient pump uses the latest technology to prevent the Lakes hypolimnion from going anoxic throughout the summer months without disrupting the Lake's natural thermocline. As discussed in Section 4.3.2, seasonal anoxia exacerbates eutrophic conditions in the Lake by triggering the benthic release of nutrients as an internal load to the water column. Eutrophic conditions that favor bluegreen algae (cyanobacteria) blooms contribute to taste and odor problems in drinking water. Operation of the SDOX device is targeted to improve oxygen levels in the Lake to support the warm water fishery but also to reduce the treatment cost for drinking water. Since the SDOX system became operational after the study period of 2008 - 2009, the effects of the oxygen injection system are not represented in either calibration of the model to existing conditions or to the projection of the water quality impact of the 35% removal scenario.

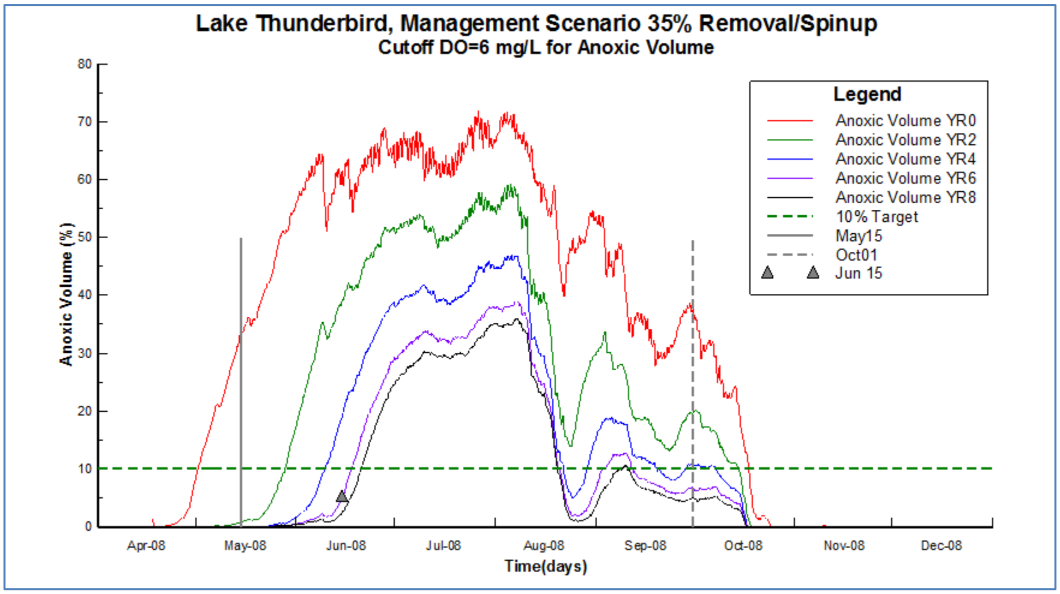
Figure 4-9 Sediment Oxygen Demand (G O_2/M^2-Day), Whole Lake Average for Seasonal Stratified Period from May 15th - October 1st, 2008 for the 35% Removal Scenario



Non-Stratified Period, Entire Water Column: Compliance with water quality criteria for DO during well-mixed conditions when the lake is not stratified requires that 10% or less of the DO records be (a) greater than 6 mg/L from April 1 to June 15 and (b) greater than 5 mg/L for the remainder of the year (i.e., June 16 through March 31). Based on the beginning and ending dates for stratification of Lake Thunderbird of May 15 through October 1, DO over the entire water column must be greater than 6 mg/L from April 1 until May 15 when seasonal stratification begins. DO over the entire water column must then be greater than 5 mg/L after October 1 when the lake is once again well-mixed.

Computations were performed with a post-processing utility in EFDC_Explorer designed to evaluate the anoxic volume of a lake based on input of a cutoff DO concentration. In order to assess compliance with Oklahoma DO criteria for non-stratified conditions, lake volumes less than specified cutoff oxygen concentrations were compiled for (a) 6 mg/L to cover the non-stratified period from April 1 through May 15; and (b) 5 mg/L to cover the remainder of the year after October 1. Figure 4-10 shows the time series for the lake volume less than 6 mg/L and Figure 4-11 shows the time series for the lake volume less than 5 mg/L. Spin-up model results are presented in the time series plots for every other year of the spin-up series (Year 0, Year 2, Year 4, Year 6 and Year 8). The water quality criterion requires that 10% or less of the samples be less than the target levels (5 or 6 mg/L). The 10% target for the DO criteria is shown on the plots as the dashed line. Marker lines are included on the plots to show the beginning date (May 15) and ending date (October 1) for thermal stratification in Lake Thunderbird.

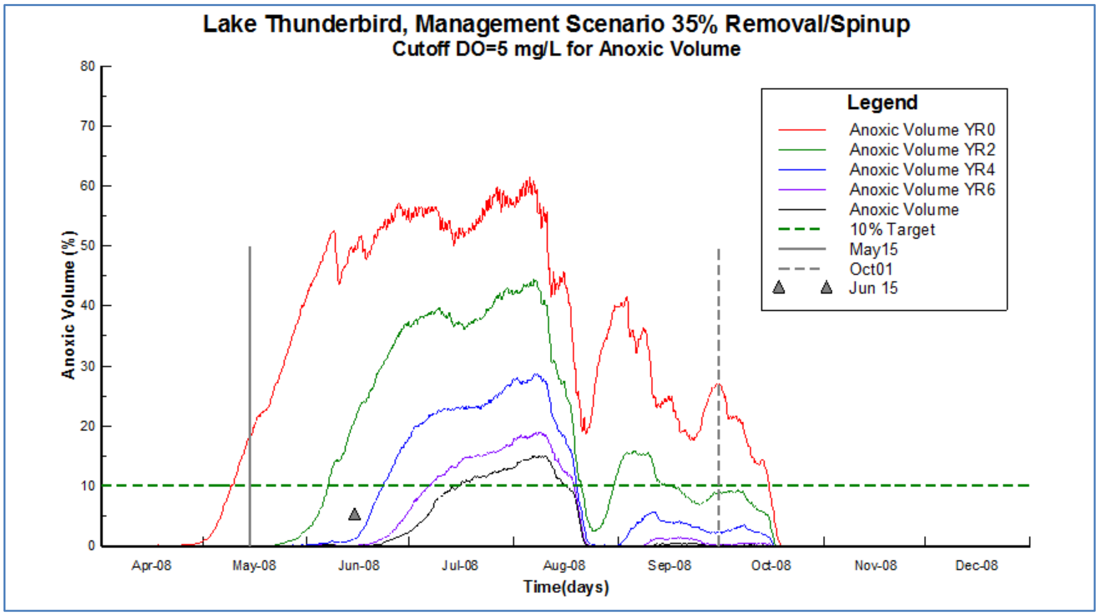
Figure 4-10 Whole Lake Volume Weighted Percentage of Lake Less than Cutoff Concentration of 6 mg/L for Spin-Up Years (Year 0, Year 2, Year 4, Year 6, and Year 8).



April 1 through May 15, Non-stratified: The model results for the spin-up years Year 2, Year 4, Year 6 and Year 8 are all much less than the 10% lake volume for the target cutoff criterion of 6 mg/L for the period from April 1 until May 15 when the water column begins to stratify (Figure 4-10). The model results thus demonstrate that the entire water column of Lake Thunderbird will be in compliance with the criterion of 6 mg/L for the non-stratified period from April 1 through May 15.

October 1 through May 15, Non-stratified: The model results for spin-up year Year 2 are just below the 10% target for the criterion of 5 mg/L. The model results for spin-up years Year 4, Year 6 and Year 8, however, are all seen to be much lower than the 10% lake volume target cutoff criterion of 5 mg/L for the period after October 1 when stratification begins to erode and the lake is well-mixed (Figure 4-11). The model results thus demonstrate that the entire water column of Lake Thunderbird will be in compliance with the non-stratified criterion of 5 mg/L for the period from October 1 through the following May 15 when the Lake begins to stratify in the following summer. As demonstrated with the analysis of model results for the spin-up years, the 35% reduction of nutrients and sediment loads determined for the TMDL is expected to result in compliance with Oklahoma water quality criteria for dissolved oxygen under both stratified and non-stratified conditions.

Figure 4-11 Whole Lake Volume Weighted Percentage of Lake Less than Cutoff Concentration of 5 mg/L for Spin-Up Years (Year 0, Year 2, Year 4, Year 6, and Year 8)



4.6 Pollutant Loads for 35% Removal Scenario

Table 4-4 presents a summary of the April 2008 - April 2009 loads for the 35% removal scenario for HSPF watershed loads, and comparison, of the external sources and internal benthic flux loading rates for the 35% removal scenario.

Table 4-4 Annual Loading of Nutrients, CBOD and Suspended Solids for 35% Removal Scenario

Model 35% Removal Source Year 8 Spinup	Annual HSPF kg/day	Annual AtmDep kg/day	Annual SedFlux kg/day	Annual Total kg/day
Total Nitrogen (TN)	209.3	112.1	-35.3	286.1
Nitrate (NO3)	20.2	79.5	-21.8	77.9
Ammonia (NH4)	5.0	32.6	-13.5	24.1
Total_OrgN	184.0	0.0	0.0	184.0
Algae_PON	0.15	0.00	0.00	0.15
DIN(NO3+NH4)	25.2	112.1	-35.3	102.0
Total Phosphorus (TP)	41.1	0.5	21.6	63.2
Phosphate(PO4)	5.1	0.5	21.6	27.2
Total_OrgP	36.0	0.0	0.0	36.0
Algae_POP	0.02	0.00	0.00	0.02
CBOD	647.1	0.0	0.0	647.1
Suspended solids	20,466.4	0.0	0.0	20,466.4

Table 4-5 presents the percentage contributions of watershed, atmospheric deposition and benthic flux loading to the total nutrient load for the 35% removal scenario. As shown in Table 4-5, the contribution of the internal benthic flux of phosphate decreases from 89% of the phosphate load and 51% of the total phosphorus load for the existing calibration condition to 79% of the phosphate load and 34% of the total phosphorus load for the 35% removal case after a spin-up period of eight years.

In contrast to the existing conditions for model calibration where the sediment bed is a significant source of inorganic nitrogen (DIN) to the lake, the model spin-up results after eight years suggest that the sediment bed may be a sink for DIN. The results of the spin-up after eight years for the 35% removal scenario indicates that DIN may be lost from the water column to the sediment bed under the simulated conditions for the bed. As shown in Table 4-4, a negative sediment flux load for ammonia and nitrate represents a loss of inorganic nitrogen from the water column to the sediment bed**.** With reduced external watershed loading and organic matter deposition from the water column, organic matter in the sediment bed is slowly decomposed and DIN concentrations in porewater decline. Benthic release rates gradually decrease over time until conditions exist where the DIN concentration in the sediment bed is lower than the DIN concentration in the overlying water column; and DIN is transported by diffusion from the water column to the sediment bed.

As shown in Table 4-4 for the 35% removal scenario, the external input of nitrate from the watershed (~20 kg/day) is approximately equivalent to the internal loss of nitrate from the water column to the bed (~22 kg/day). The internal loss of ammonia from the water column to the sediment bed (~13.5 kg/day) is almost three times the external input of ammonia from the watershed (5 kg/day). Overall, the total estimated inputs of phosphate are decreased by 33% with the phosphate load declining from 66.5 kg/day for the existing calibration case to 21.6 kg/day for the 35% removal scenario (Table 4-4). Similarly, the total estimated inputs of inorganic nitrogen are decreased by 42% with the sum of the nitrate and ammonia (DIN) load declining from 241.0 kg/day for the existing calibration case to 102.0 kg/day for the 35% removal scenario (Table 4-4).

Table 4-5 Percentage Contribution of Annual Watershed Loading, Atmospheric Deposition and Sediment Flux for Nutrients, CBOD and Sediment for 35% Removal Scenario

Model 35% Removal	Annual	Annual	Annual	Annual
Source	**HSPF**	**AtmDep**	**SedFlux**	**Total**
Year 8 Spinup	**%**	**%**	**%**	**%**
Total Nitrogen (TN)	73.2%	39.2%	-12.3%	100%
Nitrate (NO3)	25.9%	102.1%	-28.0%	100%
Ammonia (NH4)	20.9%	135.3%	-56.2%	100%
Total_OrgN	100.0%	0.0%	0.0%	100%
Algae_PON	100.0%	0.0%	0.0%	100%
DIN(NO3+NH4)	24.7%	109.9%	-34.6%	100%
Total Phosphorus (TP)	65.1%	0.8%	34.1%	100%
Phosphate(PO4)	18.9%	1.8%	79.3%	100%
Total_OrgP	100.0%	0.0%	0.0%	100%
Algae_POP	100.0%	0.0%	0.0%	100%
CBOD	100.0%	0.0%	0.0%	100%
Suspended solids	100.0%	0.0%	0.0%	100%

4.7 Summary

The EFDC lake model incorporates watershed loading and internal coupling of organic matter deposition to the sediment bed with decomposition processes in the bed that, in turn, produce benthic fluxes of nutrients and sediment oxygen demand (SOD) across the sediment-water interface. Lake Thunderbird, like many reservoirs, is characterized by seasonal thermal stratification and hypolimnetic anoxia. Summer anoxic conditions, in turn, are associated with internal nutrient loading from the benthic release of phosphate and ammonia into the water column that is triggered, in part, by low oxygen conditions. The mass balance based model, calibrated to 2008 - 2009 data, accounts for the cause-effect interactions of water clarity, nutrient cycling, algal production, organic matter deposition, sediment decay, and sediment-water fluxes of nutrients and oxygen.

The spin-up results for the 35% removal scenario suggest that chlorophyll-*a* may increase initially because of the availability of nutrients combined with the reduction of turbidity and improvement in water clarity, all favorable conditions for algae growth. Over time, however, the sediment bed reservoir of nutrients will diminish, benthic release of nutrients to the Lake will be reduced and the pool of nutrients available to support algal production will be reduced. The model results demonstrate a gradual reduction in internal loading of nutrients from the sediment bed and an improvement in water quality conditions over the years based on the spin-up runs for the 35% removal scenario.

The model indicates that water quality conditions are expected to be in compliance with the SWS water quality criteria for chlorophyll-*a* of 10 µg/L within a reasonable timeframe. It is important to note, however, that the spin-up results for the 35% removal scenario should not be taken as absolute projections of future water quality conditions in the Lake with certainty as to some future calendar date because of the idealized spin-up conditions of a precisely maintained watershed load reduction level and repeated climatic conditions of a past year. The model, does however, provide a technically credible framework that clearly shows that water quality improvements can be achieved in Lake Thunderbird within a reasonable time frame to support the desired beneficial uses if watershed loading can be controlled and sustained to a level based on 35% reduction of the existing loading conditions. Attainment of water quality standards will occur, however, only over a period of time and only after full implementation of source controls and BMPs considered necessary to achieve an overall 35% removal of sediment and nutrients from the watershed.

Although the model demonstrates that internal loading of phosphate is a significant controlling factor for eutrophication in the Lake, loading from the watershed is a direct factor in the deterioration of water quality conditions and ultimately the accumulation in the Lake sediment of excessive nutrients and organic matter from the watershed over the past five decades is the source of the internal loading. Reductions in watershed loading are therefore required to achieve improvements in Lake water quality. The model results suggest that compliance with water quality criteria for turbidity, dissolved oxygen and chlorophyll-a can be achieved with a 35% removal of sediments and nutrients from watershed loading to the Lake within a reasonable time frame. The model results thus support the development of TMDLs for sediments, CBOD, TN and TP to achieve compliance with water quality standards for turbidity, chlorophyll-*a* and dissolved oxygen. The calibrated HSPF watershed runoff model and the EFDC hydrodynamic and water quality model of Lake Thunderbird provides DEQ with a scientifically defensible surface water model framework to support development of TMDLs and water quality management plans for Lake Thunderbird.

SECTION 5 TMDLS AND LOAD ALLOCATIONS

The linked watershed (HSPF) and lake (EFDC) models were used to calculate average annual sediment, CBOD, nitrogen and phosphorus loads (as kg/yr) that, if achieved, should meet the water quality targets established for turbidity, chlorophyll-a, and dissolved oxygen. For reporting purposes, the final TMDLs, according to EPA guidelines (Grumbles, 2007), are expressed for Lake Thunderbird as daily maximum loads (as kg/day).

5.1 Wasteload Allocation (WLA)

The waste load allocation for the TMDL for Lake Thunderbird will be assigned to regulated NPDES point source facilities located within the watershed as described below.

5.1.1 NPDES Municipal and Industrial Wastewater Facilities

There are no municipal or industrial wastewater facilities located in the Lake Thunderbird watershed.

5.1.2 No-Discharge WWTPs

A no-discharge WWTP facility does not discharge wastewater effluent to surface waters. For the purposes of this TMDL, it is assumed that no-discharge wastewater facilities do not contribute sediment, organic matter, or nutrient loading to watershed streams and Lake Thunderbird. It is possible, however, that the wastewater collection system associated with no-discharge facilities could be a source of pollutant loading to streams, or that discharges from the WWTP may occur during large rainfall events that exceed the storage capacity of the wastewater system. These types of unauthorized wastewater discharges are typically reported as sanitary sewer overflows (SSOs) or bypass overflows. As shown on Table 3-1, there are 14 no-discharge facilities in the Lake Thunderbird watershed. Pollutant loads from bypass overflows are not considered in the waste load allocation of point sources for the TMDL determination because any mitigation of bypass overflows is considered to be an enforcement action rather than a load allocation since bypass overflows are not allowed.

5.1.3 NPDES Municipal Separate Storm Sewer System (MS4)

The waste load allocation for the TMDL for Lake Thunderbird will be assigned to point sources accounted for by MS4 stormwater permits. Within the watershed area for Lake Thunderbird is the Phase I MS4 permit issued to Oklahoma City and the Phase II permits issued to Moore and Norman. Since there are no numeric load limits for MS4 permits, each of these three MS4 cities receives a separate WLA where the TMDL calculations are based on the proportional contribution of the existing pollutant loading from each of the three cities relative to the total watershed pollutant load determined by the HSPF watershed model. Pollutant loads derived from the HSPF watershed model for the existing 2008 - 2009 conditions are presented in Section 3.3.6 of this report.

As discussed in Section 3, the cities of Noble and Midwest City also have Phase II MS4 permits for stormwater discharges and stormwater management. Noble comprises 0.26% of the watershed and Midwest City comprises 0.05%. Since the Noble and Midwest City urban areas are only partially located in the Lake Thunderbird watershed, they account for a very small contribution to the total watershed area. Therefore, these two MS4 cities are not included as part of the WLA determined for the MS4 areas for the three larger cities in the watershed. However, the small portion of the watershed accounted for by the MS4 areas for Noble and Midwest City are included in the Load Allocation (LA) for the part of the watershed that is not include in the area covered by the three MS4 permits for Moore, Norman, and Oklahoma City.

5.1.4 NPDES Construction Site Permits

NPDES permit authorizations are required for stormwater discharges from construction activities that disturb more than one acre or less than one acre if the construction activity is part of a larger common plan of development that totals at least one acre. As discussed in Section 3 of this report, a total of 243 construction site permits have been issued within the Lake Thunderbird watershed by September 2012. Sediment and nutrient loading from construction site permit activities will be accounted for as part of the overall WLA determined for each of the three MS4 stormwater permits for Moore, Norman and Oklahoma City.

5.1.5 NPDES Multi-Sector General Permits (MSGP) for Industrial Sites

NPDES permit authorizations are required for stormwater discharges from industrial activities listed in the OKR05 General Permit (DEQ, 2011). Within the Lake Thunderbird watershed, 14 MSGP permits have been issued for ready-mixed concrete operations, used motor vehicle parts and scrap yards, asphalt paving mixtures and other categories of industrial activity as identified in Table 3-. The MSGP permits will be accounted for in this TMDL as part of the overall WLA for the three MS4 permits for Moore, Norman and Oklahoma City.

5.1.6 NPDES Animal CAFOs

There are no concentrated animal feeding operations (CAFO) located in the Lake Thunderbird watershed.

5.2 Load Allocation (LA)

5.2.1 Nonpoint Sources

The area of the watershed that is covered by the three MS4 permits for Moore, Norman and Oklahoma City accounts for a very large percentage of the watershed. The Load Allocation for the TMDL for Lake Thunderbird will, therefore, be assigned in proportion to the small land area of the watershed that is not included in the land area for the three MS4 permits. The area covered by the two MS4 permits for Noble and Midwest City and the remaining small unincorporated areas of the watershed and the city of Slaughterville are too small to be separated and are included in the Load Allocation for the TMDL. The LA for the unincorporated areas may be converted at some time in the future to a WLA if the unincorporated areas are annexed by any of the three MS4 cities of Moore, Norman and Oklahoma City. The Load Allocation of the watershed is based on the watershed loads for sediment and nutrients estimated with the watershed model for the existing 2008 - 2009 conditions rather than the load for this small area that would be based on 35% removal of the existing load.

5.3 Seasonal Variability

Federal regulations (40 CFR §130.7(c)(1))require that TMDLs account for seasonal variation in watershed hydrologic conditions and pollutant loading. Seasonal variation was accounted for in the TMDL determination for Lake Thunderbird in two ways: (1) water quality standards, and (2) the time period represented by the watershed and lake models. As described in Section 2, Oklahoma's water quality standards for dissolved oxygen for lakes are developed on a seasonal basis to be protective of fish and wildlife propagation for a warm water aquatic community at all life stages, including spawning. Within the surface layer, dissolved oxygen standards specifies that DO levels shall be no less than 6 mg/L from April 1 to June 15 to be protective of early life stages and no less than 5 mg/L for the remainder of the year (June 16 to March 31). Under summer stratified conditions during the period from mid-May to October, the hypoxic volume of the lake, defined by a DO target of 2 mg/L, is not to be greater than 50% of the lake volume. Seasonality was also accounted for in the TMDL analysis by developing the models based on one full year of water quality data collected as part of a special study of Lake Thunderbird from April 2008-April 2009. Water quality data collected during 2008 - 2009 for this TMDL study is considered to be representative of typical average hydrologic conditions. The watershed (HSPF) and lake (EFDC) models developed to support this TMDL study are both time variable models with results reported at hourly and daily intervals for the one year study period from April 2008 through April 2009. The models thus included hydrologic and limnological conditions for a full cycle of the four seasons.

5.4 Margin of Safety (MOS)

Federal regulations [40 CFR §130.7(c)(1)] require that TMDLs include a Margin of Safety (MOS). The MOS is a conservative measure incorporated into the TMDL determination that accounts for uncertainty and the lack of knowledge associated with calculating the allowable pollutant loading to ensure WQSs are attained. EPA guidance allows for use of either implicit or explicit expressions of the MOS, or both. When conservative assumptions are used in development of the TMDL, or conservative factors are used in the TMDL calculations, the MOS is implicit. When a specific percentage of the TMDL is set aside to account for the lack of knowledge, then the MOS is considered explicit.

The TMDL determined for Lake Thunderbird accounts for an implicit MOS. The implicit MOS is incorporated in the TMDL determination by decreasing the water quality targets for chlorophyll-*a* and turbidity by 10%. Using a 10% MOS for the water quality targets, the target for turbidity is decreased from 25 to 22.5 NTU and the target for chlorophyll- *a* is decreased from 10 to 9 µg/L. TMDL for ultimate CBOD was set the same as the load at the calibration condition because DO standards were met at the calibration condition with reserved capacities. As shown in Figure 4-8, the predicted volumetric anoxic volume for Lake Thunderbird is only about 30% while the standards allows up to 50% anoxic volume. This reserved capacity will act as the implicit margin of safety for dissolved oxygen.

5.5 TMDL Calculations

A TMDL is expressed as the sum of all WLAs (point source loads), LAs (nonpoint source loads), and an appropriate MOS. This definition can be expressed by the following equation:

$$TMDL = \Sigma\, WLA + \Sigma\, LA + MOS$$

Load reduction scenario simulations were run using the linked watershed (HSPF) and lake (EFDC) models to calculate annual average suspended solids, CBOD, phosphorus and nitrogen loads (in kg/yr) that, if achieved, should improve dissolved oxygen concentrations and decrease turbidity and chlorophyll-*a* concentrations to meet the water quality targets for Lake Thunderbird. Given that mass transport, assimilation, and dynamics of suspended solids, CBOD, and nutrients vary both temporally and spatially, pollutant loading to Lake Thunderbird from a practical perspective must be managed on a long-term basis with loads expressed typically as pounds or kilograms per year. However, a recent court decision (*Friends of the Earth, Inc. v. EPA, et al.,* often referred to as the Anacostia Decision) states that TMDLs must include a daily load expression (Grumbles, 2006). It is important to recognize that the dissolved oxygen, turbidity and chlorophyll-*a* response to sediment and nutrient loading in Lake Thunderbird is affected by many factors such as: internal lake nutrient loading, hypolimnetic oxygen depletion, water residence time, wind action, resuspension and the interaction between light penetration, nutrients, suspended solids and algal response. As such, it is important to note that expressing this TMDL on a daily basis does not imply that a daily response to a daily load from the watershed is practical from an implementation perspective.

Two documents available from EPA provide a statistical basis for the determination of a daily loading rate from an annual loading rate. "*Options for Expressing Daily Loads in TMDLs"* was published by EPA (2007) in response to the Anacostia Decision discussed above. The statistical basis for the calculation of a daily loading rate from an annual load was previously documented by EPA (1991b) in *"Technical Support Document for Water Quality-Based Toxics Control".* These documents provide the statistical methods for identifying a maximum daily limit based on a long-term average and considering temporal variability in the load time series dataset.

The methodology for the MDL is based on calculations of the (a) long-term average load (LTA) of untransformed pollutant loading data calculated by the watershed (HSPF) model; and (b) an estimation of the statistical variability of the time series for untransformed loading data based on calculations of the mean (μ), standard deviation (σ), variance (σ^2) and the coefficient of variation (CV). The CV, a measure of variability of the loading data, is computed as the ratio of the standard deviation (σ) to the mean (μ). Based on the long-term average annual loading rate (LTA) required to attain compliance with water quality standards, the maximum daily load (MDL) is determined to represent the allowable upper limit of loading data that is consistent with the long-term average load (LTA) determined by the TMDL study. The allowable upper limit takes into account temporal variability of the watershed loading data, the desired confidence interval of the upper bound for the MDL determination and the assumption that loading data can be described with a lognormal distribution. EPA (1991b) presents the rationale and derivation of the equations based on the lognormal distribution used to determine the maximum daily load. The MDL is computed from the LTA and the probability-based statistics of the pollutant loading data by the following equations as:

$$MDL = LTA * \exp(Z\sigma - 0.5\sigma^2)$$

$$\sigma^2 = \ln(1 + CV^2)$$

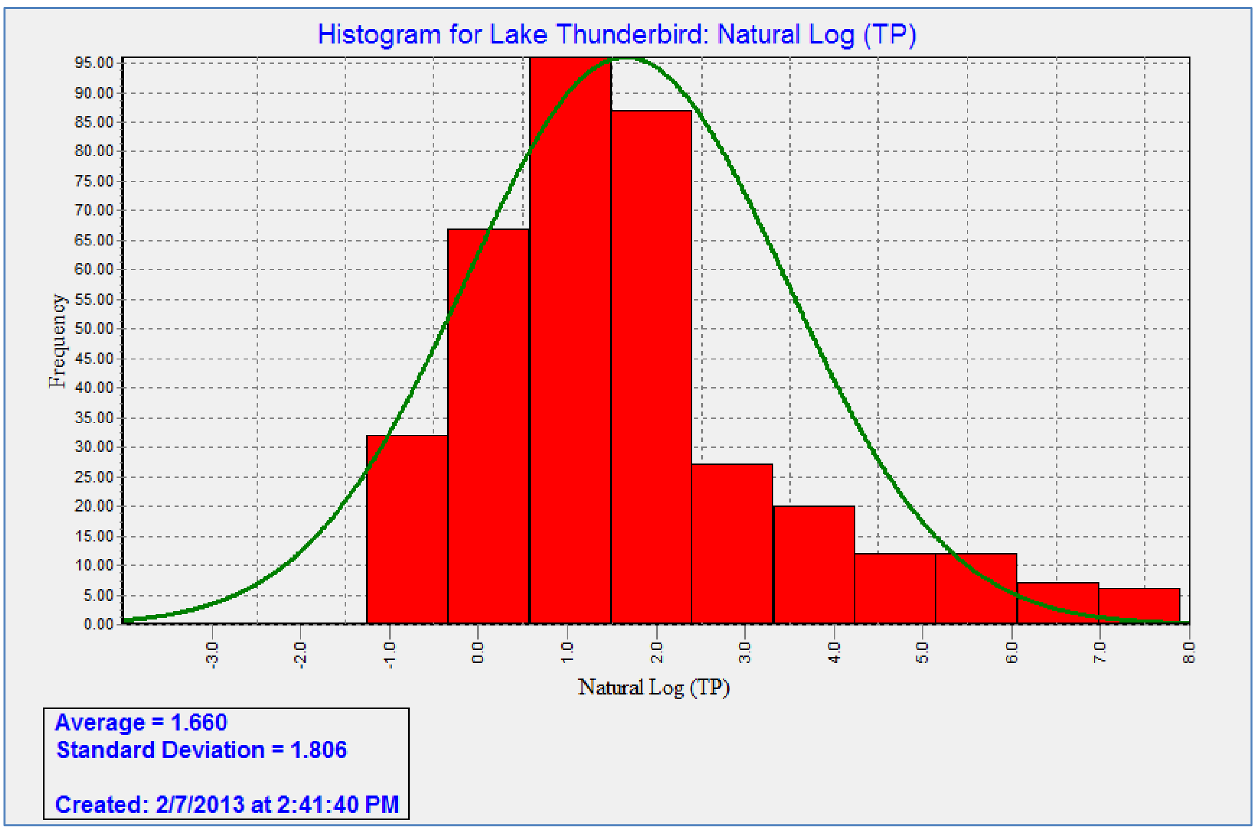
Where:

MDL	=	Maximum daily load limit (as kg/day)
LTA	=	Long-term average load with required reduction scenario (as kg/day)
Z	=	Z-score statistic for the probability of occurrence for upper percentile limit
CV	=	Coefficient of Variation
σ	=	Standard Deviation
σ^2	=	Variance

The equations used for calculating the Maximum Daily Load (MDL) from the Long Term Average (LTA) load are based on the assumption that streamflow, water quality concentration and watershed loading data are lognormally distributed. It is well documented in numerous studies that a two-parameter lognormal distribution defined by the mean and variance of the log transformed data set provides a very useful approximation to the probabilistic distribution of streamflow (Nash, 1994; Limbrunner et al., 2000; Vogel et al., 2005). In addition, Van Buren et al., (1997) and Di Toro (1984) determined that water quality analyses based on an assumption of the lognormal probability distribution for both streamflow and water quality concentration are quite realistic for many streams and rivers, including waterbodies investigated in the United States.

Although it is well documented, data is presented to show that the assumption of a lognormal distribution for watershed loading data holds true for Lake Thunderbird. Total Phosphorus (TP) loading data derived from the watershed model is used as an example to demonstrate that (a) natural log transformed TP data follows a normal distribution and (b) a lognormal distribution for loading data is an appropriate assumption for TMDL determinations for Lake Thunderbird. As shown in Figure 5-1, a typical bell shaped curve is produced from the log transformed TP load data, indicating a normal distribution of the transformed data set.

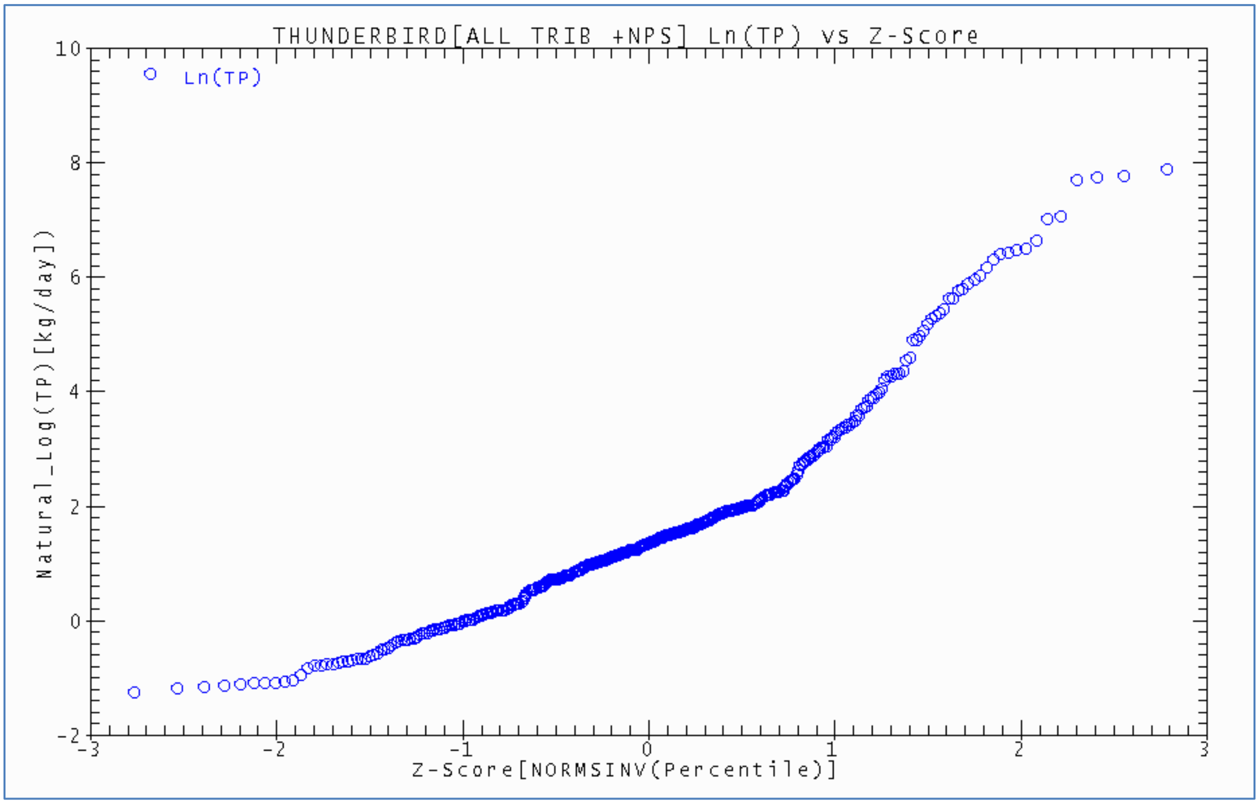
Figure 5-1 Density Distribution of the Log Transformed Total Phosphorus Data



The probability plot for the log transformed time series of TP data is presented as the natural log of the TP load against the Z-score statistic computed from the percentile ranking of the TP load data (Figure 5-1). The log transformed TP loading data shown in Figure 5-2 shows an almost linear relationship with the Z-score statistic (r^2 of 0.96) also indicating a lognormal distribution. Since streamflow is common to all loads derived from the watershed model, suspended sediment, TN and CBOD loads also have similar lognormal distributions as demonstrated with r^2 of 0.99, 0.97, and 0.94 for sediment, TN and CBOD, respectively.

Time series derived from the sum of all the daily loads contributed by each of the 18 tributaries and 18 distributed runoff catchments included in the HSPF watershed model were used to compute the mean, standard deviation and the coefficient of variation (CV) of the loads for suspended solids, TN, TP and CBOD. The variability of the loading data simulated by the HSPF model was determined using the CVs computed from the daily time series (N=365) of the total HSPF loads accounted for by HSPF tributary and distributed runoff loads. Loads from each tributary and distributed runoff catchment were summed to compute long-term averages of the total mass loading over a 365 day period from April 25, 2008 through April 25, 2009. For the Lake Thunderbird TMDL calculations, a 95% probability level of occurrence was used and the Z-score statistic was assigned a value of Z=1.645.

Figure 5-2 Probability Plot of Log Transformed Total Phosphorus Load from Watershed to Lake Thunderbird



The WLA and LA for Suspended Solids, TN and TP, determined from the lake model response to watershed load reductions, is based on 35% reduction of the existing 2008 - 2009 watershed loads estimated with the HSPF model. A load reduction from the watershed is needed because the criteria for turbidity and chlorophyll-*a* are not satisfied under the existing loading conditions. For CBOD, however, the WLA and LA is based on the existing 2008 - 2009 ultimate CBOD loading from the HSPF watershed model to the lake since the water quality criteria for dissolved oxygen is satisfied under existing loading conditions for both surface layer/epilimnion dissolved oxygen levels and the anoxic volume of the hypolimnion. For monitoring purposes, 20-day CBOD is considered to be ultimate CBOD. Table 5-1 presents the watershed loads as the long term average (LTA) load for the existing conditions and for the projected 35% removal management scenario.

Table 5-1 Long Term Average (LTA) Load for Suspended Solids, TN, TP, and BOD: Existing Conditions and 35% Removal in Lake Thunderbird

Water Quality Constituent	LTA Existing Annual Load	Load Reduction Rate	LTA Reduced Annual Load	LTA Reduced Daily Load
	kg/yr	Percent	kg/yr	kg/day
Total Nitrogen (TN)	117,537.9	35%	76,399.6	209.3
Total Phosphorus (TP)	23,086.7	35%	15,006.4	41.1
CBOD	236,186.6	0%	236,186.6	647.1
Suspended Solids (TSS)	11,492,695.8	35%	7,470,252.3	20,466.4

The LTA load and the coefficient of variation (CV) of the HSPF time series load data is used to compute the MDL for Suspended Solids, TN, TP and ultimate CBOD given in Table 5-2.

Table 5-2 Maximum Daily Load (MDL) for Suspended Solids, TN, TP, and CBOD to Meet Water Quality Targets for Turbidity, Chlorophyll-*a* and Dissolved Oxygen in Lake Thunderbird

Water Quality Constituent	LTA Reduced Daily Load	HSPF CV	MDL (TMDL) Load
	kg/day	N=365	kg/day
Total Nitrogen (TN)	209.3	4.252	807.7
Total Phosphorus (TP)	41.1	4.398	158.4
CBOD	647.1	4.774	2,480.8
Suspended Solids (TSS)	20,466.4	5.817	76,950.8

Z-Score =1.645 for 95% probability LTA- Long Term Average Load CV- Coefficient of Variation

Table 5-3 presents the load-based percentages of the existing 2008 - 2009 loads for the three MS4 cities area derived from the total existing watershed load that is accounted for by the loads contributed by each of the three MS4 Cities and the remaining unincorporated land area of the watershed. The percentage splits for the unincorporated area given in Table 5-3 were used to compute the LA (as kg/day) based on the existing loads given in Table 5-2 after conversion of the annual load to daily load.

Table 5-3 Percentage of Total TMDL for Three MS4 Cities (WLA) and Unincorporated Areas (LA)

Existing Load %	TOTAL	TOTAL	TOTAL	Moore	Norman	OKC
WQ_Variable	WLA(3-City)	LA	WLA+LA	WLA	WLA	WLA
	%	%	%	%	%	%
Total Nitrogen (TN)	97.36	2.64	100	25.40	39.54	32.42
Total Phosphorus (TP)	97.23	2.77	100	28.10	37.95	31.17
CBOD	97.68	2.32	100	31.49	38.52	27.67
Suspended Solids (TSS)	97.31	2.69	100	21.10	41.06	35.15

WLA% (City)= Existing[City Load/Total Watershed Load]
WLA% (3-Cities)= Existing[3-City Load/Total Watershed Load]
LA% = Existing[Unincorporated Area Load/Total Watershed Load]

The total WLA load for the three MS4 cities was computed from the MDL load given in Table 5-3 and the LA loading rate computed from the total existing loading and the small percentage of the watershed load that is accounted for by the unincorporated areas. The total TMDL load is split between the WLA for the three MS4 cities and the LA for the unincorporated area of the watershed as shown in the following equations:

TMDL = WLA + LA+ Implicit MOS

Where: LA= Existing Load from Unincorporated Area

TMDL = MDL load given in Table 5-2

WLA=WLA (3 Cities) = TMDL – LA

WLA (City) = WLA (3 Cities) * % Load of each City given in Table 5-2

Table 5-4 gives the percentage of the existing load contributed by each MS4 city to the total existing load for the three MS4 cities. The percentage splits for each MS4 city given in Table 5-4 were then used with the MDL given in Table 5-5 and the calculation of the total WLA loads from the relationships given above to determine the WLA for each of the three MS4 cities.

Table 5-4 Percentage of Total WLA for Three MS4 Cities (WLA)

Existing Load %	Moore	Norman	OKC	TOTAL
WQ_Variable (Splits)	WLA	WLA	WLA	WLA
	%	%	%	%
Total Nitrogen (TN)	26.09	40.62	33.30	100
Total Phosphorus (TP)	28.91	39.03	32.06	100
CBOD	32.24	39.43	28.33	100
Suspended solids (TSS)	21.68	42.19	36.12	100
City WLA% = Existing City Load/Total 3 City Load				

Table 5-4 gives the percentage of the existing load contributed by each MS4 city to the total existing load for the three MS4 cities. The percentage splits for each MS4 city given in Table 5-4 were then used with the MDL given in Table 5-5 and the calculation of the total WLA loads from the relationships given above to determine the WLA for each of the three MS4 cities. Table 5-5 presents the WLA for the three MS4 cities of Moore, Norman and Oklahoma City and the LAs for the unincorporated areas of the watershed and the small areas in Noble and Midwest City that are not included in the MS4 boundaries for the three cities. The small differences between the percentage values in Table 5-3 and Table 5-4 are due to the fact that no load reduction is given to the LA portion of the TMDL. Consequently, WLA's to the MS4 cities were reduced beyond the 35% by a small fraction to compensate for the required overall watershed reduction. Table 5-5 gives the final TMDL appropriations for all sources and pollutants.

Table 5-5 TMDL for Lake Thunderbird

Water Quality Constituent	TMDL	LA	WLA				MOS
			Total	Moore	Norman	OKC	
	(Kg/day)	(Kg/day)	(Kg/day)	(Kg/day)	(Kg/day)	(Kg/day)	(Kg/day)
Total Nitrogen (TN)	807.7	21.3	786.4	205.1	319.4	261.8	Implicit
Total Phosphorus (TP)	158.4	4.4	154.0	44.5	60.1	49.4	Implicit
CBOD	2,480.8	57.4	2,423.4	781.3	955.6	686.5	Implicit
Suspended solids (TSS)	76,950.8	2,068.7	74,882.1	16,236.0	31,596.1	27,049.9	Implicit

5.6 TMDL Implementation

DEQ will collaborate with a host of other state agencies and local governments working within the boundaries of state and local regulations to target available funding and technical assistance to support implementation of pollution controls and management measures. Various water quality management programs and funding sources will be utilized so that the pollutant reductions as required by these TMDLs can be achieved and water quality can be restored to maintain designated uses. DEQ's Continuing Planning Process (CPP), required by the CWA §303(e)(3) and 40 CFR 130.5, summarizes Oklahoma's commitments and programs aimed at restoring and protecting water quality throughout the State (DEQ 2012). The CPP can be viewed at DEQ's website at the following web address:
http://www.deq.state.ok.us/wqdnew/305b_303d/Final%20CPP.pdf. Table 5-3 provides a partial list of the State partner agencies DEQ will collaborate with to address point and nonpoint source reduction goals established by TMDLs.

Table 5-6 Partial List of Oklahoma Water Quality Management Agencies

Agency	Web Link
Oklahoma Conservation Commission	http://www.ok.gov/conservation/Agency_Divisions/Water_Quality_Division
Oklahoma Department of Wildlife Conservation	http://www.wildlifedepartment.com/wildlifemgmt/endangeredspecies.htm
Oklahoma Department of Agriculture, Food, and Forestry	http://www.ok.gov/~okag/aems
Oklahoma Water Resources Board	http://www.owrb.state.ok.us/quality/index.php

5.6.1 Point sources:

As authorized by Section 402 of the CWA, the DEQ has delegation of the NPDES Program in Oklahoma, except for certain jurisdictional areas related to agriculture (retained by State Department of Agriculture, Food, and Forestry), and the oil & gas industry (retained by the Oklahoma Corporation Commission) for which the EPA has retained permitting authority. The NPDES Program in Oklahoma, in accordance with an agreement between DEQ and EPA relating to administration and enforcement of the delegated NPDES Program, is implemented via the Oklahoma Pollution Discharge Elimination System (OPDES) Act [Title 252, Chapter 606 (http://www.deq.state.ok.us/rules/611.pdf)]. Point source WLAs are outlined in the Oklahoma Water Quality Management Plan (aka the 208 Plan) under the OPDES program.

As shown in Section 3 of the report, urban stormwater related discharges are the main sources of controllable pollutants to Lake Thunderbird. The three main municipalities in the watershed will therefore be required to undertake certain pollutant reduction measures within the terms of their MS4 permits under the OPDES system. These measures must be designed to achieve progress toward meeting the reduction goals established in the TMDL in order to comply with the WLAs of this TMDL. These stormwater best management practices (BMPs) based requirements are addressed in Appendix E of this report. MS4 permittees will review the adequacy of their Storm Water Management Program (SWMP) against these requirements. The SWMP must be modified in accordance with Appendix E within 24 months after the TMDL is approved by US EPA.

In addition to the specific requirements for a TMDL Compliance Plan outlined in Appendix E, some general strategies are recommended here as examples of what the MS4s in the watershed could do to improve the management of stormwater runoff and reduce its associated pollutant loading:

- Improve control of sanitary sewer overflows (SSOs).
- Implement enhanced oversight and controls to improve performance of on-site wastewater treatment systems (septic tanks).
- Establish a stakeholder/citizen advisory committee to involve the public in designing and implementing pollutant load reduction strategies.

Although this TMDL does not specify a WLA for construction stormwater activities, permittees are required to meet the conditions of the Stormwater Construction General Permit (OKR10) issued by the DEQ and properly select, install and maintain all BMPs required under the permit, including applicable additional BMPs required in Appendix E, and meet local construction stormwater requirements if they are more restrictive. After EPA approval of this TMDL, specific stormwater construction permit requirements pertaining to this TMDL will be included as site-specific requirements in authorizations issued under permit OKR10 by the DEQ for construction activities located in the Lake Thunderbird watershed. Appendix E outlines these requirements.

This TMDL does not specify a WLA for industrial stormwater. However, industrial stormwater permittees in the Lake Thunderbird watershed are required to meet the conditions of the industrial stormwater general permit (the Multi-Sector General Permit [MSGP, OKR05]) and properly select, install and maintain all BMPs required by the permit, including applicable additional BMPs required in Appendix E, for sediment and nutrient control. Existing permittees within the sectors specified in Appendix E located in the Lake Thunderbird watershed must update their SWP3 to comply with the requirements in this TMDL within 12 months of EPA approval of the TMDL. Future MSGP permits proposed within the Lake Thunderbird watershed will be evaluated on a case-by-case basis for additional requirements if it is determined that sediment and nutrients are potential pollutants in the stormwater discharge. Appendix E outlines these requirements.

5.6.2 Nonpoint Sources

Nonpoint source pollution in Oklahoma is managed by the Oklahoma Conservation Commission. The Oklahoma Conservation Commission works with state partners such as Oklahoma Department of Agriculture, Food, and Forestry (ODAFF) and federal partners such as the EPA and the National Resources Conservation Service of the USDA, to address water quality problems similar to those seen in the Lake Thunderbird watershed. The primary mechanisms used for management of nonpoint source pollution are incentive-based programs that support the installation of BMPs and public education and outreach.

Although most of the watershed is covered by MS4 permits, the majority of the watershed land use is rural and consequently, pollution associated with stormwater runoff from these areas are nonpoint sources in nature. Measures to control and reduce loading from these sources should be considered by the MS4 municipalities and when appropriate, in cooperation with the OCC. The primary mechanisms used for management of nonpoint source pollution are incentive-based programs that support the installation of BMPs and public education and outreach.

Specifically, there are loading control practices that have the potential to improve water quality in Lake Thunderbird in the near term before watershed pollutant loading can be reduced to the TMDL required levels. For example, COMCD should consider continuing or expanding the hypolimnetic oxygen injection program currently being evaluated. This could prove effective in retarding lake internal loading of nutrients and lowering lake bottom oxygen demand. Another potential project that would require COMCD involvement is the establishment of treatment wetlands on the Little River arm of the Lake above the Alameda Drive bridge/causeway, where natural sedimentation and resuspension has made this particularly shallow part of the Lake not suitable for most of the designated uses of the Lake.

5.6.3 Section 404 Permits

Section 404 of the Clean Water Act establishes programs to regulate the discharge of dredged or fill material into waters of the United States, including wetlands. Activities in waters of the United States regulated under this program include fill for development, water resource projects (such as dams and levees), infrastructure development (such as highways and airports) and mining projects. Section 404 requires a permit before dredged or fill material may be discharged into waters of the United States, unless the activity is exempt from Section 404 regulation (e.g. certain farming and forestry activities).

Section 404 permits are administrated by the U.S. Army Corps of Engineers. EPA reviews and provides comments on each permit application to make sure it adequately protects water quality and complies with applicable guidelines. Both USACE and EPA can take enforcement actions for violations of Section 404.

Although the projects permitted under Section 404 are generally short term in nature, the discharge of dredged or fill material can be a significant source of turbidity/TSS while the project is active. No TSS wasteload allocations are set aside for future Section 404 permits. The State will use its Section 401 certification authority to ensure Section 404 permits protect Oklahoma water quality standards and comply with the TSS TMDL in this report. Section 401 certifications will be conditioned to meet one of the following two conditions to be certified by the State:

- Include TSS limits in the permit and establish a monitoring requirement to ensure compliance with the TSS TMDL.

or

- Submit to DEQ a BMP turbidity/TSS reduction plan which should include all practicable turbidity control techniques. The turbidity/TSS reduction plan must be approved first before a Section 401 certification can be issued.

Compliance with the Section 401 certification conditions will be considered compliance with this TMDL.

SECTION 6 PUBLIC PARTICIPATION

On May 4, 2012, an Informational Meeting was held to notify the public and other stakeholders in the area that a TMDL project was going to be conducted at Lake Thunderbird because it is an impaired waterbody. TMDL models were discussed and participants had the opportunity to ask questions. A webpage regarding the Lake Thunderbird TMDL Project was set up at http://www.deq.state.ok.us/wqdnew/tmdl/thunderbird/index.html.

The draft TMDL report was submitted to EPA to be preliminarily reviewed. After they reviewed it, DEQ was given permission to send out a draft of the TMDL report for public notice. The Public Notice was sent:

- To local newspapers and other publications in the Lake Thunderbird watershed.
- To stakeholders who have requested all notices regarding the Lake Thunderbird area.
- To stakeholders who have requested copies of all TMDL public notices.

The Public Notice and draft TMDL report was also posted at the DEQ website: http://www.deq.state.ok.us/wqdnew/index.htm. The public comment period was open for 51 days. During that time, the public had the opportunity to review the draft of the Lake Thunderbird TMDL report and make written comments. On the afternoon of July 23, 2013, there was an in-depth workshop about the modeling that was done to develop the Lake Thunderbird Watershed TMDLs. That evening, there was a public meeting that was held near the Lake Thunderbird watershed in Norman, Oklahoma. At the public meeting, some members of the public made formal oral comments.

All of the written comments that were received during the Public Notice period became a part of the record of this TMDL report. All comments were considered and some revisions were made. After that, the Lake Thunderbird TMDL Report was submitted to EPA for final approval.

After EPA's final approval, each TMDL was adopted into the Water Quality Management Plan (WQMP). These TMDLs provide a mathematical solution to meet ambient water quality criterion with a given set of facts. The adoption of these TMDLs into the WQMP provides a mechanism to recalculate acceptable loads when information changes in the future. Updates to the WQMP demonstrate compliance with the water quality criterion. The updates to the WQMP are also useful when the water quality criterion changes and the loading scenario is reviewed to ensure that the in-stream criterion is predicted to be met.

SECTION 7 REFERENCES

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Appendix A

HSPF Watershed Model

Appendix A

HSPF Watershed Model

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Appendix A - HSPF WATERSHED MODEL

A.1 Overview of HSPF model

The Hydrological Simulation Program FORTRAN (HSPF), supported by EPA and the USGS as a public domain model (Bicknell et al., 2001), is a lumped parameter watershed runoff model that simulates watershed hydrology and non-point source pollutant loadings for organic matter, nutrients, sediments, bacteria and toxic chemicals within a watershed network of delineated sub-basins. The internal stream model routes flow and water quality constituents through a network of river reaches for each sub-basin of the watershed. The HSPF hydrologic sub-model provides for simulation of water balances in each sub-basin based on precipitation, evaporation, water withdrawals, irrigation, diversions, wastewater discharges, infiltration, and active and deep groundwater reservoirs. Empirical model parameters are assigned for each sub-basin land use through model calibration to simulate the water balance and pollutant loading from a sub-basin. HSPF is designed as a time variable model with results generated on an hourly or daily basis. Hundreds of applications of HSPF over the past two decades have included short-term storm events and/or continuous simulations over annual and decadal cycles. BMP alternatives designed to reduce pollutant loads to receiving waters can be represented in HSPF by adjustments of land use-based yield coefficients for a pollutant. Windows-based user-friendly GUI software tools such as WinHSPF (Duda et al., 2001), GenScn (Kittle et al., 1998) and HSPFParm (Donigian et al., 1999) have been developed to facilitate pre- and post-processing tasks for HSPF. Time series results for streamflow and pollutant loads generated by HSPF have been linked for input to hydrodynamic (e.g., EFDC) and water quality models (e.g., EFDC, WASP7) in numerous applications over the past decade. HSPF is considered a Level 3 Complex or Advanced Model.

The URL for HSPF is http://www.epa.gov/ceampubl/swater/hspf/index.htm.

A.2 Model Setup and Data Sources

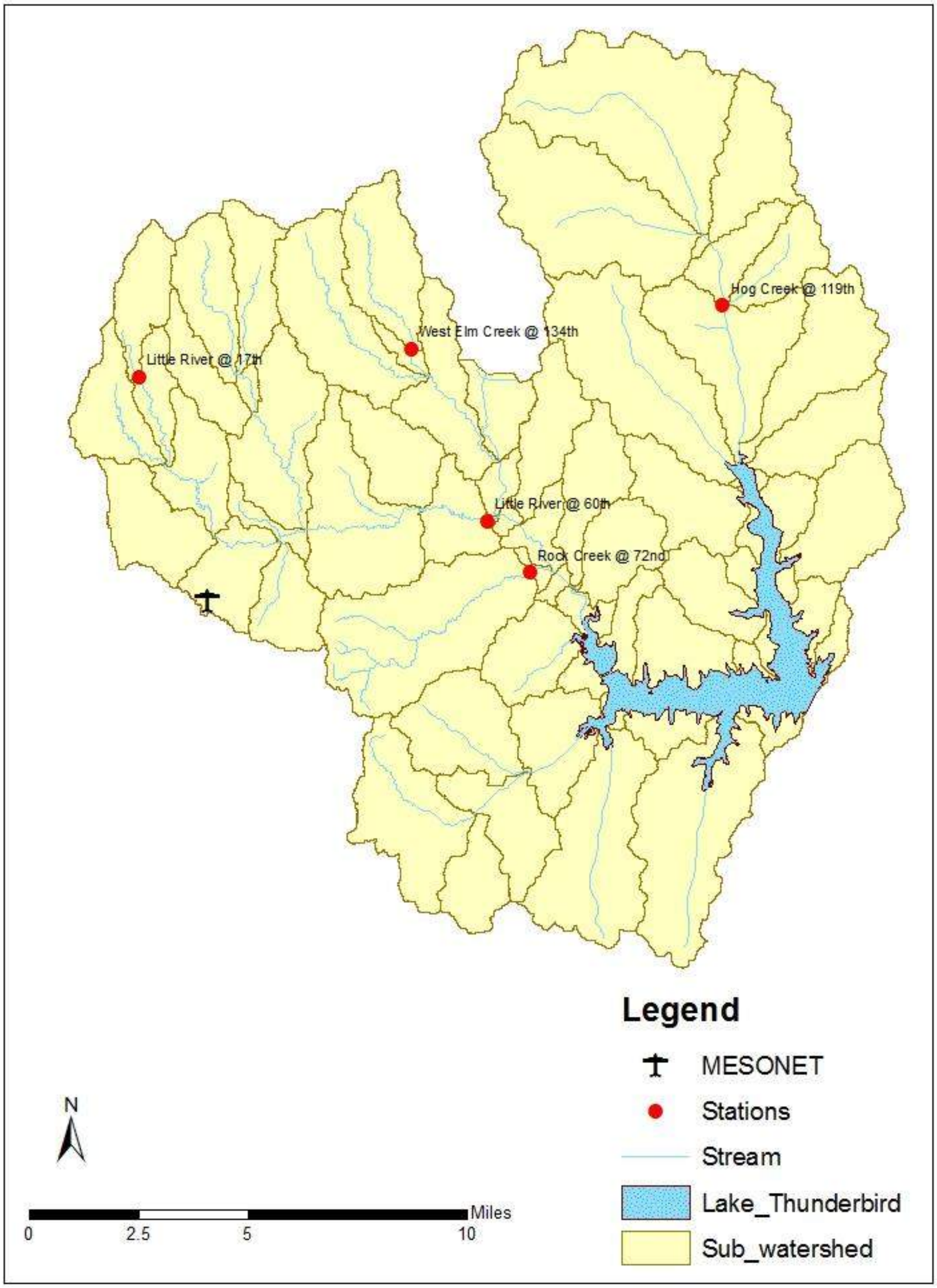
A.2.1 Model domain for watershed representation

Lake Thunderbird watershed model domain was developed based on the stream network in the watershed as described by USGS's NHD database and flow path calculations based on the USGS's 10-m Digital Elevation Model (DEM) dataset. The total watershed drainage area to the lake is 256 square miles.

A.2.2 Model discretization sub-watersheds

For a better representation of spatial variations of land use/cover, precipitation, soil type and topography, the lake watershed model was disaggregated into 64 subwatersheds/stream reaches, as shown in Figure A-1, based on the stream network in the watershed as described by USGS's NHD database and flow path calculations based on the DEM dataset. These subwatersheds were further grouped into six (6) groups and each group was assigned to one (1) weather station or rainfall gage. All other meteorological data (e.g., air temperature and solar radiation) as reported by the Oklahoma MESONET station at the Westheimer Airport just outside the watershed in Norman were shared by all the subwatersheds.

Figure A-1 Subwatershed and Stream Network



A.2.3 Land use data

During the watershed model setup, the NLCD 2006 land use/cover for the lake watershed was not available. Therefore, the NLCD 2001 land use/cover was used. However, more recent land use/cover was desirable because years 2008 and 2009 were selected for the watershed model calibration years. A comparison of the land use/cover change between 2006 and 2001 was made when the NLCD 2006 land use/cover data (Fry et al., 2011) became available later, as summarized in Table A-1. It was found that very minor land use/cover was changed between 2006 and 2001. Less than 1.4% of the total land use/cover was changed to the Developed Land Use (Open Space, Low Intensity, Medium Intensity, and High Intensity) from other types of land use/cover from 2001 to 2006. Therefore, using 2001 land use/cover data for the watershed model was considered to be appropriate.

Table A-1 Comparison of the land use/cover change between 2006 and 2001

Land Use Category	2001 Land Use	2006 Land Use	Difference (2006 - 2001)
Open Water	4.37%	3.48%	-0.89%
Developed, Open Space	9.17%	10.18%	1.01%
Developed, Low Intensity	4.34%	4.56%	0.23%
Developed, Medium Intensity	2.01%	2.15%	0.14%
Developed, High Intensity	0.43%	0.44%	0.01%
Barren Land, Rock, Sand, Clay	0.02%	0.06%	0.05%
Deciduous Forest	35.28%	35.08%	-0.21%
Evergreen Forest	0.23%	0.23%	-0.01%
Grassland, Herbaceous	38.52%	38.06%	-0.46%
Pasture, Hay	3.48%	3.43%	-0.05%
Cultivated Crops	2.15%	2.29%	0.14%
Emergent Herbaceous Wetlands	0.01%	0.05%	0.04%
Total	100.00%	100.00%	0.00%

In the Lake Thunderbird watershed model, the land use/cover was regrouped into twelve (12) land use categories, that is, Water, Bermuda grass/roadways, Deciduous Forest, Range Land, Urban Medium Density, Pasture, Agriculture, Wetland, Urban High Density, Evergreen Forest, Urban Commercial, and Urban Low Density

A.2.4 Meteorological forcing data

Precipitation data were obtained from five (5) OCC (the Oklahoma Conservation Commission) rain gages and one (1) MESONET station at the Westheimer Airport just outside the watershed in Norman. All other meteorological data (e.g., air temperature and solar radiation) were obtained from the MESONET station at the Westheimer Airport.

Meteorological data were either aggregated/averaged or disintegrated into hourly values if the raw station data were with a time step smaller or larger than one hour, respectively. Data gaps in the raw station data were filled by using data from the nearby station or by linear interpretation. All time marks for timed model input data and monitoring data were converted to Central Daylight Saving Time (CDT). The HSPF timer was also set based on the CDT.

A.3 HSPF Model Calibration

Computer water quality models are simplified representation of the physical world. In addition, observed data from monitoring have inherent errors from the sample collection process, equipment used, and lab analysis procedures. As a result, models, even after calibration, do not produce results that match exactly with observed data. To judge if a model performs as designed and simulates pollutant loads with a reasonable accuracy, graphic comparison and statistical analysis are conducted to evaluate model performance. In this study, observed stream discharge and water quality parameters were plotted on the same graphs with model simulated time series of these same parameters. Visual inspections were made to compare the observed and simulated data. Three statistics, percent difference of average values (% error), correlation coefficient (r^2), and Nash-Sutcliffe coefficient (N-S), were calculated to evaluate how well model simulation matched observed data. The targets for all parameters except TSS for the three statistics are ±20%, 0.5, and 0.5, respectively. For TSS, the targets for the three statistics are ±50%, 0.5, and 0.5, respectively. Among the three statistics, % error was targeted as a necessary condition for a calibrated model for all parameters and monitoring sites. The other two statistics were targeted but not used as rigid criteria for rejection or acceptance of model calibration and results.

As Figure A-2 shows, among the five monitoring sites the Little River at 60th Ave site (the L60 site) has the largest drainage area (21% of the entire watershed) and most diverse landuse types. Therefore, during the calibration process, the L60 site carried the most weight in determining the end point of calibration for all water quality parameters.

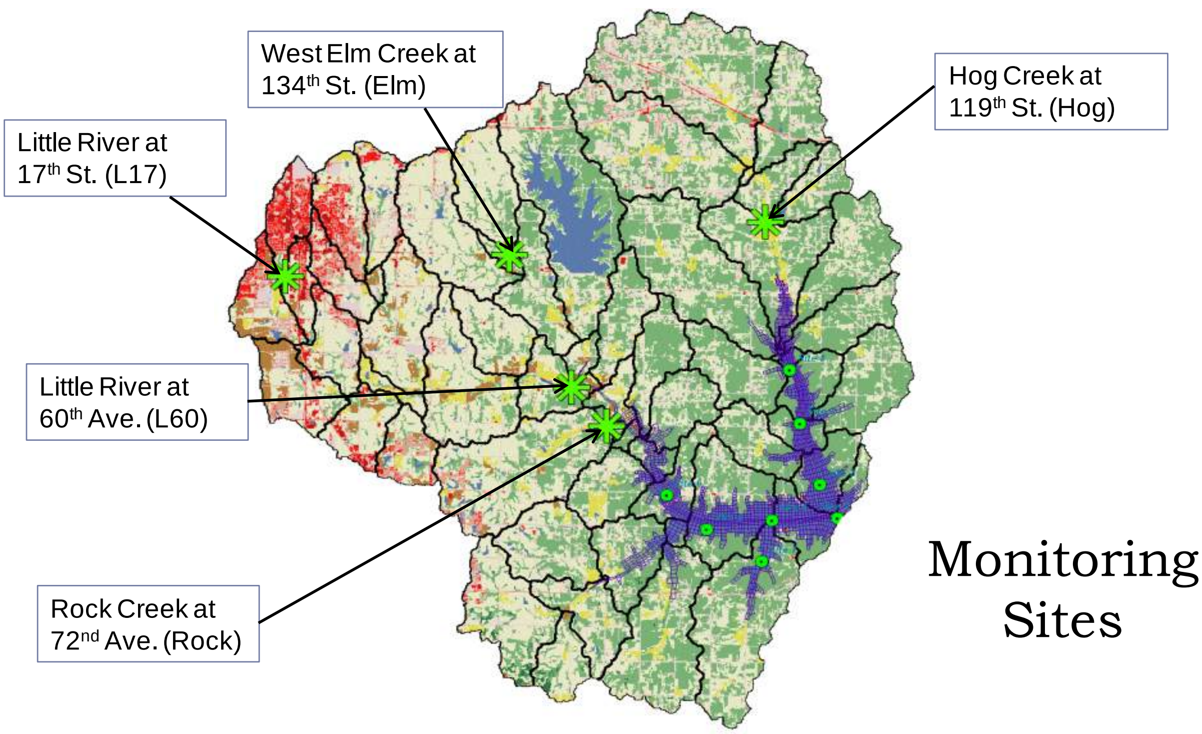
Water quality constituents or pollutants were simulated using HSPF's PQUAL module with simple accumulation and washoff relationships with water and sediment yield (Bicknell et al., 2001). Existing land management practices, including pollutant reducing best management practices for urban and agricultural land uses, were implicitly simulated with this approach.

Based on model structure and their physicochemical properties, water quality constituents were calibrated in the following order--stream flow, water temperature, total suspended sediment, total organic carbon, nitrogen, phosphorus and finally dissolved oxygen. After the initial calibration, fine tuning was conducted to further calibrate individual constituents without following that order.

A.3.1 Model simulation period

Development and calibration of the HSPF watershed model requires a host of site specific data. In addition to obtaining available data from various national data sources, an intensive one-year stream monitoring was conducted by the Oklahoma Conservation Commission (OCC) with support from DEQ from April 2008 to April 2009. Five monitoring stations were set up in the lake watershed on major tributaries with programmable automatic samplers (autosamplers) and rain gages (Figure A-2). Data obtained from these stations provided the basis for the model calibration.

Figure A-2. Stream monitoring sites for the HSPF calibration (green dots are the monitoring sites for lake water quality by OWRB)



Ideally, multiple year flow and water quality datasets collected at several key locations throughout a watershed are needed to calibrate and validate a watershed loading model such as HSPF model such that the calibrated watershed model is robust enough to be able to reproduce different wet, dry and average weather conditions reasonably well. However, for this study, because of data limitation, April 17, 2008 – April 26, 2009 where necessary data for model building and calibration is available was selected for the watershed model calibration period and no validation was conducted.

According to the annual precipitation analysis based on data from the MESONET Norman stations, 2008 and 2009, where the calibration period lies, the watershed area had annual precipitation of 36.0 and 35.7 inches, respectively. These annual amounts are very close to the 30-year normal of 37.4 inches for the area. This suggests that in the calibration period the pollutant loadings from the watershed can be considered "average". Therefore, loadings simulated by the HSPF model in the same period were used in this study for the lake model to calculate average load reduction needs for the watershed.

A.3.2 Streamflow

Five monitoring stations, as shown in Figure A-2, were set up in the lake watershed on major tributaries with programmable automatic samplers (autosamplers) by OCC. Due to various reasons, such as vandalism, equipment breakdowns and malfunctions, and extreme flows, autosamplers and the attached depth loggers at all five stations were not functioning for at one time or another during the one-year monitoring period. In addition, some of the stations did not start operation until several months into the monitoring period. As a result, data gaps exist to various degrees at all five stations.

Stream discharge rating curves based on water depth were initially developed for the monitoring stations using stream survey data, limited number of discharge measurements, and Manning's equation. As more stream discharge measurements with a wider range of discharge rates became available well into the monitoring period, the rating curves were refined and updated. They were finalized after the monitoring work was completed and the discharge record was revised retrospectively. This affected the flow-weighted sampling for total phosphorus (TP) and total Kjeldahl nitrogen (TKN) as they required accurate discharge rate for correct flow weighting. The model calibration process accounted for this inconsistency by simulating water depth at the monitoring sites and using the initial rating curves to simulate the concentrations of TP and TKN of the flow-weighted composite samples.

Discharge by the stream, or flow volume in the stream, resulting from the hydrologic processes in the watershed, is the foundation of a watershed water quality model. Much effort was devoted to this part of the model calibration in this study. Figure A-3 to Figure A-6 shows the hourly stream discharge simulated by the HSPF model at the five monitoring stations in the watershed. Discharge rates derived from water depth measurements taken by the autosamplers are also shown on the plots (blue asterisks). Different from traditional stream gages, depth measurements by the autosamplers were not made on a pre-set equal time step. Instead, they were made based on equal passing-through discharge at the gage in the stream channel to accommodate the flow weighted sampling of TP and TKN. As a result, direct comparison between measured and simulate stream discharges were not possible. Instead, daily average discharges calculated from the hourly model simulation were compared to daily average discharges calculated from the autosampler measurements for model calibration. Statistics for comparing the observed data and the model simulation were calculated as shown in Table A-2.

Data gaps exist in all 5 monitoring sites for depth measurements due to the occasional failures of the autosamplers. Therefore, a direct calculation of the measured total discharge at each of the five monitoring sites and the entire watershed during the calibration period was not possible.

Figure A-3 West Elm Creek (Elm) site stream discharge plot

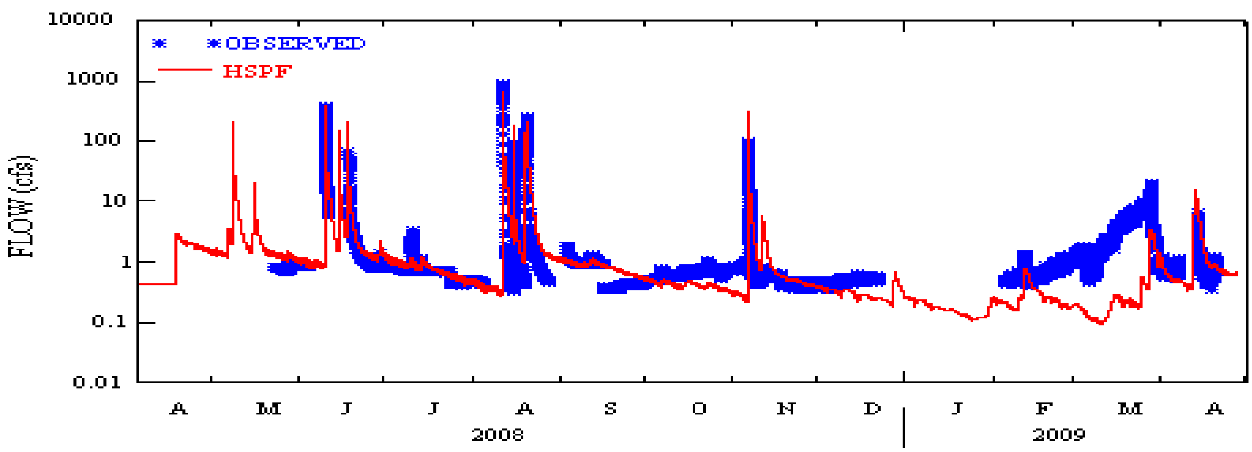


Figure A-4 Little River at 17th St. (L17) site stream discharge plot

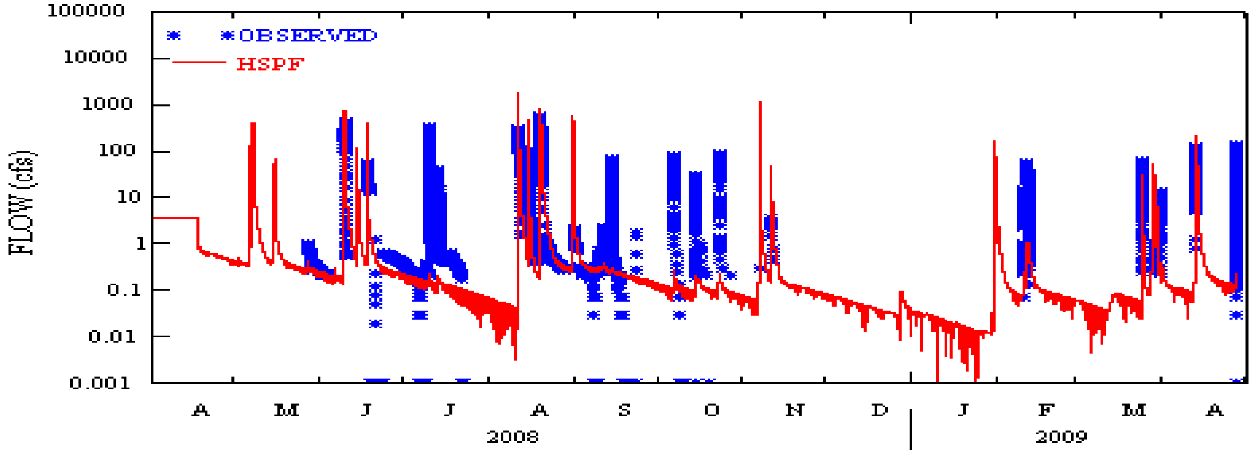


Figure A-5 Little River at 60th Ave. (L60) site stream discharge (Log scale)

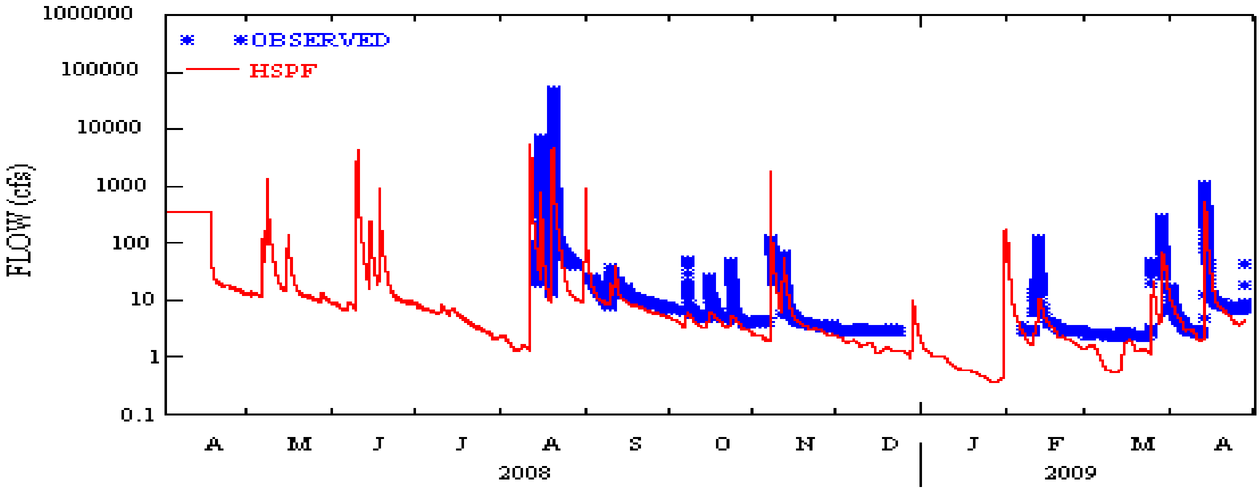


Figure A-6 Rock Creek at 72th Ave. (Rock) site stream discharge (Log scale) plot

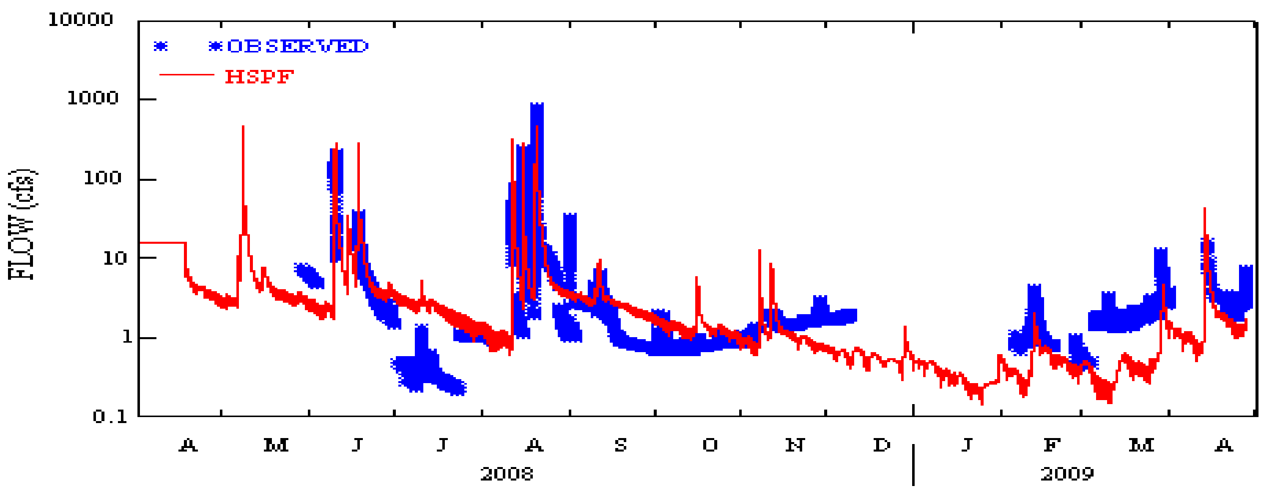


Figure A-7 Hog Creek at 119th St. (Hog) site stream discharge plot (Log scale) plot

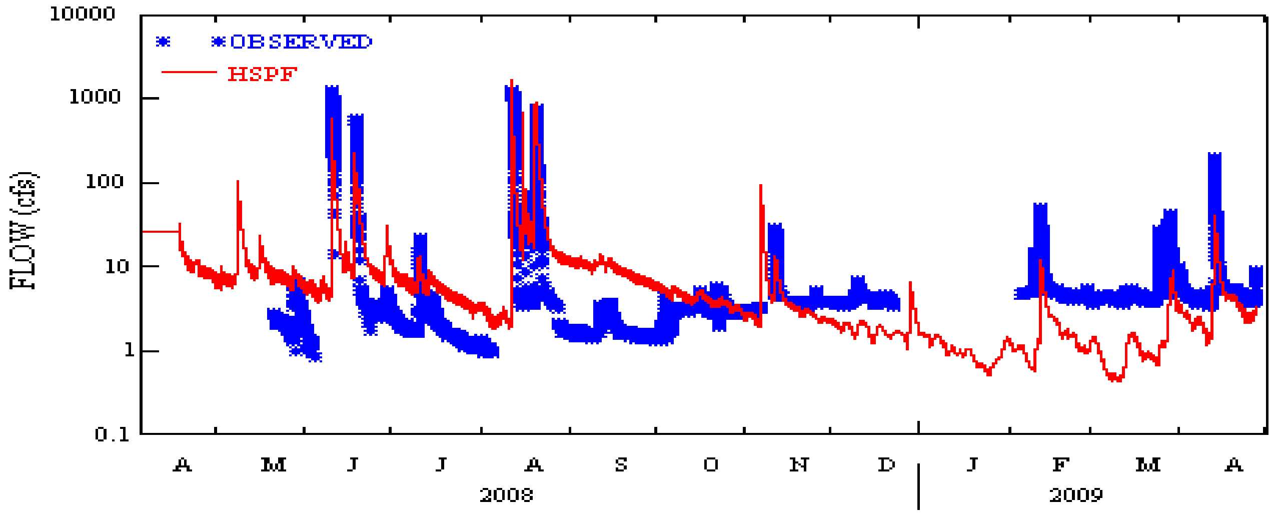


Table A-2 Daily flow statistics of the HSPF model simulation

Sites	Daily Average (observed, cfs) *	Daily Average (HSPF, cfs) #	% difference	r^2	Nash-Sutcliffe coefficient
L17	7.6	6.2	-18%	0.92	0.66
Elm	2.3	2.4	+4%	0.90	0.89
L60	9.6	11.0	+15%	0.66	0.63
Rock	3.6	3.5	-3%	0.78	0.78
Hog	13.2	15.3	+16%	0.60	0.56

* Obs. data not available all the time; #simulated data corresponding to obs.

Finally, as an overall check of the model, the total discharge (in million cubic feet) from the watershed into the lake (lake inflow) simulated by the model for the entire calibration period was compared to those calculated by the Army Corps of Engineers (ACOE) and COMCD. The ACOE and COMCD's calculations are based on a mass balance of the lake storage:

Lake inflow = lake volume change + outflow + evaporation + withdrawal

The methods of the ACOE and COMCD differ in their treatment of evaporation estimation and the accounting of the water withdrawal for municipal uses. The total inflow simulated by the HSPF model was 77,200 million cubic feet over the period, comparing to 80,100 and 70,400 million cubic feet from ACOE and COMCD, respectively.

The key HSPF parameters in stream discharge calibration were: MFACT, LZSN, LZETP, INFILT, AGWRC, UZSN, INTFW, IRC, and RETSC.

A.3.3 Water temperature

Water temperature in the stream is influenced by air temperature, available solar radiation, shading by riparian vegetation, the temperature of runoff and groundwater input to the stream, and the heat exchange between the flowing water and stream bed. It is an important indication of the model's ability in correctly accounting for all the watershed conditions mentioned above. In addition, water temperature of the flow into the lake from the lake tributaries direct affect the lake thermal regime, especially during high flow events, leading to changes of the nutrient balances in the lake and in turn, algal growth.

Water temperature calibration was based on the instantaneous field measurements of the stream water temperature at the monitoring stations during the weekly sample collection trip. HSPF simulated water temperature values at the hour nearest to the sampling time were extracted for the statistical calculations. As shown in Table A-3 and Figure A-8, the model did an excellent job in simulating water temperature, including the diurnal fluctuation. This is the result of the well calibrated stream discharge and the fact that heat exchange between water and the environment is determined mostly by physically based processes where parameters such as water heat capacity have mostly been well documented or measured in the literature.

Figure A-8 Little River at 17th St. (L17) site water temperature plot.

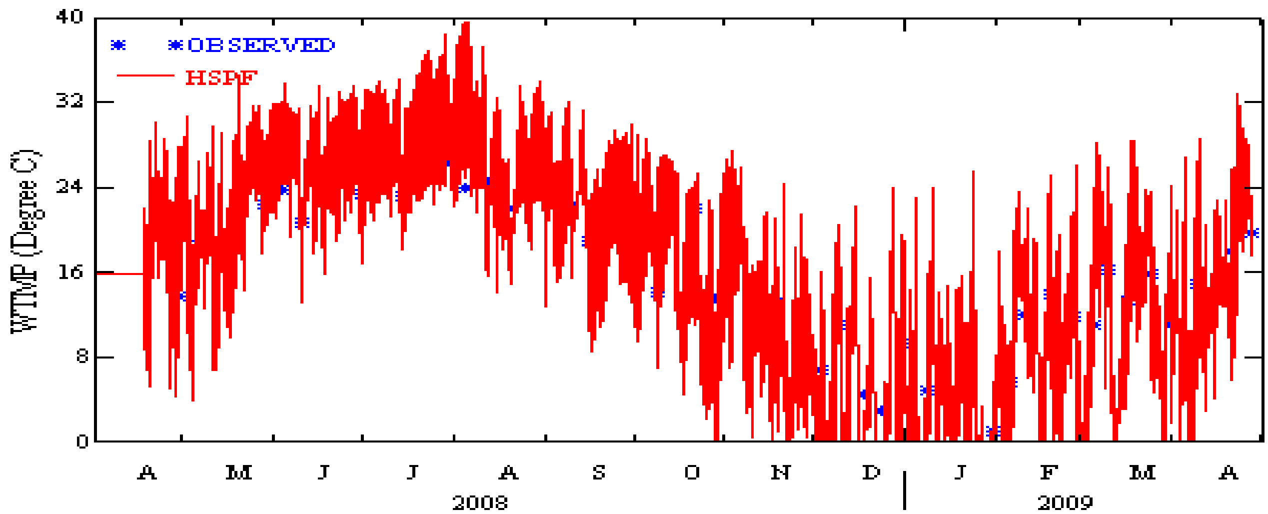


Table A-3 Instantaneous sample statistics of the HSPF model simulation for water temperature

Sites	Sample average (°C)	HSPF average (°C)	% difference	r^2	Nash-Sutcliffe coefficient
L17	16.3	16.3	0%	0.72	0.71
Elm	13.7	13.6	-1%	0.94	0.93
L60	13.8	13.6	-1%	0.95	0.92
Rock	17.0	16.2	-11%	0.90	0.88
Hog	14.4	14.5	+1%	0.94	0.94

The key HSPF parameters in water temperature calibration were CFSAEX and LGPT1.

A.3.4 Total suspended sediment (TSS)

TSS calibration was based on the lab measurements of the grab samples taken at the monitoring stations during the weekly sample collection trip. HSPF simulated TSS at the hour nearest to the sampling time were extracted for the statistical calculations. Because the weekly trips were made on a schedule that did not take into account flow conditions, most TSS samples were taken under low flow conditions with a few under medium flow conditions. As TSS is highly dependent on flow conditions, high TSS levels were not captured by the grab samples. This data limitation also applies to monitoring data of other water quality parameters based on grab samples, namely, dissolved phosphate (PO4), total organic carbon (TOC), Nitrate (NO3), and ammonium (NH4).

Figure A-9, Figure A-10 and Figure A-11 show the observed TSS plotted along with simulated hourly levels at three monitoring sites. It should be noted that the detection limit for TSS is 10 mg/L and many of the observed TSS were below this detection limit. Overall, the model very well captured the rise and fall of the TSS in the streams. Table A-4 indicates that the TSS calibration at all five sites met the % error criterion while deviating from the r2 criterion at four sites and did not meet the N-S target in any of these sites.

Historical data and regular field observations indicate that streambank erosion is a major source of sediment in the streams of the watershed. Although HSPF simulates stream bed erosion with a simple sheer stress based algorithm, the model does not fully account for factors such as localized differences in water and sediment supply to stream and bank stability as influenced by soil property and riparian vegetation.

Figure A-9 Little River at 17th St. (L17) site total suspended sediment plot.

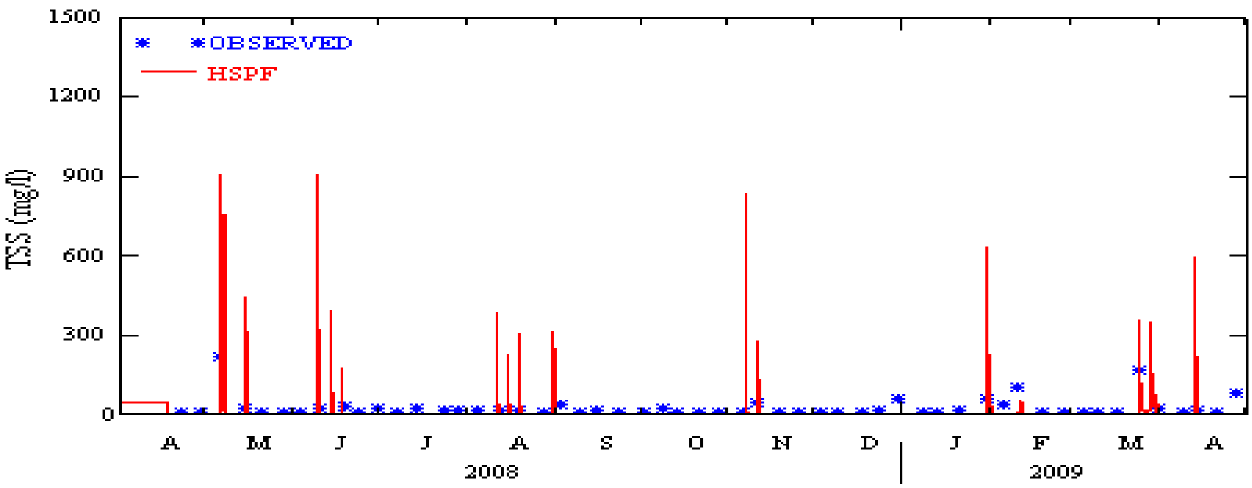


Figure A-10 Little River at 60th Ave. (L60) site total suspended sediment plot.

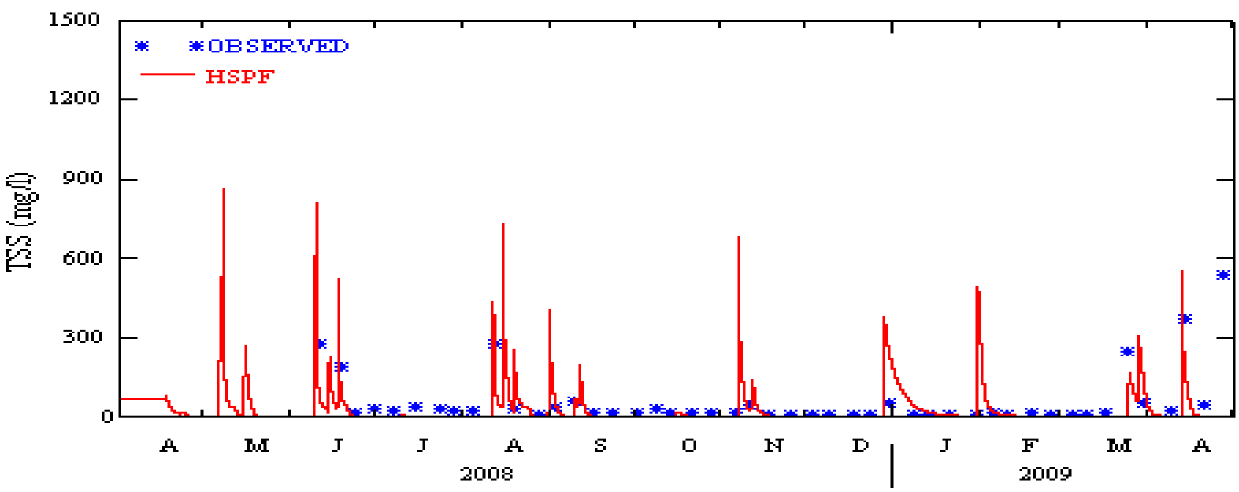


Figure A-11 Hog Creek at 119th St. (Hog) site total suspended sediment plot.

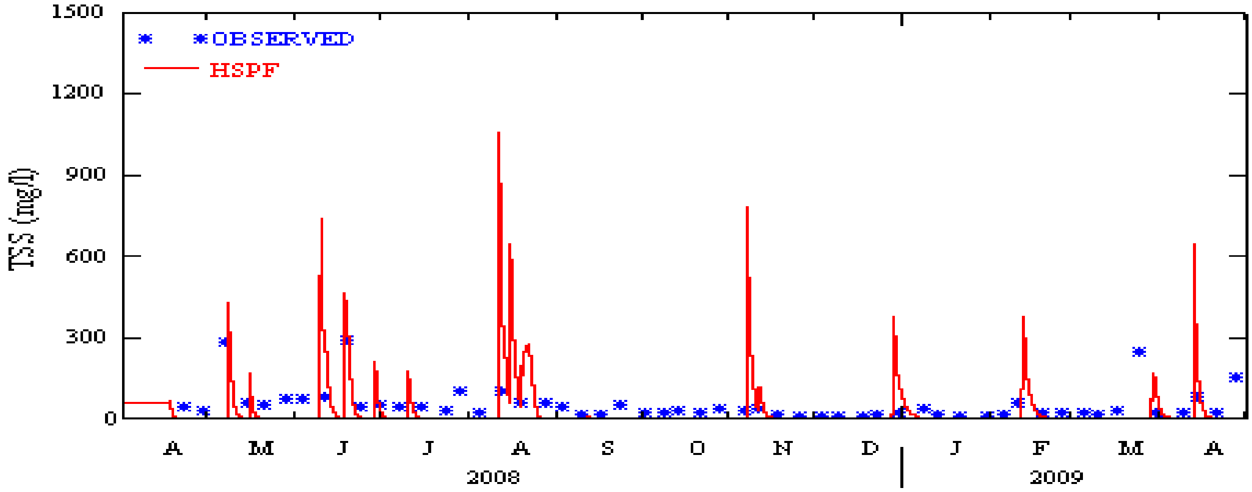


Table A-4 Grab sample statistics of the HSPF model simulation for TSS

Sites	Grabs ample average* (mg/L)	HSPF average (mg/L)	% difference	r^2	Nash-Sutcliffe coefficient
L17	19.0	20.7	8.9%	0.63	-0.56
Elm	7.2	9.8	29.3%	0.47	-0.65
L60	45.6	25.2	-44.7%	0.46	0.4
Rock	20.7	26.9	28.7%	0.40	-0.48
Hog	47.8	32.2	-32.6%	0.21	-0.98

* Samples below the 10 mg/L detection limit were assigned a value of 5 mg/L.

The key HSPF parameters in TSS calibration were COVER, AFFIX, KRER, KSER, KGER, KEIM, ACCSDP and REMSDP for sediment production; and TAUCD and TAUCS for sediment in-stream transport.

A.3.5 Dissolved Oxygen

Similar to water temperature, DO calibration was based on the instantaneous field measurements of the stream DO at the monitoring stations during the weekly sample collection trip. Dissolved oxygen level in streams is a function of flow rate, air and water temperatures, oxygen demand material (BOD) and algal activities in the water. While HSPF simulated all these factors in this study, it should be noted that no field measurements were available to calibrate BOD and algae abundance levels in streams in the lake watershed. Only default or assumed model parameter values were used. Nevertheless, model simulation of DO at all five sites met all three the statistical targets except N-S at the in Rock Creek site (Table A-5). Figure A-12, as a representative of all sites, shows that the simulation mirrored well the field measurements except during the winter months of December and January. The DO supersaturation in those months indicated by the field measurements suggests algal growth that was not captured by the model.

Figure A-12 Little River at 60th Ave. (L60) site DO plot.

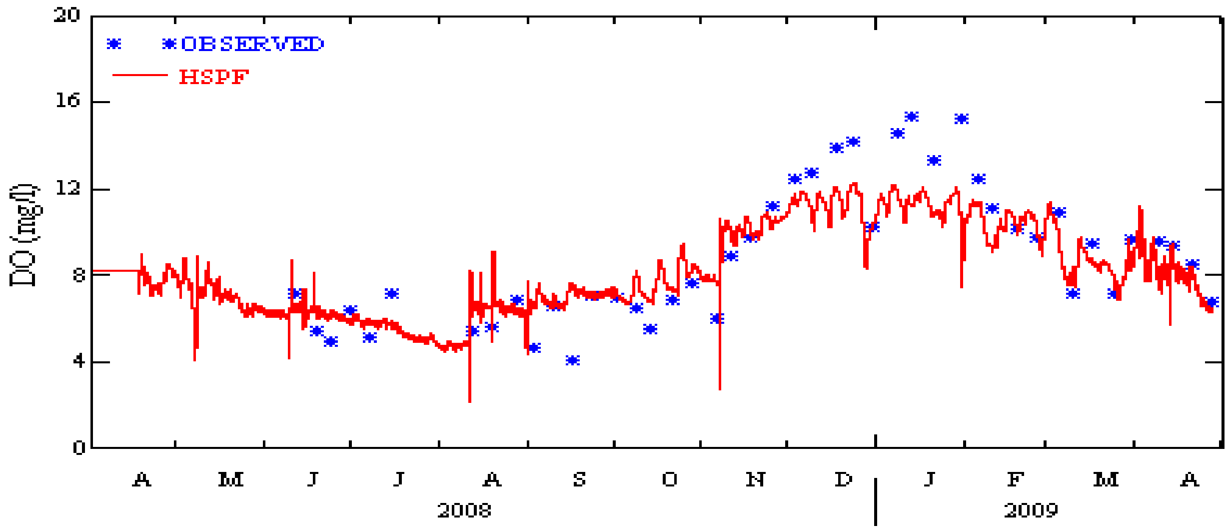


Table A-5 Instantaneous sample statistics of the HSPF model simulation for DO

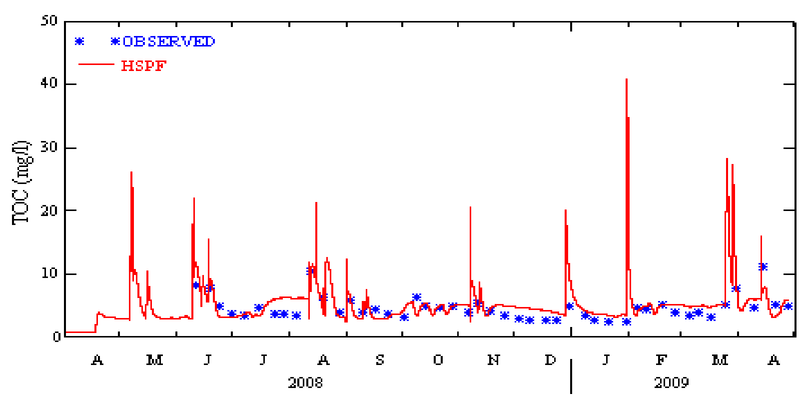
Sites	Sample average (mg/L)	HSPF average (mg/L)	% difference	r^2	Nash-Sutcliffe coefficient
L17	8.5	8.0	-6.2%	0.71	0.71
Elm	8.6	8.4	-3.1%	0.79	0.77
L60	8.6	8.5	-0.1%	0.86	0.77
Rock	7.3	8.5	+16.5%	0.55	0.25
Hog	8.9	8.7	-2.6%	0.84	0.80

The key HSPF parameters in DO calibration were POTFW, IFLW-CONC, GRND-CONC, ACQOP, and SQOLIM for BOD; and IFWDOX, GRNDDOX, KBOD20, and BENOD for in-stream DO processes.

A.3.6 Organic Carbon

Similar to TSS, calibration for total organic carbon (TOC) was based on grab sample data that represented mostly low and medium flow conditions. Figure A-13 shows that the model gave close simulation of the measured data in the stream for the L60 site. Calibration statistics for TOC were not used as targets for calibration.

Figure A-13 Little River at 60th Ave. (L60) site TOC plot



A.3.7 Phosphorus

Total phosphorus (TP) and Total Kjeldahl nitrogen (TKN) monitoring was conducted using the autosamplers programmed to take equal amount (15 mL) of water samples each time a preset amount of discharge passing through the stream. These aliquots of water samples were composited and preserved with sulfuric acid for about one week before sent to the lab for analysis. These essentially discharge-weighted measurements of TP and TKN concentration gave a better indication of TP and TKN loadings from the watershed than grab samples that often miss high discharge events. However, the success of discharge-weighted water sampling is highly dependent on the accuracy of stream discharge measurements and hence the discharge rating curve used to translate stream depth measurements to discharge rates.

It should be noted here that the rating curves used to calculate stream discharges from depth measurements were not fully established until the data collection phase was completed. Flow conditions in the streams at the initial stage of the project limited the discharge measurements to low and medium levels. Consequently rating curves based on these discharge measurements and used in the first several sampling events were not suitable for high discharge conditions. The rating curves were updated later when higher discharge measurements became available. Nevertheless, equipment limitation and field conditions prevented the measurement of peak discharges. Eventually rating curves that accounted for high to extremely high discharges were developed using both discharge measurements and the Manning's equation with assumed roughness coefficients. The result of the continuous revision of the rating curves was that the discharge-weighted sampling of TP and TKN was not executed as designed.

Nevertheless, data collected from the TP and TKN sampling still served their purpose of capturing the fluctuation of TP and TKN levels in the streams under all discharge conditions and providing this information for model calibration of TP and TKN loadings from the watershed. To accomplish this, water depth as simulated by HSPF at each monitoring site was extracted from model runs and the rating curves used at the time corresponding to each simulated depth were used to calculate the discharge. Next, simulated TP or TKN concentrations were extracted from the model runs. Then a discharge weighted TP or TKN concentration was calculated using those modeled discharge and concentrations. In essence, model data in conjunction with the rating curves used at the time of sampling were used to simulate the TP or TKN levels in the samples collected.

Table A-6 shows the results of the TP calibration as described above. All three statistical criteria were met for the West Elm Creek (Elm) site. The Elm site drainage is dominated by the landuse type of rangeland (74%), which also the most common landuse type (38%) for the entire lake watershed. The L60 site drains the most area among the five sites and has the most diverse landuse types. The % error criterion was met at four sites but failed at L60 site. The Little River at 17th Ave (L17) and the Rock Creek (Rock) sites did not meet the r^2 or the N-S criteria.

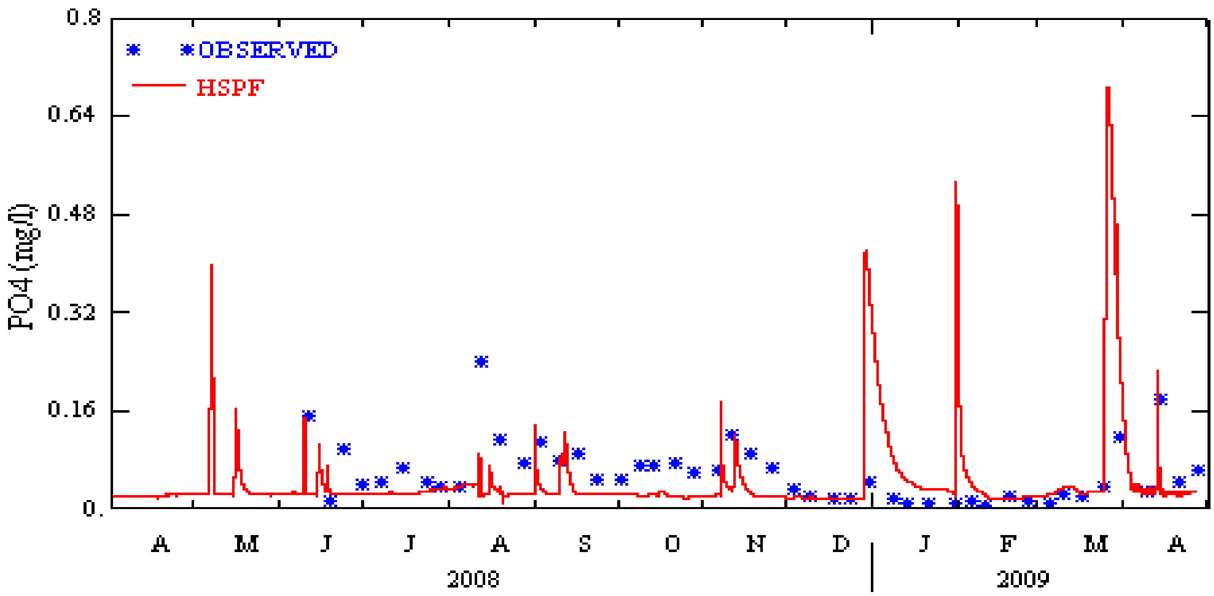
Table A-6 Composite (discharge weighted) sample statistics of the HSPF model simulation for TP

Sites	Sample average (mg/L)	HSPF average (mg/L)	% difference	r^2	Nash-Sutcliffe coefficient
L17	0.215	0.25	5.5%	0.0	-1.54
Elm	0.074	0.074	0.3%	0.85	0.84
L60	0.247	0.151	-38.7%	0.52	0.37
Rock	0.235	0.195	-17.1%	0.10	-0.25
Hog	0.170	0.156	-8.3%	0.52	0.34

PO4 data was also available for calibration. Similar to TSS, calibration for PO4 was based on grab sample data that represented mostly low and medium flow conditions. In addition, observed PO4 concentrations were often below its detection limit, which made point to point comparison of model-data difficult.

Figure A-14 shows that the model gave close simulation of the measured data in the stream for the L60 site. Calibration statistics of PO4 were not used as targets for calibration.

Figure A-14 Little River at 60th Ave. (L60) site PO_4 plot



A.3.8 Nitrogen

Total Kjeldahl nitrogen (TKN) data were available for calibration. The TKN was calibrated the same way as TP and had very similar calibration results at the monitoring sites (Table A-7). The Elm and L60 sites had excellent statistics for all three criteria while the L17 and Rock sites did not meet the r^2 or the N-S criteria.

Table A-7 Composite (discharge weighted) sample statistics of the HSPF model simulation for TKN

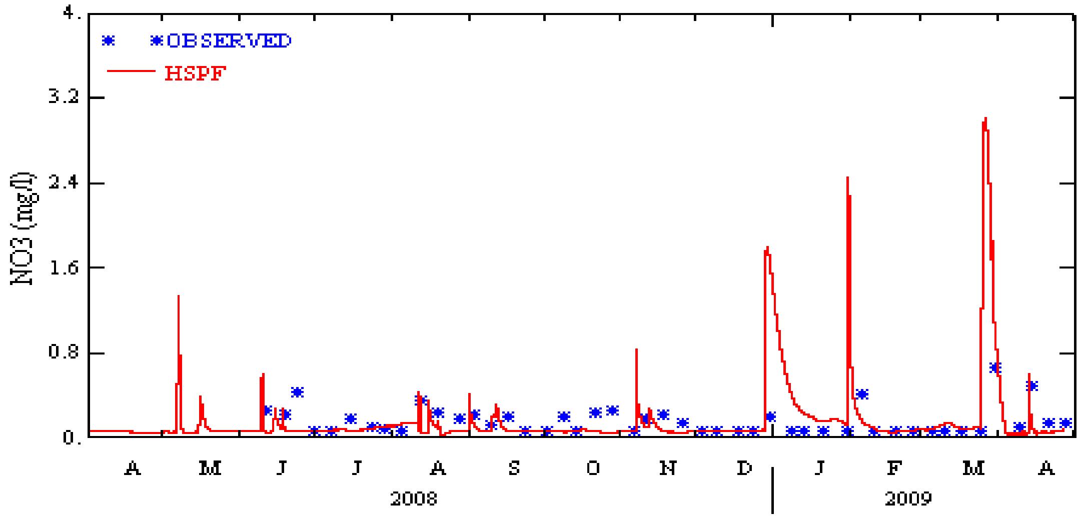
Sites	Sample average (mg/L)	HSPF average (mg/L)	% difference	r^2	Nash-Sutcliffe coefficient
L17	1.35	1.56	9.1%	0.09	-1.56
Elm	0.51	0.52	1.6%	0.79	0.78
L60	1.33	1.11	-16.6%	0.67	0.59
Rock	1.14	1.03	-10.1%	0.19	-0.08
Hog	1.11	0.91	-17.7%	0.65	0.47

NO3 data was also available for calibration. Similar to TSS, calibration for NO3 was based on grab sample data that represented mostly low and medium flow conditions. In addition, observed NO3 concentrations were often below its detection limit, which made point to point comparison of model-data difficult.

Figure A-15 shows that the model gave close simulation of the measured data in the stream for the L60 site for NO3. Calibration statistics of NO3 were not used as targets for calibration.

Sample data for NH4 were mostly below detection limit of 0.1 mg/L. Out of the over 250 samples collected, only 4 were above detection limit. As a result NH4 calibration was attempted only for the general trend that showed very low levels (< 0.1 mg/L) in low and medium flow conditions.

Figure A-15 Little River at 60th Ave. (L60) site NO3 plot



The key HSPF parameters in the calibration of these parameters were POTFW, IFLW-CONC, GRND-CONC, ACQOP, and SQOLIM.

A.3.9 Load budget for TSS, TN, TP and CBOD/TOC loads from HSPF watershed for existing calibration conditions

The HSPF model framework consists of a network of sub-watersheds that generate flow and pollutant loading from runoff over the land uses of sub-watersheds defined within a larger watershed domain for a project. Sub-watersheds are defined by an in-stream reach where flow and pollutant loads simulated as land use dependent runoff are input and routed through a reach that is defined by length, volume, surface area, depth and hydraulic residence time. In this study, sub-watersheds that drain into Lake Thunderbird via a tributary generate flow and water quality concentrations at specific downstream outlet locations at the lake. Sub-watersheds that are adjacent to and drain directly into Lake Thunderbird generate water volume and loads from distributed runoff over the entire sub-watershed. By aggregating the pollutant loading from all the tributaries and NPS overland area, the pollutant annual budget estimated by HSPF model is given by Table A-8. The pollutant loadings for each sub-watershed loadings on a per acre per year basis are given by Figure A-16 through Figure A-20.

Table A-8 HSPF load budget

Total HSPF Watershed Loads:	4/25/2008	4/25/2009			
Watershed Load	TN 1000 lb/yr	TP 1000 lb/yr	CBOD 1000 lb/yr	Sediment 1000 lb/yr	TOC 1000 lb/yr
Tributary	243.82	48.37	490.90	24086.71	1251.77
Distributed	15.30	2.52	29.80	1250.09	88.58
Total	259.12	50.90	520.70	25336.80	1340.34

Total HSPF Watershed Loads:	4/25/2008	4/25/2009			
Watershed Load	TN kg/day	TP kg/day	CBOD kg/day	Sediment kg/day	TOC kg/day
Tributary	303.01	60.11	610.05	29933.32	1555.61
Distributed	19.01	3.14	37.04	1553.52	110.08
Total	322.02	63.25	647.09	31486.84	1665.69

Figure A-16 Calculated sub-watershed sediment loadings by HSPF model

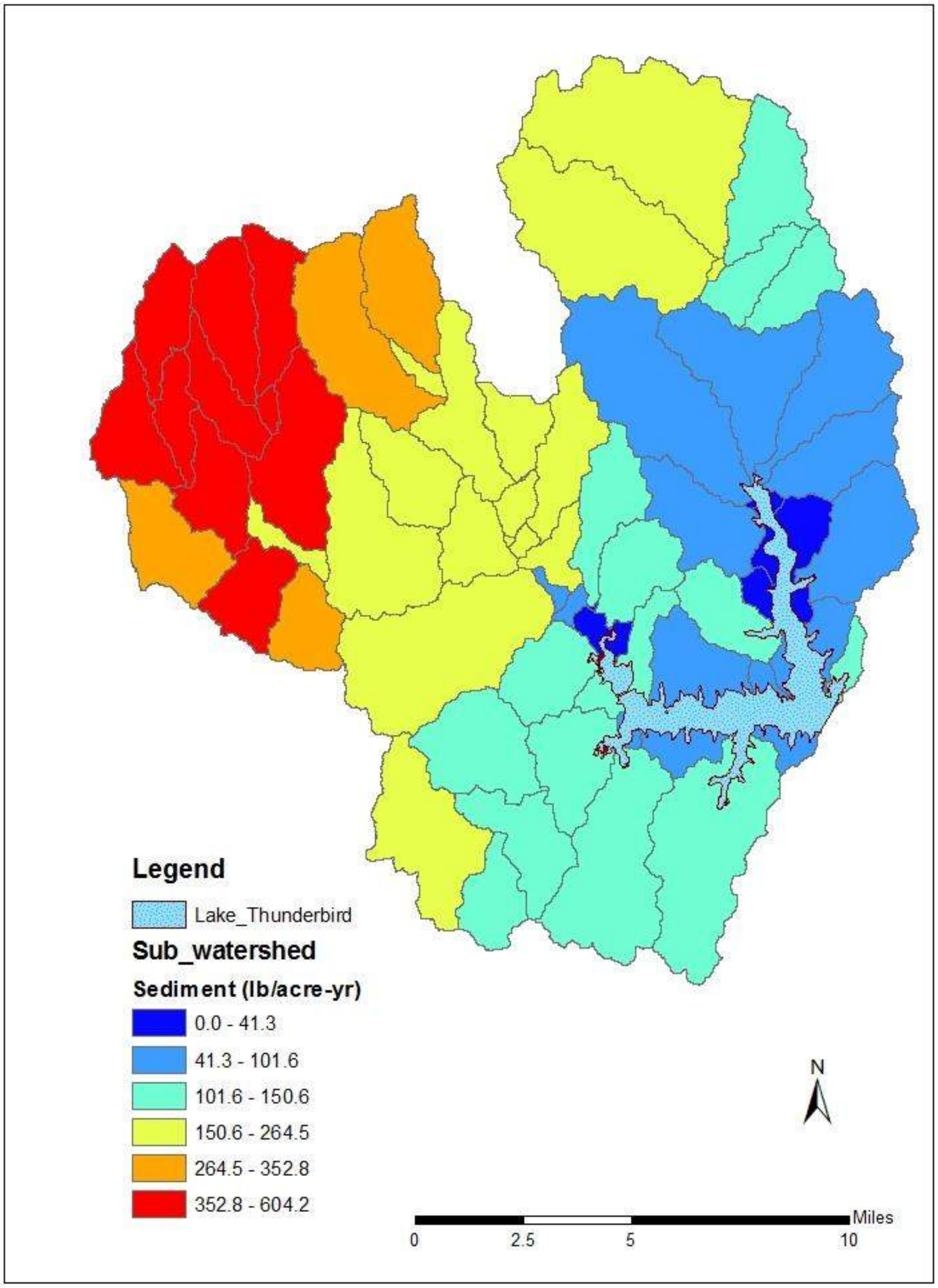


Figure A-17 Calculated sub-watershed BOD loadings by HSPF model

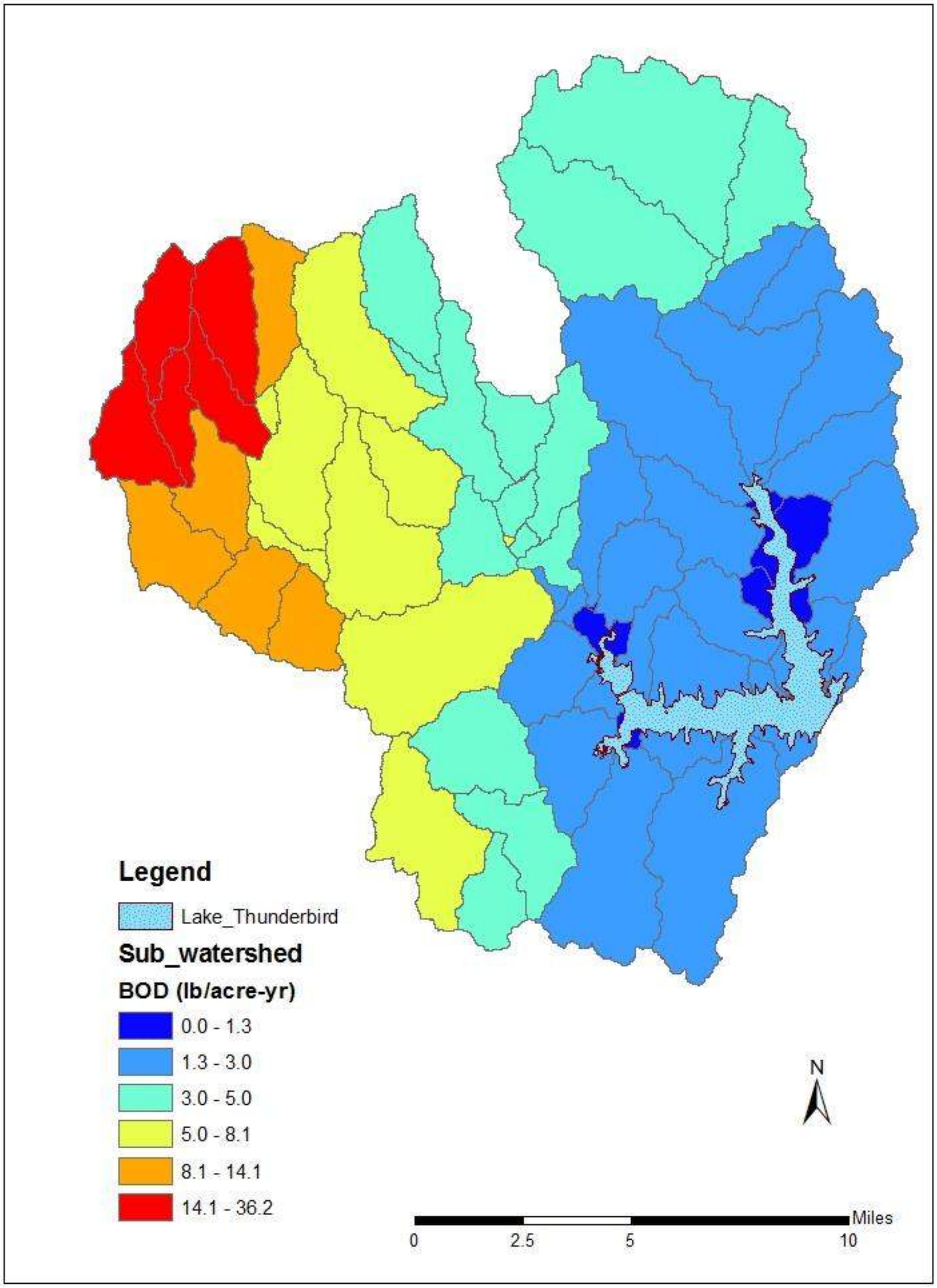


Figure A-18 Calculated sub-watershed TOC loadings by HSPF model

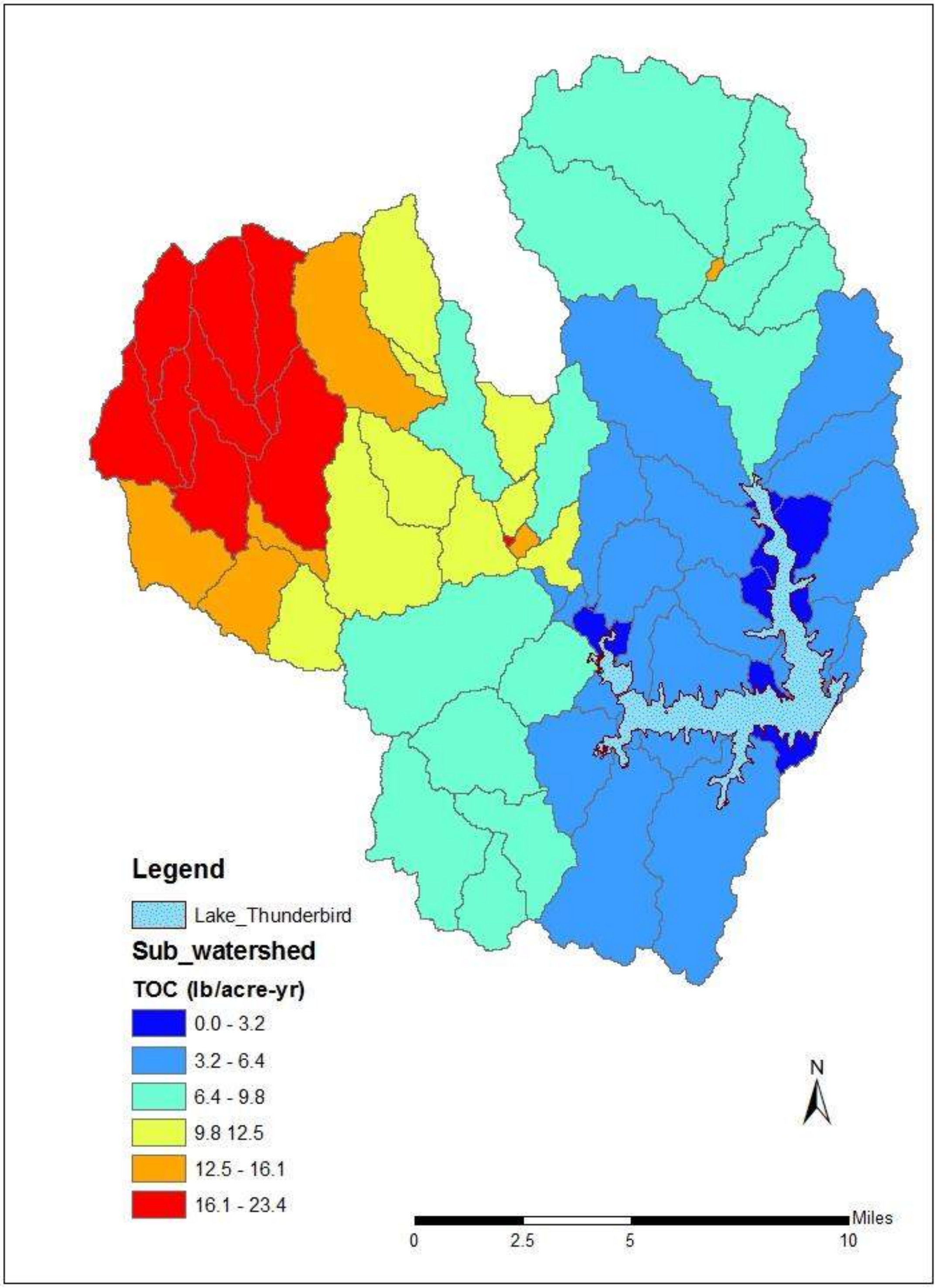


Figure A-19 Calculated sub-watershed TN loadings by HSPF model

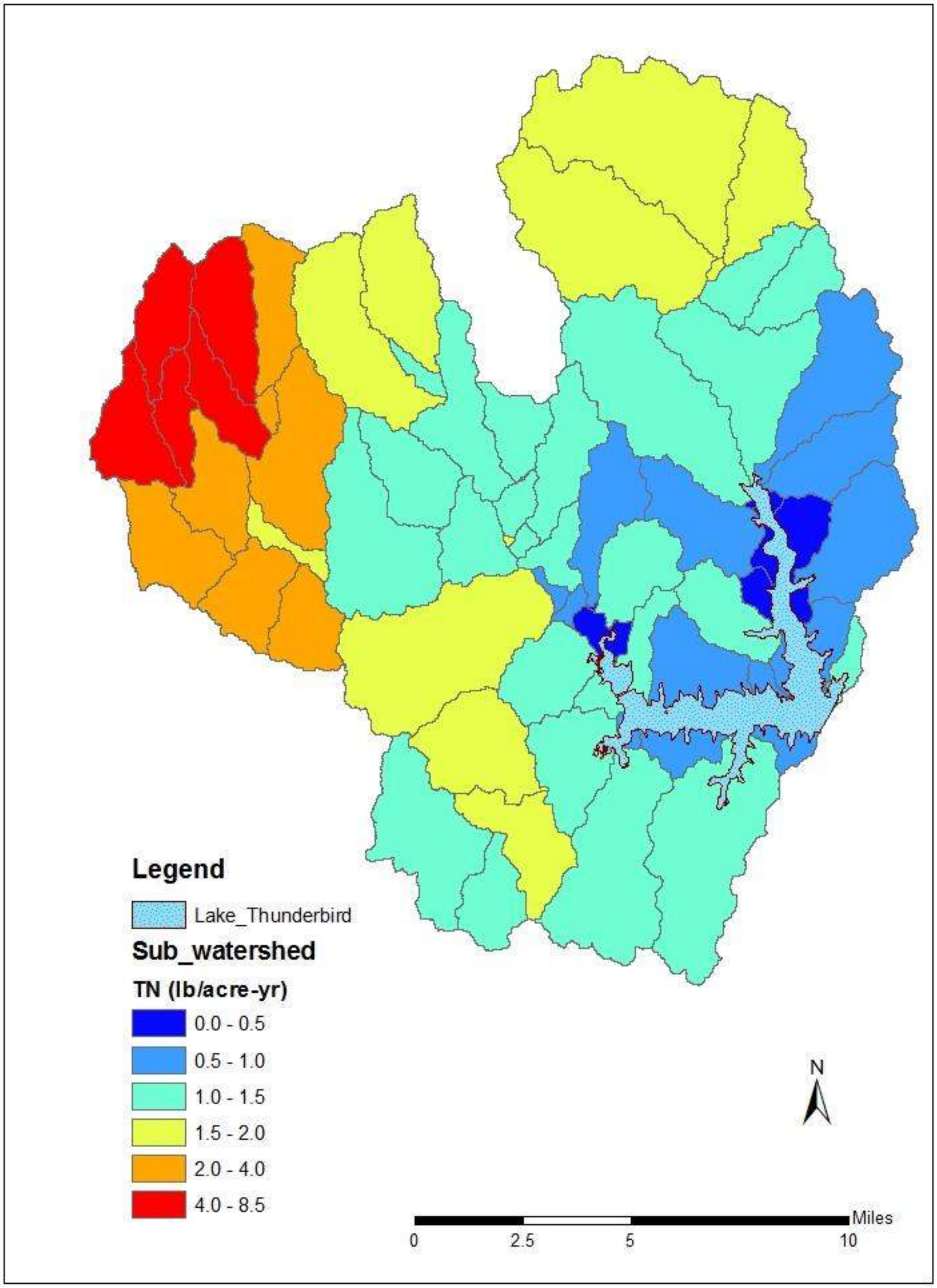
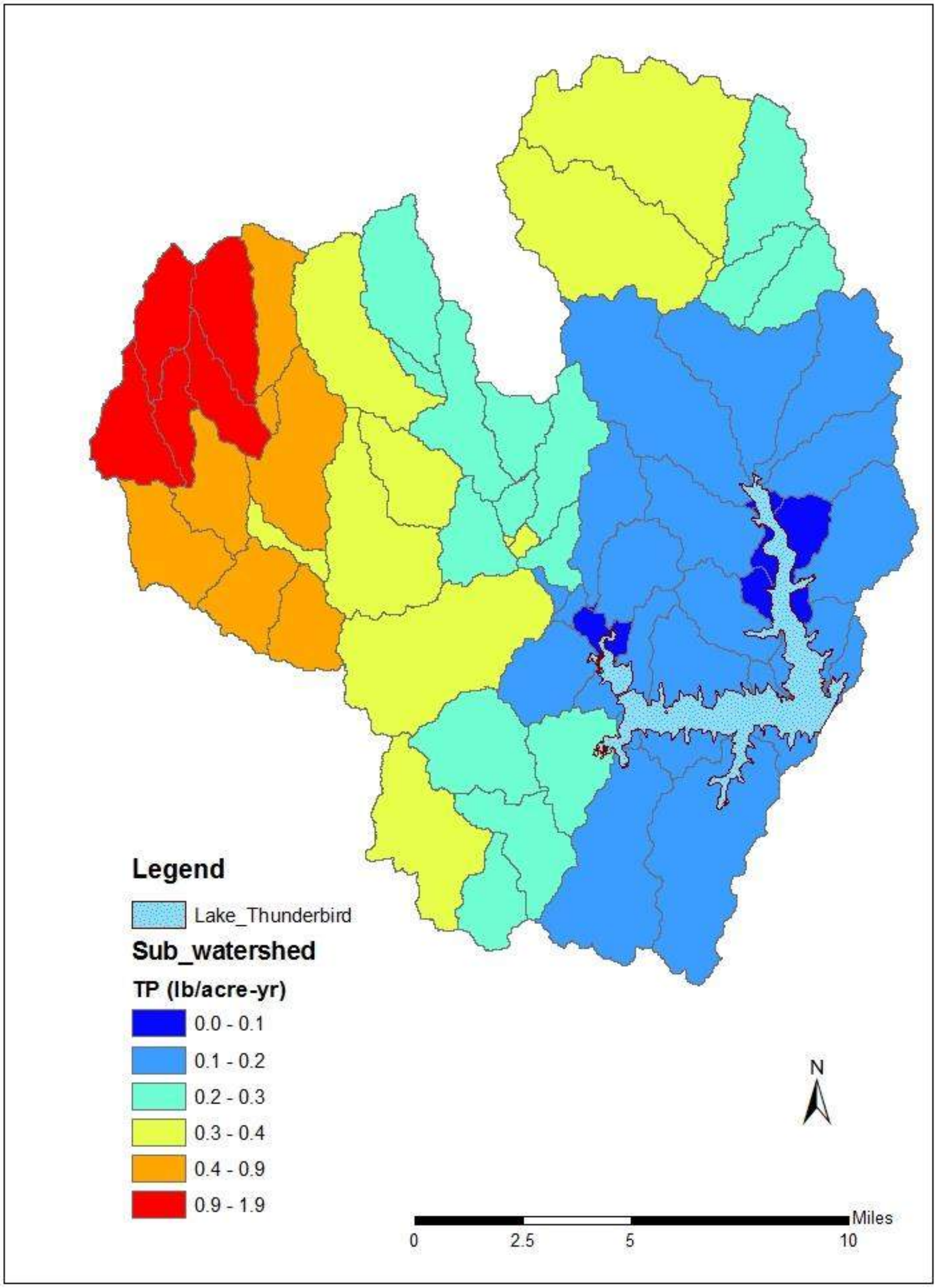


Figure A-20 Calculated sub-watershed TP loadings by HSPF model



A.4 Time series plots of all HSPF Flow, WTEMP, TSS and WQ results

For easy reference, all the model-data comparisons of flow, water temperature, TSS, and water quality at all the sites are presented below in Figure -21 through Figure A-46.

Figure A-21 Comparison of observed and simulated stream flows at Elm station

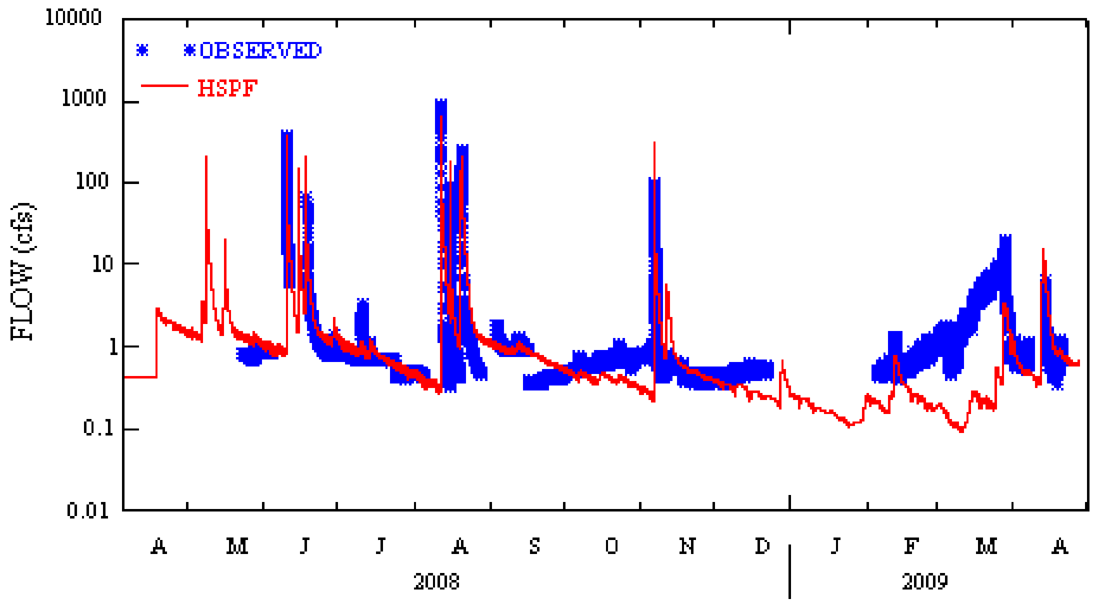


Figure A-22 Comparison of observed and simulated stream flows at Hog station

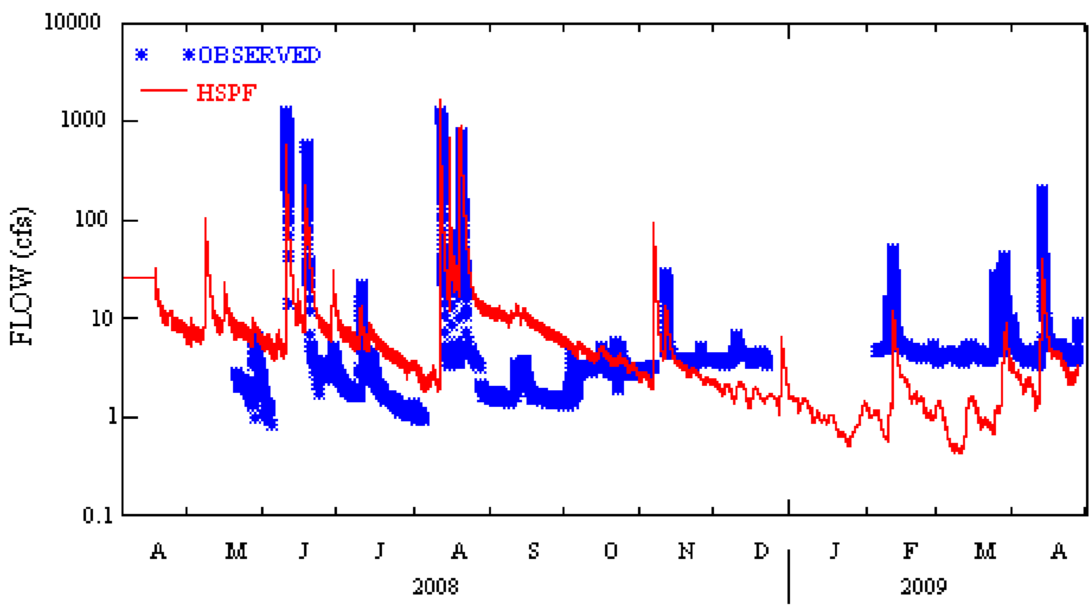


Figure A-23 Comparison of observed and simulated stream flows at L17 station

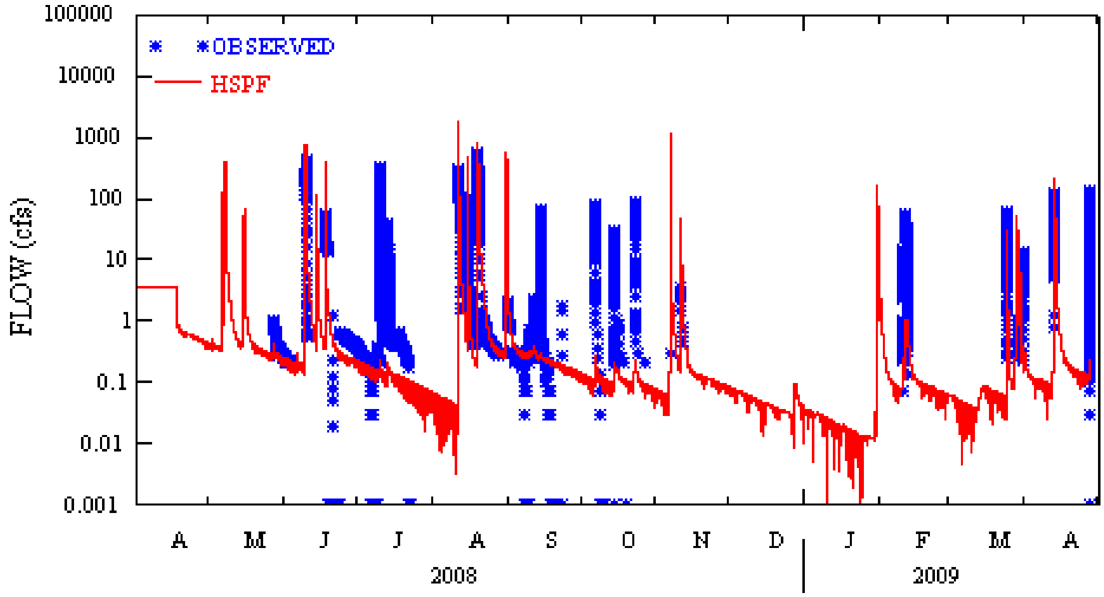


Figure A-24 Comparison of observed and simulated stream flows at L60 station

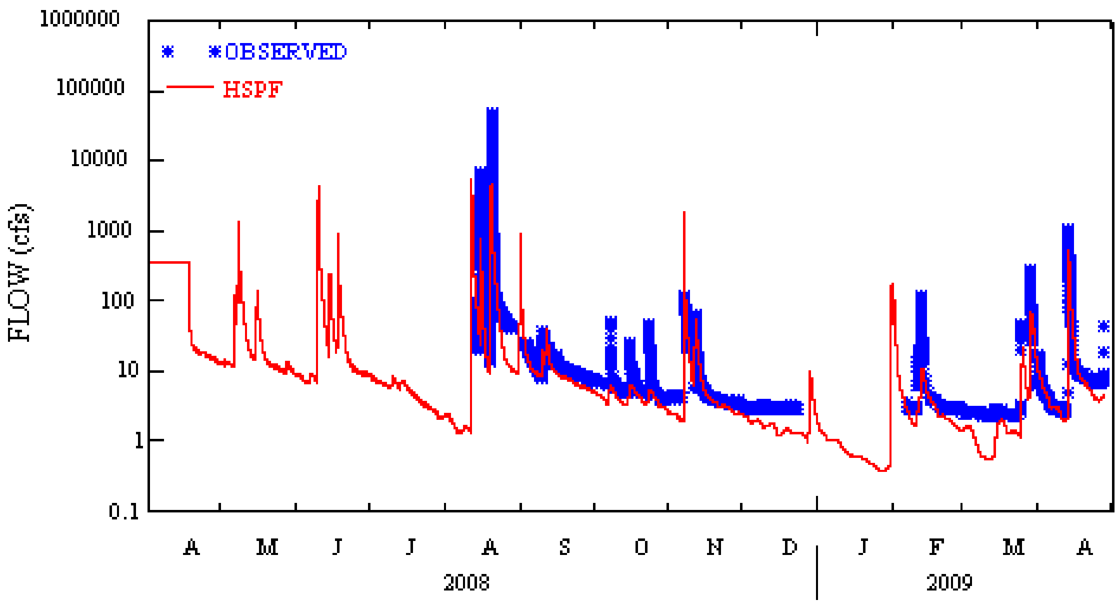


Figure A-25 Comparison of observed and simulated stream flows at Rock station

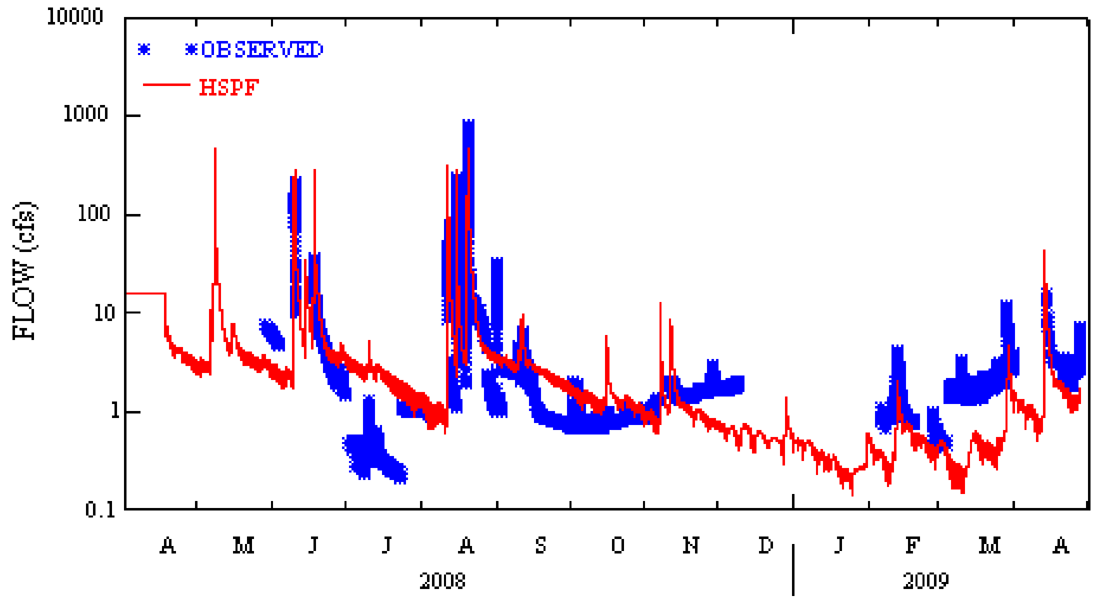


Figure A-26 Comparison of observed and simulated stream temperatures at ELM station

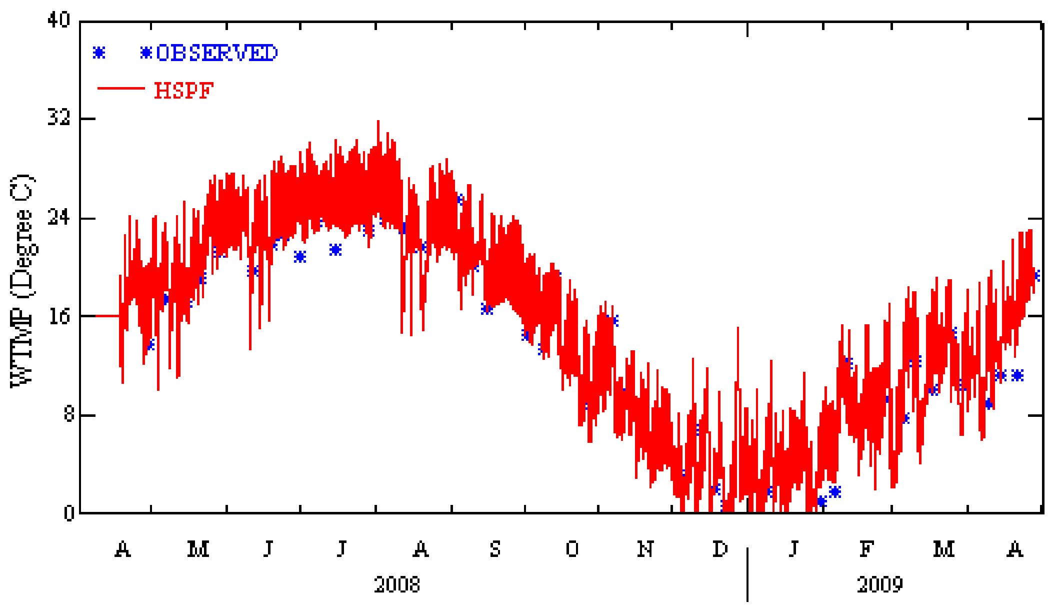


Figure A-27 Comparison of observed and simulated stream temperatures at Hog station

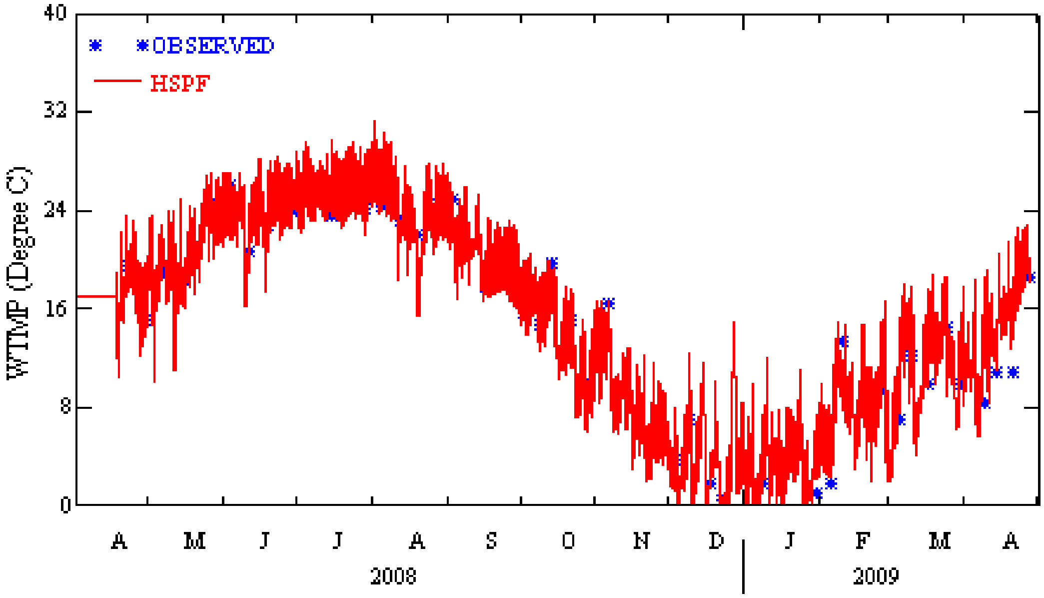


Figure A-28 Comparison of observed and simulated stream temperatures at L17 station

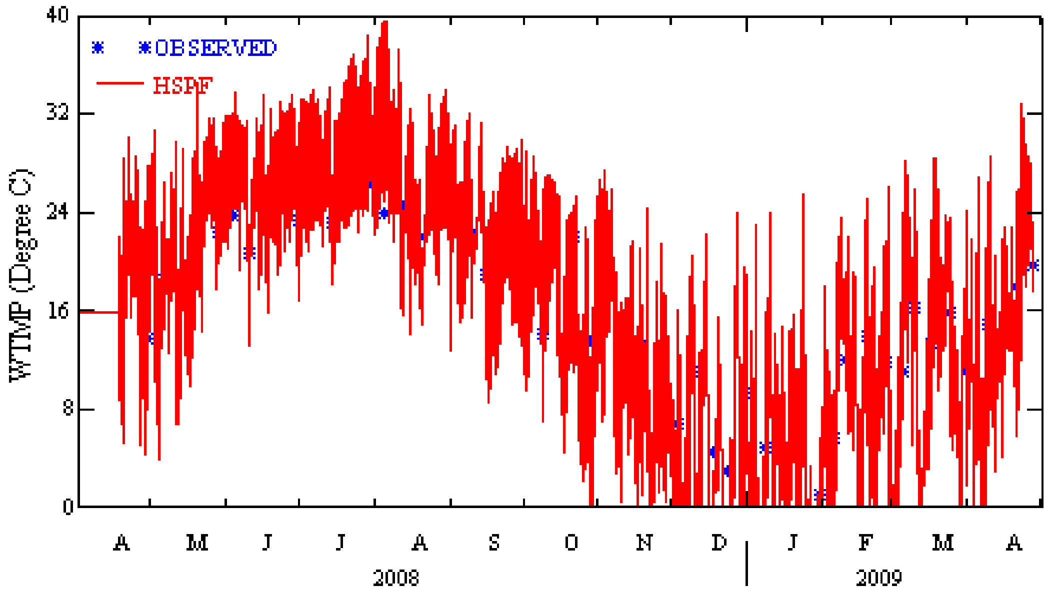


Figure A-29 Comparison of observed and simulated stream temperatures at L60 station

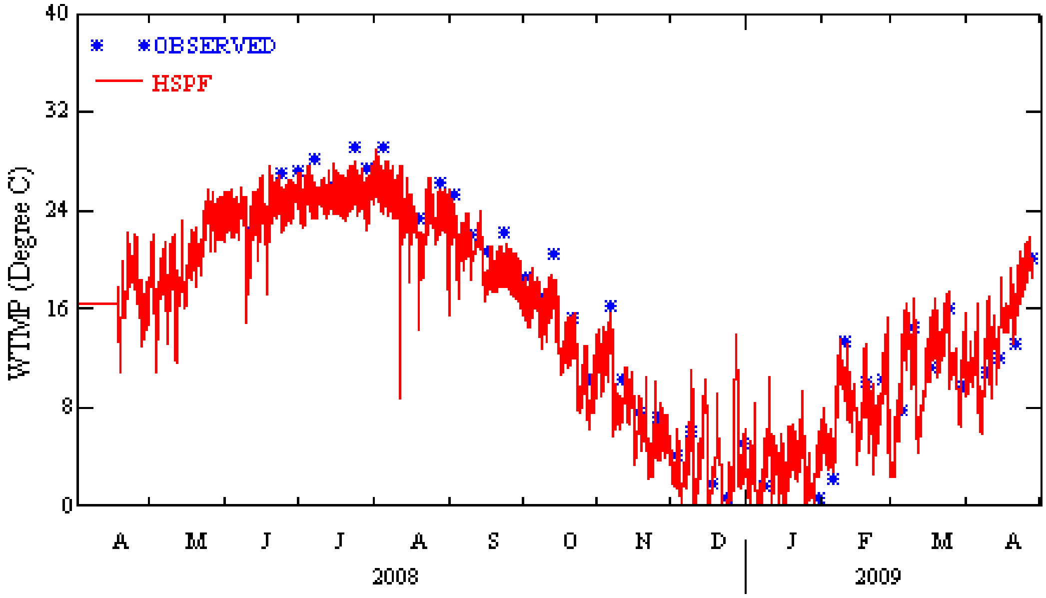


Figure A-30 Comparison of observed and simulated stream temperatures at Rock station

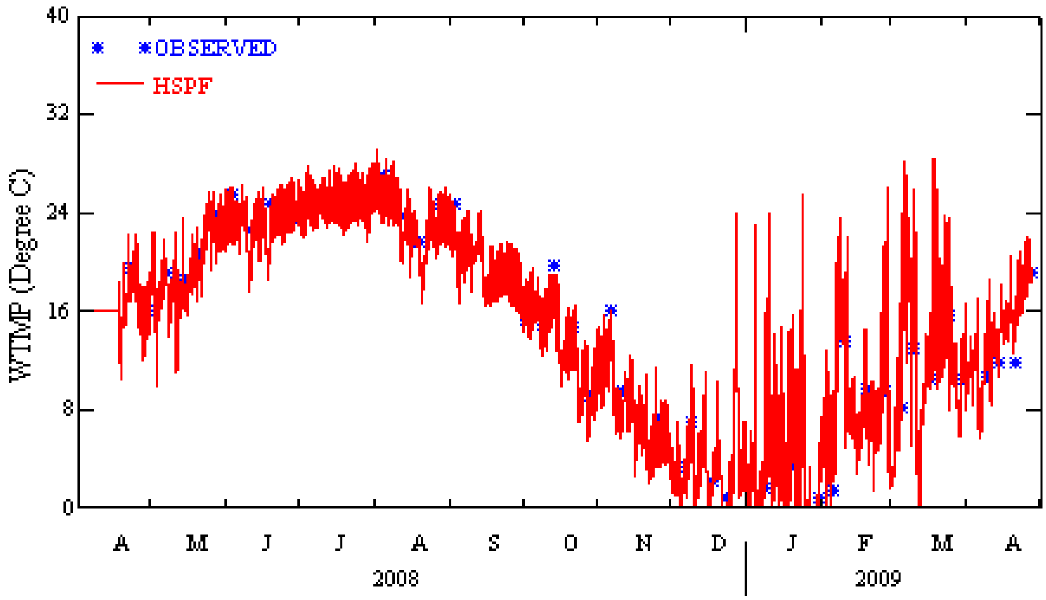


Figure A-31 Comparison of observed and simulated stream TSS concentrations at Elm station

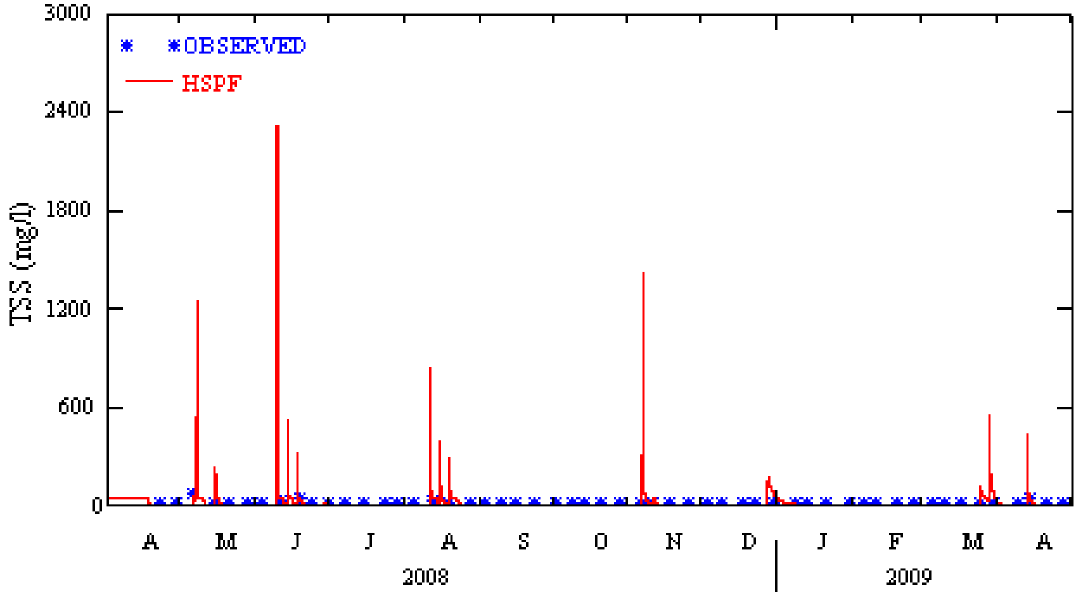


Figure A-32 Comparison of observed and simulated stream TSS concentrations at Hog station

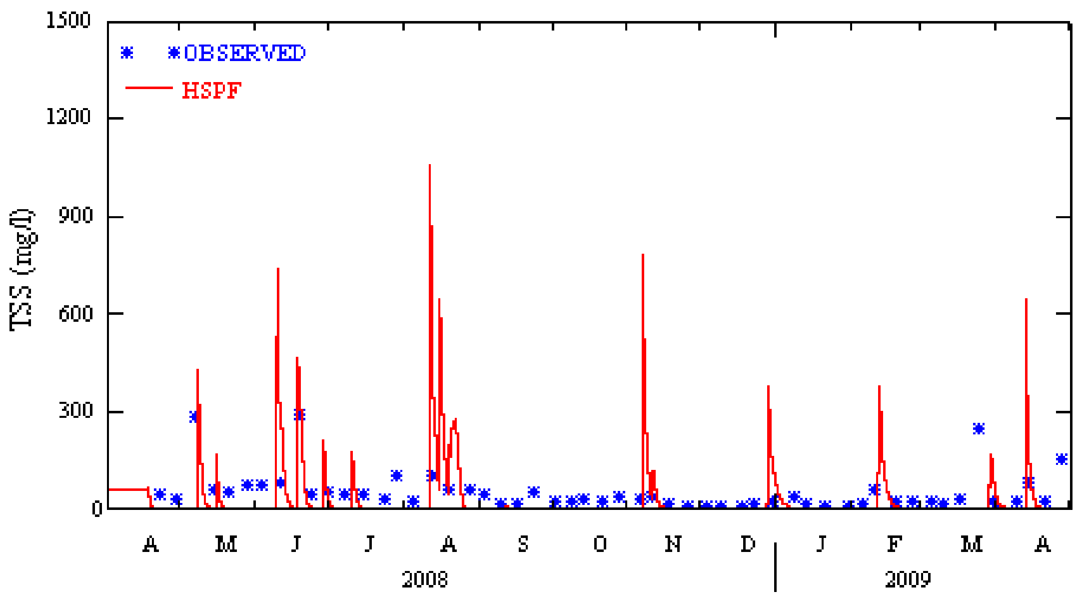


Figure A-33 Comparison of observed and simulated stream TSS concentrations at L17station

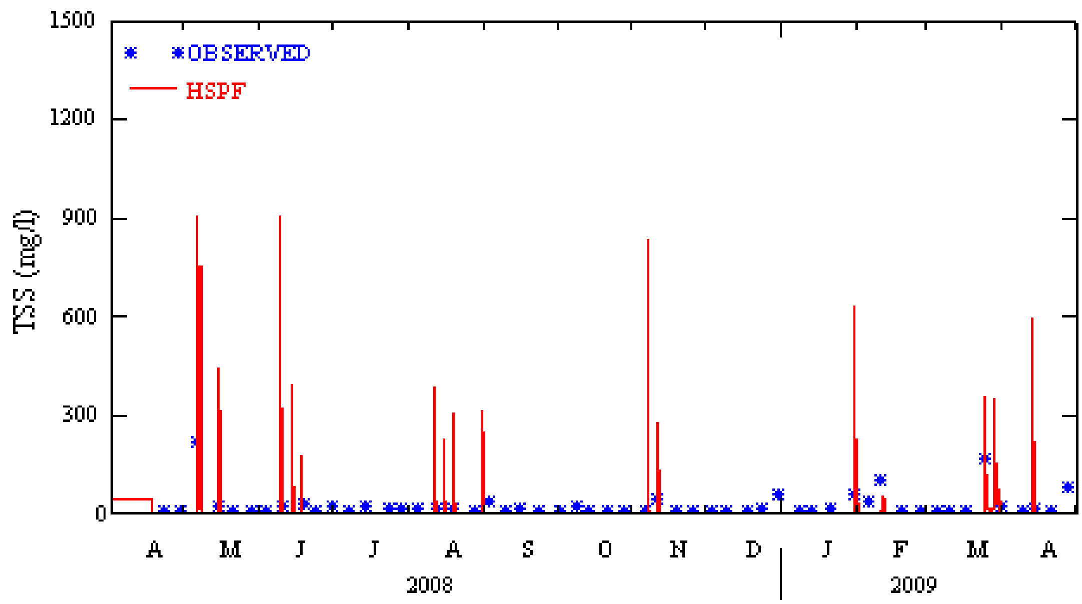


Figure A-34 Comparison of observed and simulated stream TSS concentrations at L60 station

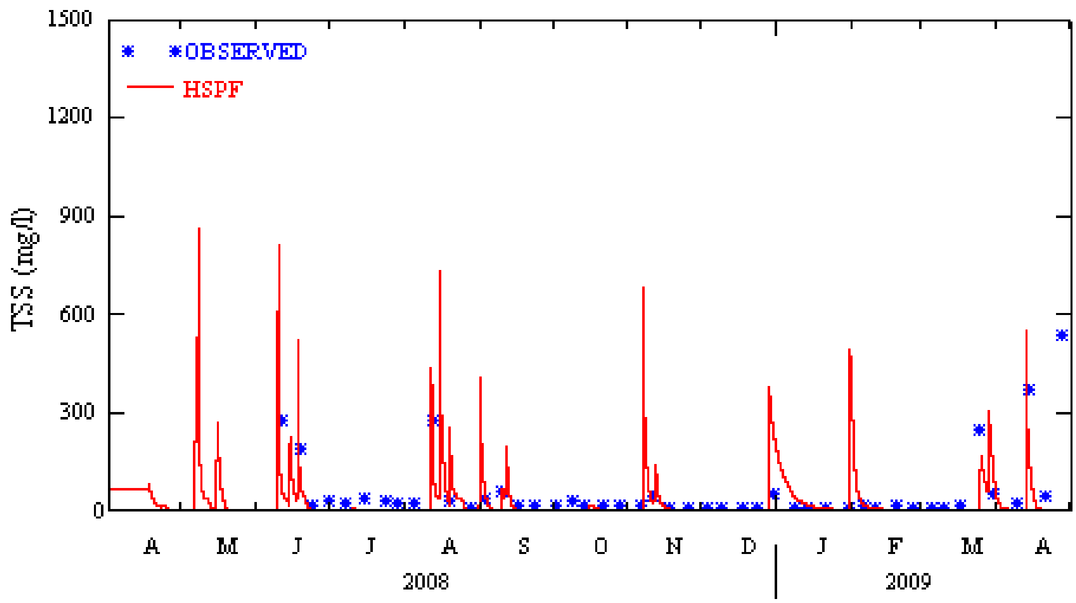


Figure A-35 Comparison of observed and simulated stream TSS concentrations at Rock station

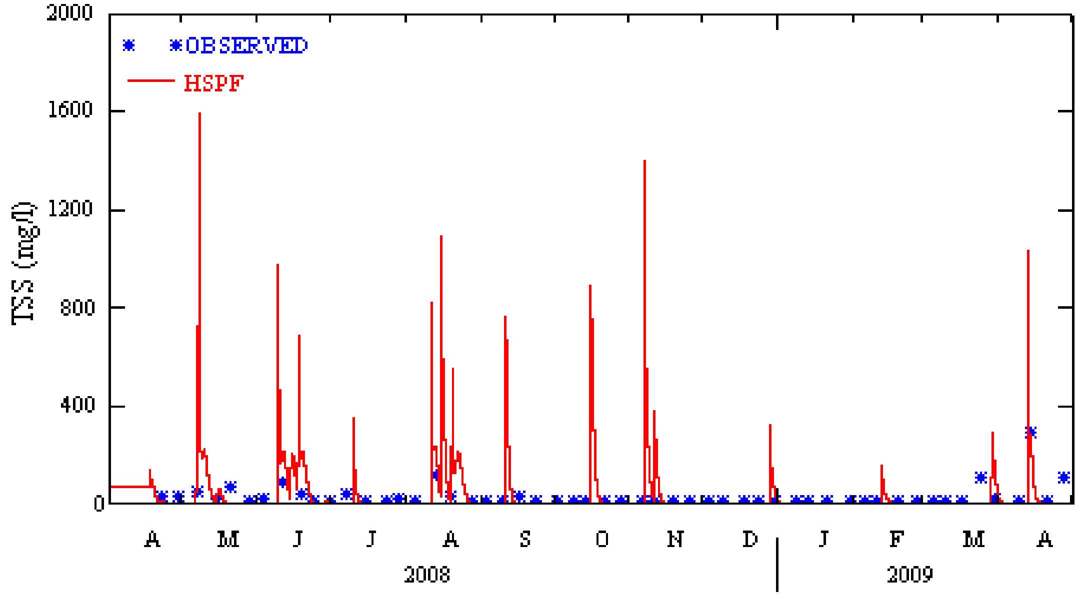


Figure A-36 Comparison of observed and simulated stream DO concentrations at Elm station

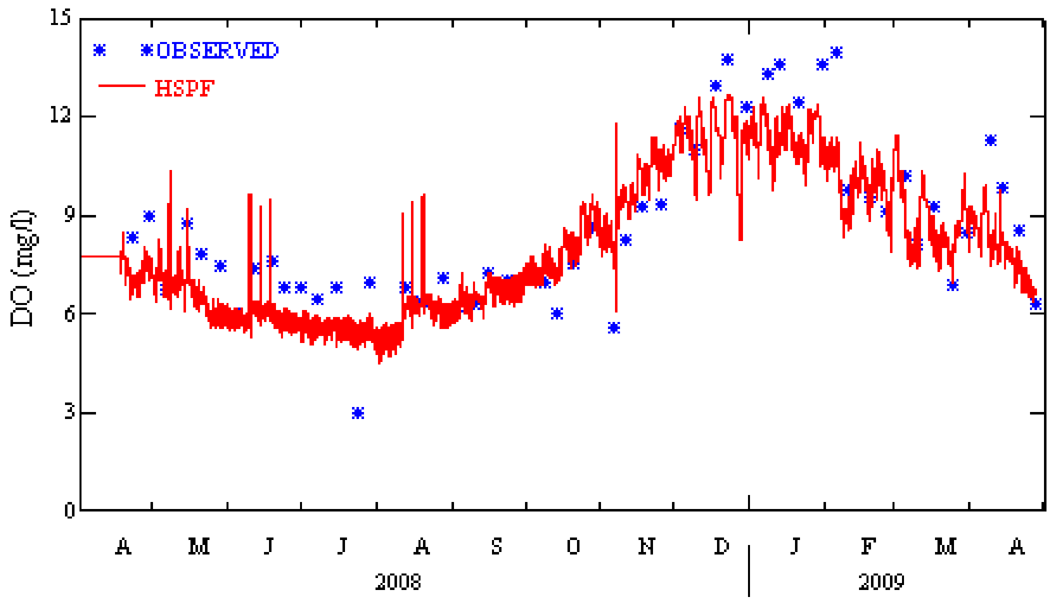


Figure A-37 Comparison of observed and simulated stream DO concentrations at Hog station

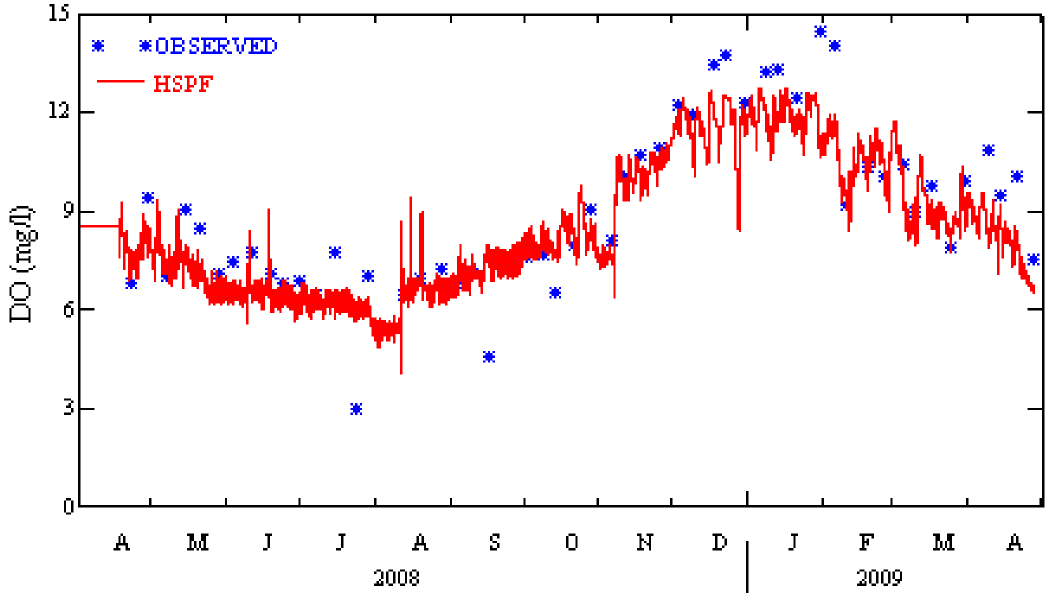


Figure A-38 Comparison of observed and simulated stream DO concentrations at L17 station

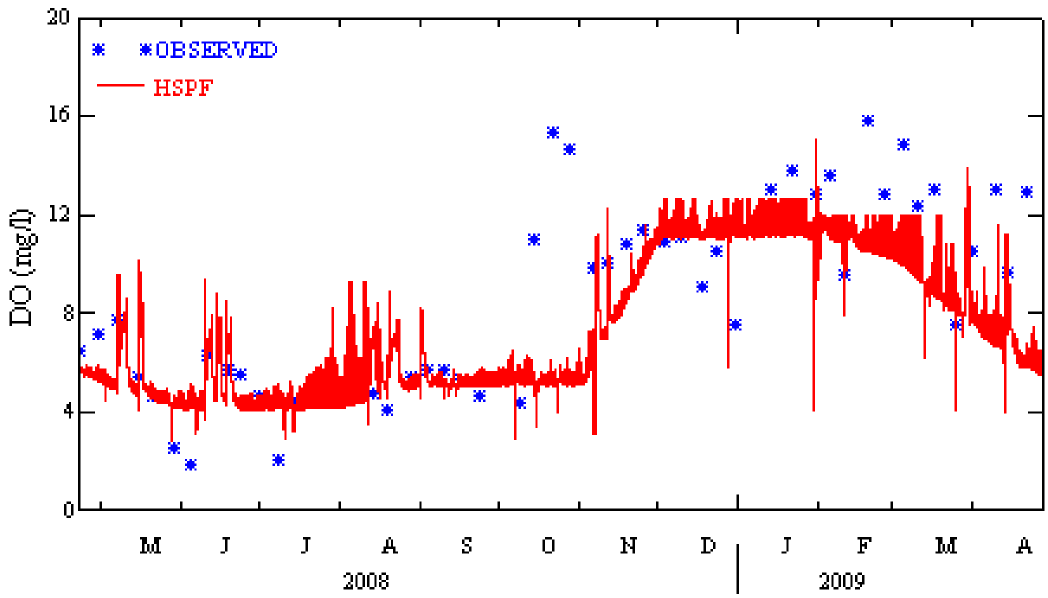


Figure A-39 Comparison of observed and simulated stream DO concentrations at L60 station

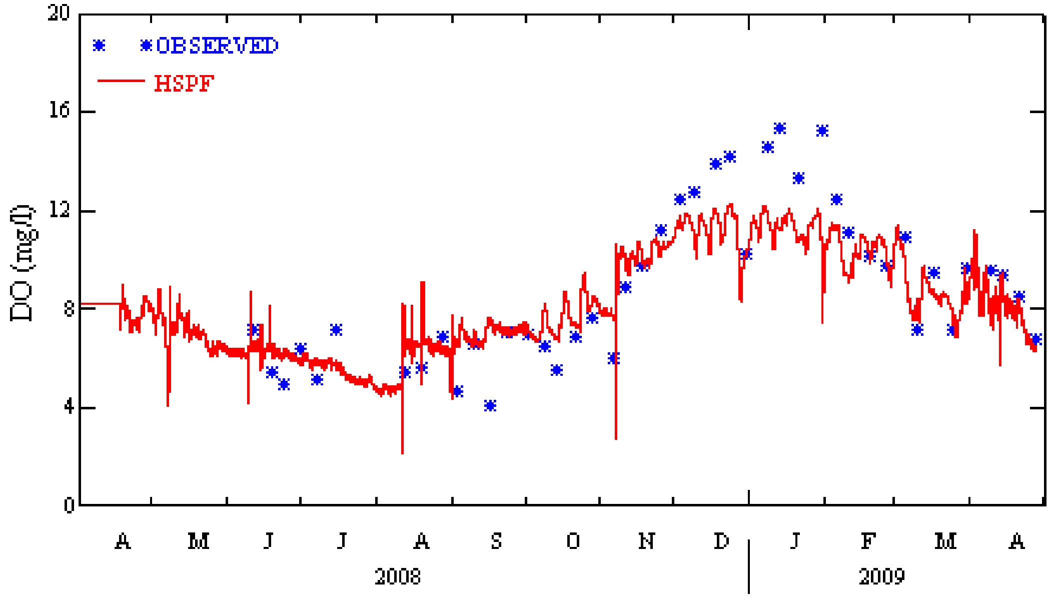


Figure A-40 Comparison of observed and simulated stream DO concentrations at Rock station

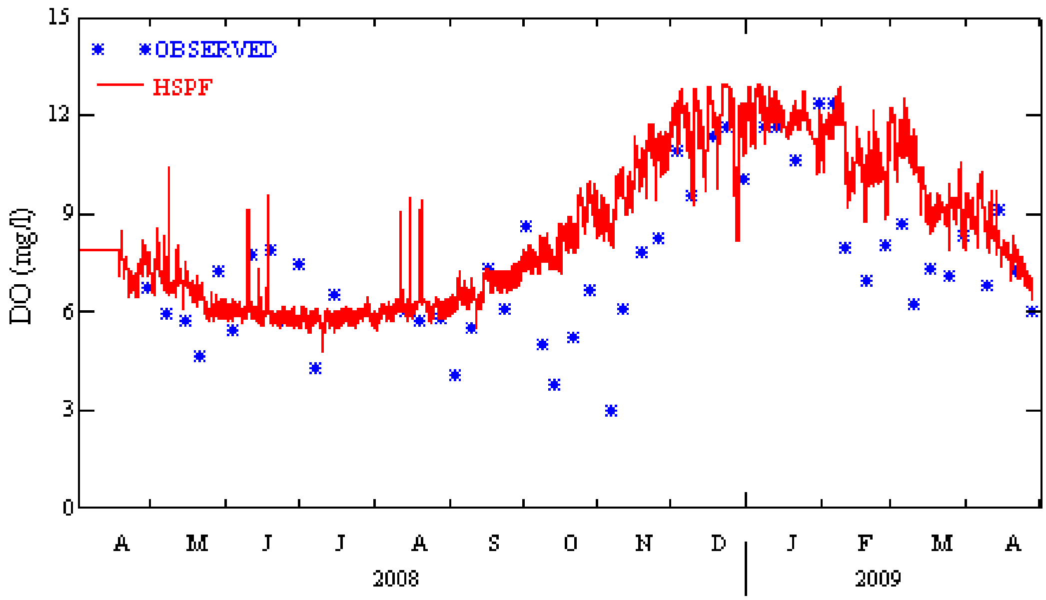


Figure A-41 Comparison of observed and simulated stream TKN concentrations at Elm station

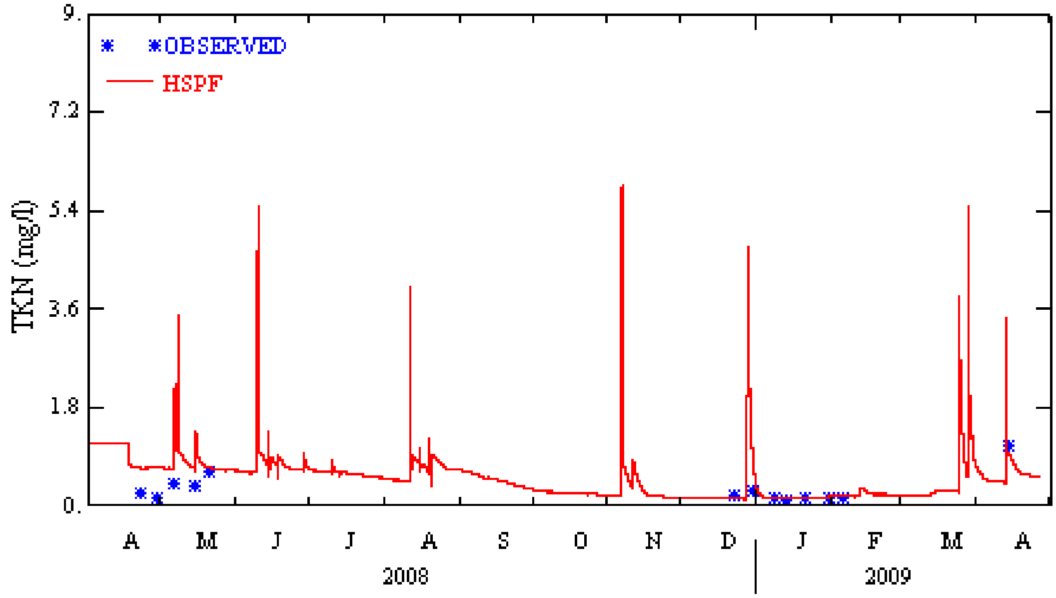


Figure A-42 Comparison of observed and simulated stream TKN concentrations at Hog station

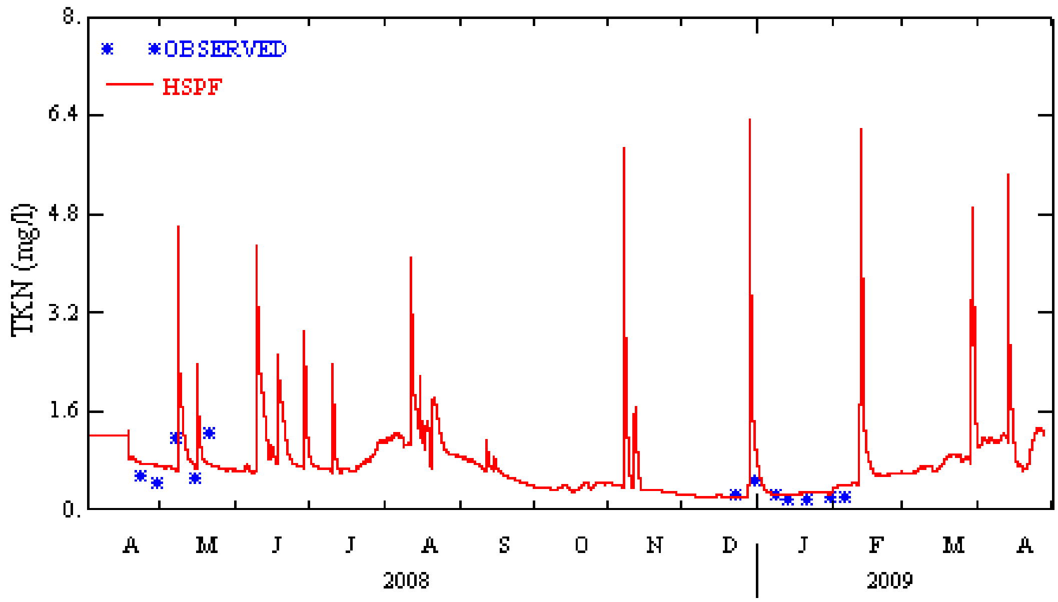


Figure A-43 Comparison of observed and simulated stream TKN concentrations at L17 station

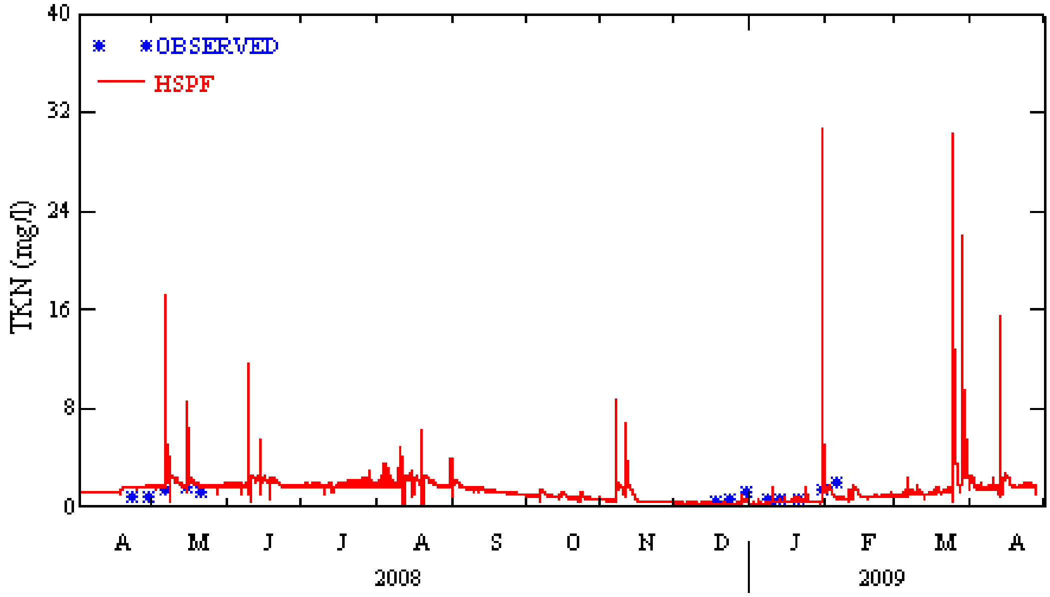


Figure A-44 Comparison of observed and simulated stream TP concentrations at Elm station

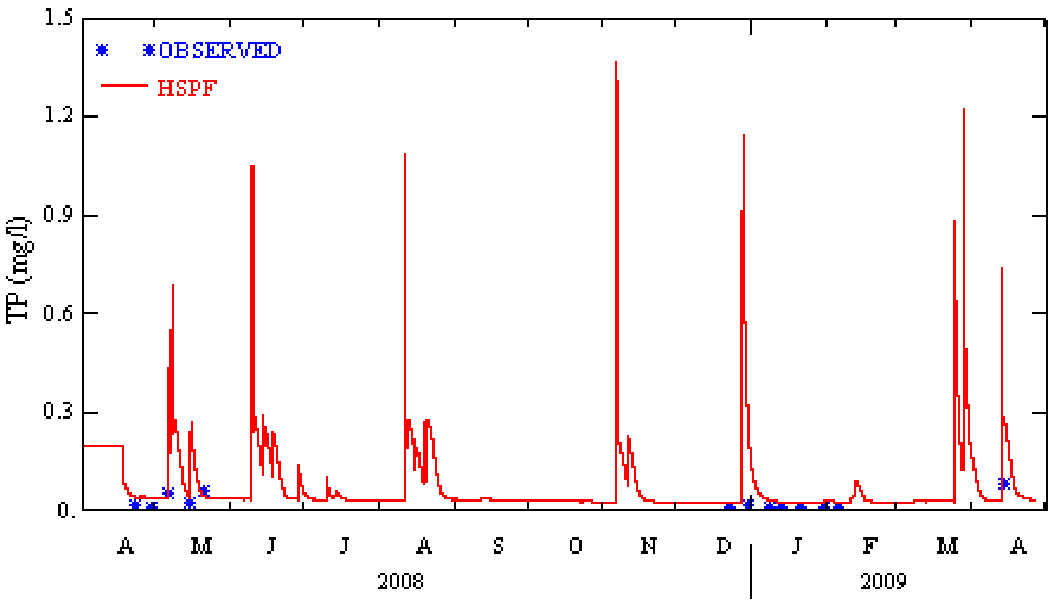


Figure A-45 Comparison of observed and simulated stream TP concentrations at Hog station

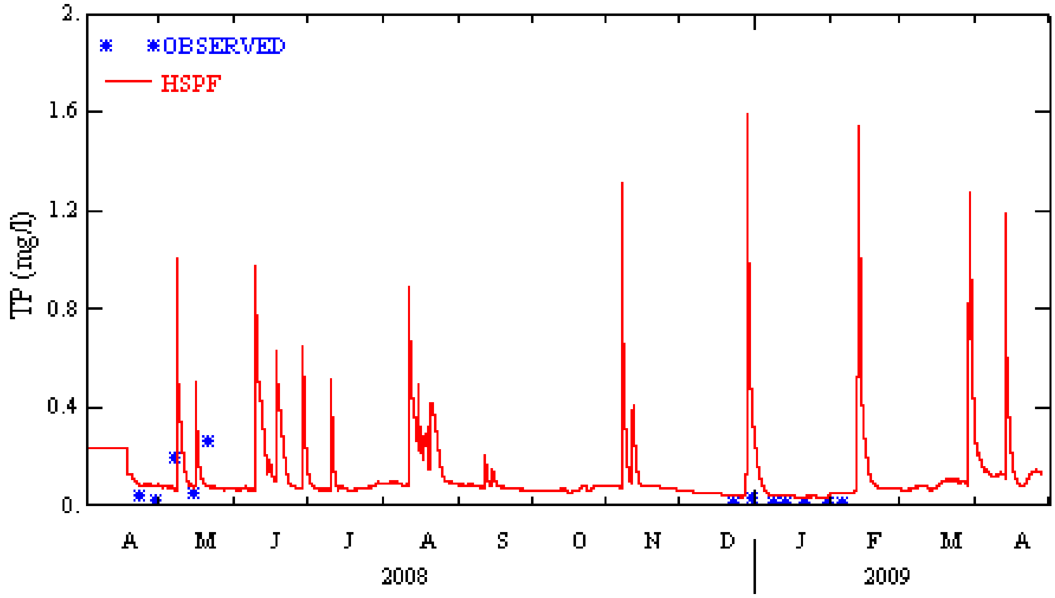
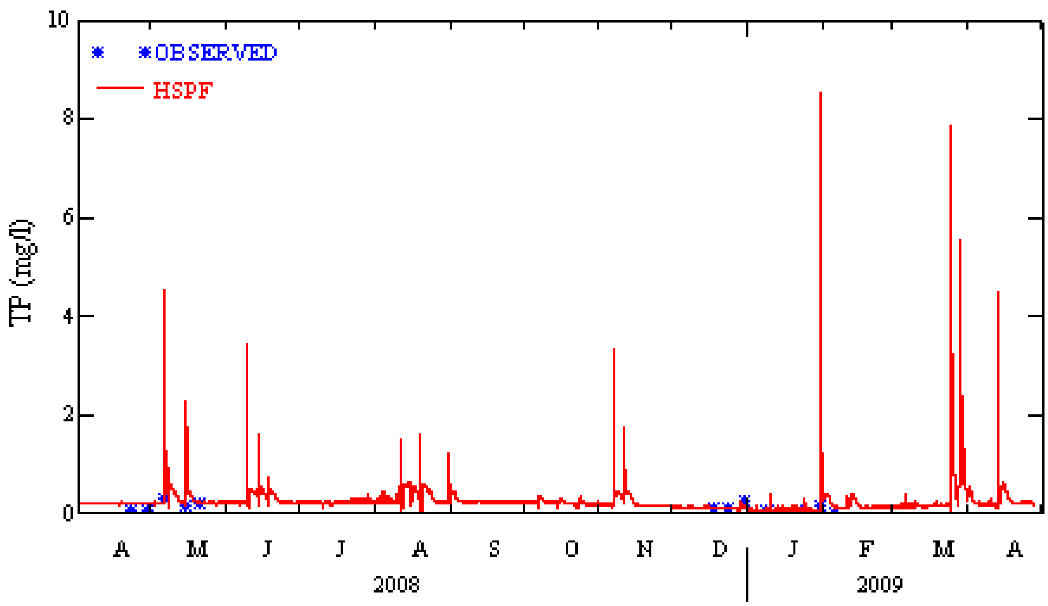


Figure A-46 Comparison of observed and simulated stream TP concentrations at L17 station



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Appendix B

EFDC Hydrodynamic and Water Quality Model

Appendix B

EFDC Hydrodynamic and Water Quality Model

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Appendix B - EFDC Hydrodynamic and Water Quality Model

The technical foundation for the determination of the required TMDL load reductions is based on a public domain surface water model framework that includes (1) a watershed hydrology and runoff model, and (2) a lake hydrodynamic and water quality model. The Hydrologic Simulation Program FORTRAN (HSPF) model has been developed to provide stream flow, sediment and water quality loading from the upper Little River watershed. The Environmental Fluid Dynamics Code (EFDC) model has been developed to link watershed flow and pollutant loading from the HSPF model to describe the water quality response of Lake Thunderbird to watershed loading.

An overview of the HSPF watershed model is presented in Section 3.3 of the main TMDL report and Appendix A of this TMDL report presents a description of the HSPF model, setup, data sources, model results and analysis of watershed loads. This appendix describes the water quality modeling analysis of the EFDC linkage between water quality conditions in Lake Thunderbird and HSPF watershed pollutant loading. This appendix presents a description of the EFDC model, setup, data sources, model results and analysis of the effect of load reductions on lake water quality.

B.1 EFDC MODEL DESCRIPTION - See section 4.1 of the main TMDL report.

B.2 EFDC MODEL SETUP, DATA SOURCES, BOUNDARY CONDITIONS AND INITIAL CONDITIONS - See section 4.2 of the main TMDL report.

B.2.1 Model Domain

In order to accurately describe the physical properties of Lake Thunderbird, a curvilinear horizontal computational grid was developed using the Delft Hydraulics grid generation software Delf3D-RGFGRID (Delft Hydraulics, 2007). The wetting and drying feature of the EFDC model was used to represent cells as dry when lake water surface elevation is less than the bottom elevation of a grid cell. Horizontal projection for the XY data used to define shoreline and grid coordinates is UTM Zone 14 as meters with a horizontal datum of NAD83. Lake elevation, shoreline and bathymetry data was converted from a vertical datum of NGVD29 as feet (MSL) to a datum of NAVD88 as meters (MSL) for model setup. The Twin Bridges causeway on East Alameda Drive across the southwestern area of the Little River arm of the lake was represented in the model grid as a barrier to flow by removing selected model grid cells to force flow to be transported around the roadway.

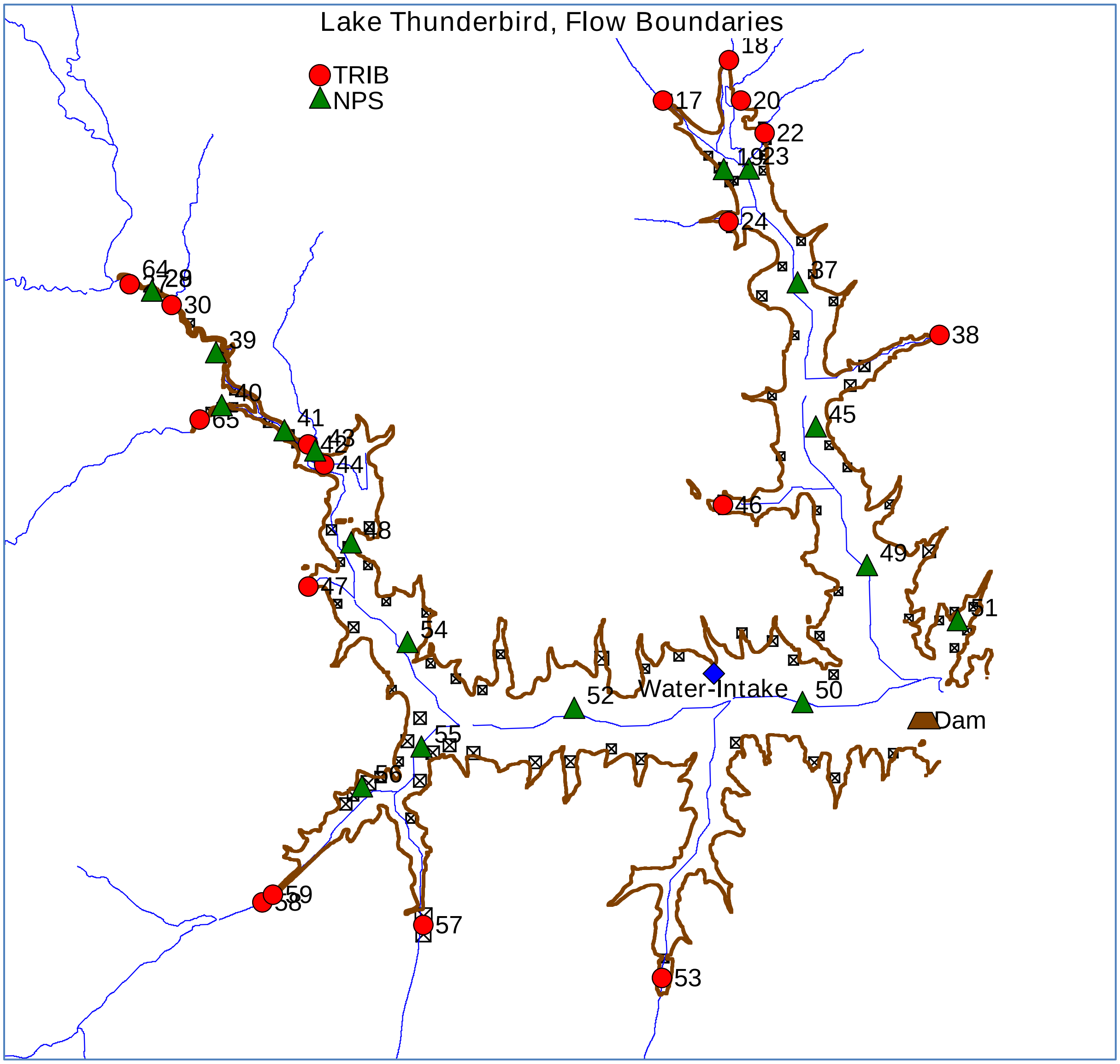
B.2.2 Data Sources - See section 4.2 of the main TMDL report.

B.2.3 Boundary Conditions

The lake model requires the specification of external boundary data to describe: (1) flow and pollutant loading from the watershed; (2) withdrawals from water supply intakes and releases at the dam; (3) meteorological and wind forcing; and (4) atmospheric deposition of nutrients.

Watershed Flow and Pollutant Loading: As described in Section 3.3 of the main TMDL report, flow and pollutant loading from the watershed was provided by the HSPF model as hourly time series data for tributaries and distributed flow areas. Tributary inflows included the Little River, Elm Creek, Rock Creek, Hog Creek, Dave Blue Creek, Jim Blue Creek, Clear Creek, Willow Branch and a number of unnamed streams. Figure B-1 shows the locations of the 18 tributary (red circles) and 18 distributed flow (green triangles) boundary inputs to the lake model.

Figure B-1 Boundary Locations for HSPF tributary outlets and NPS distributed flow, Water Supply Intakes and Release at the Dam



TRIBUTARIES	TRIBUTARIES	DISTRIBUTED NPS	DISTRIBUTED NPS
17_[unknown]	44_[Little-River]	19_[Distributed]	45_[Distributed]
18_[Hog-Creek]	46_[Willow-Br]	23_[Distributed]	48_[Little-River]
20_[unknown]	47_[unknown]	28_[Little-River]	49_[Hog-Creek]
22_[unknown]	53_[Clear-Creek]	29_[Little-River]	50_[Little-River]
24_[unknown]	57_[Jim-Blue-Ck]	37_[Distributed]	51_[Distributed]
27_[Elm-Creek]	58_[unknown]	39_[Little-River]	52_[Little-River]
30_[unknown]	59_[Dave-Blue-Ck]	40_[Rock-Creek]	54_[Distributed]
38_[unknown]	64_[Little-River]	41_[Little-River]	55_[Distributed]
42_[unknown]	65_[Rock-Creek]	43_[Little-River]	56_[Dave-Blue-Ck]

Although HSPF and EFDC both model sediments, nutrients, organic matter, algae and dissolved oxygen, the model results for some HSPF state variables require stoichiometric transformations for linkage to EFDC state variables as shown in Table B-1. Stoichiometric coefficients assigned for input to the HSPF model are used for the HSPF-EFDC linkage to ensure that the mass loading of organic matter from HSPF is accurately assigned for input to the EFDC model.

Table B-1 Linkage of HSPF and EFDC State Variables

HSPF	Stoichiometry	EFDC	Units
Streamflow		Flow	cms
Distributed Runoff			
Water Temperature		Water Temperature	Deg-C
Sediment (sand)		Non Cohesive Sediment (not used)	mg/L
Sediment (silt)		Cohesive Sediment, CohSS	mg/L
Sediment (clay)			
Algae Biomass	C/CHL Chl/P	Bluegreen & Green Algae	mg C/L
BOD	CVBO	TOC, POC, DOC	mg C/L
Organic-Carbon	C/DW		
Organic-Phosphorus	C/P	TOP, POP, DOP	mg P/L
Organic-Nitrogen	C/N	TON, PON, DON	mg N/L
Total OrthoPhosphate		Total OrthoPhosphate, TPO4	mg P/L
Ammonium		Ammonium, NH4	mg N/L
Nitrite+Nitrate		Nitrite+Nitrate, NO23	mg N/L
Dissolved Oxygen		Dissolved Oxygen, DO	mg/L

C/CHL carbon:chlorophyll-a
Chl/P chlorophyll-a: phosphorus
CVBO oxygen: dry weight biomass
C/DW carbon: dry weight biomass
C/P carbon: phosphorus
C/N carbon:nitrogen

Labile HSPF BOD and refractory HSPF organic carbon (ORC), organic phosphorus (ORP), and organic nitrogen (ORN) are added as shown in the HSPF-EFDC linkage in Table B-1 to derive non-living TOC, TOP and TON for input to the EFDC model. HSPF derived TOC, TOP and TON is then split for input to EFDC as refractory, labile and dissolved components of total organic matter using the fractions given in Table B-2.

Table B-2. Refractory, Labile and Dissolved Splits for Organic Matter

	Refractory RPOM	Labile LPOM	Dissolved DOM
TOC	0.08	0.02	0.90
TOP	0.72	0.18	0.10
TON	0.30	0.20	0.50

HSPF-derived concentrations for TOC, TON and TOP are split for input to EFDC as refractory particulate organic matter, labile particulate organic matter and dissolved organic matter (Table B-2). The DOC:TOC fraction of 0.9 is supported by two very different data sets. The first data set is a composite database of worldwide rivers compiled by Meybeck (1982) where the DOC:TOC ratio was shown to be related to TSS concentration. DOC:TOC ratios greater than ~0.8 were consistent with TSS levels of ~5-50 mg/L. The second site-specific data set is based on a compilation of watershed station data records for DOC and TOC that were compiled and analyzed to determine a mean estimate of the DOC:TOC ratio for watershed loading to Lake Thunderbird. For the Lake Thunderbird watershed, TOC concentrations ranged from 2.6 to 7.4 while DOC concentrations ranged from 2.4 to 6.8. The ratio of DOC:TOC varied from 0.92 to 1.08 with a mean of 0.96.

BOD is represented as ultimate BOD in the HSPF model. The stoichiometric ratio for oxygen; dry weight of biomass (CVBO) has a value of CVBO=1.4 mg O2/mg-DW and the ratio of carbon: dry weight (C/DW) is 0.49 mg C/mg-DW. The parameter values used to convert BOD to an equivalent organic carbon basis are taken from parameter values assigned for the HSPF model. The stoichiometric ratios for Phosphorus to Carbon (P/C) and Nitrogen to Carbon (N/C) are based on Redfield ratios where C/P = 41.1 mg C/mg-P and C/N = 5.7 mg C/mg-N (Di Toro 2001). The stoichiometric ratios for Chl/P (0.5 mg Chl/mg P) and C/Chl (82.1 mg C/mg Chl) for algae biomass are taken from parameter values assigned for the HSPF model.

Withdrawals from Water Supply Intakes and Releases at the Dam: A flow boundary was assigned to represent water supply withdrawals at a common intake location from the reservoir for the municipalities of Norman, Midwest City and Del City. Water supply withdrawal data was provided by the Central Oklahoma Master Conservancy District (COMCD). A flow boundary was assigned to account for release flow at the dam (designated by the U.S. Army Corps of Engineers as Station NRM02) with flow data provided by the Army Corps of Engineers. The primary spillway release from the lake is an overflow drawing from the base of the flood pool elevation (1039 ft MSL) while the secondary spillway releases is through the dam with water removed at a base elevation of 997 ft MSL. Secondary spillway releases over and above the primary spillway releases are controlled by the Tulsa District U.S. Army Corps of Engineers. COMCD drinking water withdrawals are generally from the center intake gate with the base set at an elevation of 1023 ft MSL. The base of the upper gate is at 1043 ft MSL while the base of the lower gate is at an elevation of 1004 ft MSL. In the lake model setup, releases over the dam and water supply withdrawals are assigned equally as 1/6 of the flow rate to each of the 6 vertical layers for two grid cells selected by proximity to the dam release site and the water intake structure (Paul Koenig, OWRB, personal communication, May 16, 2012). Figure B-1 shows the locations of the water intakes and the flow release at the dam. The only sources of water inflow to the lake model are from the simulated HSPF flows and precipitation and the only withdrawals of water are assigned from water supply withdrawals, release flow at the dam and evaporation.

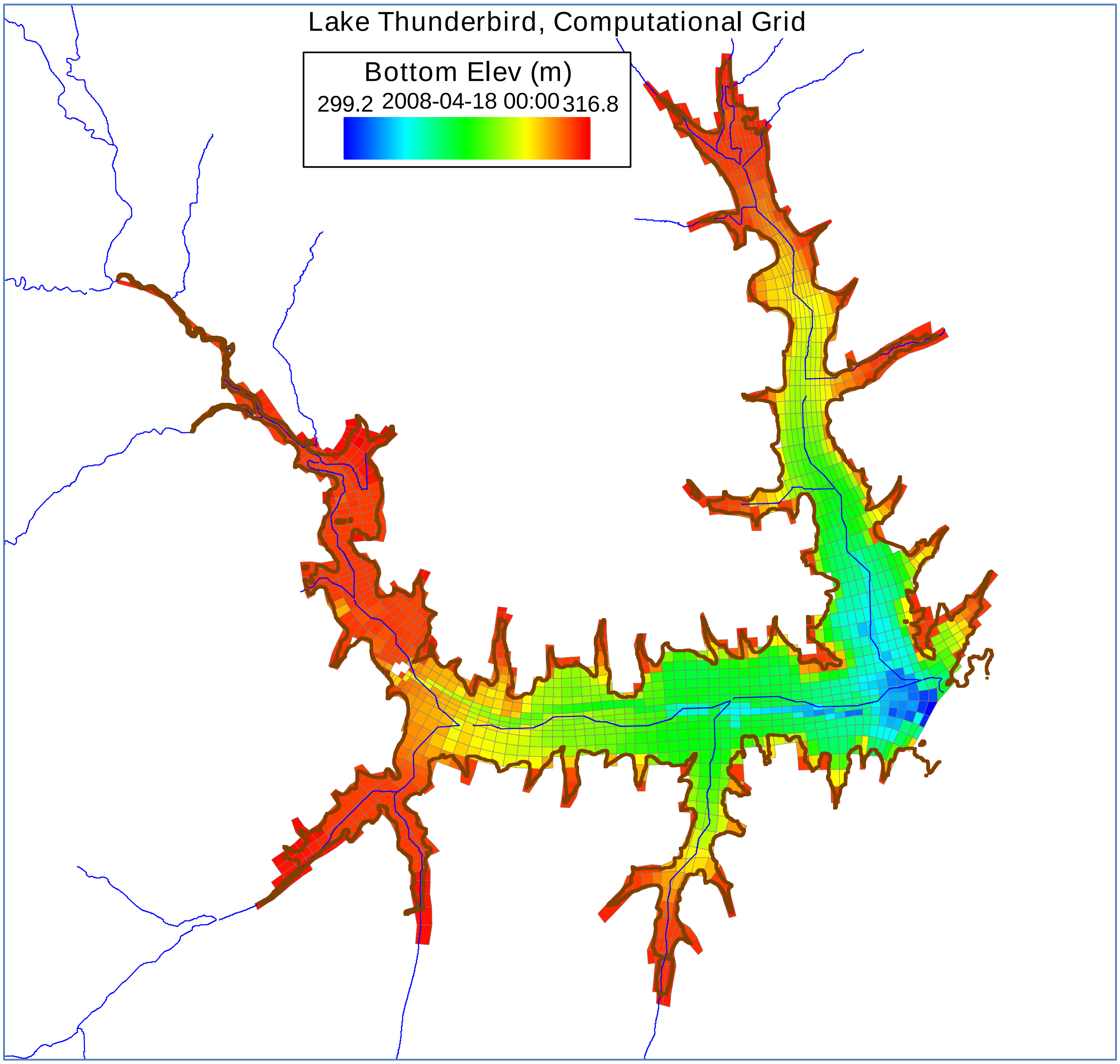
Meteorological Forcing: The EFDC model requires time series data to describe the effect of meteorological forcing and winds on lake circulation processes. Wind speed/direction and meteorological data was obtained from the Oklahoma MESONET database at Station NRMN. Meteorological data needed for the model includes wind, air temperature, air pressure, relative humidity, precipitation, evaporation, cloud cover and solar radiation.

Atmospheric Deposition of Nutrients: For Lake Thunderbird, wet and dry deposition data (Table B-3) was estimated as the average of annual data from 2008-2009 for ammonia and nitrate from the National Atmospheric Deposition Program (NADP) for Station OK17 (Kessler Farm Field Laboratory, Lat 34.98; Lon -97.5214) and the Clean Air Status and Trends Network (CASTNET) Station CHE185 (Cherokee Nation, Lat 35.7507, Lon -94.67). Data was not available from the CASTNET or NADP sites for phosphate. Dry deposition for phosphate was estimated using annual average ratios of N/P for atmospheric deposition of N and P reported for six sites located in Iowa (Anderson and Downing, 2006) and the ammonia and nitrate data obtained from the NADP and CASTNET data sources. Using annual rainfall for Lake Thunderbird for the simulation period from 2008-2009 (36.9 inches) and the estimate obtained for dry deposition of phosphate, the annual average wet phosphate concentration was estimated in proportion to the Dry/Wet ratio for phosphate deposition fluxes reported in Table VII by Anderson and Downing (2006).

Table B-3 Dry and Wet Atmospheric Deposition for Nitrogen and Phosphorus for Lake Thunderbird

	Dry	Dry, Annual	Data
	g/m^2-day	kg/ha-yr	Source
TPO4	1.3275E-05	0.048	Anderson & Downing (2006) Table VII
NH4	1.0359E-04	0.378	CASTNET, CHE185
NO3	1.4663E-04	0.535	CASTNET, CHE185
DIN (NO3+NH4)	2.5022E-04	0.913	CASTNET, CHE185
	Wet	Wet, Annual	Data
	mg/L	kg/ha-yr	Source
TPO4	0.001	0.009	Anderson & Downing (2006) Table VII
NH4	0.370	3.377	NADP, OK17 (2008-2009)
NO3	0.945	8.624	NADP, OK17 (2008-2009)
DIN (NO3+NH4)	1.315	12.001	NADP, OK17 (2008-2009)

Figure B-2 Lake Thunderbird Computational Grid and Bottom Elevation



B.2.4 Initial Conditions

See Section 4.2 of the main TMDL report. Bed concentrations of carbon, nitrogen and phosphorus are derived from the OWRB sediment bed survey data collected in 2008 (see Appendix D), solids density of 2.6 g/cm^3 and spatially dependent estimates of bed porosity for the riverine zone (0.5), transition zone (0.6) and lacustrine zone (0.7). The parameter values assigned for porosity are consistent with the dependency of porosity with median particle diameter shown by Di Toro (2001) where larger particle sizes are characterized by denser bed material and a lower porosity.

B.3 EFDC MODEL CALIBRATION

Calibration of the Lake Thunderbird model was performed using the following sequence of steps:

1. Compile observed data required for lake model setup and comparison of model results with observed data at OWRB station locations.

2. Develop computational grid to represent the spatial domain, bathymetry of the lake, and lake level vs. volume relationship.

3. Assign grid cell locations for boundary inflows and develop linkage of flow and load data for input to EFDC model from water withdrawals, flow release over the dam and streamflow and water quality data from HSPF model results.

4. Develop hydrodynamic model water balance to calibrate lake volume and stage height.

5. Add linkage of atmospheric forcing data and water temperature from watershed model to test ability of hydrodynamic model to simulate density effects, onset and erosion of lake stratification, and seasonal variation of water temperature.

6. Add linkage of sediment loading from watershed model and setup in-lake sediment transport model with cohesive parameters for critical shear stress, deposition velocity and resuspension rate.

7. Add linkage of algae, organic carbon, and nutrient loading from watershed model, assign splits for dissolved and particulate forms of organic carbon and nutrients, and setup in-lake water quality model with water quality kinetics.

8. Compile sediment bed observation data and add linkage of sediment diagenesis model with sediment flux kinetics to internally couple organic matter deposition from the water column to the sediment bed for simulation of sediment oxygen demand and benthic recycle of inorganic nutrients back to the water column.

Kinetic coefficients for the sediment transport, water quality model and the sediment flux model were initially assigned from the literature for hydrodynamic, sediment transport, water quality models and the sediment flux model. Based on model performance statistics and visual comparisons of model-data plots, selected model kinetic coefficients were adjusted, within the range of literature values, to achieve an acceptable calibration of the Lake Thunderbird model with the observed data sets for water temperature, TSS and water quality constituents.

Calibration of the lake model was accomplished by comparison of model results to observed data extracted from grid cells matching specific OWRB station locations in Lake Thunderbird. Model-data comparisons were evaluated for water temperature, TSS, dissolved oxygen, nutrients, algae biomass as chlorophyll-a and organic carbon. Model results were extracted and compiled with observed data to prepare (a) time series plots of surface layer and bottom layer results; and (b) vertical profiles as time snapshots of model results that match sampling dates. In addition to a visual inspection of model-data plots, model performance statistics were computed for the Root Mean Square (RMS) Error and the Relative RMS Error.

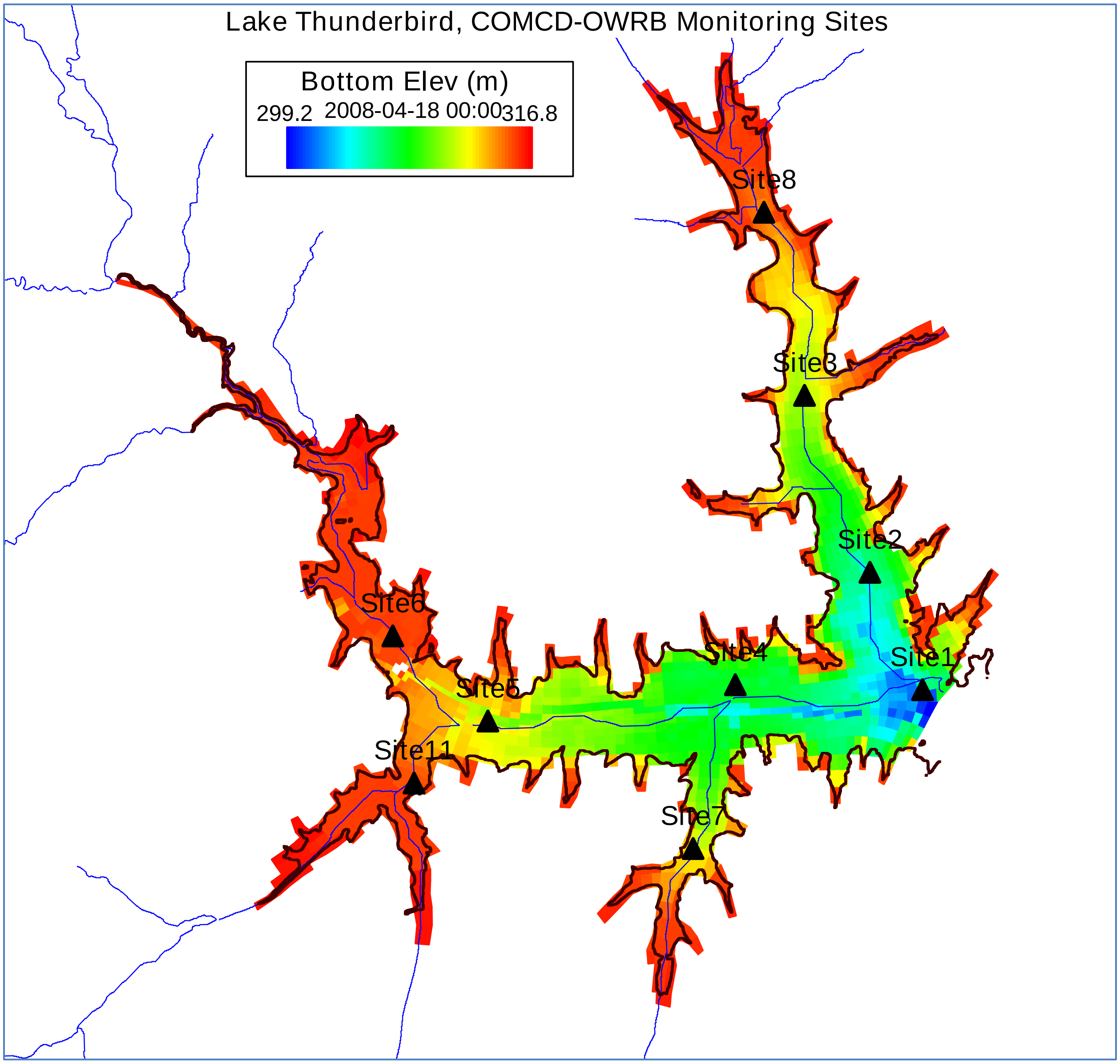
B.3.1 Observed Data

The Central Oklahoma Conservancy District (COMCD), in cooperation with OWRB, has been monitoring chlorophyll-*a*, nutrients, sediment, water temperature, organic matter and dissolved oxygen in the lake since 2000. In support of this TMDL study of Lake Thunderbird, OWRB and OCC conducted a special monitoring program from April 2008 through April 2009 to supplement the monitoring program conducted as part of the routine COMCD-BUMP surveys of Lake Thunderbird. Figure B-3 and Table B-4 summarize the site designation names, station numbers and locations of the eight water quality monitoring stations maintained by OWRB in Lake Thunderbird as a component of the Oklahoma Beneficial Use Monitoring Program (BUMP) network (OWRB, 2008). Separate data tables are presented for Hydro Lab vertical profiles (water temperature, dissolved oxygen), water quality chemistry grab samples (TSS, turbidity, secchi depth, organic carbon, nutrients, chlorophyll-*a*) and sediment bed samples (nutrients, solids).

Table B-4 OWRB Water Quality Monitoring Stations for Lake Thunderbird

Site	Station Number	Latitude	Longitude	Represents
1	520810000020-1sX	35.223333	-97.220833	Dam Site; Lacustrine
	520810000020-1-4X			
	520810000020-1-8X			
	520810000020-1-12X			
	520810000020-1bX			
2	520810000020-2X	35.238889	-97.228889	Lacustrine
	520810000020-2bX			
3	520810000020-3X	35.262222	-97.238889	Transition
4	520810000020-4X	35.224444	-97.250833	Lacustrine
	520810000020-4bX			
5	520810000020-5X	35.220278	-97.290556	Transition
6	520810000020-6X	35.231667	-97.305556	Riverine
7	520810000020-7X	35.203056	-97.258056	Riverine
8	520810000020-8X	35.286409	-97.244887	Riverine
11	520810000020-11X	35.212292	-97.302545	Riverine

Figure B-3 OWRB Water Quality Monitoring Stations for Lake Thunderbird



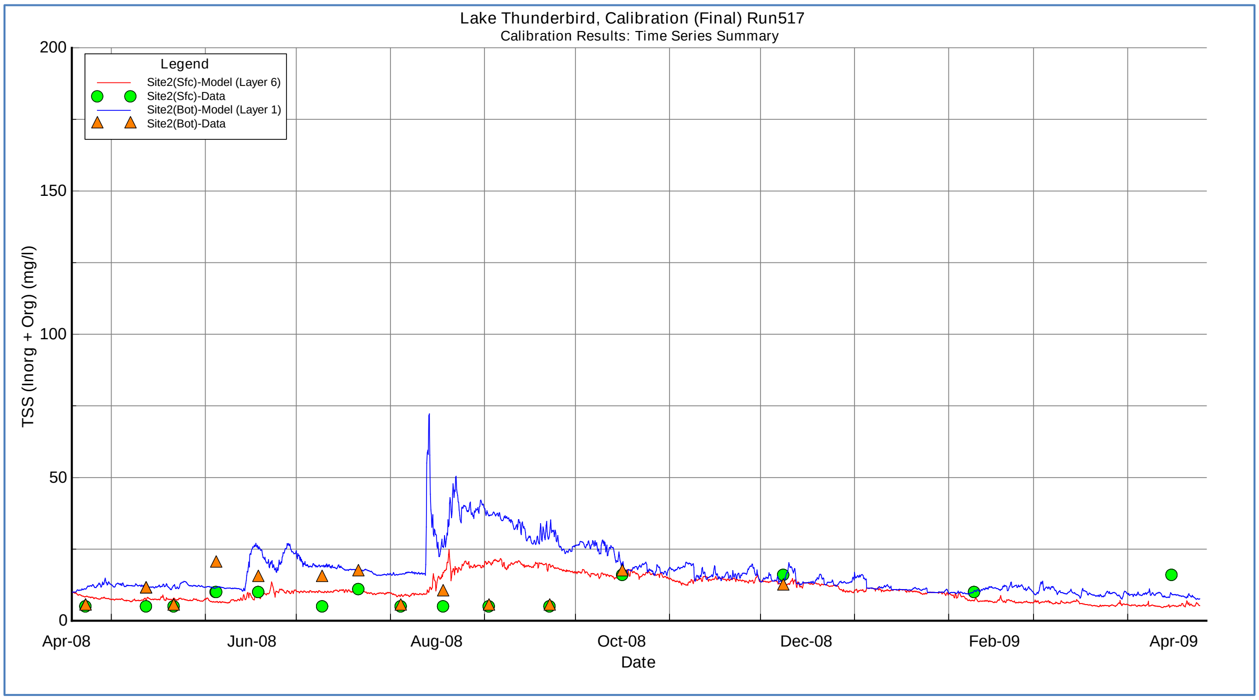
B.3.2 Model Calibration

See section 4.3 of the main TMDL report.

Model results for Site 2 are presented in this section to show model-data comparison for parameters that directly relate to the water quality criteria targets for turbidity, chlorophyll-a and dissolved oxygen. Results are also presented to show the benthic flux rates of phosphate and sediment oxygen demand simulated with the sediment diagenesis model. Selected time series plots are presented in Section B.7 for the lacustrine zone (Site 2), transition zone (Site 3) and riverine zone (Site 6) to show the spatial variation of model results. A composite summary of model performance statistics for all sites is presented for each water quality variable.

Total Suspended Solids (TSS) and Turbidity: EFDC state variables for cohesive sediment, detrital organic matter and algae are summed to compute a derived output variable for total suspended solids (TSS). TSS results are presented in Figure B-4 for comparison to observed data for the surface layer (k=6) and bottom layer (k=1) for the lacustrine zone (Site 2). As can be seen in the model-data plot for Site 2, the model results for the surface and bottom layer are in reasonable agreement with measured TSS except for the time period that corresponded to the two large storm events in August 2008. Model results show a bottom layer peak in TSS of ~20-50 mg/L at Site 2. Simulated TSS during the winter-spring months of 2009 is seen to be lower than the observed TSS measurements.

Figure B-4 Model-Data Comparison of TSS for Surface Layer (k=6) and Bottom Layer (k=1) for Site 2



With an r^2 value of 0.7276, the TSS vs, turbidity relationship shown in Figure B-5 was considered acceptable to apply a site-specific correlation to compute simulated turbidity from modeled TSS. The TSS vs. turbidity relationship was used to transform EFDC model results for TSS to turbidity for comparison to the water quality criteria for turbidity of 25 NTU. Model-data turbidity results are presented for the surface layer (k=6) for Site 2 (Figure B-6). As can be seen in the model-data plot, the model results for turbidity, mimicking the results obtained for TSS, are in reasonable agreement with measured turbidity except for the time period that corresponded to the two large storm events in August 2008.

Figure B-5 TSS (mg/L) vs. Turbidity (NTU) Regression Relationship (R^2=0.7276) for Lake Thunderbird

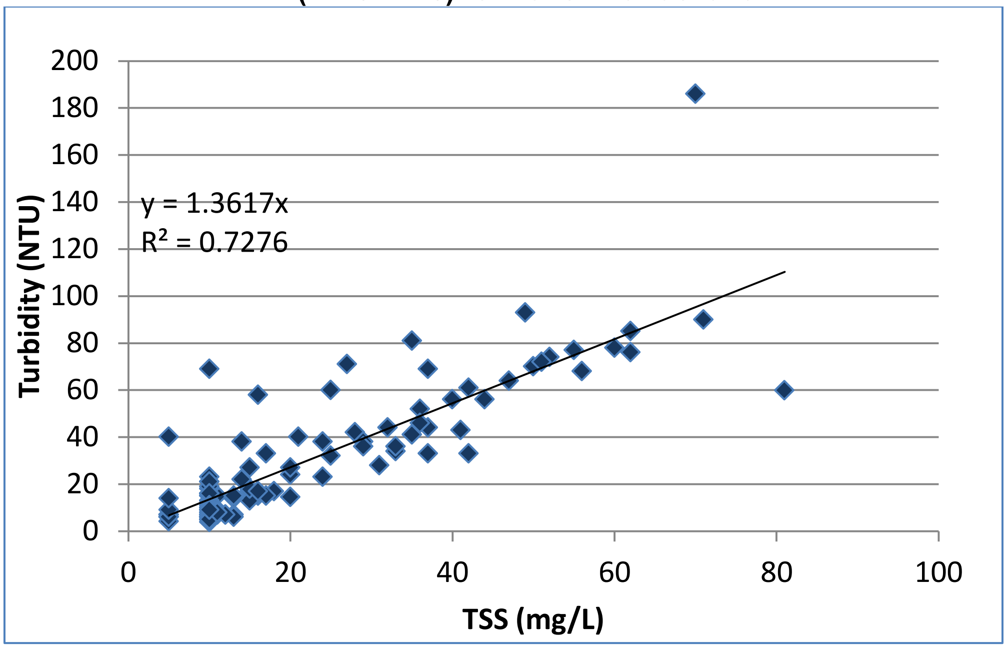
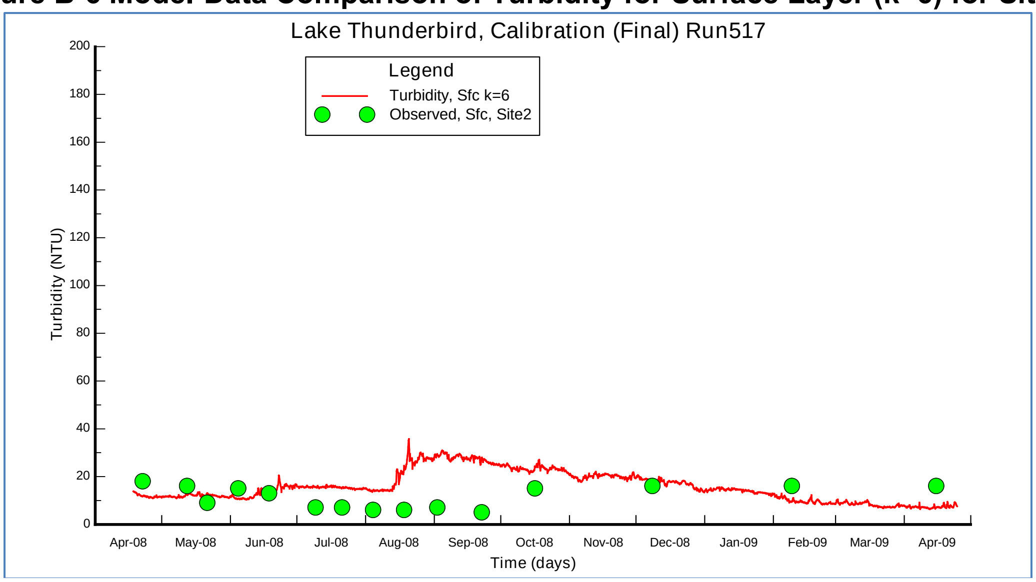
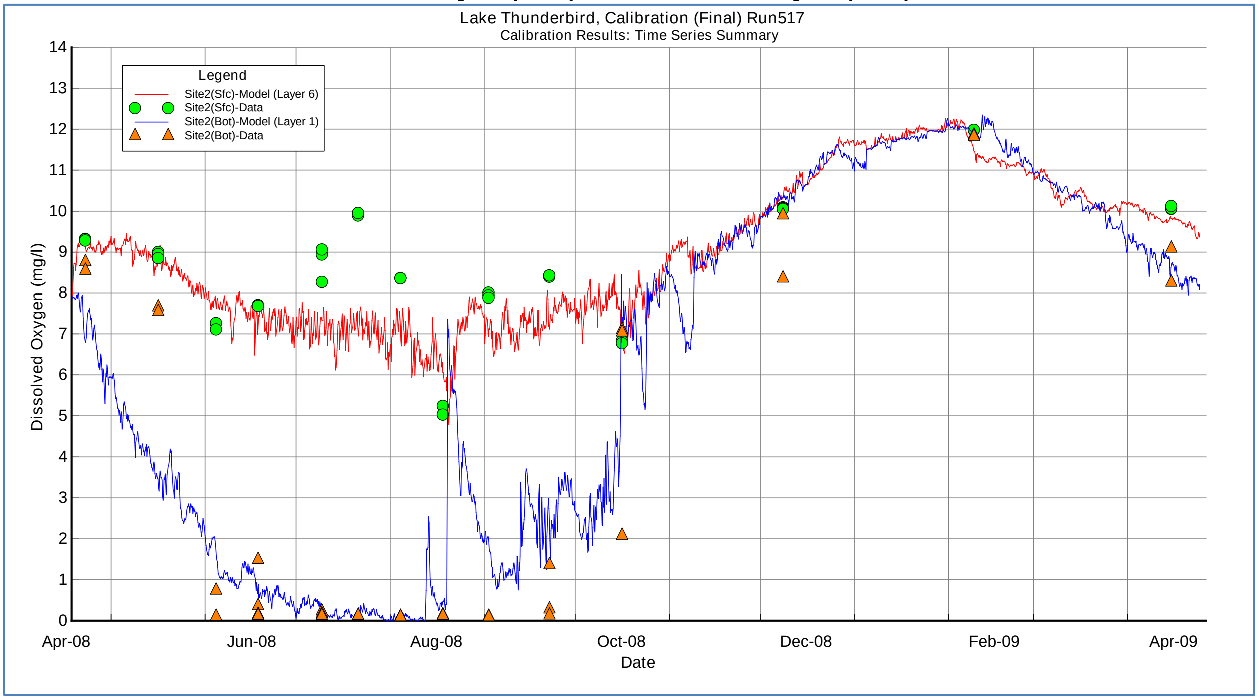


Figure B-6 Model-Data Comparison of Turbidity for Surface Layer (k=6) for Site 2



Dissolved Oxygen and Anoxic Volume: Dissolved Oxygen results are presented in Figure B-7 for comparison to observed data for the surface layer (k=6) and bottom layer (k=1) for the Site 2 in the lacustrine zone**.** As can be seen in the model-data plot, the model results for Site 2 for both the surface and bottom layer are in very good agreement with measured oxygen. The exception is the period characterized by super saturated oxygen conditions that were observed in the surface layer during July in the lacustrine zone at Site 2. The contribution of algal photosynthetic oxygen production that is distributed over the surface layer thickness of ~ 2 m at this site is apparently "diluted" by the relatively coarse 6 layer vertical resolution of the surface layer. Similar super saturated oxygen conditions were also observed, and not matched by the model, at the other lacustrine stations (Site 1 and Site 4). What is most notable about the model results is that surface and bottom layer oxygen results at Site 2 clearly show the hydrodynamic impact of increased vertical mixing that resulted from the storm events in August 2008. Water column stratification was eroded and the water column became well mixed with only a very small gradient between bottom layer and surface layer oxygen. When the water column re-stratified in September bottom oxygen was once again reduced to anoxic levels less than 2 mg/L that persisted until seasonal stratification was finally eroded in October. As shown in the surface layer observations and results for Site 2, dissolved oxygen levels within the epilimnion are in compliance with the water quality standards of 5 to 6 mg/L.

Figure B-7 Model-Data Comparison of Dissolved Oxygen for Surface Layer (k=6) and Bottom Layer (k=1) for Site 2



Model results for dissolved oxygen for each grid cell are post-processed to derive a composite time series to compute the percentage of the whole lake volume defined as anoxic by the cutoff target DO level of 2 mg/L. Model results are presented first as a map of anoxic volume of the lake on Aug-4-2008 08:00 to show a time snapshot of the spatial distribution of anoxic volume of the lake. Aug-4 is selected for the snapshot because the highest estimates of anoxic lake volume occur in early August and observed data is available from the OWRB survey on Aug-4. Figure B-8 shows the spatial distribution of anoxic volume on Aug-4-2008 08:00. Model results for dissolved oxygen are presented in Figure B9 as a composite whole lake time series for the percentage of the lake volume that is defined as anoxic with the cutoff target level of 2 mg/L. Figure B-10 shows a time series of the anoxic volume extracted for eight model grid cells that surround the location of Site 2. As shown in Figure B-10, the model anoxic volume computed at Site 2 is in good agreement with the estimate of 58% for the observed anoxic volume at Site 2 on August 4, 2008. August 4 was selected for comparison to the model because the highest estimates of anoxic lake volume occur in early August and observed oxygen profile data is available from the OWRB survey on August 4, 2008.

As shown in Figure B-8, the area defined by anoxic conditions is bounded by the deeper parts of the lake within the lacustrine zone at Site 1, 2 and 4. On a volume-weighted basis computed for all the grid cells of the model domain, the maximum percentage of the lake volume defined by the target oxygen level of 2 mg/L gradually increases from onset of stratification to a peak of ~25% in July with a maximum of ~30% in early August (Figure B-9). Stratification is eroded with the storm event in August, bottom oxygen increases and the anoxic volume percentage of the lake drops to zero. Stratification is re-established after the storm and the anoxic volume increases to a maximum of less than 10%. Since the maximum anoxic volume for the whole lake shown in Figure B-9 is ~30%, the water quality anoxic volume target of no more than 50% of the lake volume less than 2 mg/L dissolved oxygen content during seasonal stratification is attained for model calibration.

Figure B-8 Anoxic Volume of Lake Thunderbird on August 4, 2008 at 08:00

Color gradient for 6-layer model as follows for anoxic volume percentage:
dark blue=0%; light blue=16%; green=33%; yellow=50% and red =66%

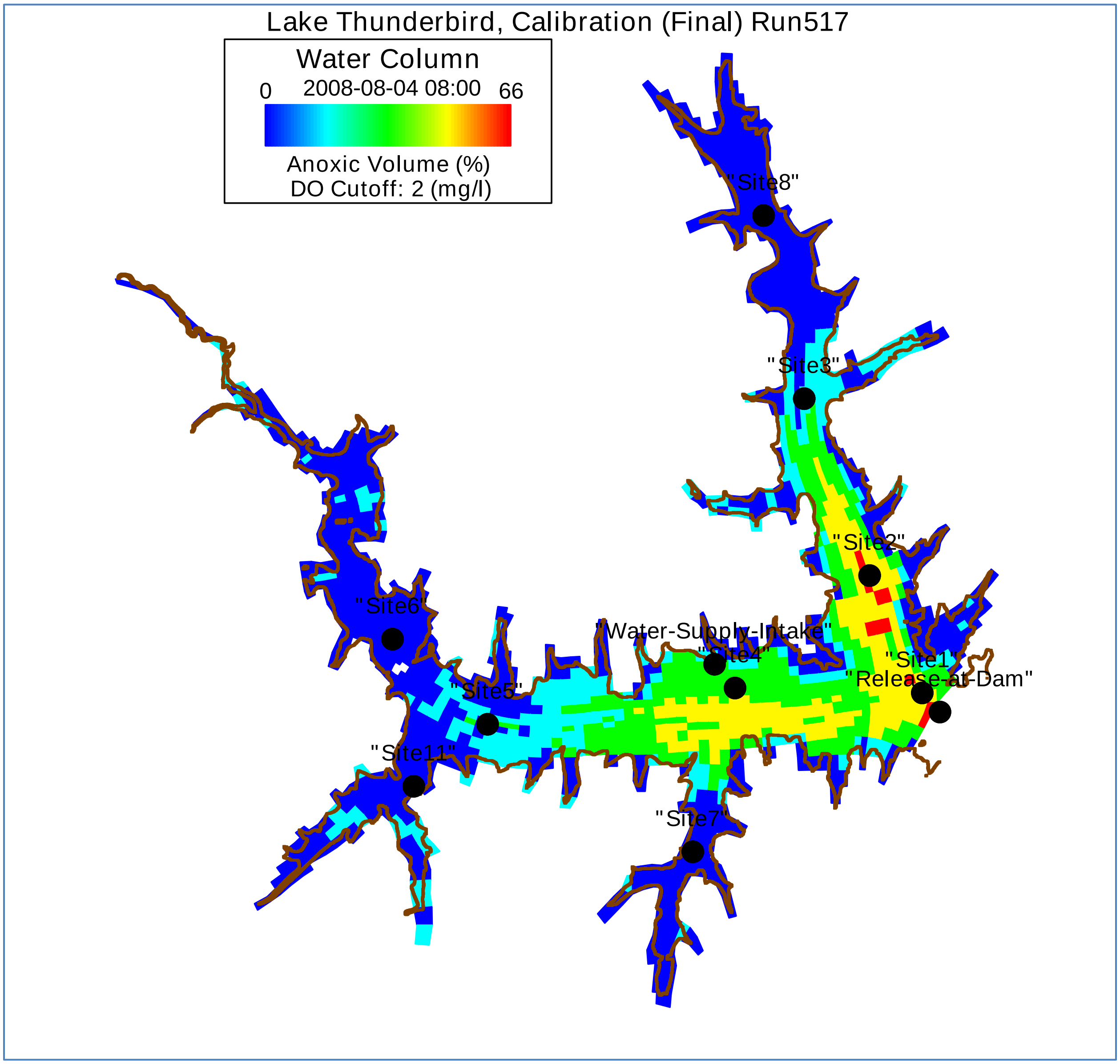


Figure B-9 Time series of anoxic volume of whole lake for model calibration. Percentage of anoxic volume is based on aggregation of all grid cells in the lake.

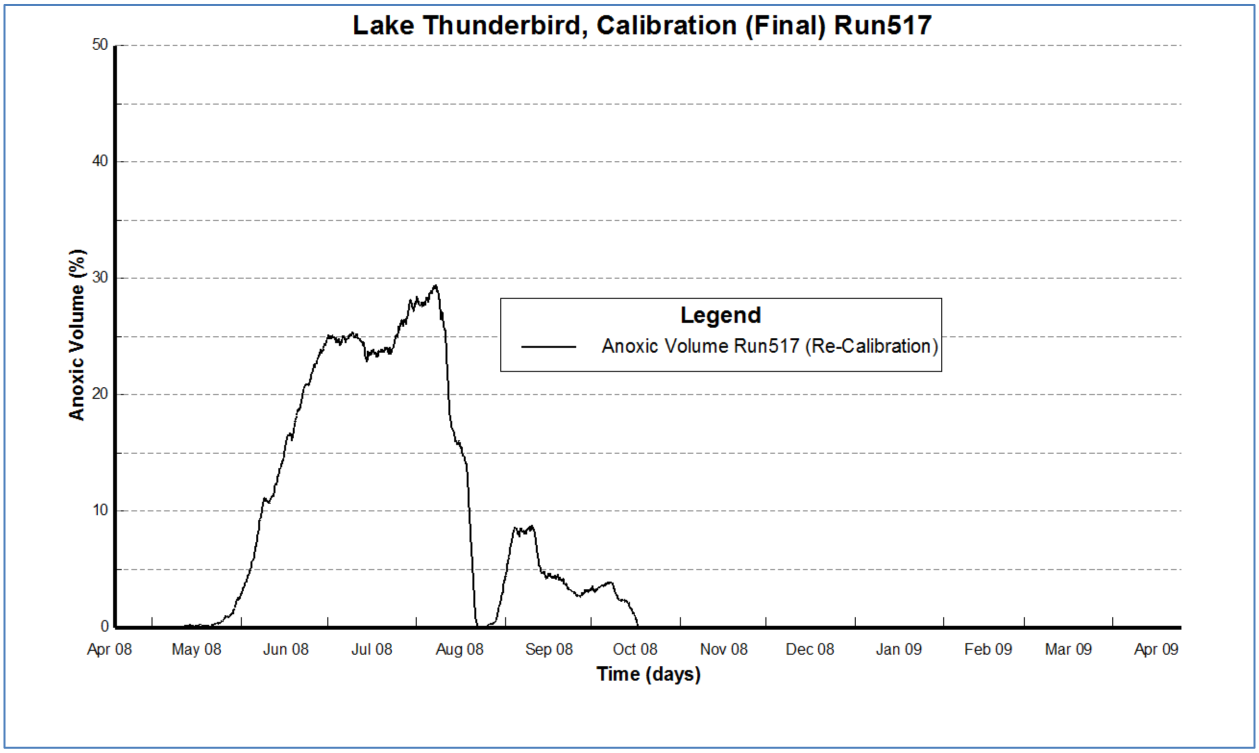
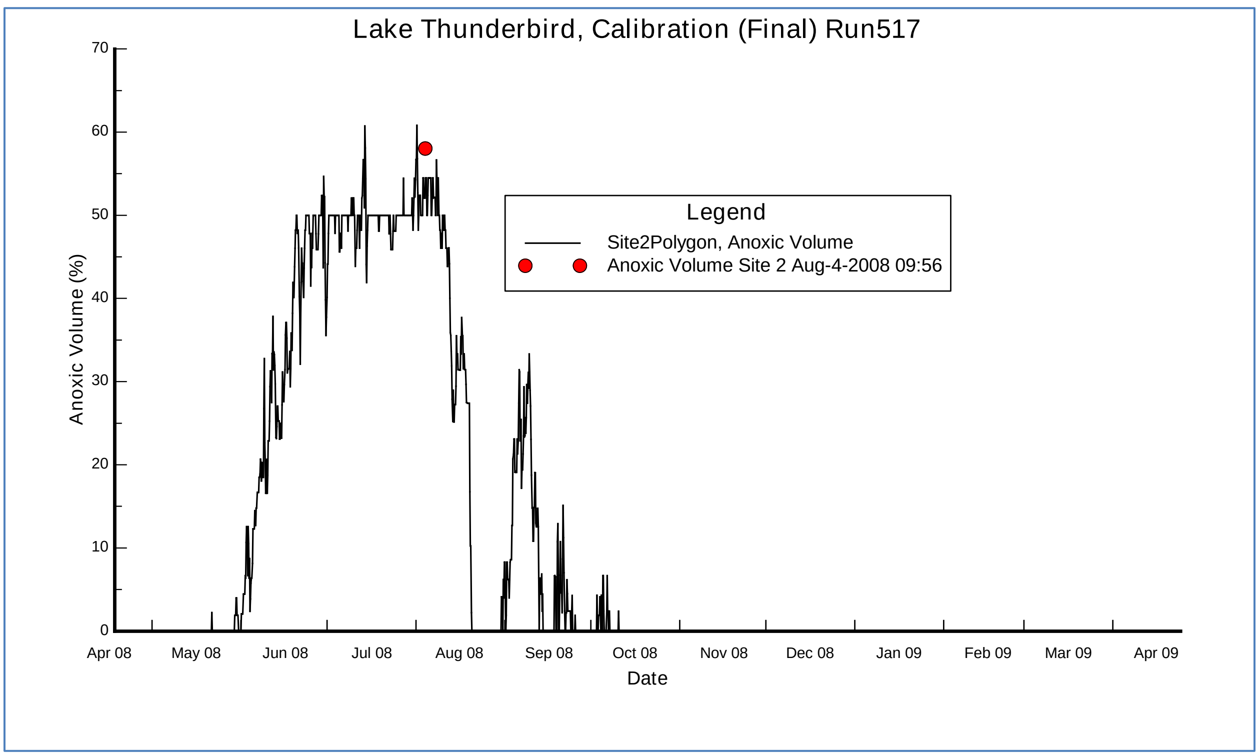


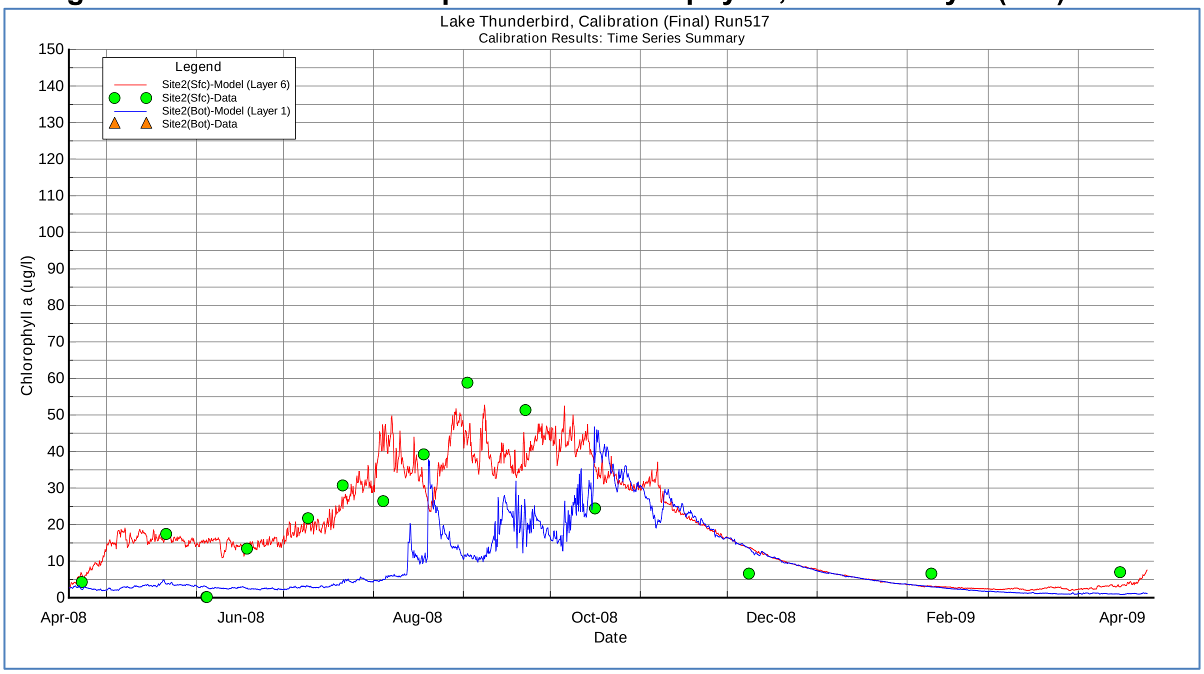
Figure B-10 Time series of anoxic volume of Site 2 for model calibration.

Percentage of anoxic volume is based on eight grid cells that surround Site 2 in the Lake.
Red circle shows estimate of anoxic volume for Site 2 based on observed dissolved oxygen profile for August 4, 2008 at 09:56.



Algae Chlorophyll-a Algae biomass results (as chlorophyll-*a*) are presented for comparison to observed data for the surface layer (k=6) for Site 2 in the lacustrine zone (Figure B-11). As can be seen in the model-data plot, the model results are in good agreement with measured biomass for most of the calibration period. The exception to the good agreement with the observations is the late summer period in September where the model results (~35-45 µg/L) underestimate somewhat the observed chlorophyll-*a* biomass of ~50-60 µg/L at Site 2. The discrepancy between the observed and simulated Chlorophyll-*a* during this period appears to be related to the small peak of simulated TSS that is still larger than the observed TSS in the surface layer during the two storm events in August 2008. The peak simulated overestimate of TSS results in an increase in light limitation for the algae groups, suppression of the growth rate and a decline in algae biomass that did not match the somewhat higher observed levels of chlorophyll-*a* at Site 2.

Figure B-11 Model-Data Comparison of Chlorophyll-a, Surface Layer (k=6) for Site 2.



Phosphorus: Total Phosphorus (TP), and total-phosphate (TPO4) results are presented for comparison to observed data for the surface layer (k=6) and bottom layer (k=1) for Site 2 in the lacustrine zone**.** As can be seen in the model-data plots shown for Site 2, the model results are in fair agreement with measured TP (Figure B-12) and TPO4 (Figure B-13) for the bottom layer from April 2008 through August 2008. The model results then overestimate surface and bottom layer TP and TPO4 beginning in September through winter-spring 2009. Observed data for bottom layer phosphate shows a sharp increase from relatively low concentrations (<0.05 mg/L) in April-June to much higher concentrations (~0.1-0.2 mg/L) in response to the onset and persistence of anoxia during July-August 2008. Bottom layer phosphate is overestimated early in the model simulation in May-June because thermal stratification is initiated in the model somewhat earlier than observed and bottom oxygen at Site 2 in the model then decreases more rapidly than was observed in May. Bottom phosphate then increases as a result of the increased benthic flux of dissolved phosphate triggered by anoxic conditions in the overlying hypolimnion. Following erosion of the thermocline, the model results for TP and phosphate are slightly higher than the lower levels of TP and phosphate observed during the winter-spring from October-November 2008 through April 2009.

Figure B-12 Model-Data Comparison of Total-P (TP) for Surface Layer (k=6) and Bottom Layer (k=1) for Site 2.

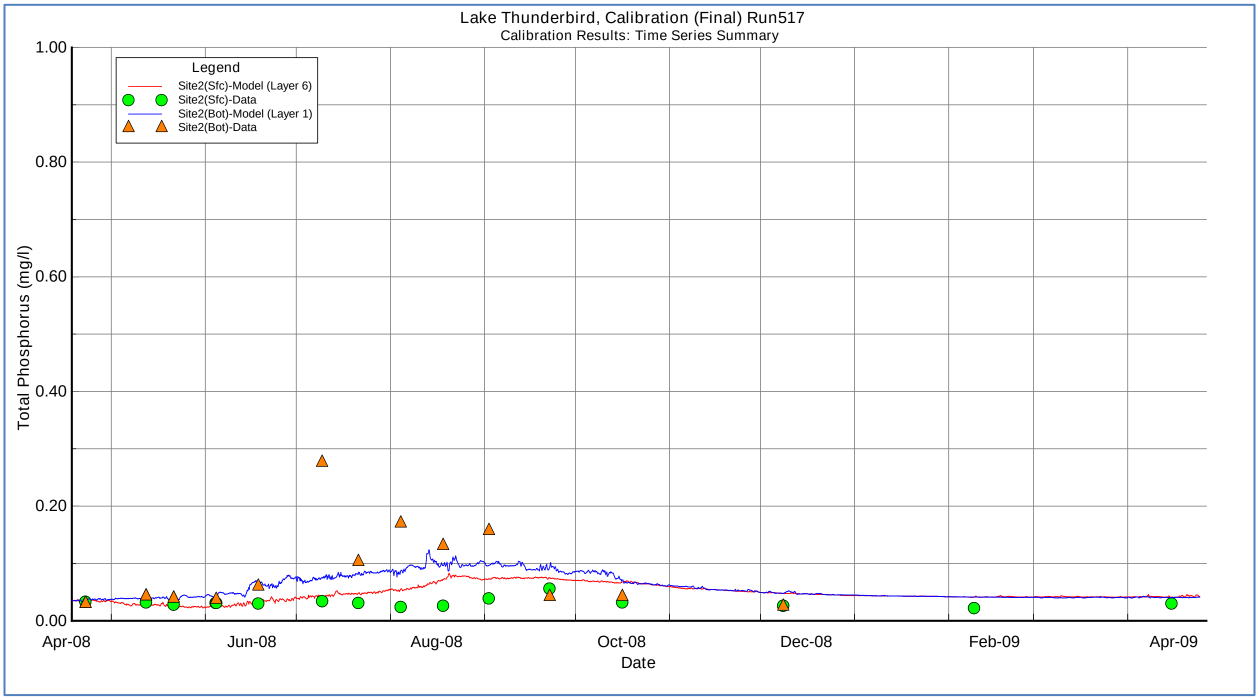
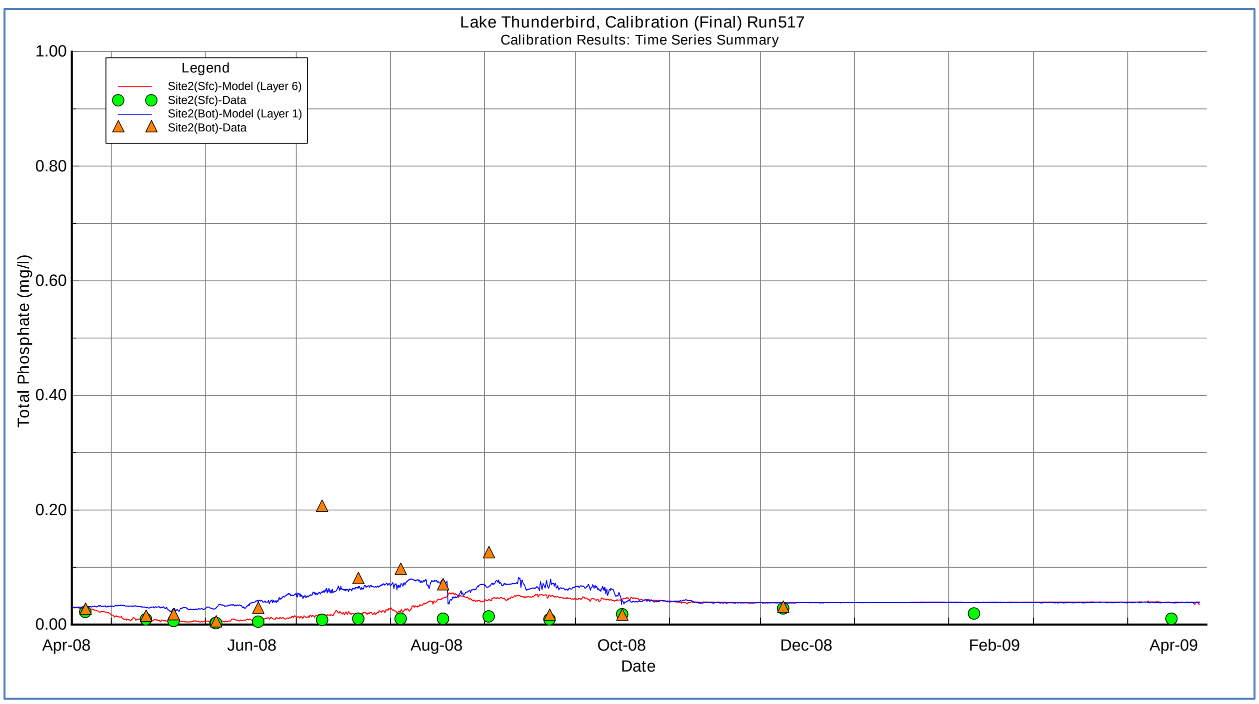


Figure B-13 Model-Data Comparison of Total-Phosphate-P (TPO4) for Surface Layer (k=6) and Bottom Layer (k=1) for Site 2.



The simulated benthic flux for phosphate is shown in Figure B-14 for the lacustrine zone stations (Site 1, 2 and 4). Using the data shown in Figure B-14, summary statistics for benthic phosphate fluxes for each site are computed for the summer stratified period from May 15 through October 1, 2008. The mean benthic flux for phosphate for the lacustrine sites, computed as 4.8, 3.4 and 5.4 mg P/m^2-day for Site 1, 2 and 4, respectively, are thus consistent with the range of anoxic phosphate fluxes of ~2-8 mg P/m^2-day measured by Dzialowski and Carter (2011) in mesotrophic reservoirs in the Central Plains (see Figure B-15).

Figure B-14 Model Results for Benthic Flux of Dissolved Phosphate-P (PO4) (as g/m^2-day) for Sediment Diagenesis Model for Lacustrine Sites 1, 2 and 4.

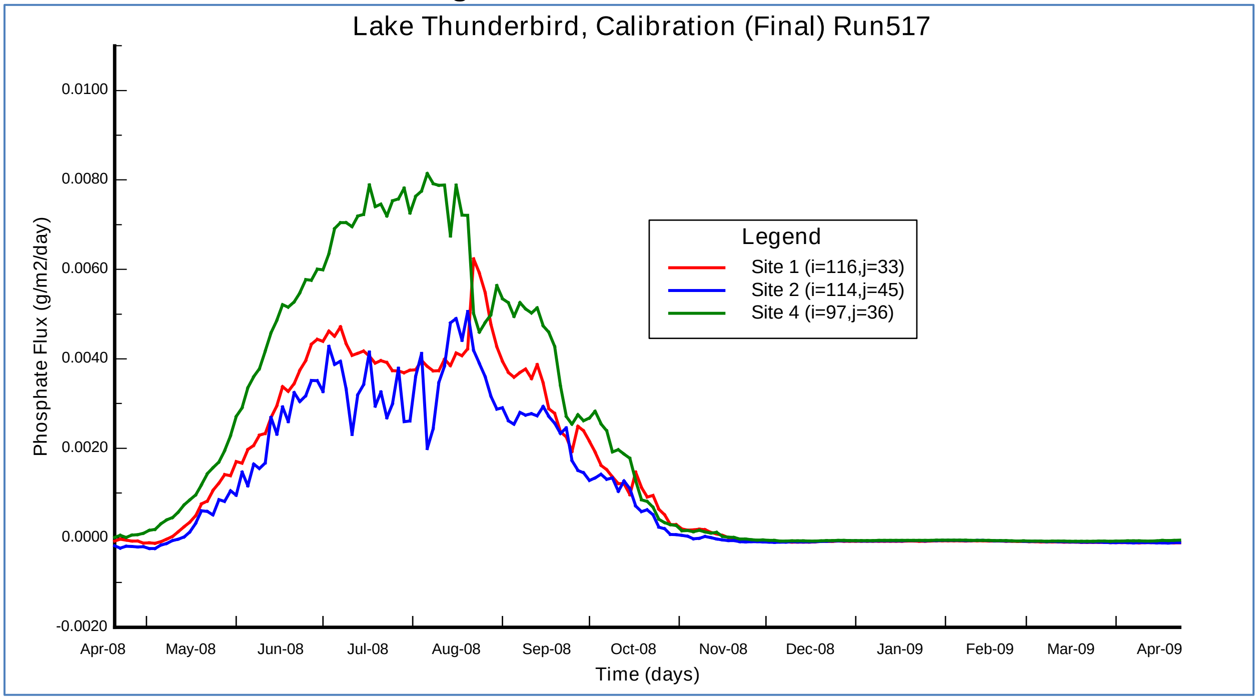
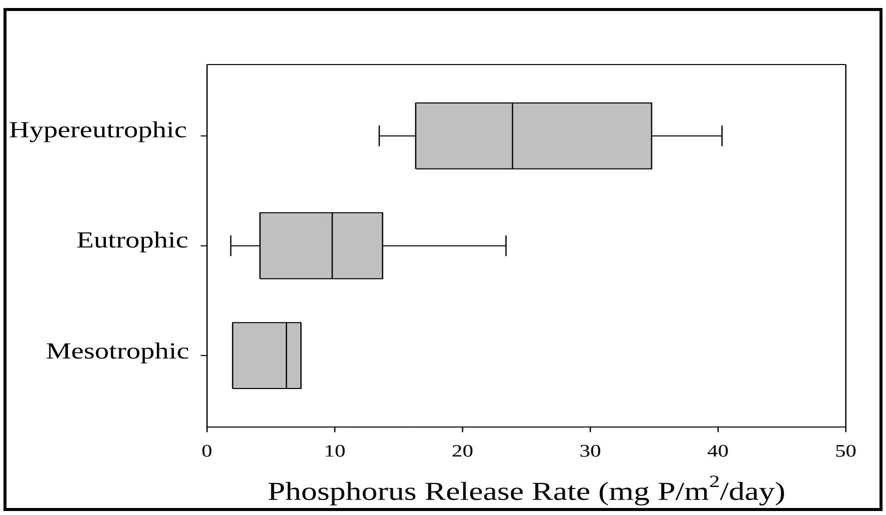


Figure B-15 Comparison of anoxic release rates of phosphorus (as mg P/m^2-day).

Mesotrophic (n=3), eutrophic (n=9), and hypereutrophic (n=5) reservoirs in the Central Plains. Line within the box represents the median; edges of the box represent the 25th and 75th percentiles; error bars represent the 10th and 90th percentiles (Dzialowski and Carter, 2011).



B.3.3 Summary of Model Performance

Model performance is evaluated to determine the endpoint for model calibration using a “weight of evidence” approach that has been adopted for many modeling studies. The “weight of evidence” approach includes the following steps: (a) visual inspection of plots of model results compared to observed data sets (e.g., station time series); and (b) analysis of model-data performance statistics as the Root Mean Square (RMSE) Error and the Relative RMS Error as described below. The “weight of evidence” approach recognizes that, as an approximation of a waterbody, perfect agreement between observed data and model results is not expected and is not specified as a performance criterion for the success of model calibration. Model performance statistics are used, not as absolute criteria for acceptance of the model, but rather, as guidelines to supplement the visual evaluation of model-data time series plots to determine the endpoint for calibration of the model. The “weight of evidence” approach used for this study thus acknowledges the approximate nature of the model and the inherent uncertainty in both model input data and observed data.

The model-data model performance statistics selected for calibration of the hydrodynamic and water quality model are the Root Mean Square Error (RMSE) and the Relative RMS Error. The RMSE, also known as the Standard Error of the Mean, has units defined by the units of each state variable of the model. The Relative RMS error, computed as the ratio of the RMSE to the observed range of each water quality constituent is as a percentage (Ji, 2008). Since the Relative RMS error is expressed as a percentage, this performance measure provides a straightforward statistic to evaluate agreement between model results and observations.

Observed station data has been processed to define time series for each station location for the surface layer and bottom layer of the water column. Observed data is assigned to a vertical layer based on surface water elevation, station bottom elevation and the total depth of the water column estimated for the sampling date/time. Station locations are overlaid on the model grid to define a set of discrete grid cells that correspond to each monitoring site for extraction of model results.

The equations for the RMSE and the Relative RMS Error are,

$$\mathrm{RMSE} = \sqrt{\frac{1}{N}\Sigma(O-P)^2}$$

$$\text{Relative RMS Error} = \frac{\mathrm{RMSE}}{(O_{range})} x100$$

Where

N is the number of paired records of observed data and EFDC model results,

O is the observed water quality data,

P is the predicted EFDC model result, and

O_{range} is the range of observed data computed from maximum and minimum values.

In evaluating the results obtained with the EFDC model, a Relative RMS Error performance measure of $\pm 20\%$ is adopted for evaluation of the comparison of the model predicted results and observed measurements of water surface elevation of the lake. For the hydrographic state variables simulated with the EFDC hydrodynamic model, a Relative RMS Error performance measure of $\pm 50\%$ is adopted for evaluation of the comparison of the predicted results and observed measurements for water temperature. For the water quality state variables simulated with the EFDC water quality model, a Relative RMS Error performance measure of $\pm 20\%$ is adopted for dissolved oxygen; $\pm 50\%$ for nutrients and suspended solids; and $\pm 100\%$ for algal biomass for the evaluation of the comparison of the predicted results and observed water quality measurements for model calibration. These targets for hydrodynamic, sediment transport and water quality model performance, defined for the overall composite statistic computed from the set of station-specific statistics, are consistent with the range of model performance targets recommended for surface water models (Donigian, 2000).

Given the lack of a general consensus for defining quantitative model performance criteria, the inherent errors in input and observed data, and the approximate nature of model formulations, *absolute* criteria for model acceptance or rejection are not appropriate for studies such as the development of the lake model for Lake Thunderbird. The Relative RMS Errors are used as targets for performance evaluation of the calibration of the model, but not as rigid absolute criteria for rejection or acceptance of model results. The "weight of evidence" approach used in this study recognizes that, as an approximation of a waterbody, perfect agreement between observed data and model results is not expected and is not specified as performance criteria for defining the success of model calibration.

As presented in Table B-5, the model performance results for water level, water temperature, chlorophyll-*a*, dissolved oxygen, nitrate and total organic phosphorus are either much better than, or close to, the target criteria.

Table B-5 Composite Model Performance for Lake Thunderbird Hydrodynamic and Water Quality Model Based on Model-Data Comparison at All Station Locations

Composite Statistics, All eight Station Locations (Apr 2008 – Apr 2009)						Target
Parameter	**#Data Pairs**	**Avg Observed**	**Avg Model**	**RMS Error**	**Relative RMS**	**Relative RMS**
Water Surface Elevation (m)	8921	316.92	316.916	0.008	0.6%	20%
Temperature (Deg C)	465	20.726	20.817	1.834	8.4%	50%
TSS (Inorg + Org) (mg/L)	184	17.576	15.59	13.374	52.3%	50%
Chlorophyll a (µg/l)	217	23.332	25.419	11.038	20.8%	100%
Dissolved Oxygen (mg/L)	432	6.68	6.626	1.648	19.2%	20%
Total P (mg/L)	184	0.065	0.056	0.05	55.9%	50%
Total Org P (mg/L)	107	0.031	0.024	0.019	29.8%	50%
Total Phosphate (mg/L)	184	0.037	0.032	0.046	55.8%	50%
Total N (mg/L)	114	0.805	0.616	0.945	55.1%	50%
Nitrate Nitrogen (mg/L)	111	0.15	0.165	0.084	28.5%	50%
Total Org N (mg/L)	114	0.603	0.308	0.37	87.7%	50%
Total Organic Carbon (mg/L)	200	5.666	5.212	1.301	77.5%	50%
RMS Error = Root Mean Square Error Relative RMS% = Relative Root Mean Square Error%						

B.3.4 Pollutant Loads: Existing Model Calibration (2008-2009)

See Section 4.4 of the main TMDL report.

In addition to documentation of lake inputs of nutrients, CBOD and suspended solids, a more detailed analysis of model data is presented to compare the inputs (source) and exports (sink) of phosphorus. Inputs of phosphorus were compiled for (a) watershed loading; (b) atmospheric deposition; and (c) sediment flux from the bed to the water column. Exports of phosphorus were compiled for (d) release flow over the dam; and (e) water withdrawals from the three water intakes. Mass load data, extracted from model calibration results, was compiled for a 365 day period from 25 April 2008 through 25 April 2009 to derive annual loads. Whole lake total phosphorus (TP) mass was computed for the same 1-year time period to evaluate phosphorus mass at the beginning and end of the simulation.

Phosphorus retention was estimated using a metric first defined by Dillon and Rigler (1974) where the retention ratio is defined by the input of total phosphorus to the lake and the net sedimentation of total phosphorus in the lake. The retention ratio (R) is computed as follows:

$$R = \frac{NetSed}{Input}$$

Net sedimentation of total phosphorus over the year is estimated from the internal phosphorus mass balance given by the following equation:

$$NetSed = -\Delta P + Input - Export$$

Where ΔP is the change in total phosphorus content of the water column (as kg) over the 1-year period from April 25, 2008 to April 25, 2009; *Input* is the sum of sources of total phosphorus from the watershed, atmospheric deposition and sediment flux; and *Export* is the sum of outflows of total phosphorus from release flow at the dam and water supply withdrawals.

This metric was used by OWRB (2002) for an analysis of phosphorus loads for Lake Eucha and Lake Spavinaw where OWRB estimated phosphorus retention of 0.8 for 1998-1999 for Lake Eucha. The estimates of Input, Export, Net Sedimentation, net change in mass over the 1-year period and phosphorus retention are presented in Table B-6. The source and sink terms are presented as annual loads in Table B-4 and as area normalized daily fluxes in Table B-7.

Table B-6 Phosphorus Source/Sinks and Phosphorus Retention Metric in Lake Thunderbird

Phosphorus Source/Sinks	TP=PO4+	PO4	TOP	ALGAE
EXISTING LOADS	TOP+ALGPOP			POP
Annual, 365 days	kg/yr	kg/yr	kg/yr	kg/yr
INPUTS				
Watershed	23,087	2,887	20,188	11
Atm Deposition(wet+dry)	182	182	0	0
Sediment Flux	24,277	24,277	0	0
OUTPUTS				
Release flow at Dam	-2,800	-1,760	-736	-303
Water Intake Withdrawals	-1,174	-830	-217	-127
P-RETENTION FACTORS				
Net Sedimentation	43,353			
P-Inputs	47,546			

P-Exports	-3,974
P-Retention (R)	0.92
Mass @ t=25 April 2008 (kg)	6,645
Mass @ t=25 April 2009 (kg)	6,865
Net Mass (End -Begin) (kg)	220

Table B-7 Sources and Sinks of Phosphorus as Area Based Fluxes for Lake Thunderbird

Phosphorus Source/Sinks EXISTING LOADS Annual, 365 days	TP=PO4+ TOP+ALGPOP mg-P/m^2-d	PO4 mg-P/m^2-d	TOP mg-P/m^2-d	ALGAE POP mg-P/m^2-d
INPUTS				
Watershed (HSPF)	1.996	0.250	1.746	0.001
Atm Deposition(wet+dry)	0.016	0.016	0.000	0.000
Sediment Flux	2.099	2.099	0.000	0.000
OUTPUTS				
Release flow at Dam	-0.242	-0.152	-0.064	-0.026
Water Intake Withdrawals	-0.102	-0.072	-0.019	-0.011
P-RETENTION FACTORS				
Net Sedimentation	3.749			
P-Inputs	4.112			
P-Exports	-0.344			
Lake Surface Area (m^2)	31,682,800			

B.5 MODELED LOAD REDUCTION SCENARIOS

See Section 4.5 of the main TMDL report.

The lake model is applied as a "what-if?" tool to evaluate the long-term impact of the 35% removal scenario for external loads on changes in water quality conditions in Lake Thunderbird. Key management questions addressed with the lake model include:

- Will the 35% load reduction scenario succeed in attaining compliance with water quality standards for turbidity, chlorophyll-*a* and dissolved oxygen?

- Is the time frame for projected water quality conditions to attain compliance with water quality standards considered reasonable?

In evaluating the simulated impact of a 35% reduction in external loads of pollutants to the lake, the significant differences in the time scales needed for the response of the water column and the sediment bed to changes in external loading must be considered. Sediment bed conditions are known to respond to changes in external loads over a time scale that is measured on the order of several years (Di Toro, 2001). As shown with the analysis of nutrient loading from the watershed and the sediment bed for model calibration, loading from the sediment bed dominates total loading of nutrients to the lake. Any changes that will occur in water quality conditions of the lake are controlled by changes in organic matter deposition from the water column to the bed, the reservoir of nutrients in the sediment bed and the resulting sediment flux loading of nutrients from the bed to the water column.

Based on the data used for the 35% removal of nutrients and sediment from the watershed, the change in external loading of pollutants from the watershed to the lake is specified. The initial conditions for water quality for the 35% removal scenario are assigned from the actual observed conditions from mid-April 2008 that are used to assign initial water quality conditions for model development and calibration to 2008-2009 data. The initial conditions that need to be assigned as input data to characterize the concentrations of organic matter and nutrients in the sediment bed for the projected 35% removal scenario are, however, unknown. It is only known that projected sediment bed conditions will be different than historical conditions measured by OWRB in 2008 and used for initial conditions of the bed for model calibration to the 2008-2009 data. A characterization of altered sediment bed conditions that might be expected under the 35% load reduction scenario can, however, be developed by repeatedly running the lake model for several years in a series of sequential restart runs. Each time the model is run, the sediment flux model provides new data about changes in sediment bed conditions and nutrient fluxes. Initial conditions for water quality in the water column and initial conditions for the sediment flux model are reset using model restart conditions simulated at the end of the 1-year period. The spatial distribution of model conditions at the end of the 1-year model run is saved and written to restart files that are then used as input to the water quality and sediment flux model for the next restart run.

Using the watershed loading data developed for the 35% removal scenario, the lake model is repeatedly run with a series of restart runs to track how water quality and sediment bed conditions within the lake change over time, or spin-up, in response to the changes in sediment bed conditions and sediment fluxes of nutrients from the bed to the water column. Lake water quality conditions are compared to the standards for turbidity, chlorophyll-a and dissolved oxygen and tracked over time for each restart run to evaluate how lake water quality conditions spin-up in response to the 35% removal of external loads and the changes in internal loads. The results of the eight sequential restart runs are post-processed to track how sediment bed conditions and benthic nutrient flux rates change and how water quality conditions in the lake, in turn, change over time because of the reduced watershed load and changes in the sediment bed.

Model calibration is defined by the 1-year period from April 18, 2008 to April 29, 2009. The results of the initial 35% removal run are reported as Year 0 and the eight sequential restart runs are reported as Year 1, 2, 3, 4, 5, 6, 7, and 8. Based on extraction of model results generated for the final restart run for Year 8, a mass-balance budget of TSS, nutrients and BOD is compiled and presented in Section B.4.2 to determine the magnitude of external controllable sources and internal uncontrollable sources of loading to the lake under projected conditions for the final Year 8 spin-up run for the 35% removal load allocation scenario.

B.5.1 Lake Water Quality Response with 35% Removal of Watershed Loads

Turbidity and Chlorophyll-*a*: See Section 2 and Section 4.5 of the main TMDL report.

Dissolved Oxygen and Sediment Oxygen Demand: See Section 4.5 of the main TMDL report.

B.5.2 Pollutant Loads: 35% Removal Scenario

See Section 4.6 of the main TMDL report.

B.6 SUMMARY

The EFDC lake model incorporates external watershed loading and internal coupling of organic matter production and deposition from the water column to the sediment bed with decomposition processes in the sediment bed that, in turn, produce benthic fluxes of nutrients and sediment oxygen demand across the sediment-water interface. Lake Thunderbird, like many reservoirs, is characterized by seasonal thermal stratification and hypolimnetic anoxia. Summer anoxic conditions, in turn, are associated with internal nutrient loading from the benthic release of phosphate and ammonia into the water column that is triggered, in part, by low dissolved oxygen conditions. The mass balance based model, calibrated to 2008-2009 data, accounts for the cause-effect interactions of water clarity, nutrient cycling, algal production, organic matter deposition, sediment decay, and sediment-water fluxes of nutrients and oxygen.

The spin-up results for the 35% removal scenario suggest that chlorophyll-a may increase initially because of the availability of nutrients combined with the reduction of turbidity and the related improvement in water clarity, all favorable conditions for algal growth. Over time, however, the sediment bed reservoir of nutrients will diminish, benthic release of nutrients to the lake will be reduced and the pool of nutrients available in the water column to support algal production will be diminished. The model spin-up results demonstrate a gradual reduction in internal loading of nutrients from the sediment bed and an improvement in water quality conditions over the years based on the spin-up runs for the 35% removal scenario simulation.

The model indicates that water quality conditions are expected to be in compliance with the SWS water quality criteria for chlorophyll-a of 10 µg/L within a reasonable timeframe. It is important to note, however, that the spin-up results for the 35% removal scenario should not be taken as absolute projections of future water quality conditions in the lake with certainty as to some future calendar date because of the idealized spin-up conditions of a precisely maintained watershed load reduction level and repeated climatic conditions of a past year. The model, does however, provide a technically credible framework that clearly shows that water quality improvements can be achieved in Lake Thunderbird within a reasonable time frame to support the desired beneficial uses if watershed loading can be controlled and sustained to a level based on 35% reduction of the existing loading conditions. Attainment of water quality standards will occur, however, only over a period of time and only after full implementation of source controls and BMPs considered necessary to achieve an overall 35% removal of sediment and nutrients from the watershed.

Although the model demonstrates that internal loading of phosphate is a significant controlling factor for eutrophication in the lake, loading from the watershed is a direct factor in the deterioration of water quality conditions and ultimately the accumulation in the lake sediment of excessive nutrients and organic matter from the watershed over the past five decades is the source of the internal loading. Reductions in watershed loading are therefore required to achieve improvements in lake water quality. The model results suggest that compliance with water quality criteria for turbidity, dissolved oxygen and chlorophyll-a can be achieved with a 35% removal of sediments and nutrients from watershed loading to the lake within a reasonable time frame. The model results thus support the development of TMDLs for sediments, BOD, TN and TP to achieve compliance with water quality standards for turbidity, chlorophyll-*a* and dissolved oxygen. The calibrated HSPF watershed runoff model and the EFDC hydrodynamic and water quality model of Lake Thunderbird provides DEQ with a scientifically defensible surface water model framework to support development of TMDLs and water quality management plans for Lake Thunderbird.

B.7 TIME SERIES PLOTS FOR EFDC LAKE MODEL RESULTS FOR LACUSTRINE, TRANSITION AND RIVERINE ZONES OF LAKE THUNDERBIRD

Figure B-16 TS_Cal003_Temp_Site2 (Surface & Bottom)

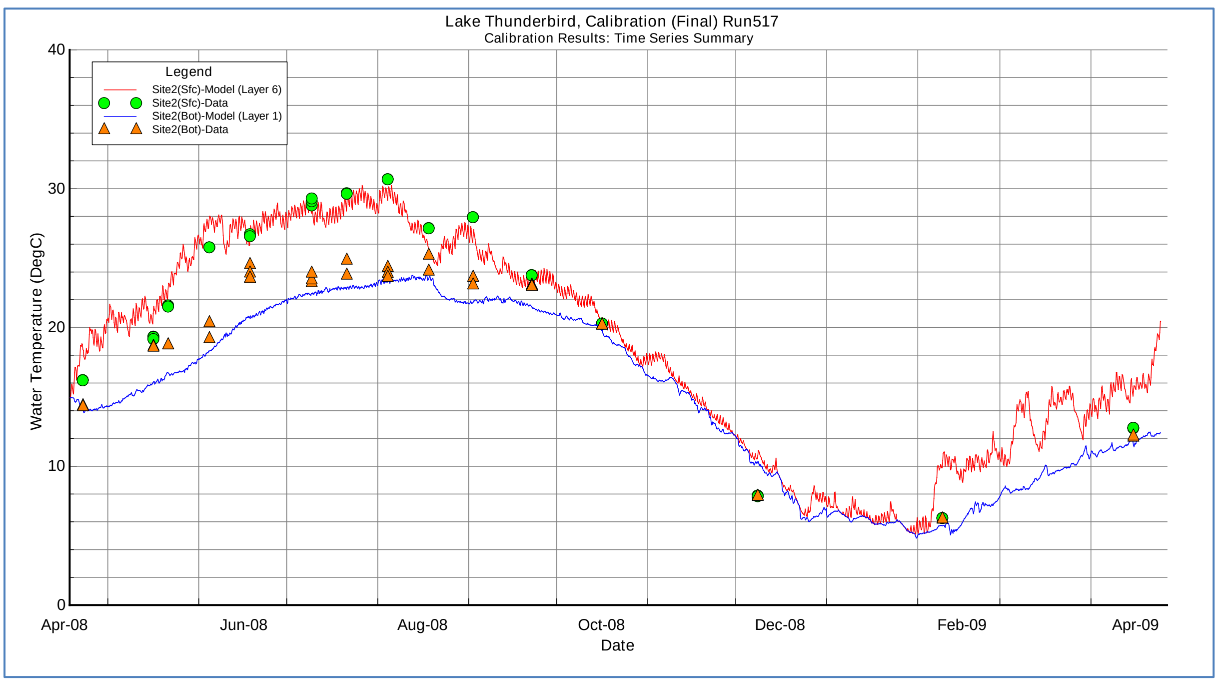


Figure B-17 TS_Cal004_Temp_Site3 (Surface & Bottom)

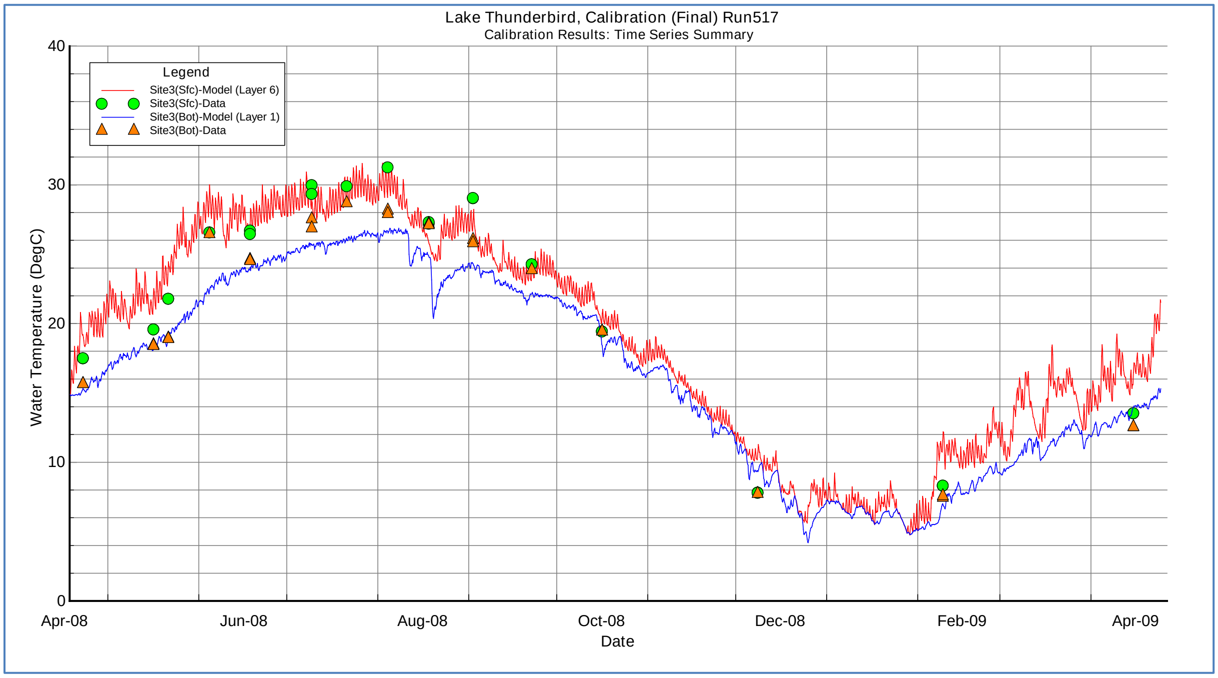


Figure B-18 TS_Cal007_Temp_Site6 (Surface & Bottom)

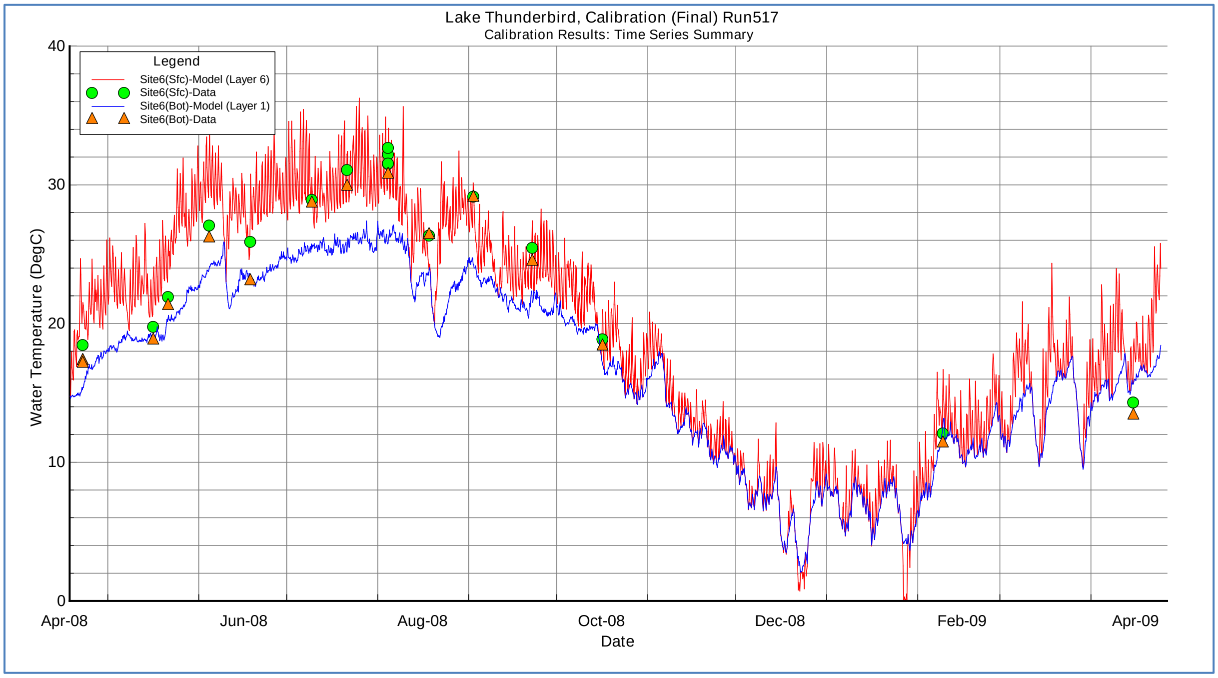


Figure B-19 TS_Cal011_TSS(io)_Site2 (Surface & Bottom)

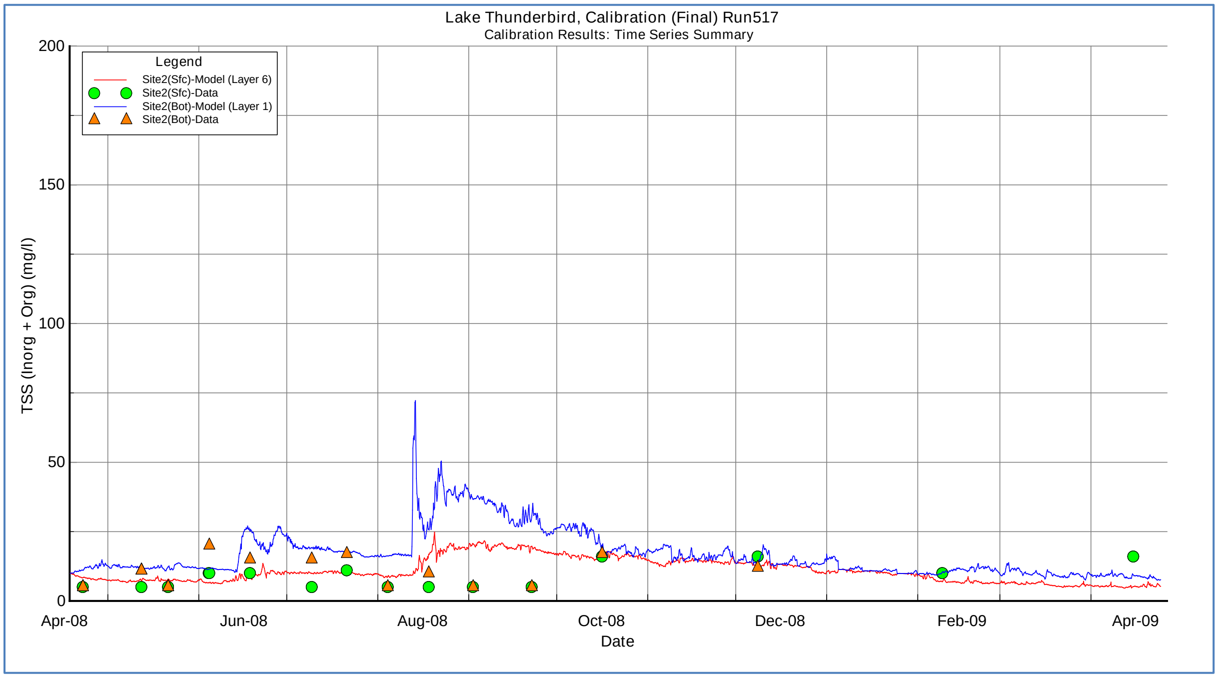


Figure B-20 TS_Cal015_TSS(io)_Site6 (Surface)

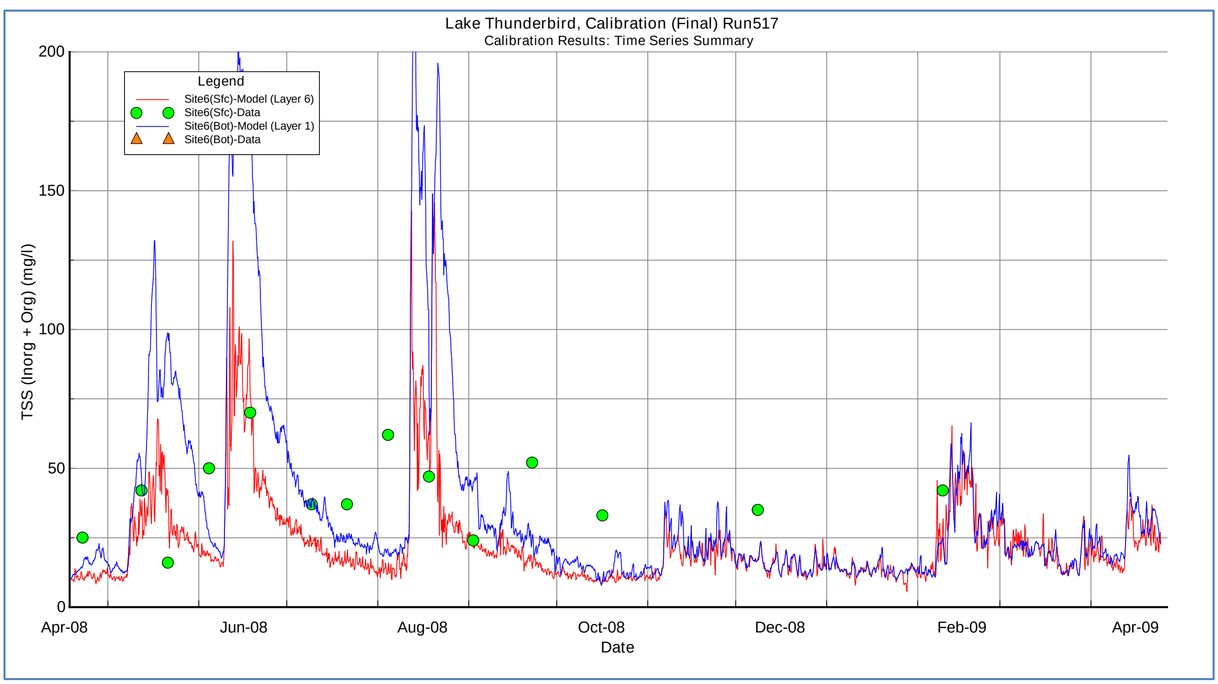


Figure B-21 TS_Cal019_DO_Site2 (Surface & Bottom)

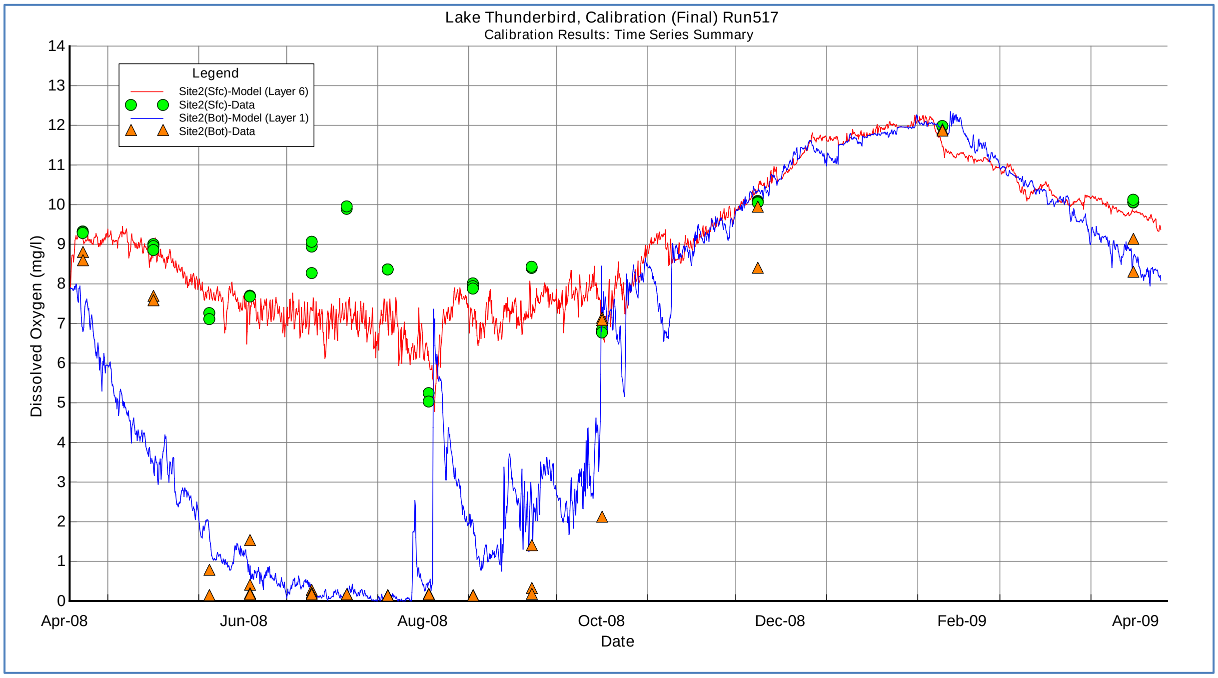


Figure B-22 TS_Cal020_DO_Site3 (Surface & Bottom)

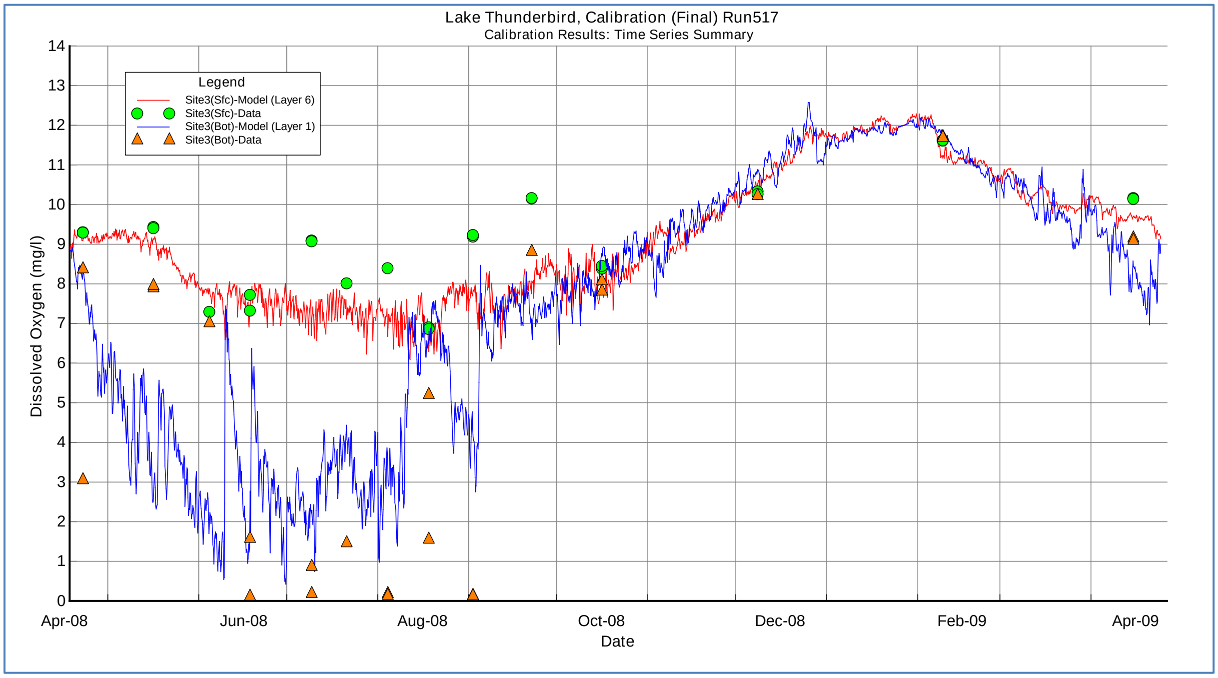


Figure B-23 TS_Cal023_DO_Site6 (Surface & Bottom)

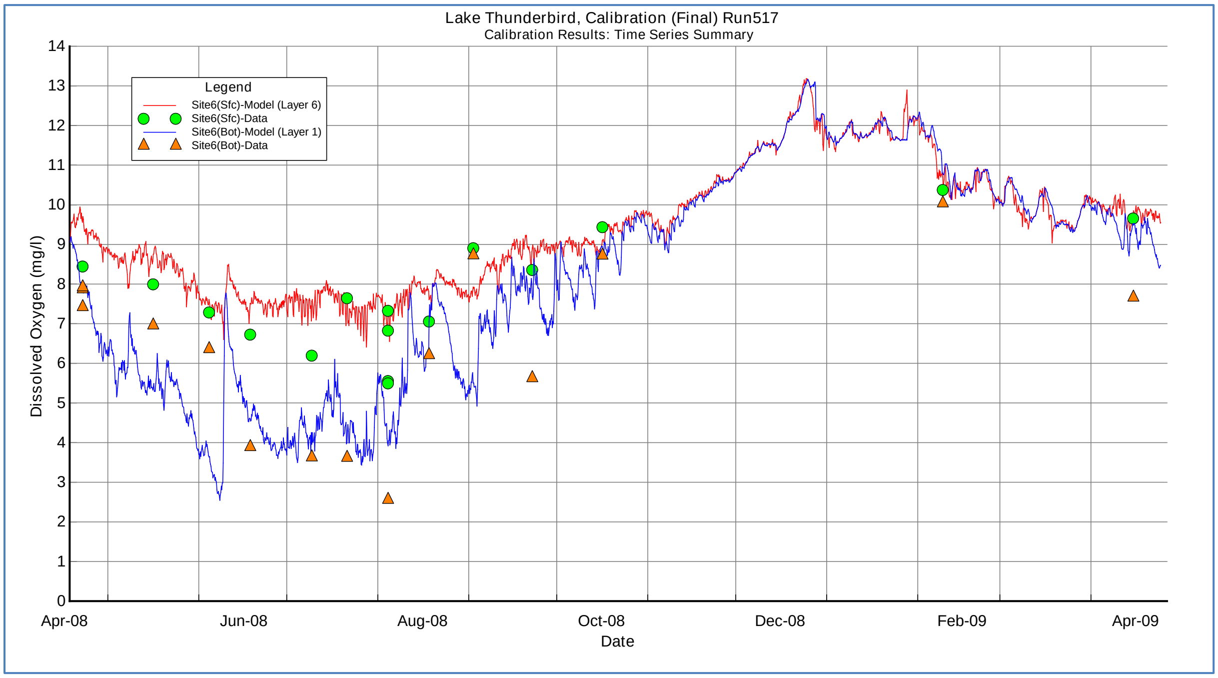


Figure B-24 TS_Cal027_Chl-a_Site2 (Surface)

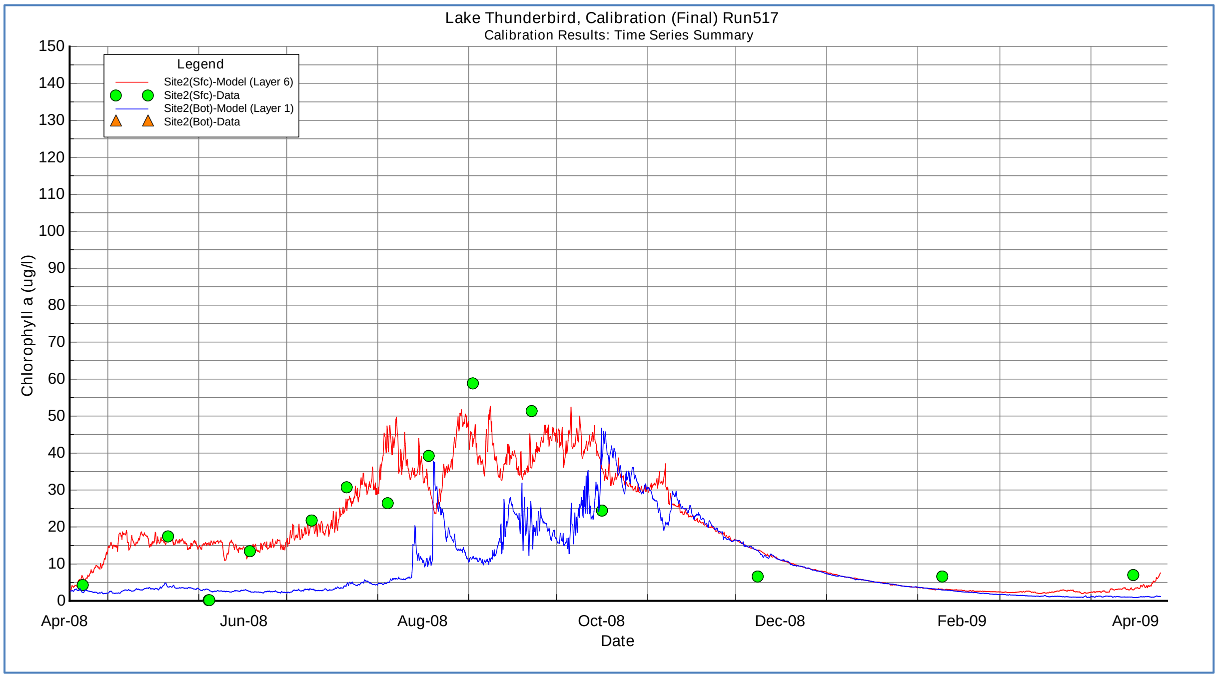


Figure B-25 TS_Cal031_Chl-a_Site6 (Surface)

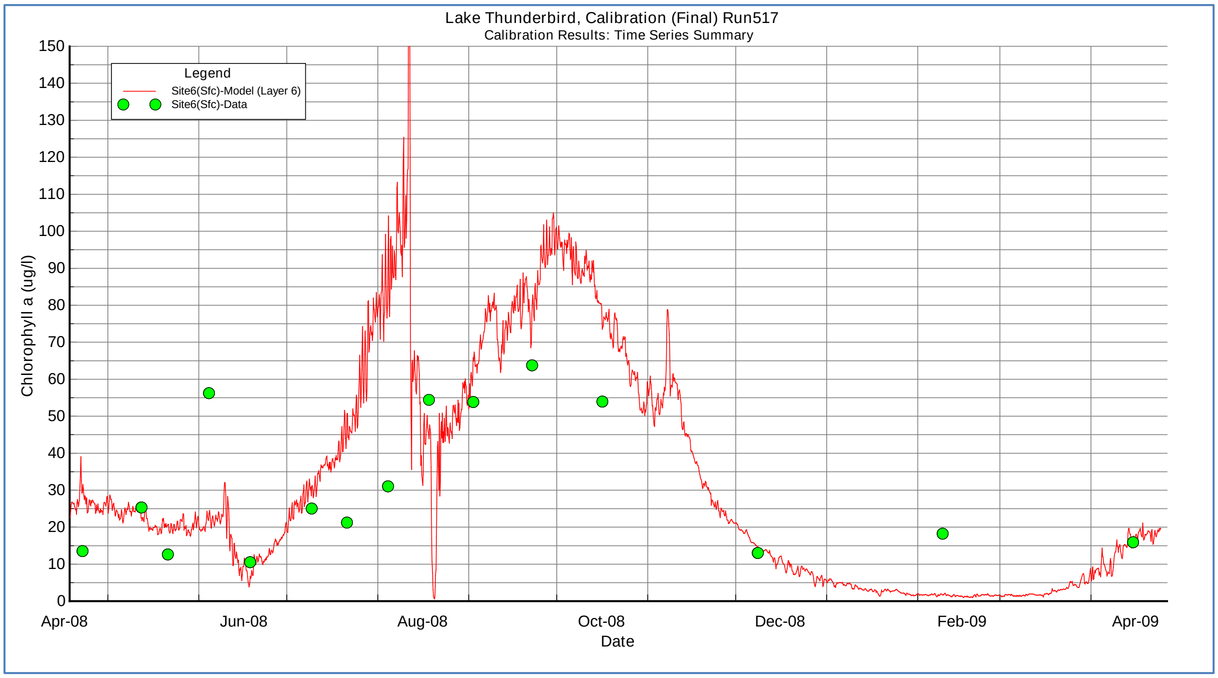


Figure B-26 TS_Cal035_Tot N_Site2 (Surface & Bottom)

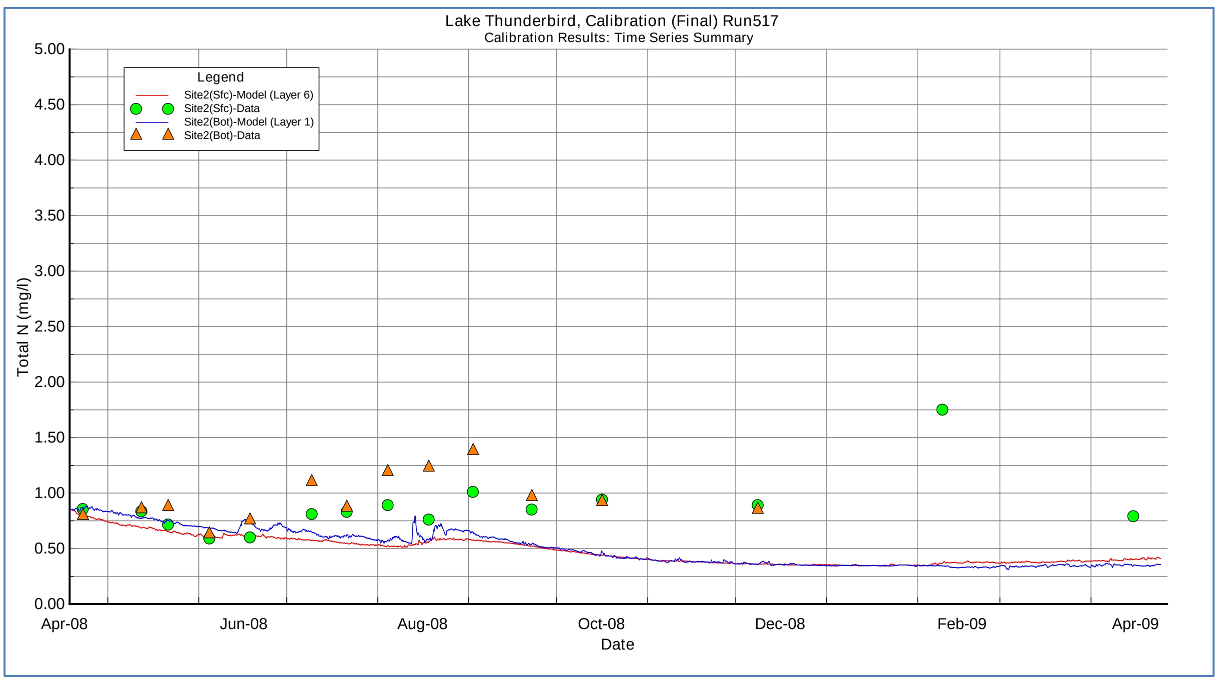


Figure B-27 TS_Cal039_Tot N_Site6 (Surface)

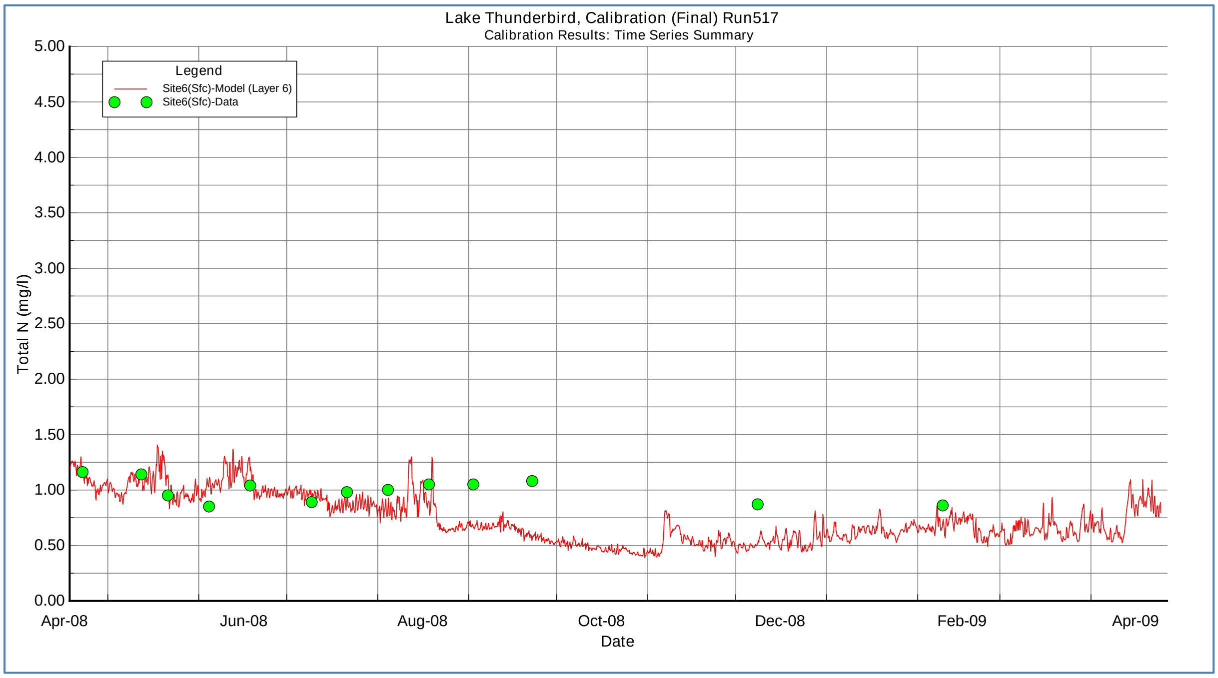


Figure B-28 TS_Cal043_Tot P_Site2 (Surface & Bottom)

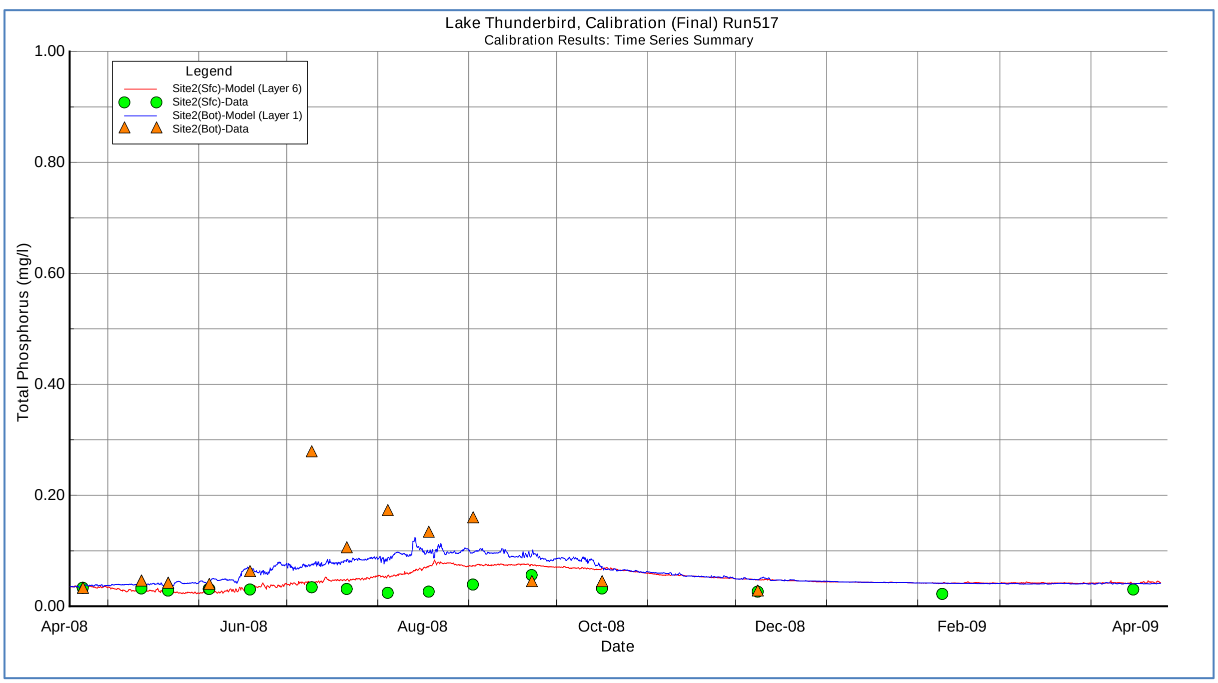


Figure B-29 TS_Cal047_Tot P_Site6 (Surface)

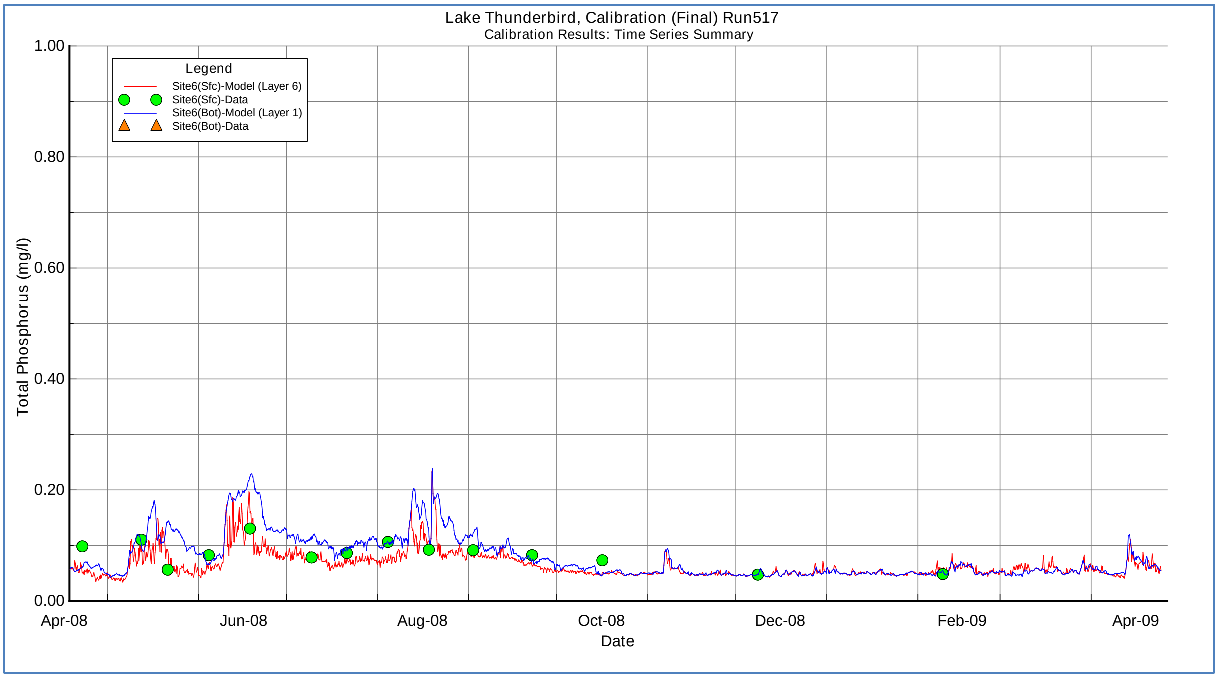


Figure B-30 TS_Cal051_TPO4-P_Site2 (Surface & Bottom)

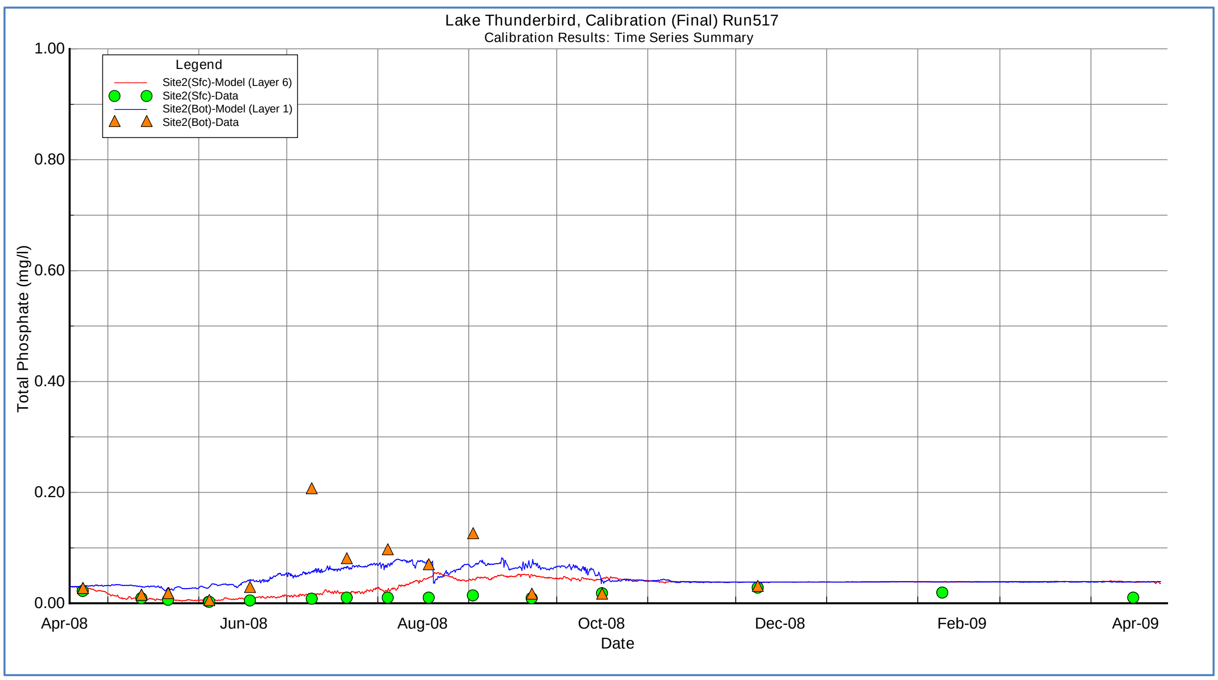


Figure B-31 TS_Cal055_TPO4-P_Site6 (Surface)

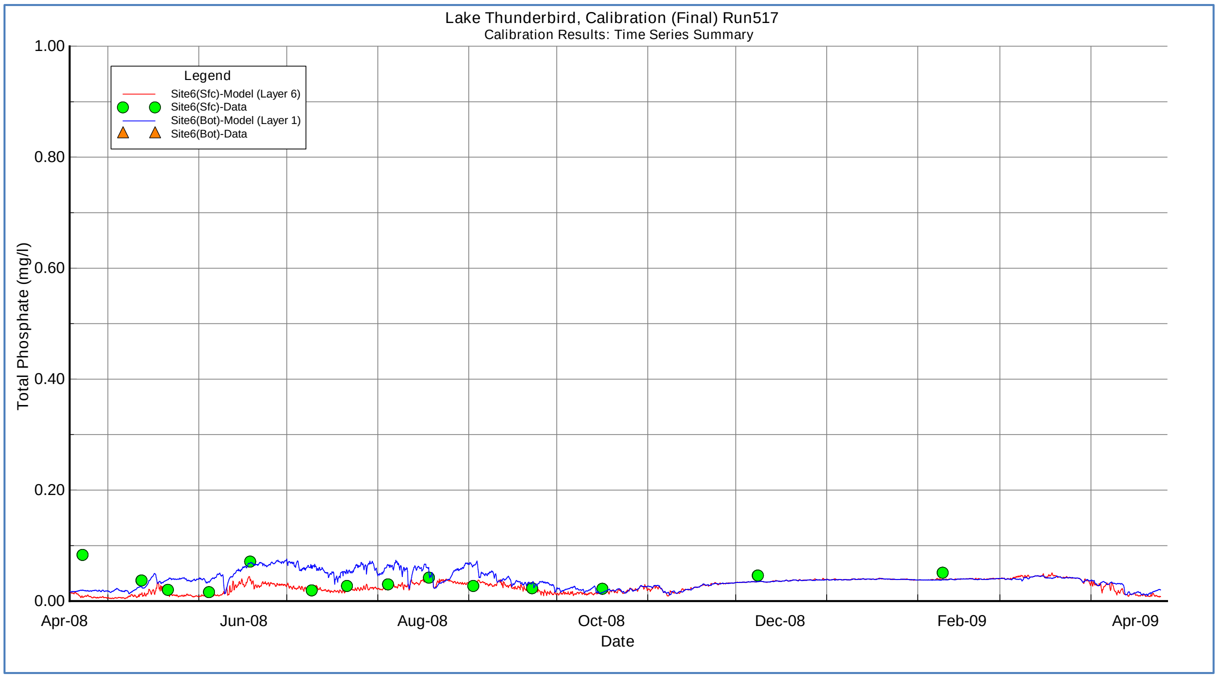


Figure B-32 TS_Cal059_NH4-N_Site2 (Surface & Bottom)

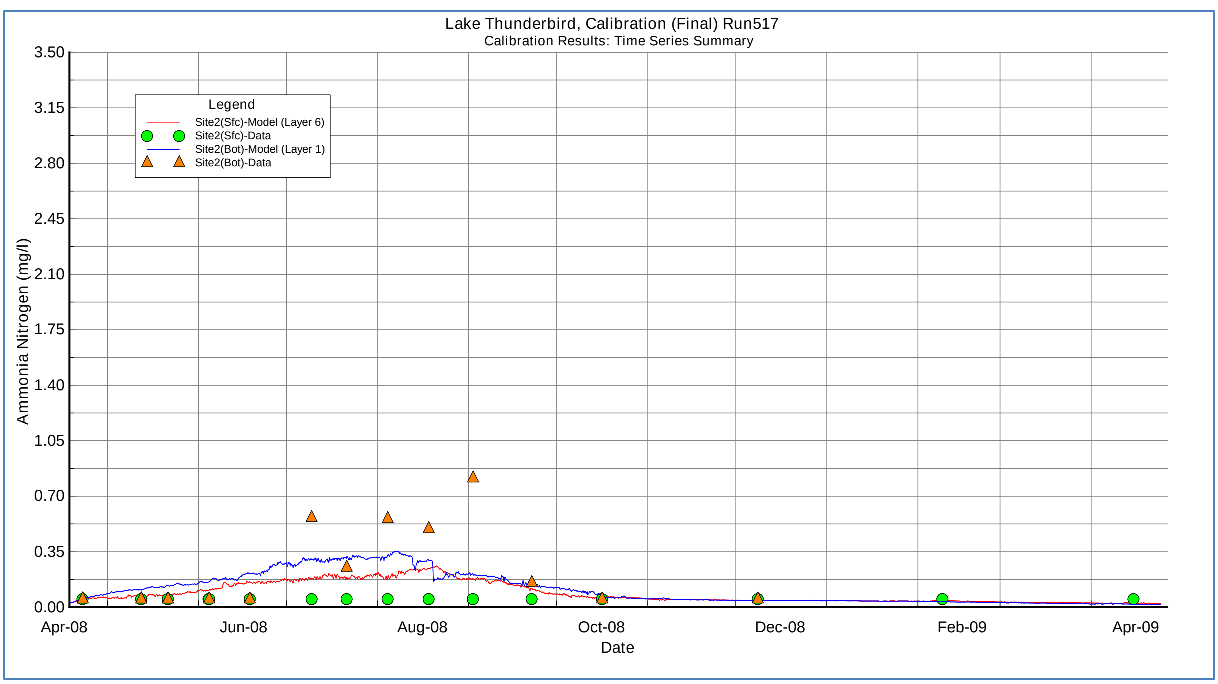


Figure B-33 TS_Cal063_NH4-N_Site6 (Surface)

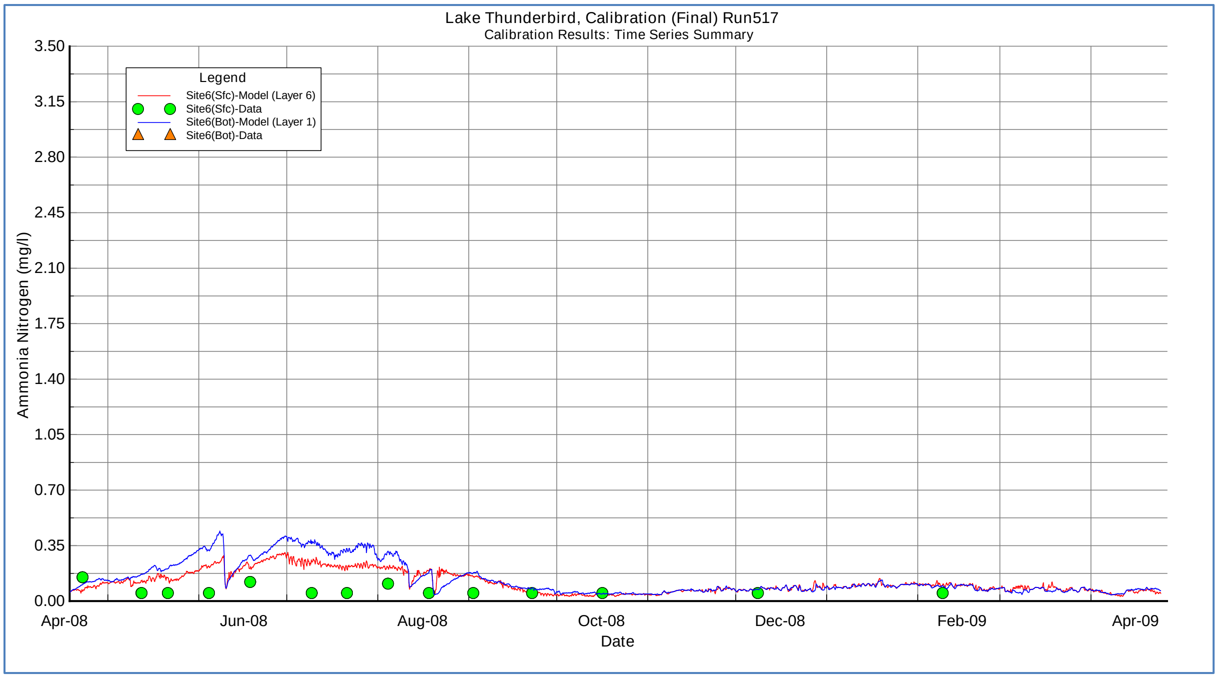


Figure B-34 TS_Cal067_NO3-N_Site2 (Surface & Bottom)

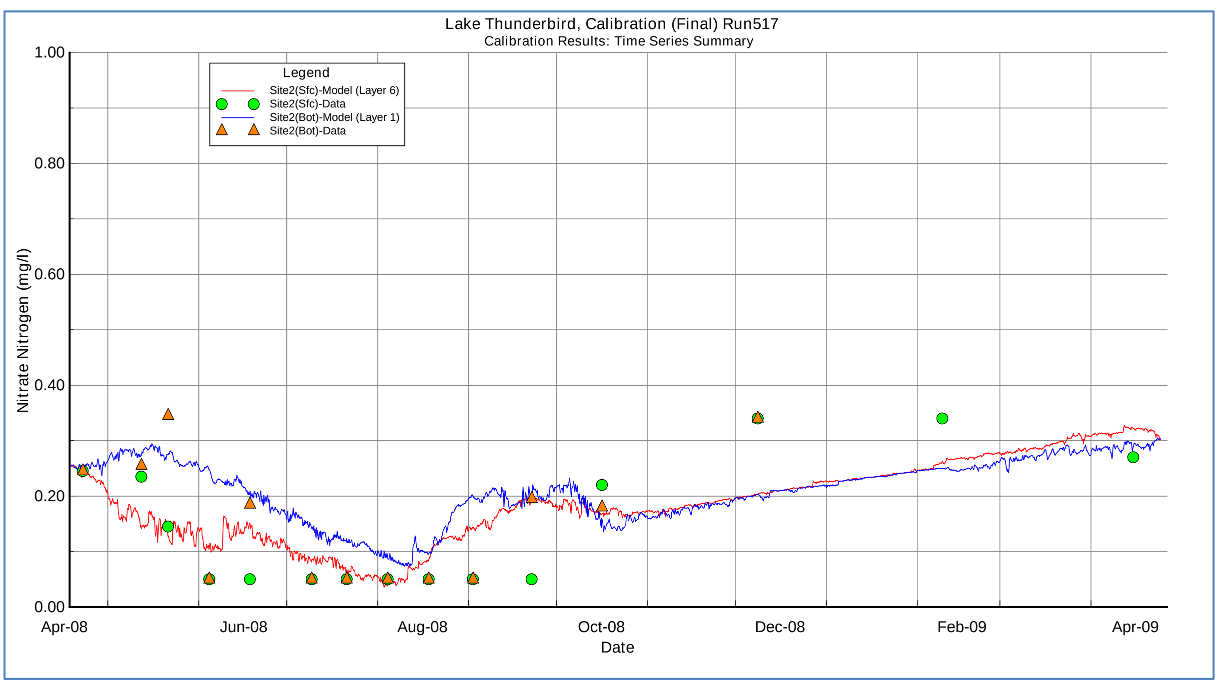
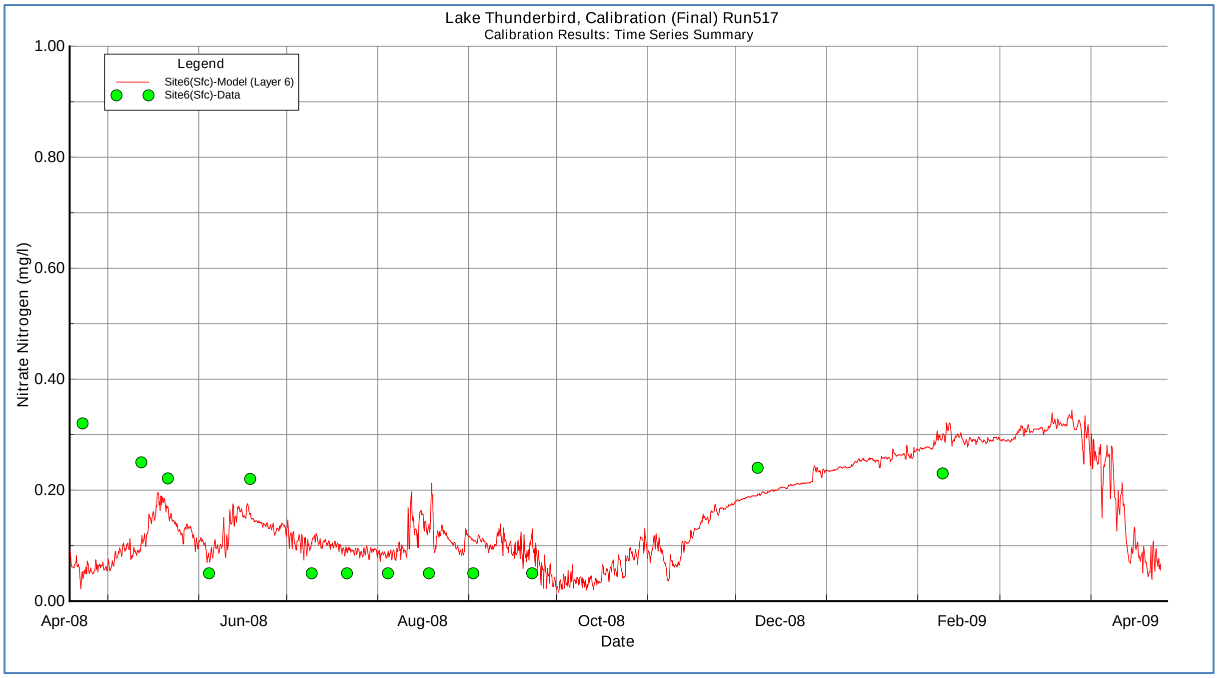


Figure B-35 TS_Cal071_NO3-N_Site6 (Surface)



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Appendix C

State of Oklahoma Anti-degradation Policy

SECTION 8 APPENDIX C - STATE OF OKLAHOMA ANTIDEGRADATION POLICY

785:45-3-1. Purpose; Antidegradation policy statement

(a) Waters of the state constitute a valuable resource and shall be protected, maintained and improved for the benefit of all the citizens.

(b) It is the policy of the State of Oklahoma to protect all waters of the state from degradation of water quality, as provided in OAC 785:45-3-2 and Subchapter 13 of OAC 785:46.

785:45-3-2. Applications of antidegradation policy

(a) Application to outstanding resource waters (ORW). Certain waters of the State constitute an outstanding resource or have exceptional recreational and/or ecological significance. These waters include streams designated "Scenic River" or "ORW" in Appendix A of this Chapter, and waters of the State located within watersheds of Scenic Rivers. Additionally, these may include waters located within National and State parks, forests, wilderness areas, wildlife management areas, and wildlife refuges, and waters which contain species listed pursuant to the federal Endangered Species Act as described in 785:45-5-25(c)(2)(A) and 785:46-13-6(c). No degradation of water quality shall be allowed in these waters.

(b) Application to high quality waters (HQW). It is recognized that certain waters of the state possess existing water quality which exceeds those levels necessary to support propagation of fishes, shellfishes, wildlife, and recreation in and on the water. These high quality waters shall be maintained and protected.

(c) Application to beneficial uses. No water quality degradation which will interfere with the attainment or maintenance of an existing or designated beneficial use shall be allowed.

(d) Application to improved waters. As the quality of any waters of the State improve, no degradation of such improved waters shall be allowed.

785:46-13-1. Applicability and scope

(a) The rules in this Subchapter provide a framework for implementing the antidegradation policy stated in OAC 785:45-3-2 for all waters of the state. This policy and framework includes three tiers, or levels, of protection.

(b) The three tiers of protection are as follows:

(1) Tier 1. Attainment or maintenance of an existing or designated beneficial use.

(2) Tier 2. Maintenance or protection of High Quality Waters and Sensitive Public and Private Water Supply waters.

(3) Tier 3. No degradation of water quality allowed in Outstanding Resource Waters.

(c) In addition to the three tiers of protection, this Subchapter provides rules to implement the protection of waters in areas listed in Appendix B of OAC 785:45. Although Appendix B areas are not mentioned in OAC 785:45-3-2, the framework for protection of Appendix B areas is similar to the implementation framework for the antidegradation policy.

(d) In circumstances where more than one beneficial use limitation exists for a waterbody, the most protective limitation shall apply. For example, all antidegradation policy implementation rules applicable to Tier 1 waterbodies shall be applicable also to Tier 2 and Tier 3 waterbodies or areas, and implementation rules applicable to Tier 2 waterbodies shall be applicable also to Tier 3 waterbodies.

(e) Publicly owned treatment works may use design flow, mass loadings or concentration, as appropriate, to calculate compliance with the increased loading requirements of this section if those flows, loadings or concentrations were approved by the Oklahoma Department of Environmental Quality as a portion of Oklahoma's Water Quality Management Plan prior to the application of the ORW, HQW or SWS limitation.

785:46-13-2. Definitions

The following words and terms, when used in this Subchapter, shall have the following meaning, unless the context clearly indicates otherwise:

"Specified pollutants" means

(A) Oxygen demanding substances, measured as Carbonaceous Biochemical Oxygen Demand (CBOD) and/or Biochemical Oxygen Demand (BOD).

(B) Ammonia Nitrogen and/or Total Organic Nitrogen.

(C) Phosphorus.

(D) Total Suspended Solids (TSS).

(E) Such other substances as may be determined by the Oklahoma Water Resources Board or the permitting authority.

785:46-13-3. Tier 1 protection; attainment or maintenance of an existing or designated beneficial use

(a) General.

(1) Beneficial uses which are existing or designated shall be maintained and protected.

(2) The process of issuing permits for discharges to waters of the state is one of several means employed by governmental agencies and affected persons which are designed to attain or maintain beneficial uses which have been designated for those waters. For example, Subchapters 3, 5, 7, 9 and 11 of this Chapter are rules for the permitting process. As such, the latter Subchapters not only implement numerical and narrative criteria, but also implement Tier 1 of the antidegradation policy.

(b) Thermal pollution. Thermal pollution shall be prohibited in all waters of the state. Temperatures greater than 52 degrees Centigrade shall constitute thermal pollution and shall be prohibited in all waters of the state.

(c) Prohibition against degradation of improved waters. As the quality of any waters of the state improves, no degradation of such improved waters shall be allowed.

785:46-13-4. Tier 2 protection; maintenance and protection of High Quality Waters and Sensitive Water Supplies

(a) General rules for High Quality Waters. New point source discharges of any pollutant after June 11, 1989, and increased load or concentration of any specified pollutant from any point source discharge existing as of June 11, 1989, shall be prohibited in any waterbody or watershed designated in Appendix A of OAC 785:45 with the limitation "HQW". Any discharge of any pollutant to a waterbody designated "HQW" which would, if it occurred, lower existing water quality shall be prohibited. Provided however, new point source discharges or increased load or concentration of any specified pollutant from a discharge existing as of June 11, 1989, may be approved by the permitting authority in circumstances where the discharger demonstrates to the satisfaction of the permitting authority that such new discharge or increased load or concentration would result in maintaining or improving the level of water quality which exceeds that necessary to support recreation and propagation of fishes, shellfishes, and wildlife in the receiving water.

(b) General rules for Sensitive Public and Private Water Supplies. New point source discharges of any pollutant after June 11, 1989, and increased load of any specified pollutant from any point source discharge existing as of June 11, 1989, shall be prohibited in any waterbody or watershed designated in Appendix A of OAC 785:45 with the limitation "SWS". Any discharge of any pollutant to a waterbody designated "SWS" which would, if it occurred, lower existing water quality shall be prohibited. Provided however, new point source discharges or increased load of any specified pollutant from a discharge existing as of June 11, 1989, may be approved by the permitting authority in circumstances where the discharger demonstrates to the satisfaction of the permitting authority that such new discharge or increased load will result in maintaining or improving the water quality in both the direct receiving water, if designated SWS, and any downstream waterbodies designated SWS.

(c) Stormwater discharges. Regardless of subsections (a) and (b) of this Section, point source discharges of stormwater to waterbodies and watersheds designated "HQW" and "SWS" may be approved by the permitting authority.

(d) Nonpoint source discharges or runoff. Best management practices for control of nonpoint source discharges or runoff should be implemented in watersheds of waterbodies designated "HQW" or "SWS" in Appendix A of OAC 785:45.

785:46-13-5. Tier 3 protection; prohibition against degradation of water quality in outstanding resource waters

(a) General. New point source discharges of any pollutant after June 11, 1989, and increased load of any pollutant from any point source discharge existing as of June 11, 1989, shall be prohibited in any waterbody or watershed designated in Appendix A of OAC 785:45 with the limitation "ORW" and/or "Scenic River", and in any waterbody located within the watershed of any waterbody designated with the limitation "Scenic River". Any discharge of any pollutant to a waterbody designated "ORW" or "Scenic River" which would, if it occurred, lower existing water quality shall be prohibited.

(b) Stormwater discharges. Regardless of 785:46-13-5(a), point source discharges of stormwater from temporary construction activities to waterbodies and watersheds designated "ORW" and/or "Scenic River" may be permitted by the permitting authority. Regardless of 785:46-13-5(a), discharges of stormwater to waterbodies and watersheds designated "ORW" and/or "Scenic River" from point sources existing as of June 25, 1992, whether or not such stormwater discharges were permitted as point sources prior to June 25, 1992, may be permitted by the permitting authority; provided, however, increased load of any pollutant from such stormwater discharge shall be prohibited.

(c) Nonpoint source discharges or runoff. Best management practices for control of nonpoint source discharges or runoff should be implemented in watersheds of waterbodies designated "ORW" in Appendix A of OAC 785:45, provided, however, that development of conservation plans shall be required in sub-watersheds where discharges or runoff from nonpoint sources are identified as causing or significantly contributing to degradation in a waterbody designated "ORW".

(d) LMFO's. No licensed managed feeding operation (LMFO) established after June 10, 1998 which applies for a new or expanding license from the State Department of Agriculture after March 9, 1998 shall be located...[w]ithin three (3) miles of any designated scenic river area as specified by the Scenic Rivers Act in 82 O.S. Section 1451 and following, or [w]ithin one (1) mile of a waterbody [2:9-210.3(D)] designated in Appendix A of OAC 785:45 as "ORW".

785:46-13-6. Protection for Appendix B areas

(a) General. Appendix B of OAC 785:45 identifies areas in Oklahoma with waters of recreational and/or ecological significance. These areas are divided into Table 1, which includes national and state parks, national forests, wildlife areas, wildlife management areas and wildlife refuges; and Table 2, which includes areas which contain threatened or endangered species listed as such by the federal government pursuant to the federal Endangered Species Act as amended.

(b) Protection for Table 1 areas. New discharges of pollutants after June 11, 1989, or increased loading of pollutants from discharges existing as of June 11, 1989, to waters within the boundaries of areas listed in Table 1 of Appendix B of OAC 785:45 may be approved by the permitting authority under such conditions as ensure that the recreational and ecological significance of these waters will be maintained.

(c) Protection for Table 2 areas. Discharges or other activities associated with those waters within the boundaries listed in Table 2 of Appendix B of OAC 785:45 may be restricted through agreements between appropriate regulatory agencies and the United States Fish and Wildlife Service. Discharges or other activities in such areas shall not substantially disrupt the threatened or endangered species inhabiting the receiving water.

(d) Nonpoint source discharges or runoff. Best management practices for control of nonpoint source discharges or runoff should be implemented in watersheds located within areas listed in Appendix B of OAC 785:45.

Appendix D

Ambient Monitoring Data: Watershed Stations and Lake Stations

Appendix D

Ambient Monitoring Data: Lake Stations

HYDROLAB

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Table D-1 OWRB Water Quality Monitoring Stations for Lake Thunderbird

Site	Station Number	Latitude	Longitude	Represents
1	520810000020-1sX	35.223333	-97.220833	Dam Site; Lacustrine
	520810000020-1-4X			
	520810000020-1-8X			
	520810000020-1-12X			
	520810000020-1bX			
2	520810000020-2X	35.238889	-97.228889	Lacustrine
	520810000020-2bX			
3	520810000020-3X	35.262222	-97.238889	Transition
4	520810000020-4X	35.224444	-97.250833	Lacustrine
	520810000020-4bX			
5	520810000020-5X	35.220278	-97.290556	Transition
6	520810000020-6X	35.231667	-97.305556	Riverine
7	520810000020-7X	35.203056	-97.258056	Riverine
8	520810000020-8X	35.286409	-97.244887	Riverine
11	520810000020-11X	35.212292	-97.302545	Riverine

Figure D-1 OWRB Water Quality Monitoring Stations for Lake Thunderbird

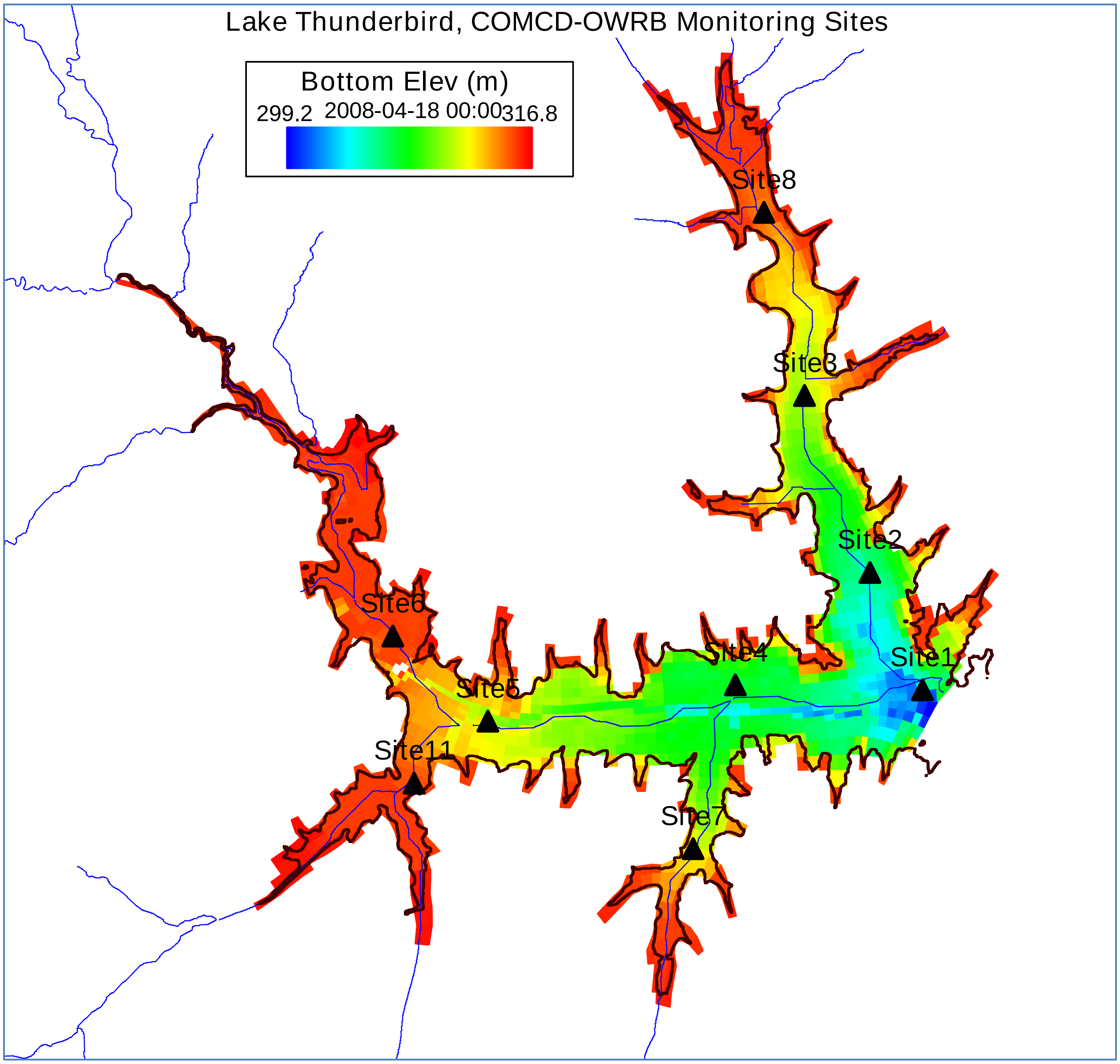

Table D-2 Site 1 HYDROLAB Station Data*

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site1	2/4/2008 14:31	1	5.13	8.03	366	0.18	547	0.2343	107	12.9
Site1	2/4/2008 14:32	2	5.11	8.11	366.1	0.18	543	0.2344	107	12.9
Site1	2/4/2008 14:33	0.1	5.2	8.26	366.4	0.18	538	0.2345	107.3	12.92
Site1	2/4/2008 14:34	2	5.18	8.19	366.2	0.18	535	0.2343	106.7	12.85
Site1	2/4/2008 14:35	3	5.15	8.2	366	0.18	533	0.2342	106.7	12.86
Site1	2/4/2008 14:35	4.1	5.13	8.16	366.2	0.18	532	0.2344	106.6	12.86
Site1	2/4/2008 14:36	5	5.1	8.21	366.8	0.18	531	0.2348	106.4	12.85
Site1	2/4/2008 14:37	6	5.07	8.2	365.8	0.18	529	0.2341	105.8	12.78
Site1	2/4/2008 14:38	7	5.05	8.18	365.9	0.18	527	0.2342	105.6	12.76
Site1	2/4/2008 14:38	8	5.05	8.17	365.9	0.18	526	0.2342	105.5	12.75
Site1	2/4/2008 14:39	9	5.04	8.18	366	0.18	524	0.2343	105.5	12.75
Site1	2/4/2008 14:41	9.8	5.04	8.19	365.9	0.18	522	0.2343	105.1	12.71
Site1	2/4/2008 14:42	11.1	5.03	8.18	365.9	0.18	521	0.2342	105.1	12.71
Site1	2/4/2008 14:42	12	5.02	8.18	366.1	0.18	520	0.2343	105.1	12.71
Site1	2/4/2008 14:43	13	5.03	8.18	365.9	0.18	519	0.2342	104.8	12.67
Site1	2/4/2008 14:43	13.3	5.02	8.14	366	0.18	515	0.2342	103.6	12.53
Site1	4/22/2008 9:44	0.3	15.92	8.19	390	0.19	381	0.2496	99.9	9.39
Site1	4/22/2008 9:44	0.2	15.9	8.2	390.2	0.19	381	0.2497	100.1	9.41
Site1	4/22/2008 9:45	0.9	15.72	8.21	389.9	0.19	381	0.2495	98.9	9.33
Site1	4/22/2008 9:46	2	15.71	8.22	390	0.19	381	0.2496	98.6	9.31
Site1	4/22/2008 9:47	3	15.67	8.23	389.9	0.19	381	0.2495	98.4	9.3
Site1	4/22/2008 9:48	3.9	15.6	8.24	389.8	0.19	381	0.2494	97.8	9.25
Site1	4/22/2008 9:49	5	15.28	8.24	389.3	0.19	381	0.2492	96.4	9.18
Site1	4/22/2008 9:50	5.9	15.22	8.24	389.7	0.19	381	0.2494	96.4	9.19
Site1	4/22/2008 9:52	7.1	15.19	8.25	389.7	0.19	380	0.2494	95.9	9.15
Site1	4/22/2008 9:53	7.9	15.13	8.25	389.5	0.19	380	0.2493	95.6	9.14
Site1	4/22/2008 9:53	7.8	15.12	8.26	389.6	0.19	380	0.2493	95.7	9.14
Site1	4/22/2008 9:54	9	14.82	8.26	389	0.19	380	0.249	94.5	9.09
Site1	4/22/2008 9:55	9.9	14.7	8.25	389.7	0.19	380	0.2494	94	9.06
Site1	4/22/2008 9:56	10.9	14.65	8.26	390.3	0.19	380	0.2498	93.9	9.06
Site1	4/22/2008 9:58	9.9	14.69	8.26	389.8	0.19	380	0.2495	94	9.07
Site1	4/22/2008 9:58	12	14.53	8.26	390.3	0.19	380	0.2498	93.3	9.03
Site1	4/22/2008 9:58	12	14.53	8.26	390.3	0.19	380	0.2498	93.3	9.03
Site1	4/22/2008 10:00	13	14.41	8.25	390.9	0.19	381	0.2501	91.8	8.91
Site1	4/22/2008 10:00	14.1	14.33	8.25	391.1	0.19	381	0.2503	90.6	8.8
Site1	4/22/2008 10:02	15	14.27	8.24	391.1	0.19	381	0.2503	89.5	8.71
Site1	4/22/2008 10:02	15	14.28	8.24	391.3	0.19	381	0.2504	89.6	8.72
Site1	4/22/2008 10:03	17	14.15	8.22	392.2	0.19	382	0.251	86.1	8.41

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site1	4/22/2008 10:07	17.2	14.13	8.14	392.2	0.19	147	0.251	5.3	0.52
Site1	5/16/2008 11:17	0.1	19.12	8.1	390.5	0.19	416	0.2499	100.6	8.86
Site1	5/16/2008 11:18	1.1	19.07	8.26	390.5	0.19	409	0.25	100.3	8.84
Site1	5/16/2008 11:21	2.1	18.92	8.24	391.3	0.19	400	0.2504	98.5	8.71
Site1	5/16/2008 11:22	3.1	18.82	8.24	390.5	0.19	399	0.2499	97	8.59
Site1	5/16/2008 11:26	4.1	18.86	8.26	390.4	0.19	394	0.2499	97	8.59
Site1	5/16/2008 11:26	5.2	18.89	8.26	390.6	0.19	394	0.25	97.8	8.66
Site1	5/16/2008 11:27	6	18.91	8.27	390.6	0.19	393	0.25	98	8.67
Site1	5/16/2008 11:31	6.8	18.77	8.26	390.7	0.19	381	0.2501	95.8	8.5
Site1	5/16/2008 11:32	8.1	18.78	8.26	390.7	0.19	382	0.2501	95.3	8.45
Site1	5/16/2008 11:32	9	18.79	8.26	390.7	0.19	382	0.2501	95.5	8.47
Site1	5/16/2008 11:33	10	18.77	8.25	390.7	0.19	382	0.2501	95	8.42
Site1	5/16/2008 11:33	11	18.75	8.25	390.7	0.19	383	0.25	94.2	8.36
Site1	5/16/2008 11:34	12.1	18.72	8.25	390.8	0.19	383	0.2501	93.8	8.32
Site1	5/16/2008 11:34	13	18.72	8.25	390.8	0.19	383	0.2501	93.5	8.31
Site1	5/16/2008 11:35	14	18.7	8.24	390.7	0.19	383	0.2501	93.1	8.27
Site1	5/16/2008 11:36	15	18.69	8.24	390.8	0.19	384	0.2501	93	8.26
Site1	5/16/2008 11:37	16	18.69	8.24	390.9	0.19	384	0.2502	92.8	8.24
Site1	5/16/2008 11:38	16.9	18.46	8.14	392.3	0.2	383	0.2511	78.3	6.99
Site1	5/21/2008 11:34	0.3	21.43	8.45	393.5	0.2	415	0.2518		
Site1	5/21/2008 11:35	1	21.44	8.5	393.5	0.2	414	0.2518		
Site1	5/21/2008 11:36	2	21.34	8.5	393.6	0.2	414	0.2519		
Site1	5/21/2008 11:40	2	21.28	8.51	393.7	0.2	408	0.252		
Site1	5/21/2008 11:41	3	20.84	8.43	395.2	0.2	410	0.2529		
Site1	5/21/2008 11:42	4	20.33	8.35	397.1	0.2	412	0.2541		
Site1	5/21/2008 11:43	5	20.22	8.32	398.1	0.2	412	0.2548		
Site1	5/21/2008 11:54	4	20.29	8.31	397.5	0.2	370	0.2544		
Site1	5/21/2008 11:55	4.9	20.17	8.29	397.9	0.2	370	0.2546		
Site1	5/21/2008 11:56	6	19.53	8.21	397.4	0.2	371	0.2544		
Site1	5/21/2008 11:57	7	19.03	8.13	396.5	0.2	371	0.2538		
Site1	5/21/2008 11:58	8.1	18.91	8.1	396.7	0.2	371	0.2539		
Site1	5/21/2008 11:59	9	18.77	8.07	397.7	0.2	371	0.2546		
Site1	5/21/2008 12:00	10	18.73	8.06	397.7	0.2	371	0.2545		
Site1	5/21/2008 12:01	11	18.61	8.02	396.3	0.2	371	0.2536		
Site1	5/21/2008 12:01	12.1	18.6	8.01	396.2	0.2	371	0.2536		
Site1	5/21/2008 12:02	13.1	18.59	8	396.2	0.2	371	0.2536		
Site1	5/21/2008 12:03	13.9	18.54	7.98	396.4	0.2	371	0.2536		
Site1	5/21/2008 12:04	15	18.54	7.96	396.4	0.2	371	0.2537		

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site1	5/21/2008 12:05	16	18.53	7.96	396.4	0.2	371	0.2538		
Site1	5/21/2008 12:06	16.6	18.52	7.94	396.7	0.2	326	0.2539		
Site1	6/4/2008 13:10	4.1	25.35	8.38	357	0.2	433	0.229	92.2	7.3
Site1	6/4/2008 13:11	3.2	25.36	8.38	358	0.2	434	0.229	92.3	7.31
Site1	6/4/2008 13:12	2.9	25.35	8.38	358	0.2	435	0.229	91.5	7.24
Site1	6/4/2008 13:12	2.9	25.35	8.38	358	0.2	436	0.229	91.6	7.25
Site1	6/4/2008 13:13	2	25.39	8.38	357	0.2	437	0.229	93.3	7.38
Site1	6/4/2008 13:14	1	25.45	8.39	357	0.2	437	0.229	94.5	7.47
Site1	6/4/2008 13:14	0.6	25.45	8.39	357	0.2	438	0.229	94	7.43
Site1	6/4/2008 13:15	0.3	25.44	8.39	358	0.2	439	0.229	93.7	7.41
Site1	6/4/2008 13:18	15.9	18.68	7.08	496	0.25	32	0.3174	3	0.27
Site1	6/4/2008 13:18	15.9	18.69	7.07	497.5	0.25	31	0.3184	2.7	0.23
Site1	6/4/2008 13:19	14.9	18.66	7.46	363	0.18	36	0.2324	3.1	0.28
Site1	6/4/2008 13:19	13.9	18.8	7.44	360.5	0.18	58	0.2307	3	0.29
Site1	6/4/2008 13:21	12.9	18.96	7.43	360.4	0.18	145	0.2307	3.9	0.35
Site1	6/4/2008 13:22	12	19.07	7.42	360.3	0.18	213	0.2306	3.5	0.31
Site1	6/4/2008 13:24	11	19.44	7.42	360.5	0.18	288	0.2305	4.9	0.43
Site1	6/4/2008 13:25	10.1	20.01	7.46	360.5	0.18	342	0.2306	10.3	0.9
Site1	6/4/2008 13:26	10.1	20.11	7.47	360.8	0.18	353	0.2309	10.7	0.92
Site1	6/4/2008 13:27	9	21.54	7.65	361.7	0.18	382	0.2315	27.6	2.35
Site1	6/4/2008 13:28	8.9	22.25	7.79	361.2	0.18	396	0.2312	38.1	3.19
Site1	6/4/2008 13:29	8	25.14	8.35	357.6	0.18	396	0.2289	88.4	6.99
Site1	6/4/2008 13:31	7	25.24	8.38	357.5	0.18	405	0.2288	91.1	7.23
Site1	6/4/2008 13:32	6.1	25.25	8.38	357.7	0.18	412	0.2289	90.5	7.18
Site1	6/4/2008 13:34	5.1	25.32	8.38	357.2	0.18	418	0.2286	91.7	7.26
Site1	6/18/2008 9:35	0.3	25.61	8.17	405.4	0.2	544	0.2595	86	6.74
Site1	6/18/2008 9:35	0.1	25.61	8.17	405.5	0.2	542	0.2595	86.1	6.75
Site1	6/18/2008 9:37	1.1	25.44	8.18	405.3	0.2	532	0.2594	83.6	6.57
Site1	6/18/2008 9:37	1.9	25.41	8.16	405.5	0.2	527	0.2595	82.2	6.47
Site1	6/18/2008 9:39	3.1	25.4	8.17	405.5	0.2	518	0.2595	81.4	6.41
Site1	6/18/2008 9:40	4	25.39	8.17	405.5	0.2	511	0.2595	81.2	6.39
Site1	6/18/2008 9:41	5.1	25.39	8.15	405.5	0.2	506	0.2595	81	6.38
Site1	6/18/2008 9:42	6	25.39	8.13	405.6	0.2	503	0.2596	80.7	6.35
Site1	6/18/2008 9:43	7.1	25.38	8.13	405.6	0.2	498	0.2596	80.6	6.35
Site1	6/18/2008 9:45	8	25.37	8.13	405.4	0.2	493	0.2594	80.3	6.32
Site1	6/18/2008 9:46	9.1	25.35	8.1	405.5	0.2	489	0.2595	79.8	6.29
Site1	6/18/2008 9:47	10.1	25.3	8.06	405.6	0.2	488	0.2596	78.2	6.17
Site1	6/18/2008 9:48	10.5	25.16	8.11	406.2	0.2	478	0.2599	75	5.93

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site1	6/18/2008 9:51	11	24.66	7.91	405.8	0.2	476	0.2597	57	4.55
Site1	6/18/2008 9:53	11.5	24.04	7.56	412.6	0.21	479	0.2641	16.7	1.35
Site1	6/18/2008 9:54	12	23.84	7.51	413.2	0.21	477	0.2646	13.8	1.12
Site1	6/18/2008 9:55	12.9	22.55	7.4	416.6	0.21	477	0.2666	1.8	0.15
Site1	6/18/2008 9:58	14	20.2	7.38	419.5	0.21	328	0.2685	1.4	0.12
Site1	6/18/2008 9:59	15	19.87	7.34	420.5	0.21	240	0.2691	1.4	0.12
Site1	6/18/2008 10:02	16.1	19.42	7.4	424.5	0.21	54	0.2717	1.3	0.11
Site1	6/18/2008 10:04	16.6	19.28	7.33	428.5	0.21	-6	0.2742	1.1	0.1
Site1	7/9/2008 10:12	13.9	21.83	7.66	411.7	0.21	-96	0.2635	3.1	0.26
Site1	7/9/2008 10:13	12.7	22.71	7.7	406.4	0.2	-107	0.2601	2.3	0.19
Site1	7/9/2008 10:15	12	23.39	7.71	403	0.2	-107	0.2579	1.7	0.14
Site1	7/9/2008 10:17	11	23.71	7.69	401.7	0.2	-108	0.2571	1.5	0.12
Site1	7/9/2008 10:19	10	24.51	7.73	398.8	0.2	-88	0.2552	1.5	0.12
Site1	7/9/2008 10:21	8.9	25.06	7.75	397.6	0.2	-65	0.2544	1.4	0.11
Site1	7/9/2008 10:23	8	25.78	7.78	397.2	0.2	-56	0.2542	1.3	0.1
Site1	7/9/2008 10:25	7.1	26.48	7.8	396.1	0.2	-48	0.2535	1.2	0.09
Site1	7/9/2008 10:26	6.1	26.93	7.87	395.4	0.2	30	0.2531	10.3	0.78
Site1	7/9/2008 10:29	5	27.98	8.32	387.2	0.19	140	0.2478	66.1	4.95
Site1	7/9/2008 10:31	4	28.32	8.53	382.4	0.19	173	0.2447	98.5	7.33
Site1	7/9/2008 10:33	3.1	28.35	8.58	381.8	0.19	185	0.2444	105.9	7.87
Site1	7/9/2008 10:34	1.5	28.42	8.62	382	0.19	193	0.2445	110.5	8.21
Site1	7/9/2008 10:36	1	28.62	8.62	380.4	0.19	199	0.2435	115.5	8.55
Site1	7/9/2008 10:38	0.3	28.65	8.63	380.4	0.19	202	0.2435	116.4	8.62
Site1	7/21/2008 11:03	0.3	29.63	8.53	362.3	0.18	196	0.2319	146.8	10.68
Site1	7/21/2008 11:04	1	29.56	8.56	362	0.18	201	0.2317	148.3	10.8
Site1	7/21/2008 11:06	2	29.28	8.55	363	0.18	206	0.2323	140.9	10.32
Site1	7/21/2008 11:08	3.1	29.15	8.46	364.6	0.18	212	0.2334	129.1	9.48
Site1	7/21/2008 11:09	4	28.61	8.26	372.2	0.18	216	0.2382	93.8	6.95
Site1	7/21/2008 11:11	5	28.22	8.14	376.1	0.19	218	0.2407	79.5	5.93
Site1	7/21/2008 11:13	6.2	27.64	7.88	382.3	0.19	211	0.2447	39.7	2.99
Site1	7/21/2008 11:15	7	27.24	7.64	385.4	0.19	199	0.2466	9.6	0.73
Site1	7/21/2008 11:17	8.1	26.9	7.59	387.4	0.19	123	0.248	1.6	0.12
Site1	7/21/2008 11:18	9.1	26.23	7.58	390.3	0.19	-49	0.2498	1.5	0.11
Site1	7/21/2008 11:19	10	24.29	7.5	396.3	0.2	-105	0.2536	1.4	0.11
Site1	7/21/2008 11:20	11	23.87	7.48	397.3	0.2	-118	0.2543	1.4	0.11
Site1	7/21/2008 11:21	12	23.56	7.46	399.6	0.2	-125	0.2558	1.4	0.11
Site1	7/21/2008 11:22	13	22.38	7.42	406	0.2	-133	0.2598	1.3	0.11
Site1	7/21/2008 11:23	14	22.03	7.42	408.1	0.2	-136	0.2612	1.3	0.11

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site1	7/21/2008 11:24	14.5	21.69	7.35	412.1	0.21	-134	0.2637	1.3	0.11
Site1	8/4/2008 10:47	0.3	30.57	8.54	396.5	0.2	203	0.2537	128	9.15
Site1	8/4/2008 10:48	1	30.57	8.53	396.2	0.2	211	0.2538	127.9	9.14
Site1	8/4/2008 10:51	2	30.48	8.52	396.5	0.2	220	0.2537	126.8	9.07
Site1	8/4/2008 10:52	2	30.48	8.52	396.5	0.2	220	0.2537	126	9.02
Site1	8/4/2008 10:53	3	30.3	8.44	397.5	0.2	226	0.2544	118.8	8.53
Site1	8/4/2008 10:54	4	30.2	8.38	398.8	0.2	229	0.2552	114	8.2
Site1	8/4/2008 10:56	5.1	29.16	7.74	414.5	0.21	205	0.2653	23.8	1.74
Site1	8/4/2008 10:57	6.1	28.64	7.58	419	0.21	111	0.2682	2.8	0.21
Site1	8/4/2008 10:58	7	27.64	7.55	430.2	0.22	-64	0.2753	1.9	0.14
Site1	8/4/2008 10:59	8	27.02	7.53	433.9	0.22	-87	0.2777	1.6	0.12
Site1	8/4/2008 11:00	9	26.26	7.51	437.6	0.22	-94	0.2801	1.4	0.11
Site1	8/4/2008 11:01	9.9	24.91	7.44	443.5	0.22	-98	0.2838	1.4	0.11
Site1	8/4/2008 11:03	11	23.89	7.38	449	0.23	-105	0.2875	1.3	0.1
Site1	8/4/2008 11:05	12	23.35	7.35	451.6	0.23	-107	0.289	1.2	0.1
Site1	8/4/2008 11:06	12	23.22	7.37	452.5	0.23	-109	0.2896	1.2	0.1
Site1	8/4/2008 11:07	13	22.41	7.31	459.2	0.23	-110	0.2939	1.2	0.1
Site1	8/4/2008 11:09	14.1	21.98	7.27	464.4	0.23	-111	0.2972	1.2	0.1
Site1	8/4/2008 11:11	15	21.56	7.24	469.4	0.24	-111	0.3004	1.2	0.1
Site1	8/4/2008 11:12	16.1	21.48	7.23	471.5	0.24	-110	0.3018	1.2	0.1
Site1	8/4/2008 11:13	16.1	21.29	7.22	473.2	0.24	-110	0.3029	1.2	0.1
Site1	8/18/2008 10:05	0.3	26.89	8.41	363.2	0.18	217	0.2325	72.7	5.57
Site1	8/18/2008 10:06	1.3	27.02	8.37	363.5	0.18	230	0.2326	68.7	5.25
Site1	8/18/2008 10:07	2.1	26.95	8.35	363.8	0.18	239	0.2328	68.7	5.25
Site1	8/18/2008 10:09	3.2	26.95	8.33	363.5	0.18	248	0.2327	68.2	5.21
Site1	8/18/2008 10:10	4	27.02	8.31	363.5	0.18	251	0.2326	67.9	5.18
Site1	8/18/2008 10:11	5	27.01	8.31	363.6	0.18	254	0.2327	67.6	5.17
Site1	8/18/2008 10:12	6	27	8.3	363.5	0.18	258	0.2327	67.2	5.13
Site1	8/18/2008 10:13	7.1	27.02	8.29	363.5	0.18	262	0.2326	66.8	5.1
Site1	8/18/2008 10:14	8.4	27.01	8.26	363.7	0.18	265	0.2328	64.3	4.91
Site1	8/18/2008 10:15	9	26.64	8.29	376.8	0.19	52	0.2411	14.3	1.1
Site1	8/18/2008 10:16	10	25.02	8.34	406.6	0.2	-45	0.2602	2.5	0.2
Site1	8/18/2008 10:17	11	24.28	8.3	409.2	0.2	-66	0.2619	2	0.16
Site1	8/18/2008 10:18	12.1	23.6	8.26	415.4	0.21	-75	0.2659	1.7	0.14
Site1	8/18/2008 10:19	13	22.58	8.2	421.6	0.21	-82	0.27	1.6	0.13
Site1	8/18/2008 10:20	14	22.29	8.16	425.6	0.21	-83	0.2724	1.5	0.12
Site1	8/18/2008 10:21	15	21.87	8.09	431.4	0.22	-84	0.2761	1.5	0.12
Site1	8/18/2008 10:22	16	21.57	8.05	434.4	0.22	-84	0.278	1.5	0.13

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site1	8/18/2008 10:23	16.1	21.68	8.03	433.1	0.22	-85	0.2772	1.5	0.13
Site1	8/18/2008 10:24	16.1	21.47	8.01	435.9	0.22	-85	0.279	1.4	0.12
Site1	9/2/2008 11:59	0.3	27.34	8.3	359	0.18	223	0.2298	87	6.58
Site1	9/2/2008 12:02	1	27.3	8.29	358.9	0.18	232	0.2297	85	6.43
Site1	9/2/2008 12:03	2	27.31	8.31	358.9	0.18	234	0.2297	83.2	6.29
Site1	9/2/2008 12:06	3	27.26	8.3	359	0.18	237	0.2298	79.8	6.04
Site1	9/2/2008 12:08	3.5	27.22	8.3	359.4	0.18	240	0.23	78.8	5.97
Site1	9/2/2008 12:10	4.1	27.18	8.28	359.4	0.18	242	0.23	75.9	5.75
Site1	9/2/2008 12:13	5	26.96	7.96	364.1	0.18	247	0.2331	47	3.58
Site1	9/2/2008 12:17	6	26.56	7.63	366	0.18	240	0.2342	11	0.84
Site1	9/2/2008 12:20	7	25.88	7.5	364.8	0.18	68	0.2335	1.3	0.1
Site1	9/2/2008 12:23	7.9	25.21	7.46	356.4	0.18	-8	0.2281	1	0.08
Site1	9/2/2008 12:24	9	24.88	7.44	353.3	0.17	-25	0.2261	1.2	0.1
Site1	9/2/2008 12:27	10	24.23	7.39	343	0.17	-42	0.2195	1.1	0.09
Site1	9/2/2008 12:29	11	23.69	7.3	361	0.18	-54	0.2311	1	0.08
Site1	9/2/2008 12:31	12	23.01	7.18	390.7	0.19	-62	0.25	1	0.08
Site1	9/2/2008 12:33	13	22.41	7.07	427.1	0.21	-63	0.2733	1	0.08
Site1	9/2/2008 12:34	14	22.07	7.02	438.6	0.22	-62	0.2807	1	0.09
Site1	9/2/2008 12:36	15	21.67	6.95	450.1	0.23	-61	0.288	1	0.09
Site1	9/2/2008 12:36	16	21.45	6.91	455.8	0.23	-62	0.2917	1	0.08
Site1	9/22/2008 12:14	0.3	23.35	8.28	339.9	0.17	229	0.2176	81.5	5.77
Site1	9/22/2008 12:15	1.1	23.34	8.27	339.7	0.17	236	0.2174	80.9	5.72
Site1	9/22/2008 12:16	2.1	23.25	8.22	339.8	0.17	244	0.2174	75.8	5.37
Site1	9/22/2008 12:18	3	23.18	8.15	340.4	0.17	247	0.2178	67.3	4.77
Site1	9/22/2008 12:20	4	23.1	7.99	341.2	0.17	246	0.2184	49	3.48
Site1	9/22/2008 12:21	5.1	23.07	7.92	341.3	0.17	242	0.2184	36.9	2.63
Site1	9/22/2008 12:22	6	23.06	7.91	341.4	0.17	241	0.2185	36.9	2.63
Site1	9/22/2008 12:24	7	23.04	7.92	341.2	0.17	242	0.2184	37.5	2.66
Site1	9/22/2008 12:26	8.1	23.03	7.9	341.4	0.17	243	0.2185	35.3	2.51
Site1	9/22/2008 12:28	9.1	22.98	7.85	342.3	0.17	242	0.2191	26	1.85
Site1	9/22/2008 12:29	10.1	22.98	7.85	342.3	0.17	242	0.2191	26.9	1.91
Site1	9/22/2008 12:31	11	22.94	7.82	342.6	0.17	241	0.2193	19.8	1.41
Site1	9/22/2008 12:35	12.1	22.89	7.74	343.8	0.17	233	0.22	1.9	0.13
Site1	9/22/2008 12:36	13.1	22.8	7.74	348.2	0.17	232	0.2229	1.5	0.11
Site1	9/22/2008 12:37	14	22.77	7.75	349.2	0.17	225	0.2235	1.5	0.11
Site1	9/22/2008 12:39	15.1	22.6	7.72	358.7	0.18	137	0.2296	1.4	0.1
Site1	9/22/2008 12:40	15.9	22.58	7.71	359.9	0.18	85	0.2304	1.4	0.1
Site1	10/16/2008 11:05	0.3	20.26	8.01	377.5	0.19	400	0.2416	72.4	6.29

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site1	10/16/2008 11:07	1.01	20.26	8.02	377.5	0.19	396	0.2416	71.8	6.23
Site1	10/16/2008 11:08	2.07	20.27	8.05	377.4	0.19	393	0.2415	71.3	6.19
Site1	10/16/2008 11:10	2.98	20.26	8.05	377.4	0.19	392	0.2415	71.7	6.23
Site1	10/16/2008 11:11	4.09	20.27	8.04	377.2	0.19	391	0.2414	71.1	6.17
Site1	10/16/2008 11:12	5.08	20.25	8.04	377.5	0.19	390	0.2416	70.5	6.13
Site1	10/16/2008 11:13	6.1	20.24	8.04	377.5	0.19	390	0.2416	69.9	6.07
Site1	10/16/2008 11:15	7.06	20.23	8.03	377.5	0.19	389	0.2416	69.8	6.06
Site1	10/16/2008 11:17	8.04	20.21	8.04	377.6	0.19	389	0.2416	70	6.08
Site1	10/16/2008 11:18	9.03	20.22	8.03	377.6	0.19	389	0.2417	69.3	6.02
Site1	10/16/2008 11:50	10.1	20.19	8.08	377.4	0.19	359	0.2415	69.7	6.07
Site1	10/16/2008 11:52	11.15	20.19	8.07	377.4	0.19	353	0.2414	69.6	6.05
Site1	10/16/2008 11:53	12.09	20.19	8.07	377.5	0.19	351	0.2416	69.5	6.05
Site1	10/16/2008 11:54	13.16	20.19	8.07	377.5	0.19	350	0.2416	69.3	6.03
Site1	10/16/2008 11:55	13.99	20.18	8.06	377.4	0.19	349	0.2415	68.9	5.99
Site1	10/16/2008 11:57	15.13	20.17	8.06	377.4	0.19	348	0.2415	68.7	5.97
Site1	10/16/2008 11:57	16.04	20.18	8	377.8	0.19	299	0.2418	66.8	5.82
Site1	12/8/2008 12:34	0.3	8	8.03	372		430		86.3	9.95
Site1	12/8/2008 12:36	1	7.97	8.06	372.5		425		86	9.93
Site1	12/8/2008 12:37	2	7.99	8.08	372.8		422		85.9	9.91
Site1	12/8/2008 12:38	3	8	8.08	372.2		420		85.7	9.89
Site1	12/8/2008 12:40	4	7.97	8.08	372		419		85.5	9.87
Site1	12/8/2008 12:41	5	7.97	8.08	372		418		85.4	9.86
Site1	12/8/2008 12:43	6	7.97	8.08	372		417		85.4	9.85
Site1	12/8/2008 12:45	7	7.94	8.07	372.2		416		85.2	9.84
Site1	12/8/2008 12:46	8	7.97	8.08	372.4		415		85.1	9.81
Site1	12/8/2008 12:48	9	7.97	8.08	372		415		85	9.81
Site1	12/8/2008 12:49	10	7.96	8.08	371.5		414		84.9	9.8
Site1	12/8/2008 12:51	11	7.91	8.07	372		414		84.5	9.76
Site1	12/8/2008 13:09	12	7.95	8.15	371.8		412		84.7	9.78
Site1	12/8/2008 13:11	13	7.95	8.14	372.6		411		84.7	9.78
Site1	12/8/2008 13:12	14	7.95	8.13	371.7		410		84.7	9.78
Site1	12/8/2008 13:13	15	7.96	8.13	371.8		409		84.5	9.75
Site1	2/9/2009 11:07	16.38	5.81	8.03	379.8	0.19	407	0.243	97	11.62
Site1	2/9/2009 11:08	16	5.83	8.07	380	0.19	406	0.2432	98.2	11.76
Site1	2/9/2009 11:11	15.09	5.84	8.07	379.6	0.19	407	0.2429	98.6	11.81
Site1	2/9/2009 11:11	14.01	5.83	8.09	380	0.19	406	0.2432	98.8	11.83
Site1	2/9/2009 11:11	13.01	5.84	8.07	379.7	0.19	407	0.243	98.9	11.84
Site1	2/9/2009 11:25	11.99	5.86	8.12	379.6	0.19	392	0.243	98.9	11.84

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site1	2/9/2009 11:26	11.03	5.86	8.12	380	0.19	392	0.2432	99.2	11.86
Site1	2/9/2009 11:26	9.83	5.87	8.13	379.8	0.19	391	0.2431	99.2	11.87
Site1	2/9/2009 11:27	9	5.89	8.12	379.7	0.19	392	0.2429	99.5	11.89
Site1	2/9/2009 11:27	7.96	5.86	8.14	379.9	0.19	391	0.2431	99.6	11.91
Site1	2/9/2009 11:27	6.87	5.89	8.14	379.5	0.19	391	0.2429	99.7	11.92
Site1	2/9/2009 11:28	5.89	5.91	8.16	380	0.19	390	0.2432	99.9	11.94
Site1	2/9/2009 11:28	5.1	5.9	8.16	379.7	0.19	391	0.243	99.9	11.94
Site1	2/9/2009 11:29	4.08	5.92	8.15	379.8	0.19	391	0.2431	100.2	11.97
Site1	2/9/2009 11:29	3.01	5.95	8.16	379.9	0.19	391	0.2431	100.3	11.97
Site1	2/9/2009 11:30	2.05	5.96	8.11	380	0.19	394	0.2432	100.5	11.99
Site1	2/9/2009 11:30	1.03	5.95	8.15	379.6	0.19	392	0.243	100.7	12.02
Site1	2/9/2009 11:31	0.13	5.98	8.15	380	0.19	392	0.2432	100.9	12.03
Site1	4/15/2009 9:10	0.16	12.31	7.73	412.6	0.21	424	0.2641	98.7	10.08
Site1	4/15/2009 9:14	16.58	11.81	8.14	412.2	0.21	407	0.2638	86.1	8.89
Site1	4/15/2009 9:15	16.03	11.81	8.16	411.8	0.21	408	0.2636	87.2	9.01
Site1	4/15/2009 9:16	15.01	11.84	8.2	411	0.21	408	0.263	90	9.3
Site1	4/15/2009 9:17	13.98	11.85	8.23	410.5	0.2	410	0.2627	93.2	9.62
Site1	4/15/2009 9:18	12.99	11.92	8.26	411.2	0.21	411	0.2632	93.8	9.67
Site1	4/15/2009 9:20	11.87	12.04	8.28	411.8	0.21	413	0.2636	94.2	9.68
Site1	4/15/2009 9:21	10.89	12.08	8.29	412.1	0.21	415	0.2637	94.8	9.74
Site1	4/15/2009 9:22	9.98	12.09	8.3	411.8	0.21	417	0.2635	95.3	9.79
Site1	4/15/2009 9:23	8.79	12.09	8.31	412.2	0.21	418	0.2638	95.1	9.77
Site1	4/15/2009 9:24	8.05	12.11	8.3	412	0.21	420	0.2637	94.9	9.75
Site1	4/15/2009 9:25	6.99	12.12	8.29	412.4	0.21	422	0.2639	95	9.75
Site1	4/15/2009 9:26	6.02	12.12	8.3	412.3	0.21	423	0.2639	95.5	9.8
Site1	4/15/2009 9:27	4.98	12.14	8.33	412.5	0.21	423	0.264	95.7	9.82
Site1	4/15/2009 9:27	3.97	12.15	8.32	412.5	0.21	425	0.264	95.9	9.84
Site1	4/15/2009 9:28	2.84	12.23	8.35	413.1	0.21	425	0.2644	97	9.93
Site1	4/15/2009 9:29	1.98	12.24	8.35	412.9	0.21	426	0.2643	97.6	9.99
Site1	4/15/2009 9:30	1.02	12.28	8.36	413.3	0.21	427	0.2645	98.3	10.05
Site1	4/22/2009 9:17	0.1	16.01	8.12	412.7	0.21	375	0.2641	108.3	10.22
Site1	4/22/2009 9:18	1.03	15.65	8.2	412.6	0.21	375	0.2641	107.3	10.2
Site1	4/22/2009 9:19	2.01	13.94	8.23	413.3	0.21	376	0.2645	94.7	9.34
Site1	4/22/2009 9:20	3.01	13.83	8.24	414.5	0.21	377	0.2653	92.8	9.17
Site1	4/22/2009 9:21	4	13.79	8.26	412.4	0.21	379	0.2639	92.6	9.16
Site1	4/22/2009 9:23	4.99	13.76	8.28	412	0.21	381	0.2637	92.9	9.2
Site1	4/22/2009 9:24	5.99	13.75	8.29	412.2	0.21	383	0.2638	92.8	9.19
Site1	4/22/2009 9:24	6.99	13.74	8.31	412.3	0.21	384	0.2639	92.7	9.18

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site1	4/22/2009 9:25	8	13.68	8.31	412.2	0.21	386	0.2638	92	9.13
Site1	4/22/2009 9:26	8.99	13.64	8.32	412	0.21	388	0.2637	91	9.04
Site1	4/22/2009 9:27	10	13.54	8.31	412	0.21	389	0.2638	89.6	8.92
Site1	4/22/2009 9:29	11	13.51	8.32	412	0.21	392	0.2637	88.7	8.83
Site1	4/22/2009 9:30	11.99	13.47	8.3	412.4	0.21	395	0.2639	86.8	8.65
Site1	4/22/2009 9:31	12.98	13.42	8.29	413.5	0.21	396	0.2646	83.2	8.3
Site1	4/22/2009 9:32	14.02	13.39	8.27	413.8	0.21	398	0.2648	80.5	8.04
Site1	4/22/2009 9:34	14.99	13.37	8.25	414.7	0.21	401	0.2654	77	7.69
Site1	4/22/2009 9:35	16.01	13.34	8.21	415.3	0.21	403	0.2659	73.9	7.39
Site1	4/22/2009 9:37	16.36	13.31	8.2	416.1	0.21	406	0.2663	72.3	7.24
Site1	4/30/2009 8:57	0.11	17.16	8.02	414.6	0.21	362	0.2653	96.9	8.9
Site1	4/30/2009 8:58	0.97	17.15	8.11	414.7	0.21	361	0.2654	96.9	8.9
Site1	4/30/2009 8:59	2.02	17.13	8.16	414.7	0.21	361	0.2654	96.4	8.86
Site1	4/30/2009 9:01	3.03	17.12	8.19	414.8	0.21	362	0.2655	96.4	8.86
Site1	4/30/2009 9:02	4.05	17.11	8.21	415	0.21	365	0.2656	96	8.82
Site1	4/30/2009 9:04	5.01	17.11	8.22	414.9	0.21	367	0.2656	95.8	8.81
Site1	4/30/2009 9:06	6.03	17.11	8.24	414.9	0.21	370	0.2656	95.8	8.8
Site1	4/30/2009 9:09	7.01	17.1	8.24	414.9	0.21	374	0.2656	95.6	8.79
Site1	4/30/2009 9:10	7.99	16.87	8.18	416.9	0.21	377	0.2668	90.3	8.34
Site1	4/30/2009 9:12	9.06	16.54	8.14	418.6	0.21	380	0.2679	84.7	7.88
Site1	4/30/2009 9:14	10	16.08	8.09	419.5	0.21	381	0.2685	79.8	7.49
Site1	4/30/2009 9:16	11.06	15.96	8.08	419.9	0.21	382	0.2687	78.3	7.37
Site1	4/30/2009 9:18	12.02	15.85	8.06	420.2	0.21	383	0.269	76.6	7.23
Site1	4/30/2009 9:22	13.05	15.68	8.07	420.2	0.21	386	0.2689	75.1	7.11
Site1	4/30/2009 9:23	14.01	15.49	8.05	420.3	0.21	388	0.269	72.5	6.9
Site1	4/30/2009 9:25	15.06	15.15	8.02	420.2	0.21	389	0.2689	70.9	6.79
Site1	4/30/2009 9:28	15.94	14.1	7.93	422.8	0.21	391	0.2706	57.9	5.68
Site1	4/30/2009 9:32	16.7	13.8	7.82	427.1	0.21	361	0.2734	39.4	3.89
Site1	5/7/2009 10:28	0.1	19.09	8.02	417	0.21	387	0.2669	103.3	9.11
Site1	5/7/2009 10:30	0.99	17.42	8.02	416	0.21	387	0.2662	94.2	8.59
Site1	5/7/2009 10:31	2	17.16	8.05	416.7	0.21	386	0.2667	91.1	8.35
Site1	5/7/2009 10:32	2.03	17.16	8.09	416.7	0.21	384	0.2667	90.7	8.31
Site1	5/7/2009 10:33	2.98	17.15	8.08	416.7	0.21	385	0.2667	90.7	8.32
Site1	5/7/2009 10:34	4	17.13	8.09	416.7	0.21	385	0.2667	90.3	8.29
Site1	5/7/2009 10:35	5.02	17.13	8.1	416.5	0.21	385	0.2666	90	8.26
Site1	5/7/2009 10:36	5.98	17.12	8.12	416.8	0.21	385	0.2667	89.8	8.24
Site1	5/7/2009 10:37	7	17.12	8.11	416.6	0.21	386	0.2667	89.8	8.24
Site1	5/7/2009 10:38	7.99	17.1	8.12	416.8	0.21	386	0.2667	89.5	8.22

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site1	5/7/2009 10:39	9	17.08	8.12	416.9	0.21	386	0.2668	88.1	8.09
Site1	5/7/2009 10:40	10	17.06	8.12	416.9	0.21	386	0.2668	87.6	8.05
Site1	5/7/2009 10:40	10.99	17.01	8.11	416.8	0.21	386	0.2668	86.8	7.98
Site1	5/7/2009 10:42	12	16.7	8	419.2	0.21	387	0.2683	72.7	6.73
Site1	5/7/2009 10:44	13.01	16.31	7.88	424.5	0.21	388	0.2717	57.9	5.41
Site1	5/7/2009 10:45	14	16.14	7.81	425.8	0.21	388	0.2725	52.2	4.89
Site1	5/7/2009 10:47	14.99	15.74	7.74	427.5	0.21	388	0.2736	43.7	4.13
Site1	5/7/2009 10:48	16	15.25	7.67	430.2	0.22	388	0.2753	31.7	3.02
Site1	5/7/2009 10:50	16.01	15.26	7.67	430	0.22	385	0.2752	31.6	3.02
Site1	5/7/2009 10:57	16.52	14.91	7.64	436	0.22	382	0.279	17.1	1.65
Site1	5/15/2009 10:35	16.08	16.52	7.69	419.1	0.21	415	0.2682	30.2	2.81
Site1	5/15/2009 10:36	16.04	16.46	7.69	419.5	0.21	415	0.2685	31.6	2.94
Site1	5/15/2009 10:37	15.01	16.8	7.75	417.1	0.21	414	0.2669	39.5	3.65
Site1	5/15/2009 10:40	15.03	16.82	7.76	417	0.21	415	0.2669	40.4	3.73
Site1	5/15/2009 10:41	14.04	16.97	7.8	416.3	0.21	415	0.2664	44.3	4.08
Site1	5/15/2009 10:42	13.01	17.1	7.84	415.6	0.21	415	0.266	49.6	4.55
Site1	5/15/2009 10:44	11.81	17.33	7.93	415.3	0.21	416	0.2658	59.2	5.41
Site1	5/15/2009 10:45	10.56	17.86	8.1	412.9	0.21	415	0.2643	76.3	6.89
Site1	5/15/2009 10:46	10.04	18.09	8.15	412.5	0.21	416	0.264	82.2	7.39
Site1	5/15/2009 10:47	9.03	18.14	8.13	412.3	0.21	418	0.2639	82.1	7.38
Site1	5/15/2009 10:49	8.01	18.23	8.14	412.1	0.21	419	0.2638	82.5	7.4
Site1	5/15/2009 10:50	6.99	18.47	8.18	411.4	0.21	420	0.2633	87.9	7.84
Site1	5/15/2009 10:51	6.03	18.59	8.2	411.2	0.21	420	0.2632	90.2	8.03
Site1	5/15/2009 10:52	5	18.73	8.23	411	0.21	421	0.263	92.4	8.2
Site1	5/15/2009 10:53	3.99	18.78	8.22	411.1	0.21	422	0.2632	93.1	8.25
Site1	5/15/2009 10:54	3	18.79	8.23	411.1	0.21	422	0.2631	93.4	8.27
Site1	5/15/2009 10:55	2.01	18.82	8.23	411.1	0.21	424	0.2631	93.7	8.3
Site1	5/15/2009 10:56	0.96	18.92	8.26	411.1	0.21	423	0.2631	94.3	8.34
Site1	5/15/2009 10:58	0.13	18.94	8.24	411.1	0.21	425	0.2631	94.6	8.36
Site1	5/20/2009 9:09	0.1	20.3	8.01	414.3	0.21	450	0.2652	117.1	10.2
Site1	5/20/2009 9:12	16.77	17.11	7.61	429	0.21	441	0.2746	17.5	1.62
Site1	5/20/2009 9:14	16.03	17.41	7.67	425.7	0.21	434	0.2724	30.9	2.86
Site1	5/20/2009 9:17	15.05	17.61	7.73	424.5	0.21	430	0.2717	36.9	3.4
Site1	5/20/2009 9:19	14	17.79	7.78	423.7	0.21	427	0.2711	43.7	4.01
Site1	5/20/2009 9:21	13.05	17.97	7.83	422.8	0.21	426	0.2706	50	4.57
Site1	5/20/2009 9:24	12.06	18.09	7.87	423	0.21	425	0.2708	53.5	4.87
Site1	5/20/2009 9:26	11.05	18.39	7.97	420.4	0.21	424	0.269	63	5.7
Site1	5/20/2009 9:27	10.03	18.81	8.09	418.4	0.21	422	0.2677	73.8	6.62

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site1	5/20/2009 9:30	9.03	18.96	8.16	417.8	0.21	423	0.2674	80.7	7.22
Site1	5/20/2009 9:32	8.02	19	8.18	417.4	0.21	423	0.2671	82.7	7.39
Site1	5/20/2009 9:33	6.99	19.04	8.17	417.3	0.21	424	0.2671	81.6	7.29
Site1	5/20/2009 9:34	6	19.09	8.19	417.3	0.21	423	0.2671	81.6	7.28
Site1	5/20/2009 9:36	5.07	19.37	8.27	417	0.21	424	0.2669	92.6	8.22
Site1	5/20/2009 9:38	4	19.46	8.29	416.4	0.21	424	0.2665	93.6	8.29
Site1	5/20/2009 9:39	2.92	19.68	8.33	416.3	0.21	424	0.2664	96	8.47
Site1	5/20/2009 9:41	1.98	20.21	8.49	415	0.21	423	0.2656	113.9	9.94
Site1	5/20/2009 9:42	1	20.32	8.5	414.5	0.21	423	0.2653	117	10.19
Site1	5/29/2009 11:03	0.1	24.51	8.27	401.4	0.2	278	0.2569	126.5	10.07
Site1	5/29/2009 11:10	15.77	17.58	7.51	425	0.21	188	0.272	3.3	0.3
Site1	5/29/2009 11:11	15.05	17.71	7.53	423.2	0.21	170	0.2709	6.7	0.61
Site1	5/29/2009 11:13	14.08	17.81	7.56	421.9	0.21	159	0.27	9.2	0.84
Site1	5/29/2009 11:16	12.93	18.02	7.58	420.5	0.21	156	0.2691	13.9	1.26
Site1	5/29/2009 11:17	12.04	18.11	7.6	420.5	0.21	157	0.2691	16	1.44
Site1	5/29/2009 11:19	10.99	18.29	7.62	419.1	0.21	162	0.2682	18.7	1.68
Site1	5/29/2009 11:21	9.96	18.52	7.66	418.2	0.21	169	0.2677	22.7	2.03
Site1	5/29/2009 11:22	8.99	19.01	7.77	415.8	0.21	187	0.2661	38.1	3.37
Site1	5/29/2009 11:26	7.72	19.75	7.89	414.4	0.21	222	0.2652	51.7	4.51
Site1	5/29/2009 11:28	7	20.46	7.94	415.2	0.21	235	0.2657	53	4.56
Site1	5/29/2009 11:29	6.04	21.41	8.12	414.6	0.21	246	0.2653	62.7	5.29
Site1	5/29/2009 11:31	4.96	21.91	8.29	411.7	0.21	264	0.2635	74.9	6.26
Site1	5/29/2009 11:34	3.97	23.09	8.67	401.6	0.2	290	0.257	114	9.32
Site1	5/29/2009 11:34	2.97	23.27	8.69	400.8	0.2	299	0.2565	120.9	9.85
Site1	5/29/2009 11:36	1.98	23.39	8.71	400.2	0.2	309	0.2561	127	10.32
Site1	5/29/2009 11:38	1.02	23.75	8.73	399.6	0.2	324	0.2557	134.8	10.88
Site1	6/4/2009 9:43	14.81	17.94	7.5	424	0.21	522	0.2713	2.2	0.2
Site1	6/4/2009 9:44	13.91	18.08	7.51	422.1	0.21	521	0.2702	2	0.18
Site1	6/4/2009 9:45	13.01	18.12	7.5	421.8	0.21	527	0.27	2	0.18
Site1	6/4/2009 9:46	12.07	18.17	7.5	421.2	0.21	531	0.2696	1.9	0.17
Site1	6/4/2009 9:47	10.96	18.46	7.51	419	0.21	533	0.2681	3.7	0.33
Site1	6/4/2009 9:47	10.03	18.62	7.51	418.5	0.21	535	0.2678	5.6	0.49
Site1	6/4/2009 9:49	10.02	18.66	7.52	418.3	0.21	538	0.2677	6.2	0.55
Site1	6/4/2009 9:50	9.02	19.02	7.54	417.4	0.21	540	0.2672	9.4	0.82
Site1	6/4/2009 9:51	7.99	20.38	7.58	418.1	0.21	541	0.2676	9.4	0.8
Site1	6/4/2009 9:52	6.96	21.74	7.76	416.6	0.21	539	0.2666	27	2.23
Site1	6/4/2009 9:54	6.01	23.27	8.43	401.8	0.2	535	0.2572	86.6	6.94
Site1	6/4/2009 9:55	4.97	23.35	8.45	402.1	0.2	535	0.2574	87.4	7

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site1	6/4/2009 9:55	4	23.44	8.44	401.6	0.2	537	0.257	90.4	7.23
Site1	6/4/2009 9:57	3	23.44	8.43	401.6	0.2	537	0.257	91.1	7.28
Site1	6/4/2009 9:58	1.99	23.45	8.42	401.3	0.2	538	0.2568	91.4	7.3
Site1	6/4/2009 9:59	0.51	23.48	8.47	401.3	0.2	537	0.2568	92.6	7.39
Site1	6/4/2009 10:00	0.14	23.49	8.45	401.2	0.2	537	0.2567	92.9	7.41
Site1	6/25/2009 9:23	16.38	18.68	7.31	438.3	0.22	29	0.2805	3	0.27
Site1	6/25/2009 9:26	15	18.9	7.43	434.4	0.22	-17	0.278	2.1	0.19
Site1	6/25/2009 9:27	13.94	18.95	7.45	433.4	0.22	-26	0.2774	1.9	0.17
Site1	6/25/2009 9:28	13.03	19.02	7.45	432.9	0.22	-30	0.277	1.9	0.17
Site1	6/25/2009 9:28	12	19.1	7.47	432.5	0.22	-32	0.2768	1.8	0.16
Site1	6/25/2009 9:30	11.05	19.59	7.49	430.7	0.22	-33	0.2756	1.7	0.15
Site1	6/25/2009 9:31	9.99	20.09	7.52	430.3	0.22	-36	0.2754	1.8	0.16
Site1	6/25/2009 9:32	9.01	21.01	7.56	429.4	0.22	-41	0.2748	1.6	0.14
Site1	6/25/2009 9:34	8.02	22.9	7.62	426.7	0.21	-44	0.2731	1.5	0.12
Site1	6/25/2009 9:36	7.02	25.53	7.67	424	0.21	-22	0.2713	1.4	0.11
Site1	6/25/2009 9:37	6.03	26.93	7.82	422.5	0.21	41	0.2704	18.6	1.42
Site1	6/25/2009 9:38	5.04	27.46	8.07	420.6	0.21	94	0.2692	51.8	3.91
Site1	6/25/2009 9:39	3.95	28.45	8.4	415	0.21	150	0.2656	100.7	7.46
Site1	6/25/2009 9:40	2.97	28.67	8.45	412.9	0.21	170	0.2642	110.7	8.17
Site1	6/25/2009 9:41	1.5	28.9	8.48	410	0.2	193	0.2624	122.7	9.01
Site1	6/25/2009 9:42	1.09	29.51	8.52	406.7	0.2	212	0.2603	133.4	9.7
Site1	6/25/2009 9:43	0.12	30.07	8.52	406.6	0.2	226	0.2602	135.3	9.74
Site1	6/25/2009 9:25	16	18.77	7.36	435.5	0.22	-11	0.2787	2.4	0.21
Site1	7/9/2009 8:45	16.05	18.82	7.47	445.3	0.22	-16	0.285	2.3	0.2
Site1	7/9/2009 8:47	15	18.95	7.51	443.1	0.22	-40	0.2835	1.9	0.17
Site1	7/9/2009 8:49	13.98	19.1	7.55	441.9	0.22	-50	0.2827	1.7	0.15
Site1	7/9/2009 8:50	12.97	19.31	7.57	440.4	0.22	-58	0.2819	1.7	0.14
Site1	7/9/2009 8:52	11.87	19.43	7.59	439.6	0.22	-64	0.2814	1.6	0.14
Site1	7/9/2009 8:53	10.72	19.54	7.59	439.4	0.22	-67	0.2812	1.5	0.13
Site1	7/9/2009 8:54	9.84	20.71	7.66	437.2	0.22	-69	0.2798	1.5	0.13
Site1	7/9/2009 8:55	9	21.51	7.7	435.7	0.22	-70	0.2788	1.4	0.12
Site1	7/9/2009 8:56	8.01	23.33	7.75	434	0.22	-72	0.2778	1.4	0.11
Site1	7/9/2009 8:57	7	25.72	7.83	427.7	0.21	-62	0.2737	1.3	0.1
Site1	7/9/2009 8:59	6	26.41	7.82	423.9	0.21	-4	0.2713	6.8	0.52
Site1	7/9/2009 9:00	5	26.66	7.9	422.4	0.21	34	0.2703	21.9	1.67
Site1	7/9/2009 9:02	3.99	27.45	8.32	414.4	0.21	104	0.2652	72.4	5.44
Site1	7/9/2009 9:03	3	27.47	8.32	414.1	0.21	145	0.265	73.5	5.52
Site1	7/9/2009 9:05	2.01	27.47	8.3	414.2	0.21	170	0.2651	74.2	5.57

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site1	7/9/2009 9:06	1	27.48	8.31	414.1	0.21	187	0.265	75	5.63
Site1	7/9/2009 9:07	0.1	27.51	8.32	414	0.21	195	0.265	75.6	5.67
Site1	7/23/2009 8:56	0.11	27.64	8.07	399.4	0.2	391	0.2556	91.8	6.87
Site1	7/23/2009 8:59	16.01	19.07	7.12	447	0.22	16	0.2861	2.5	0.22
Site1	7/23/2009 9:00	14.97	19.14	7.15	444.4	0.22	-5	0.2844	2.2	0.19
Site1	7/23/2009 9:02	13.98	19.22	7.2	443.6	0.22	-16	0.2839	2	0.18
Site1	7/23/2009 9:02	12.98	19.51	7.25	441.4	0.22	-22	0.2825	1.9	0.17
Site1	7/23/2009 9:03	11.96	19.78	7.28	440.5	0.22	-29	0.2819	1.8	0.16
Site1	7/23/2009 9:04	11.01	20.12	7.3	439.6	0.22	-34	0.2814	1.8	0.15
Site1	7/23/2009 9:05	9.98	21.03	7.36	438.4	0.22	-38	0.2807	1.7	0.15
Site1	7/23/2009 9:06	9	23.02	7.45	434.6	0.22	-42	0.2781	1.7	0.14
Site1	7/23/2009 9:07	8.01	27.4	8.33	399.7	0.2	69	0.2558	87	6.54
Site1	7/23/2009 9:09	7.03	27.54	8.34	399.3	0.2	112	0.2556	87.4	6.56
Site1	7/23/2009 9:09	6.02	27.59	8.34	399.3	0.2	124	0.2556	87.2	6.54
Site1	7/23/2009 9:10	5.02	27.6	8.33	399.7	0.2	146	0.2558	87	6.52
Site1	7/23/2009 9:11	3.93	27.6	8.34	401.5	0.2	157	0.2569	86.4	6.48
Site1	7/23/2009 9:12	2.98	27.64	8.33	399.7	0.2	170	0.2558	86.4	6.47
Site1	7/23/2009 9:14	2.02	27.66	8.36	399.6	0.2	180	0.2557	89.2	6.68
Site1	7/23/2009 9:15	1.02	27.75	8.4	398.1	0.2	198	0.2548	96.5	7.21
Site1	7/23/2009 9:17	0.11	27.85	8.44	397.7	0.2	208	0.2545	102.1	7.62
Site1	8/6/2009 9:53	16.54	19.36	7.26	448.3	0.23	-23	0.2869	4.6	0.42
Site1	8/6/2009 9:55	16.01	19.38	7.21	448.2	0.23	-31	0.2868	2.5	0.23
Site1	8/6/2009 9:56	15.25	19.47	7.23	446.5	0.22	-53	0.2858	2.1	0.19
Site1	8/6/2009 9:57	14.01	19.71	7.27	445.2	0.22	-62	0.2849	1.9	0.17
Site1	8/6/2009 9:58	13	20.02	7.3	443.7	0.22	-68	0.284	1.9	0.17
Site1	8/6/2009 10:00	12.01	20.45	7.33	442.8	0.22	-74	0.2834	1.7	0.15
Site1	8/6/2009 10:00	11	21.12	7.37	441.9	0.22	-76	0.2828	1.7	0.15
Site1	8/6/2009 10:02	10.01	23.41	7.51	431	0.22	-78	0.2758	1.6	0.13
Site1	8/6/2009 10:03	8.84	26.77	7.96	396.7	0.2	-11	0.2539	26.3	2.08
Site1	8/6/2009 10:04	7.8	26.77	8.01	396.7	0.2	10	0.2539	31	2.46
Site1	8/6/2009 10:05	7.01	27.27	8.17	392.6	0.2	39	0.2513	49.7	3.9
Site1	8/6/2009 10:06	5.82	27.49	8.26	390.2	0.19	76	0.2497	62.3	4.87
Site1	8/6/2009 10:07	4.81	27.8	8.49	384	0.19	106	0.2458	96	7.46
Site1	8/6/2009 10:08	4	27.82	8.52	383.4	0.19	124	0.2453	98.7	7.67
Site1	8/6/2009 10:08	2.97	27.81	8.52	383.3	0.19	136	0.2453	99.4	7.72
Site1	8/6/2009 10:10	2	27.82	8.51	383.4	0.19	155	0.2454	99.9	7.76
Site1	8/6/2009 10:11	1	27.8	8.52	382.8	0.19	167	0.245	100.3	7.79
Site1	8/6/2009 10:11	0.09	27.77	8.53	382.8	0.19	173	0.245	100.4	7.81

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Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site1	8/24/2009 9:17	0.1	26.68	8.51	385.9	0.19	345	0.247	70.5	5.39
Site1	8/24/2009 9:18	1	26.69	8.5	385.7	0.19	344	0.2468	70	5.35
Site1	8/24/2009 9:19	2	26.7	8.5	386	0.19	343	0.2469	67.2	5.14
Site1	8/24/2009 9:20	3	26.71	8.5	385.8	0.19	342	0.2469	66.7	5.1
Site1	8/24/2009 9:20	4	26.7	8.48	385.6	0.19	342	0.2468	65.3	4.99
Site1	8/24/2009 9:22	5	26.7	8.48	386.3	0.19	342	0.2472	64.5	4.93
Site1	8/24/2009 9:23	6	26.7	8.46	386.4	0.19	342	0.2473	63.5	4.85
Site1	8/24/2009 9:24	7	26.7	8.46	386.4	0.19	342	0.2473	62.9	4.81
Site1	8/24/2009 9:25	8	26.68	8.44	386.9	0.19	343	0.2476	60.8	4.65
Site1	8/24/2009 9:27	9	26.6	8.29	389.6	0.19	347	0.2493	39.1	3
Site1	8/24/2009 9:29	10	25.48	7.89	409.4	0.2	64	0.262	2	0.16
Site1	8/24/2009 9:30	11	22.91	7.56	439.2	0.22	24	0.2811	1.6	0.13
Site1	8/24/2009 9:31	12	21.19	7.39	449.5	0.23	3	0.2877	1.5	0.13
Site1	8/24/2009 9:39	13	20.52	7.33	451.1	0.23	-23	0.2887	1.7	0.15
Site1	8/24/2009 9:40	13.9	20.24	7.3	452.8	0.23	-30	0.2898	1.5	0.13
Site1	8/24/2009 9:42	15	20.01	7.27	455.4	0.23	-38	0.2914	1.4	0.12
Site1	8/24/2009 9:42	16.1	19.78	7.12	460.9	0.23	-39	0.295	1.3	0.11
Site1	8/24/2009 9:43	16.1	19.72	7.09	461.7	0.23	-38	0.2955	1.3	0.12
Site1	9/3/2009 9:20	16.05	19.71	6.79	478.2	0.24	6	0.306	2.1	0.19
Site1	9/3/2009 9:21	15.04	19.89	6.87	467.3	0.24	-8	0.299	2	0.17
Site1	9/3/2009 9:22	14.02	20.38	6.97	460.7	0.23	-21	0.2948	1.8	0.16
Site1	9/3/2009 9:23	13.03	20.79	7.02	458.1	0.23	-27	0.2932	1.7	0.15
Site1	9/3/2009 9:24	12.02	21.47	7.09	456	0.23	-32	0.2918	1.6	0.14
Site1	9/3/2009 9:25	11.02	23.35	7.29	442.4	0.22	-37	0.2831	1.6	0.13
Site1	9/3/2009 9:27	10.03	24.98	7.92	389.5	0.19	62	0.2492	50.2	3.98
Site1	9/3/2009 9:28	9.02	25	7.93	389	0.19	88	0.249	51.1	4.05
Site1	9/3/2009 9:30	8.05	25.02	7.95	388.8	0.19	108	0.2488	54.3	4.31
Site1	9/3/2009 9:31	7.01	25.03	7.96	388.6	0.19	117	0.2487	55	4.36
Site1	9/3/2009 9:32	6.01	25.04	7.96	388.5	0.19	127	0.2486	55.9	4.43
Site1	9/3/2009 9:33	5.01	25.05	7.97	388.3	0.19	134	0.2485	56	4.43
Site1	9/3/2009 9:34	4.03	25.05	7.98	388.4	0.19	140	0.2486	57	4.52
Site1	9/3/2009 9:34	3.03	25.05	7.97	388.5	0.19	145	0.2486	57.9	4.58
Site1	9/3/2009 9:36	2.05	25.05	7.98	388.4	0.19	152	0.2486	57.8	4.58
Site1	9/3/2009 9:37	1.04	25.04	7.99	388.2	0.19	157	0.2485	59.3	4.7
Site1	9/3/2009 9:39	0.1	25.04	7.98	388.2	0.19	167	0.2485	60.3	4.77
Site1	9/17/2009 9:37	15.65	19.77	7.42	496.1	0.25	76	0.3175	2.5	0.22
Site1	9/17/2009 9:38	15.03	19.94	7.44	486.7	0.25	68	0.3115	2.1	0.18
Site1	9/17/2009 9:38	14.02	20.25	7.55	481.8	0.24	59	0.3083	1.9	0.17

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site1	9/17/2009 9:39	13.04	23.47	8.49	389.8	0.19	113	0.2495	60.1	4.83
Site1	9/17/2009 9:40	11.96	23.47	8.45	389.8	0.19	132	0.2495	60.8	4.89
Site1	9/17/2009 9:40	10.95	23.47	8.49	389.8	0.19	136	0.2495	61	4.9
Site1	9/17/2009 9:41	10.04	23.48	8.41	389.7	0.19	151	0.2494	61.2	4.92
Site1	9/17/2009 9:42	9.06	23.48	8.42	389.7	0.19	155	0.2494	61.1	4.92
Site1	9/17/2009 9:42	8.01	23.48	8.52	389.8	0.19	151	0.2495	61.3	4.93
Site1	9/17/2009 9:43	6.99	23.48	8.37	390.1	0.19	166	0.2496	61.5	4.95
Site1	9/17/2009 9:44	5.89	23.48	8.41	389.9	0.19	168	0.2496	61.6	4.96
Site1	9/17/2009 9:45	5	23.48	8.37	389.8	0.19	173	0.2495	61.8	4.97
Site1	9/17/2009 9:45	4.04	23.48	8.35	389.9	0.19	178	0.2496	62	4.98
Site1	9/17/2009 9:47	2.99	23.48	8.29	389.9	0.19	186	0.2496	62.1	4.99
Site1	9/17/2009 9:47	2.05	23.48	8.31	389.8	0.19	188	0.2495	62.2	5
Site1	9/17/2009 9:48	0.95	23.48	8.34	389.8	0.19	188	0.2495	61.9	4.98
Site1	9/17/2009 9:49	0.05	23.48	8.31	389.9	0.19	193	0.2495	62.8	5.05
Site1	9/30/2009 10:02	16.2	21.42	7.11	399.6	0.2	348	0.2557	18.7	1.59
Site1	9/30/2009 10:03	16.02	21.46	7.23	395.3	0.2	342	0.253	28.8	2.43
Site1	9/30/2009 10:04	15.02	21.5	7.3	391.5	0.19	341	0.2506	39.7	3.37
Site1	9/30/2009 10:05	14.03	21.58	7.33	391.7	0.19	330	0.2507	42.4	3.6
Site1	9/30/2009 10:06	13.04	21.65	7.35	391.4	0.19	331	0.2505	45.5	3.85
Site1	9/30/2009 10:07	12.06	21.78	7.4	390.5	0.19	332	0.2499	53.3	4.5
Site1	9/30/2009 10:08	11.03	21.78	7.41	390.4	0.19	333	0.2498	54.2	4.58
Site1	9/30/2009 10:09	10.02	21.79	7.42	390.1	0.19	333	0.2497	54.5	4.6
Site1	9/30/2009 10:10	9.05	21.79	7.42	390.1	0.19	334	0.2497	55	4.64
Site1	9/30/2009 10:11	8.05	21.79	7.43	390.2	0.19	334	0.2498	55.1	4.66
Site1	9/30/2009 10:12	7.03	21.79	7.43	390.8	0.19	334	0.2501	54.9	4.64
Site1	9/30/2009 10:14	6	21.79	7.44	390.4	0.19	334	0.2498	54.8	4.63
Site1	9/30/2009 10:15	5.02	21.79	7.46	390.4	0.19	333	0.2499	55	4.65
Site1	9/30/2009 10:17	4.01	21.79	7.47	390	0.19	333	0.2496	55.1	4.66
Site1	9/30/2009 10:18	3.05	21.81	7.49	390	0.19	333	0.2496	57	4.81
Site1	9/30/2009 10:19	2.04	21.82	7.51	390.7	0.19	333	0.25	57	4.82
Site1	9/30/2009 10:20	1.02	21.84	7.51	390.2	0.19	333	0.2497	58.6	4.96
Site1	9/30/2009 10:21	0.17	21.86	7.52	390.4	0.19	334	0.2498	59.6	5.03
Site1	10/19/2009 9:18	16.13	16.17	7.45	383	0.19	166	0.2451	47.9	4.51
Site1	10/19/2009 9:19	15.86	16.17	7.49	382.8	0.19	222	0.245	58	5.47
Site1	10/19/2009 9:20	15	16.23	7.6	379.7	0.19	251	0.243	71	6.68
Site1	10/19/2009 9:22	14.01	16.31	7.65	379.5	0.19	284	0.2429	73.8	6.93
Site1	10/19/2009 9:23	13.18	16.31	7.66	379.5	0.19	292	0.2429	75.4	7.08
Site1	10/19/2009 9:24	11.99	16.35	7.68	379.4	0.19	298	0.2428	76.3	7.16

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site1	10/19/2009 9:25	11.05	16.35	7.69	379.3	0.19	308	0.2427	76.3	7.16
Site1	10/19/2009 9:27	9.99	16.36	7.7	379.3	0.19	318	0.2427	76.4	7.17
Site1	10/19/2009 9:28	9.01	16.36	7.71	379.3	0.19	320	0.2427	76.6	7.18
Site1	10/19/2009 9:29	7.99	16.36	7.71	379.2	0.19	323	0.2427	76.6	7.19
Site1	10/19/2009 9:30	6.98	16.37	7.71	379.4	0.19	326	0.2428	77.1	7.23
Site1	10/19/2009 9:31	5.74	16.36	7.71	379	0.19	329	0.2426	76.9	7.21
Site1	10/19/2009 9:31	5	16.37	7.72	379.4	0.19	331	0.2428	76.9	7.21
Site1	10/19/2009 9:32	4.02	16.37	7.72	379.2	0.19	332	0.2427	77	7.22
Site1	10/19/2009 9:33	3.01	16.37	7.72	379.7	0.19	334	0.243	77.1	7.23
Site1	10/19/2009 9:33	2	16.38	7.72	379.3	0.19	335	0.2427	77.4	7.25
Site1	10/19/2009 9:34	1	16.37	7.72	379.2	0.19	336	0.2429	77.3	7.25
Site1	10/19/2009 9:34	0.09	16.34	7.72	379.5	0.19	336	0.0012	77.5	7.28

Table D-3 Site 2 HYDROLAB Station Data*

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site2	4/22/2008 12:30	0.2	16.2	8.32	388.1	0.19	327	0.2484	99.8	9.32
Site2	4/22/2008 12:31	0.9	16.19	8.33	388.7	0.19	326	0.2487	99.7	9.31
Site2	4/22/2008 12:32	2	16.18	8.32	388.2	0.19	326	0.2485	99.3	9.28
Site2	4/22/2008 12:33	3.1	15.98	8.33	388.3	0.19	326	0.2485	98.7	9.26
Site2	4/22/2008 12:33	4	15.8	8.32	387.5	0.19	326	0.248	97.7	9.21
Site2	4/22/2008 12:34	5	15.65	8.32	387.7	0.19	326	0.2481	97.2	9.18
Site2	4/22/2008 12:35	6	15.51	8.31	386	0.19	327	0.247	95.9	9.09
Site2	4/22/2008 12:35	7	15.1	8.3	386.8	0.19	327	0.2476	94.3	9.01
Site2	4/22/2008 12:36	8	15.02	8.3	387.7	0.19	327	0.2481	93.8	8.98
Site2	4/22/2008 12:36	9.1	14.79	8.3	388.8	0.19	327	0.2488	93.3	8.98
Site2	4/22/2008 12:37	10	14.58	8.29	389.8	0.19	328	0.2495	92.1	8.91
Site2	4/22/2008 12:38	11	14.4	8.28	390.7	0.19	328	0.2501	91.2	8.86
Site2	4/22/2008 12:39	12	14.34	8.28	391.1	0.19	328	0.2503	90.1	8.76
Site2	4/22/2008 12:39	13.1	14.27	8.26	391.3	0.19	329	0.2504	87.8	8.55
Site2	5/16/2008 13:19	0.1	19.34	8.28	389.2	0.19	365	0.2491	102.6	9
Site2	5/16/2008 13:20	1	19.31	8.29	389.3	0.19	363	0.2491	102	8.95
Site2	5/16/2008 13:21	2	19.15	8.28	389.3	0.19	361	0.2492	100.6	8.85
Site2	5/16/2008 13:22	4.1	18.82	8.24	389.8	0.19	360	0.2495	94.3	8.36
Site2	5/16/2008 13:23	5	18.78	8.25	389.3	0.19	358	0.2491	94.7	8.4
Site2	5/16/2008 13:24	6	18.76	8.21	390.6	0.19	357	0.25	91.1	8.09
Site2	5/16/2008 13:26	7.1	18.74	8.21	391.1	0.19	356	0.2503	90.7	8.05
Site2	5/16/2008 13:28	8	18.7	8.21	390.9	0.19	353	0.2502	91.5	8.13
Site2	5/16/2008 13:30	9	18.7	8.21	391.1	0.19	353	0.2503	90.3	8.02
Site2	5/16/2008 13:32	10	18.69	8.2	391.3	0.19	352	0.2504	89.5	7.95

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site2	5/16/2008 13:33	11	18.62	8.17	391.8	0.19	352	0.2508	86	7.65
Site2	5/16/2008 13:35	11.7	18.55	8.15	391.1	0.19	335	0.2503	84.6	7.54
Site2	5/21/2008 14:14	0.1	21.56	8.49	390.4	0.19	422	0.2498		
Site2	5/21/2008 14:15	1	21.57	8.5	390.3	0.19	422	0.2498		
Site2	5/21/2008 14:16	2	21.5	8.5	390.6	0.19	421	0.25		
Site2	5/21/2008 14:17	3.1	21.34	8.5	390.8	0.19	421	0.2501		
Site2	5/21/2008 14:17	4	21.27	8.49	391.2	0.19	420	0.2504		
Site2	5/21/2008 14:18	5	21.23	8.49	391.5	0.19	419	0.2506		
Site2	5/21/2008 14:19	6	21.11	8.47	392	0.19	419	0.2509		
Site2	5/21/2008 14:20	7.1	20.97	8.46	390.9	0.19	418	0.2502		
Site2	5/21/2008 14:21	8	18.82	8.19	393.8	0.2	423	0.252		
Site2	5/21/2008 14:21	9	18.75	8.1	393.8	0.2	423	0.252		
Site2	5/21/2008 14:22	10	18.74	8.07	393.7	0.2	421	0.2519		
Site2	5/21/2008 14:23	11	18.72	8.05	393.8	0.2	420	0.252		
Site2	5/21/2008 14:24	11.8	18.73	8.03	393.6	0.2	407	0.2519		
Site2	6/4/2008 15:06	0.1	25.76	8.42	357	0.2	412	0.229	92.4	7.26
Site2	6/4/2008 15:07	1	25.76	8.42	358	0.2	420	0.229	90.5	7.11
Site2	6/4/2008 15:09	2.1	25.77	8.42	358	0.2	427	0.229	90.3	7.09
Site2	6/4/2008 15:11	3.1	25.74	8.41	358	0.2	433	0.229	89.3	7.02
Site2	6/4/2008 15:13	3.8	25.7	8.4	358	0.2	437	0.229	88.4	6.95
Site2	6/4/2008 15:14	5.1	25.72	8.41	358	0.2	439	0.229	88.4	6.92
Site2	6/4/2008 15:16	6.1	25.62	8.4	358	0.2	442	0.229	87.4	6.88
Site2	6/4/2008 15:18	7.1	25.59	8.4	358	0.2	443	0.229	87.8	6.92
Site2	6/4/2008 15:19	8	25.52	8.39	358	0.2	444	0.229	86.2	6.8
Site2	6/4/2008 15:21	9.2	25.44	8.37	358	0.2	446	0.229	84.1	6.64
Site2	6/4/2008 15:22	10.2	25.41	8.37	358	0.2	447	0.229	83.5	6.6
Site2	6/4/2008 15:24	11.2	20.32	7.47	363	0.2	479	0.232	8.5	0.74
Site2	6/4/2008 15:26	12.2	19.17	7.41	364	0.2	479	0.233	1.1	0.1
Site2	6/18/2008 11:23	0.1	26.71	8.31	397	0.2	237	0.2541	100.2	7.7
Site2	6/18/2008 11:24	1	26.56	8.37	395.9	0.2	232	0.2534	99.6	7.68
Site2	6/18/2008 11:26	2.5	25.79	8.29	400.3	0.2	233	0.2562	84.8	6.63
Site2	6/18/2008 11:29	3	25.25	8.34	405.3	0.2	213	0.2594	82.7	6.53
Site2	6/18/2008 11:30	4.1	25.46	8.32	403.7	0.2	209	0.2584	81.7	6.43
Site2	6/18/2008 11:31	5.3	25.45	8.29	404.4	0.2	208	0.2588	78	6.13
Site2	6/18/2008 11:32	6	25.35	8.26	405.3	0.2	207	0.2594	74.3	5.85
Site2	6/18/2008 11:33	7.4	25.22	8.19	406.2	0.2	208	0.26	67.4	5.32
Site2	6/18/2008 11:35	8.1	25.13	8.13	407	0.2	209	0.2604	62.8	4.96
Site2	6/18/2008 11:36	9.3	24.98	8.11	407.2	0.2	210	0.2606	62.9	4.99

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site2	6/18/2008 11:37	10.4	24.5	7.74	403.8	0.2	204	0.2592	18.6	1.49
Site2	6/18/2008 11:38	11.1	23.9	7.62	412.9	0.21	200	0.2643	4.5	0.36
Site2	6/18/2008 11:39	12	23.48	7.55	418.8	0.21	55	0.2681	1.9	0.15
Site2	6/18/2008 11:40	12.1	23.53	7.44	507.8	0.26	20	0.3254	1.4	0.12
Site2	7/9/2008 12:11	12.23	23.2	7.72	409.5	0.2	-118	0.2621	2.8	0.23
Site2	7/9/2008 12:13	11.9	23.4	7.72	407.7	0.2	-127	0.2609	1.9	0.16
Site2	7/9/2008 12:15	11.02	23.89	7.81	402.1	0.2	-124	0.2574	1.5	0.12
Site2	7/9/2008 12:16	10.16	24.25	7.86	399.7	0.2	-116	0.2558	1.4	0.12
Site2	7/9/2008 12:18	8.68	25.09	7.86	397	0.2	-87	0.2541	1.4	0.11
Site2	7/9/2008 12:19	8.02	25.79	7.88	396.5	0.2	-82	0.2538	1.2	0.1
Site2	7/9/2008 12:20	6.97	26.45	7.93	396.8	0.2	-78	0.254	1.2	0.1
Site2	7/9/2008 12:22	5.94	27.7	8.22	389.8	0.19	67	0.2494	41.6	3.13
Site2	7/9/2008 12:23	5.53	28.13	8.48	385.4	0.19	101	0.2466	78.9	5.89
Site2	7/9/2008 12:23	4.59	28.38	8.6	383	0.19	123	0.2454	95.2	7.08
Site2	7/9/2008 12:24	3.99	28.56	8.66	381.5	0.19	151	0.2441	102	7.56
Site2	7/9/2008 12:25	4.03	28.59	8.65	381.3	0.19	159	0.244	103	7.63
Site2	7/9/2008 12:26	2.91	28.69	8.65	381.5	0.19	164	0.2442	100	7.4
Site2	7/9/2008 12:26	1.92	28.78	8.71	381.2	0.19	171	0.244	112	8.27
Site2	7/9/2008 12:27	1.05	29.08	8.75	381.1	0.19	181	0.2439	121.7	8.94
Site2	7/9/2008 12:28	0.11	29.28	8.75	380.4	0.19	182	0.2434	123.8	9.06
Site2	7/21/2008 10:23	0.15	29.66	8.41	363.4	0.18	351	0.2326	136	9.89
Site2	7/21/2008 10:24	0.98	29.62	8.42	363.1	0.18	341	0.2324	136.7	9.95
Site2	7/21/2008 10:25	1.98	29.54	8.47	363	0.18	328	0.2323	135.1	9.84
Site2	7/21/2008 10:26	3	29.29	8.4	364.8	0.18	322	0.2335	121.7	8.91
Site2	7/21/2008 10:28	3.98	29.22	8.32	365.9	0.18	319	0.2342	115.3	8.45
Site2	7/21/2008 10:30	5.03	28.66	8.01	373.6	0.18	315	0.2391	67	4.96
Site2	7/21/2008 10:31	6	27.7	7.67	382.7	0.19	313	0.245	22.5	1.7
Site2	7/21/2008 10:33	7	27.17	7.54	385.2	0.19	308	0.2465	6.6	0.5
Site2	7/21/2008 10:34	8.09	26.52	7.5	389	0.19	99	0.2489	1.6	0.12
Site2	7/21/2008 10:35	9.04	25.57	7.46	392.9	0.2	-70	0.2515	1.6	0.13
Site2	7/21/2008 10:36	10	24.82	7.44	396.3	0.2	-99	0.2536	1.5	0.12
Site2	7/21/2008 10:38	10.89	23.74	7.36	402.7	0.2	-130	0.2577	1.5	0.12
Site2	8/4/2008 9:56	0.5	30.67	8.41	398.7	0.2	218	0.2552	117.2	8.36
Site2	8/4/2008 9:59	1	30.66	8.43	398.3	0.2	226	0.2549	117.1	8.36
Site2	8/4/2008 10:01	2.1	30.63	8.41	398.5	0.2	231	0.255	116	8.28
Site2	8/4/2008 10:03	3	30.57	8.38	398.5	0.2	235	0.255	114	8.15
Site2	8/4/2008 10:06	4.1	30.5	8.35	398.4	0.2	239	0.255	113.1	8.09
Site2	8/4/2008 10:10	4.9	29.42	7.61	416	0.21	197	0.2663	7.3	0.53

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site2	8/4/2008 10:13	6.1	28.34	7.56	423.1	0.21	-69	0.2708	1.4	0.11
Site2	8/4/2008 10:15	7.1	27.29	7.5	431.6	0.22	-100	0.2762	1.2	0.09
Site2	8/4/2008 10:16	8	26.25	7.47	437.1	0.22	-107	0.2797	1.2	0.09
Site2	8/4/2008 10:17	9	25.89	7.45	439	0.22	-109	0.281	1.2	0.09
Site2	8/4/2008 10:18	10.1	24.3	7.38	448	0.23	-111	0.2867	1.2	0.1
Site2	8/4/2008 10:19	11	23.88	7.33	450.9	0.23	-112	0.2886	1.1	0.09
Site2	8/4/2008 10:20	11.3	23.58	7.3	453.7	0.23	-112	0.2904	1.2	0.09
Site2	8/18/2008 9:27	0.1	27.15	8.18	364.7	0.18	390	0.2334	68.8	5.24
Site2	8/18/2008 9:28	1	27.13	8.14	364.6	0.18	389	0.2333	66.1	5.03
Site2	8/18/2008 9:29	2	27.15	8.13	364.8	0.18	388	0.2337	65.6	5
Site2	8/18/2008 9:31	3	27.13	8.13	364.9	0.18	387	0.2335	66.7	5.08
Site2	8/18/2008 9:33	4	27.15	8.13	364.8	0.18	386	0.2335	65.2	4.97
Site2	8/18/2008 9:34	5.1	27.17	8.13	364.7	0.18	386	0.2334	65.9	5.02
Site2	8/18/2008 9:35	6.1	27.17	8.14	364.5	0.18	385	0.2333	66.7	5.08
Site2	8/18/2008 9:38	7.1	27.17	8.13	364.6	0.18	385	0.2333	64.5	4.92
Site2	8/18/2008 9:40	8.1	27.13	8.07	366	0.18	384	0.2342	54.1	4.12
Site2	8/18/2008 9:42	9.1	26.31	8.52	372.1	0.18	-40	0.2381	2.1	0.16
Site2	8/18/2008 9:43	10	25.18	8.5	404.2	0.2	-67	0.2587	1.8	0.14
Site2	8/18/2008 9:44	11.1	24.03	8.39	414.7	0.21	-83	0.2654	1.5	0.12
Site2	9/2/2008 10:45	6.8	25.79	7.49	365.8	0.18	53	0.2341	1.5	0.11
Site2	9/2/2008 11:03	0.2	27.93	8.5	354.7	0.17	246	0.227	107.1	8.01
Site2	9/2/2008 11:04	1	27.93	8.46	354.8	0.17	260	0.227	106.2	7.94
Site2	9/2/2008 11:06	2	27.93	8.48	354.9	0.17	268	0.2271	105.3	7.88
Site2	9/2/2008 11:07	3	27.92	8.5	354.9	0.17	273	0.2271	100.4	7.51
Site2	9/2/2008 11:09	3.5	27.9	8.49	354.9	0.17	277	0.2272	92.9	6.95
Site2	9/2/2008 11:12	4.1	27.82	8.37	357.8	0.18	281	0.229	85.4	6.4
Site2	9/2/2008 11:13	5	26.41	7.55	367.3	0.18	286	0.2351	3.2	0.25
Site2	9/2/2008 11:15	4.5	26.82	7.64	366.5	0.18	280	0.2345	9.4	0.71
Site2	9/2/2008 11:16	6	26.22	7.53	366.8	0.18	254	0.2347	2	0.15
Site2	9/2/2008 11:19	7	26	7.52	365.2	0.18	146	0.2337	1.5	0.11
Site2	9/2/2008 11:20	8.1	25.06	7.45	357.9	0.18	37	0.229	1.2	0.1
Site2	9/2/2008 11:22	9	24.74	7.45	350.6	0.17	19	0.2244	1.3	0.1
Site2	9/2/2008 11:23	9.9	24.29	7.39	349.2	0.17	-3	0.2235	1.1	0.09
Site2	9/2/2008 11:25	11	23.59	7.27	368.3	0.18	-23	0.2357	1.2	0.1
Site2	9/2/2008 11:26	11.9	23.04	7.13	393.6	0.2	-35	0.2519	1.1	0.09
Site2	9/22/2008 11:30	0.1	23.76	8.6	337.3	0.17	249	0.2159	119.7	8.4
Site2	9/22/2008 11:31	1	23.74	8.59	337.3	0.17	263	0.2158	120.1	8.43
Site2	9/22/2008 11:34	2.1	23.75	8.58	337.4	0.17	277	0.2159	119.2	8.36

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (millivolts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site2	9/22/2008 11:36	3	23.68	8.55	337.6	0.17	287	0.2161	114.8	8.07
Site2	9/22/2008 11:39	4	23.57	8.47	338.5	0.17	296	0.2167	102.3	7.2
Site2	9/22/2008 11:41	5.1	23.44	8.33	339.9	0.17	296	0.2175	87.7	6.19
Site2	9/22/2008 11:45	6.1	23.4	8.16	342.3	0.17	313	0.2191	67	4.73
Site2	9/22/2008 11:47	7	23.23	7.97	342.6	0.17	286	0.2193	43.9	3.11
Site2	9/22/2008 11:49	8	23.18	7.89	342.6	0.17	270	0.2193	37.7	2.68
Site2	9/22/2008 11:51	9	23.05	7.84	342.3	0.17	264	0.2191	27	1.92
Site2	9/22/2008 11:53	10.1	23.03	7.79	342.8	0.17	256	0.2194	19.1	1.36
Site2	9/22/2008 11:54	11	22.99	7.73	345.6	0.17	251	0.2212	3.9	0.28
Site2	9/22/2008 11:55	11.2	22.92	7.71	350.3	0.17	218	0.2242	1.8	0.13
Site2	10/16/2008 10:29	0.08	20.26	8.17	377.4	0.19	424	0.2415	78.7	6.83
Site2	10/16/2008 10:30	1.06	20.28	8.14	377.4	0.19	425	0.2415	78	6.77
Site2	10/16/2008 10:32	2.04	20.28	8.17	377.7	0.19	423	0.2417	77.6	6.74
Site2	10/16/2008 10:33	3.03	20.29	8.15	377.4	0.19	422	0.2415	76.8	6.67
Site2	10/16/2008 10:34	4.01	20.3	8.15	377.4	0.19	421	0.2415	76	6.59
Site2	10/16/2008 10:35	5.02	20.3	8.15	377.3	0.19	420	0.2415	76.2	6.61
Site2	10/16/2008 10:36	6.01	20.29	8.15	377.3	0.19	420	0.2415	76.5	6.64
Site2	10/16/2008 10:37	7.03	20.26	8.16	377.2	0.19	420	0.2414	77.4	6.72
Site2	10/16/2008 10:38	8.02	20.21	8.19	376.9	0.19	419	0.2412	79.5	6.91
Site2	10/16/2008 10:39	9.01	20.16	8.21	376.7	0.19	418	0.2411	81	7.05
Site2	10/16/2008 10:40	9.99	20.14	8.22	376.5	0.19	418	0.241	81.5	7.1
Site2	10/16/2008 10:40	11.04	20.14	8.22	376.6	0.19	418	0.2411	80.9	7.04
Site2	10/16/2008 10:41	11.29	20.15	8.21	376.7	0.19	390	0.2411	23.9	2.08
Site2	12/8/2008 11:42	0.1	7.88	8.03	372		500		87.3	10.09
Site2	12/8/2008 11:43	0.5	7.85	8.06	372.2		497		87	10.07
Site2	12/8/2008 11:44	1	7.84	8.07	372.2		493		86.8	10.05
Site2	12/8/2008 11:45	2	7.82	8.08	372.4		489		86.6	10.02
Site2	12/8/2008 11:46	3	7.84	8.08	372.2		487		86.5	10.01
Site2	12/8/2008 11:47	4	7.83	8.08	372.2		485		86.3	9.99
Site2	12/8/2008 11:48	5	7.8	8.08	372.4		483		86.2	9.99
Site2	12/8/2008 11:49	6	7.81	8.08	372.4		482		86	9.97
Site2	12/8/2008 11:50	7	7.81	8.09	372.1		480		85.9	9.95
Site2	12/8/2008 11:50	8	7.79	8.09	372.4		479		85.9	9.95
Site2	12/8/2008 11:51	9	7.79	8.08	373.1		479		85.8	9.94
Site2	12/8/2008 11:51	10	7.8	8.08	372.3		475		85.4	9.9
Site2	12/8/2008 11:52	11	7.82	7.88	372.9		374		72.2	8.36
Site2	2/9/2009 10:14	0.05	6.26	7.75	379.8	0.19	404	0.243	101.1	11.97
Site2	2/9/2009 10:15	1.13	6.26	7.87	379.8	0.19	403	0.2431	101.1	11.98

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site2	2/9/2009 10:16	1.95	6.25	7.9	379.8	0.19	403	0.2431	100.9	11.96
Site2	2/9/2009 10:16	3.05	6.25	7.93	379.8	0.19	403	0.2431	100.8	11.94
Site2	2/9/2009 10:17	4.02	6.24	7.96	380.1	0.19	404	0.2432	100.7	11.92
Site2	2/9/2009 10:18	5.02	6.24	7.96	380.1	0.19	404	0.2433	100.5	11.91
Site2	2/9/2009 10:18	5.99	6.24	7.96	379.8	0.19	404	0.2431	100.5	11.91
Site2	2/9/2009 10:19	7.06	6.24	7.98	380.1	0.19	404	0.2432	100.3	11.88
Site2	2/9/2009 10:19	8	6.21	7.99	380	0.19	404	0.2432	100.2	11.88
Site2	2/9/2009 10:20	8.97	6.2	8.01	380.1	0.19	404	0.2432	100	11.86
Site2	2/9/2009 10:21	10.03	6.16	8.01	380.2	0.19	404	0.2433	99.8	11.85
Site2	2/9/2009 10:21	11.06	6.18	8.01	380.3	0.19	404	0.2434	99.6	11.82
Site2	4/15/2009 11:35	11.81	12.07	8.23	415.7	0.21	383	0.2661	80.4	8.26
Site2	4/15/2009 11:36	11.03	12.16	8.32	413	0.21	383	0.2643	88.7	9.09
Site2	4/15/2009 11:39	10	12.17	8.38	413	0.21	391	0.2643	91.9	9.42
Site2	4/15/2009 11:39	9.02	12.18	8.38	412.9	0.21	393	0.2642	92.4	9.47
Site2	4/15/2009 11:40	7.98	12.21	8.39	412.6	0.21	395	0.2641	92.7	9.49
Site2	4/15/2009 11:41	7.05	12.21	8.38	412.4	0.21	397	0.264	93	9.53
Site2	4/15/2009 11:42	6.01	12.41	8.39	412.5	0.21	400	0.264	94.3	9.62
Site2	4/15/2009 11:42	4.38	12.57	8.45	413.1	0.21	399	0.2644	96.3	9.79
Site2	4/15/2009 11:43	3.99	12.61	8.42	412.6	0.21	403	0.2641	97.9	9.94
Site2	4/15/2009 11:44	2.68	12.72	8.42	412.8	0.21	407	0.2642	99	10.03
Site2	4/15/2009 11:45	1.98	12.73	8.45	412.8	0.21	407	0.2642	99.2	10.05
Site2	4/15/2009 11:46	0.86	12.75	8.47	412.8	0.21	407	0.2642	99.4	10.06
Site2	4/15/2009 11:47	0.03	12.77	8.45	412.9	0.21	410	0.2643	100.1	10.12
Site2	5/7/2009 13:15	12.01	16.55	7.76	425.8	0.21	396	0.2725	43.7	4.06
Site2	5/7/2009 13:17	11.06	16.81	8	419	0.21	390	0.2681	65.9	6.08
Site2	5/7/2009 13:18	9.95	17.01	8.21	415.5	0.21	388	0.2659	85.3	7.85
Site2	5/7/2009 13:19	8.97	17.02	8.24	415	0.21	388	0.2656	87.1	8.01
Site2	5/7/2009 13:20	7.96	17.03	8.26	415.2	0.21	388	0.2657	88	8.09
Site2	5/7/2009 13:21	7.01	17.07	8.26	415.3	0.21	389	0.2658	88.6	8.14
Site2	5/7/2009 13:22	6.04	17.1	8.25	415.7	0.21	391	0.2661	89.8	8.25
Site2	5/7/2009 13:23	5	17.12	8.25	415.7	0.21	391	0.2661	90.2	8.28
Site2	5/7/2009 13:24	3.99	17.16	8.27	415.6	0.21	390	0.266	90.7	8.32
Site2	5/7/2009 13:25	2.98	17.35	8.31	415.4	0.21	390	0.2659	94.5	8.63
Site2	5/7/2009 13:26	2.02	18.51	8.35	415.2	0.21	389	0.2658	100.7	8.98
Site2	5/7/2009 13:27	1.01	19.21	8.4	416.8	0.21	388	0.2667	107.2	9.42
Site2	5/7/2009 13:28	0.12	19.34	8.39	406.2	0.2	389	0.26	107.5	9.42
Site2	5/20/2009 11:44	-0.04	20.54	8.32	414.6	0.21	406	0.2654	115.7	10.03
Site2	5/20/2009 11:45	0.92	20.51	8.48	414.9	0.21	405	0.2655	115.6	10.03

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site2	5/20/2009 11:47	1.95	20.5	8.46	414.8	0.21	407	0.2655	114.7	9.96
Site2	5/20/2009 11:48	3.01	20.43	8.46	414.8	0.21	409	0.2655	113.4	9.86
Site2	5/20/2009 11:49	4.02	20.33	8.44	415.1	0.21	411	0.2656	111.7	9.73
Site2	5/20/2009 11:50	5.11	20.25	8.4	414.8	0.21	412	0.2655	107.3	9.36
Site2	5/20/2009 11:51	5.05	20.25	8.28	415.3	0.21	417	0.2658	105.9	9.24
Site2	5/20/2009 11:52	5.99	20.15	8.33	415.4	0.21	418	0.2659	100.8	8.81
Site2	5/20/2009 11:53	7.01	20.05	8.3	415.7	0.21	419	0.266	94.9	8.31
Site2	5/20/2009 11:55	7.91	19.08	8.09	418.8	0.21	423	0.2681	74.7	6.67
Site2	5/20/2009 11:56	9.08	18.92	8.09	418.8	0.21	424	0.268	75.1	6.73
Site2	5/20/2009 11:57	9.95	18.77	8.01	420	0.21	425	0.2688	68.1	6.12
Site2	5/20/2009 11:59	11.08	18.49	7.95	420.9	0.21	426	0.2694	62.2	5.62
Site2	5/20/2009 12:00	11.99	18.24	7.81	423	0.21	428	0.2707	48.7	4.42
Site2	5/20/2009 12:02	12.54	18.16	7.81	424.1	0.21	182	0.2714	42.2	3.84
Site2	6/4/2009 12:34	-0.03	23.52	8.38	402.7	0.2	517	0.2575	105	8.37
Site2	6/4/2009 12:35	1.03	23.53	8.4	402.3	0.2	519	0.2575	103.6	8.27
Site2	6/4/2009 12:36	1.97	23.34	8.39	403.1	0.2	519	0.258	99.8	7.99
Site2	6/4/2009 12:37	3.05	23.21	8.34	403.5	0.2	520	0.2582	91.3	7.33
Site2	6/4/2009 12:38	4.12	23.16	8.34	403.9	0.2	521	0.2584	88.9	7.14
Site2	6/4/2009 12:39	4.95	23.15	8.33	404.1	0.2	522	0.2586	86.4	6.95
Site2	6/4/2009 12:42	6	21.41	7.69	417.4	0.21	534	0.2671	23.1	1.92
Site2	6/4/2009 12:46	7.01	21.05	7.66	418.5	0.21	535	0.2679	18.5	1.55
Site2	6/4/2009 12:48	7.94	20.33	7.57	417.7	0.21	539	0.2674	13.2	1.12
Site2	6/4/2009 12:49	9.02	19.28	7.52	418.2	0.21	537	0.2676	8.7	0.76
Site2	6/4/2009 12:51	9.96	18.7	7.49	420.3	0.21	534	0.269	2.8	0.25
Site2	6/4/2009 12:53	11	18.54	7.49	421	0.21	533	0.2694	2.1	0.19
Site2	6/25/2009 11:32	0.15	31.33	8.47	402.9	0.2	433	0.2578	145.9	10.28
Site2	6/25/2009 11:34	2.05	31.15	8.53	402.2	0.2	433	0.2574	147.7	10.43
Site2	6/25/2009 11:35	2.01	29.74	8.36	413.6	0.21	437	0.2647	104	7.53
Site2	6/25/2009 11:36	2.98	28.66	8.38	414.4	0.21	438	0.2652	107.5	7.93
Site2	6/25/2009 11:36	3.25	28.47	8.37	415.1	0.21	439	0.2657	103.1	7.63
Site2	6/25/2009 11:37	3.94	28.08	8.26	417.5	0.21	441	0.2672	83.6	6.23
Site2	6/25/2009 11:38	4	28.13	8.3	417.2	0.21	440	0.267	84	6.26
Site2	6/25/2009 11:39	5.23	27.69	8.13	419.5	0.21	443	0.2685	61.6	4.62
Site2	6/25/2009 11:40	6.03	26.82	7.77	423.5	0.21	443	0.2711	18.7	1.42
Site2	6/25/2009 11:41	6.98	26.12	7.64	424.3	0.21	441	0.2716	3.2	0.24
Site2	6/25/2009 11:42	8.06	22.83	7.53	427.2	0.21	195	0.2734	2.1	0.17
Site2	6/25/2009 11:44	9.04	20.69	7.49	429.9	0.22	112	0.2751	1.8	0.15
Site2	6/25/2009 11:44	11.13	19.82	7.45	431.4	0.22	88	0.2759	1.7	0.15

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site2	6/25/2009 11:45	11.46	19.52	7.47	432.8	0.22	53	0.277	1.7	0.15
Site2	6/25/2009 11:46	12.12	19.22	7.4	437.8	0.22	28	0.2802	1.7	0.15
Site2	6/25/2009 11:46	12.04	19.19	7.4	438.9	0.22	16	0.2809	1.7	0.15
Site2	7/9/2009 10:57	11.09	19.73	7.59	441.1	0.22	68	0.2823	2.7	0.23
Site2	7/9/2009 10:58	10.05	20.69	7.67	439.3	0.22	39	0.2811	2.1	0.18
Site2	7/9/2009 10:59	9.04	22.56	7.77	435.6	0.22	23	0.2788	1.9	0.16
Site2	7/9/2009 11:00	7.69	24.16	7.82	433.8	0.22	6	0.2776	1.7	0.14
Site2	7/9/2009 11:01	7	27.58	8.47	412.4	0.21	88	0.264	72.8	5.46
Site2	7/9/2009 11:02	5.92	27.65	8.53	412.2	0.21	120	0.2638	87.4	6.54
Site2	7/9/2009 11:03	5.06	27.69	8.52	412.2	0.21	153	0.2638	89.1	6.67
Site2	7/9/2009 11:04	4.04	27.77	8.52	411.9	0.21	178	0.2636	91.5	6.84
Site2	7/9/2009 11:05	3.05	27.82	8.5	411.6	0.21	199	0.2634	92.4	6.9
Site2	7/9/2009 11:06	1.99	27.88	8.52	411.5	0.21	212	0.2633	95.9	7.15
Site2	7/9/2009 11:07	1.02	27.98	8.53	411.2	0.21	223	0.2632	98.7	7.35
Site2	7/9/2009 11:08	-0.01	27.96	8.51	411	0.21	233	0.2631	98.2	7.31
Site2	7/9/2009 11:18	6.06	28.11	8.54	410.7	0.2	299	0.2628	92.8	6.89
Site2	7/9/2009 11:18	5.94	28.13	8.56	410.6	0.2	302	0.2628	92.9	6.89
Site2	7/9/2009 11:20	5.11	28.22	8.6	409.8	0.2	309	0.2623	99.2	7.35
Site2	7/9/2009 11:20	3.99	28.31	8.6	409.7	0.2	312	0.2622	101.3	7.49
Site2	7/9/2009 11:21	2.93	28.39	8.59	409.8	0.2	318	0.2623	101.8	7.52
Site2	7/9/2009 11:22	1.82	28.49	8.61	409.9	0.2	324	0.2623	104.7	7.72
Site2	7/9/2009 11:23	1.04	28.54	8.61	409.5	0.2	328	0.2621	105.7	7.79
Site2	7/9/2009 11:24	0.05	28.55	8.58	409.7	0.2	334	0.2622	105.7	7.79
Site2	7/23/2009 11:01	0.14	28.4	8.51	394.6	0.2	342	0.2526	116.1	8.58
Site2	7/23/2009 11:02	1.09	28.02	8.44	396	0.2	341	0.2535	102	7.58
Site2	7/23/2009 11:03	2.06	27.99	8.43	396.5	0.2	340	0.2538	97.9	7.28
Site2	7/23/2009 11:05	2.98	27.9	8.37	398.1	0.2	340	0.2548	89.3	6.65
Site2	7/23/2009 11:05	4.03	27.82	8.39	397.3	0.2	340	0.2543	92.4	6.89
Site2	7/23/2009 11:06	5	27.8	8.39	397.1	0.2	341	0.2542	92.8	6.93
Site2	7/23/2009 11:08	6.01	27.65	8.37	397.6	0.2	341	0.2545	89.2	6.68
Site2	7/23/2009 11:09	7.03	27.38	8.21	402.3	0.2	342	0.2575	67.7	5.09
Site2	7/23/2009 11:15	8.05	26.87	7.86	410.3	0.2	333	0.2626	27.9	2.11
Site2	7/23/2009 11:16	9.01	24.43	7.56	430.2	0.22	87	0.2753	2	0.16
Site2	7/23/2009 11:17	9.99	21.35	7.38	439	0.22	45	0.281	1.8	0.15
Site2	7/23/2009 11:18	11.01	20.26	7.29	441	0.22	9	0.2823	1.7	0.15
Site2	7/23/2009 11:18	11.25	20.06	7.27	443.7	0.22	1	0.284	1.6	0.14
Site2	8/6/2009 11:33	11.48	20.86	7.36	445.5	0.22	21	0.2851	2.9	0.25
Site2	8/6/2009 11:35	10.76	22.13	7.5	439.8	0.22	-7	0.2815	2	0.17

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site2	8/6/2009 11:36	10.08	24.99	7.74	413.3	0.21	-2	0.2645	1.9	0.16
Site2	8/6/2009 11:37	8.78	25.85	7.79	405.9	0.2	12	0.2598	1.8	0.14
Site2	8/6/2009 11:38	8.13	26.33	7.8	400.1	0.2	26	0.2561	1.7	0.13
Site2	8/6/2009 11:40	6.98	27.17	8.09	394	0.2	84	0.2521	32.8	2.58
Site2	8/6/2009 11:42	5.92	27.74	8.42	387.4	0.19	129	0.2479	75.5	5.87
Site2	8/6/2009 11:44	5.05	27.93	8.55	383.4	0.19	157	0.2454	95.3	7.39
Site2	8/6/2009 11:45	3.93	27.94	8.53	383.5	0.19	173	0.2454	96.2	7.46
Site2	8/6/2009 11:46	3	27.96	8.52	383.4	0.19	184	0.2454	96.3	7.46
Site2	8/6/2009 11:47	2.03	27.96	8.52	383.4	0.19	192	0.2454	96.2	7.45
Site2	8/6/2009 11:48	1	27.96	8.52	383.3	0.19	199	0.2453	97.6	7.57
Site2	8/6/2009 11:50	0.12	27.96	8.52	383.4	0.19	210	0.2454	97.1	7.53
Site2	8/24/2009 12:14	0.12	27.24	8.7	223.8	0.1	295	0.1432	111.1	8.41
Site2	8/24/2009 12:15	1.14	27.34	8.69	381.5	0.19	304	0.244	106.8	8.07
Site2	8/24/2009 12:17	2.07	27.19	8.65	382.2	0.19	311	0.2446	102.2	7.74
Site2	8/24/2009 12:17	3	27.17	8.63	382.6	0.19	316	0.2449	96.3	7.29
Site2	8/24/2009 12:18	3.94	27.04	8.58	383.5	0.19	320	0.2455	87	6.61
Site2	8/24/2009 12:19	5.08	27	8.57	383.5	0.19	323	0.2455	84.9	6.45
Site2	8/24/2009 12:21	5.98	26.99	8.57	383.8	0.19	326	0.2456	84.9	6.45
Site2	8/24/2009 12:21	6.99	26.99	8.57	383.9	0.19	327	0.2457	83.8	6.37
Site2	8/24/2009 12:21	8.02	26.98	8.55	384	0.19	328	0.2458	80.9	6.15
Site2	8/24/2009 12:22	8.1	26.98	8.56	384	0.19	328	0.2458	81.1	6.16
Site2	8/24/2009 12:22	9.09	26.99	8.56	384	0.19	329	0.2458	79.3	6.03
Site2	8/24/2009 12:24	10.07	25.53	7.82	412.1	0.21	28	0.2638	2.4	0.18
Site2	8/24/2009 12:24	11.16	23.44	7.55	439.8	0.22	6	0.2821	1.9	0.15
Site2	8/24/2009 12:25	11.16	23.37	7.47	472.7	0.24	-14	0.3025	1.6	0.13
Site2	9/3/2009 11:26	0.1	25.21	8.14	387.2	0.19	307	0.2478	76	6
Site2	9/3/2009 11:27	1.05	25.2	8.12	387.3	0.19	306	0.2479	74.5	5.89
Site2	9/3/2009 11:28	2	25.19	8.11	387.4	0.19	304	0.2479	73.6	5.82
Site2	9/3/2009 11:29	3.01	25.19	8.1	387.4	0.19	303	0.2479	73.3	5.79
Site2	9/3/2009 11:30	4.04	25.19	8.1	387.4	0.19	303	0.2479	72.9	5.76
Site2	9/3/2009 11:31	4.98	25.2	8.09	387.4	0.19	303	0.248	73.2	5.78
Site2	9/3/2009 11:32	6	25.2	8.08	387.4	0.19	303	0.248	72.9	5.76
Site2	9/3/2009 11:33	7	25.19	8.08	387.6	0.19	303	0.248	71.9	5.68
Site2	9/3/2009 11:33	8.03	25.2	8.07	387.7	0.19	304	0.2481	71.5	5.65
Site2	9/3/2009 11:34	9	25.19	8.06	387.5	0.19	304	0.248	71.4	5.64
Site2	9/3/2009 11:35	10.03	25.19	8.05	387.4	0.19	304	0.2479	71	5.61
Site2	9/3/2009 11:36	11.01	25.18	8.06	387.6	0.19	304	0.2481	70.4	5.56
Site2	9/3/2009 11:37	12.04	21.46	7.08	478.9	0.24	54	0.3065	2.3	0.2

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site2	9/3/2009 11:38	12.32	21.33	7.05	480.7	0.24	39	0.3076	2.2	0.19
Site2	9/17/2009 11:25	11.29	23.12	7.81	409	0.2	195	0.2618	5.9	0.48
Site2	9/17/2009 11:25	11.03	23.2	7.91	404.8	0.2	194	0.2591	16.2	1.31
Site2	9/17/2009 11:26	9.95	23.4	8.03	391.3	0.19	199	0.2504	48.3	3.89
Site2	9/17/2009 11:28	9.05	23.43	8.12	391	0.19	200	0.2502	51.5	4.15
Site2	9/17/2009 11:29	7.9	23.45	8.06	390.5	0.19	211	0.2499	56.3	4.53
Site2	9/17/2009 11:30	6.94	23.46	8.17	390.3	0.19	207	0.2498	58.1	4.67
Site2	9/17/2009 11:31	5.81	23.46	8.11	390.1	0.19	214	0.2497	58.7	4.72
Site2	9/17/2009 11:32	4.86	23.46	8.11	390.1	0.19	216	0.2497	58.9	4.74
Site2	9/17/2009 11:33	3.96	23.46	8.07	390.3	0.19	220	0.2498	59	4.75
Site2	9/17/2009 11:33	2.97	23.46	8.1	390.1	0.19	220	0.2497	58.7	4.72
Site2	9/17/2009 11:34	2.02	23.46	8.17	390.3	0.19	217	0.2498	58.6	4.72
Site2	9/17/2009 11:35	0.99	23.46	8.1	390.3	0.19	223	0.2498	59.8	4.81
Site2	9/17/2009 11:36	0.07	23.46	8.12	390.4	0.19	223	0.2498	60.2	4.85
Site2	9/30/2009 10:36	11.18	21.72	7.61	390.9	0.19	343	0.2502	56.3	4.76
Site2	9/30/2009 10:37	11.06	21.72	7.61	391.2	0.19	343	0.2504	56.6	4.79
Site2	9/30/2009 10:42	9.9	21.78	7.67	390.1	0.19	343	0.2497	64.4	5.44
Site2	9/30/2009 10:43	8.88	21.8	7.68	389.3	0.19	343	0.2492	66.5	5.62
Site2	9/30/2009 10:44	8.06	21.82	7.7	389.4	0.19	344	0.2492	70.1	5.92
Site2	9/30/2009 10:45	5.96	21.86	7.72	389.2	0.19	344	0.2491	73.4	6.2
Site2	9/30/2009 10:46	4.99	21.87	7.72	389.2	0.19	344	0.2491	73.5	6.2
Site2	9/30/2009 10:47	6.95	21.87	7.73	389.4	0.19	344	0.2492	73.1	6.17
Site2	9/30/2009 10:48	5.03	21.87	7.73	389.3	0.19	344	0.2492	73	6.16
Site2	9/30/2009 10:49	4.01	21.87	7.72	389.3	0.19	345	0.2492	73.6	6.21
Site2	9/30/2009 10:50	3.03	21.87	7.73	389.5	0.19	345	0.2493	74.1	6.25
Site2	9/30/2009 10:51	1.98	21.88	7.74	389.4	0.19	345	0.2492	74.5	6.29
Site2	9/30/2009 10:52	0.96	21.88	7.74	389.3	0.19	345	0.2491	75	6.33
Site2	9/30/2009 10:52	0.1	21.86	7.74	389.3	0.19	345	0.2492	75.8	6.4
Site2	10/19/2009 12:31	11.47	16.3	7.51	378.9	0.19	84	0.2425	4.2	0.39
Site2	10/19/2009 12:32	10.94	16.2	7.89	379.1	0.19	234	0.2426	80.7	7.59
Site2	10/19/2009 12:32	9.88	16.2	7.9	379.1	0.19	252	0.2426	82.4	7.76
Site2	10/19/2009 12:33	9.04	16.21	7.9	379.1	0.19	265	0.2426	83.1	7.82
Site2	10/19/2009 12:34	8.03	16.2	7.9	379.1	0.19	280	0.2426	83.4	7.85
Site2	10/19/2009 12:34	7.02	16.21	7.91	379.1	0.19	287	0.2426	83.7	7.87
Site2	10/19/2009 12:35	5.64	16.21	7.91	379.1	0.19	294	0.2426	83.8	7.88
Site2	10/19/2009 12:35	5.03	16.21	7.91	379.1	0.19	300	0.2426	83.9	7.89
Site2	10/19/2009 12:36	4.06	16.22	7.9	379.1	0.19	305	0.2426	83.9	7.89
Site2	10/19/2009 12:36	2.98	16.27	7.92	379.1	0.19	308	0.2426	84.4	7.93

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site2	10/19/2009 12:36	3.01	16.27	7.91	379	0.19	309	0.2426	84.6	7.95
Site2	10/19/2009 12:36	1.93	16.24	7.91	379	0.19	312	0.2425	84.8	7.98
Site2	10/19/2009 12:37	0.97	16.24	7.92	379	0.19	316	0.2425	84.8	7.97
Site2	10/19/2009 12:37	0.11	16.26	7.91	379.1	0.19	315	0.2426	85	7.99

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Table D-4 Site 3 HYDROLAB Station Data*

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site3	4/22/2008 12:51	0.3	17.48	8.34	381.1	0.19	327	0.2439	102.3	9.3
Site3	4/22/2008 12:51	0.9	17.49	8.34	381.1	0.19	327	0.2439	102.2	9.29
Site3	4/22/2008 12:52	1.9	17.39	8.34	381	0.19	327	0.2439	101.6	9.26
Site3	4/22/2008 12:53	3	17.07	8.33	381.2	0.19	327	0.244	100.1	9.18
Site3	4/22/2008 12:53	3.9	16.79	8.32	381.4	0.19	327	0.2441	99.1	9.14
Site3	4/22/2008 12:54	5	16.58	8.32	382.6	0.19	328	0.2449	98.6	9.14
Site3	4/22/2008 12:56	6	16.1	8.31	383	0.19	328	0.2451	97.5	9.13
Site3	4/22/2008 12:57	7.1	15.65	8.26	383.3	0.19	330	0.2453	88.5	8.37
Site3	4/22/2008 13:00	7.7	15.64	8.13	383.4	0.19	140	0.2454	32.3	3.05
Site3	5/16/2008 13:46	0.2	19.57	8.36	386.4	0.19	395	0.2473	108.1	9.43
Site3	5/16/2008 13:46	1	19.57	8.38	386.6	0.19	391	0.2474	107.7	9.4
Site3	5/16/2008 13:48	2	19.36	8.36	386.7	0.19	387	0.2475	106.1	9.3
Site3	5/16/2008 13:50	3	19.05	8.33	387.4	0.19	382	0.2479	101.4	8.94
Site3	5/16/2008 13:50	4	18.74	8.3	388.3	0.19	382	0.2485	96.5	8.57
Site3	5/16/2008 13:51	5	18.65	8.27	389	0.19	381	0.249	93.4	8.3
Site3	5/16/2008 13:52	6	18.62	8.21	390.4	0.19	381	0.2498	87.4	7.78
Site3	5/16/2008 13:52	7	18.45	8.22	389.6	0.19	380	0.2493	88.3	7.89
Site3	5/16/2008 13:53	7.4	18.39	8.21	389.2	0.19	379	0.2491	89	7.95
Site3	5/21/2008 14:43	0.1	21.78	8.46	388.9	0.19	437	0.2489		
Site3	5/21/2008 14:44	1	21.78	8.51	388.9	0.19	440	0.2489		
Site3	5/21/2008 14:45	2	21.7	8.53	389.1	0.19	437	0.249		
Site3	5/21/2008 14:45	3	21.28	8.48	390	0.19	437	0.2496		
Site3	5/21/2008 14:46	4	20.44	8.36	392	0.19	438	0.2509		
Site3	5/21/2008 14:47	5	19.78	8.21	392.8	0.2	439	0.2514		
Site3	5/21/2008 14:48	6.1	18.93	8.11	393.6	0.2	440	0.2519		
Site3	5/21/2008 14:49	7	18.89	8.06	393.5	0.2	439	0.2518		
Site3	6/4/2008 15:41	0.2	26.56	8.42	357	0.2	421	0.229	94.1	7.29
Site3	6/4/2008 15:42	1.1	26.55	8.42	357	0.2	427	0.229	92.8	7.19
Site3	6/4/2008 15:44	2.2	26.53	8.41	358	0.2	434	0.229	92	7.12
Site3	6/4/2008 15:45	3.3	26.56	8.41	357	0.2	437	0.229	92	7.12
Site3	6/4/2008 15:46	4.1	26.53	8.41	357	0.2	441	0.229	92	7.13
Site3	6/4/2008 15:48	5.3	26.48	8.4	358	0.2	444	0.229	90.6	7.03
Site3	6/4/2008 15:49	6.1	26.45	8.39	358	0.2	446	0.229	90.4	7.01
Site3	6/18/2008 11:01	0.15	26.7	8.35	393.5	0.2	240	0.2518	100.5	7.72
Site3	6/18/2008 11:03	1.01	26.45	8.33	394	0.2	239	0.2522	94.8	7.32
Site3	6/18/2008 11:04	2	26.31	8.28	395	0.2	241	0.2528	86.9	6.73
Site3	6/18/2008 11:06	3	25.82	8.16	400.1	0.2	243	0.2561	72.3	5.65

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site3	6/18/2008 11:07	4.02	25.65	8.08	400.3	0.2	244	0.2562	64.7	5.07
Site3	6/18/2008 11:09	5.03	25.38	7.87	395.8	0.2	246	0.2533	47.7	3.76
Site3	6/18/2008 11:10	5.98	24.96	7.76	401.6	0.2	246	0.257	36.7	2.91
Site3	6/18/2008 11:12	7.25	24.59	7.47	375.7	0.19	30	0.2392	19.7	1.57
Site3	6/18/2008 11:14	7.31	24.51	7.44	371.1	0.18	47	0.2375	1.4	0.11
Site3	7/9/2008 11:48	0.11	29.97	8.64	378.6	0.19	234	0.2423	125.7	9.09
Site3	7/9/2008 11:49	0.99	29.33	8.57	378	0.19	235	0.2419	124	9.07
Site3	7/9/2008 11:51	1.98	29.21	8.54	378.9	0.19	232	0.2425	111.6	8.17
Site3	7/9/2008 11:52	2.99	29.13	8.42	381.1	0.19	234	0.2439	97.5	7.15
Site3	7/9/2008 11:52	3.99	29.14	8.34	381.4	0.19	238	0.2441	95.9	7.03
Site3	7/9/2008 11:53	5.02	29.09	8.26	382.1	0.19	241	0.2446	89.2	6.55
Site3	7/9/2008 11:54	6.02	27.52	7.79	392.8	0.2	246	0.2514	11.3	0.86
Site3	7/9/2008 11:55	6.48	26.87	7.69	397.7	0.2	183	0.2545	2.4	0.18
Site3	7/21/2008 9:59	0.12	29.89	8.3	366	0.18	354	0.2343	110.5	8.01
Site3	7/21/2008 10:00	1.07	29.9	8.29	366.1	0.18	346	0.2343	110.1	7.97
Site3	7/21/2008 10:02	1.98	29.88	8.33	366	0.18	335	0.2343	109.9	7.96
Site3	7/21/2008 10:03	3.05	29.87	8.29	366.2	0.18	330	0.2344	108.3	7.85
Site3	7/21/2008 10:04	4.03	29.86	8.24	366.1	0.18	328	0.2343	107.4	7.78
Site3	7/21/2008 10:06	5.01	29.83	8.18	366.5	0.18	326	0.2346	103.8	7.53
Site3	7/21/2008 10:08	6.05	28.68	7.59	376.1	0.19	333	0.2407	19.8	1.46
Site3	8/4/2008 9:32	0.08	31.25	8.26	398.7	0.2	274	0.2551	118.8	8.39
Site3	8/4/2008 9:33	1.1	31.23	8.34	398.6	0.2	264	0.2551	118.6	8.38
Site3	8/4/2008 9:35	2	31.17	8.35	398.7	0.2	260	0.2551	118.5	8.39
Site3	8/4/2008 9:37	3.02	31.02	8.32	398.9	0.2	259	0.2553	116.7	8.27
Site3	8/4/2008 9:38	4.02	31.01	8.27	399.1	0.2	261	0.2555	115.5	8.19
Site3	8/4/2008 9:40	4.98	29.86	7.57	416.4	0.21	262	0.2665	12.6	0.91
Site3	8/4/2008 9:41	6.01	28.15	7.45	428	0.21	-81	0.2739	2.4	0.18
Site3	8/4/2008 9:43	5.5	27.9	7.46	428.3	0.21	-107	0.2741	1.7	0.13
Site3	8/18/2008 9:05	0.1	27.19	8.4	357.5	0.18	397	0.2288	90.7	6.9
Site3	8/18/2008 9:06	1	27.3	8.37	357.1	0.18	394	0.2286	90.3	6.86
Site3	8/18/2008 9:08	2.05	27.14	8.35	358.2	0.18	390	0.2294	90.5	6.9
Site3	8/18/2008 9:10	2.97	27.25	8.34	357.7	0.18	389	0.2289	88.9	6.76
Site3	8/18/2008 9:11	4.02	27.32	8.33	357.3	0.18	388	0.2287	88.9	6.75
Site3	8/18/2008 9:11	5.04	27.32	8.33	357.2	0.18	388	0.2286	88.4	6.71
Site3	8/18/2008 9:13	6.5	27.19	8.02	356	0.18	390	0.2278	68.4	5.2
Site3	8/18/2008 9:16	6.51	27.1	7.83	354.8	0.17	391	0.2271	20.4	1.55
Site3	9/2/2008 10:33	0.1	29.02	8.59	351.7	0.17	311	0.2251	125.3	9.19
Site3	9/2/2008 10:35	1	29.04	8.61	351.3	0.17	330	0.2249	125.8	9.23

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site3	9/2/2008 10:35	2	29.01	8.62	351.5	0.17	335	0.225	123.1	9.03
Site3	9/2/2008 10:37	3	28.84	8.6	351.7	0.17	343	0.2251	115.1	8.47
Site3	9/2/2008 10:39	4	26.9	7.61	368.1	0.18	373	0.2356	6.3	0.48
Site3	9/2/2008 10:40	3.5	27.5	7.83	364.4	0.18	367	0.2332	27.9	2.1
Site3	9/2/2008 10:42	5	26.22	7.53	366.7	0.18	262	0.2347	2.2	0.17
Site3	9/2/2008 10:43	6	26.03	7.52	365.9	0.18	158	0.2342	1.7	0.13
Site3	9/2/2008 10:44	6.8	25.8	7.49	365.5	0.18	79	0.2339	1.6	0.12
Site3	9/22/2008 10:58	1	24.27	8.79	335.2	0.16	384	0.2146	146.2	10.15
Site3	9/22/2008 10:58	0.1	24.27	8.8	335.2	0.16	386	0.2146	146.2	10.16
Site3	9/22/2008 11:00	2	24.27	8.8	335.2	0.16	390	0.2146	145.9	10.14
Site3	9/22/2008 11:01	3	24.23	8.78	335.3	0.16	395	0.2146	144.7	10.06
Site3	9/22/2008 11:03	4	24.14	8.76	335.5	0.16	398	0.2147	140.9	9.81
Site3	9/22/2008 11:04	5	23.99	8.7	336.2	0.16	401	0.2151	134.1	9.37
Site3	9/22/2008 11:05	6.2	23.86	8.68	336.6	0.17	403	0.2154	125.8	8.81
Site3	10/16/2008 10:05	0.14	19.42	8.49	375.1	0.19	433	0.2401	94.9	8.38
Site3	10/16/2008 10:07	1.02	19.42	8.53	374.8	0.19	429	0.2399	95.6	8.45
Site3	10/16/2008 10:08	2.05	19.44	8.52	375	0.19	427	0.24	94.5	8.35
Site3	10/16/2008 10:09	3.04	19.46	8.52	374.9	0.19	425	0.2399	94.9	8.38
Site3	10/16/2008 10:10	4.06	19.45	8.5	374.9	0.19	424	0.2399	93.8	8.28
Site3	10/16/2008 10:12	5.01	19.45	8.5	375.3	0.19	423	0.2402	93	8.21
Site3	10/16/2008 10:14	6.02	19.43	8.5	375.6	0.19	421	0.2404	91.3	8.07
Site3	10/16/2008 10:15	6.38	19.43	8.48	375.8	0.19	417	0.2405	88.5	7.81
Site3	12/8/2008 11:13	0.5	7.81	7.8	371.9		470		89.2	10.33
Site3	12/8/2008 11:14	1	7.79	7.91	372		468		88.5	10.26
Site3	12/8/2008 11:15	2	7.79	7.97	371.9		465		88.3	10.24
Site3	12/8/2008 11:16	3	7.73	8	372.3		463		88.3	10.25
Site3	12/8/2008 11:16	4	7.76	8.02	372.1		461		88.3	10.24
Site3	12/8/2008 11:17	5	7.74	8.04	373.1		460		88.1	10.23
Site3	12/8/2008 11:17	6	7.72	8.04	372.3		460		88.2	10.24
Site3	12/8/2008 11:18	7	7.73	8.04	372.1		459		88	10.22
Site3	2/9/2009 13:54	5.65	7.45	8.3	381.3	0.19	394	0.244	101.9	11.71
Site3	2/9/2009 13:54	5.15	7.56	8.31	382.1	0.19	391	0.2437	101.9	11.69
Site3	2/9/2009 13:55	4.03	8.17	8.31	384.1	0.19	389	0.2458	102.9	11.62
Site3	2/9/2009 13:55	3.07	8.31	8.31	384.3	0.19	388	0.2459	102.8	11.57
Site3	2/9/2009 13:56	2.12	8.26	8.31	383.9	0.19	386	0.2457	103	11.61
Site3	2/9/2009 13:56	0.99	8.3	8.34	384.2	0.19	383	0.2459	103.1	11.61
Site3	2/9/2009 13:57	0.07	8.31	8.32	384.4	0.19	382	0.246	103.2	11.62
Site3	4/15/2009 11:57	0.08	13.52	8.4	411.6	0.21	391	0.2634	102.2	10.16

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site3	4/15/2009 11:58	0.99	13.53	8.42	411.7	0.21	393	0.2635	101.9	10.14
Site3	4/15/2009 11:59	2.04	13.47	8.43	411.7	0.21	394	0.2635	101.6	10.12
Site3	4/15/2009 12:00	3	13.43	8.43	411.7	0.21	397	0.2635	101	10.07
Site3	4/15/2009 12:01	3.97	13.17	8.44	411.9	0.21	399	0.2636	99.3	9.96
Site3	4/15/2009 12:01	5.05	12.84	8.4	412.1	0.21	402	0.2637	94.7	9.56
Site3	4/15/2009 12:02	6.04	12.53	8.37	412.3	0.21	404	0.2639	90	9.15
Site3	4/15/2009 12:03	5.93	12.54	8.35	412.2	0.21	405	0.2638	89.4	9.09
Site3	5/7/2009 13:41	0.04	19.44	8.38	412.6	0.21	390	0.2641	118.5	10.37
Site3	5/7/2009 13:43	1.01	19.27	8.4	412.5	0.21	390	0.264	118.5	10.4
Site3	5/7/2009 13:44	2.04	19.03	8.42	412.3	0.21	390	0.2639	117.2	10.34
Site3	5/7/2009 13:45	3	17.58	8.28	411.7	0.21	393	0.2635	96.7	8.79
Site3	5/7/2009 13:46	4.02	17.09	8.22	412.3	0.21	393	0.2639	87.9	8.07
Site3	5/7/2009 13:47	4.99	17.03	8.22	412.7	0.21	394	0.2641	87.5	8.04
Site3	5/7/2009 13:49	6	16.88	8.18	412.7	0.21	394	0.2641	83.9	7.74
Site3	5/7/2009 13:50	7.04	16.71	8.01	415.7	0.21	396	0.2661	65.9	6.1
Site3	5/7/2009 13:51	7.09	16.7	7.99	415.7	0.21	396	0.2661	65.3	6.04
Site3	5/20/2009 12:20	0.15	21.03	8.44	413.9	0.21	366	0.2649	114	9.79
Site3	5/20/2009 12:21	0.96	21.04	8.49	414	0.21	363	0.2649	114	9.79
Site3	5/20/2009 12:22	2.02	20.98	8.46	414	0.21	364	0.2649	113.4	9.75
Site3	5/20/2009 12:23	3.09	20.91	8.48	414	0.21	365	0.265	112.5	9.68
Site3	5/20/2009 12:24	3.98	20.89	8.45	414.2	0.21	367	0.2651	111.6	9.62
Site3	5/20/2009 12:25	5.01	20.86	8.46	414.3	0.21	369	0.2651	110.9	9.55
Site3	5/20/2009 12:26	5.96	20.83	8.45	414.4	0.21	371	0.2652	109.2	9.42
Site3	5/20/2009 12:30	6.45	20.77	8.45	414.3	0.21	375	0.2651	107.1	9.25
Site3	5/20/2009 12:38	6.62	20.56	8.33	413.7	0.21	366	0.2648	92.3	8
Site3	6/4/2009 13:11	0.36	22.74	8.2	410	0.2	506	0.2624	80.9	6.55
Site3	6/4/2009 13:12	1	22.7	8.22	409.9	0.2	507	0.2623	79.9	6.48
Site3	6/4/2009 13:13	2.16	22.57	8.21	410	0.2	510	0.2624	76.9	6.25
Site3	6/4/2009 13:14	3.1	22.51	8.2	409.7	0.2	511	0.2622	73.8	6
Site3	6/4/2009 13:15	4.52	22.35	8.14	410.2	0.2	513	0.2625	64.9	5.29
Site3	6/4/2009 13:17	5.03	21.52	7.92	414.7	0.21	518	0.2654	44.1	3.65
Site3	6/4/2009 13:18	6.04	19.58	7.6	419.3	0.21	525	0.2683	7.4	0.64
Site3	6/4/2009 13:19	6.52	19.46	7.56	419.9	0.21	518	0.2687	5.3	0.45
Site3	6/25/2009 12:04	0.11	32.22	8.51	401.4	0.2	343	0.2568	145.7	10.11
Site3	6/25/2009 12:05	1	32.13	8.51	401.1	0.2	351	0.2567	146.5	10.18
Site3	6/25/2009 12:06	2.01	30.6	8.25	408.3	0.2	357	0.2613	85.1	6.07
Site3	6/25/2009 12:08	2.96	28.25	8.17	418.3	0.21	361	0.2677	65	4.83
Site3	6/25/2009 12:09	4.08	27.7	8.07	420.5	0.21	363	0.2691	52.5	3.94

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site3	6/25/2009 12:11	4.96	27.11	7.82	422.9	0.21	360	0.2706	18.2	1.38
Site3	6/25/2009 12:12	5.99	26.61	7.66	425.3	0.21	302	0.2722	1.9	0.15
Site3	6/25/2009 12:13	6.4	26.28	7.63	427.2	0.21	210	0.2734	1.8	0.13
Site3	7/9/2009 11:18	6.06	28.11	8.54	410.7	0.2	299	0.2628	92.8	6.89
Site3	7/9/2009 11:18	5.94	28.13	8.56	410.6	0.2	302	0.2628	92.9	6.89
Site3	7/9/2009 11:20	5.11	28.22	8.6	409.8	0.2	309	0.2623	99.2	7.35
Site3	7/9/2009 11:20	3.99	28.31	8.6	409.7	0.2	312	0.2622	101.3	7.49
Site3	7/9/2009 11:21	2.93	28.39	8.59	409.8	0.2	318	0.2623	101.8	7.52
Site3	7/9/2009 11:22	1.82	28.49	8.61	409.9	0.2	324	0.2623	104.7	7.72
Site3	7/9/2009 11:23	1.04	28.54	8.61	409.5	0.2	328	0.2621	105.7	7.79
Site3	7/9/2009 11:24	0.05	28.55	8.58	409.7	0.2	334	0.2622	105.7	7.79
Site3	7/23/2009 11:25	0.15	28.58	8.53	393.4	0.2	223	0.2518	116.1	8.55
Site3	7/23/2009 11:26	1.03	28.18	8.54	393.2	0.2	229	0.2516	113.4	8.41
Site3	7/23/2009 11:28	2.04	27.73	8.42	395.6	0.2	241	0.2532	93.4	6.98
Site3	7/23/2009 11:29	3.01	27.69	8.38	396.4	0.2	247	0.2537	86.5	6.47
Site3	7/23/2009 11:31	4.02	27.42	8.3	396.4	0.2	254	0.2537	76.5	5.75
Site3	7/23/2009 11:32	4.99	27.37	8.22	399.1	0.2	260	0.2554	66.3	4.99
Site3	7/23/2009 11:34	5.97	26.79	7.73	414.9	0.21	250	0.2655	4.5	0.34
Site3	8/6/2009 12:00	6.14	28.34	8.54	381.7	0.19	252	0.2443	91.3	7.03
Site3	8/6/2009 12:01	6.01	28.37	8.54	381.6	0.19	254	0.2443	91.7	7.05
Site3	8/6/2009 12:02	4.97	28.37	8.55	381.5	0.19	256	0.2442	91.7	7.06
Site3	8/6/2009 12:03	3.99	28.39	8.54	381.6	0.19	258	0.2442	91.6	7.04
Site3	8/6/2009 12:04	3.03	28.39	8.53	381.3	0.19	261	0.244	92.3	7.1
Site3	8/6/2009 12:05	2	28.38	8.52	381.4	0.19	264	0.2441	92	7.08
Site3	8/6/2009 12:06	0.97	28.38	8.51	381.5	0.19	266	0.2442	92.3	7.1
Site3	8/24/2009 12:36	0.13	27.56	8.69	379.1	0.19	255	0.2426	112.7	8.48
Site3	8/24/2009 12:37	1.04	27.54	8.71	378.9	0.19	262	0.2425	111.1	8.36
Site3	8/24/2009 12:38	2.03	27.41	8.69	379.3	0.19	271	0.2427	104.1	7.86
Site3	8/24/2009 12:39	3.06	27.32	8.68	379.7	0.19	275	0.243	102.2	7.72
Site3	8/24/2009 12:39	4.03	27.32	8.68	379.7	0.19	279	0.243	101.8	7.69
Site3	8/24/2009 12:40	5.04	27.3	8.66	379.6	0.19	283	0.2429	100.6	7.61
Site3	8/24/2009 12:41	6.06	27.17	8.65	379.9	0.19	285	0.2432	95.2	7.21
Site3	8/24/2009 12:42	6.44	27.14	8.58	380.5	0.19	222	0.2435	83	6.29
Site3	9/3/2009 11:52	0.11	25.06	8.16	385.6	0.19	240	0.2468	89.5	7.09
Site3	9/3/2009 11:54	1.06	25	8.14	386	0.19	243	0.247	87.4	6.93
Site3	9/3/2009 11:55	1.97	24.97	8.14	386	0.19	245	0.247	85.5	6.78
Site3	9/3/2009 11:56	3.04	24.94	8.14	386.2	0.19	247	0.2472	84.8	6.73
Site3	9/3/2009 11:57	3.94	24.93	8.14	385.9	0.19	250	0.247	85.4	6.78

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site3	9/3/2009 11:58	4.99	24.91	8.16	385.6	0.19	252	0.2468	87	6.91
Site3	9/3/2009 11:59	6	24.89	8.15	385.8	0.19	255	0.2469	84.9	6.74
Site3	9/3/2009 12:00	6.13	24.87	8.13	386	0.19	257	0.247	80.2	6.37
Site3	9/17/2009 11:46	0.08	22.88	8.19	387.6	0.19	255	0.2481	77.9	6.33
Site3	9/17/2009 11:47	1.01	22.88	8.17	387.9	0.19	257	0.2483	77.4	6.3
Site3	9/17/2009 11:48	1.98	22.88	8.16	388	0.19	259	0.2483	77.3	6.29
Site3	9/17/2009 11:49	2.99	22.9	8.19	387.9	0.19	258	0.2483	76.7	6.24
Site3	9/17/2009 11:50	4.01	22.88	8.17	388	0.19	260	0.2483	76.2	6.2
Site3	9/17/2009 11:51	5.01	22.87	8.12	387.8	0.19	264	0.2482	75.3	6.13
Site3	9/17/2009 11:52	6.01	22.86	8.19	388	0.19	260	0.2483	72	5.86
Site3	9/17/2009 11:52	6.09	22.86	8.15	388.2	0.19	262	0.2485	72.8	5.92
Site3	9/30/2009 11:13	6.02	21.74	7.91	388.3	0.19	353	0.2485	83.4	7.06
Site3	9/30/2009 11:14	4.98	21.8	7.95	387.9	0.19	353	0.2483	89.4	7.56
Site3	9/30/2009 11:15	3.96	21.81	7.95	387.5	0.19	353	0.248	89.5	7.56
Site3	9/30/2009 11:16	3.02	21.81	7.95	388.2	0.19	354	0.2484	89.9	7.6
Site3	9/30/2009 11:16	1.97	21.82	7.95	388.1	0.19	354	0.2484	90.1	7.61
Site3	9/30/2009 11:17	1	21.84	7.96	387.9	0.19	354	0.2482	90.6	7.65
Site3	9/30/2009 11:18	0.06	21.84	7.96	353	0.17	354	0.2259	92.2	7.78
Site3	10/19/2009 12:51	6.63	15.68	8.1	378.7	0.19	348	0.2423	97.4	9.26
Site3	10/19/2009 12:52	6.38	15.71	8.12	378.4	0.19	353	0.2422	97.8	9.3
Site3	10/19/2009 12:53	5.03	15.74	8.12	378.7	0.19	355	0.2424	97.8	9.29
Site3	10/19/2009 12:54	3.96	15.76	8.12	378.6	0.19	358	0.2423	98.4	9.35
Site3	10/19/2009 12:54	3.03	15.75	8.12	378.5	0.19	359	0.2423	98.5	9.35
Site3	10/19/2009 12:55	1.64	15.77	8.14	378.6	0.19	360	0.2423	98.2	9.33
Site3	10/19/2009 12:55	1.01	15.78	8.13	378.4	0.19	361	0.2422	98.6	9.36
Site3	10/19/2009 12:55	0.22	15.79	8.13	378.6	0.19	361	0.2423	98.8	9.38

Table D-5 Site 4 HYDROLAB Station Data*

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site4	4/22/2008 12:06	0.3	16.57	8.32	388.4	0.19	349	0.2486	100.9	9.34
Site4	4/22/2008 12:07	0.9	16.5	8.32	388.3	0.19	348	0.2485	100.3	9.31
Site4	4/22/2008 12:08	2	16.37	8.31	388.8	0.19	348	0.2489	99	9.21
Site4	4/22/2008 12:09	2.9	15.99	8.31	389.2	0.19	348	0.2491	97.6	9.16
Site4	4/22/2008 12:10	3.9	15.33	8.28	389.6	0.19	348	0.2493	95.7	9.11
Site4	4/22/2008 12:11	3.9	15.33	8.29	389.6	0.19	348	0.2493	95.6	9.09
Site4	4/22/2008 12:11	5	15.28	8.29	389.6	0.19	348	0.2493	95.4	9.09
Site4	4/22/2008 12:12	5.9	14.85	8.29	389.4	0.19	348	0.2492	94.4	9.08

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site4	4/22/2008 12:13	6.9	14.46	8.28	390.3	0.19	348	0.2498	92.1	8.93
Site4	4/22/2008 12:14	7.9	14.44	8.27	389.8	0.19	348	0.2495	90.4	8.76
Site4	4/22/2008 12:15	8.9	14.43	8.25	389.9	0.19	348	0.2496	90.2	8.75
Site4	4/22/2008 12:15	8.9	14.42	8.27	389.9	0.19	348	0.2496	90.1	8.74
Site4	4/22/2008 12:16	10	14.23	8.24	390.9	0.19	349	0.2502	86.4	8.42
Site4	4/22/2008 12:17	10.9	14.18	8.22	391	0.19	349	0.2503	83.8	8.18
Site4	4/22/2008 12:18	11.1	14.16	8.18	391.4	0.19	313	0.2505	81.1	7.92
Site4	5/16/2008 12:54	0.1	19.75	8.27	398	0.2	367	0.2547	105	9.13
Site4	5/16/2008 12:55	1	19.82	8.28	398.3	0.2	361	0.2549	104.4	9.06
Site4	5/16/2008 12:55	2	19.24	8.28	395.7	0.2	358	0.2533	102.9	9.04
Site4	5/16/2008 12:56	3	18.97	8.26	394.5	0.2	356	0.2525	98.6	8.71
Site4	5/16/2008 12:57	4	18.89	8.24	394.8	0.2	353	0.2527	95.4	8.44
Site4	5/16/2008 12:58	5	18.87	8.23	394.9	0.2	351	0.2527	95	8.41
Site4	5/16/2008 12:58	6	18.85	8.23	394.7	0.2	349	0.2526	94.4	8.36
Site4	5/16/2008 12:59	7	18.85	8.23	394.6	0.2	348	0.2525	94.8	8.39
Site4	5/16/2008 13:00	8	18.83	8.24	394.1	0.2	347	0.2523	95	8.42
Site4	5/16/2008 13:01	9	18.82	8.25	394.2	0.2	346	0.2523	95.6	8.47
Site4	5/16/2008 13:01	10	18.77	8.24	394.5	0.2	346	0.2525	94.5	8.38
Site4	5/16/2008 13:02	10.4	18.7	8.2	394.5	0.2	300	0.2525	7.2	0.64
Site4	5/21/2008 13:46	0.1	21.68	8.55	397.3	0.2	413	0.2543	N/A	N/A
Site4	5/21/2008 13:46	1	21.69	8.56	397.3	0.2	413	0.2543	N/A	N/A
Site4	5/21/2008 13:47	2	21.51	8.55	396.8	0.2	413	0.254	N/A	N/A
Site4	5/21/2008 13:48	2.9	21.43	8.55	396.4	0.2	413	0.2537	N/A	N/A
Site4	5/21/2008 13:48	3.9	21.33	8.53	395.7	0.2	413	0.2532	N/A	N/A
Site4	5/21/2008 13:49	5	21.24	8.52	394.8	0.2	413	0.2527	N/A	N/A
Site4	5/21/2008 13:50	6	21.18	8.51	395.3	0.2	412	0.253	N/A	N/A
Site4	5/21/2008 13:50	7	21.12	8.48	397	0.2	412	0.2541	N/A	N/A
Site4	5/21/2008 13:51	8	19.25	8.24	401.2	0.2	417	0.2568	N/A	N/A
Site4	5/21/2008 13:52	9.1	18.84	8.13	402.7	0.2	419	0.2577	N/A	N/A
Site4	5/21/2008 13:53	10.1	18.88	8.1	403	0.2	418	0.2579	N/A	N/A
Site4	5/21/2008 13:53	11.1	18.81	8.07	403.2	0.2	418	0.258	N/A	N/A
Site4	5/21/2008 13:54	12	18.75	8.03	404.6	0.2	418	0.259	N/A	N/A
Site4	5/21/2008 13:55	13	18.73	8.02	405.7	0.2	418	0.2596	N/A	N/A
Site4	5/21/2008 13:55	13.2	18.69	7.99	406.9	0.2	409	0.2604	N/A	N/A
Site4	6/4/2008 14:36	0.1	25.43	8.34	362	0.2	421	0.231	94.3	7.45
Site4	6/4/2008 14:37	0.6	25.4	8.35	362	0.2	427	0.231	92.4	7.31
Site4	6/4/2008 14:38	1.1	25.39	8.35	361	0.2	431	0.231	91.4	7.23
Site4	6/4/2008 14:40	2	25.39	8.34	361	0.2	435	0.231	91.8	7.26

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site4	6/4/2008 14:41	3	25.36	8.32	362	0.2	439	0.232	90.6	7.17
Site4	6/4/2008 14:43	4	25.36	8.34	362	0.2	441	0.232	90.7	7.18
Site4	6/4/2008 14:44	6.1	25.22	8.32	363	0.2	443	0.232	87.4	6.93
Site4	6/4/2008 14:47	7.1	25.06	8.29	363	0.2	445	0.232	82.9	6.59
Site4	6/4/2008 14:49	8	23.29	7.94	364	0.2	459	0.232	45.4	3.74
Site4	6/4/2008 14:51	9	20.36	7.45	365	0.2	472	0.233	6.2	0.54
Site4	6/4/2008 14:52	10	19.58	7.42	365	0.2	471	0.234	1.5	0.13
Site4	6/4/2008 14:54	10.6	19.5	7.45	364	0.2	446	0.233	5.1	0.45
Site4	6/4/2008 14:55	13.1	19.23	7.4	373	0.2	386	0.239	3.2	0.28
Site4	6/18/2008 11:52	0.2	26.62	8.45	405.6	0.2	207	0.2596	101.6	7.82
Site4	6/18/2008 11:56	1.2	25.87	8.52	404.2	0.2	201	0.2587	98.1	7.66
Site4	6/18/2008 11:57	2.1	25.85	8.52	404.7	0.2	200	0.259	97.1	7.58
Site4	6/18/2008 11:58	3.3	25.71	8.47	407	0.2	202	0.2604	89.6	7.02
Site4	6/18/2008 11:59	4.1	25.66	8.44	407.6	0.2	204	0.2609	84.4	6.61
Site4	6/18/2008 11:59	4.2	25.65	8.44	407.6	0.2	204	0.2609	84.4	6.61
Site4	6/18/2008 12:00	5.8	25.63	8.41	407.7	0.2	207	0.2609	84.2	6.6
Site4	6/18/2008 12:01	6	25.64	8.36	407.7	0.2	210	0.2609	84	6.58
Site4	6/18/2008 12:02	7	25.64	8.36	407.7	0.2	211	0.2609	83	6.51
Site4	6/18/2008 12:03	8.1	25.6	8.37	408	0.2	211	0.2611	79.7	6.25
Site4	6/18/2008 12:05	9.8	25.11	8.22	407.8	0.2	213	0.2617	69.5	5.51
Site4	6/18/2008 12:07	10	24.64	7.88	414.3	0.21	212	0.2652	20.3	1.62
Site4	6/18/2008 12:08	11.1	23.7	7.71	415	0.21	207	0.2656	9.1	0.74
Site4	6/18/2008 12:09	12.1	23.06	7.67	417.8	0.21	199	0.2674	1.7	0.14
Site4	6/18/2008 12:10	12.9	22.57	7.66	420.8	0.21	191	0.2693	1.5	0.12
Site4	6/18/2008 12:11	13.8	21.96	7.59	429.1	0.21	97	0.2746	1.6	0.13
Site4	7/9/2008 13:31	0.1	28.66	8.76	381.9	0.19	316	0.2444	121.7	9
Site4	7/9/2008 13:32	1	28.46	8.68	383.4	0.19	314	0.2454	115.3	8.56
Site4	7/9/2008 13:33	2	28.37	8.68	384.2	0.19	308	0.2459	108.1	8.04
Site4	7/9/2008 13:33	3.1	28.35	8.64	384.4	0.19	305	0.246	104.6	7.78
Site4	7/9/2008 13:34	4	28.33	8.58	384.9	0.19	304	0.2463	101.2	7.53
Site4	7/9/2008 13:35	5	28.28	8.5	385.8	0.19	303	0.2469	95.4	7.1
Site4	7/9/2008 13:36	6.1	27.67	8.16	392.7	0.2	305	0.2513	46.9	3.53
Site4	7/9/2008 13:38	7.4	27.43	8.05	394.4	0.2	296	0.2524	29.4	2.22
Site4	7/9/2008 13:39	8	27.06	7.89	396.8	0.2	295	0.254	11.1	0.85
Site4	7/9/2008 13:40	9	26.1	7.75	398.6	0.2	228	0.2551	1.8	0.14
Site4	7/9/2008 13:41	10.1	24.64	7.64	401.6	0.2	-40	0.257	1.6	0.12
Site4	7/9/2008 13:41	11	24.35	7.62	401.7	0.2	-101	0.2571	1.5	0.12
Site4	7/9/2008 13:42	12	23.26	7.6	407.6	0.2	-128	0.2609	1.4	0.11
Site4	7/9/2008 13:43	12.9	22.81	7.36	416.2	0.21	-103	0.2664	1.3	0.11

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site4	7/21/2008 11:51	0.1	29.92	8.56	366.1	0.18	180	0.2343	147.7	10.7
Site4	7/21/2008 11:52	0.98	29.84	8.6	364.6	0.18	186	0.2334	150.4	10.91
Site4	7/21/2008 11:53	2.05	29.38	8.61	367.8	0.18	189	0.2354	144.9	10.59
Site4	7/21/2008 11:55	2.98	29.11	8.55	369.5	0.18	194	0.2365	134.9	9.9
Site4	7/21/2008 11:56	4.05	29.03	8.49	370.6	0.18	200	0.2372	129.1	9.49
Site4	7/21/2008 11:58	5.05	28.23	8.17	376.4	0.19	201	0.2409	75.4	5.62
Site4	7/21/2008 12:00	5.95	28.02	8.05	379.4	0.19	199	0.2428	57.3	4.29
Site4	7/21/2008 12:01	7.07	27.56	7.69	387.8	0.19	180	0.2482	6.5	0.49
Site4	7/21/2008 12:03	7.95	27.3	7.65	388.1	0.19	105	0.2484	1.7	0.13
Site4	7/21/2008 12:04	9	26.09	7.61	395	0.2	-86	0.2528	1.8	0.14
Site4	7/21/2008 12:05	9.98	24.87	7.49	397.5	0.2	-115	0.2544	1.6	0.13
Site4	8/4/2008 11:29	0.4	30.56	8.7	397.6	0.2	176	0.2545	130.8	9.35
Site4	8/4/2008 11:30	1.1	30.55	8.66	397.1	0.2	186	0.2541	131.3	9.38
Site4	8/4/2008 11:33	2	30.3	8.62	397.2	0.2	196	0.2542	126.6	9.1
Site4	8/4/2008 11:35	3	30.04	8.47	400.4	0.2	200	0.2563	107.7	7.77
Site4	8/4/2008 11:38	4.1	29.59	8.08	410.7	0.2	186	0.2628	48.5	3.53
Site4	8/4/2008 11:41	5	29.34	7.98	412.3	0.21	183	0.2639	39.8	2.9
Site4	8/4/2008 11:43	6	28.57	7.71	420.4	0.21	-6	0.2691	1.6	0.12
Site4	8/4/2008 11:45	6.9	28.25	7.68	423.7	0.21	-56	0.2712	1.4	0.1
Site4	8/4/2008 11:46	8.5	27.44	7.62	430.9	0.22	-89	0.2758	1.1	0.09
Site4	8/4/2008 11:47	9.2	25.6	7.5	444.2	0.22	-100	0.2844	1.2	0.09
Site4	8/4/2008 11:49	9.8	24.64	7.44	449	0.23	-108	0.2874	1	0.08
Site4	8/18/2008 10:53	0.2	27.02	8.46	360.8	0.18	220	0.2309	78.6	6.01
Site4	8/18/2008 10:54	1.1	27.09	8.44	361	0.18	226	0.231	77.8	5.93
Site4	8/18/2008 10:56	2	27.07	8.42	360.8	0.18	233	0.2309	77.2	5.89
Site4	8/18/2008 10:57	3	27.1	8.4	360.9	0.18	238	0.231	77	5.87
Site4	8/18/2008 10:58	4.1	27.07	8.4	361.1	0.18	241	0.2311	77.4	5.9
Site4	8/18/2008 10:59	5.1	27.08	8.39	361.5	0.18	244	0.2314	77.2	5.89
Site4	8/18/2008 11:00	6.1	27.1	8.38	360.9	0.18	247	0.2309	77.1	5.88
Site4	8/18/2008 11:01	7.1	27.1	8.38	360.9	0.18	248	0.231	76.1	5.8
Site4	8/18/2008 11:02	8.1	27.09	8.37	361.5	0.18	250	0.2314	76.4	5.82
Site4	8/18/2008 11:03	9.1	27.08	8.37	360.8	0.18	247	0.2309	74.5	5.69
Site4	8/18/2008 11:05	10.1	24.99	8.27	403.2	0.2	-45	0.2578	2.4	0.19
Site4	9/2/2008 13:02	0.1	28.15	8.6	353.1	0.17	207	0.226	127.6	9.5
Site4	9/2/2008 13:03	1	28.14	8.59	353.1	0.17	211	0.226	126.7	9.44
Site4	9/2/2008 13:04	2	28.12	8.6	353	0.17	212	0.2259	125.3	9.34
Site4	9/2/2008 13:05	3	28.04	8.6	353.2	0.17	215	0.2261	123	9.18
Site4	9/2/2008 13:06	4	27.97	8.56	352.4	0.17	217	0.2255	114.9	8.59

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site4	9/2/2008 13:08	5.1	27.76	8.47	354.5	0.17	222	0.2269	96.7	7.26
Site4	9/2/2008 13:10	6	27	7.69	363.4	0.18	218	0.2326	17.1	1.3
Site4	9/2/2008 13:12	6.9	26.05	7.5	365.1	0.18	90	0.2337	1.9	0.15
Site4	9/2/2008 13:14	8.1	25.59	7.47	360.8	0.18	11	0.2309	1.4	0.11
Site4	9/2/2008 13:15	9	25.08	7.45	352.5	0.17	-17	0.2256	1.3	0.1
Site4	9/2/2008 13:16	10	24.15	7.32	340	0.17	-41	0.2176	1.3	0.11
Site4	9/2/2008 13:18	10.5	23.72	7.15	344	0.17	-59	0.2201	1.3	0.1
Site4	9/22/2008 13:56	0.2	23.89	8.6	338.6	0.17	249	0.2167	99.4	6.96
Site4	9/22/2008 13:57	1.1	23.83	8.53	338.4	0.17	250	0.2166	97.8	6.85
Site4	9/22/2008 13:58	2	23.69	8.53	338.9	0.17	248	0.2169	93.3	6.55
Site4	9/22/2008 14:00	3.1	23.6	8.47	339.4	0.17	244	0.2172	82.8	5.83
Site4	9/22/2008 14:03	4	23.52	8.41	339.9	0.17	241	0.2176	75.4	5.31
Site4	9/22/2008 14:05	5.1	23.31	8.21	340.6	0.17	233	0.218	50.6	3.58
Site4	9/22/2008 14:06	5.1	23.26	8.19	340.8	0.17	227	0.2181	53.3	3.78
Site4	9/22/2008 14:10	6.1	23.23	8.06	341.2	0.17	218	0.2184	37.8	2.68
Site4	9/22/2008 14:13	7	23.22	8.01	341.3	0.17	215	0.2184	32.3	2.29
Site4	9/22/2008 14:14	8	23.13	7.98	341.6	0.17	214	0.2186	25	1.77
Site4	9/22/2008 14:16	9	23.05	7.91	344.8	0.17	209	0.2207	6.4	0.45
Site4	9/22/2008 14:18	10	23.04	7.89	345.1	0.17	200	0.2208	4.9	0.35
Site4	9/22/2008 14:21	11	23.03	7.88	345.8	0.17	195	0.2213	4	0.28
Site4	9/22/2008 14:22	11.9	23.01	7.88	347.6	0.17	191	0.2225	1.4	0.1
Site4	9/22/2008 14:24	12.6	22.96	7.89	352.9	0.17	186	0.2259	1.4	0.1
Site4	9/22/2008 14:27	12.9	22.92	7.31	359.7	0.18	61	0.2302	1.4	0.1
Site4	10/16/2008 12:19	0.1	20.4	8.35	378.1	0.19	375	0.242	88.4	7.66
Site4	10/16/2008 12:20	1.04	20.39	8.32	378.1	0.19	376	0.242	87.7	7.6
Site4	10/16/2008 12:21	2.03	20.36	8.38	378.1	0.19	373	0.242	86.5	7.5
Site4	10/16/2008 12:22	3.02	20.34	8.36	378.3	0.19	371	0.2421	85.9	7.45
Site4	10/16/2008 12:24	3.98	20.3	8.38	378.2	0.19	370	0.2421	84.7	7.35
Site4	10/16/2008 12:24	5.01	20.28	8.41	378.2	0.19	370	0.242	84.2	7.31
Site4	10/16/2008 12:25	6.01	20.24	8.39	378.1	0.19	369	0.242	84.4	7.33
Site4	10/16/2008 12:26	7.02	20.18	8.37	378.2	0.19	369	0.242	84.5	7.35
Site4	10/16/2008 12:27	8.01	20.12	8.38	378.1	0.19	369	0.242	84.6	7.36
Site4	10/16/2008 12:28	9.03	20.03	8.38	378.4	0.19	369	0.2422	83	7.24
Site4	10/16/2008 12:29	9.25	20.05	8.36	378.4	0.19	365	0.2422	82.1	7.16
Site4	12/8/2008 13:34	0.5	7.88	8.17	373.8	N/A	416	N/A	85.8	9.91
Site4	12/8/2008 13:36	1	7.89	8.14	373.4	N/A	415	N/A	85.7	9.91
Site4	12/8/2008 13:36	2	7.89	8.14	373.5	N/A	415	N/A	85.9	9.94
Site4	12/8/2008 13:37	3	7.88	8.15	373.8	N/A	414	N/A	85.9	9.94

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Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site4	12/8/2008 13:38	4	7.88	8.13	373.5	N/A	414	N/A	86.1	9.95
Site4	12/8/2008 13:38	5	7.9	8.16	373.6	N/A	412	N/A	86.4	9.98
Site4	12/8/2008 13:39	6	7.92	8.16	373.6	N/A	411	N/A	86.4	9.99
Site4	12/8/2008 13:40	7	7.92	8.18	373.5	N/A	410	N/A	86.5	9.99
Site4	12/8/2008 13:40	8	7.92	8.19	373.6	N/A	410	N/A	86.6	10.01
Site4	12/8/2008 13:40	9	7.94	8.2	373.5	N/A	409	N/A	86.7	10.01
Site4	2/9/2009 12:15	0.25	6.64	8.16	384.2	0.19	432	0.2459	102.1	11.98
Site4	2/9/2009 12:15	1.08	6.62	8.16	384.8	0.19	431	0.2463	102	11.97
Site4	2/9/2009 12:16	2	6.61	8.18	384.8	0.19	429	0.2463	101.9	11.96
Site4	2/9/2009 12:17	3.06	6.58	8.18	384.4	0.19	429	0.246	101.8	11.96
Site4	2/9/2009 12:17	4.04	6.57	8.19	384.4	0.19	428	0.246	101.7	11.95
Site4	2/9/2009 12:18	5.07	6.54	8.19	384.2	0.19	428	0.2459	101.5	11.93
Site4	2/9/2009 12:18	5.99	6.54	8.19	384.5	0.19	428	0.2461	101.5	11.93
Site4	2/9/2009 12:19	7.06	6.58	8.19	384.5	0.19	428	0.2461	101.4	11.92
Site4	2/9/2009 12:20	8.58	6.49	8.2	383.8	0.19	428	0.2457	101.2	11.91
Site4	2/9/2009 12:21	9.02	6.51	8.2	384.3	0.19	428	0.246	101	11.88
Site4	2/9/2009 12:22	9.91	6.58	8.2	384.6	0.19	427	0.2462	100.8	11.84
Site4	2/9/2009 12:22	11.02	6.54	8.19	384.4	0.19	428	0.246	100.8	11.85
Site4	2/9/2009 12:23	12.01	6.51	8.19	384.2	0.19	428	0.2459	100.7	11.85
Site4	2/9/2009 12:23	13.04	6.36	7.83	385.7	0.19	351	0.2468	74	8.74
Site4	2/9/2009 12:38	12.91	6.44	8.25	384	0.19	202	0.2457	99.8	11.77
Site4	2/9/2009 12:39	11.83	6.44	8.21	383.7	0.19	187	0.2458	83	9.79
Site4	4/15/2009 10:03	12.6	12.05	8.25	417.4	0.21	435	0.2672	80.8	8.31
Site4	4/15/2009 10:05	11.96	12.07	8.31	415.1	0.21	435	0.2657	88	9.04
Site4	4/15/2009 10:06	11.01	12.11	8.34	415.2	0.21	436	0.2657	90.3	9.27
Site4	4/15/2009 10:07	9.89	12.17	8.34	414.6	0.21	437	0.2653	90.9	9.32
Site4	4/15/2009 10:14	9.11	12.21	8.35	414.6	0.21	445	0.2653	93.6	9.59
Site4	4/15/2009 10:16	7.96	12.26	8.36	414.8	0.21	446	0.2655	94.3	9.65
Site4	4/15/2009 10:16	7.02	12.29	8.35	414.9	0.21	448	0.2655	94.5	9.66
Site4	4/15/2009 10:17	6	12.32	8.35	415.1	0.21	448	0.2657	94.8	9.68
Site4	4/15/2009 10:18	5.01	12.35	8.36	415.1	0.21	449	0.2657	94.8	9.68
Site4	4/15/2009 10:19	4	12.44	8.38	415.4	0.21	449	0.2658	95.6	9.74
Site4	4/15/2009 10:20	2.59	12.64	8.41	415	0.21	448	0.2657	97.7	9.91
Site4	4/15/2009 10:20	2.06	12.94	8.42	415.5	0.21	449	0.2659	99.4	10.01
Site4	4/15/2009 10:21	0.91	13.02	8.45	415.6	0.21	450	0.266	101.9	10.25
Site4	4/15/2009 10:22	0.12	13.1	8.45	415.7	0.21	449	0.266	102.3	10.27
Site4	5/7/2009 11:19	0.11	19.15	8.2	417.6	0.21	367	0.2673	101.8	8.96
Site4	5/7/2009 11:19	0.23	19.15	8.2	417.7	0.21	368	0.2674	102	8.98

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site4	5/7/2009 11:20	1.01	18.18	8.23	415.6	0.21	369	0.266	98.5	8.85
Site4	5/7/2009 11:21	2.01	17.37	8.22	416.6	0.21	370	0.2666	93.6	8.54
Site4	5/7/2009 11:22	2.98	17.29	8.21	416.9	0.21	371	0.2668	90.3	8.26
Site4	5/7/2009 11:24	3.99	17.22	8.2	417.1	0.21	373	0.267	88.8	8.13
Site4	5/7/2009 11:25	5.02	17.21	8.2	416.8	0.21	375	0.2668	87.3	8
Site4	5/7/2009 11:26	6	17.2	8.21	417	0.21	376	0.2669	87.9	8.05
Site4	5/7/2009 11:28	7	17.17	8.23	417.1	0.21	378	0.2669	89.1	8.17
Site4	5/7/2009 11:29	8.02	17.16	8.22	416.8	0.21	379	0.2668	88.8	8.14
Site4	5/7/2009 11:32	9	17.11	8.09	415.5	0.21	382	0.2659	75.7	6.95
Site4	5/7/2009 11:34	9.93	16.81	8	420.7	0.21	385	0.2693	66	6.1
Site4	5/7/2009 11:35	10.96	16.74	7.99	421	0.21	386	0.2694	66.5	6.15
Site4	5/7/2009 11:36	12.04	16.69	7.97	418.4	0.21	387	0.2678	67.2	6.23
Site4	5/7/2009 11:37	13.03	16.61	7.89	422.8	0.21	390	0.2706	56.5	5.24
Site4	5/20/2009 10:00	0.14	20.3	8.43	415.2	0.21	410	0.2658	113.1	9.86
Site4	5/20/2009 10:02	0.96	20.29	8.44	415.4	0.21	413	0.2659	113.3	9.87
Site4	5/20/2009 10:03	2.02	20.28	8.44	415.4	0.21	416	0.2658	113.1	9.86
Site4	5/20/2009 10:04	2.98	20.17	8.41	415.5	0.21	418	0.2659	110.8	9.68
Site4	5/20/2009 10:06	4.1	20	8.32	416.1	0.21	420	0.2663	99.9	8.76
Site4	5/20/2009 10:07	5.04	19.76	8.3	416.3	0.21	422	0.2664	96.4	8.5
Site4	5/20/2009 10:08	5.95	19.11	8.18	417.1	0.21	425	0.2669	85.6	7.64
Site4	5/20/2009 10:09	7.03	19.06	8.17	417.2	0.21	426	0.267	83.9	7.49
Site4	5/20/2009 10:11	8	18.99	8.15	417.8	0.21	427	0.2674	81	7.25
Site4	5/20/2009 10:12	8.99	18.96	8.1	418.7	0.21	428	0.268	75.6	6.77
Site4	5/20/2009 10:14	10.06	18.59	7.93	421.4	0.21	431	0.2697	58.3	5.26
Site4	5/20/2009 10:15	11.05	18.54	7.9	421.7	0.21	432	0.2699	55.9	5.05
Site4	5/20/2009 10:16	11.93	18.48	7.88	422.3	0.21	432	0.2703	52.8	4.77
Site4	5/20/2009 10:17	12.93	18.4	7.85	422.9	0.21	433	0.2706	49.8	4.5
Site4	5/20/2009 10:20	13.34	18.24	7.75	425.7	0.21	159	0.2724	31.4	2.85
Site4	6/4/2009 10:25	0.1	23.67	8.51	400	0.2	548	0.256	100.4	7.99
Site4	6/4/2009 10:26	0.98	23.68	8.5	399.8	0.2	548	0.2558	99.7	7.93
Site4	6/4/2009 10:28	1.98	23.65	8.48	399.9	0.2	550	0.256	98.4	7.83
Site4	6/4/2009 10:28	3.05	23.67	8.48	399.9	0.2	551	0.2559	99.3	7.9
Site4	6/4/2009 10:29	4.01	23.63	8.46	400.2	0.2	552	0.2561	96.2	7.66
Site4	6/4/2009 10:30	4.99	23.61	8.45	400.1	0.2	552	0.2561	95.2	7.58
Site4	6/4/2009 10:31	6	23.59	8.43	400.6	0.2	553	0.2564	92.1	7.34
Site4	6/4/2009 10:32	6.95	21.75	7.87	419.5	0.21	559	0.2685	29	2.39
Site4	6/4/2009 10:32	7.97	20.31	7.62	419.8	0.21	560	0.2687	6.1	0.52
Site4	6/4/2009 10:34	9.02	18.73	7.51	421.1	0.21	560	0.2695	2.3	0.2

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site4	6/4/2009 10:35	9.99	18.64	7.49	421.8	0.21	555	0.2699	2	0.18
Site4	6/4/2009 10:36	11.06	18.32	7.5	421.9	0.21	557	0.27	1.8	0.16
Site4	6/4/2009 10:37	12.03	18.21	7.5	422.8	0.21	557	0.2706	1.8	0.16
Site4	6/4/2009 10:38	12	18.2	7.54	422.7	0.21	535	0.2705	1.7	0.15
Site4	6/4/2009 10:39	12.9	18.14	7.52	423.8	0.21	527	0.2712	1.7	0.15
Site4	6/25/2009 10:00	0.19	30.83	8.45	405	0.2	342	0.2592	141.3	10.04
Site4	6/25/2009 10:01	0.98	30.56	8.43	407.1	0.2	352	0.2606	143.1	10.21
Site4	6/25/2009 10:02	2.04	29.6	8.39	409.5	0.2	364	0.262	136.8	9.93
Site4	6/25/2009 10:03	3.05	28.87	8.28	419.9	0.21	370	0.2687	101.4	7.45
Site4	6/25/2009 10:04	4.09	28.17	8.16	420.5	0.21	373	0.2691	80.2	5.97
Site4	6/25/2009 10:05	5.05	27.43	7.93	423.9	0.21	372	0.2713	43.7	3.3
Site4	6/25/2009 10:06	6.07	26.89	7.78	423.3	0.21	370	0.2709	24.7	1.88
Site4	6/25/2009 10:07	7.08	24.49	7.58	425.3	0.21	184	0.2722	2.2	0.18
Site4	6/25/2009 10:08	8.06	23.26	7.54	426.6	0.21	119	0.273	2.1	0.17
Site4	6/25/2009 10:08	9.08	21.61	7.47	430.4	0.22	66	0.2755	2	0.16
Site4	6/25/2009 10:09	10.04	20.27	7.39	434.4	0.22	30	0.278	1.9	0.16
Site4	6/25/2009 10:10	11.14	19.59	7.39	432.9	0.22	11	0.2771	1.8	0.16
Site4	6/25/2009 10:10	12.07	19.29	7.4	433.5	0.22	-8	0.2774	1.8	0.16
Site4	6/25/2009 10:11	12.92	19.09	7.38	436.4	0.22	-29	0.2793	1.6	0.15
Site4	7/9/2009 9:20	12.38	19.5	7.55	442.7	0.22	-18	0.2833	2	0.17
Site4	7/9/2009 9:24	12.04	19.5	7.58	442.8	0.22	-64	0.2834	1.5	0.13
Site4	7/9/2009 9:25	10.98	20.21	7.62	442.9	0.22	-74	0.2835	1.4	0.12
Site4	7/9/2009 9:27	9.91	20.33	7.62	443.3	0.22	-81	0.2837	1.4	0.12
Site4	7/9/2009 9:27	8.97	21.77	7.7	438.5	0.22	-82	0.2807	1.3	0.11
Site4	7/9/2009 9:29	7.98	23.52	7.76	435.8	0.22	-82	0.2789	1.2	0.1
Site4	7/9/2009 9:30	6.25	26.22	7.96	425.4	0.21	-5	0.2722	12	0.92
Site4	7/9/2009 9:30	6	27.79	8.42	413.8	0.21	49	0.2648	70.4	5.26
Site4	7/9/2009 9:31	5.09	27.88	8.47	413.6	0.21	77	0.2647	77	5.74
Site4	7/9/2009 9:32	4.01	27.93	8.46	413.6	0.21	116	0.2647	78.2	5.83
Site4	7/9/2009 9:33	2.99	27.95	8.44	413.8	0.21	130	0.2648	78.5	5.85
Site4	7/9/2009 9:34	1.88	27.96	8.41	413.5	0.21	156	0.2647	79.4	5.91
Site4	7/9/2009 9:35	0.97	27.96	8.4	413.4	0.21	170	0.2646	79.9	5.95
Site4	7/9/2009 9:36	0.16	27.95	8.4	413.6	0.21	188	0.2647	80.3	5.98
Site4	7/23/2009 9:32	0.13	28.11	8.45	397.1	0.2	272	0.2542	104.9	7.79
Site4	7/23/2009 9:33	1.01	27.94	8.41	397.4	0.2	276	0.2544	100.4	7.48
Site4	7/23/2009 9:34	2.04	27.92	8.4	397.7	0.2	277	0.2545	97.8	7.28
Site4	7/23/2009 9:35	3.02	27.91	8.4	398	0.2	279	0.2547	95.1	7.09
Site4	7/23/2009 9:36	4.01	27.9	8.38	398.1	0.2	282	0.2548	94.1	7.01

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site4	7/23/2009 9:37	5	27.87	8.37	398.2	0.2	284	0.2548	93	6.93
Site4	7/23/2009 9:38	5.96	27.86	8.37	398.1	0.2	287	0.2548	93.5	6.98
Site4	7/23/2009 9:39	6.99	27.84	8.37	398.2	0.2	290	0.2549	93.2	6.96
Site4	7/23/2009 9:40	8.01	26.95	8.06	411.1	0.21	292	0.2631	17.7	1.34
Site4	7/23/2009 9:43	8.99	22.35	7.41	436.1	0.22	14	0.2791	2.2	0.18
Site4	7/23/2009 9:44	10.04	21.1	7.32	440.4	0.22	-15	0.2818	2.1	0.18
Site4	7/23/2009 9:45	10.3	20.39	7.28	442.6	0.22	-34	0.2832	1.8	0.15
Site4	8/6/2009 10:22	12.54	19.93	7.28	448.4	0.23	-29	0.287	2.8	0.26
Site4	8/6/2009 10:24	11.79	19.99	7.26	448.8	0.23	-50	0.2872	2.2	0.2
Site4	8/6/2009 10:25	11	20.9	7.32	446.3	0.22	-68	0.2856	1.9	0.17
Site4	8/6/2009 10:26	9.96	21.93	7.41	441.9	0.22	-74	0.2828	1.8	0.16
Site4	8/6/2009 10:27	8.59	24.97	7.69	414.2	0.21	-71	0.2651	1.6	0.13
Site4	8/6/2009 10:27	7.99	26.57	7.84	399.8	0.2	-35	0.2559	9.1	0.72
Site4	8/6/2009 10:28	7	27.15	8.07	395.2	0.2	11	0.2529	35.6	2.8
Site4	8/6/2009 10:29	5.92	27.51	8.26	392.4	0.2	53	0.2511	60.2	4.7
Site4	8/6/2009 10:30	4.96	27.76	8.48	386.5	0.19	89	0.2473	89.9	6.99
Site4	8/6/2009 10:31	3.4	27.77	8.49	386.4	0.19	111	0.2473	91.9	7.14
Site4	8/6/2009 10:33	2.38	27.77	8.51	386.2	0.19	135	0.2472	93.8	7.3
Site4	8/6/2009 10:33	1.98	27.78	8.49	386.2	0.19	145	0.2472	94.5	7.35
Site4	8/6/2009 10:34	0.82	27.78	8.49	386.1	0.19	152	0.2471	94.4	7.34
Site4	8/6/2009 10:34	0.21	27.76	8.46	386.2	0.19	162	0.2472	94.7	7.36
Site4	8/24/2009 11:08	0.22	27.36	8.62	0.9	-0	311	0.0006	101.9	7.7
Site4	8/24/2009 11:10	1.04	27.45	8.64	381.8	0.19	315	0.2444	102.4	7.72
Site4	8/24/2009 11:11	2.14	27.38	8.64	382.1	0.19	318	0.2446	97.1	7.33
Site4	8/24/2009 11:12	3.09	27.33	8.63	382.5	0.19	320	0.2448	94.2	7.12
Site4	8/24/2009 11:13	4.1	27.28	8.61	382.9	0.19	323	0.2451	90.5	6.85
Site4	8/24/2009 11:14	5.09	27.26	8.63	382.7	0.19	324	0.2449	92.4	6.99
Site4	8/24/2009 11:14	6.03	27.19	8.67	382.1	0.19	324	0.2445	96.1	7.28
Site4	8/24/2009 11:15	7.04	27.13	8.65	382.6	0.19	326	0.2449	92.2	6.99
Site4	8/24/2009 11:16	8.05	26.66	7.99	395.7	0.2	243	0.2532	5.7	0.44
Site4	8/24/2009 11:17	8.98	26.25	7.91	402.2	0.2	73	0.2574	2.5	0.19
Site4	8/24/2009 11:17	9.56	26.04	7.89	402.7	0.2	37	0.2578	2.1	0.16
Site4	9/3/2009 10:01	0.15	25.31	8.14	385.3	0.19	236	0.2466	77.3	6.09
Site4	9/3/2009 10:01	1.11	25.31	8.14	385.4	0.19	235	0.2467	76.8	6.05
Site4	9/3/2009 10:02	2.01	25.32	8.13	385.9	0.19	233	0.247	74.9	5.9
Site4	9/3/2009 10:03	3	25.32	8.14	385.6	0.19	232	0.2468	74.2	5.85
Site4	9/3/2009 10:04	4	25.32	8.13	385.6	0.19	232	0.2468	75.2	5.93
Site4	9/3/2009 10:04	4.03	25.32	8.13	385.7	0.19	232	0.2469	74.8	5.89

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site4	9/3/2009 10:04	5.05	25.32	8.13	385.6	0.19	232	0.2468	74.6	5.88
Site4	9/3/2009 10:05	6.05	25.32	8.13	385.6	0.19	232	0.2468	74.7	5.88
Site4	9/3/2009 10:06	6.97	25.32	8.13	385.7	0.19	232	0.2469	74.6	5.88
Site4	9/3/2009 10:06	8.02	25.32	8.12	385.6	0.19	232	0.2468	74.2	5.85
Site4	9/3/2009 10:07	8.97	25.32	8.12	385.6	0.19	233	0.2468	73.9	5.83
Site4	9/3/2009 10:08	10.06	25.32	8.12	385.6	0.19	233	0.2468	73.3	5.78
Site4	9/3/2009 10:08	10.95	25.32	8.11	385.7	0.19	234	0.2469	72.8	5.74
Site4	9/3/2009 10:09	11.9	22.03	7.08	468.2	0.24	66	0.2997	4.2	0.35
Site4	9/3/2009 10:10	12.45	21.23	7	473.3	0.24	42	0.3029	3.7	0.32
Site4	9/3/2009 10:10	12.35	21.24	6.97	473.6	0.24	28	0.3031	2.2	0.19
Site4	9/17/2009 10:09	12.37	23.61	8.52	386.6	0.19	228	0.2474	72	5.78
Site4	9/17/2009 10:10	11.81	23.59	8.51	386.6	0.19	230	0.2474	72.4	5.81
Site4	9/17/2009 10:10	10.98	23.62	8.57	386.4	0.19	227	0.2473	72.6	5.83
Site4	9/17/2009 10:11	9.98	23.62	8.49	386.4	0.19	233	0.2473	72.9	5.84
Site4	9/17/2009 10:13	9.02	23.63	8.48	386.7	0.19	234	0.2475	72.9	5.85
Site4	9/17/2009 10:13	8	23.64	8.58	386.4	0.19	228	0.2473	73.2	5.87
Site4	9/17/2009 10:14	7	23.64	8.52	386.3	0.19	233	0.2472	73.4	5.88
Site4	9/17/2009 10:14	6.02	23.65	8.51	386.5	0.19	234	0.2473	73.3	5.88
Site4	9/17/2009 10:15	5.01	23.65	8.46	386.3	0.19	238	0.2472	73.5	5.89
Site4	9/17/2009 10:16	3.98	23.65	8.44	386.4	0.19	240	0.2473	73.6	5.9
Site4	9/17/2009 10:16	3.02	23.65	8.47	386.3	0.19	238	0.2472	73.6	5.9
Site4	9/17/2009 10:17	2.01	23.65	8.45	386.5	0.19	240	0.2473	73.6	5.9
Site4	9/17/2009 10:18	1.02	23.65	8.47	386.5	0.19	240	0.2473	73.9	5.92
Site4	9/17/2009 10:19	-0.16	23.65	8.43	386.5	0.19	243	0.2473	74.1	5.94
Site4	9/30/2009 12:01	12.8	21.23	7.51	385.3	0.19	363	0.2466	65.9	5.63
Site4	9/30/2009 12:02	12.07	21.23	7.84	383.7	0.19	355	0.2455	22.9	1.95
Site4	9/30/2009 12:03	11.03	21.27	7.87	384.1	0.19	344	0.2459	68	5.81
Site4	9/30/2009 12:05	9.97	21.36	7.79	386.3	0.19	345	0.2472	60.6	5.17
Site4	9/30/2009 12:10	8.97	21.49	7.74	387.3	0.19	344	0.2479	64.6	5.49
Site4	9/30/2009 12:11	8.01	21.6	7.8	387.5	0.19	344	0.248	71.5	6.06
Site4	9/30/2009 12:12	7.01	21.63	7.8	388	0.19	344	0.2483	72.7	6.17
Site4	9/30/2009 12:13	6.03	21.64	7.8	387.7	0.19	344	0.2481	74.1	6.28
Site4	9/30/2009 12:14	6.02	21.63	7.8	387.3	0.19	345	0.2479	72.8	6.17
Site4	9/30/2009 12:15	5.11	21.65	7.8	387.1	0.19	345	0.2477	74.3	6.29
Site4	9/30/2009 12:16	4.03	21.64	7.8	387.3	0.19	345	0.2479	74.2	6.29
Site4	9/30/2009 12:16	3.02	21.65	7.81	387.1	0.19	346	0.2477	75.3	6.38
Site4	9/30/2009 12:17	2.02	21.65	7.82	387.5	0.19	346	0.248	76.5	6.48
Site4	9/30/2009 12:18	1.02	21.66	7.82	387.6	0.19	346	0.2481	76.3	6.46

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site4	9/30/2009 12:19	0.09	21.66	7.82	386.8	0.19	346	0.2476	76.9	6.52
Site4	10/19/2009 11:52	12.56	16.35	7.85	379.2	0.19	386	0.2427	75.5	7.09
Site4	10/19/2009 11:54	12.05	16.35	7.92	378.4	0.19	376	0.2422	84.5	7.93
Site4	10/19/2009 11:54	10.95	16.37	7.93	378.3	0.19	377	0.2421	85.2	7.99
Site4	10/19/2009 11:54	9.66	16.38	7.93	378.3	0.19	378	0.2421	85.4	8.01
Site4	10/19/2009 11:55	11.2	16.36	7.92	378.6	0.19	379	0.2423	84.9	7.96
Site4	10/19/2009 11:56	10.13	16.37	7.93	378.5	0.19	380	0.2423	85.6	8.02
Site4	10/19/2009 11:57	9	16.39	7.94	378.4	0.19	381	0.2422	86.4	8.1
Site4	10/19/2009 11:57	7.93	16.39	7.94	378.4	0.19	381	0.2422	86.5	8.1
Site4	10/19/2009 11:58	7.01	16.4	7.95	378.4	0.19	382	0.2422	86.6	8.11
Site4	10/19/2009 11:58	5.98	16.41	7.96	378.3	0.19	383	0.2421	86.9	8.14
Site4	10/19/2009 11:58	4.97	16.41	7.97	378.6	0.19	383	0.2423	86.9	8.14
Site4	10/19/2009 11:59	4.6	16.42	7.95	378.5	0.19	384	0.2423	87.3	8.18
Site4	10/19/2009 12:00	4.01	16.44	7.95	378.4	0.19	385	0.2421	87.6	8.2
Site4	10/19/2009 12:01	2.88	16.46	7.96	378.4	0.19	386	0.2422	87.6	8.2
Site4	10/19/2009 12:02	2.01	16.45	7.97	378.3	0.19	387	0.2421	87.8	8.21
Site4	10/19/2009 12:02	1.07	16.46	7.96	378.4	0.19	387	0.2422	88	8.23
Site4	10/19/2009 12:02	0.26	16.47	7.96	378.6	0.19	386	0.2423	88.6	8.29

Table D-6 Site 5 HYDROLAB Station Data*

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site5	4/22/2008 11:17	0.2	17.31	8.27	378.4	0.19	337	0.2422	97.8	8.92
Site5	4/22/2008 11:18	1	17.3	8.27	378.2	0.19	336	0.2421	97.6	8.91
Site5	4/22/2008 11:18	1.9	17.24	8.26	378.4	0.19	336	0.2422	97.2	8.88
Site5	4/22/2008 11:19	2.9	16.87	8.25	377.6	0.19	336	0.2416	95.7	8.81
Site5	4/22/2008 11:20	3.9	16.56	8.25	380	0.19	336	0.2432	96.1	8.91
Site5	4/22/2008 11:21	4.9	16.05	8.24	379	0.19	336	0.2425	93.6	8.77
Site5	4/22/2008 11:22	5.9	14.95	8.22	382.1	0.19	336	0.2446	89.7	8.6
Site5	4/22/2008 11:23	6.7	14.42	8.07	386.3	0.19	320	0.2472	69.2	6.71
Site5	5/16/2008 12:11	0.1	19.85	8.34	408.3	0.2	425	0.2613	108	9.38
Site5	5/16/2008 12:11	1	19.63	8.33	407.4	0.2	424	0.2607	107.1	9.34
Site5	5/16/2008 12:12	2	19.04	8.3	405.7	0.2	423	0.2596	100.2	8.84
Site5	5/16/2008 12:13	3	18.96	8.28	407.4	0.2	422	0.2607	95.7	8.46
Site5	5/16/2008 12:14	4	18.96	8.28	407.6	0.2	421	0.2609	95.7	8.46
Site5	5/16/2008 12:15	5	18.95	8.28	407	0.2	420	0.2605	96	8.48
Site5	5/16/2008 12:16	6	18.94	8.29	407	0.2	419	0.2605	96.7	8.55
Site5	5/16/2008 12:17	6.9	18.67	7.83	406.8	0.2	38	0.2603	82	7.28

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site5	5/21/2008 13:10	0.1	21.6	8.48	406.9	0.2	417	0.2604		
Site5	5/21/2008 13:11	1	21.53	8.51	407	0.2	417	0.2605		
Site5	5/21/2008 13:11	2	21.38	8.49	405.7	0.2	416	0.2596		
Site5	5/21/2008 13:12	3	21.29	8.48	404.8	0.2	415	0.2591		
Site5	5/21/2008 13:13	4	21.27	8.48	404.8	0.2	414	0.2591		
Site5	5/21/2008 13:14	5	21.19	8.46	406.1	0.2	413	0.2599		
Site5	5/21/2008 13:15	6	20.2	8.24	423	0.21	417	0.2707		
Site5	5/21/2008 13:16	6.1	20.19	8.19	423.5	0.21	413	0.271		
Site5	6/4/2008 13:47	0	25.79	8.29	371	0.2	429	0.237	90.7	7.12
Site5	6/4/2008 13:48	0.6	25.78	8.29	371	0.2	435	0.237	89.5	7.03
Site5	6/4/2008 13:49	1	25.78	8.29	371	0.2	440	0.238	88.5	6.95
Site5	6/4/2008 13:50	2	25.74	8.29	372	0.2	443	0.238	88.2	6.93
Site5	6/4/2008 13:51	2.9	25.69	8.27	373	0.2	445	0.239	86.4	6.8
Site5	6/4/2008 13:52	3.9	25.59	8.26	373	0.2	447	0.239	84.3	6.65
Site5	6/4/2008 13:53	5	23.73	7.86	369	0.2	458	0.236	39	3.18
Site5	6/4/2008 13:56	5.7	23.2	7.68	370	0.2	216	0.237	14.5	1.2
Site5	6/18/2008 13:28	0.14	28	8.74	405.3	0.2	151	0.2594	119.7	9
Site5	6/18/2008 13:29	0.97	26.11	8.59	406.3	0.2	167	0.26	96.7	7.51
Site5	6/18/2008 13:31	2.07	26.07	8.58	406.6	0.2	174	0.2602	94.8	7.37
Site5	6/18/2008 13:32	3	26.02	8.51	407.2	0.2	181	0.2606	88.8	6.91
Site5	6/18/2008 13:32	4	25.98	8.43	407.3	0.2	186	0.2607	86.4	6.73
Site5	6/18/2008 13:34	5.04	25.88	8.31	403.6	0.2	189	0.2583	77.7	6.06
Site5	6/18/2008 13:35	6.03	25.18	7.96	388.8	0.19	187	0.2488	49.6	3.92
Site5	6/18/2008 13:36	6.41	25.19	7.8	392.2	0.19	44	0.251	22	1.73
Site5	7/9/2008 13:08	0.11	28.87	8.71	385.4	0.19	336	0.2467	118.4	8.73
Site5	7/9/2008 13:09	1	28.45	8.62	387.5	0.19	331	0.248	109.3	8.11
Site5	7/9/2008 13:10	2	28.31	8.56	391.3	0.19	325	0.2504	100	7.44
Site5	7/9/2008 13:11	3	28.27	8.47	393	0.2	324	0.2515	91.2	6.79
Site5	7/9/2008 13:12	4.05	28.13	8.29	395.5	0.2	325	0.2532	70.7	5.28
Site5	7/9/2008 13:13	5.04	27.81	8.08	396.7	0.2	323	0.2539	43.6	3.28
Site5	7/9/2008 13:14	5.98	27.35	7.87	400.2	0.2	292	0.2561	9.9	0.75
Site5	7/21/2008 12:48	0.13	30.12	8.55	369.7	0.18	152	0.2366	147.7	10.66
Site5	7/21/2008 12:50	1.04	29.83	8.57	368.9	0.18	160	0.2361	148.2	10.75
Site5	7/21/2008 12:51	2.09	29.13	8.49	371.3	0.18	161	0.2376	128.8	9.45
Site5	7/21/2008 12:52	3.15	28.9	8.3	379.3	0.19	163	0.2427	98.3	7.24
Site5	7/21/2008 12:53	4	28.52	8.12	378.4	0.19	165	0.2422	75.3	5.59
Site5	7/21/2008 12:54	5.08	28.05	7.81	384	0.19	159	0.2457	34.9	2.61
Site5	7/21/2008 12:56	5.86	27.67	7.7	392.4	0.2	16	0.2511	2.2	0.17

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site5	8/4/2008 12:32	0.35	30.73	8.46	417	0.21	201	0.2669	101.9	7.26
Site5	8/4/2008 12:34	1.04	30.59	8.47	417.2	0.21	207	0.267	100.3	7.16
Site5	8/4/2008 12:36	1.93	30.41	8.44	415.3	0.21	212	0.2658	97.1	6.96
Site5	8/18/2008 11:42	0.2	27.06	8.57	351.4	0.17	257	0.2249	92.1	7.02
Site5	8/18/2008 11:43	1.14	27.1	8.56	351.4	0.17	259	0.2249	91.2	6.95
Site5	8/18/2008 11:43	2.13	27.09	8.55	351.3	0.17	262	0.2248	91.1	6.94
Site5	8/18/2008 11:45	3.04	27.12	8.54	351.1	0.17	265	0.2247	91	6.93
Site5	8/18/2008 11:46	4.06	27.06	8.53	351.5	0.17	267	0.2249	91	6.94
Site5	8/18/2008 11:47	5.02	27.11	8.52	350.8	0.17	269	0.2245	91.1	6.94
Site5	9/2/2008 13:37	0.06	29.1	8.58	347.8	0.17	211	0.2226	121.1	8.87
Site5	9/2/2008 13:39	1.07	29.14	8.6	347.5	0.17	215	0.2224	121.5	8.9
Site5	9/2/2008 13:40	1.07	29.12	8.6	347.6	0.17	217	0.2225	122.8	9
Site5	9/2/2008 13:41	1.99	29.04	8.6	348.1	0.17	219	0.2228	119	8.73
Site5	9/2/2008 13:43	2.98	28.97	8.62	348	0.17	221	0.2227	117.4	8.62
Site5	9/2/2008 13:45	3.98	28.89	8.62	347.3	0.17	223	0.2223	116.6	8.58
Site5	9/2/2008 13:47	4.97	28.68	8.59	347.5	0.17	225	0.2224	109.4	8.07
Site5	9/2/2008 13:49	5.22	28.66	7.08	346.4	0.17	-13	0.2217	30.9	2.28
Site5	9/22/2008 14:46	1.08	24.78	8.9	337.1	0.17	284	0.2158	132.9	9.15
Site5	9/22/2008 14:47	0.12	24.8	8.94	337	0.17	286	0.2157	134.6	9.26
Site5	9/22/2008 14:50	2.03	24.76	8.92	337.1	0.17	296	0.2157	132.3	9.11
Site5	9/22/2008 14:51	3.07	24.69	8.93	337.3	0.17	298	0.2159	128	8.82
Site5	9/22/2008 14:53	4.01	24.34	8.74	342.7	0.17	303	0.2193	95.5	6.62
Site5	9/22/2008 14:55	4.72	24.29	8.65	343.7	0.17	289	0.22	87.7	6.09
Site5	10/16/2008 13:11	0.08	20.01	8.72	381	0.19	282	0.2439	100.4	8.76
Site5	10/16/2008 13:13	1.03	19.97	8.6	381	0.19	277	0.2438	99.2	8.66
Site5	10/16/2008 13:14	2.02	19.88	8.67	381.3	0.19	274	0.244	98.1	8.58
Site5	10/16/2008 13:15	3	19.66	8.67	381.7	0.19	272	0.2443	96.2	8.45
Site5	10/16/2008 13:16	3.98	19.23	8.65	382.7	0.19	271	0.2449	89.9	7.97
Site5	10/16/2008 13:17	4.6	19.2	8.6	382.8	0.19	265	0.245	88	7.81
Site5	2/9/2009 13:10	6.75	7.91	8.21	394.7	0.2	297	0.2526	100.5	11.43
Site5	2/9/2009 13:11	5.92	8.31	8.26	397	0.2	293	0.2541	101.6	11.44
Site5	2/9/2009 13:12	5.04	8.43	8.29	398.4	0.2	289	0.255	102.5	11.5
Site5	2/9/2009 13:12	3	8.5	8.24	399.2	0.2	289	0.2555	103.1	11.55
Site5	2/9/2009 13:13	2	8.55	8.28	399.3	0.2	286	0.2556	103.2	11.54
Site5	2/9/2009 13:13	1.01	8.61	8.29	399.3	0.2	285	0.2555	103.7	11.59
Site5	2/9/2009 13:14	0.09	8.64	8.31	399.3	0.2	284	0.2555	103.8	11.59
Site5	4/15/2009 10:53	7.01	12.29	8.16	448.4	0.23	444	0.287	72	7.37
Site5	4/15/2009 10:54	5.94	12.3	8.16	448.8	0.23	444	0.2872	71.7	7.33

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site5	4/15/2009 10:54	5.01	12.42	8.24	423.9	0.21	441	0.2713	79	8.05
Site5	4/15/2009 10:55	5.04	12.42	8.28	423.6	0.21	444	0.2711	84.6	8.63
Site5	4/15/2009 10:56	4.03	12.6	8.35	419.2	0.21	445	0.2683	92.1	9.35
Site5	4/15/2009 10:58	3	13.34	8.42	422	0.21	446	0.2701	99	9.89
Site5	4/15/2009 10:58	1.91	13.45	8.44	421.9	0.21	446	0.27	101.1	10.08
Site5	4/15/2009 10:59	0.8	13.47	8.5	422.1	0.21	444	0.2702	101.8	10.13
Site5	4/15/2009 11:00	0.16	13.47	8.48	422.3	0.21	446	0.2703	102.1	10.17
Site5	5/7/2009 12:20	6.94	16.03	7.73	445.6	0.22	356	0.2852	53.6	5.03
Site5	5/7/2009 12:21	6.02	16.14	7.75	441.2	0.22	354	0.2824	56.4	5.28
Site5	5/7/2009 12:23	5.01	16.84	7.91	415.8	0.21	353	0.2661	65.6	6.05
Site5	5/7/2009 12:24	4	17.25	8.11	412.7	0.21	353	0.264	81	7.41
Site5	5/7/2009 12:25	3	17.34	8.16	414.6	0.21	353	0.2653	82.6	7.55
Site5	5/7/2009 12:26	2.03	17.54	8.21	415.5	0.21	354	0.2659	86.9	7.91
Site5	5/7/2009 12:27	0.98	19.12	8.32	417.5	0.21	354	0.2672	99.5	8.76
Site5	5/7/2009 12:28	0.11	19.36	8.32	416.2	0.21	356	0.2664	101.2	8.88
Site5	5/20/2009 10:54	0.06	21.26	8.4	416.4	0.21	366	0.2665	113.9	9.74
Site5	5/20/2009 10:55	1.02	21.21	8.39	416.7	0.21	367	0.2667	113	9.67
Site5	5/20/2009 10:56	2.03	21.23	8.39	416.7	0.21	369	0.2667	111.6	9.55
Site5	5/20/2009 10:56	2.99	21.15	8.39	416.8	0.21	370	0.2668	110.8	9.49
Site5	5/20/2009 10:58	3.99	21.06	8.35	416.9	0.21	373	0.2668	107	9.19
Site5	5/20/2009 10:59	5.18	19.43	7.95	418.4	0.21	377	0.2678	54.9	4.87
Site5	5/20/2009 11:00	6.01	19.36	7.93	419.2	0.21	376	0.2683	55.2	4.9
Site5	5/20/2009 11:01	6.99	19.25	7.95	420.8	0.21	375	0.2693	56.9	5.07
Site5	5/20/2009 11:02	7.39	19.19	7.95	421.5	0.21	364	0.2698	56.6	5.05
Site5	6/4/2009 11:24	0.1	23.93	8.38	422.1	0.21	519	0.2701	93	7.37
Site5	6/4/2009 11:25	0.99	23.87	8.36	422.7	0.21	521	0.2706	91	7.21
Site5	6/4/2009 11:27	2	23.66	8.32	427.2	0.21	522	0.2734	86.3	6.87
Site5	6/4/2009 11:28	3.01	23.55	8.3	428.3	0.21	523	0.2741	85	6.77
Site5	6/4/2009 11:29	4.02	23.49	8.31	428.2	0.21	523	0.2741	84.6	6.75
Site5	6/4/2009 11:30	5	23.34	8.26	432.3	0.22	516	0.2766	79.4	6.36
Site5	6/4/2009 11:32	5.08	23.34	8.28	431.6	0.22	506	0.2762	78.9	6.32
Site5	6/25/2009 10:39	0.1	31.9	8.46	407.2	0.2	386	0.2606	146.9	10.25
Site5	6/25/2009 10:41	1	31.78	8.45	406.9	0.2	393	0.2604	149.3	10.44
Site5	6/25/2009 10:45	1.91	31	8.36	416.5	0.21	406	0.2666	126.3	8.95
Site5	6/25/2009 10:47	3	28.95	8.24	420.6	0.21	411	0.2692	90.6	6.65
Site5	6/25/2009 10:48	3.99	27.67	7.9	426.1	0.21	411	0.2727	42.7	3.2
Site5	6/25/2009 10:50	5.02	27.39	7.66	431.5	0.22	397	0.2762	8.9	0.67
Site5	6/25/2009 10:51	5.99	25.96	7.61	441.3	0.22	110	0.2824	1.9	0.14

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site5	6/25/2009 10:51	6.45	24.36	7.53	436.6	0.22	68	0.2794	1.9	0.16
Site5	7/9/2009 9:58	6.43	28.12	8.51	412.3	0.21	310	0.2639	87.1	6.47
Site5	7/9/2009 9:59	5.63	28.14	8.53	412.3	0.21	313	0.2639	88.5	6.57
Site5	7/9/2009 10:00	4.98	28.29	8.53	412.1	0.21	318	0.2638	90.1	6.67
Site5	7/9/2009 10:02	4.04	28.3	8.52	411.8	0.21	326	0.2635	91.4	6.77
Site5	7/9/2009 10:03	3.04	28.31	8.5	411.7	0.21	331	0.2635	92.3	6.83
Site5	7/9/2009 10:04	1.97	28.32	8.5	411.5	0.21	335	0.2634	93.1	6.89
Site5	7/9/2009 10:05	0.53	28.36	8.52	411.3	0.21	335	0.2632	94	6.95
Site5	7/9/2009 10:06	0.08	28.38	8.51	411.1	0.21	341	0.2631	95.3	7.05
Site5	7/23/2009 9:55	0.1	28.53	8.47	397	0.2	218	0.2541	109.6	8.08
Site5	7/23/2009 9:56	1.01	28.14	8.38	397.9	0.2	226	0.2547	95.8	7.11
Site5	7/23/2009 9:58	2.01	28.09	8.35	398.4	0.2	235	0.2549	89.9	6.68
Site5	7/23/2009 9:59	3	28.04	8.34	398.5	0.2	241	0.255	87.4	6.5
Site5	7/23/2009 10:00	3.99	28	8.37	397.6	0.2	247	0.2545	90.6	6.74
Site5	7/23/2009 10:01	5	27.97	8.33	398.2	0.2	253	0.2549	86.3	6.42
Site5	7/23/2009 10:04	5.96	27.87	8.1	404.2	0.2	257	0.2587	53.8	4.01
Site5	7/23/2009 10:07	6.94	27.84	7.8	409.5	0.2	250	0.2621	20.7	1.54
Site5	8/6/2009 10:43	6.84	27.34	7.81	404.7	0.2	201	0.259	2.8	0.22
Site5	8/6/2009 10:44	5.88	27.5	7.9	400.8	0.2	195	0.2565	16.9	1.32
Site5	8/6/2009 10:45	4.91	27.68	8.41	390.4	0.19	202	0.2498	80.9	6.3
Site5	8/6/2009 10:47	4	27.71	8.4	390.2	0.19	213	0.2497	84.7	6.59
Site5	8/6/2009 10:48	3	27.69	8.41	389.8	0.19	218	0.2495	83.9	6.53
Site5	8/6/2009 10:49	1.97	27.69	8.42	389.6	0.19	224	0.2493	85.7	6.67
Site5	8/6/2009 10:50	1.01	27.69	8.4	389.8	0.19	230	0.2495	85.8	6.68
Site5	8/6/2009 10:51	0.11	27.67	8.38	389.6	0.19	235	0.2494	86.1	6.71
Site5	8/24/2009 11:26	0.18	27.57	8.73	381.1	0.19	263	0.2439	111.4	8.38
Site5	8/24/2009 11:27	0.96	27.53	8.73	381	0.19	277	0.2438	109	8.21
Site5	8/24/2009 11:29	2.05	27.51	8.72	381.2	0.19	286	0.244	106.3	8.01
Site5	8/24/2009 11:29	3.07	27.51	8.73	381.2	0.19	289	0.244	106.6	8.03
Site5	8/24/2009 11:30	3.99	27.51	8.73	381.2	0.19	292	0.244	106.4	8.02
Site5	8/24/2009 11:31	5.06	27.44	8.72	381.1	0.19	295	0.2439	104.2	7.86
Site5	8/24/2009 11:31	5.02	27.43	8.7	381.6	0.19	296	0.2442	101.6	7.67
Site5	9/3/2009 10:22	0.11	25.21	8.18	384.9	0.19	213	0.2463	85.2	6.73
Site5	9/3/2009 10:23	1.04	25.23	8.2	384.9	0.19	214	0.2464	85.2	6.73
Site5	9/3/2009 10:24	2.05	25.23	8.19	385.1	0.19	216	0.2465	83.3	6.58
Site5	9/3/2009 10:26	3.13	25.23	8.19	385.1	0.19	218	0.2465	82.5	6.51
Site5	9/3/2009 10:26	4.02	25.23	8.19	385.1	0.19	220	0.2465	81.9	6.46
Site5	9/3/2009 10:27	5.03	25.21	8.18	384.9	0.19	223	0.2463	82.1	6.49

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site5	9/3/2009 10:29	6.06	25.14	8.17	385.3	0.19	226	0.2466	80.1	6.34
Site5	9/3/2009 10:31	6.96	25.14	7.42	394.1	0.2	68	0.2522	2	0.16
Site5	9/17/2009 10:27	6.54	22.55	8.52	380.3	0.19	252	0.2434	79.2	6.49
Site5	9/17/2009 10:27	6.54	22.55	8.51	380.7	0.19	253	0.2436	79	6.47
Site5	9/17/2009 10:27	6.53	22.55	8.5	380.7	0.19	253	0.2436	78.9	6.46
Site5	9/17/2009 10:27	6.5	22.57	8.48	380.4	0.19	254	0.2435	79	6.46
Site5	9/17/2009 10:28	6	22.59	8.53	380.4	0.19	251	0.2434	81	6.63
Site5	9/17/2009 10:29	4.99	22.73	8.57	381.6	0.19	251	0.2442	81.4	6.64
Site5	9/17/2009 10:29	3.99	22.73	8.57	381.6	0.19	251	0.2442	82	6.69
Site5	9/17/2009 10:30	3.01	22.75	8.47	381.7	0.19	257	0.2443	81.9	6.68
Site5	9/17/2009 10:31	1.99	22.76	8.49	381.6	0.19	256	0.2443	82	6.69
Site5	9/17/2009 10:31	0.94	22.75	8.46	381.6	0.19	259	0.2442	82.5	6.73
Site5	9/17/2009 10:32	0.12	22.8	8.44	381.7	0.19	261	0.2443	83.2	6.78
Site5	9/30/2009 12:42	6.74	20.8	7.86	377.3	0.19	351	0.2414	54.5	4.7
Site5	9/30/2009 12:44	6.28	20.86	7.89	377.4	0.19	351	0.2415	56.9	4.89
Site5	9/30/2009 12:46	5.87	20.91	7.9	377.2	0.19	351	0.2414	60.3	5.18
Site5	9/30/2009 12:47	4.89	21.55	8.07	383.5	0.19	350	0.2454	93.9	7.97
Site5	9/30/2009 12:48	3.99	21.55	8.08	384.4	0.19	350	0.246	94.2	7.99
Site5	9/30/2009 12:48	2.9	21.58	8.09	383.7	0.19	350	0.2455	96	8.14
Site5	9/30/2009 12:49	2.05	21.57	8.08	383.4	0.19	351	0.2454	96.3	8.18
Site5	9/30/2009 12:49	1.02	21.6	8.09	384.2	0.19	351	0.2459	96.8	8.21
Site5	9/30/2009 12:50	0.07	21.6	8.1	383.6	0.19	351	0.2455	97.3	8.25
Site5	10/19/2009 11:23	7.09	15.84	7.96	375	0.19	240	0.24	79.8	7.56
Site5	10/19/2009 11:24	6.98	15.82	8.05	374.9	0.19	278	0.2399	90.9	8.63
Site5	10/19/2009 11:24	5.98	15.84	8.07	374.8	0.19	289	0.2398	92.9	8.81
Site5	10/19/2009 11:25	5.01	15.89	8.07	375	0.19	300	0.24	93.5	8.86
Site5	10/19/2009 11:26	4.34	15.91	8.07	375.3	0.19	317	0.2402	93.8	8.88
Site5	10/19/2009 11:26	2.96	15.93	8.07	374.9	0.19	321	0.2399	94	8.9
Site5	10/19/2009 11:27	2.06	15.91	8.07	375	0.19	328	0.24	94.3	8.93
Site5	10/19/2009 11:27	1.01	15.92	8.08	375	0.19	332	0.24	94.3	8.93
Site5	10/19/2009 11:28	0.14	15.94	8.08	375	0.19	334	0.24	95	8.99

Table D-7 Site 6 HYDROLAB Station Data*

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site6	4/22/2008 10:50	0.3	18.44	8.2	437.6	0.22	327	0.2801	94.7	8.44
Site6	4/22/2008 10:51	1	18.42	8.2	436.8	0.22	326	0.2795	94.5	8.43
Site6	4/22/2008 10:52	2	18.21	8.19	429.6	0.22	326	0.275	92.2	8.26

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site6	4/22/2008 10:53	3	17.31	8.17	402.6	0.2	326	0.2576	86.3	7.87
Site6	4/22/2008 10:53	3	17.3	8.16	404.8	0.2	326	0.2591	86.7	7.92
Site6	4/22/2008 10:54	3.2	17.1	8.12	426	0.21	306	0.2726	81	7.42
Site6	5/16/2008 11:57	0.1	19.75	8.04	503.9	0.26	441	0.3225	91.9	7.99
Site6	5/16/2008 11:58	1	19.58	8.05	503.4	0.25	436	0.3222	89.6	7.81
Site6	5/16/2008 11:59	2	19.42	8.03	493.5	0.25	432	0.3158	84.3	7.38
Site6	5/16/2008 12:00	3	18.75	8.08	443.8	0.22	430	0.2842	81.4	7.23
Site6	5/16/2008 12:00	3.4	18.78	8.06	445.4	0.22	425	0.2851	78.5	6.96
Site6	5/21/2008 12:46	0.1	21.9	8.29	456.2	0.23	428	0.2919		
Site6	5/21/2008 12:47	1	21.87	8.29	457.4	0.23	423	0.2928		
Site6	5/21/2008 12:48	2	21.76	8.28	455.1	0.23	420	0.2912		
Site6	5/21/2008 12:49	3	21.65	8.21	458.5	0.23	419	0.2934		
Site6	5/21/2008 12:50	3.4	21.27	8.09	470.8	0.24	421	0.3013		
Site6	6/4/2008 13:33	0.1	27.05	8.21	442	0.2	438	0.283	94.9	7.28
Site6	6/4/2008 13:35	1	26.52	8.14	442	0.2	444	0.283	85.7	6.54
Site6	6/4/2008 13:36	2	26.21	8.13	432	0.2	444	0.276	80.8	6.29
Site6	6/4/2008 13:38	3	26.14	8.14	423	0.2	444	0.271	81.5	6.36
Site6	6/18/2008 13:10	0.11	25.88	8.35	371.7	0.18	211	0.2379	86.1	6.72
Site6	6/18/2008 13:12	1.01	24.33	8.06	347.3	0.17	120	0.2223	68.7	5.51
Site6	6/18/2008 13:14	1.99	23.55	7.97	314	0.15	142	0.201	64.4	5.25
Site6	6/18/2008 13:15	2.68	23.06	7.82	270.4	0.13	152	0.173	47.2	3.89
Site6	7/9/2008 12:48	0.08	28.91	8.48	419.4	0.21	172	0.2684	84	6.19
Site6	7/9/2008 12:48	1	28.84	8.4	421.9	0.21	181	0.27	79.6	5.87
Site6	7/9/2008 12:49	2.02	28.72	8.32	429	0.21	182	0.2745	62.6	4.62
Site6	7/9/2008 12:50	3	28.65	8.2	432	0.22	183	0.2765	49.1	3.63
Site6	7/21/2008 13:10	0.14	31.06	8.29	411.6	0.21	165	0.2634	107.6	7.64
Site6	7/21/2008 13:10	1.02	30.23	8.33	412.4	0.21	161	0.264	102.2	7.36
Site6	7/21/2008 13:14	1.99	29.87	8.04	417.8	0.21	152	0.2674	50	3.62
Site6	8/4/2008 12:22	0.14	32.18	8.51	397.8	0.2	378	0.2546	97.9	6.82
Site6	8/4/2008 12:26	0.08	32.65	8.56	395	0.2	365	0.2528	105.9	7.32
Site6	8/4/2008 12:28	1.02	30.95	8.37	410.2	0.2	372	0.2625	76.7	5.46
Site6	8/4/2008 12:30	2.03	30.86	8.2	413.7	0.21	374	0.2648	55	3.92
Site6	8/4/2008 12:32	2.73	30.74	8.08	415.1	0.21	365	0.2657	35.8	2.56
Site6	8/4/2008 12:35	0.49	31.49	8.38	405.9	0.2	355	0.2598	78.8	5.55
Site6	8/4/2008 12:36	0.48	31.52	8.38	405.9	0.2	355	0.2598	77.9	5.49
Site6	8/18/2008 11:59	0.13	26.33	8.56	342.2	0.17	271	0.219	91.2	7.05
Site6	8/18/2008 12:00	1.03	26.41	8.54	341.9	0.17	275	0.2188	90.6	7

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site6	8/18/2008 12:01	2.04	26.33	8.51	335.4	0.16	277	0.2146	87.9	6.79
Site6	8/18/2008 12:03	2.88	26.39	8.45	335.1	0.16	280	0.2145	80.4	6.21
Site6	9/2/2008 14:02	0.11	29.14	8.54	355	0.17	219	0.2272	121.6	8.9
Site6	9/2/2008 14:04	1	29.12	8.55	354.8	0.17	223	0.227	121.4	8.89
Site6	9/2/2008 14:05	2.01	29.12	8.56	354.6	0.17	224	0.2269	120.6	8.83
Site6	9/2/2008 14:06	2.54	29.07	8.56	354.7	0.17	223	0.227	119.1	8.73
Site6	9/22/2008 15:10	0.15	25.44	8.88	352.1	0.17	311	0.2254	122.9	8.35
Site6	9/22/2008 15:12	1.1	25.15	8.81	352.3	0.17	315	0.2255	104.9	7.16
Site6	9/22/2008 15:13	2.15	24.59	8.8	353.5	0.17	315	0.2262	97	6.7
Site6	9/22/2008 15:16	2.99	24.46	7.93	354.7	0.17	249	0.227	81.4	5.63
Site6	10/16/2008 13:32	0.12	18.85	8.6	421.7	0.21	317	0.2699	105.6	9.43
Site6	10/16/2008 13:33	1.07	18.71	8.66	420.5	0.21	315	0.2691	102.8	9.21
Site6	10/16/2008 13:35	2.03	18.41	8.65	417.5	0.21	312	0.2672	98.3	8.86
Site6	10/16/2008 13:36	2.62	18.35	8.64	416.7	0.21	311	0.2667	96.6	8.72
Site6	2/9/2009 13:25	0.12	12.07	8.27	468.1	0.24	344	0.2996	100.7	10.37
Site6	2/9/2009 13:26	1.05	11.84	8.29	467.5	0.24	341	0.2992	99.9	10.34
Site6	2/9/2009 13:27	2.04	11.45	8.26	465.1	0.23	336	0.2976	96.7	10.1
Site6	2/9/2009 13:28	2.31	11.36	8.26	463.4	0.23	335	0.2966	95.9	10.04
Site6	4/15/2009 11:09	0.09	14.3	8.42	440.4	0.22	436	0.2818	98.7	9.65
Site6	4/15/2009 11:10	1.04	14.25	8.38	440.5	0.22	439	0.2819	98.1	9.6
Site6	4/15/2009 11:11	2.05	14.08	8.36	441.7	0.22	440	0.2827	92.9	9.13
Site6	4/15/2009 11:12	2.53	13.37	8.26	455.4	0.23	444	0.2915	76.8	7.66
Site6	5/7/2009 12:43	0.1	19.65	8	408.2	0.2	354	0.2613	91.2	7.94
Site6	5/7/2009 12:46	1.01	17.69	7.76	410.1	0.2	359	0.2624	69	6.26
Site6	5/7/2009 12:47	2	16.03	7.7	448.4	0.23	361	0.2869	62.1	5.83
Site6	5/7/2009 12:50	3	15.76	7.72	479.8	0.24	362	0.3071	53	5
Site6	5/7/2009 12:50	3.19	15.75	7.73	482.5	0.24	363	0.3088	46.8	4.42
Site6	5/20/2009 11:15	0.15	21.77	8.01	388.6	0.19	394	0.2487	88.3	7.47
Site6	5/20/2009 11:16	0.99	21.29	7.94	390.6	0.19	394	0.25	79.8	6.82
Site6	5/20/2009 11:17	2.01	21.17	7.86	392.8	0.2	395	0.2513	71.7	6.14
Site6	5/20/2009 11:18	3	21.08	7.81	393.9	0.2	395	0.2521	65	5.58
Site6	5/20/2009 11:20	3.32	21.09	7.79	392.9	0.2	378	0.2514	60.9	5.22
Site6	6/4/2009 11:47	0.08	23.39	8.13	535.9	0.27	526	0.343	84.9	6.79
Site6	6/4/2009 11:48	0.96	23.27	8.13	535.8	0.27	527	0.3429	83.7	6.71
Site6	6/4/2009 11:50	2.04	22.98	8.04	537.8	0.27	508	0.3442	70.3	5.67
Site6	6/4/2009 11:52	2.2	22.84	7.99	537.1	0.27	491	0.3437	63.3	5.11
Site6	6/25/2009 11:09	0.13	32.82	8.44	426.4	0.21	374	0.2729	133.8	9.19

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site6	6/25/2009 11:11	1.05	31.78	8.31	442.7	0.22	381	0.2833	103.4	7.23
Site6	6/25/2009 11:13	2.3	31.21	8.06	459.5	0.23	382	0.2941	57	4.02
Site6	6/25/2009 11:15	2.22	31.12	8.01	461.2	0.23	384	0.2951	49.5	3.5
Site6	7/9/2009 10:32	0.11	27.63	8.39	436.8	0.22	373	0.2795	85.9	6.44
Site6	7/9/2009 10:32	1	27.52	8.38	437.8	0.22	376	0.2802	84	6.3
Site6	7/9/2009 10:33	1.98	27.27	8.36	441.6	0.22	377	0.2826	78	5.88
Site6	7/9/2009 10:34	2.39	27.23	8.35	442.3	0.22	379	0.2831	76.4	5.77
Site6	7/23/2009 10:29	0.11	28.52	8.39	407	0.2	318	0.2605	100.7	7.43
Site6	7/23/2009 10:30	1.04	27.53	8.26	423.5	0.21	318	0.2711	83	6.23
Site6	7/23/2009 10:31	2	27.24	8.2	429.5	0.22	317	0.2749	75.3	5.68
Site6	7/23/2009 10:32	2.39	27.14	8.17	430.4	0.22	317	0.2754	72.8	5.5
Site6	8/6/2009 11:00	2.47	28.08	8.14	412	0.21	253	0.2637	57.3	4.43
Site6	8/6/2009 11:01	1.99	28.09	8.16	410.8	0.21	253	0.2629	60.3	4.67
Site6	8/6/2009 11:02	0.63	28.1	8.16	412	0.21	255	0.2637	62.5	4.83
Site6	8/6/2009 11:03	0.08	28.11	8.15	412.6	0.21	256	0.264	61.8	4.78
Site6	8/24/2009 11:53	0.13	27.1	8.64	384.7	0.19	306	0.2462	103.8	7.88
Site6	8/24/2009 11:55	1	26.83	8.62	384.9	0.19	314	0.2466	97.7	7.45
Site6	8/24/2009 11:56	2.04	26.42	8.52	386.8	0.19	319	0.2475	82.2	6.31
Site6	8/24/2009 11:57	2.34	26.34	8.5	386.3	0.19	317	0.2472	79.8	6.14
Site6	9/3/2009 11:01	0.09	23.66	8.2	382.5	0.19	284	0.2448	91.4	7.43
Site6	9/3/2009 11:02	1.05	23.66	8.21	382.5	0.19	282	0.2448	90.5	7.36
Site6	9/3/2009 11:03	2.01	23.55	8.16	382.6	0.19	282	0.2449	85.6	6.97
Site6	9/3/2009 11:04	2.3	23.54	8.16	382.8	0.19	281	0.245	84.3	6.87
Site6	9/17/2009 10:57	2.34	21.29	7.94	344.1	0.17	253	0.2202	85	7.13
Site6	9/17/2009 10:58	2	21.31	8.22	343.7	0.17	175	0.22	83.9	7.04
Site6	9/17/2009 10:58	2	21.31	8.33	343.8	0.17	173	0.22	84.6	7.09
Site6	9/17/2009 10:59	0.99	21.31	8.22	343.5	0.17	188	0.2198	84.7	7.1
Site6	9/17/2009 10:59	0.07	21.32	8.26	343.5	0.17	189	0.2198	85.1	7.14
Site6	9/30/2009 13:12	2.34	20.61	8.28	365.9	0.18	359	0.2342	96.6	8.36
Site6	9/30/2009 13:13	2.03	20.75	8.3	369	0.18	358	0.2362	99	8.54
Site6	9/30/2009 13:13	1.01	20.95	8.34	367.1	0.18	358	0.235	105.1	9.03
Site6	9/30/2009 13:14	0.1	21	8.34	366.6	0.18	358	0.2346	105.8	9.08
Site6	10/19/2009 10:46	2.54	14.79	8.21	348.4	0.17	386	0.223	101.5	9.84
Site6	10/19/2009 10:47	1.98	14.79	8.2	349.2	0.17	385	0.2235	101.6	9.85
Site6	10/19/2009 10:47	0.96	14.81	8.21	350	0.17	385	0.224	101.8	9.87
Site6	10/19/2009 10:47	0.09	14.89	8.21	351.4	0.17	385	0.2249	101.8	9.86

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Table D-8 Site 7 HYDROLAB Station Data*

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site7	4/22/2008 11:42	0.1	16.12	8.3	391.6	0.19	346	0.2506	97.4	9.11
Site7	4/22/2008 11:43	1	16.1	8.29	391.3	0.19	345	0.2505	97	9.08
Site7	4/22/2008 11:44	2	15.88	8.28	391.3	0.19	345	0.2504	95.6	8.99
Site7	4/22/2008 11:45	3	15.4	8.28	390	0.19	344	0.2496	95.3	9.05
Site7	4/22/2008 11:46	4	15.03	8.27	389.9	0.19	344	0.2496	92.5	8.85
Site7	4/22/2008 11:47	5	14.5	8.26	389.9	0.19	345	0.2496	90	8.71
Site7	4/22/2008 11:48	6	14.36	8.22	390.2	0.19	345	0.2497	85	8.26
Site7	4/22/2008 11:49	6.3	14.34	8.19	390.6	0.19	312	0.25	82.3	8
Site7	5/16/2008 12:30	0.1	19.73	8.34	394.8	0.2	272	0.2527	108.3	9.43
Site7	5/16/2008 12:31	1	19.6	8.35	394.5	0.2	275	0.2525	108.4	9.46
Site7	5/16/2008 12:33	2	19.34	8.36	394.4	0.2	282	0.2524	107.7	9.45
Site7	5/16/2008 12:34	3.1	18.93	8.32	394.9	0.2	285	0.2528	101.6	8.99
Site7	5/16/2008 12:36	4.1	18.79	8.29	395.7	0.2	287	0.2532	98.3	8.71
Site7	5/16/2008 12:37	5.1	18.76	8.29	395.9	0.2	289	0.2534	97.8	8.68
Site7	5/16/2008 12:39	6.1	18.66	8.25	396.4	0.2	290	0.2537	94.1	8.37
Site7	5/16/2008 12:40	6.2	18.65	8.24	396.6	0.2	291	0.2538	93.3	8.3
Site7	5/21/2008 13:29	0.1	22.01	8.55	399.2	0.2	409	0.2554		
Site7	5/21/2008 13:31	1	21.96	8.56	399.2	0.2	411	0.2555		
Site7	5/21/2008 13:31	2	21.89	8.56	399.3	0.2	410	0.2555		
Site7	5/21/2008 13:33	3	21.46	8.5	399.9	0.2	411	0.2559		
Site7	5/21/2008 13:33	4	20.93	8.42	401.3	0.2	413	0.2568		
Site7	5/21/2008 13:34	5	20.76	8.37	401.5	0.2	413	0.257		
Site7	5/21/2008 13:35	5.6	20.69	8.33	402	0.2	414	0.2573		
Site7	6/4/2008 14:08	0.1	23.99	7.95	368	0.2	426	0.235	72.2	5.86
Site7	6/4/2008 14:09	1	23.94	7.94	367	0.2	431	0.235	71.2	5.78
Site7	6/4/2008 14:11	1.9	23.84	7.93	368	0.2	437	0.235	68.3	5.56
Site7	6/4/2008 14:12	3	23.76	7.91	367	0.2	440	0.235	65.5	5.39
Site7	6/4/2008 14:13	3.8	23.57	7.88	367	0.2	442	0.235	61.9	5.06
Site7	6/4/2008 14:14	5	22.34	7.68	366	0.2	440	0.234	31.6	2.64
Site7	6/18/2008 12:39	5.71	24.69	8.03	410.7	0.2	179	0.2629	11.3	0.9
Site7	6/18/2008 12:39	5.71	24.7	8.03	410.9	0.21	180	0.263	9.6	0.76
Site7	6/18/2008 12:40	5.04	25.11	8.3	409.8	0.2	183	0.2623	50.4	3.98
Site7	6/18/2008 12:42	4.02	25.52	8.54	406.2	0.2	193	0.26	52.1	4.09
Site7	6/18/2008 12:44	3.06	25.6	8.56	406.7	0.2	200	0.2603	93.5	7.33
Site7	6/18/2008 12:45	2.02	25.67	8.59	407.2	0.2	210	0.2606	96.8	7.58
Site7	6/18/2008 12:47	1.01	26.18	8.65	406.4	0.2	224	0.2601	109.2	8.47
Site7	6/18/2008 12:49	0.11	27.35	8.67	407.6	0.2	227	0.2609	113.9	8.65

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site7	7/9/2008 14:00	0.09	29.63	8.76	386.9	0.19	162	0.2476	127.4	9.26
Site7	7/9/2008 14:01	0.99	28.42	8.76	385.5	0.19	169	0.2467	120.3	8.94
Site7	7/9/2008 14:02	1.93	28.38	8.75	385.3	0.19	174	0.2466	112.2	8.34
Site7	7/9/2008 14:03	3.02	28.16	8.59	389	0.19	180	0.2491	98.4	7.34
Site7	7/9/2008 14:04	4	28.05	8.49	390.7	0.19	185	0.2501	89.6	6.7
Site7	7/9/2008 14:04	4.99	27.61	8.22	395	0.2	183	0.2528	58.6	4.42
Site7	7/9/2008 14:05	5.33	27.41	8.16	396.4	0.2	179	0.2537	53.5	4.05
Site7	7/21/2008 12:21	0.14	29.46	8.31	374.9	0.19	146	0.2399	128.7	9.39
Site7	7/21/2008 12:22	1.01	29.08	8.32	373.8	0.19	146	0.2393	127.1	9.34
Site7	7/21/2008 12:23	2.01	28.79	8.3	375.6	0.19	149	0.2404	120.6	8.91
Site7	7/21/2008 12:25	3.07	28.42	8.07	376.8	0.19	149	0.2411	84.2	6.25
Site7	7/21/2008 12:27	4.01	28.32	8.01	377.9	0.19	154	0.2419	78.5	5.85
Site7	7/21/2008 12:29	5.09	27.86	7.75	384.2	0.19	140	0.2459	34.9	2.62
Site7	7/21/2008 12:31	5.56	27.67	7.69	385.8	0.19	130	0.2469	27.4	2.06
Site7	8/4/2008 12:04	0.07	30.01	8.49	410.9	0.21	166	0.263	93	6.71
Site7	8/4/2008 12:05	0.92	29.88	8.45	410.5	0.2	179	0.2627	92	6.66
Site7	8/4/2008 12:06	2.02	29.68	8.42	410.4	0.2	184	0.2627	87.8	6.38
Site7	8/4/2008 12:07	3.97	29.21	7.96	416.9	0.21	175	0.2668	38.9	2.85
Site7	8/4/2008 12:09	4.85	28.56	7.73	423.3	0.21	35	0.2709	2.4	0.18
Site7	8/18/2008 11:18	0.12	26.72	8.51	363.7	0.18	207	0.2328	76.6	5.88
Site7	8/18/2008 11:20	1	26.84	8.48	364.4	0.18	218	0.2332	74.3	5.69
Site7	8/18/2008 11:21	2.06	27.24	8.47	361.5	0.18	223	0.2314	73.9	5.62
Site7	8/18/2008 11:22	3.03	27.27	8.46	361.5	0.18	227	0.2313	73.7	5.6
Site7	8/18/2008 11:23	4.08	27.26	8.45	361.5	0.18	231	0.2313	73.5	5.59
Site7	8/18/2008 11:23	5.2	27.24	8.43	361.7	0.18	233	0.2315	72.4	5.51
Site7	8/18/2008 11:24	5.13	27.25	8.42	361.7	0.18	235	0.2316	71.6	5.45
Site7	9/2/2008 14:29	0.18	28.59	8.58	352.3	0.17	237	0.2255	132.8	9.82
Site7	9/2/2008 14:30	1.05	28.59	8.62	352.3	0.17	238	0.2255	132.6	9.8
Site7	9/2/2008 14:31	2.03	28.51	8.6	352.8	0.17	239	0.2258	131.9	9.76
Site7	9/2/2008 14:32	3.03	28.52	8.63	352.8	0.17	239	0.2258	129.4	9.58
Site7	9/2/2008 14:33	4.04	28.51	8.62	352.9	0.17	240	0.2259	128	9.47
Site7	9/2/2008 14:34	5.08	28.39	8.52	355.7	0.18	240	0.2276	106.5	7.9
Site7	9/22/2008 15:41	1.01	24.09	8.49	340.5	0.17	330	0.2179	89.4	6.24
Site7	9/22/2008 15:43	0.17	24.5	8.56	340.2	0.17	328	0.2176	97.4	6.74
Site7	9/22/2008 15:47	1.97	23.64	8.4	340.9	0.17	330	0.2182	73.2	5.15
Site7	9/22/2008 15:49	3	23.29	8.26	341.5	0.17	329	0.2185	48.5	3.43
Site7	9/22/2008 15:50	4.01	23.15	8.08	344.4	0.17	321	0.2204	22.4	1.59
Site7	9/22/2008 15:53	4.96	23.13	8.01	345.2	0.17	307	0.221	16.3	1.16

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site7	10/16/2008 12:45	0.15	19.43	8.55	376.5	0.19	371	0.2409	100.3	8.86
Site7	10/16/2008 12:46	1.04	19.42	8.55	376.4	0.19	373	0.2409	99.8	8.81
Site7	10/16/2008 12:48	2.09	19.39	8.59	376.3	0.19	372	0.2407	99	8.75
Site7	10/16/2008 12:49	3.13	19.16	8.59	376.4	0.19	371	0.2409	97.8	8.68
Site7	10/16/2008 12:50	4.04	18.88	8.61	376.7	0.19	371	0.2411	97.3	8.69
Site7	10/16/2008 12:51	4.68	18.46	8.6	376.8	0.19	370	0.2412	94.5	8.51
Site7	12/8/2008 14:02	0.5	7.89	8.32	373.5		455		90.2	10.43
Site7	12/8/2008 14:03	1	7.82	8.26	373.7		456		91.6	10.61
Site7	12/8/2008 14:04	2	7.83	8.23	373.8		451		91	10.54
Site7	12/8/2008 14:05	3	7.81	8.23	374.5		448		90.8	10.52
Site7	12/8/2008 14:06	4	7.81	8.23	374		447		90.7	10.5
Site7	12/8/2008 14:07	5	7.81	8.22	373.9		446		90.5	10.49
Site7	2/9/2009 12:53	4.8	7.42	8.24	383.7	0.19	242	0.2456	100.8	11.59
Site7	2/9/2009 12:53	3.91	7.47	8.29	383.7	0.19	239	0.2456	101.5	11.66
Site7	2/9/2009 12:54	3.02	7.63	8.29	383.2	0.19	239	0.2453	102	11.67
Site7	2/9/2009 12:54	2.02	7.82	8.27	383.7	0.19	240	0.2456	102.3	11.65
Site7	2/9/2009 12:55	1	7.79	8.3	383.8	0.19	240	0.2456	102.6	11.69
Site7	2/9/2009 12:55	0.06	7.84	8.29	383.8	0.19	241	0.2456	102.8	11.7
Site7	2/9/2009 12:56	0.09	7.8	8.23	383.7	0.19	244	0.2456	102.8	11.72
Site7	4/15/2009 10:32	0.07	12.79	8.43	414.5	0.21	447	0.2653	102.3	10.34
Site7	4/15/2009 10:33	1	12.78	8.41	414.2	0.21	448	0.2651	102.1	10.33
Site7	4/15/2009 10:34	1.98	12.7	8.46	414.7	0.21	449	0.2654	101.4	10.27
Site7	4/15/2009 10:35	2.96	12.57	8.42	415	0.21	451	0.2656	98.4	10
Site7	4/15/2009 10:36	4.03	12.39	8.41	415	0.21	452	0.2656	94.9	9.68
Site7	4/15/2009 10:38	5.03	12.28	8.26	417.7	0.21	455	0.2674	78.5	8.02
Site7	5/7/2009 11:53	0.09	18.84	8.35	414.7	0.21	316	0.2654	115.1	10.19
Site7	5/7/2009 11:56	0.99	18.74	8.38	414.7	0.21	324	0.2654	114	10.12
Site7	5/7/2009 11:58	2.01	17.44	8.23	416.9	0.21	330	0.2668	90.5	8.25
Site7	5/7/2009 11:58	2.99	17.31	8.23	417.2	0.21	332	0.267	88.5	8.09
Site7	5/7/2009 11:59	4	17.26	8.23	417.4	0.21	332	0.2671	88.3	8.08
Site7	5/7/2009 12:00	5	17.21	8.24	417.1	0.21	334	0.267	89	8.15
Site7	5/7/2009 12:01	5	17.18	8.25	417.2	0.21	335	0.267	89.4	8.2
Site7	5/7/2009 12:03	5.24	17.01	8.16	416.3	0.21	339	0.2664	79.7	7.33
Site7	5/20/2009 10:31	0.09	19.82	8.34	414.9	0.21	297	0.2655	101.2	8.91
Site7	5/20/2009 10:32	1.02	19.79	8.34	414.8	0.21	299	0.2655	101.1	8.9
Site7	5/20/2009 10:33	2.03	19.75	8.33	415.1	0.21	302	0.2656	100	8.81
Site7	5/20/2009 10:34	3.02	19.73	8.34	415.2	0.21	305	0.2657	99.3	8.75
Site7	5/20/2009 10:37	4.03	19.47	8.26	416.8	0.21	310	0.2667	89.7	7.95

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site7	5/20/2009 10:38	5.02	18.93	7.98	419.8	0.21	312	0.2687	61.2	5.48
Site7	5/20/2009 10:40	5.32	18.91	8	420.2	0.21	308	0.2689	60.1	5.38
Site7	6/4/2009 10:55	0.07	23.51	8.46	405.2	0.2	474	0.2593	102	8.14
Site7	6/4/2009 10:56	1.07	23.51	8.46	404.7	0.2	479	0.259	101.6	8.11
Site7	6/4/2009 10:58	1.94	23.45	8.46	404.8	0.2	484	0.2591	100.8	8.05
Site7	6/4/2009 10:59	3	23.39	8.46	404.9	0.2	488	0.2591	99.8	7.98
Site7	6/4/2009 11:01	4.01	23.25	8.46	405.2	0.2	491	0.2594	99.3	7.96
Site7	6/4/2009 11:02	4.62	23.1	8.4	406.6	0.2	493	0.2602	94.8	7.62
Site7	6/25/2009 10:24	4.07	27.99	7.83	424.9	0.21	280	0.2719	42.1	3.14
Site7	6/25/2009 10:25	2.88	28.78	8.25	420.5	0.21	297	0.2691	93.7	6.9
Site7	6/25/2009 10:26	1.82	29.37	8.44	411.6	0.21	308	0.2634	136.5	9.95
Site7	6/25/2009 10:26	1	30.41	8.51	410.6	0.2	315	0.2628	143.4	10.26
Site7	6/25/2009 10:28	0.02	28.2	8.19	0	0	325	0	106.8	7.96

Table D-9 Site 8 HYDROLAB Station Data*

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site8	4/22/2008 13:12	0.2	18.92	8.28	373.6	0.18	273	0.2391	101.3	8.95
Site8	4/22/2008 13:12	1	18.84	8.28	373.8	0.19	272	0.2392	100.5	8.88
Site8	4/22/2008 13:13	1.9	18.79	8.26	373.9	0.19	273	0.2393	100	8.85
Site8	4/22/2008 13:14	3	17.19	8.28	376.6	0.19	274	0.241	96.4	8.82
Site8	4/22/2008 13:14	4	17.16	8.27	376.7	0.19	274	0.2411	95.7	8.76
Site8	4/22/2008 13:15	4.2	17.15	8.25	377.1	0.19	271	0.2413	95.4	8.73
Site8	5/16/2008 14:02	0.1	19.76	8.42	383.7	0.19	377	0.2456	113.7	9.88
Site8	5/16/2008 14:03	1	19.63	8.41	384	0.19	377	0.2457	113.5	9.9
Site8	5/16/2008 14:03	2	19.48	8.4	383.9	0.19	376	0.2457	112.2	9.81
Site8	5/16/2008 14:04	3	18.52	8.29	385.3	0.19	377	0.2466	93.3	8.32
Site8	5/16/2008 14:05	3.5	18.47	8.27	385.4	0.19	376	0.2467	92.4	8.25
Site8	5/21/2008 14:58	0.1	21.52	8.43	392.7	0.2	412	0.2514		
Site8	5/21/2008 14:59	1	21.5	8.42	392.8	0.2	412	0.2514		
Site8	5/21/2008 15:00	2	21.46	8.41	393.2	0.2	413	0.2516		
Site8	5/21/2008 15:01	3	21.3	8.35	394.4	0.2	414	0.2524		
Site8	6/4/2008 16:08	0.1	27.3	8.34	362	0.2	431	0.232	95.8	7.32
Site8	6/4/2008 16:09	0.6	27.3	8.34	362	0.2	435	0.232	95.2	7.27
Site8	6/4/2008 16:10	1	27.3	8.34	362	0.2	438	0.232	94.5	7.22
Site8	6/4/2008 16:11	2.1	27.29	8.34	363	0.2	441	0.232	94	7.18
Site8	6/4/2008 16:12	3	27.23	8.32	362	0.2	443	0.232	93.3	7.13
Site8	6/18/2008 10:37	0.11	26.82	8.31	383.1	0.19	274	0.2452	98.9	7.59
Site8	6/18/2008 10:41	1.02	26.14	8.21	376.4	0.19	271	0.2409	84.2	6.54

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site8	6/18/2008 10:43	2.05	26.05	8.18	373.3	0.18	271	0.2389	82.9	6.45
Site8	6/18/2008 10:46	2.99	24.3	7.43	271.8	0.13	267	0.1739	40.1	3.22
Site8	6/18/2008 10:51	3.34	24.03	7.34	274.9	0.13	115	0.1759	1.2	0.1
Site8	7/9/2008 11:19	2.89	29.11	8.37	383.8	0.19	211	0.2456	82.4	6.05
Site8	7/9/2008 11:21	2.01	29.19	8.47	383.5	0.19	210	0.2455	94.1	6.9
Site8	7/9/2008 11:22	1.06	29.33	8.55	381.8	0.19	211	0.2444	105.3	7.69
Site8	7/9/2008 11:23	0.17	29.43	8.55	383.1	0.19	211	0.2452	107.1	7.82
Site8	7/21/2008 9:41	0.06	30.58	8.35	370	0.18	410	0.2368	110	7.87
Site8	7/21/2008 9:42	1.05	30.57	8.27	370.3	0.18	405	0.237	109	7.8
Site8	7/21/2008 9:43	2.01	30.41	8.29	369.7	0.18	393	0.2366	102.5	7.36
Site8	7/21/2008 9:44	3	30.22	8.22	370.9	0.18	389	0.2374	92.6	6.67
Site8	8/4/2008 9:09	2.9	31.5	8.11	416.1	0.21	340	0.2663	82.9	5.83
Site8	8/4/2008 9:14	2.1	31.71	8.18	412.5	0.21	298	0.264	89.5	6.27
Site8	8/4/2008 9:17	1.03	31.81	8.26	408.8	0.2	277	0.2617	96.4	6.74
Site8	8/4/2008 9:19	0.2	31.82	8.3	408.1	0.2	269	0.2612	98.9	6.92
Site8	8/18/2008 8:49	0.11	26.75	8.41	348.2	0.17	397	0.2228	89.1	6.84
Site8	8/18/2008 8:50	1.02	27	8.36	347.1	0.17	395	0.2221	88.1	6.73
Site8	8/18/2008 8:52	2.02	27.03	8.34	347.1	0.17	392	0.2222	88.5	6.76
Site8	8/18/2008 8:55	3.08	27.09	8.33	346.9	0.17	389	0.222	88.6	6.76
Site8	9/2/2008 10:09	0.1	29.41	8.48	365.8	0.18	326	0.2342	99.9	7.28
Site8	9/2/2008 10:10	1.04	29.43	8.45	365.9	0.18	338	0.234	98.8	7.19
Site8	9/2/2008 10:11	2.02	29.42	8.48	365.9	0.18	341	0.2342	96.8	7.05
Site8	9/2/2008 10:12	3.02	29.34	8.47	365.9	0.18	346	0.2342	92.7	6.77
Site8	9/2/2008 10:13	3.28	29.22	8.43	366.3	0.18	314	0.2344	86.5	6.32
Site8	9/22/2008 10:38	0.45	24.84	8.71	340.3	0.17	385	0.2178	124.9	8.58
Site8	9/22/2008 10:38	0.45	24.83	8.72	340.1	0.17	385	0.2177	125	8.59
Site8	9/22/2008 10:38	0.16	24.85	8.75	340.3	0.17	385	0.2178	125.1	8.59
Site8	9/22/2008 10:39	1.07	24.82	8.74	340.1	0.17	388	0.2177	124.6	8.57
Site8	9/22/2008 10:40	1.96	24.75	8.75	340	0.17	391	0.2176	124.6	8.58
Site8	9/22/2008 10:41	1.96	24.75	8.74	340	0.17	393	0.2176	124.7	8.59
Site8	9/22/2008 10:42	2.98	24.61	8.7	339.8	0.17	396	0.2175	118.4	8.18
Site8	10/16/2008 9:48	0.11	18.41	8.53	376.5	0.19	419	0.2409	96.3	8.68
Site8	10/16/2008 9:49	1.01	18.41	8.58	375.9	0.19	418	0.2406	96.9	8.73
Site8	10/16/2008 9:50	2	18.38	8.6	376.2	0.19	416	0.2407	93.7	8.45
Site8	10/16/2008 9:51	2.07	18.35	8.57	376.3	0.19	418	0.2408	92.9	8.39
Site8	12/8/2008 10:56	0.5	6.59	8.01	377.5		472		93.2	11.13
Site8	12/8/2008 10:57	1	6.59	8.05	377.4		468		93.2	11.12

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site8	12/8/2008 10:58	2	6.58	8.07	377.8		466		93.1	11.11
Site8	12/8/2008 10:59	3	6.58	8.08	377.4		458		93	11.11
Site8	2/9/2009 14:08	2.66	10.65	8.3	393.2	0.2	390	0.2517	100.8	10.73
Site8	2/9/2009 14:08	2.07	10.89	8.31	395.1	0.2	387	0.2529	101	10.69
Site8	2/9/2009 14:08	1.02	10.94	8.32	395.3	0.2	385	0.253	101.2	10.7
Site8	2/9/2009 14:09	0.08	10.99	8.32	395.5	0.2	385	0.2531	102	10.77
Site8	4/15/2009 12:13	0.12	15.12	8.4	414	0.21	414	0.265	101.6	9.76
Site8	4/15/2009 12:13	1.03	15.08	8.38	414	0.21	416	0.265	101.6	9.77
Site8	4/15/2009 12:14	1.99	14.99	8.38	414.2	0.21	417	0.2651	101	9.73
Site8	4/15/2009 12:14	2.76	14.7	8.36	415.6	0.21	418	0.266	98.7	9.56
Site8	4/15/2009 12:15	2.82	14.69	8.34	415.8	0.21	419	0.2661	95.6	9.27
Site8	5/7/2009 14:02	0.09	19.68	8.28	407.7	0.2	395	0.2609	118.3	10.3
Site8	5/7/2009 14:04	1	19.63	8.32	407.7	0.2	393	0.2609	118.6	10.34
Site8	5/7/2009 14:05	2.02	18.72	8.2	407.2	0.2	394	0.2606	102	9.07
Site8	5/7/2009 14:07	2.94	16.85	7.86	427.7	0.21	397	0.2737	67.7	6.24
Site8	5/7/2009 14:08	3.64	16.45	7.75	446.1	0.22	398	0.2855	59.2	5.51
Site8	5/20/2009 12:47	0.08	22.16	8.33	401.5	0.2	401	0.257	109.3	9.18
Site8	5/20/2009 12:49	1.12	22.07	8.35	402.3	0.2	396	0.2575	108.6	9.15
Site8	5/20/2009 12:50	2.07	21.6	8.34	404.9	0.2	396	0.2591	104.8	8.9
Site8	5/20/2009 12:51	3.01	21.4	8.32	406.4	0.2	396	0.2601	101.2	8.63
Site8	5/20/2009 12:53	3.21	21.35	8.34	406.2	0.2	397	0.2599	100.4	8.57
Site8	6/4/2009 13:36	0.11	22.87	8.09	415.7	0.21	470	0.2661	76.4	6.17
Site8	6/4/2009 13:37	1	22.86	8.11	416.2	0.21	470	0.2664	74.7	6.04
Site8	6/4/2009 13:39	2.01	21.81	7.84	417.7	0.21	474	0.2673	40.3	3.33
Site8	6/4/2009 13:39	2	21.28	7.79	417.9	0.21	476	0.2675	38.3	3.19
Site8	6/4/2009 13:40	3.01	20.34	7.6	419.3	0.21	480	0.2684	11.7	1
Site8	6/4/2009 13:41	3.15	20.33	7.6	419.1	0.21	480	0.2682	11.5	0.97
Site8	6/4/2009 13:42	3.11	20.35	7.61	419.2	0.21	479	0.2683	11.1	0.94
Site8	6/25/2009 12:31	0.11	33.01	8.44	403.2	0.2	384	0.258	148	10.13
Site8	6/25/2009 12:33	1.02	32.68	8.47	403.9	0.2	387	0.2585	145.5	10.02
Site8	6/25/2009 12:34	2.3	31.62	8.31	409.3	0.2	390	0.262	101.2	7.1
Site8	6/25/2009 12:34	2.82	29.12	7.68	427	0.21	384	0.2733	4.5	0.33
Site8	7/9/2009 11:36	2.39	27.8	8.5	414.3	0.21	369	0.2652	93.8	7
Site8	7/9/2009 11:37	2.02	27.93	8.55	413.2	0.21	370	0.2644	99	7.37
Site8	7/9/2009 11:38	1.02	27.93	8.55	413	0.21	372	0.2644	100.2	7.47
Site8	7/9/2009 11:39	0	28.04	8.58	104.4	0.04	372	0.0668	101.3	7.54
Site8	7/23/2009 11:44	0.1	28.09	8.36	394.4	0.2	297	0.2524	87.3	6.48

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Station	Sample Date/Time	Depth	Temperature (°C)	pH	SC	SAL	ORP	TDS	DO%	DO
Site8	7/23/2009 11:46	1.02	27.66	8.31	394.6	0.2	300	0.2525	81.2	6.08
Site8	7/23/2009 11:47	1.99	27.3	8.35	393	0.2	301	0.2515	78.4	5.91
Site8	7/23/2009 11:48	2.12	27.26	8.34	393.2	0.2	303	0.2516	77.5	5.84
Site8	8/6/2009 12:14	2.47	28.45	8.34	378	0.19	284	0.2419	72.9	5.6
Site8	8/6/2009 12:15	1.99	28.48	8.39	377.9	0.19	283	0.2418	77.3	5.94
Site8	8/6/2009 12:16	0.61	28.55	8.38	378	0.19	282	0.242	76	5.83
Site8	8/6/2009 12:17	0.08	28.56	8.37	8	-0	283	0.0051	77.1	5.92
Site8	8/24/2009 12:52	0.18	27.25	8.53	379.3	0.19	286	0.2428	98	7.42
Site8	8/24/2009 12:53	0.97	27.22	8.54	379.4	0.19	291	0.2428	97.3	7.37
Site8	8/24/2009 12:54	2.08	26.99	8.5	379.5	0.19	297	0.2429	90.9	6.91
Site8	8/24/2009 12:56	2.88	26.78	8.41	380.3	0.19	292	0.2434	74.6	5.69
Site8	9/3/2009 12:08	0.12	23.97	8.14	384.3	0.19	281	0.2459	98.5	7.96
Site8	9/3/2009 12:09	1.04	23.96	8.14	384.9	0.19	281	0.2463	96.9	7.83
Site8	9/3/2009 12:10	2.05	23.79	8.11	385	0.19	282	0.2464	91.9	7.46
Site8	9/3/2009 12:11	2.4	23.74	8.05	385.4	0.19	283	0.2467	86.2	7
Site8	9/17/2009 12:04	0.09	21.89	8.3	386.2	0.19	283	0.2472	92.8	7.69
Site8	9/17/2009 12:05	1.02	21.89	8.27	386.1	0.19	285	0.2471	92.3	7.65
Site8	9/17/2009 12:06	1.99	21.87	8.26	386.2	0.19	286	0.2471	91.8	7.61
Site8	9/17/2009 12:06	2.7	21.8	8.29	386.3	0.19	283	0.2472	90.3	7.5
Site8	9/30/2009 11:31	2.63	21.27	8.28	383.2	0.19	358	0.2453	107.5	9.17
Site8	9/30/2009 11:32	2.03	21.42	8.3	382.8	0.19	358	0.245	108.5	9.23
Site8	9/30/2009 11:34	0.94	21.45	8.3	382.5	0.19	358	0.2448	108.7	9.24
Site8	9/30/2009 11:35	0.14	21.48	8.3	385.2	0.19	358	0.2465	109.1	9.28
Site8	10/19/2009 13:07	2.84	15.65	8.28	379.9	0.19	368	0.2432	106.2	10.12
Site8	10/19/2009 13:08	1.58	15.64	8.28	379.9	0.19	368	0.2431	106.4	10.13
Site8	10/19/2009 13:09	0.97	15.68	8.28	379.8	0.19	368	0.2431	107	10.18
Site8	10/19/2009 13:09	0.15	15.68	8.28	379.9	0.19	368	0.2432	107.1	10.19

* Depth = Sampling depth (in meters); Temperature = Water temperature (°C); pH = Water pH; SC = Specific conductivity (mS/cm); SAL = Salinity calculated from conductivity (ppt); ORP = Oxidation reduction potential (milli-volts); TDS = Total dissolved solids (g/L); DO% = Dissolved oxygen saturation (percentage); DO = Dissolved oxygen concentration (mg/L); N/A = Missing data

Table D-10 Sediment Bed Parameters

7/16/2008 - Unit: mg/kg sediment			
Site ID	TKN (mg/kg)	TP (mg/kg)	% solids
Site 1	683.50	146.50	20.50
Site 2	586.00	125.50	21.50
Site 4	670.50	139.00	23.25
Site 6	611.50	166.00	48.35
Site 8	369.00	53.55	49.65
12/12/2008 - Unit: mg/kg sediment			
Site ID	TKN (mg/kg)	TP (mg/kg)	% solids
Site 1	691.50	148.00	22.10
Site 2	576.00	120.50	23.15
Site 4	577.00	136.00	21.80
Site 6	589.00	167.00	47.65
Site 8	592.00	102.00	37.30
AVERAGE (July 2008 & Dec 2008) - Unit: mg/kg sediment			
Site ID	TKN (mg/kg)	TP (mg/kg)	% solids
Site 1	687.50	147.25	21.30
Site 2	581.00	123.00	22.33
Site 4	623.75	137.50	22.53
Site 6	600.25	166.50	48.00
Site 8	480.50	77.78	43.48

Table D-11 OWRB Water Quality Monitoring Stations for Streams in Lake Thunderbird Watershed

Station ID	Site Name	Lat (N)	Long (W)	Description
OK520810-00-0080W	Little River @ 17th	35.32350	-97.49630	Moore urban site on Little River at 17th street bridge
OK520810-00-0140P	West Elm Creek @ 134th	35.33400	-97.38540	Control site on West Elm at 134th street bridge
OK520810-00-0080H	Little River @ 60th	35.27763	-97.35321	Little River site at 60th street bridge
OK520810-00-0090C	Rock Creek @ 72nd	35.26100	-97.33550	Rock Creek site at 72nd Ave bridge
OK520810-00-0030G	Hog Creek @ 119th	35.34957	-97.25816	Hog Creek site upstream of 119th street bridge

Figure D-2 OWRB Water Quality Monitoring Stations for Streams in Lake Thunderbird Watershed

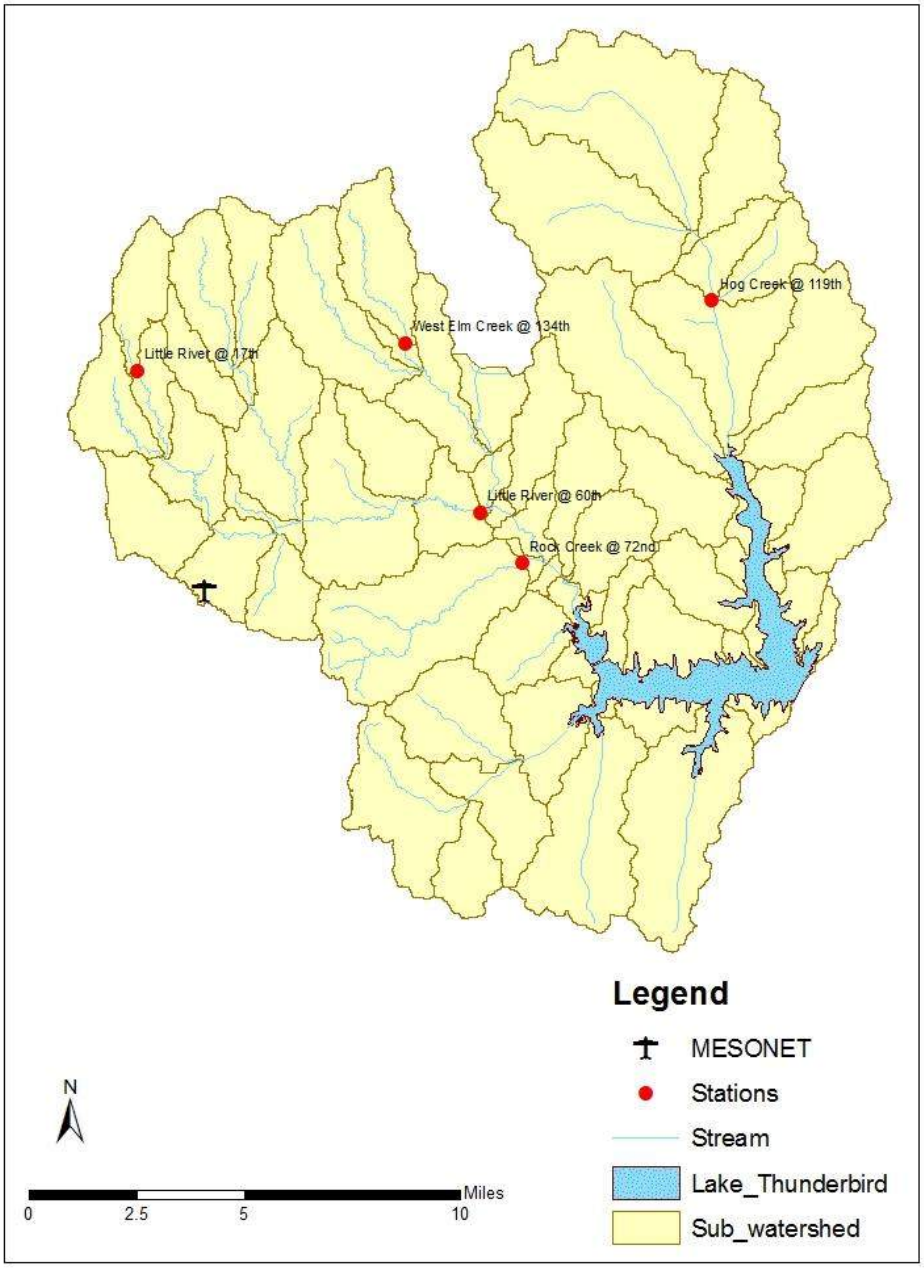

Table D-12 OWRB Water Quality Monitoring Results*

Station	Date	Time	DO (mg/L)	Temperature (°C)	TP (mg/L)	TKN (mg/L)	Type of sample
Rock Creek @ 72nd							
Rock	4/22/2008	1415	5.65	19.5	0.048	0.51	Grab
Rock	4/29/2008	1230	6.71	16.0	0.055	0.59	Grab
Rock	5/6/2008	1315	5.92	19.2	0.078	0.54	Grab
Rock	5/14/2008	1300	5.69	18.6	0.136	0.78	Grab
Rock	5/20/2008	1130	4.67	20.7	0.196	1.14	Grab
Rock	5/28/2008	1445	7.26	24.0	0.06	0.63	Grab
Rock	6/3/2008	1245	5.47	25.6	0.1	0.66	composite
Rock	6/10/2008	1345	7.74	22.6	0.84	4.6	composite
Rock	6/18/2008	1300	7.88	24.7	0.358	1.73	composite
Rock	6/23/2008	1215	5.72	24.2	0.11	0.85	composite
Rock	6/30/2008	1245	7.46	23.4	0.054	0.44	composite
Rock	7/7/2008	1100	4.27	25.0	0.212	0.87	composite
Rock	7/14/2008	1300	6.54	25.0	0.171	0.96	composite
Rock	7/23/2008	1100	4.00	25.5	0.158	1	composite
Rock	7/28/2008	1100	3.72	25.1	0.059	0.41	composite
Rock	8/4/2008	1200	4.39	27.1	0.092	0.54	composite
Rock	8/12/2008	1100	6.05	23.8	1.95	9.02	composite
Rock	8/18/2008	1145	5.73	21.6	1.19	4.16	composite
Rock	8/27/2008	1300	5.78	24.8	1.19	4.06	composite
Rock	9/2/2008	1200	4.08	24.7	0.077	0.54	composite
Rock	9/9/2008	1300	5.50	20.6	0.085	0.62	composite
Rock	9/15/2008	1230	7.33	17.7	0.337	2.09	composite
Rock	9/22/2008	1245	6.09	20.1	0.369	1.98	composite
Rock	10/1/2008	1230	8.63	15.2	0.284	1.43	composite
Rock	10/8/2008	1315	5.01	14.8	0.266	1.38	composite
Rock	10/13/2008	1215	3.79	19.7	0.208	1.04	composite
Rock	10/20/2008	1200	5.25	14.7	0.19	0.78	composite
Rock	10/27/2008	1145	6.68	9.1	0.096	0.44	composite
Rock	11/5/2008	1000	2.99	16.0	0.071	0.37	composite
Rock	11/10/2008	1100	6.10	9.5	0.135	0.77	composite
Rock	11/17/2008	1115	7.83	7.0	0.129	0.56	composite
Rock	11/24/2008	1030	8.25	7.2	0.12	0.55	composite
Rock	12/2/2008	1030	10.93	3.3	0.07	0.38	composite
Rock	12/8/2008	1100	9.54	6.9	0.083	0.46	composite
Rock	12/17/2008	1100	11.35	2.1	0.431	2.19	composite

* DO = Dissolved oxygen concentration (mg/L); Temperature = Water temperature (°C); TP = Total Phosphorus (mg/L); TKN = Total Kjeldahl Nitrogen (mg/L)

Station	Date	Time	DO (mg/L)	Temperature (°C)	TP (mg/L)	TKN (mg/L)	Type of sample
Rock	12/22/2008	1100	11.64	0.8	0.014	0.19	Grab
Rock	12/29/2008	1100	10.06	3.1	0.027	0.27	Grab
Rock	1/7/2009	1100	11.65	1.5	0.016	0.31	Grab
Rock	1/12/2009	1100	11.64	3.2	0.013	0.19	Grab
Rock	1/20/2009	1100	10.66	3.3	0.013	0.12	Grab
Rock	1/29/2009	1200	12.42	0.8	0.017	0.15	Grab
Rock	2/4/2009	1100	12.36	1.4	0.009	0.16	Grab
Rock	2/9/2009	1320	8.00	13.5	0.098	0.61	composite
Rock	2/18/2009	1045	6.96	9.6	0.147	0.88	composite
Rock	2/25/2009	1015	8.02	9.4	0.062	0.38	composite
Rock	3/4/2009	1030	8.70	8.1	0.149	0.78	composite
Rock	3/9/2009	1100	6.20	13.0	0.096	0.47	composite
Rock	3/16/2009	1045	7.34	10.4	0.063	0.37	composite
Rock	3/24/2009	1230	7.10	15.7	0.115	0.48	composite
Rock	3/30/2009	1045	8.33	10.4	0.196	1.19	composite
Rock	4/8/2009	1045	6.83	10.7	0.063	0.53	composite
Rock	4/13/2009	1045	9.10	11.8	0.239	1.45	Grab
Rock	4/20/2009	1015	7.28	11.7	0.317	1.55	composite
Rock	4/27/2009	0930	6.05	19.2			
Little River @ 60th							
L60	6/10/2008	1300	7.11	22.4	0.324	1.35	Grab
L60	6/18/2008	1200	5.38	24.1	0.291	0.98	Grab
L60	6/23/2008	1115	4.93	27.0	0.122	0.48	Grab
L60	6/30/2008	1150	6.34	27.3	0.085	0.48	Grab
L60	7/7/2008	1015	5.14	28.3	0.074	0.39	Grab
L60	7/14/2008	1215	7.17	26.1	0.123	0.56	Grab
L60	7/23/2008	1000	2.07	29.2	0.09	0.45	Grab
L60	7/28/2008	0940	4.38	27.4	0.116	0.61	composite
L60	8/4/2008	1045	4.65	29.2	0.095	0.53	composite
L60	8/12/2008	1015	5.43	24.4	1.34	5.47	composite
L60	8/18/2008	1030	5.59	23.4	0.9	2.95	composite
L60	8/27/2008	1200	6.84	26.3	1.04	2.79	composite
L60	9/2/2008	1130	4.68	25.4	0.684	1.51	composite
L60	9/9/2008	1130	6.61	22.1	0.168	0.76	composite
L60	9/15/2008	1130	4.06	20.6	0.126	0.61	composite
L60	9/22/2008	1130	7.02	22.2	0.108	0.57	composite
L60	10/1/2008	1115	6.97	18.6	0.097	0.55	composite
L60	10/8/2008	1200	6.49	16.9	0.096	0.54	composite
L60	10/13/2008	1130	5.54	20.4	0.109	0.69	composite

* DO = Dissolved oxygen concentration (mg/L); Temperature = Water temperature (°C); TP = Total Phosphorus (mg/L); TKN = Total Kjeldahl Nitrogen (mg/L)

Station	Date	Time	DO (mg/L)	Temperature (°C)	TP (mg/L)	TKN (mg/L)	Type of sample
L60	10/20/2008	1100	6.83	15.3	0.101	0.59	composite
L60	10/27/2008	1030	7.60	10.3	0.153	0.72	composite
L60	11/5/2008	0900	5.98	16.2	0.117	0.58	composite
L60	11/10/2008	0945	8.92	10.2	2.32	7.7	composite
L60	11/17/2008	1015	9.76	7.6	0.184	0.86	composite
L60	11/24/2008	0930	11.16	7.1	0.131	0.45	composite
L60	12/2/2008	0930	12.49	4.0	0.07	0.32	composite
L60	12/8/2008	1000	12.80	6.0	0.067	0.34	composite
L60	12/17/2008	1000	13.95	1.7	0.073	0.39	composite
L60	12/22/2008	1000	14.20	0.5	0.029	0.24	composite
L60	12/29/2008	1000	10.20	5.1	0.101	0.66	Grab
L60	1/7/2009	1000	14.59	1.5	0.03	0.32	Grab
L60	1/12/2009	1000	15.33	3.1	0.01	0.21	Grab
L60	1/20/2009	1000	13.30	3.3	0.007	0.16	Grab
L60	1/29/2009	1045	15.22	0.6	0.01	0.2	Grab
L60	2/4/2009	1000	12.43	2.1	0.033	0.65	Grab
L60	2/9/2009	1215	11.09	13.4	0.073	0.95	composite
L60	2/18/2009	0945	10.10	10.0	0.337	2.29	composite
L60	2/25/2009	0930	9.79	10.3	0.123	0.67	composite
L60	3/4/2009	0930	10.92	7.8	0.107	0.59	composite
L60	3/9/2009	1000	7.19	14.4	0.005	0.61	composite
L60	3/16/2009	1000	9.44	11.3	0.091	0.55	composite
L60	3/24/2009	1130	7.14	16.0	0.14	0.65	composite
L60	3/30/2009	1000	9.66	9.7	1.98	7.24	composite
L60	4/8/2009	1000	9.55	10.9	0.268	1.72	composite
L60	4/13/2009	0945	9.38	11.9	0	3.15	composite
L60	4/20/2009	0930	8.53	13.1	0.449	1.94	composite
L60	4/27/2009	0900	6.72	20.0			
Hog Creek @ 119th							
Hog	4/22/2008	1230	6.80	19.6	0.041	0.55	Grab
Hog	4/29/2008	1015	9.40	15.1	0.024	0.42	Grab
Hog	5/6/2008	1100	7.06	19.0	0.198	1.17	Grab
Hog	5/14/2008	1115	9.06	18.4	0.047	0.49	Grab
Hog	5/20/2008	1000	8.46	20.7	0.263	1.22	Grab
Hog	5/28/2008	1200	7.13	24.8	0.284	1.59	composite
Hog	6/3/2008	1100	7.44	26.0	0.273	1.76	composite
Hog	6/10/2008	1100	7.75	20.6	0.431	2.68	composite
Hog	6/18/2008	1030	7.08	22.8	0.222	1.33	composite
Hog	6/23/2008	1000	6.83	24.2	0.274	1.51	composite

* DO = Dissolved oxygen concentration (mg/L); Temperature = Water temperature (°C); TP = Total Phosphorus (mg/L); TKN = Total Kjeldahl Nitrogen (mg/L)

Station	Date	Time	DO (mg/L)	Temperature (°C)	TP (mg/L)	TKN (mg/L)	Type of sample
Hog	6/30/2008	1015	6.85	23.9	0.15	1.25	composite
Hog	7/7/2008	0915	6.47	25.4	0.13	0.86	composite
Hog	7/14/2008	1115	7.77	23.6	0.17	1.23	composite
Hog	7/23/2008	0900	2.97	25.2	0.151	1.24	composite
Hog	7/28/2008	0845	7.01	24.1	0.105	0.8	composite
Hog	8/4/2008	1000	3.68	24.3	0.071	0.7	composite
Hog	8/12/2008	0900	6.43	23.2	0.398	1.96	composite
Hog	8/18/2008	0930	6.95	22.1	0.55	2.59	composite
Hog	8/27/2008	1045	7.23	24.6	0.337	1.33	composite
Hog	9/2/2008	1000	6.81	24.9	0.237	1.24	composite
Hog	9/9/2008	1015	7.12	21.2	0.146	1	composite
Hog	9/15/2008	1030	4.53	17.8	0.125	0.95	composite
Hog	9/22/2008	1030	7.64	20.9	0.102	0.82	composite
Hog	10/1/2008	1000	7.64	15.7	0.104	0.85	composite
Hog	10/8/2008	1045	7.67	14.6	0.084	0.64	composite
Hog	10/13/2008	1015	6.51	19.7	0.053	0.5	composite
Hog	10/20/2008	1000	7.97	15.1	0.081	0.72	composite
Hog	10/27/2008	0930	9.03	9.8	0.074	0.71	composite
Hog	11/5/2008	0800	8.12	16.4	0.071	0.67	composite
Hog	11/10/2008	0830	10.10	9.6	0.483	2.92	composite
Hog	11/17/2008	0900	10.71	7.3	0.101	0.75	composite
Hog	11/24/2008	0830	10.96	7.1	0.03	0.39	composite
Hog	12/2/2008	0830	12.23	3.6	0.016	0.28	composite
Hog	12/8/2008	0900	11.99	6.9	0.052	0.5	composite
Hog	12/17/2008	0900	13.48	1.8	0.065	0.52	composite
Hog	12/22/2008	0900	13.80	0.3	0.005	0.25	Grab
Hog	12/29/2008	0900	12.35	3.6	0.025	0.46	Grab
Hog	1/7/2009	0900	13.28	1.7	0.009	0.24	Grab
Hog	1/12/2009	0900	13.32	3.7	0.005	0.16	Grab
Hog	1/20/2009	0900	12.46	3.3	0.005	0.15	Grab
Hog	1/29/2009	0945	14.48	0.9	0.005	0.18	Grab
Hog	2/4/2009	0900	14.04	1.7	0.005	0.19	Grab
Hog	2/9/2009	1115	9.23	13.3	0.088	0.63	composite
Hog	2/18/2009	0845	10.33	9.1	0.167	1.4	composite
Hog	2/25/2009	0830	10.04	9.3	0.059	0.42	composite
Hog	3/4/2009	0830	10.43	6.9	0.094	0.65	composite
Hog	3/9/2009	0900	8.99	12.2	0.009	0.83	composite
Hog	3/16/2009	0900	9.77	9.8	0.042	0.67	composite
Hog	3/24/2009	1000	7.87	14.5	0.194	1.09	composite

* DO = Dissolved oxygen concentration (mg/L); Temperature = Water temperature (°C); TP = Total Phosphorus (mg/L); TKN = Total Kjeldahl Nitrogen (mg/L)

Station	Date	Time	DO (mg/L)	Temperature (°C)	TP (mg/L)	TKN (mg/L)	Type of sample
Hog	3/30/2009	0900	9.94	9.9	0.253	1.94	composite
Hog	4/8/2009	0845	10.84	8.3	0.105	0.86	composite
Hog	4/13/2009	0845	9.48	10.8	0.473	2.92	composite
Hog	4/20/2009	0830	10.08	10.9	0.434	2.33	composite
Hog	4/27/2009	0800	7.52	18.6			
West Elm Creek @ 134th							
Elm	4/22/2008	1045	8.36	18.3	0.011	0.21	Grab
Elm	4/29/2008	0900	9.02	13.7	0.007	0.13	Grab
Elm	5/6/2008	0900	6.72	17.4	0.052	0.41	Grab
Elm	5/14/2008	1000	8.79	17.2	0.024	0.36	Grab
Elm	5/20/2008	0900	7.82	19.2	0.055	0.61	Grab
Elm	5/28/2008	0945	7.43	21.2	0.027	0.33	composite
Elm	6/3/2008	0900	6.04	23.0	0.038	0.24	composite
Elm	6/10/2008	0915	7.37	19.8	0.496	2.81	composite
Elm	6/18/2008	0830	7.58	21.9	0.255	1.34	composite
Elm	6/23/2008	0800	6.78	22.6	0.051	0.54	composite
Elm	6/30/2008	0815	6.83	20.8	0.039	0.44	composite
Elm	7/7/2008	0800	6.42	23.8	0.027	0.28	composite
Elm	7/14/2008	0915	6.78	21.5	0.07	0.55	composite
Elm	7/23/2008	0730	2.95	24.0	0.045	0.45	composite
Elm	7/28/2008	0720	6.98	23.0	0.039	0.35	composite
Elm	8/4/2008	0800	5.43	23.9	0.035	0.33	composite
Elm	8/12/2008	0800	6.80	23.2	0.775	2.49	composite
Elm	8/18/2008	0800	6.37	21.7	0.303	1.49	composite
Elm	8/27/2008	0915	7.08	22.5	0.348	1.52	composite
Elm	9/2/2008	1330	6.21	25.5	0.03	0.22	composite
Elm	9/9/2008	0845	6.30	20.1	0.031	0.26	composite
Elm	9/15/2008	0830	7.23	16.7	0.029	0.23	composite
Elm	9/22/2008	0900	7.03	18.9	0.015	0.15	composite
Elm	10/1/2008	0845	7.24	14.5	0.053	0.31	composite
Elm	10/8/2008	0915	6.99	13.4	0.007	0.22	composite
Elm	10/13/2008	0800	6.01	19.1	0.018	0.21	composite
Elm	10/20/2008	0800	7.56	13.6	0.021	0.21	composite
Elm	10/27/2008	0800	8.65	8.8	0.007	0.15	composite
Elm	11/5/2008	0630	5.57	15.7	0.01	0.16	composite
Elm	11/10/2008	0700	8.29	9.6	0.4	2.24	composite
Elm	11/17/2008	0715	9.24	6.4	0.024	0.29	composite
Elm	11/24/2008	0700	9.35	7.0	0.014	0.2	composite
Elm	12/2/2008	0700	11.68	3.1	0.006	0.13	composite

* DO = Dissolved oxygen concentration (mg/L); Temperature = Water temperature (°C); TP = Total Phosphorus (mg/L); TKN = Total Kjeldahl Nitrogen (mg/L)

Station	Date	Time	DO (mg/L)	Temperature (°C)	TP (mg/L)	TKN (mg/L)	Type of sample
Elm	12/8/2008	0715	10.98	6.8	0.064	0.46	composite
Elm	12/17/2008	0730	12.96	1.9	0.047	0.37	composite
Elm	12/22/2008	0730	13.76	0.6	0.006	0.16	Grab
Elm	12/29/2008	0730	12.34	2.5	0.013	0.24	Grab
Elm	1/7/2009	0730	13.33	1.8	0.005	0.15	Grab
Elm	1/12/2009	0730	13.64	3.4	0.005	0.1	Grab
Elm	1/20/2009	0730	12.46	3.7	0.005	0.12	Grab
Elm	1/29/2009	0830	13.60	0.9	0.01	0.13	Grab
Elm	2/4/2009	0730	13.95	1.7	0.005	0.14	Grab
Elm	2/9/2009	0945	9.75	12.1	0.045	0.4	Grab
Elm	2/18/2009	0715	9.53	9.3	0.032	0.4	composite
Elm	2/25/2009	0700	9.16	9.3	0.022	0.17	composite
Elm	3/4/2009	0700	10.22	7.8	0.027	0.22	composite
Elm	3/9/2009	0730	8.11	12.3	0.014	0.24	composite
Elm	3/16/2009	0730	9.29	10.0	0.005	0.19	composite
Elm	3/24/2009	0800	6.87	14.6	0.015	0.21	composite
Elm	3/30/2009	0730	8.50	10.4	0.054	0.54	composite
Elm	4/8/2009	0700	11.30	8.8	0.026	0.4	composite
Elm	4/13/2009	0730	9.88	11.2	0.082	1.07	Grab
Elm	4/20/2009	0700	8.58	11.2	0.059	0.68	composite
Elm	4/27/2009	0645	6.29	19.4			
Little River @ 17th							
L17	4/22/2008	0845	6.51	20.6	0.037	0.73	Composite
L17	4/29/2008	0745	7.13	13.8	0.037	0.71	Composite
L17	5/6/2008	0730	7.74	18.5	0.302	1.29	Composite
L17	5/14/2008	0730	5.43	17.4	0.150	1.77	Composite
L17	5/20/2008	0730	4.65	21.8	0.194	1.07	Composite
L17	5/28/2008	0730	2.51	22.5	0.073	0.78	Composite
L17	6/3/2008	0730	1.88	23.7	0.056	0.73	Composite
L17	6/10/2008	0715	6.28	20.6	0.39	1.4	Composite
L17	6/18/2008	0700	5.74	23.2	0.341	1.65	Composite
L17	6/23/2008	0630	5.54	24.8	0.094	0.88	Composite
L17	6/30/2008	0700	4.62	23.4	0.083	1.12	Composite
L17	7/7/2008	0700	2.07	24.6	0.092	0.99	Composite
L17	7/14/2008	0730	4.40	23.1	0.251	1.47	Composite
L17	7/23/2008	0645	3.03	25.1	0.242	1.56	Composite
L17	7/28/2008	0645	7.14	26.2			
L17	8/4/2008	0700	1.45	24.0			
L17	8/12/2008	0700	4.76	24.5	0.715	2.16	Composite

* DO = Dissolved oxygen concentration (mg/L); Temperature = Water temperature (°C); TP = Total Phosphorus (mg/L); TKN = Total Kjeldahl Nitrogen (mg/L)

Station	Date	Time	DO (mg/L)	Temperature (°C)	TP (mg/L)	TKN (mg/L)	Type of sample
L17	8/18/2008	0630	4.02	22.1	0.416	2.01	Composite
L17	8/27/2008	0730	5.42	24.9	0.257	1.16	Composite
L17	9/2/2008	0845	5.69	25.0	0.438	1.43	Composite
L17	9/9/2008	0730	5.68	22.5	0.209	1.78	Composite
L17	9/15/2008	0730	5.34	19.0	0.178	1.2	Composite
L17	9/22/2008	0745	4.66	20.5			
L17	10/1/2008	0745	4.34	15.0			
L17	10/8/2008	0800	4.39	14.1	0.341	1.63	Composite
L17	10/13/2008	1315	11.04	22.3			
L17	10/20/2008	1300	15.39	22.1	0.129	0.9	Composite
L17	10/27/2008	1330	14.69	13.6	0.338	1.85	Composite
L17	11/5/2008	1100	9.86	18.7	0.087	0.84	Composite
L17	11/10/2008	1200	10.04	10.7	0.349	1.53	Composite
L17	11/17/2008	1230	10.81	13.4			
L17	11/24/2008	1130	11.37	9.6			
L17	12/2/2008	1130	10.88	6.7			
L17	12/8/2008	1200	11.15	11.0			
L17	12/17/2008	1200	9.07	4.5	0.091	0.43	Composite
L17	12/22/2008	1200	10.55	2.9	0.08	0.58	Composite
L17	12/29/2008	1215	7.58	9.2	0.231	1.19	Composite
L17	1/7/2009	1200	11.55	4.8	0.071	0.58	Composite
L17	1/12/2009	1200	13.09	6.0	0.032	0.49	Composite
L17	1/20/2009	1200	13.77	6.6	0.035	0.60	Composite
L17	1/29/2009	1300	12.81	1.0	0.138	1.33	Composite
L17	2/4/2009	1200	13.61	5.7	0.01	1.86	Composite
L17	2/9/2009	0830	9.54	12.0	0.458	3.11	Composite
L17	2/18/2009	1200	15.86	13.9	0.363	2.59	Composite
L17	2/25/2009	1115	12.83	11.7	0.049	0.59	Composite
L17	3/4/2009	1130	14.92	11.0	0.036	0.63	Composite
L17	3/9/2009	1200	12.41	16.2	0.075	0.58	Composite
L17	3/16/2009	1130	13.00	13.4	0.005	0.58	Composite
L17	3/24/2009	1330	7.54	15.9	0	3.13	Composite
L17	3/30/2009	1130	10.55	11.1	0.49	2.79	Composite
L17	4/8/2009	1130	13.08	14.9	0.035	0.64	Composite
L17	4/13/2009	1130	9.62	11.3	0.39	1.62	Composite
L17	4/20/2009	1100	12.92	18.0	0.058	0.76	Composite
L17	4/27/2009	1100	6.62	19.7			

* DO = Dissolved oxygen concentration (mg/L); Temperature = Water temperature (°C); TP = Total Phosphorus (mg/L); TKN = Total Kjeldahl Nitrogen (mg/L)

Table D-13: Ambient Monitoring Data - Water Chemistry Results

Station	Sampling Date/Time	Depth	Secchi	TURB	Color	TSS	DL TSS	TOC	DOC	POC	Chl-a
Site1	02/04/2008 14:33:21	0.1	68	N/A	N/A	N/A		N/A	N/A	N/A	N/A
Site1	04/22/2008 09:44:22	0.3	68	16	56	10	<	5.35	N/A	N/A	5.11
Site1	04/22/2008 09:48:27	3.9	N/A	N/A	N/A	10	<	5.43	N/A	N/A	N/A
Site1	04/22/2008 09:53:25	7.9	N/A	N/A	N/A	10	<	5.41	N/A	N/A	N/A
Site1	04/22/2008 09:58:58	12	N/A	N/A	N/A	10	<	5.41	N/A	N/A	N/A
Site1	04/22/2008 10:03:58	17	N/A	N/A	N/A	10	<	5.41	N/A	N/A	N/A
Site1	05/12/2008 12:00:00	0.3	62	11	31	10	<	5.09	N/A	N/A	5.73
Site1	05/12/2008 12:00:00	4	N/A	N/A	36	10	<	5.12	N/A	N/A	N/A
Site1	05/12/2008 12:00:00	8	N/A	N/A	36	10	<	5.14	N/A	N/A	N/A
Site1	05/12/2008 12:00:00	12	N/A	N/A	42	10	<	5.15	N/A	N/A	N/A
Site1	05/12/2008 12:00:00	15	N/A	N/A	82	56		5.14	N/A	N/A	N/A
Site1	05/21/2008 11:34:37	0.3	75	9	23	10	<	5.13	4.98	0.15	11.1
Site1	05/21/2008 11:42:42	4.0	N/A	N/A	29	10	<	5.12	5.04	0.08	N/A
Site1	05/21/2008 11:58:38	8.1	N/A	N/A	38	10	<	4.78	5.01	N/A	N/A
Site1	05/21/2008 12:01:44	12.1	N/A	N/A	47	10	<	4.99	4.54	0.45	N/A
Site1	05/21/2008 12:05:06	16.0	N/A	N/A	56	16		5.04	5.21	N/A	N/A
Site1	06/04/2008 13:10:23	4.1	N/A	N/A	18	10	<	5.49	N/A	N/A	N/A
Site1	06/04/2008 13:15:23	0.3	90	11	18	10	<	5.47	N/A	N/A	14.9
Site1	06/04/2008 13:19:10	14.9	N/A	N/A	67	34		5.18	N/A	N/A	N/A
Site1	06/04/2008 13:22:22	12	N/A	N/A	77	22		5.03	N/A	N/A	N/A
Site1	06/04/2008 13:29:57	8	N/A	N/A	18	10	<	5.34	N/A	N/A	N/A
Site1	06/18/2008 09:35:31	0.3	74	10	27	10	<	5.47	N/A	N/A	16.2
Site1	06/18/2008 09:40:29	4.0	N/A	N/A	N/A	10	<	5.35	N/A	N/A	N/A
Site1	06/18/2008 09:45:10	8.0	N/A	N/A	N/A	10		5.41	N/A	N/A	N/A
Site1	06/18/2008 09:54:23	12.0	N/A	N/A	N/A	13		5.18	N/A	N/A	N/A
Site1	06/18/2008 10:02:46	16.1	N/A	N/A	N/A	64		5.52	N/A	N/A	N/A
Site1	07/09/2008 10:12:13	13.9	N/A	N/A	N/A	68		6.12	5.78	0.34	N/A
Site1	07/09/2008 10:15:27	12.0	N/A	N/A	N/A	11		5.5	5.38	0.12	N/A
Site1	07/09/2008 10:23:18	8.0	N/A	N/A	N/A	10	<	5.51	5.28	0.23	N/A
Site1	07/09/2008 10:31:24	4.0	N/A	N/A	N/A	10	<	5.73	5.33	0.4	N/A
Site1	07/09/2008 10:38:55	0.3	84	9	12	10	<	5.9	5.52	0.38	21.9
Site1	07/21/2008 11:03:38	0.3	75	7	12	13		6.69	N/A	N/A	20.2
Site1	07/21/2008 11:09:25	4.0	N/A	N/A	N/A	10		6.55	N/A	N/A	N/A
Site1	07/21/2008 11:17:00	8.1	N/A	N/A	N/A	10	<	5.58	N/A	N/A	N/A
Site1	07/21/2008 11:21:36	12.0	N/A	N/A	N/A	13		5.93	N/A	N/A	N/A

* Depth = Sampling depth (meters); Secchi = Secchi depth (centimeters); Turbidity (NTU); Color = Water color (Platinum Cobalt Units); TSS (mg/L); DL TSS < = below the detection limit of 10mg/L; TOC = Total Organic Carbon (mg/L); DOC = Dissolved Organic Carbon (mg/L); POC = Particlulate Organic Carbon (mg/L); Chl-a = Chlorophyll-a (μg/L); N/A = Missing data

Station	Sampling Date/Time	Depth	Secchi	TURB	Color	TSS	DL TSS	TOC	DOC	POC	Chl-a
Site1	07/21/2008 11:23:50	14.0	N/A	N/A	N/A	13		6.16	N/A	N/A	N/A
Site1	08/04/2008 10:47:45	0.3	58	6	9	10	<	6.69	N/A	N/A	30.7
Site1	08/04/2008 10:54:18	4.0	N/A	N/A	N/A	10	<	6.59	N/A	N/A	N/A
Site1	08/04/2008 10:59:54	8.0	N/A	N/A	N/A	10	<	5.67	N/A	N/A	N/A
Site1	08/04/2008 11:05:05	12.0	N/A	N/A	N/A	10		5.89	N/A	N/A	N/A
Site1	08/04/2008 11:12:45	16.1	N/A	N/A	N/A	10	<	6.62	N/A	N/A	N/A
Site1	08/18/2008 10:05:21	0.3	74	6	11	10	<	5.72	5.29	0.43	N/A
Site1	08/18/2008 10:10:11	4.0	N/A	N/A	N/A	10	<	5.69	5.29	0.4	N/A
Site1	08/18/2008 10:13:30	8.0	N/A	N/A	N/A	10	<	5.71	5.28	0.43	N/A
Site1	08/18/2008 10:18:46	12.1	N/A	N/A	N/A	12		5.92	5.64	0.28	N/A
Site1	08/18/2008 10:22:57	16.0	N/A	N/A	N/A	10		6.54	6.02	0.52	N/A
Site1	09/02/2008 11:59:19	0.3	51	6	23	10	<	5.89	N/A	N/A	52.3
Site1	09/02/2008 12:00:00	15.5	N/A	N/A	N/A	10	<	7.14	N/A	N/A	N/A
Site1	09/02/2008 12:10:38	4.1	N/A	N/A	N/A	10	<	6.01	N/A	N/A	N/A
Site1	09/02/2008 12:23:20	7.9	N/A	N/A	N/A	10	<	5.36	N/A	N/A	N/A
Site1	09/02/2008 12:31:35	12.0	N/A	N/A	N/A	10	<	5.73	N/A	N/A	N/A
Site1	09/22/2008 12:14:10	0.3	70	6	7	10	<	5.93	N/A	N/A	34.9
Site1	09/22/2008 12:20:18	4.0	N/A	N/A	N/A	10		5.7	N/A	N/A	N/A
Site1	09/22/2008 12:26:22	8.1	N/A	N/A	N/A	10	<	5.56	N/A	N/A	N/A
Site1	09/22/2008 12:35:16	12.1	N/A	N/A	N/A	12		5.4	N/A	N/A	N/A
Site1	09/22/2008 12:40:06	15.9	N/A	N/A	N/A	18		5.94	N/A	N/A	N/A
Site1	10/16/2008 11:05:04	0.3	61	17	20	15		5.35	5.09	0.26	19.8
Site1	10/16/2008 11:11:13	4.09	N/A	N/A	N/A	14		5.3	5.11	0.19	N/A
Site1	10/16/2008 11:17:03	8.04	N/A	N/A	N/A	15		5.33	5.1	0.23	N/A
Site1	10/16/2008 11:53:39	12.09	N/A	N/A	N/A	20		5.28	5.06	0.22	N/A
Site1	10/16/2008 11:57:56	16.04	N/A	N/A	N/A	20		5.29	5.09	0.2	N/A
Site1	12/08/2008 12:34:19	0.3	73	15	31	10	<	5.61	N/A	N/A	N/A
Site1	12/08/2008 12:40:07	4	N/A	N/A	N/A	10	<	N/A	N/A	N/A	N/A
Site1	12/08/2008 12:46:48	8	N/A	N/A	N/A	10	<	N/A	N/A	N/A	N/A
Site1	12/08/2008 13:09:55	12	N/A	N/A	N/A	10	<	N/A	N/A	N/A	N/A
Site1	12/08/2008 13:13:44	15	N/A	N/A	N/A	10	<	N/A	N/A	N/A	N/A
Site1	02/09/2009 11:07:44	16.38	N/A	N/A	N/A	11		4.86	N/A	N/A	N/A
Site1	02/09/2009 11:25:07	11.99	N/A	N/A	N/A	10		4.9	N/A	N/A	N/A
Site1	02/09/2009 11:27:25	7.96	N/A	N/A	N/A	10	<	4.94	N/A	N/A	N/A
Site1	02/09/2009 11:29:15	4.08	N/A	N/A	N/A	10		4.99	N/A	N/A	N/A
Site1	02/09/2009 11:31:34	0.13	52	15	56	11		4.93	N/A	N/A	7.67
Site1	04/15/2009 09:10:44	0.16	71	17	49	16		5.13	N/A	N/A	9.57

* Depth = Sampling depth (meters); Secchi = Secchi depth (centimeters); Turbidity (NTU); Color = Water color (Platinum Cobalt Units); TSS (mg/L); DL TSS < = below the detection limit of 10mg/L; TOC = Total Organic Carbon (mg/L); DOC = Dissolved Organic Carbon (mg/L); POC = Particlulate Organic Carbon (mg/L); Chl-a = Chlorophyll-a (μg/L); N/A = Missing data

Station	Sampling Date/Time	Depth	Secchi	TURB	Color	TSS	DL TSS	TOC	DOC	POC	Chl-a
Site1	04/15/2009 09:14:14	16.58	N/A	N/A	N/A	27		N/A	N/A	N/A	N/A
Site1	04/15/2009 09:20:11	11.87	N/A	N/A	N/A	19		N/A	N/A	N/A	N/A
Site1	04/15/2009 09:24:11	8.05	N/A	N/A	N/A	19		N/A	N/A	N/A	N/A
Site1	04/15/2009 09:27:58	3.97	N/A	N/A	N/A	14		N/A	N/A	N/A	N/A
Site1	05/07/2009 10:28:30	0.1	109	6	25	10	<	5.07	N/A	N/A	4.64
Site1	05/07/2009 10:34:13	4	N/A	N/A	N/A	10	<	N/A	N/A	N/A	N/A
Site1	05/07/2009 10:38:08	7.99	N/A	N/A	N/A	10	<	N/A	N/A	N/A	N/A
Site1	05/07/2009 10:42:38	12	N/A	N/A	N/A	10	<	N/A	N/A	N/A	N/A
Site1	05/07/2009 10:57:14	16.52	N/A	N/A	N/A	10	<	N/A	N/A	N/A	N/A
Site1	05/20/2009 09:09:45	0.1	95	6	16	10	<	5.09	N/A	N/A	13.7
Site1	05/20/2009 09:12:57	16.77	N/A	N/A	N/A	16		N/A	N/A	N/A	N/A
Site1	05/20/2009 09:24:05	12.06	N/A	N/A	N/A	13		N/A	N/A	N/A	N/A
Site1	05/20/2009 09:32:01	8.02	N/A	N/A	N/A	10	<	N/A	N/A	N/A	N/A
Site1	05/20/2009 09:38:14	4	N/A	N/A	N/A	10	<	N/A	N/A	N/A	N/A
Site1	06/04/2009 09:43:39	14.81	N/A	N/A	N/A	14		N/A	N/A	N/A	N/A
Site1	06/04/2009 09:46:12	12.07	N/A	N/A	N/A	12		N/A	N/A	N/A	N/A
Site1	06/04/2009 09:51:56	7.99	N/A	N/A	N/A	10		N/A	N/A	N/A	N/A
Site1	06/04/2009 09:55:58	4	N/A	N/A	N/A	10		N/A	N/A	N/A	N/A
Site1	06/04/2009 10:00:12	0.14	98	6	N/A	10		6.21	N/A	N/A	22
Site1	06/25/2009 09:23:46	16.38	N/A	N/A	N/A	11		N/A	N/A	N/A	N/A
Site1	06/25/2009 09:28:51	12	N/A	N/A	N/A	11		N/A	N/A	N/A	N/A
Site1	06/25/2009 09:34:12	8.02	N/A	N/A	N/A	10	<	N/A	N/A	N/A	N/A
Site1	06/25/2009 09:39:44	3.95	N/A	N/A	N/A	10	<	N/A	N/A	N/A	N/A
Site1	06/25/2009 09:43:27	0.12	110	5	14	10	<	6.41	N/A	N/A	9.28
Site1	07/09/2009 08:45:48	16.05	N/A	N/A	N/A	10		N/A	N/A	N/A	N/A
Site1	07/09/2009 08:52:15	11.87	N/A	N/A	N/A	13		N/A	N/A	N/A	N/A
Site1	07/09/2009 08:56:16	8.01	N/A	N/A	N/A	10		N/A	N/A	N/A	N/A
Site1	07/09/2009 09:02:09	3.99	N/A	N/A	N/A	10	<	N/A	N/A	N/A	N/A
Site1	07/09/2009 09:07:15	0.1	95	3.9	12	10	<	5.61	N/A	N/A	13.9
Site1	07/23/2009 08:56:39	0.11	70	8	14	11		5.76	N/A	N/A	38
Site1	07/23/2009 08:59:20	16.01	N/A	N/A	N/A	10	<	N/A	N/A	N/A	N/A
Site1	07/23/2009 09:03:48	11.96	N/A	N/A	N/A	10	<	N/A	N/A	N/A	N/A
Site1	07/23/2009 09:07:50	8.01	N/A	N/A	N/A	10	<	N/A	N/A	N/A	N/A
Site1	07/23/2009 09:11:55	3.93	N/A	N/A	N/A	10	<	N/A	N/A	N/A	N/A
Site1	08/06/2009 09:53:38	16.54	N/A	N/A	N/A	10	<	N/A	N/A	N/A	N/A
Site1	08/06/2009 10:00:07	12.01	N/A	N/A	N/A	11		N/A	N/A	N/A	N/A
Site1	08/06/2009 10:04:18	7.8	N/A	N/A	N/A	10	<	N/A	N/A	N/A	N/A

* Depth = Sampling depth (meters); Secchi = Secchi depth (centimeters); Turbidity (NTU); Color = Water color (Platinum Cobalt Units); TSS (mg/L); DL TSS < = below the detection limit of 10mg/L; TOC = Total Organic Carbon (mg/L); DOC = Dissolved Organic Carbon (mg/L); POC = Particlulate Organic Carbon (mg/L); Chl-a = Chlorophyll-a (μg/L); N/A = Missing data

Station	Sampling Date/Time	Depth	Secchi	TURB	Color	TSS	DL TSS	TOC	DOC	POC	Chl-a
Site1	08/06/2009 10:08:11	4	N/A	N/A	N/A	11		N/A	N/A	N/A	N/A
Site1	08/06/2009 10:11:50	0.09	58	6	22	10	<	6.81	N/A	N/A	69.1
Site1	08/24/2009 09:17:54	0.1	38	7	34	12		7.33	N/A	N/A	57.9
Site1	08/24/2009 09:20:51	4	N/A	N/A	N/A	12		N/A	N/A	N/A	N/A
Site1	08/24/2009 09:25:55	8	N/A	N/A	N/A	10	<	N/A	N/A	N/A	N/A
Site1	08/24/2009 09:31:12	12	N/A	N/A	N/A	10	<	N/A	N/A	N/A	N/A
Site1	08/24/2009 09:43:24	16.1	N/A	N/A	N/A	29		N/A	N/A	N/A	N/A
Site1	09/03/2009 09:20:00	16.05	N/A	N/A	N/A	10	<	N/A	N/A	N/A	N/A
Site1	09/03/2009 09:24:50	12.02	N/A	N/A	N/A	10	<	N/A	N/A	N/A	N/A
Site1	09/03/2009 09:30:07	8.05	N/A	N/A	N/A	10	<	N/A	N/A	N/A	N/A
Site1	09/03/2009 09:34:00	4.03	N/A	N/A	N/A	10	<	N/A	N/A	N/A	N/A
Site1	09/03/2009 09:39:04	0.1	95	8	22	10	<	6.13	N/A	N/A	39.2
Site1	09/17/2009 09:37:08	15.65	N/A	N/A	N/A	17		N/A	N/A	N/A	N/A
Site1	09/17/2009 09:40:25	11.96	N/A	N/A	N/A	10		N/A	N/A	N/A	N/A
Site1	09/17/2009 09:42:54	8.01	N/A	N/A	N/A	11		N/A	N/A	N/A	N/A
Site1	09/17/2009 09:45:52	4.04	N/A	N/A	N/A	40		N/A	N/A	N/A	N/A
Site1	09/17/2009 09:49:39	0.05	105	9	14	11		6.01	N/A	N/A	28
Site1	09/30/2009 10:02:45	16.2	N/A	N/A	N/A	21		N/A	N/A	N/A	N/A
Site1	09/30/2009 10:07:21	12.06	N/A	N/A	N/A	11		N/A	N/A	N/A	N/A
Site1	09/30/2009 10:11:18	8.05	N/A	N/A	N/A	10	<	N/A	N/A	N/A	N/A
Site1	09/30/2009 10:17:13	4.01	N/A	N/A	N/A	10	<	N/A	N/A	N/A	N/A
Site1	09/30/2009 10:21:18	0.17	80	13	27	10	<	5.57	N/A	N/A	22.6
Site1	10/19/2009 09:18:57	16.13	N/A	N/A	N/A	22		N/A	N/A	N/A	N/A
Site1	10/19/2009 09:24:19	11.99	N/A	N/A	N/A	14		N/A	N/A	N/A	N/A
Site1	10/19/2009 09:29:15	7.99	N/A	N/A	N/A	13		N/A	N/A	N/A	N/A
Site1	10/19/2009 09:32:29	4.02	N/A	N/A	N/A	12		N/A	N/A	N/A	N/A
Site1	10/19/2009 09:34:25	0.09	51	21	36	10		5.22	N/A	N/A	12
Site2	04/22/2008 12:30:42	0.2	60	18	77	10	<	5.49	N/A	N/A	4.24
Site2	04/22/2008 12:39:05	12	N/A	N/A	N/A	10	<	5.4	N/A	N/A	N/A
Site2	05/12/2008 12:00:00	N/A	60	16	33	10	<	5.2	N/A	N/A	N/A
Site2	05/12/2008 12:00:00	N/A	N/A	N/A	40	11		5.17	N/A	N/A	N/A
Site2	05/21/2008 14:14:33	0.1	79	9	22	10	<	5.37	4.52	0.85	17.4
Site2	05/21/2008 14:23:35	11	N/A	N/A	51	10	<	4.93	5.16	N/A	N/A
Site2	06/04/2008 13:47:51	11.2	N/A	N/A	34	20		5.45	N/A	N/A	N/A
Site2	06/04/2008 14:55:36	0.1	50	15	23	10		5.5	N/A	N/A	0.16
Site2	06/18/2008 11:23:50	0.1	82	13	27	10		5.66	N/A	N/A	13.4
Site2	06/18/2008 11:38:22	11.1	N/A	N/A	N/A	15		5.3	N/A	N/A	N/A
Site2	07/09/2008 12:13:23	11.9	N/A	N/A	N/A	15		5.9	5.6	0.3	N/A

* Depth = Sampling depth (meters); Secchi = Secchi depth (centimeters); Turbidity (NTU); Color = Water color (Platinum Cobalt Units); TSS (mg/L); DL TSS < = below the detection limit of 10mg/L; TOC = Total Organic Carbon (mg/L); DOC = Dissolved Organic Carbon (mg/L); POC = Particlulate Organic Carbon (mg/L); Chl-a = Chlorophyll-a (μg/L); N/A = Missing data

Station	Sampling Date/Time	Depth	Secchi	TURB	Color	TSS	DL TSS	TOC	DOC	POC	Chl-a
Site2	07/09/2008 12:28:45	0.11	71	7	11	10	<	5.77	5.47	0.3	21.7
Site2	07/21/2008 10:23:56	0.15	60	7	11	11		6.54	N/A	N/A	30.7
Site2	07/21/2008 10:36:16	10	N/A	N/A	N/A	17		5.86	N/A	N/A	N/A
Site2	08/04/2008 09:56:12	0.5	68	6	9	10	<	6.41	N/A	N/A	26.4
Site2	08/04/2008 10:19:10	11.0	N/A	N/A	N/A	10	<	5.75	N/A	N/A	N/A
Site2	08/18/2008 09:27:35	0.1	84	6	11	10	<	6.01	5.66	0.35	39.2
Site2	08/18/2008 09:44:34	11.1	N/A	N/A	N/A	10		6	5.47	0.53	N/A
Site2	09/02/2008 11:03:40	0.2	52	7	27	10	<	6.43	N/A	N/A	58.8
Site2	09/02/2008 11:25:23	11.0	N/A	N/A	N/A	10	<	5.95	N/A	N/A	N/A
Site2	09/22/2008 11:30:28	0.1	90	5	11	10	<	5.95	N/A	N/A	51.3
Site2	09/22/2008 11:54:11	11.0	N/A	N/A	N/A	10	<	5.9	N/A	N/A	N/A
Site2	10/16/2008 10:29:47	0.08	40	15	25	16		5.35	5.19	0.16	24.4
Site2	10/16/2008 10:41:42	11.29	N/A	N/A	N/A	17		5.43	5.17	0.26	N/A
Site2	12/08/2008 11:42:48	0.1	44	16	33	16		5.42	N/A	N/A	6.56
Site2	12/08/2008 11:52:36	11	N/A	N/A	N/A	12		5.27	N/A	N/A	N/A
Site2	02/09/2009 10:14:21	0.05	58	16	56	10		4.94	N/A	N/A	6.57
Site2	04/15/2009 11:47:06	0.03	70	16	47	16		5	N/A	N/A	6.94
Site2	05/07/2009 13:28:26	0.12	130	6	16	5		5.19	N/A	N/A	6.87
Site2	05/20/2009 11:44:19	-0.04	92	7	14	5		5.72	N/A	N/A	17.5
Site2	06/04/2009 12:34:42	-0.03	91	7	N/A	N/A		N/A	N/A	N/A	27.3
Site2	06/25/2009 11:32:43	0.15	113	6	N/A	N/A		N/A	N/A	N/A	6.74
Site2	07/09/2009 11:08:35	-0.01	87	7.1	N/A	N/A		N/A	N/A	N/A	20
Site2	07/23/2009 11:01:17	0.14	69	7	N/A	N/A		N/A	N/A	N/A	43.6
Site2	08/06/2009 11:50:25	0.12	51	8	N/A	N/A		N/A	N/A	N/A	60.5
Site2	08/24/2009 12:14:55	0.12	58	7	N/A	N/A		N/A	N/A	N/A	64.2
Site2	09/03/2009 11:26:16	0.1	73	23	N/A	N/A		N/A	N/A	N/A	49.4
Site2	09/17/2009 11:36:04	0.07	79	21	N/A	N/A		N/A	N/A	N/A	30.2
Site2	09/30/2009 10:52:51	0.1	64	26	N/A	N/A		N/A	N/A	N/A	21.8
Site2	10/19/2009 12:37:45	0.11	53	20	N/A	N/A		N/A	N/A	N/A	14.1
Site3	04/22/2008 12:51:17	0.3	50	23	N/A	N/A		N/A	N/A	N/A	6.9
Site3	05/12/2008 12:00:00	N/A	52	9	N/A	N/A		N/A	N/A	N/A	12.9
Site3	05/21/2008 14:43:23	0.1	69	14	N/A	N/A		N/A	N/A	N/A	12.2
Site3	06/04/2008 14:08:57	0.2	36	24	N/A	N/A		N/A	N/A	N/A	22.7
Site3	06/18/2008 11:01:35	0.15	74	12	N/A	N/A		N/A	N/A	N/A	16.8
Site3	07/09/2008 11:48:51	0.11	60	10	N/A	N/A		N/A	N/A	N/A	22.9
Site3	07/21/2008 09:59:38	0.12	51	14	N/A	N/A		N/A	N/A	N/A	27.1
Site3	08/04/2008 09:32:34	0.08	N/A	10	N/A	N/A		N/A	N/A	N/A	27.8

* Depth = Sampling depth (meters); Secchi = Secchi depth (centimeters); Turbidity (NTU); Color = Water color (Platinum Cobalt Units); TSS (mg/L); DL TSS < = below the detection limit of 10mg/L; TOC = Total Organic Carbon (mg/L); DOC = Dissolved Organic Carbon (mg/L); POC = Particlulate Organic Carbon (mg/L); Chl-a = Chlorophyll-a (μg/L); N/A = Missing data

Station	Sampling Date/Time	Depth	Secchi	TURB	Color	TSS	DL TSS	TOC	DOC	POC	Chl-a
Site3	08/18/2008 09:05:29	0.1	52	12	N/A	N/A		N/A	N/A	N/A	51.9
Site3	09/02/2008 10:33:19	0.1	51	11	N/A	N/A		N/A	N/A	N/A	56.9
Site3	09/22/2008 10:58:12	1.0	51	9	N/A	N/A		N/A	N/A	N/A	42.5
Site3	10/16/2008 10:05:32	0.14	54	12	N/A	N/A		N/A	N/A	N/A	46
Site3	12/08/2008 11:13:24	0.5	72	16	N/A	N/A		N/A	N/A	N/A	8.75
Site3	02/09/2009 13:57:36	0.07	N/A	23	N/A	N/A		N/A	N/A	N/A	10.2
Site3	04/15/2009 11:57:33	0.08	72	16	N/A	N/A		N/A	N/A	N/A	6.54
Site3	05/07/2009 13:41:57	0.04	95	9	N/A	N/A		N/A	N/A	N/A	14.7
Site3	05/20/2009 12:20:55	0.15	101	6	N/A	N/A		N/A	N/A	N/A	16
Site3	06/04/2009 13:11:22	0.36	100	7	N/A	N/A		N/A	N/A	N/A	17.2
Site3	06/25/2009 12:04:01	0.11	91	10	N/A	N/A		N/A	N/A	N/A	9.03
Site3	07/09/2009 11:24:43	0.05	65	6	N/A	N/A		N/A	N/A	N/A	16.5
Site3	07/23/2009 11:25:54	0.15	45	8	N/A	N/A		N/A	N/A	N/A	39.4
Site3	08/06/2009 12:06:14	0.97	48	13	N/A	N/A		N/A	N/A	N/A	56.9
Site3	08/24/2009 12:36:16	0.13	48	20	N/A	N/A		N/A	N/A	N/A	60.5
Site3	09/03/2009 11:52:40	0.11	42	22	N/A	N/A		N/A	N/A	N/A	56.9
Site3	09/17/2009 11:46:37	0.08	49	20	N/A	N/A		N/A	N/A	N/A	29.1
Site3	09/30/2009 11:18:04	0.06	50	33	N/A	N/A		N/A	N/A	N/A	37.2
Site3	10/19/2009 12:55:38	0.22	49	31	N/A	N/A		N/A	N/A	N/A	24.4
Site4	04/22/2008 12:06:29	0.3	49	23	99	10	<	5.46	N/A	N/A	5.5
Site4	04/22/2008 12:17:48	10.9	N/A	N/A	N/A	11		5.39	N/A	N/A	N/A
Site4	05/12/2008 12:00:00	N/A	63	9	40	10	<	5.26	N/A	N/A	9.82
Site4	05/12/2008 12:00:00	N/A	N/A	N/A	93	50		5.27	N/A	N/A	N/A
Site4	05/21/2008 13:46:05	0.1	67	12	25	10	<	5.18	5.47	N/A	19.2
Site4	05/21/2008 13:55:22	13	N/A	N/A	71	10	<	5.06	5.05	0.01	N/A
Site4	06/04/2008 14:36:21	13.1	N/A	N/A	78	52		5.21	N/A	N/A	N/A
Site4	06/04/2008 15:41:55	0.1	66	10	23	10	<	5.57	N/A	N/A	9.73
Site4	06/18/2008 11:52:32	0.2	74	15	25	10		5.42	N/A	N/A	14.3
Site4	06/18/2008 12:10:22	12.9	N/A	N/A	N/A	23		5.36	N/A	N/A	N/A
Site4	07/09/2008 13:31:50	0.1	72	5	12	10	<	5.77	5.36	0.41	12.8
Site4	07/09/2008 13:43:18	12.9	N/A	N/A	N/A	28		6.69	5.66	1.03	N/A
Site4	07/21/2008 11:51:04	0.1	59	6	12	13		6.57	N/A	N/A	14.5
Site4	07/21/2008 12:04:15	9	N/A	N/A	N/A	20		5.72	N/A	N/A	N/A
Site4	08/04/2008 11:29:22	0.4	69	5	9	10	<	6.39	N/A	N/A	20.1
Site4	08/04/2008 11:47:40	9.2	N/A	N/A	N/A	14		5.66	N/A	N/A	N/A
Site4	08/18/2008 10:53:35	0.2	84	7	12	10	<	5.82	5.37	0.45	41.3
Site4	08/18/2008 11:05:03	10.1	N/A	N/A	N/A	11		5.95	5.39	0.56	N/A
Site4	09/02/2008 13:02:17	0.1	52	6	25	10	<	6.51	N/A	N/A	59.5

* Depth = Sampling depth (meters); Secchi = Secchi depth (centimeters); Turbidity (NTU); Color = Water color (Platinum Cobalt Units); TSS (mg/L); DL TSS < = below the detection limit of 10mg/L; TOC = Total Organic Carbon (mg/L); DOC = Dissolved Organic Carbon (mg/L); POC = Particlulate Organic Carbon (mg/L); Chl-a = Chlorophyll-a (μg/L); N/A = Missing data

Station	Sampling Date/Time	Depth	Secchi	TURB	Color	TSS	DL TSS	TOC	DOC	POC	Chl-a
Site4	09/02/2008 13:16:48	10.0	N/A	N/A	N/A	10	<	5.4	N/A	N/A	N/A
Site4	09/22/2008 13:56:59	0.2	59	9	11	10	<	5.93	N/A	N/A	34.8
Site4	09/22/2008 14:22:31	11.9	N/A	N/A	N/A	11		5.82	N/A	N/A	N/A
Site4	10/16/2008 12:19:44	0.1	43	17	31	18		5.35	5.22	0.13	33.4
Site4	10/16/2008 12:29:22	9.25	N/A	N/A	N/A	17		5.41	5.18	0.23	N/A
Site4	12/08/2008 13:34:34	0.5	69	16	34	10		5.34	N/A	N/A	6.82
Site4	12/08/2008 13:40:52	9	N/A	N/A	N/A	17		5.38	N/A	N/A	N/A
Site4	02/09/2009 12:15:15	0.25	57	19	62	10		4.97	N/A	N/A	10.7
Site4	04/15/2009 10:22:14	0.12	71	15	36	17		5.02	N/A	N/A	7.06
Site4	05/07/2009 11:19:32	0.11	138	7	27	5		5	N/A	N/A	4.21
Site4	05/20/2009 10:00:20	0.14	83	6	16	5		5.19	N/A	N/A	17.2
Site4	06/04/2009 10:25:47	0.1	93	7	16	5		5.98	N/A	N/A	22.6
Site4	06/25/2009 10:00:04	0.19	122	5	N/A	N/A		N/A	N/A	N/A	9.47
Site4	07/09/2009 09:36:56	0.16	81	6.2	N/A	N/A		N/A	N/A	N/A	19.3
Site4	07/23/2009 09:32:25	0.13	70	6	N/A	N/A		N/A	N/A	N/A	36.5
Site4	08/06/2009 10:34:46	0.21	64	8	N/A	N/A		N/A	N/A	N/A	60
Site4	08/24/2009 11:08:50	0.22	47	22	N/A	N/A		N/A	N/A	N/A	61.4
Site4	09/03/2009 10:01:05	0.15	45	17	N/A	N/A		N/A	N/A	N/A	55.3
Site4	09/17/2009 10:09:15	12.37	62	20	N/A	N/A		N/A	N/A	N/A	33.2
Site4	09/30/2009 12:01:00	12.8	70	26	N/A	N/A		N/A	N/A	N/A	22.8
Site4	10/19/2009 11:52:58	12.56	45	20	N/A	N/A		N/A	N/A	N/A	14.3
Site5	04/22/2008 11:17:20	0.2	29	44	N/A	N/A		N/A	N/A	N/A	4.37
Site5	05/12/2008 12:00:00	N/A	37	12	N/A	N/A		N/A	N/A	N/A	6.73
Site5	05/21/2008 13:10:18	0.1	59	16	N/A	N/A		N/A	N/A	N/A	5.94
Site5	06/04/2008 15:06:39	0	59	19	N/A	N/A		N/A	N/A	N/A	18.4
Site5	06/18/2008 13:28:02	0.14	60	20	N/A	N/A		N/A	N/A	N/A	14.1
Site5	07/09/2008 13:08:33	0.11	61	6	N/A	N/A		N/A	N/A	N/A	N/A
Site5	07/21/2008 12:48:32	0.13	40	8	N/A	N/A		N/A	N/A	N/A	15.2
Site5	08/04/2008 12:32:00	0.35	N/A	11	N/A	N/A		N/A	N/A	N/A	30.6
Site5	08/18/2008 11:42:09	0.2	34	32	N/A	N/A		N/A	N/A	N/A	64.3
Site5	09/02/2008 13:37:57	0.06	30	19	N/A	N/A		N/A	N/A	N/A	54.5
Site5	09/22/2008 14:46:33	1.08	47	16	N/A	N/A		N/A	N/A	N/A	39.5
Site5	10/16/2008 13:11:29	0.08	43	16	N/A	N/A		N/A	N/A	N/A	50.9
Site5	12/08/2008 12:00:00	N/A	28	26	N/A	N/A		N/A	N/A	N/A	9.41
Site5	02/09/2009 13:14:19	0.09	41	59	N/A	N/A		N/A	N/A	N/A	17.7
Site5	04/15/2009 11:00:00	0.16	69	16	N/A	N/A		N/A	N/A	N/A	10.3
Site5	05/07/2009 12:28:39	0.11	84	13	N/A	N/A		N/A	N/A	N/A	8.34
Site5	05/20/2009 10:54:03	0.06	46	21	N/A	N/A		N/A	N/A	N/A	24.6

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Station	Sampling Date/Time	Depth	Secchi	TURB	Color	TSS	DL TSS	TOC	DOC	POC	Chl-a
Site5	06/04/2009 11:24:33	0.1	45	17	N/A	N/A		N/A	N/A	N/A	29.1
Site5	06/25/2009 10:39:59	0.1	85	10	N/A	N/A		N/A	N/A	N/A	13.7
Site5	07/09/2009 10:06:26	0.08	47	17.5	N/A	N/A		N/A	N/A	N/A	29.5
Site5	07/23/2009 09:55:41	0.1	36	17	N/A	N/A		N/A	N/A	N/A	38.8
Site5	08/06/2009 10:51:29	0.11	51	9	N/A	N/A		N/A	N/A	N/A	55.9
Site5	08/24/2009 11:26:13	0.18	38	23	N/A	N/A		N/A	N/A	N/A	56.9
Site5	09/03/2009 10:22:54	0.11	42	39	N/A	N/A		N/A	N/A	N/A	N/A
Site5	09/17/2009 10:32:23	0.12	36	37	N/A	N/A		N/A	N/A	N/A	37.8
Site5	09/30/2009 12:50:25	0.07	35	27	N/A	N/A		N/A	N/A	N/A	36.1
Site5	10/19/2009 11:28:24	0.14	53	28	N/A	N/A		N/A	N/A	N/A	19.7
Site6	04/22/2008 10:50:52	0.3	20	60	N/A	25		N/A	N/A	N/A	13.5
Site6	05/12/2008 12:00:00	N/A	15	33	137	42		6.28	N/A	N/A	25.3
Site6	05/21/2008 12:46:45	0.1	23	58	71	16		5.3	5.8	N/A	12.6
Site6	06/04/2008 13:33:58	0.1	29	70	58	50		5.91	N/A	N/A	56.2
Site6	06/18/2008 13:10:28	0.11	7	186	N/A	70		6.17	N/A	N/A	10.5
Site6	07/09/2008 12:48:07	0.08	24	33	N/A	37		5.97	5.92	0.05	25
Site6	07/21/2008 13:10:08	0.14	21	44	N/A	37		6.15	N/A	N/A	21.2
Site6	08/04/2008 12:26:35	0.08	16	76	N/A	62		5.99	N/A	N/A	31
Site6	08/18/2008 11:59:19	0.13	5	64	N/A	47		5.96	5.65	0.31	54.4
Site6	09/02/2008 14:02:47	0.11	9	38	N/A	24		5.7	N/A	N/A	53.8
Site6	09/22/2008 15:10:55	0.15	14	74	N/A	52		6.09	N/A	N/A	63.7
Site6	10/16/2008 13:32:35	0.12	14	34	N/A	33		5.59	5.38	0.21	53.9
Site6	12/08/2008 12:00:00	N/A	26	41	N/A	35		5.29	N/A	N/A	13
Site6	02/09/2009 13:25:32	0.12	N/A	61	NA	42		4.56	N/A	N/A	18.2
Site6	04/15/2009 11:09:48	0.09	33	41	N/A	N/A		N/A	N/A	N/A	15.9
Site6	05/07/2009 12:43:47	0.1	28	37	N/A	N/A		N/A	N/A	N/A	14.4
Site6	05/20/2009 11:15:19	0.15	19	60	N/A	N/A		N/A	N/A	N/A	51.1
Site6	06/04/2009 11:47:58	0.08	21	49	N/A	N/A		N/A	N/A	N/A	32.5
Site6	06/25/2009 11:09:56	0.13	39	21	N/A	N/A		N/A	N/A	N/A	20.8
Site6	07/09/2009 10:32:00	0.11	11	59.8	110	81		5.74	N/A	N/A	34.5
Site6	07/23/2009 10:29:32	0.11	20	36	73	33		5.59	N/A	N/A	41.3
Site6	08/06/2009 11:00:11	0.08	20	85	128	62		5.69	N/A	N/A	35.6
Site6	08/24/2009 11:53:30	0.13	11	90	130	71		5.62	N/A	N/A	61.7
Site6	09/03/2009 11:01:15	0.09	18	77	77	55		5.73	N/A	N/A	70.9
Site6	09/17/2009 10:57:24	0.07	9	72	141	51		5.32	N/A	N/A	27
Site6	09/30/2009 13:12:29	0.1	14	78	122	60		5.64	N/A	N/A	44
Site6	10/19/2009 10:46:36	0.09	25	52	89	36		5.28	N/A	N/A	28.4

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Station	Sampling Date/Time	Depth	Secchi	TURB	Color	TSS	DL TSS	TOC	DOC	POC	Chl-a
Site7	04/22/2008 11:42:35	0.1	48	23	N/A	N/A		N/A	N/A	N/A	6.16
Site7	05/12/2008 12:00:00	N/A	53	9	N/A	N/A		N/A	N/A	N/A	10.4
Site7	05/21/2008 13:29:58	0.1	62	17	N/A	N/A		N/A	N/A	N/A	17.3
Site7	06/04/2008 15:24:54	0.1	50	28	N/A	N/A		N/A	N/A	N/A	11.5
Site7	06/18/2008 12:39:06	5.71	74	16	N/A	N/A		N/A	N/A	N/A	10.4
Site7	07/09/2008 14:00:35	0.09	62	8	N/A	N/A		N/A	N/A	N/A	21.6
Site7	07/21/2008 12:21:46	0.14	58	9	N/A	N/A		N/A	N/A	N/A	25.2
Site7	08/04/2008 12:04:34	0.07	N/A	9	N/A	N/A		N/A	N/A	N/A	29.9
Site7	08/18/2008 11:18:43	0.12	38	16	N/A	N/A		N/A	N/A	N/A	46.2
Site7	09/02/2008 14:29:05	0.18	36	11	N/A	N/A		N/A	N/A	N/A	73.3
Site7	09/22/2008 15:41:44	1.01	40	14	N/A	N/A		N/A	N/A	N/A	36.5
Site7	10/16/2008 12:45:33	0.15	54	13	N/A	N/A		N/A	N/A	N/A	40.3
Site7	12/08/2008 14:02:23	0.5	43	19	N/A	N/A		N/A	N/A	N/A	7.45
Site7	02/09/2009 12:53:41	4.8	N/A	21	N/A	N/A		N/A	N/A	N/A	11.9
Site7	04/15/2009 10:32:25	0.07	71	13	N/A	N/A		N/A	N/A	N/A	10.8
Site7	05/07/2009 11:53:32	0.09	N/A	N/A	N/A	N/A		N/A	N/A	N/A	17.3
Site7	05/20/2009 10:31:32	0.09	83	9	N/A	N/A		N/A	N/A	N/A	10.6
Site7	06/04/2009 10:55:48	0.07	81	12	N/A	N/A		N/A	N/A	N/A	2.91
Site7	06/25/2009 10:28:01	0.02	N/A	N/A	N/A	N/A		N/A	N/A	N/A	15
Site8	04/22/2008 13:12:00	0.2	31	38	N/A	14		5.98	N/A	N/A	9.43
Site8	05/12/2008 12:00:00	N/A	35	13	47	15		6.14	N/A	N/A	11
Site8	05/21/2008 14:58:53	0.1	39	21	29	10	<	5.33	5.77	N/A	12.5
Site8	06/04/2008 16:08:45	0.1	39	32	34	25		5.75	N/A	N/A	24
Site8	06/18/2008 10:37:18	0.11	40	33	N/A	17		6.09	1	1	18.4
Site8	07/09/2008 11:23:39	0.17	42	14.5	N/A	20		5.92	5.73	0.19	29.5
Site8	07/21/2008 09:41:17	0.06	34	24	N/A	20		5.78	N/A	N/A	11.7
Site8	08/04/2008 09:09:29	2.9	41	18	N/A	15		6.72	N/A	N/A	21.5
Site8	08/18/2008 08:49:47	0.11	31	42	N/A	28		6.76	5.88	0.88	35.1
Site8	09/02/2008 10:09:42	0.1	26	27	N/A	15		6.17	N/A	N/A	46.3
Site8	09/22/2008 10:38:23	0.45	21	38	N/A	29		6.45	N/A	N/A	32.6
Site8	10/16/2008 09:48:43	0.11	36	23	N/A	24		5.63	5.48	0.15	42.8
Site8	12/08/2008 10:56:41	0.5	63	17	N/A	16		5.37	N/A	N/A	9.18
Site8	12/08/2008 10:58:19	2	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A
Site8	12/08/2008 10:59:05	3	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A
Site8	02/09/2009 14:08:05	2.66	N/A	42	N/A	N/A		N/A	N/A	N/A	12.7
Site8	04/15/2009 12:13:01	0.12	35	36	N/A	N/A		N/A	N/A	N/A	7.12
Site8	05/07/2009 14:02:55	0.09	72	14	N/A	N/A		N/A	N/A	N/A	17.9

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Station	Sampling Date/Time	Depth	Secchi	TURB	Color	TSS	DL TSS	TOC	DOC	POC	Chl-a
Site8	05/20/2009 12:47:55	0.08	53	26	N/A	N/A		N/A	N/A	N/A	14.9
Site8	06/04/2009 13:36:27	0.11	55	14	N/A	N/A		N/A	N/A	N/A	14.8
Site8	06/25/2009 12:31:50	0.11	75	5	N/A	N/A		N/A	N/A	N/A	10.5
Site8	07/09/2009 11:36:56	2.39	26	40.1	23	21		5.76	N/A	N/A	27.3
Site8	07/23/2009 11:44:31	0.1	18	28	47	31		5.99	N/A	N/A	37.2
Site8	08/06/2009 12:14:51	2.47	22	56	77	44		5.76	N/A	N/A	33.1
Site8	08/24/2009 12:52:48	0.18	22	93	102	49		5.97	N/A	N/A	45.3
Site8	09/03/2009 12:08:57	0.12	25	81	42	35		N/A	N/A	N/A	71.4
Site8	09/17/2009 12:04:11	0.09	28	71	47	27		5.85	N/A	N/A	48.8
Site8	09/30/2009 11:31:52	2.63	30	36	38	29		5.87	N/A	N/A	37.4
Site8	10/19/2009 13:07:49	2.84	40	27	31	20		5.3	N/A	N/A	29.3

Table D-14: Ambient Monitoring Data - Water Chemistry Results†

Station	Sampling date/time	Depth	NH4	DL_NH4	NO2	DL_NO2	NO3	DL_NO3	NO23	TKN	ON	TN
Site1	02/04/2008 14:33:21	0.1	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site1	04/22/2008 09:44:22	0.3	0.1	<	0.05	<	0.23		0.255	0.56	0.46	0.815
Site1	04/22/2008 09:48:27	3.9	0.1	<	0.05	<	0.23		0.255	0.56	0.46	0.815
Site1	04/22/2008 09:53:25	7.9	0.1	<	0.05	<	0.23		0.255	0.55	0.45	0.805
Site1	04/22/2008 09:58:58	12	0.1	<	0.05	<	0.23		0.255	0.54	0.44	0.795
Site1	04/22/2008 10:03:58	17	0.1		0.05	<	0.23		0.255	0.58	0.48	0.835
Site1	05/12/2008 12:00:00	0.3	0.1	<	0.05	<	0.25		0.275	0.5	0.4	0.775
Site1	05/12/2008 12:00:00	4	0.1	<	0.05	<	0.24		0.265	0.49	0.39	0.755
Site1	05/12/2008 12:00:00	8	0.1	<	0.05	<	0.25		0.275	0.51	0.41	0.785
Site1	05/12/2008 12:00:00	12	0.1	<	0.05	<	0.26		0.285	0.66	0.56	0.945
Site1	05/12/2008 12:00:00	15	0.1	<	0.05	<	0.31	<	0.18	0.78	0.68	0.96
Site1	05/21/2008 11:34:37	0.3	0.1	<	0.05	<	0.12		0.145	0.63	0.53	0.775
Site1	05/21/2008 11:42:42	4.0	0.1	<	0.05	<	0.23		0.255	0.52	0.42	0.775
Site1	05/21/2008 11:58:38	8.1	0.1	<	0.05	<	0.3		0.325	0.48	0.38	0.805
Site1	05/21/2008 12:01:44	12.1	0.1	<	0.05	<	0.34		0.365	0.53	0.43	0.895
Site1	05/21/2008 12:05:06	16.0	0.1	<	0.05	<	0.36		0.385	0.58	0.48	0.965
Site1	06/04/2008 13:10:23	4.1	0.1	<	0.05	<	0.05	<	0.05	0.52	0.42	0.57
Site1	06/04/2008 13:15:23	0.3	0.1	<	0.05	<	0.05	<	0.05	0.56	0.46	0.61

† NH4 = Ammonia-N (mg/L); DL_NH4 = Less than the detection limit for NH4 of 0.1; NO2 = Nitrite-N (mg/L); DL_NO2 = Less than the detection limit for NO2 of 0.05; NO3 = Nitrate-N (mg/L); D_LNO3 = Less than the detection limit for NO3 of 0.05; NO23 = NO2 + NO3 or nitrite + nitrate; TKN = Total Kjeldahl Nitrogen-N (mg/L); ON = Organic nitrogen-N (mg/L); TN = Total Nitrogen (mg/L)

* Depth = Sampling depth (meters); Secchi = Secchi depth (centimeters); Turbidity (NTU); Color = Water color (Platinum Cobalt Units); TSS (mg/L); DL TSS < = below the detection limit of 10mg/L; TOC = Total Organic Carbon (mg/L); DOC = Dissolved Organic Carbon (mg/L); POC = Particlulate Organic Carbon (mg/L); Chl-a = Chlorophyll-a (μg/L); N/A = Missing data

Station	Sampling date/time	Depth	NH4	DL_NH4	NO2	DL_NO2	NO3	DL_NO3	NO23	TKN	ON	TN
Site1	06/04/2008 13:19:10	14.9	0.1	<	0.05	<	0.32		0.345	0.65	0.55	1.02
Site1	06/04/2008 13:22:22	12	0.1	<	0.05	<	0.3		0.325	0.55	0.45	0.875
Site1	06/04/2008 13:29:57	8	0.1	<	0.05	<	0.05	<	0.05	0.52	0.42	0.57
Site1	06/18/2008 09:35:31	0.3	0.1	<	0.05	<	0.05	<	0.05	0.54	0.44	0.59
Site1	06/18/2008 09:40:29	4.0	0.1	<	0.05	<	0.05	<	0.05	0.53	0.43	0.58
Site1	06/18/2008 09:45:10	8.0	0.1	<	0.05	<	0.05	<	0.05	0.44	0.34	0.49
Site1	06/18/2008 09:54:23	12.0	0.1	<	0.05	<	0.17		0.195	0.52	0.42	0.715
Site1	06/18/2008 10:02:46	16.1	0.27		0.06		0.05	<	0.085	1.04	0.77	1.125
Site1	07/09/2008 10:12:13	13.9	0.924		0.05	<	0.05	<	0.05	1.44	0.52	1.49
Site1	07/09/2008 10:15:27	12.0	0.364		0.05	<	0.05	<	0.05	0.83	0.47	0.88
Site1	07/09/2008 10:23:18	8.0	0.1	<	0.05	<	0.05	<	0.05	0.49	0.39	0.54
Site1	07/09/2008 10:31:24	4.0	0.1	<	0.05	<	0.05	<	0.05	0.65	0.55	0.7
Site1	07/09/2008 10:38:55	0.3	0.1	<	0.05	<	0.05	<	0.05	0.73	0.63	0.78
Site1	07/21/2008 11:03:38	0.3	0.1	<	0.05	<	0.05	<	0.05	0.79	0.69	0.84
Site1	07/21/2008 11:09:25	4.0	0.1	<	0.05	<	0.05	<	0.05	0.72	0.62	0.77
Site1	07/21/2008 11:17:00	8.1	0.1	<	0.05	<	0.05	<	0.05	0.54	0.44	0.59
Site1	07/21/2008 11:21:36	12.0	0.294		0.05	<	0.05	<	0.05	0.91	0.62	0.96
Site1	07/21/2008 11:23:50	14.0	0.633		0.05	<	0.05	<	0.05	1.27	0.64	1.32
Site1	08/04/2008 10:47:45	0.3	0.1	<	0.05	<	0.05	<	0.05	0.82	0.72	0.87
Site1	08/04/2008 10:54:18	4.0	0.1	<	0.05	<	0.05	<	0.05	0.76	0.66	0.81
Site1	08/04/2008 10:59:54	8.0	0.117		0.05	<	0.05	<	0.05	0.7	0.58	0.75
Site1	08/04/2008 11:05:05	12.0	0.904		0.05	<	0.05	<	0.05	1.34	0.44	1.39
Site1	08/04/2008 11:12:45	16.1	1.96		0.05	<	0.05	<	0.05	2.31	0.35	2.36
Site1	08/18/2008 10:05:21	0.3	0.1	<	0.05	<	0.05	<	0.05	0.79	0.69	0.84
Site1	08/18/2008 10:10:11	4.0	0.1	<	0.05	<	0.05	<	0.05	0.72	0.62	0.77
Site1	08/18/2008 10:13:30	8.0	0.1	<	0.05	<	0.05	<	0.05	0.74	0.64	0.79
Site1	08/18/2008 10:18:46	12.1	1.12		0.05	<	0.05	<	0.05	1.66	0.54	1.71
Site1	08/18/2008 10:22:57	16.0	1.92		0.05	<	0.05	<	0.05	2.27	0.35	2.32
Site1	09/02/2008 11:59:19	0.3	0.1	<	0.05	<	0.05	<	0.05	0.89	0.79	0.94
Site1	09/02/2008 12:00:00	15.5	3.19		0.05	<	0.05	<	0.05	3.78	0.59	3.83
Site1	09/02/2008 12:10:38	4.1	0.1	<	0.05	<	0.05	<	0.05	0.77	0.67	0.82
Site1	09/02/2008 12:23:20	7.9	0.184		0.05	<	0.05	<	0.05	0.76	0.58	0.81
Site1	09/02/2008 12:31:35	12.0	0.813		0.05	<	0.05	<	0.05	1.34	0.53	1.39
Site1	09/22/2008 12:14:10	0.3	0.1	<	0.05	<	0.08		0.105	0.74	0.64	0.845
Site1	09/22/2008 12:20:18	4.0	0.1	<	0.05	<	0.14		0.165	0.71	0.61	0.875
Site1	09/22/2008 12:26:22	8.1	0.1	<	0.05	<	0.19		0.215	0.69	0.59	0.905
Site1	09/22/2008 12:35:16	12.1	0.149		0.05	<	0.18		0.205	0.84	0.69	1.045
Site1	09/22/2008 12:40:06	15.9	0.58		0.05	<	0.07		0.095	1.43	0.85	1.525

* Depth = Sampling depth (meters); NH_4 = Ammonia-N (mg/L); DL_NH_4 = Less than the detection limit for NH_4 of 0.1; NO_2 = Nitrite-N (mg/L); DL_NO_2 = Less than the detection limit for NO_2 of 0.05; NO_3 = Nitrate-N (mg/L); D_LNO_3 = Less than the detection limit for NO_3 of 0.05; NO23 = NO_2 + NO_3 or nitrite + nitrate; TKN = Total Kjeldahl Nitrogen-N (mg/L); ON = Organic nitrogen-N (mg/L); TN = Total Nitrogen (mg/L); N/A = Missing data

Station	Sampling date/time	Depth	NH4	DL_NH4	NO2	DL_NO2	NO3	DL_NO3	NO23	TKN	ON	TN
Site1	10/16/2008 11:05:04	0.3	0.1	<	N/A		N/A		0.28	0.67	0.57	0.95
Site1	10/16/2008 11:11:13	4.09	0.1	<	N/A		N/A		0.27	0.73	0.63	1
Site1	10/16/2008 11:17:03	8.04	0.1	<	N/A		N/A		0.28	0.73	0.63	1.01
Site1	10/16/2008 11:53:39	12.09	0.1	<	N/A		N/A		0.27	0.8	0.7	1.07
Site1	10/16/2008 11:57:56	16.04	0.1	<	N/A		N/A		0.27	0.8	0.7	1.07
Site1	12/08/2008 12:34:19	0.3	0.1	<	N/A		N/A		0.36	0.55	0.45	0.91
Site1	12/08/2008 12:40:07	4	0.1	<	N/A		N/A		0.35	0.54	0.44	0.89
Site1	12/08/2008 12:46:48	8	0.1	<	N/A		N/A		0.35	0.54	0.44	0.89
Site1	12/08/2008 13:09:55	12	0.1	<	N/A		N/A		0.36	0.51	0.41	0.87
Site1	12/08/2008 13:13:44	15	0.1	<	N/A		N/A		0.36	0.49	0.39	0.85
Site1	02/09/2009 11:07:44	16.38	0.1	<	N/A		N/A		0.34	0.67	0.62	1.01
Site1	02/09/2009 11:25:07	11.99	0.1	<	N/A		N/A		0.34	0.58	0.53	0.92
Site1	02/09/2009 11:27:25	7.96	0.1	<	N/A		N/A		0.34	0.61	0.56	0.95
Site1	02/09/2009 11:29:15	4.08	0.1	<	N/A		N/A		0.34	0.71	0.66	1.05
Site1	02/09/2009 11:31:34	0.13	0.1	<	N/A		N/A		0.34	0.61	0.56	0.95
Site1	04/15/2009 09:10:44	0.16	0.1	<	N/A		N/A		0.27	0.53	0.48	0.8
Site1	04/15/2009 09:14:14	16.58	0.1	<	N/A		N/A		0.28	0.59	0.54	0.87
Site1	04/15/2009 09:20:11	11.87	0.1	<	N/A		N/A		0.27	0.51	0.46	0.78
Site1	04/15/2009 09:24:11	8.05	0.1	<	N/A		N/A		0.28	0.51	0.46	0.79
Site1	04/15/2009 09:27:58	3.97	0.1	<	N/A		N/A		0.28	0.51	0.46	0.79
Site1	05/07/2009 10:28:30	0.1	0.1	<	N/A		N/A		0.22	0.52	0.47	0.74
Site1	05/07/2009 10:34:13	4	0.1	<	N/A		N/A		0.25	0.48	0.43	0.73
Site1	05/07/2009 10:38:08	7.99	0.1	<	N/A		N/A		0.28	0.48	0.43	0.76
Site1	05/07/2009 10:42:38	12	0.1	<	N/A		N/A		0.23	0.5	0.45	0.73
Site1	05/07/2009 10:57:14	16.52	0.16		N/A		N/A		0.28	0.26	0.1	0.54
Site1	05/20/2009 09:09:45	0.1	0.1	<	N/A		N/A		0.15	0.62	0.57	0.77
Site1	05/20/2009 09:12:57	16.77	0.1	<	N/A		N/A		0.39	0.6	0.55	0.99
Site1	05/20/2009 09:24:05	12.06	0.1	<	N/A		N/A		0.33	0.57	0.52	0.9
Site1	05/20/2009 09:32:01	8.02	0.1	<	N/A		N/A		0.24	0.83	0.78	1.07
Site1	05/20/2009 09:38:14	4	0.1	<	N/A		N/A		0.2	0.53	0.48	0.73
Site1	06/04/2009 09:43:39	14.81	0.13		N/A		N/A		0.06	0.68	0.55	0.74
Site1	06/04/2009 09:46:12	12.07	0.1	<	N/A		N/A		0.025	0.51	0.46	0.535
Site1	06/04/2009 09:51:56	7.99	0.1	<	N/A		N/A		0.025	0.48	0.43	0.505
Site1	06/04/2009 09:55:58	4	0.1	<	N/A		N/A		0.025	0.64	0.59	0.665
Site1	06/04/2009 10:00:12	0.14	0.1	<	N/A		N/A		0.025	0.7	0.65	0.725
Site1	06/25/2009 09:23:46	16.38	0.35		N/A		N/A		0.025	1.03	0.68	1.055
Site1	06/25/2009 09:28:51	12	0.15		N/A		N/A		0.025	0.72	0.57	0.745
Site1	06/25/2009 09:34:12	8.02	0.1	<	N/A		N/A		0.025	0.56	0.51	0.585

* Depth = Sampling depth (meters); NH_4 = Ammonia-N (mg/L); DL_NH_4 = Less than the detection limit for NH_4 of 0.1; NO_2 = Nitrite-N (mg/L); DL_NO_2 = Less than the detection limit for NO_2 of 0.05; NO_3 = Nitrate-N (mg/L); D_LNO_3 = Less than the detection limit for NO_3 of 0.05; NO23 = NO_2 + NO_3 or nitrite + nitrate; TKN = Total Kjeldahl Nitrogen-N (mg/L); ON = Organic nitrogen-N (mg/L); TN = Total Nitrogen (mg/L); N/A = Missing data

Station	Sampling date/time	Depth	NH4	DL_NH4	NO2	DL_NO2	NO3	DL_NO3	NO23	TKN	ON	TN
Site1	06/25/2009 09:39:44	3.95	0.1	<	N/A		N/A		0.025	0.66	0.61	0.685
Site1	06/25/2009 09:43:27	0.12	0.1	<	N/A		N/A		0.025	0.72	0.67	0.745
Site1	07/09/2009 08:45:48	16.05	0.5		N/A		N/A		0.025	1.23	0.73	1.255
Site1	07/09/2009 08:52:15	11.87	0.29		N/A		N/A		0.025	0.94	0.65	0.965
Site1	07/09/2009 08:56:16	8.01	0.1	<	N/A		N/A		0.025	0.86	0.81	0.885
Site1	07/09/2009 09:02:09	3.99	0.1	<	N/A		N/A		0.025	0.73	0.68	0.755
Site1	07/09/2009 09:07:15	0.1	0.1	<	N/A		N/A		0.025	0.65	0.6	0.675
Site1	07/23/2009 08:56:39	0.11	0.1	<	N/A		N/A		0.025	0.83	0.78	0.855
Site1	07/23/2009 08:59:20	16.01	0.81		N/A		N/A		0.025	1.56	0.75	1.585
Site1	07/23/2009 09:03:48	11.96	0.49		N/A		N/A		0.025	1.17	0.68	1.195
Site1	07/23/2009 09:07:50	8.01	0.1	<	N/A		N/A		0.025	0.82	0.77	0.845
Site1	07/23/2009 09:11:55	3.93	0.1	<	N/A		N/A		0.025	0.98	0.93	1.005
Site1	08/06/2009 09:53:38	16.54	1.13		N/A		N/A		0.025	1.97	0.84	1.995
Site1	08/06/2009 10:00:07	12.01	0.81		N/A		N/A		0.025	1.56	0.75	1.585
Site1	08/06/2009 10:04:18	7.8	0.05		N/A		N/A		0.025	0.88	0.83	0.905
Site1	08/06/2009 10:08:11	4	0.99		N/A		N/A		0.025	0.99	0	1.015
Site1	08/06/2009 10:11:50	0.09	0.1	<	N/A		N/A		0.025	0.96	0.91	0.985
Site1	08/24/2009 09:17:54	0.1	0.1	<	N/A		N/A		0.025	1.01	0.96	1.035
Site1	08/24/2009 09:20:51	4	0.1	<	N/A		N/A		0.025	1	0.95	1.025
Site1	08/24/2009 09:25:55	8	0.1	<	N/A		N/A		0.047	1.01	0.96	1.057
Site1	08/24/2009 09:31:12	12	1.55		N/A		N/A		0.025	2.33	0.78	2.355
Site1	08/24/2009 09:43:24	16.1	2.31		N/A		N/A		0.025	3.28	0.97	3.305
Site1	09/03/2009 09:20:00	16.05	2.52		N/A		N/A		0.025	3.7	1.18	3.725
Site1	09/03/2009 09:24:50	12.02	1.89		N/A		N/A		0.025	2.85	0.96	2.875
Site1	09/03/2009 09:30:07	8.05	0.1	<	N/A		N/A		0.025	0.98	0.93	1.005
Site1	09/03/2009 09:34:00	4.03	0.1	<	N/A		N/A		0.025	0.89	0.84	0.915
Site1	09/03/2009 09:39:04	0.1	0.1	<	N/A		N/A		0.025	1	0.95	1.025
Site1	09/17/2009 09:37:08	15.65	3.18		N/A		N/A		0.025	4.85	1.67	4.875
Site1	09/17/2009 09:40:25	11.96	0.14		N/A		N/A		0.07	0.86	0.72	0.93
Site1	09/17/2009 09:42:54	8.01	0.14		N/A		N/A		0.08	0.83	0.69	0.91
Site1	09/17/2009 09:45:52	4.04	0.14		N/A		N/A		0.07	0.89	0.75	0.96
Site1	09/17/2009 09:49:39	0.05	0.14		N/A		N/A		0.07	0.84	0.7	0.91
Site1	09/30/2009 10:02:45	16.2	0.2		N/A		N/A		0.27	1.22	1.02	1.49
Site1	09/30/2009 10:07:21	12.06	0.1	<	N/A		N/A		0.26	0.85	0.8	1.11
Site1	09/30/2009 10:11:18	8.05	0.1	<	N/A		N/A		0.26	0.87	0.82	1.13
Site1	09/30/2009 10:17:13	4.01	0.1	<	N/A		N/A		0.31	0.78	0.73	1.09
Site1	09/30/2009 10:21:18	0.17	0.1	<	N/A		N/A		0.27	0.92	0.87	1.19
Site1	10/19/2009 09:18:57	16.13	0.1	<	N/A		N/A		0.43	0.71	0.66	1.14

* Depth = Sampling depth (meters); NH_4 = Ammonia-N (mg/L); DL_NH_4 = Less than the detection limit for NH_4 of 0.1; NO_2 = Nitrite-N (mg/L); DL_NO_2 = Less than the detection limit for NO_2 of 0.05; NO_3 = Nitrate-N (mg/L); D_LNO_3 = Less than the detection limit for NO_3 of 0.05; NO23 = NO_2 + NO_3 or nitrite + nitrate; TKN = Total Kjeldahl Nitrogen-N (mg/L); ON = Organic nitrogen-N (mg/L); TN = Total Nitrogen (mg/L); N/A = Missing data

Station	Sampling date/time	Depth	NH4	DL_NH4	NO2	DL_NO2	NO3	DL_NO3	NO23	TKN	ON	TN
Site1	10/19/2009 09:24:19	11.99	0.1	<	N/A		N/A		0.45	0.66	0.61	1.11
Site1	10/19/2009 09:29:15	7.99	0.1	<	N/A		N/A		0.45	0.65	0.6	1.1
Site1	10/19/2009 09:32:29	4.02	0.1	<	N/A		N/A		0.45	0.61	0.56	1.06
Site1	10/19/2009 09:34:25	0.09	0.1	<	N/A		N/A		0.44	0.65	0.6	1.09
Site2	04/22/2008 12:30:42	0.2	0.1	<	0.05	<	0.22		0.245	0.61	0.51	0.855
Site2	04/22/2008 12:39:05	12	0.1	<	0.05	<	0.22		0.245	0.55	0.45	0.795
Site2	05/12/2008 12:00:00	N/A	0.1	<	0.05	<	0.21		0.235	0.6	0.5	0.835
Site2	05/12/2008 12:00:00	N/A	0.1	<	0.05	<	0.23		0.255	0.6	0.5	0.855
Site2	05/21/2008 14:14:33	0.1	0.1	<	0.05	<	0.12		0.145	0.57	0.47	0.715
Site2	05/21/2008 14:23:35	11	0.1	<	0.05	<	0.32		0.345	0.53	0.43	0.875
Site2	06/04/2008 13:47:51	11.2	0.1	<	0.05	<	0.05	<	0.05	0.58	0.48	0.63
Site2	06/04/2008 14:55:36	0.1	0.1	<	0.05	<	0.05	<	0.05	0.54	0.44	0.59
Site2	06/18/2008 11:23:50	0.1	0.1	<	0.05	<	0.05	<	0.05	0.55	0.45	0.6
Site2	06/18/2008 11:38:22	11.1	0.1	<	0.05	<	0.16		0.185	0.57	0.47	0.755
Site2	07/09/2008 12:13:23	11.9	0.563		0.05	<	0.05	<	0.05	1.05	0.49	1.1
Site2	07/09/2008 12:28:45	0.11	0.1	<	0.05	<	0.05	<	0.05	0.76	0.66	0.81
Site2	07/21/2008 10:23:56	0.15	0.1	<	0.05	<	0.05	<	0.05	0.78	0.68	0.83
Site2	07/21/2008 10:36:16	10	0.25		0.05	<	0.05	<	0.05	0.82	0.57	0.87
Site2	08/04/2008 09:56:12	0.5	0.1	<	0.05	<	0.05	<	0.05	0.84	0.74	0.89
Site2	08/04/2008 10:19:10	11.0	0.556		0.05	<	0.05	<	0.05	1.14	0.58	1.19
Site2	08/18/2008 09:27:35	0.1	0.1	<	0.05	<	0.05	<	0.05	0.71	0.61	0.76
Site2	08/18/2008 09:44:34	11.1	0.493		0.05	<	0.05	<	0.05	1.18	0.69	1.23
Site2	09/02/2008 11:03:40	0.2	0.1	<	0.05	<	0.05	<	0.05	0.96	0.86	1.01
Site2	09/02/2008 11:25:23	11.0	0.813		0.05	<	0.05	<	0.05	1.33	0.52	1.38
Site2	09/22/2008 11:30:28	0.1	0.1	<	0.05	<	0.05	<	0.05	0.8	0.7	0.85
Site2	09/22/2008 11:54:11	11.0	0.153		0.05	<	0.17		0.195	0.77	0.62	0.965
Site2	10/16/2008 10:29:47	0.08	0.1	<	N/A		N/A		0.22	0.72	0.62	0.94
Site2	10/16/2008 10:41:42	11.29	0.1	<	N/A		N/A		0.18	0.74	0.64	0.92
Site2	12/08/2008 11:42:48	0.1	0.1	<	N/A		N/A		0.34	0.55	0.45	0.89
Site2	12/08/2008 11:52:36	11	0.1	<	N/A		N/A		0.34	0.51	0.41	0.85
Site2	02/09/2009 10:14:21	0.05	0.05		N/A		N/A		0.34	1.41	1.36	1.75
Site2	04/15/2009 11:47:06	0.03	0.05		N/A		N/A		0.27	0.52	0.47	0.79
Site2	05/07/2009 13:28:26	0.12	0.05		N/A		N/A		0.15	0.76	0.71	0.91
Site2	05/20/2009 11:44:19	-0.04	0.05		N/A		N/A		0.025	0.62	0.57	0.645
Site2	06/04/2009 12:34:42	-0.03	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site2	06/25/2009 11:32:43	0.15	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site2	07/09/2009 11:08:35	-0.01	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site2	07/23/2009 11:01:17	0.14	N/A		N/A		N/A		N/A	N/A	N/A	N/A

* Depth = Sampling depth (meters); NH_4 = Ammonia-N (mg/L); DL_NH_4 = Less than the detection limit for NH_4 of 0.1; NO_2 = Nitrite-N (mg/L); DL_NO_2 = Less than the detection limit for NO_2 of 0.05; NO_3 = Nitrate-N (mg/L); D_LNO_3 = Less than the detection limit for NO_3 of 0.05; NO23 = NO_2 + NO_3 or nitrite + nitrate; TKN = Total Kjeldahl Nitrogen-N (mg/L); ON = Organic nitrogen-N (mg/L); TN = Total Nitrogen (mg/L); N/A = Missing data

Station	Sampling date/time	Depth	NH4	DL_NH4	NO2	DL_NO2	NO3	DL_NO3	NO23	TKN	ON	TN
Site2	08/06/2009 11:50:25	0.12	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site2	08/24/2009 12:14:55	0.12	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site2	09/03/2009 11:26:16	0.1	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site2	09/17/2009 11:36:04	0.07	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site2	09/30/2009 10:52:51	0.1	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site2	10/19/2009 12:37:45	0.11	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site3	04/22/2008 12:51:17	0.3	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site3	05/12/2008 12:00:00	N/A	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site3	05/21/2008 14:43:23	0.1	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site3	06/04/2008 14:08:57	0.2	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site3	06/18/2008 11:01:35	0.15	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site3	07/09/2008 11:48:51	0.11	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site3	07/21/2008 09:59:38	0.12	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site3	08/04/2008 09:32:34	0.08	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site3	08/18/2008 09:05:29	0.1	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site3	09/02/2008 10:33:19	0.1	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site3	09/22/2008 10:58:12	1.0	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site3	10/16/2008 10:05:32	0.14	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site3	12/08/2008 11:13:24	0.5	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site3	02/09/2009 13:57:36	0.07	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site3	04/15/2009 11:57:33	0.08	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site3	05/07/2009 13:41:57	0.04	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site3	05/20/2009 12:20:55	0.15	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site3	06/04/2009 13:11:22	0.36	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site3	06/25/2009 12:04:01	0.11	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site3	07/09/2009 11:24:43	0.05	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site3	07/23/2009 11:25:54	0.15	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site3	08/06/2009 12:06:14	0.97	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site3	08/24/2009 12:36:16	0.13	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site3	09/03/2009 11:52:40	0.11	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site3	09/17/2009 11:46:37	0.08	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site3	09/30/2009 11:18:04	0.06	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site3	10/19/2009 12:55:38	0.22	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site4	04/22/2008 12:06:29	0.3	0.1	<	0.05	<	0.22		0.245	0.65	0.55	0.895
Site4	04/22/2008 12:17:48	10.9	0.13		0.05	<	0.23		0.255	0.59	0.46	0.845
Site4	05/12/2008 12:00:00	N/A	0.1	<	0.05	<	0.21		0.235	0.53	0.43	0.765
Site4	05/12/2008 12:00:00	N/A	0.1	<	0.05	<	0.31		0.335	0.68	0.58	1.015

* Depth = Sampling depth (meters); NH_4 = Ammonia-N (mg/L); DL_NH_4 = Less than the detection limit for NH_4 of 0.1; NO_2 = Nitrite-N (mg/L); DL_NO_2 = Less than the detection limit for NO_2 of 0.05; NO_3 = Nitrate-N (mg/L); D_LNO_3 = Less than the detection limit for NO_3 of 0.05; NO23 = NO_2 + NO_3 or nitrite + nitrate; TKN = Total Kjeldahl Nitrogen-N (mg/L); ON = Organic nitrogen-N (mg/L); TN = Total Nitrogen (mg/L); N/A = Missing data

Station	Sampling date/time	Depth	NH4	DL_NH4	NO2	DL_NO2	NO3	DL_NO3	NO23	TKN	ON	TN
Site4	05/21/2008 13:46:05	0.1	0.1	<	0.05	<	0.11		0.135	0.61	0.51	0.745
Site4	05/21/2008 13:55:22	13	0.1	<	0.05	<	0.36		0.385	0.6	0.5	0.985
Site4	06/04/2008 14:36:21	13.1	0.1	<	0.05	<	0.29		0.315	0.7	0.6	1.015
Site4	06/04/2008 15:41:55	0.1	0.1	<	0.05	<	0.05	<	0.05	0.56	0.46	0.61
Site4	06/18/2008 11:52:32	0.2	0.1	<	0.05	<	0.05	<	0.05	0.51	0.41	0.56
Site4	06/18/2008 12:10:22	12.9	0.11		0.05	<	0.14		0.165	0.72	0.61	0.885
Site4	07/09/2008 13:31:50	0.1	0.1	<	0.05	<	0.05	<	0.05	0.68	0.58	0.73
Site4	07/09/2008 13:43:18	12.9	0.756		0.05	<	0.05	<	0.05	1.2	0.44	1.25
Site4	07/21/2008 11:51:04	0.1	0.1	<	0.05	<	0.05	<	0.05	0.71	0.61	0.76
Site4	07/21/2008 12:04:15	9	0.25		0.05	<	0.05	<	0.05	0.82	0.57	0.87
Site4	08/04/2008 11:29:22	0.4	0.1	<	0.05	<	0.05	<	0.05	0.79	0.69	0.84
Site4	08/04/2008 11:47:40	9.2	0.339		0.05	<	0.05	<	0.05	1.01	0.67	1.06
Site4	08/18/2008 10:53:35	0.2	0.1	<	0.05	<	0.05	<	0.05	0.77	0.67	0.82
Site4	08/18/2008 11:05:03	10.1	0.363		0.05	<	0.05	<	0.05	1.02	0.66	1.07
Site4	09/02/2008 13:02:17	0.1	0.1	<	0.05	<	0.05	<	0.05	0.96	0.86	1.01
Site4	09/02/2008 13:16:48	10.0	0.366		0.05	<	0.05	<	0.05	0.99	0.62	1.04
Site4	09/22/2008 13:56:59	0.2	0.1	<	0.05	<	0.05	<	0.05	0.76	0.66	0.81
Site4	09/22/2008 14:22:31	11.9	0.218		0.05	<	0.12		0.145	0.86	0.64	1.005
Site4	10/16/2008 12:19:44	0.1	0.1	<	N/A		N/A		0.13	0.72	0.62	0.85
Site4	10/16/2008 12:29:22	9.25	0.1	<	N/A		N/A		0.12	0.74	0.64	0.86
Site4	12/08/2008 13:34:34	0.5	0.1	<	N/A		N/A		0.35	0.54	0.44	0.89
Site4	12/08/2008 13:40:52	9	0.1	<	N/A		N/A		0.35	0.58	0.48	0.93
Site4	02/09/2009 12:15:15	0.25	0.05		N/A		N/A		0.34	0.6	0.55	0.94
Site4	04/15/2009 10:22:14	0.12	0.05		N/A		N/A		0.25	0.46	0.41	0.71
Site4	05/07/2009 11:19:32	0.11	0.05		N/A		N/A		0.24	0.51	0.46	0.75
Site4	05/20/2009 10:00:20	0.14	0.05		N/A		N/A		0.76	0.15	0.1	0.91
Site4	06/04/2009 10:25:47	0.1	0.05		N/A		N/A		0.025	0.67	0.62	0.695
Site4	06/25/2009 10:00:04	0.19	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site4	07/09/2009 09:36:56	0.16	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site4	07/23/2009 09:32:25	0.13	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site4	08/06/2009 10:34:46	0.21	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site4	08/24/2009 11:08:50	0.22	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site4	09/03/2009 10:01:05	0.15	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site4	09/17/2009 10:09:15	12.37	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site4	09/30/2009 12:01:00	12.8	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site4	10/19/2009 11:52:58	12.56	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site5	04/22/2008 11:17:20	0.2	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site5	05/12/2008 12:00:00	N/A	N/A		N/A		N/A		N/A	N/A	N/A	N/A

* Depth = Sampling depth (meters); NH_4 = Ammonia-N (mg/L); DL_NH_4 = Less than the detection limit for NH_4 of 0.1; NO_2 = Nitrite-N (mg/L); DL_NO_2 = Less than the detection limit for NO_2 of 0.05; NO_3 = Nitrate-N (mg/L); D_LNO_3 = Less than the detection limit for NO_3 of 0.05; NO23 = NO_2 + NO_3 or nitrite + nitrate; TKN = Total Kjeldahl Nitrogen-N (mg/L); ON = Organic nitrogen-N (mg/L); TN = Total Nitrogen (mg/L); N/A = Missing data

Station	Sampling date/time	Depth	NH4	DL_NH4	NO2	DL_NO2	NO3	DL_NO3	NO23	TKN	ON	TN
Site5	05/21/2008 13:10:18	0.1	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site5	06/04/2008 15:06:39	0	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site5	06/18/2008 13:28:02	0.14	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site5	07/09/2008 13:08:33	0.11	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site5	07/21/2008 12:48:32	0.13	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site5	08/04/2008 12:32:00	0.35	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site5	08/18/2008 11:42:09	0.2	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site5	09/02/2008 13:37:57	0.06	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site5	09/22/2008 14:46:33	1.08	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site5	10/16/2008 13:11:29	0.08	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site5	12/08/2008 12:00:00	N/A	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site5	02/09/2009 13:14:19	0.09	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site5	04/15/2009 11:00:00	0.16	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site5	05/07/2009 12:28:39	0.11	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site5	05/20/2009 10:54:03	0.06	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site5	06/04/2009 11:24:33	0.1	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site5	06/25/2009 10:39:59	0.1	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site5	07/09/2009 10:06:26	0.08	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site5	07/23/2009 09:55:41	0.1	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site5	08/06/2009 10:51:29	0.11	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site5	08/24/2009 11:26:13	0.18	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site5	09/03/2009 10:22:54	0.11	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site5	09/17/2009 10:32:23	0.12	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site5	09/30/2009 12:50:25	0.07	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site5	10/19/2009 11:28:24	0.14	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site6	04/22/2008 10:50:52	0.3	0.15		0.07		0.25		0.32	0.84	0.69	1.16
Site6	05/12/2008 12:00:00	N/A	0.1	<	0.06		0.19		0.25	0.89	0.79	1.14
Site6	05/21/2008 12:46:45	0.1	0.1	<	0.05		0.17		0.221	0.73	0.63	0.951
Site6	06/04/2008 13:33:58	0.1	0.1	<	0.05	<	0.05	<	0.05	0.8	0.7	0.85
Site6	06/18/2008 13:10:28	0.11	0.12		0.11		0.11		0.22	0.82	0.7	1.04
Site6	07/09/2008 12:48:07	0.08	0.1	<	0.05	<	0.05	<	0.05	0.84	0.74	0.89
Site6	07/21/2008 13:10:08	0.14	0.1	<	0.05	<	0.05	<	0.05	0.93	0.83	0.98
Site6	08/04/2008 12:26:35	0.08	0.109		0.05	<	0.05	<	0.05	0.95	0.84	1
Site6	08/18/2008 11:59:19	0.13	0.1	<	0.05	<	0.05	<	0.05	1	0.9	1.05
Site6	09/02/2008 14:02:47	0.11	0.1	<	0.05	<	0.05	<	0.05	1	0.9	1.05
Site6	09/22/2008 15:10:55	0.15	0.1	<	0.05	<	0.05	<	0.05	1.03	0.93	1.08
Site6	10/16/2008 13:32:35	0.12	0.1	<	N/A		N/A		N/A	1.05	0.95	-7.95
Site6	12/08/2008 12:00:00	N/A	0.1	<	N/A		N/A		0.24	0.63	0.53	0.87

* Depth = Sampling depth (meters); NH_4 = Ammonia-N (mg/L); DL_NH_4 = Less than the detection limit for NH_4 of 0.1; NO_2 = Nitrite-N (mg/L); DL_NO_2 = Less than the detection limit for NO_2 of 0.05; NO_3 = Nitrate-N (mg/L); D_LNO_3 = Less than the detection limit for NO_3 of 0.05; NO23 = NO_2 + NO_3 or nitrite + nitrate; TKN = Total Kjeldahl Nitrogen-N (mg/L); ON = Organic nitrogen-N (mg/L); TN = Total Nitrogen (mg/L); N/A = Missing data

Station	Sampling date/time	Depth	NH4	DL_NH4	NO2	DL_NO2	NO3	DL_NO3	NO23	TKN	ON	TN
Site6	02/09/2009 13:25:32	0.12	0.1	<	N/A		N/A		0.23	0.63	0.53	0.86
Site6	04/15/2009 11:09:48	0.09	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site6	05/07/2009 12:43:47	0.1	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site6	05/20/2009 11:15:19	0.15	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site6	06/04/2009 11:47:58	0.08	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site6	06/25/2009 11:09:56	0.13	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site6	07/09/2009 10:32:00	0.11	0.05		N/A		N/A		0.025	1.09	1.04	1.115
Site6	07/23/2009 10:29:32	0.11	0.05		N/A		N/A		0.025	1.02	0.97	1.045
Site6	08/06/2009 11:00:11	0.08	0.05		N/A		N/A		0.025	1.19	1.14	1.215
Site6	08/24/2009 11:53:30	0.13	0.05		N/A		N/A		0.025	0.99	0.94	1.015
Site6	09/03/2009 11:01:15	0.09	0.05		N/A		N/A		0.025	1.15	1.1	1.175
Site6	09/17/2009 10:57:24	0.07	0.15		N/A		N/A		0.11	0.99	0.84	1.1
Site6	09/30/2009 13:12:29	0.1	0.05		N/A		N/A		0.025	1.16	1.11	1.185
Site6	10/19/2009 10:46:36	0.09	0.05		N/A		N/A		0.14	0.9	0.85	1.04
Site7	04/22/2008 11:42:35	0.1	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site7	05/12/2008 12:00:00	N/A	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site7	05/21/2008 13:29:58	0.1	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site7	06/04/2008 15:24:54	0.1	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site7	06/18/2008 12:39:06	5.71	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site7	07/09/2008 14:00:35	0.09	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site7	07/21/2008 12:21:46	0.14	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site7	08/04/2008 12:04:34	0.07	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site7	08/18/2008 11:18:43	0.12	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site7	09/02/2008 14:29:05	0.18	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site7	09/22/2008 15:41:44	1.01	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site7	10/16/2008 12:45:33	0.15	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site7	12/08/2008 14:02:23	0.5	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site7	02/09/2009 12:53:41	4.8	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site7	04/15/2009 10:32:25	0.07	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site7	05/07/2009 11:53:32	0.09	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site7	05/20/2009 10:31:32	0.09	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site7	06/04/2009 10:55:48	0.07	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site7	06/25/2009 10:28:01	0.02	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site8	04/22/2008 13:12:00	0.2	0.1	<	0.05	<	0.2		0.225	0.66	0.56	0.885
Site8	05/12/2008 12:00:00	N/A	0.1	<	0.05	<	0.13		0.155	0.65	0.55	0.805
Site8	05/21/2008 14:58:53	0.1	0.1	<	0.05	<	0.08		0.105	0.67	0.57	0.775
Site8	06/04/2008 16:08:45	0.1	0.1	<	0.05	<	0.05	<	0.05	0.41	0.31	0.46

* Depth = Sampling depth (meters); NH_4 = Ammonia-N (mg/L); DL_NH_4 = Less than the detection limit for NH_4 of 0.1; NO_2 = Nitrite-N (mg/L); DL_NO_2 = Less than the detection limit for NO_2 of 0.05; NO_3 = Nitrate-N (mg/L); D_LNO_3 = Less than the detection limit for NO_3 of 0.05; NO23 = NO_2 + NO_3 or nitrite + nitrate; TKN = Total Kjeldahl Nitrogen-N (mg/L); ON = Organic nitrogen-N (mg/L); TN = Total Nitrogen (mg/L); N/A = Missing data

Station	Sampling date/time	Depth	NH4	DL_NH4	NO2	DL_NO2	NO3	DL_NO3	NO23	TKN	ON	TN
Site8	06/18/2008 10:37:18	0.11	0.1	<	0.05	<	0.05	<	0.05	0.68	0.58	0.73
Site8	07/09/2008 11:23:39	0.17	0.1	<	0.05	<	0.05	<	0.05	0.76	0.66	0.81
Site8	07/21/2008 09:41:17	0.06	0.1	<	0.05	<	0.05	<	0.05	0.77	0.67	0.82
Site8	08/04/2008 09:09:29	2.9	0.1	<	0.05	<	0.05	<	0.05	0.82	0.72	0.87
Site8	08/18/2008 08:49:47	0.11	0.1	<	0.05	<	0.05	<	0.05	0.87	0.77	0.92
Site8	09/02/2008 10:09:42	0.1	0.1	<	0.05	<	0.05	<	0.05	0.99	0.89	1.04
Site8	09/22/2008 10:38:23	0.45	0.1	<	0.05	<	0.05	<	0.05	0.87	0.77	0.92
Site8	10/16/2008 09:48:43	0.11	0.1	<	N/A		N/A		N/A	0.93	0.83	-8.07
Site8	12/08/2008 10:56:41	0.5	0.1	<	N/A		N/A		0.27	0.56	0.46	0.83
Site8	12/08/2008 10:58:19	2	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site8	12/08/2008 10:59:05	3	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site8	02/09/2009 14:08:05	2.66	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site8	04/15/2009 12:13:01	0.12	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site8	05/07/2009 14:02:55	0.09	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site8	05/20/2009 12:47:55	0.08	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site8	06/04/2009 13:36:27	0.11	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site8	06/25/2009 12:31:50	0.11	N/A		N/A		N/A		N/A	N/A	N/A	N/A
Site8	07/09/2009 11:36:56	2.39	0.05		N/A		N/A		0.025	0.83	0.78	0.855
Site8	07/23/2009 11:44:31	0.1	0.05		N/A		N/A		0.025	1	0.95	1.025
Site8	08/06/2009 12:14:51	2.47	0.05		N/A		N/A		0.025	1.14	1.09	1.165
Site8	08/24/2009 12:52:48	0.18	0.05		N/A		N/A		0.025	1.43	1.38	1.455
Site8	09/03/2009 12:08:57	0.12	0.05		N/A		N/A		0.05	1.07	1.02	1.12
Site8	09/17/2009 12:04:11	0.09	0.17		N/A		N/A		0.08	0.9	0.73	0.98
Site8	09/30/2009 11:31:52	2.63	0.05		N/A		N/A		0.025	1.11	1.06	1.135
Site8	10/19/2009 13:07:49	2.84	0.05		N/A		N/A		0.17	0.74	0.69	0.91

* Depth = Sampling depth (meters); NH_4 = Ammonia-N (mg/L); DL_NH_4 = Less than the detection limit for NH_4 of 0.1; NO_2 = Nitrite-N (mg/L); DL_NO_2 = Less than the detection limit for NO_2 of 0.05; NO_3 = Nitrate-N (mg/L); D_LNO_3 = Less than the detection limit for NO_3 of 0.05; NO23 = NO_2 + NO_3 or nitrite + nitrate; TKN = Total Kjeldahl Nitrogen-N (mg/L); ON = Organic nitrogen-N (mg/L); TN = Total Nitrogen (mg/L); N/A = Missing data

Table D-15 Ambient Monitoring Data - Water Chemistry Results

Station	Sampling_time	Depth	TP	PO4	DL_PO4	OP
Site1	02/04/2008 14:33:21	0.1	N/A	N/A		N/A
Site1	04/22/2008 09:44:22	0.3	0.029	0.021		0.008
Site1	04/22/2008 09:48:27	3.9	0.025	0.021		0.004
Site1	04/22/2008 09:53:25	7.9	0.03	0.022		0.008
Site1	04/22/2008 09:58:58	12	0.029	0.023		0.006
Site1	04/22/2008 10:03:58	17	0.032	0.024		0.008
Site1	05/12/2008 12:00:00	0.3	0.028	0.01		0.018
Site1	05/12/2008 12:00:00	4	0.03	0.012		0.018
Site1	05/12/2008 12:00:00	8	0.028	0.01		0.018
Site1	05/12/2008 12:00:00	12	0.034	0.014		0.02
Site1	05/12/2008 12:00:00	15	0.089	0.03		0.059
Site1	05/21/2008 11:34:37	0.3	0.031	0.006		0.025
Site1	05/21/2008 11:42:42	4.0	0.026	0.006		0.02
Site1	05/21/2008 11:58:38	8.1	0.028	0.01		0.018
Site1	05/21/2008 12:01:44	12.1	0.044	0.02		0.024
Site1	05/21/2008 12:05:06	16.0	0.053	0.03		0.023
Site1	06/04/2008 13:10:23	4.1	0.026	0.005	<	0.024
Site1	06/04/2008 13:15:23	0.3	0.025	0.005	<	0.023
Site1	06/04/2008 13:19:10	14.9	0.076	0.038		0.038
Site1	06/04/2008 13:22:22	12	0.043	0.018		0.025
Site1	06/04/2008 13:29:57	8	0.025	0.005	<	0.023
Site1	06/18/2008 09:35:31	0.3	0.03	0.005		0.025
Site1	06/18/2008 09:40:29	4.0	0.031	0.006		0.025
Site1	06/18/2008 09:45:10	8.0	0.022	0.006		0.016
Site1	06/18/2008 09:54:23	12.0	0.051	0.025		0.026
Site1	06/18/2008 10:02:46	16.1	0.161	0.077		0.084
Site1	07/09/2008 10:12:13	13.9	0.428	0.323		0.105
Site1	07/09/2008 10:15:27	12.0	0.163	0.143		0.02
Site1	07/09/2008 10:23:18	8.0	0.03	0.006		0.024
Site1	07/09/2008 10:31:24	4.0	0.028	0.007		0.021
Site1	07/09/2008 10:38:55	0.3	0.032	0.007		0.025
Site1	07/21/2008 11:03:38	0.3	0.03	0.01		0.02
Site1	07/21/2008 11:09:25	4.0	0.027	0.009		0.018
Site1	07/21/2008 11:17:00	8.1	0.029	0.006		0.023
Site1	07/21/2008 11:21:36	12.0	0.166	0.135		0.031
Site1	07/21/2008 11:23:50	14.0	0.339	0.323		0.016
Site1	08/04/2008 10:47:45	0.3	0.025	0.008		0.017

* Depth = Sampling depth (meters); TP = Total phosphorus-P (mg/L); PO4 = Total phosphate-P (mg/L); DL_PO4 = Less than the detection limit for PO4 of 0.05; OP = Organic phosphorus-P (mg/L)

Station	Sampling_time	Depth	TP	PO4	DL_PO4	OP
Site1	08/04/2008 10:54:18	4.0	0.026	0.009		0.017
Site1	08/04/2008 10:59:54	8.0	0.032	0.05	<	0.007
Site1	08/04/2008 11:05:05	12.0	0.257	0.2		0.057
Site1	08/04/2008 11:12:45	16.1	0.526	0.5		0.026
Site1	08/18/2008 10:05:21	0.3	0.025	0.01		0.015
Site1	08/18/2008 10:10:11	4.0	0.031	0.01		0.021
Site1	08/18/2008 10:13:30	8.0	0.031	0.009		0.022
Site1	08/18/2008 10:18:46	12.1	0.285	0.226		0.059
Site1	08/18/2008 10:22:57	16.0	0.444	0.452		N/A
Site1	09/02/2008 11:59:19	0.3	0.041	0.013		0.028
Site1	09/02/2008 12:00:00	15.5	0.734	0.671		0.063
Site1	09/02/2008 12:10:38	4.1	0.047	0.013		0.034
Site1	09/02/2008 12:23:20	7.9	0.035	0.008		0.027
Site1	09/02/2008 12:31:35	12.0	0.185	0.13		0.055
Site1	09/22/2008 12:14:10	0.3	0.036	0.008		0.028
Site1	09/22/2008 12:20:18	4.0	0.035	0.006		0.029
Site1	09/22/2008 12:26:22	8.1	0.036	0.01		0.026
Site1	09/22/2008 12:35:16	12.1	0.045	0.017		0.028
Site1	09/22/2008 12:40:06	15.9	0.12	0.045		0.075
Site1	10/16/2008 11:05:04	0.3	0.041	0.023		0.018
Site1	10/16/2008 11:11:13	4.09	0.039	0.021		0.018
Site1	10/16/2008 11:17:03	8.04	0.042	0.022		0.02
Site1	10/16/2008 11:53:39	12.09	0.047	0.023		0.024
Site1	10/16/2008 11:57:56	16.04	0.043	0.024		0.019
Site1	12/08/2008 12:34:19	0.3	0.023	0.027		N/A
Site1	12/08/2008 12:40:07	4	0.025	0.029		N/A
Site1	12/08/2008 12:46:48	8	0.025	0.026		N/A
Site1	12/08/2008 13:09:55	12	0.03	0.028		0.002
Site1	12/08/2008 13:13:44	15	0.029	0.029		0
Site1	02/09/2009 11:07:44	16.38	0.022	0.021		0.001
Site1	02/09/2009 11:25:07	11.99	0.021	0.021		0
Site1	02/09/2009 11:27:25	7.96	0.022	0.022		0
Site1	02/09/2009 11:29:15	4.08	0.024	0.022		0.002
Site1	02/09/2009 11:31:34	0.13	0.023	0.021		0.002
Site1	04/15/2009 09:10:44	0.16	0.028	0.013		0.015
Site1	04/15/2009 09:14:14	16.58	0.041	0.025		0.016
Site1	04/15/2009 09:20:11	11.87	0.029	0.015		0.014
Site1	04/15/2009 09:24:11	8.05	0.03	0.016		0.014
Site1	04/15/2009 09:27:58	3.97	0.031	0.014		0.017

* Depth = Sampling depth (meters); TP = Total phosphorus-P (mg/L); PO4 = Total phosphate-P (mg/L); DL_PO4 = Less than the detection limit for PO4 of 0.05; OP = Organic phosphorus-P (mg/L)

Station	Sampling_time	Depth	TP	PO4	DL_PO4	OP
Site1	05/07/2009 10:28:30	0.1	0.021	0.006		0.015
Site1	05/07/2009 10:34:13	4	0.023	0.011		0.012
Site1	05/07/2009 10:38:08	7.99	0.024	0.014		0.01
Site1	05/07/2009 10:42:38	12	0.03	0.02		0.01
Site1	05/07/2009 10:57:14	16.52	0.07	0.059		0.011
Site1	05/20/2009 09:09:45	0.1	0.03	0.005		0.025
Site1	05/20/2009 09:12:57	16.77	0.06	0.046		0.014
Site1	05/20/2009 09:24:05	12.06	0.042	0.029		0.013
Site1	05/20/2009 09:32:01	8.02	0.026	0.006		0.02
Site1	05/20/2009 09:38:14	4	0.024	0.005	<	0.022
Site1	06/04/2009 09:43:39	14.81	0.063	0.043		0.02
Site1	06/04/2009 09:46:12	12.07	0.036	0.021		0.015
Site1	06/04/2009 09:51:56	7.99	0.024	0.005		0.019
Site1	06/04/2009 09:55:58	4	0.037	0.005		0.032
Site1	06/04/2009 10:00:12	0.14	0.038	0.005		0.033
Site1	06/25/2009 09:23:46	16.38	0.209	0.17		0.039
Site1	06/25/2009 09:28:51	12	0.117	0.07		0.047
Site1	06/25/2009 09:34:12	8.02	0.038	0.01		0.028
Site1	06/25/2009 09:39:44	3.95	0.037	0.005		0.032
Site1	06/25/2009 09:43:27	0.12	0.03	0.006		0.024
Site1	07/09/2009 08:45:48	16.05	0.234	0.216		0.018
Site1	07/09/2009 08:52:15	11.87	0.156	0.143		0.013
Site1	07/09/2009 08:56:16	8.01	0.049	0.022		0.027
Site1	07/09/2009 09:02:09	3.99	0.028	0.007		0.021
Site1	07/09/2009 09:07:15	0.1	0.029	0.008		0.021
Site1	07/23/2009 08:56:39	0.11	0.03	0.01		0.02
Site1	07/23/2009 08:59:20	16.01	0.317	0.298		0.019
Site1	07/23/2009 09:03:48	11.96	0.216	0.169		0.047
Site1	07/23/2009 09:07:50	8.01	0.029	0.009		0.02
Site1	07/23/2009 09:11:55	3.93	0.031	0.009		0.022
Site1	08/06/2009 09:53:38	16.54	0.392	0.359		0.033
Site1	08/06/2009 10:00:07	12.01	0.288	0.267		0.021
Site1	08/06/2009 10:04:18	7.8	0.04	0.009		0.031
Site1	08/06/2009 10:08:11	4	0.034	0.012		0.022
Site1	08/06/2009 10:11:50	0.09	0.033	0.012		0.021
Site1	08/24/2009 09:17:54	0.1	0.044	0.014		0.03
Site1	08/24/2009 09:20:51	4	0.044	0.014		0.03
Site1	08/24/2009 09:25:55	8	0.047	0.015		0.032
Site1	08/24/2009 09:31:12	12	0.347	0.327		0.02

* Depth = Sampling depth (meters); TP = Total phosphorus-P (mg/L); PO4 = Total phosphate-P (mg/L); DL_PO4 = Less than the detection limit for PO4 of 0.05; OP = Organic phosphorus-P (mg/L)

Station	Sampling_time	Depth	TP	PO4	DL_PO4	OP
Site1	08/24/2009 09:43:24	16.1	0.606	0.508		0.098
Site1	09/03/2009 09:20:00	16.05	0.66	0.687		N/A
Site1	09/03/2009 09:24:50	12.02	0.437	0.471		N/A
Site1	09/03/2009 09:30:07	8.05	0.052	0.01		0.042
Site1	09/03/2009 09:34:00	4.03	0.06	0.012		0.048
Site1	09/03/2009 09:39:04	0.1	0.053	0.021		0.032
Site1	09/17/2009 09:37:08	15.65	0.874	0.816		0.058
Site1	09/17/2009 09:40:25	11.96	0.056	0.816		N/A
Site1	09/17/2009 09:42:54	8.01	0.051	0.007		0.044
Site1	09/17/2009 09:45:52	4.04	0.049	0.009		0.04
Site1	09/17/2009 09:49:39	0.05	0.053	0.009		0.044
Site1	09/30/2009 10:02:45	16.2	0.064	0.046		0.018
Site1	09/30/2009 10:07:21	12.06	0.038	0.029		0.009
Site1	09/30/2009 10:11:18	8.05	0.04	0.025		0.015
Site1	09/30/2009 10:17:13	4.01	0.037	0.027		0.01
Site1	09/30/2009 10:21:18	0.17	0.037	0.026		0.011
Site1	10/19/2009 09:18:57	16.13	0.05	0.036		0.014
Site1	10/19/2009 09:24:19	11.99	0.048	0.031		0.017
Site1	10/19/2009 09:29:15	7.99	0.046	0.031		0.015
Site1	10/19/2009 09:32:29	4.02	0.048	0.033		0.015
Site1	10/19/2009 09:34:25	0.09	0.045	0.043		0.002
Site2	04/22/2008 12:30:42	0.2	0.033	0.022		0.011
Site2	04/22/2008 12:39:05	12	0.03	0.024		0.006
Site2	05/12/2008 12:00:00	N/A	0.032	0.009		0.023
Site2	05/12/2008 12:00:00	N/A	0.043	0.012		0.031
Site2	05/21/2008 14:14:33	0.1	0.028	0.006		0.022
Site2	05/21/2008 14:23:35	11	0.039	0.015		0.024
Site2	06/04/2008 13:47:51	11.2	0.037	0.005	<	0.035
Site2	06/04/2008 14:55:36	0.1	0.031	0.005	<	0.029
Site2	06/18/2008 11:23:50	0.1	0.03	0.005		0.025
Site2	06/18/2008 11:38:22	11.1	0.06	0.026		0.034
Site2	07/09/2008 12:13:23	11.9	0.276	0.204		0.072
Site2	07/09/2008 12:28:45	0.11	0.034	0.008		0.026
Site2	07/21/2008 10:23:56	0.15	0.031	0.01		0.021
Site2	07/21/2008 10:36:16	10	0.103	0.078		0.025
Site2	08/04/2008 09:56:12	0.5	0.024	0.01		0.014
Site2	08/04/2008 10:19:10	11.0	0.17	0.094		0.076
Site2	08/18/2008 09:27:35	0.1	0.026	0.01		0.016

* Depth = Sampling depth (meters); TP = Total phosphorus-P (mg/L); PO4 = Total phosphate-P (mg/L); DL_PO4 = Less than the detection limit for PO4 of 0.05; OP = Organic phosphorus-P (mg/L)

Station	Sampling_time	Depth	TP	PO4	DL_PO4	OP
Site2	08/18/2008 09:44:34	11.1	0.131	0.067		0.064
Site2	09/02/2008 11:03:40	0.2	0.039	0.014		0.025
Site2	09/02/2008 11:25:23	11.0	0.157	0.123		0.034
Site2	09/22/2008 11:30:28	0.1	0.056	0.009		0.047
Site2	09/22/2008 11:54:11	11.0	0.042	0.014		0.028
Site2	10/16/2008 10:29:47	0.08	0.032	0.018		0.014
Site2	10/16/2008 10:41:42	11.29	0.042	0.014		0.028
Site2	12/08/2008 11:42:48	0.1	0.026	0.028		N/A
Site2	12/08/2008 11:52:36	11	0.025	0.028		N/A
Site2	02/09/2009 10:14:21	0.05	0.022	0.019		0.003
Site2	04/15/2009 11:47:06	0.03	0.03	0.01		0.02
Site2	05/07/2009 13:28:26	0.12	0.032	0.005	<	0.03
Site2	05/20/2009 11:44:19	-0.04	0.031	0.005	<	0.029
Site2	06/04/2009 12:34:42	-0.03	N/A	N/A		N/A
Site2	06/25/2009 11:32:43	0.15	N/A	N/A		N/A
Site2	07/09/2009 11:08:35	-0.01	N/A	N/A		N/A
Site2	07/23/2009 11:01:17	0.14	N/A	N/A		N/A
Site2	08/06/2009 11:50:25	0.12	N/A	N/A		N/A
Site2	08/24/2009 12:14:55	0.12	N/A	N/A		N/A
Site2	09/03/2009 11:26:16	0.1	N/A	N/A		N/A
Site2	09/17/2009 11:36:04	0.07	N/A	N/A		N/A
Site2	09/30/2009 10:52:51	0.1	N/A	N/A		N/A
Site2	10/19/2009 12:37:45	0.11	N/A	N/A		N/A
Site3	04/22/2008 12:51:17	0.3	N/A	N/A		N/A
Site3	05/12/2008 12:00:00	N/A	N/A	N/A		N/A
Site3	05/21/2008 14:43:23	0.1	N/A	N/A		N/A
Site3	06/04/2008 14:08:57	0.2	N/A	N/A		N/A
Site3	06/18/2008 11:01:35	0.15	N/A	N/A		N/A
Site3	07/09/2008 11:48:51	0.11	N/A	N/A		N/A
Site3	07/21/2008 09:59:38	0.12	N/A	N/A		N/A
Site3	08/04/2008 09:32:34	0.08	N/A	N/A		N/A
Site3	08/18/2008 09:05:29	0.1	N/A	N/A		N/A
Site3	09/02/2008 10:33:19	0.1	N/A	N/A		N/A
Site3	09/22/2008 10:58:12	1.0	N/A	N/A		N/A
Site3	10/16/2008 10:05:32	0.14	N/A	N/A		N/A
Site3	12/08/2008 11:13:24	0.5	N/A	N/A		N/A
Site3	02/09/2009 13:57:36	0.07	N/A	N/A		N/A
Site3	04/15/2009 11:57:33	0.08	N/A	N/A		N/A

* Depth = Sampling depth (meters); TP = Total phosphorus-P (mg/L); PO4 = Total phosphate-P (mg/L); DL_PO4 = Less than the detection limit for PO4 of 0.05; OP = Organic phosphorus-P (mg/L)

Station	Sampling_time	Depth	TP	PO4	DL_PO4	OP
Site3	05/07/2009 13:41:57	0.04	N/A	N/A		N/A
Site3	05/20/2009 12:20:55	0.15	N/A	N/A		N/A
Site3	06/04/2009 13:11:22	0.36	N/A	N/A		N/A
Site3	06/25/2009 12:04:01	0.11	N/A	N/A		N/A
Site3	07/09/2009 11:24:43	0.05	N/A	N/A		N/A
Site3	07/23/2009 11:25:54	0.15	N/A	N/A		N/A
Site3	08/06/2009 12:06:14	0.97	N/A	N/A		N/A
Site3	08/24/2009 12:36:16	0.13	N/A	N/A		N/A
Site3	09/03/2009 11:52:40	0.11	N/A	N/A		N/A
Site3	09/17/2009 11:46:37	0.08	N/A	N/A		N/A
Site3	09/30/2009 11:18:04	0.06	N/A	N/A		N/A
Site3	10/19/2009 12:55:38	0.22	N/A	N/A		N/A
Site4	04/22/2008 12:06:29	0.3	0.04	0.03		0.01
Site4	04/22/2008 12:17:48	10.9	0.041	0.035		0.006
Site4	05/12/2008 12:00:00	N/A	0.031	0.009		0.022
Site4	05/12/2008 12:00:00	N/A	0.085	0.033		0.052
Site4	05/21/2008 13:46:05	0.1	0.032	0.006		0.026
Site4	05/21/2008 13:55:22	13	0.032	0.032		0
Site4	06/04/2008 14:36:21	13.1	0.077	0.024		0.053
Site4	06/04/2008 15:41:55	0.1	0.026	0.005	<	0.024
Site4	06/18/2008 11:52:32	0.2	0.031	0.006		0.025
Site4	06/18/2008 12:10:22	12.9	0.093	0.048		0.045
Site4	07/09/2008 13:31:50	0.1	0.031	0.007		0.024
Site4	07/09/2008 13:43:18	12.9	0.348	0.274		0.074
Site4	07/21/2008 11:51:04	0.1	0.026	0.009		0.017
Site4	07/21/2008 12:04:15	9	0.093	0.075		0.018
Site4	08/04/2008 11:29:22	0.4	0.024	0.009		0.015
Site4	08/04/2008 11:47:40	9.2	0.092	0.028		0.064
Site4	08/18/2008 10:53:35	0.2	0.033	0.01		0.023
Site4	08/18/2008 11:05:03	10.1	0.088	0.041		0.047
Site4	09/02/2008 13:02:17	0.1	0.039	0.015		0.024
Site4	09/02/2008 13:16:48	10.0	0.069	0.03		0.039
Site4	09/22/2008 13:56:59	0.2	0.038	0.009		0.029
Site4	09/22/2008 14:22:31	11.9	0.055	0.017		0.038
Site4	10/16/2008 12:19:44	0.1	0.043	0.016		0.027
Site4	10/16/2008 12:29:22	9.25	0.04	0.013		0.027
Site4	12/08/2008 13:34:34	0.5	0.027	0.032		N/A
Site4	12/08/2008 13:40:52	9	0.022	0.032		N/A

* Depth = Sampling depth (meters); TP = Total phosphorus-P (mg/L); PO4 = Total phosphate-P (mg/L); DL_PO4 = Less than the detection limit for PO4 of 0.05; OP = Organic phosphorus-P (mg/L)

Station	Sampling_time	Depth	TP	PO4	DL_PO4	OP
Site4	02/09/2009 12:15:15	0.25	0.021	0.021		0
Site4	04/15/2009 10:22:14	0.12	0.028	0.009		0.019
Site4	05/07/2009 11:19:32	0.11	0.024	0.018		0.006
Site4	05/20/2009 10:00:20	0.14	0.032	0.005	<	0.03
Site4	06/04/2009 10:25:47	0.1	0.041	0.008		0.033
Site4	06/25/2009 10:00:04	0.19	N/A	N/A		N/A
Site4	07/09/2009 09:36:56	0.16	N/A	N/A		N/A
Site4	07/23/2009 09:32:25	0.13	N/A	N/A		N/A
Site4	08/06/2009 10:34:46	0.21	N/A	N/A		N/A
Site4	08/24/2009 11:08:50	0.22	N/A	N/A		N/A
Site4	09/03/2009 10:01:05	0.15	N/A	N/A		N/A
Site4	09/17/2009 10:09:15	12.37	N/A	N/A		N/A
Site4	09/30/2009 12:01:00	12.8	N/A	N/A		N/A
Site4	10/19/2009 11:52:58	12.56	N/A	N/A		N/A
Site5	04/22/2008 11:17:20	0.2	N/A	N/A		N/A
Site5	05/12/2008 12:00:00	N/A	N/A	N/A		N/A
Site5	05/21/2008 13:10:18	0.1	N/A	N/A		N/A
Site5	06/04/2008 15:06:39	0	N/A	N/A		N/A
Site5	06/18/2008 13:28:02	0.14	N/A	N/A		N/A
Site5	07/09/2008 13:08:33	0.11	N/A	N/A		N/A
Site5	07/21/2008 12:48:32	0.13	N/A	N/A		N/A
Site5	08/04/2008 12:32:00	0.35	N/A	N/A		N/A
Site5	08/18/2008 11:42:09	0.2	N/A	N/A		N/A
Site5	09/02/2008 13:37:57	0.06	N/A	N/A		N/A
Site5	09/22/2008 14:46:33	1.08	N/A	N/A		N/A
Site5	10/16/2008 13:11:29	0.08	N/A	N/A		N/A
Site5	12/08/2008 12:00:00	N/A	N/A	N/A		N/A
Site5	02/09/2009 13:14:19	0.09	N/A	N/A		N/A
Site5	04/15/2009 11:00:00	0.16	N/A	N/A		N/A
Site5	05/07/2009 12:28:39	0.11	N/A	N/A		N/A
Site5	05/20/2009 10:54:03	0.06	N/A	N/A		N/A
Site5	06/04/2009 11:24:33	0.1	N/A	N/A		N/A
Site5	06/25/2009 10:39:59	0.1	N/A	N/A		N/A
Site5	07/09/2009 10:06:26	0.08	N/A	N/A		N/A
Site5	07/23/2009 09:55:41	0.1	N/A	N/A		N/A
Site5	08/06/2009 10:51:29	0.11	N/A	N/A		N/A
Site5	08/24/2009 11:26:13	0.18	N/A	N/A		N/A
Site5	09/03/2009 10:22:54	0.11	N/A	N/A		N/A

* Depth = Sampling depth (meters); TP = Total phosphorus-P (mg/L); PO4 = Total phosphate-P (mg/L); DL_PO4 = Less than the detection limit for PO4 of 0.05; OP = Organic phosphorus-P (mg/L)

Station	Sampling_time	Depth	TP	PO4	DL_PO4	OP
Site5	09/17/2009 10:32:23	0.12	N/A	N/A		N/A
Site5	09/30/2009 12:50:25	0.07	N/A	N/A		N/A
Site5	10/19/2009 11:28:24	0.14	N/A	N/A		N/A
Site6	04/22/2008 10:50:52	0.3	0.098	0.083		0.015
Site6	05/12/2008 12:00:00	N/A	0.11	0.037		0.073
Site6	05/21/2008 12:46:45	0.1	0.056	0.02		0.036
Site6	06/04/2008 13:33:58	0.1	0.082	0.016		0.066
Site6	06/18/2008 13:10:28	0.11	0.13	0.071		0.059
Site6	07/09/2008 12:48:07	0.08	0.078	0.019		0.059
Site6	07/21/2008 13:10:08	0.14	0.086	0.027		0.059
Site6	08/04/2008 12:26:35	0.08	0.106	0.03		0.076
Site6	08/18/2008 11:59:19	0.13	0.092	0.042		0.05
Site6	09/02/2008 14:02:47	0.11	0.091	0.027		0.064
Site6	09/22/2008 15:10:55	0.15	0.082	0.023		0.059
Site6	10/16/2008 13:32:35	0.12	0.073	0.022		0.051
Site6	12/08/2008 12:00:00	N/A	0.047	0.046		0.001
Site6	02/09/2009 13:25:32	0.12	0.048	0.051		N/A
Site6	04/15/2009 11:09:48	0.09	N/A	N/A		N/A
Site6	05/07/2009 12:43:47	0.1	N/A	N/A		N/A
Site6	05/20/2009 11:15:19	0.15	N/A	N/A		N/A
Site6	06/04/2009 11:47:58	0.08	N/A	N/A		N/A
Site6	06/25/2009 11:09:56	0.13	N/A	N/A		N/A
Site6	07/09/2009 10:32:00	0.11	0.116	0.09		0.026
Site6	07/23/2009 10:29:32	0.11	0.08	0.038		0.042
Site6	08/06/2009 11:00:11	0.08	0.123	0.068		0.055
Site6	08/24/2009 11:53:30	0.13	0.116	0.058		0.058
Site6	09/03/2009 11:01:15	0.09	1.09	0.081		1.009
Site6	09/17/2009 10:57:24	0.07	0.108	0.103		0.005
Site6	09/30/2009 13:12:29	0.1	0.093	0.077		0.016
Site6	10/19/2009 10:46:36	0.09	0.088	0.048		0.04
Site7	04/22/2008 11:42:35	0.1	N/A	N/A		N/A
Site7	05/12/2008 12:00:00	N/A	N/A	N/A		N/A
Site7	05/21/2008 13:29:58	0.1	N/A	N/A		N/A
Site7	06/04/2008 15:24:54	0.1	N/A	N/A		N/A
Site7	06/18/2008 12:39:06	5.71	N/A	N/A		N/A
Site7	07/09/2008 14:00:35	0.09	N/A	N/A		N/A
Site7	07/21/2008 12:21:46	0.14	N/A	N/A		N/A
Site7	08/04/2008 12:04:34	0.07	N/A	N/A		N/A

* Depth = Sampling depth (meters); TP = Total phosphorus-P (mg/L); PO4 = Total phosphate-P (mg/L); DL_PO4 = Less than the detection limit for PO4 of 0.05; OP = Organic phosphorus-P (mg/L)

Station	Sampling_time	Depth	TP	PO4	DL_PO4	OP
Site7	08/18/2008 11:18:43	0.12	N/A	N/A		N/A
Site7	09/02/2008 14:29:05	0.18	N/A	N/A		N/A
Site7	09/22/2008 15:41:44	1.01	N/A	N/A		N/A
Site7	10/16/2008 12:45:33	0.15	N/A	N/A		N/A
Site7	12/08/2008 14:02:23	0.5	N/A	N/A		N/A
Site7	02/09/2009 12:53:41	4.8	N/A	N/A		N/A
Site7	04/15/2009 10:32:25	0.07	N/A	N/A		N/A
Site7	05/07/2009 11:53:32	0.09	N/A	N/A		N/A
Site7	05/20/2009 10:31:32	0.09	N/A	N/A		N/A
Site7	06/04/2009 10:55:48	0.07	N/A	N/A		N/A
Site7	06/25/2009 10:28:01	0.02	N/A	N/A		N/A
Site8	04/22/2008 13:12:00	0.2	0.04	0.028		0.012
Site8	05/12/2008 12:00:00	N/A	0.036	0.012		0.024
Site8	05/21/2008 14:58:53	0.1	0.028	0.008		0.02
Site8	06/04/2008 16:08:45	0.1	0.031	0.006		0.025
Site8	06/18/2008 10:37:18	0.11	0.045	0.007		0.038
Site8	07/09/2008 11:23:39	0.17	0.044	0.011		0.033
Site8	07/21/2008 09:41:17	0.06	0.052	0.018		0.034
Site8	08/04/2008 09:09:29	2.9	0.04	0.01		0.03
Site8	08/18/2008 08:49:47	0.11	0.056	0.028		0.028
Site8	09/02/2008 10:09:42	0.1	0.053	0.019		0.034
Site8	09/22/2008 10:38:23	0.45	0.05	0.014		0.036
Site8	10/16/2008 09:48:43	0.11	0.044	0.013		0.031
Site8	12/08/2008 10:56:41	0.5	0.016	0.014		0.002
Site8	12/08/2008 10:58:19	2	0.0412	0.0145		0.027
Site8	12/08/2008 10:59:05	3	0.044	0.013		0.031
Site8	02/09/2009 14:08:05	2.66	N/A	N/A		N/A
Site8	04/15/2009 12:13:01	0.12	N/A	N/A		N/A
Site8	05/07/2009 14:02:55	0.09	N/A	N/A		N/A
Site8	05/20/2009 12:47:55	0.08	N/A	N/A		N/A
Site8	06/04/2009 13:36:27	0.11	N/A	N/A		N/A
Site8	06/25/2009 12:31:50	0.11	N/A	N/A		N/A
Site8	07/09/2009 11:36:56	2.39	0.046	0.022		0.024
Site8	07/23/2009 11:44:31	0.1	0.066	0.027		0.039
Site8	08/06/2009 12:14:51	2.47	0.074	0.045		0.029
Site8	08/24/2009 12:52:48	0.18	0.08	0.041		0.039
Site8	09/03/2009 12:08:57	0.12	0.067	0.045		0.022
Site8	09/17/2009 12:04:11	0.09	0.056	0.026		0.03

* Depth = Sampling depth (meters); TP = Total phosphorus-P (mg/L); PO4 = Total phosphate-P (mg/L); DL_PO4 = Less than the detection limit for PO4 of 0.05; OP = Organic phosphorus-P (mg/L)

Station	Sampling_time	Depth	TP	PO4	DL_PO4	OP
Site8	09/30/2009 11:31:52	2.63	0.045	0.026		0.019
Site8	10/19/2009 13:07:49	2.84	0.01	0.014		N/A

* Depth = Sampling depth (meters); TP = Total phosphorus-P (mg/L); PO4 = Total phosphate-P (mg/L); DL_PO4 = Less than the detection limit for PO4 of 0.05; OP = Organic phosphorus-P (mg/L)

Appendix E

MS4 Stormwater Permitting Requirements and Presumptive Best Management Practices (BMP) Approach

Appendix E - Stormwater permitting Requirements and Presumptive Best Management Practices (BMPs) Approach

I. BACKGROUND

The National Pollutant Discharge Elimination System (NPDES) permitting program for stormwater discharges was established under the Clean Water Act as the result of a 1987 amendment. The Act specifies the level of control to be incorporated into the NPDES stormwater permitting program depending on the source (industrial versus municipal stormwater). These programs contain specific requirements for the regulated communities/facilities to establish a comprehensive stormwater management program (SWMP) or stormwater pollution prevention plan (SWPPP) to implement any requirements of the total maximum daily load (TMDL) allocation. [See 40 CFR §130.]

Stormwater discharges are highly variable both in terms of flow and pollutant concentration, and the relationships between discharges and water quality can be complex. For municipal stormwater discharges in particular, the current use of system-wide permits and a variety of jurisdiction-wide BMPs, including educational and programmatic BMPs, does not easily lend itself to the existing methodologies for deriving numeric water quality-based effluent limitations. These methodologies were designed primarily for process wastewater discharges which occur at predictable rates with predictable pollutant loadings under low flow conditions in receiving waters.

EPA has recognized these problems and developed permitting guidance for stormwater permits. [See "Interim Permitting Approach for Water Quality-Based Effluent Limitations in Stormwater Permits" (EPA-833-D-96-00, Date published: 09/01/1996)] Due to the nature of stormwater discharges, and the typical lack of information on which to base numeric water quality-based effluent limitations (expressed as concentration and mass), EPA recommends an interim permitting approach for NPDES stormwater permits which is based on BMPs. "The interim permitting approach uses best management practices (BMPs) in first-round stormwater permits, and expanded or better-tailored BMPs in subsequent permits, where necessary, to provide for the attainment of water quality standards." (*ibid.*)

A monitoring component is also included in the recommended BMP approach. "Each stormwater permit should include a coordinated and cost-effective monitoring program to gather necessary information to determine the extent to which the permit provides for attainment of applicable water quality standards and to determine the appropriate conditions or limitations for subsequent permits." (*ibid.*)

This approach was further elaborated in a guidance memo issued in 2002. [See Memorandum from Robert Wayland, Director of OWOW and James Hanlon, Director of OWM to Regional Water Division Directors: "Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit requirements Based on Those WLAs " (Date published: 11/22/2002)] "The policy outlined in this memorandum affirms the appropriateness of an iterative, adaptive management BMP approach, whereby permits include effluent limits (e.g., a combination of structural and non-structural BMPs) that address stormwater discharges, implement mechanisms to evaluate the performance of such controls, and make adjustments (i.e., more stringent controls or specific BMPs) as necessary to protect water quality. …… If it is determined that a BMP approach (including an iterative BMP approach) is appropriate to meet the stormwater component of the TMDL, EPA recommends that the TMDL reflect this." This BMP-based approach to stormwater sources in

TMDLs is also recognized and described in the most recent EPA guidance. [See "TMDLs To Stormwater Permits Handbook" (DRAFT; EPA, November 2008[2])]

This TMDL adopts the EPA recommended approach and relies on appropriate BMPs for implementation. No numeric effluent limitations are required or anticipated for stormwater discharge permits. All three categories of stormwater permits are covered in this Appendix: *Municipal Separate Storm Sewer System (MS4) Discharges* (Permit number OKR04), *Storm Water Discharges from Construction Activities* (Permit number OKR10), and *Storm Water Discharges from Industrial Facilities under the Multi-Sector Industrial General Permit* (Permit number OKR05). The provisions of this appendix apply only to OPDES/NPDES regulated stormwater discharges. Agricultural activities and other nonpoint sources of TSS, nutrients, and organic matters are unregulated. Voluntary measures and incentives should be used and encouraged wherever possible and such sources should strive to attain the reduction goals established in this TMDL.

II. SPECIFIC REQUIREMENTS FOR MS4 STORMWATER PERMITS

As noted in Section 3 of this report, stormwater runoff from the Phase 1 and 2 Municipal Separate Storm Sewer Systems (MS4s) is likely to contain elevated TSS, nutrients (TN and TP) and organic matter (BOD and TOC). Waste Load Allocations (WLAs) are assigned to each of these MS4s. Consequently, permits for these discharges must comply with the provisions of this TMDL. Table E-1 provides a list of Phase 1 and 2 MS4s that are affected by this TMDL report.

Table E-1 MS4 Permits affected by this TMDL Report

Entity	Permit No.	MS4 Phase	Permit Issued Date
Oklahoma City*	OKS000101	I	03/15/2013
City of Moore	OKR040012	II	12/01/2005
City of Norman	OKR040015	II	11/29/2005

* Co-permitted with Oklahoma Department of Transportation and Oklahoma Turnpike Authority

The Phase I permit under which Oklahoma City and its co-permittees operate covers all areas located within the corporate boundary of the City of Oklahoma City. The Phase II permit under which the cities of Moore and Norman operate requires implementation of the stormwater program only in the portions of the city located within the urbanized area. Since the wasteload allocations developed in this TMDL are based on the pollutant loadings generated within the entire corporate boundaries of all three cities, Moore and Norman will be required to operate their stormwater programs throughout their entire corporate boundaries within the Lake Thunderbird watershed in order to comply with this TMDL. This designation authority is found at 40 CFR 122.26(a)(9)(i)(C).

To ensure compliance with the TMDL requirements under the permit, MS4 permittees must develop strategies designed to achieve progress toward meeting the reduction goals established in the TMDL. Relying primarily upon a Best Management Practices (BMP) approach, permittees should take advantage of existing information on BMP performance and select a suite of BMPs appropriate to the local community that are expected to result in progress toward meeting the reduction goals

[2] http://www.epa.gov/owow/tmdl/pdf/tmdl-sw_permits11172008.pdf (as of November 28, 2012).

established in the TMDL. The permittee should provide its local community guidance on BMP installation and maintenance, as well as a monitoring and/or inspection schedule.

Table E–2 at the end of this appendix provides a summary description of some BMPs with reported effectiveness in reducing TSS, nutrients and organic matter. Permittees may choose different BMPs to meet the permit requirements, as long as the permittee demonstrates that these practices will result in progress toward attaining water quality standards. Permittees are particularly encouraged to consult Section 5.3 of the "*TMDLs to Stormwater Permits Handbook*" (DRAFT; EPA, November 2008[3]). That section provides technical resources on the availability, performance, and applicability of BMPs, in addition to monitoring approaches, computer models and stormwater program evaluation methods.

The watershed model (HSPF) and the lake model (EFDC) developed for this TMDL study will be made available to stakeholders in the watershed. These models are particularly useful in predicting and assessing the overall watershed pollutant load reductions and their effect on lake water quality. Stakeholders may also consider other modeling tools for specific BMP selection and evaluation. Table 12 of the "*TMDLs to Stormwater Permits Handbook*" (DRAFT; EPA, November 2008[2]) describes a range of modeling tools available for BMP selection, sizing, and siting decision making.

After EPA approval of the final TMDL, existing MS4 permittees will be notified of the TMDL provisions and schedule. Compliance with the following specific provisions will constitute compliance with the requirements of this TMDL.

1. Develop a TMDL Compliance Plan

Each permittee shall adopt their WLAs specified in the TMDL as measurable goals within their permit. Each permittee shall submit an approvable TMDL Compliance Plan to the DEQ within 24 months of EPA approval of this TMDL. Unless disapproved by the Director within 60 days of submission, the plan shall be approved and then implemented by the permittee. This plan shall, at a minimum, include the following:

A. An evaluation to identify potential significant sources of TSS, nutrients and organic matter entering your MS4. Such an evaluation should include an enhanced plan for illicit discharge screening and remediation. Following the evaluation and using guidelines outlined below, each permittee shall develop (or modify an existing program as necessary) and implement a program to reduce the discharge of TSS, nutrients and organic matters in municipal stormwater contributed by all significant sources identified in the evaluation.

B. Selecting a General Strategy for the plan: An MS4 should demonstrate, in the TMDL Compliance Plan, that it understands the TMDL requirements and that it has a strategy for meeting the WLAs. There are several ways for an MS4 to meet a TMDL waste load allocation (WLA) using BMPs and other approaches, including but not limited to:

   a. Retrofitting developed areas and other suitable sites with structural stormwater BMPs (e.g. infiltration BMPs in built out areas).

   b. Implementing BMPs that prevent additional stormwater TSS, nutrients and organic matter pollution associated with new development and re-development; (e.g. promoting Low Impact Development and green infrastructure, installing infiltration BMPs in areas converting from one land use to another).

[3] http://www.epa.gov/owow/tmdl/pdf/tmdl-sw_permits11172008.pdf (as of November 28, 2012).

c. Implementing non-structural BMPs designed for source control (e.g. fertilizer application restrictions or soil nutrient testing requirements, and riparian buffer protection requirements) by considering ordinances or other regulatory mechanisms to require TSS, nutrients and organic matter pollution control, as well as enforcement procedures for noncompliance.

d. Implementing non-structural BMPs designed to treat existing loads (e.g. more frequent street sweeping).

e. Developing and implementing water quality trading: water quality trading among the MS4 permittees may be considered as a tool to achieve the overall WLA of the TMDLs. As the authorization and enforcement agency of Oklahoma's MS4 permits, the DEQ reserves the authority for the final approval of any trades or trading programs that may be considered in the Lake Thunderbird watershed.

C. Implementing enhanced or more frequent construction site stormwater compliance inspections and considering adopting ordinance that allows "stop work" orders and other enhanced enforcement for construction permit violators.

D. Determining a schedule for achieving the WLA: This schedule can be general in nature, discussing groups of activities to be implemented within permit cycles or based on funding cycles. Specific activities need not be included in this section of the TMDL Compliance Plan. For example:

"MS4 X" will achieve necessary pollutant reductions within four permit cycles. During the first permit cycle, "MS4 X" will evaluate its existing stormwater program in relation to the TMDL compliance plan, determine if the program requires modification, outline a process for develop the TMDL compliance plan, and implement BMPs if opportunities arise. In the second permit cycle, "MS4 X" will modify its stormwater program as necessary, implement non-structural BMPs, develop a system to evaluate the effectiveness of these BMPs and implement structural BMPs if opportunities arise. In the third permit cycle, "MS4 X" will evaluate the effectiveness of non-structural BMPs, determine if structural BMPs (through retrofits) are needed, identify where and which structural BMPs will achieve the needed pollutant load reductions, and implement structural BMPs if opportunities arise. In the fourth permit cycle, "MS4 X" will implement structural BMPs as needed.

E. Implementing and Tracking BMPs

BMP Summary Sheets should be prepared for both structural and non-structural BMPs. For BMPs for which pollutant reductions can be calculated or modeled, BMP sheets should include any information used to make the calculations, BMP efficiencies, and maintenance information for the BMP (e.g. to ensure the efficiency used in the calculation is valid into the future or determine if it needs to be adjusted). Include references to support the calculations or modeling.

BMP Sheets can be prepared for ordinances, resources, or other tools needed for implementation of BMPs. Load reductions may be difficult to quantify with these BMPs, but these tools may be needed to implement BMPs that reduce loading.

F. Educational programs directed at reducing TSS, nutrients and organic matter pollution. Implement a public education program to reduce the discharge of TSS, nutrients and organic matter in municipal stormwater contributed (if applicable) by construction activities, recreational and agricultural activities, etc.

2. Develop or Participate In a Pollutant Monitoring and Tracking Program

As noted above, when a BMP approach is selected a coordinated monitoring program is necessary to establish the effectiveness of the selected BMPs and demonstrate progress toward achieving the reduction goals of the TMDL and eventually attaining water quality standards in Lake Thunderbird. The monitoring results should also be used to refine TSS, nutrient and organic matter controls in the future. With three permitted MS4 entities in the watershed, it is likely that a cooperative monitoring program would be more cost effective than three individual programs. Individual permittees are not required to participate in a coordinated program and are free to develop their own program if desired. Specific requirements for an effective monitoring and tracking program are as follows.

A. Within 24 months of EPA approval of this TMDL, each permittee shall prepare and submit to the DEQ either a TMDL monitoring plan or a commitment to participate in a coordinated regional monitoring program. Unless disapproved by the Director within 60 days of submission, the plan shall be approved and then implemented by the permittee. The plan or program shall include:

   a. Evaluation of any existing stormwater monitoring program in relation to TMDL reduction goals.

   b. A detailed description of the goals, monitoring, and sampling and analytical methods.

   c. A map that identifies discharge points, stormwater drainage areas contributing to discharge points, and within each such drainage area, mapping the conveyance system.

   d. A list and map of the selected TMDL monitoring sites, which may include sites on receiving water bodies.

   e. Consideration of methods for evaluating pollutant loading in stormwater discharges from construction and industrial sites, such as monitoring requirements for site operators or small drainage monitoring for multiple construction sites.

   f. The frequency of sample collection to occur at each station or site: at a minimum, sample collection shall include at least one representative sample of a stormwater discharge from at least 50% of the major discharge points discharging directly to surface waters of the state within the portion of the TMDL watershed in the MS4 area. A major discharge point is a pipe or open conveyance measuring 36 inches or more at its widest cross section.

   g. The parameters to be measured, as appropriate for and relevant to the TMDL: at a minimum, the sample shall be analyzed for total phosphorus (TP), total nitrogen (TN), total suspended solids(TSS), and $CBOD_{20}$.

   h. A Quality Assurance Project Plan that complies with EPA requirements [EPA Requirements for QA Project Plans (QA/R-5)].

B. The monitoring program shall be fully implemented within three years of EPA approval of this TMDL.

C. With the obtained monitoring and tracking data, periodically evaluate the effectiveness of individual BMPs if possible and the effectiveness of the overall TMDL compliance plan to ensure progress toward attainment of the waste load allocations. If progress cannot be shown, the MS4 permittee must revise its TMDL compliance plan to further its load reduction efforts.

3. Annual Reporting

The permittee shall include a TMDL implementation report as part of their annual report. The TMDL implementation report shall include the status and actions taken by the permittee to implement the TMDL compliance plan and monitoring program. The TMDL implementation report shall document relevant actions taken by the permittee that affect MS4 stormwater discharges to the waterbody segments that are the subject of the TMDL. This TMDL implementation report also shall identify the status of any applicable TMDL implementation schedule milestones.

4. Evaluating Progress

Compliance with this TMDL and progress toward achieving the wasteload allocations and load reduction goals will be evaluated at each renewal of the MS4 permit for each entity, generally every 5 years. Consideration will be given to:

- Water quality data and results from the pollutant monitoring and tracking program
- The status of achieving milestones and accomplishing items in the current compliance plan
- Any revisions that have been made to or proposed for the compliance plan
- Any proposed enhancements to the compliance plan for the next permit term

If sufficient progress is not demonstrated, an updated compliance plan and implementation schedule will be required to be submitted within 6 months. Noncompliance may subject the permittee to enforcement action.

III. SPECIFIC REQUIREMENTS FOR CONSTRUCTION STORMWATER PERMITS

In addition to the general provisions of the OKR10 General Permit (General Permit for Storm Water Discharges from Construction Activities within the State of Oklahoma), construction activities authorized after EPA approval of this TMDL which are located in the Lake Thunderbird watershed will be required to:

A. Comply with any additional pollutant prevention or discharge monitoring requirements established by the local MS4 municipalities.

B. Submit to the DEQ all Storm Water Pollution Prevention Plans (SWP3) for sites of five acres or larger.

After EPA approval of this TMDL, the following provisions will be included as site-specific requirements in all authorizations issued by DEQ for construction activities located in the Lake Thunderbird watershed:

A. Vegetated buffer. You must ensure that a vegetated buffer of at least 100 feet is retained or successfully established/planted between the area disturbed and all receiving streams. If the nature of the construction activity or the construction site makes a buffer impossible, you must provide equivalent controls. There are exceptions from this requirement for water crossings, limited water access, and stream restoration authorized under a CWA Section 404 permit.

B. Sediment basins. For all drainage locations serving 5 or more acres disturbed at one time, you must use a temporary or permanent sediment basin and/or sediment traps to minimize sediment discharges

C. Site inspections. You must conduct site inspections once every 7 calendar days at a minimum, and within 24 hours of a storm event of 0.5 inches or greater and within 24 hours of a discharge caused by snowmelt.

D. Corrective actions. You must implement the corrective actives (e.g., repair, modify, or replace any stormwater control used at the site, clean up and dispose of spills, releases, or other deposits, or remedy a permit violation) by no later than 7 calendar days from the time of discovery. If it is infeasible to complete the installation or repair within 7 calendar days, you must document in your records why it is infeasible to complete the installation or repair within the 7 calendar day timeframe and document your schedule for installing the stormwater controls and making it operational as soon as practicable after the 7 day timeframe.

E. Stabilization. You must initiate stabilization measures immediately whenever earth-disturbing activities have permanently or temporarily ceased on any portion of the site and will not resume for a period exceeding 14 calendar days. You are required to complete the stabilization activities within 7 calendar days after the permanent or temporary cessation.

F. Soil nutrient testing. You are required to conduct a soil nutrient test to determine actual nutrient needs before applying fertilizer on your site. Fertilizer application must be limited to that necessary to meet actual needs on the site.

IV. SPECIFIC REQUIREMENTS FOR MSGP (INDUSTRIAL) STORMWATER PERMITS

In addition to the general provisions of the OKR05 General Permit (General Permit for Storm Water Discharges from Industrial Facilities under the Multi-Sector Industrial General Permit [MSGP] within the State Of Oklahoma), specific requirements will be added to existing and future permits for MSGP permittees in the Lake Thunderbird Watershed engaged in activities specified by the Standard Industrial Classification (SIC) Code or Activity Code as:

- 2951,2952: Asphalt Paving and Roofing Materials (production).
- 3271-3275: Concrete, Gypsum and Plaster Products (production).
- 1442,1446: Sand and Gravel (mineral mining and dressing).
- Other activities deemed to be potential sources of nutrients and sediment to the Lake as determined by the DEQ on a case-by-case basis.

After EPA approval of this TMDL, the following provisions will be included as site-specific requirements in existing and future authorizations under OKR05 specified above:

A. Revise the SWP3 for additional TSS and nutrient reduction measures within 12 months of notification and submit the SWP3 for DEQ review.

B. Perform monthly inspection and maintenance of stormwater management devices, facility equipment and systems to avoid breakdowns or failures.

C. If the permit is for an activity that includes numeric effluent limits (See Table 1-3 of the MSGP), monitoring and reporting of the discharge is required once per month rather than once per year.

D. Comply with any additional pollutant prevention or discharge monitoring requirements established by the local MS4 municipalities.

Compliance with these specific requirements must be reflected in the permittee's annual Comprehensive Site Compliance Evaluation Report.

Table E–2. Some BMPs Applicable to TSS, Nutrients and Organic Matters

BEST MANAGEMENT PRACTICE	Reported Removal Efficiency	Note
Sediment Forebay	Required to achieve TP, TN and organic matters removal efficiency for structural practices	Sediment should be removed every 3-5 years or when 6-12 inches have accumulated.
Grassed Swale	TSS: ~50% TP: ~35% TN: 0-40%	Maintain thick vegetation at 3-6 inches, remove debris and sediment and re-establish vegetation if needed
Urban Nutrient Management	TSS: 0% TP: 10-22% TN: ~15%	Urban nutrient management involves the reduction of fertilizer to grass lawn and other urban areas. Public education and awareness is needed to avoid excessive fertilizer use.
Constructed Wetlands	TSS: 10-80% TP: 12-45% TN: ~20%	Second season reinforcement plantings are often needed. Mow biannually to reduce woody growth on outer boundary. Maintain sediment forebay. Remove sediment from forebay every 3-5 year or when 6-12 inches have accumulated.
Extended Detention-Enhanced	TSS: 60-80% TP: 20-50% TN: ~20%	Mow two times per year; remove debris from spill way and trash rack at control structure; and maintain sediment forebay
Retention Basin	TSS: ~80% TP: ~50% TN: ~25%	Mow two times per year; remove debris from spill way and trash rack at control structure; and maintain sediment forebay. Aeration may be needed in Oklahoma.
Riparian Buffers	TSS: 50-90% TP: 18-80% TN: 10-75%	Require proper slope and width of the buffer zone to achieve typical removal efficiency. Width typically varies from 4.6 to 27.4 m and slope varies from 4 to 16%

Sources:

1. Geosyntec Consultants, Inc. and Wright Water Engineers, Inc., International Stormwater Best Management Practices (BMP) Database (www.bmpdatabase.org)- Pollutant Category Summary, Statistical Addendum: TSS, Bacteria, Nutrients, and Metals, July 2012.

2. Wenger, S. A Review of the Scientific Literature on Riparian Buffer Width, Extent and Vegetation, Office of Public Service & Outreach, Institute of Ecology, University of Georgia, March, 1999.

3. Simpson, T. W., and S. E. Weammert, Riparian Forest Buffer Practice (Agriculture) and Riparian Grass Buffer Practice, Definition and Nutrient and Sediment Reduction Efficiencies for Use in Calibration of the Phase 5.0 of Chesapeake Bay Program Watershed Model, 2007.

4. Birch, G. F., C. Matthai, M. S. Fazeli, and J. Y. Suh, Efficiency of a Constructed Wetland in Removing Contaminants from Stormwater, Wetlands, Vol. 24. No. 2, June 2004.

5. National Pollutant Removal Performance Database, Version 3, September, 2007.

Appendix F

Sanitary Sewer Overflow (SSO) Bypass Events For the Cities of Norman and Moore

Table F-1 City of Norman

Facility Name	Facility ID	Bypass Date	Amount (Gallons)	Cause	Cleanup[4]	Preventive	Type of Source
Norman	S20616	9/3/2003	20,000	Ruptured pipe	C & D	Repair	Pipe
Norman	S20616	7/19/2004	12,049	Lift station disconnected by O.G.& E.	C & D	Reconnected	Lift station[5]
Norman	S20616	12/12/2007	10,000	Power outage	W & D	Generators	Lift station
Norman	S20616	12/12/2007	10,000	Power outage	W & D	Generator	
Norman	S20616	12/11/2006	10,000	Valve malfunction	C & D		Lift station
Norman	S20616	2/25/2003	10,000	Grease	C & D	Flushed[6]	
Norman	S20616	5/22/2007	6,000	Air valve broke	C & D	Replaced	Pipe
Norman	S20616	6/1/2005	5,000	Electrical failure/ lightning	W & D	Repairing	Lift station
Norman	S20616	2/25/2005	5,000	Contractor error	W & D	Pumped & vacuumed	Manhole
Norman	S20616	2/14/2005	5,000	Obstruction	W & D	Removed	Manhole
Norman	S20616	4/1/2002	3,600	Debris	Washed	Rodded	
Norman	S20616	12/22/2003	3,000	Main cut by contractor	Flushed	Advise contractor	Pipe
Norman	S20616	8/2/2002	2,500	Overflow	W & D	Removed	Manhole
Norman	S20616	1/7/2002	2,500	Manhole surcharged	W & D	Remove	
Norman	S20616	11/6/2008	2,000	Main blowout	C & D	Repair	Pipe
Norman	S20616	7/8/2003	2,000	Broken main	C & D	Repair	Pipe
Norman	S20616	11/21/2003	1,700	Contractor hit main	C & D	Repair	Pipe
Norman	S20616	5/8/2007	1,500	Collapsed main		Repair	Pipe
Norman	S20616	8/15/2006	1,500	Power failure	W & D	Restored	Lift station
Norman	S20616	1/8/2002	1,500	Main hit by contractors		Repair	
Norman	S20616	10/9/2000	1,500	Broke line		Vacuumed	
Norman	S20616	8/30/2006	1,200	Collapsed main	W & D	Repair	Pipe
Norman	S20616	1/17/2006	1,200	Obstruction	C & D	Flushed & rodded	Manhole
Norman	S20616	11/21/2005	1,200	Malfunction	W & D	Repair	Manhole
Norman	S20616	9/4/2006	1,000	Air release valve	W & D	Flushed	Manhole
Norman	S20616	2/9/2006	1,000	Obstruction	W & D	Flushed & root cut	Manhole
Norman	S20616	3/11/2002	1,000	Overflow		Regain flow	Manhole
Norman	S20616	7/20/2001	1,000	Obstruction		Removed	Manhole

4 C & D = Cleaned and disinfected to reduce the potential for human health issues and adverse environmental impacts.

5 Whenever possible, gravity is used to move sanitary sewer water from place to place. Large sewer mains are placed very deep into the earth to allow the smaller mains to slant towards them, using gravity to assure that the water moves away from residences and businesses. Occasionally, the positions of housing or business units and the nearest sewer mains require lift stations to be installed. Water moves by gravity into the lift station and is then pumped up to the level necessary to allow it to again move by gravity into the sewer main or interceptor sewer and be carried to the wastewater treatment facility.

6 This method uses high-pressure water to flush out stone, sediment or other unwanted material from the sewer. It is the combination of high pressure and high flow rates that cleans the pipe. in the circumference of the nozzle that allow the high pressure water to propel the flushing nozzle and sewer hose up the sewer to the next manhole. As the nozzle moves up and down the pipe, it dislodges sediment, stone and other debris and flushes it downstream to the manhole, where it is removed from the sewer.

Table F-2 City of Moore

Facility Name	Facility ID	Bypass Date	Amount (Gallons)	Cause	Cleanup[7]	Preventive	Type of Source
Moore	S20614	10/22/2000	>1 Million	Rain	Flushed		
Moore	S20614	1/8/2012		Lift station failure[8]	Pumped water back into system	Construction	Lagoon/basin
Moore	S20614	1/6/2011		Line break	Pumped water	Construction	Pipe
Moore	S20614	12/2/2010		Blockage	HTH	Flushed[9]	Manhole
Moore	S20614	12/17/2008		Spill from truck	Cleaned		
Moore	S20614	9/10/2004		Electrical failure		Evaluation	
Moore	S20614	5/15/2003		Collapsed manhole in creek	HTH	Repairs	Manhole
Moore	S20614	6/16/2002		Rains	HTH	New line under construction	
Moore	S20614	6/13/2002		Rain	HTH	Consent order	
Moore	S20614	6/14/2002		Rain	HTH	Consent order	
Moore	S20614	6/14/2002		Line stoppage	HTH	Flushed	
Moore	S20614	6/8/2002		Rains	HTH	Line under construction	
Moore	S20614	4/27/2002		Rains	HTH	New lines	
Moore	S20614	7/17/2000		Stoppage	HTH	Flushed	
Moore	S20614	7/2/2000		Rain	Cleaned		
Moore	S20614	7/2/2000		Rain			
Moore	S20614	7/2/2000		Rain			
Moore	S20614	6/28/2000		Rain	C & D[10]		
Moore	S20614	5/3/2000		Rains	Flushed	Repaired	
Moore	S20614	4/30/2000		Rain	C & D		
Moore	S20614	4/6/2000		Line stoppage	Cleaned	Flushed	
Moore	S20614	4/13/2000		Line stoppage	Cleaned	Flushed	
Moore	S20614	4/5/2000		Line stoppage	W & D	Clear	
Moore	S20614	2/25/2000		Blockage	HTH		
Moore	S20614	2/7/2000		Line stoppage	HTH	Flushed	
Moore	S20614	1/29/2000		Line stoppage	HTH	Flushed	

7 HTH = high-test hypochlorite (calcium hypochlorite) which is used as a disinfectant.

8 Whenever possible, gravity is used to move sanitary sewer water from place to place. Large sewer mains are placed very deep into the earth to allow the smaller mains to slant towards them, using gravity to assure that the water moves away from residences and businesses. Occasionally, the positions of housing or business units and the nearest sewer mains require lift stations to be installed. Water moves by gravity into the lift station and is then pumped up to the level necessary to allow it to again move by gravity into the sewer main or interceptor sewer and be carried to the wastewater treatment facility.

9 This method uses high-pressure water to flush out stone, sediment or other unwanted material from the sewer. It is the combination of high pressure and high flow rates that cleans the pipe. in the circumference of the nozzle that allow the high pressure water to propel the flushing nozzle and sewer hose up the sewer to the next manhole. As the nozzle moves up and down the pipe, it dislodges sediment, stone and other debris and flushes it downstream to the manhole, where it is removed from the sewer.

10 C & D = Cleaned and disinfected to reduce the potential for human health issues and adverse environmental impacts.

Facility Name	Facility ID	Bypass Date	Amount (Gallons)	Cause	Cleanup[7]	Preventive	Type of Source
Moore	S20614	1/30/2000		Line stoppage	HTH	Flushed	
Moore	S20614	1/10/2000		Debris	C & D		
Moore	S20614	1/11/2000		Debris	C & D		
Moore	S20614	1/10/2000		Line stoppage	HTH	Cleared	
Moore	S20614	1/1/2000		Line stoppage	HTH	Flushed	
Moore	S20614	1/2/2000		Line stoppage	HTH	Flushed	
Moore	S20614	1/2/2000		Line stoppage	HTH	Flushed	
Moore	S20614	6/26/2008	374,000	Eroded sewer line		Replaced line	
Moore	S20614	2/23/2001	232,000	Rain	HTH	Rehab	
Moore	S20614	10/22/2000	124,000	Rain	Flushed		
Moore	S20614	9/3/2009	100,000	Malfunction	None	Changed locks	
Moore	S20614	12/28/2002	100,000	Mechanical failure	HTH	Flushed	Lift station
Moore	S20614	9/6/2006	78,540	Open line from development	C & S	Contained sewage	
Moore	S20614	8/24/2005	39,000	Debris	Flushed	Removed & secured lid	
Moore	S20614	3/5/2004	30,000	Flooding			
Moore	S20614	3/4/2004	30,000	Rain		Currently under construction	
Moore	S20614	1/11/2001	25,912	Pump failure	Disinfected	Repaired	
Moore	S20614	1/11/2001	25912	Secondary pump failure of the check valve	Area disinfected	Pump repaired	
Moore	S20614	9/18/2001	17,985	Rain	Flushed		Manhole
Moore	S20614	9/11/2003	16,500	Rain		New lines	
Moore	S20614	4/18/2010	15,000	Malfunction of pump	C & D	Purchasing pump	Lift station
Moore	S20614	9/18/2001	13,915	Rain	Flushed		
Moore	S20614	12/1/2000	13464	Line stoppage	HTH'd & flushed	Line flushed	
Moore	S20614	12/1/2000	13,464	Line stoppage	HTH	Flushed	
Moore	S20614	11/18/2000	10,000	Line stoppage	Flowed hydrant	Flushed	
Moore	S20614	8/2/2001	9,400	Broken line	W & D	Repaired	
Moore	S20614	3/28/2004	8,000	Rain	HTH	Looking at new lift station	
Moore	S20614	11/7/2001	7,429	Stoppage	HTH	Flushed	
Moore	S20614	1/17/2004	6,000	Rain	C & S	Flushed	
Moore	S20614	2/2/2001	5,483	Stoppage	C & D	Flushed	
Moore	S20614	3/27/2010	5,000	Blockage	Washed	Flushed	Manhole
Moore	S20614	4/23/2009	5000	Blockage	HTH	Flushed	
Moore	S20614	4/10/2008	5,000	Rain	HTH	Consent order	Manhole
Moore	S20614	8/19/2007	5,000	Rain			
Moore	S20614	6/29/2007	5,000	Rain			
Moore	S20614	6/26/2007	5,000	Rain	HTH	Flushed	
Moore	S20614	5/24/2006	5,000	Blockage	HTH	Flushed	Manhole
Moore	S20614	1/16/2002	4,791	Line stoppage	W & D		
Moore	S20614	4/13/2011	4,500	Blockage	Cleaned	Replace & pumping	Manhole

Facility Name	Facility ID	Bypass Date	Amount (Gallons)	Cause	Cleanup[7]	Preventive	Type of Source
Moore	S20614	12/21/2000	4,484	Stoppage	HTH	Flushed	
Moore	S20614	12/21/2000	4484	Main line stoppage	HTH'd & flushed	Flushed main	
Moore	S20614	7/10/2007	4,000	Rain			
Moore	S20614	2/23/2006	4,000	Vandalism	HTH	Cleaned	Manhole
Moore	S20614	3/28/2004	4,000	Blockage	HTH	Flushed	
Moore	S20614	9/11/2003	4,000	Rain		New lines	
Moore	S20614	12/4/2000	3150	Main line stoppage	Area HTH'd & flushed	Flushed main line	
Moore	S20614	12/4/2000	3,150	Stoppage	HTH	Flushed	
Moore	S20614	3/19/2012	3,000	Rain	HTH	New plans	Manhole
Moore	S20614	3/19/2012	3,000	Rain	HTH		Manhole
Moore	S20614	6/9/2008	3,000	Rain	HTH	Consent order	
Moore	S20614	4/10/2008	3,000	Rain	HTH		Manhole
Moore	S20614	6/9/2004	3,000	Rain	HTH	New lift station	Lift station
Moore	S20614	3/25/2004	3,000	Collapsed line	HTH	Replaced line	
Moore	S20614	3/19/2012	2,500	Rain	HTH		Manhole
Moore	S20614	3/19/2012	2,500	Rain	HTH		Manhole
Moore	S20614	8/19/2008	2,500	Rain	C & S	Consent order	
Moore	S20614	8/11/2008	2,500	Rain	HTH	Consent order	
Moore	S20614	4/22/2004	2,500	Blockage	HTH	Flushed	Manhole
Moore	S20614	9/16/2008	2,000	Blockage	HTH	Flushed	Manhole
Moore	S20614	4/10/2008	2,000	Rain	HTH	Consent order	Manhole
Moore	S20614	10/26/2006	2,000	Power failure	Flushed	Replaced	
Moore	S20614	3/4/2004	2,000	Rain			
Moore	S20614	8/30/2003	2,000	Rain	HTH	New lines under construction	Lift station
Moore	S20614	12/25/2011	1,600	Blockage in main sewer line	HTH & flowed with a fire hydrant	Flushed line	
Moore	S20614	1/25/2012	1,500	Rain & debris	HTH	Install bar screens	Lift station
Moore	S20614	4/30/2009	1,500	Blockage	HTH	Flushed	Manhole
Moore	S20614	6/17/2008	1,500	Rain	C & D	Consent order	
Moore	S20614	3/7/2007	1,500	Manhole liner in main	HTH	Flushed	
Moore	S20614	9/10/2004	1,500	Computer failure	Cleaned	Evaluate system & make adjustments	
Moore	S20614	4/26/2004	1,500	Blockage	HTH	Flushed	Manhole
Moore	S20614	9/7/2003	1,500	Blockage	HTH	Flushed	
Moore	S20614	9/5/2003	1,500	Blockage	HTH	Flushed	
Moore	S20614	3/4/2004	1,400	Rain			
Moore	S20614	2/10/2001	1286	Line stoppage	HTH'd & flushed with fresh water	Line unstopped	
Moore	S20614	2/10/2001	1,286	Line stoppage	HTH	Flushed	
Moore	S20614	2/11/2001	1286	Line stoppage	HTH'd & flushed with fresh water	Line unstopped	
Moore	S20614	2/11/2001	1,286	Line stoppage	HTH	Flushed	
Moore	S20614	10/11/2000	1,272	Stoppage	HTH	Flushed	

Facility Name	Facility ID	Bypass Date	Amount (Gallons)	Cause	Cleanup[7]	Preventive	Type of Source
Moore	S20614	3/4/2004	1,200	Rain			
Moore	S20614	3/4/2012	1,000	Blockage	HTH	Flushed	Manhole
Moore	S20614	3/19/2011	1,000	Blockage	HTH	Flushed	Manhole
Moore	S20614	11/19/2010	1,000	Blockage	HTH	Flushed	Manhole
Moore	S20614	11/18/2010	1,000	Blockage	HTH	Flushed	Manhole
Moore	S20614	7/12/2010	1,000	Blockage	HTH	Flushed	Manhole
Moore	S20614	6/20/2010	1,000	Blockage	HTH	Flushed	Manhole
Moore	S20614	5/15/2010	1,000	Blockage	HTH	Flushed	Manhole
Moore	S20614	9/8/2009	1,000	Blockage	HTH	Flushed	Manhole
Moore	S20614	11/15/2008	1,000	Blockage	HTH	Flushed	Manhole
Moore	S20614	9/4/2008	1,000	Collapsed line	HTH	Replacing	
Moore	S20614	9/3/2008	1,000	Blockage	HTH	Flushed	
Moore	S20614	6/9/2008	1,000	Rain	HTH	Consent order	
Moore	S20614	4/10/2008	1,000	Rain	HTH		Manhole
Moore	S20614	3/19/2008	1,000	Blockage	HTH	Flushed	
Moore	S20614	3/12/2008	1,000	Blockage	HTH	Flushed	
Moore	S20614	10/24/2006	1,000	Blockage	HTH	Flushed	
Moore	S20614	4/11/2006	1,000	Vandalism	HTH	Flushed	
Moore	S20614	3/3/2006	1,000	Blockage	HTH	Flushed	
Moore	S20614	3/4/2004	1,000	Rain			
Moore	S20614	1/25/2004	1,000	Blockage	HTH	Flushed	
Moore	S20614	12/6/2003	1,000	Blockage	HTH	Flushed	
Moore	S20614	8/30/2003	1,000	Rain	HTH	New lines	Lift station
Moore	S20614	6/29/2003	1,000	Blockage	HTH	Flushed	
Moore	S20614	6/9/2003	1,000	Debris	HTH	Cleaned	Manhole
Moore	S20614	3/6/2003	1,000	Frozen floats	HTH	Insulate pipe	Lift station
Moore	S20614	2/12/2010	900	Vandalism	HTH		
Moore	S20614	4/22/2009	800	Blockage	HTH	Flushed	
Moore	S20614	1/25/2005	800	Break in line	HTH	Repair	
Moore	S20614	11/13/2004	800	Blockage	HTH	Flushed	
Moore	S20614	3/17/2004	800	Blockage	C & S	Flushed	
Moore	S20614	12/8/2003	800	Blockage	HTH	Flushed	
Moore	S20614	6/3/2005	750	Blockage	HTH	Flushed	
Moore	S20614	1/11/2010	700	Blockage	HTH	Flushed	Manhole
Moore	S20614	5/11/2010	600	Blockage	HTH	Flushed	Manhole
Moore	S20614	2/16/2010	600	Blockage	HTH	Flushed	Manhole
Moore	S20614	5/21/2007	600	Blockage	HTH	Flushed	
Moore	S20614	4/16/2007	600	Blockage	HTH	Flushed	
Moore	S20614	4/12/2007	600	Blockage	HTH	Flushed	
Moore	S20614	2/26/2007	600	Blockage	HTH	Flushed	
Moore	S20614	7/25/2005	600	Contractor hit line	HTH		

Facility Name	Facility ID	Bypass Date	Amount (Gallons)	Cause	Cleanup[7]	Preventive	Type of Source
Moore	S20614	11/19/2000	600	Line stoppage	Cleaned	Flushed	
Moore	S20614	8/30/2011	500	Blockage	HTH	Flushed	Manhole
Moore	S20614	5/1/2011	500	Blockage	HTH	Flushed	Manhole
Moore	S20614	3/21/2011	500	Blockage	HTH	Flushed	Manhole
Moore	S20614	3/3/2011	500	Blockage	HTH	Flushed	Manhole
Moore	S20614	6/1/2010	500	Rocks/vandalism	HTH	Secured lid	Manhole
Moore	S20614	4/18/2010	500	Blockage	HTH	Flushed	Manhole
Moore	S20614	3/24/2010	500	Blockage	HTH	Flushed	Manhole
Moore	S20614	2/13/2010	500	Blockage	HTH	Flushed	Manhole
Moore	S20614	1/21/2010	500	Blockage	HTH	Flushed	Manhole
Moore	S20614	12/16/2009	500	Blockage	HTH	Flushed	Manhole
Moore	S20614	5/8/2009	500	Blockage	HTH	Flushed	Manhole
Moore	S20614	1/28/2009	500	Blockage	HTH	Flushed	Manhole
Moore	S20614	12/23/2008	500	Blockage	HTH	Flushed	Manhole
Moore	S20614	12/5/2008	500	Blockage	HTH	Flushed	
Moore	S20614	9/21/2008	500	Blockage	HTH	Flushed	
Moore	S20614	9/11/2008	500	Grease	HTH	Flushed	
Moore	S20614	7/8/2008	500	Blockage	HTH	Flushed	
Moore	S20614	4/21/2008	500	Blockage	HTH	Flushed	Manhole
Moore	S20614	3/28/2008	500	Blockage	HTH	Flushed	Manhole
Moore	S20614	3/17/2008	500	Rain	HTH	Flushed	
Moore	S20614	11/22/2007	500	Blockage	HTH	Flushed	
Moore	S20614	8/22/2007	500	Blockage	HTH	Flushed	
Moore	S20614	6/29/2007	500	Rain			
Moore	S20614	6/29/2007	500	Rain			
Moore	S20614	6/29/2007	500	Rain			
Moore	S20614	4/19/2007	500	Blockage	HTH	Flushed	
Moore	S20614	2/21/2007	500	Blockage	HTH	Flushed	
Moore	S20614	2/8/2007	500	Blockage	HTH	Flushed	
Moore	S20614	2/7/2007	500	Grease	HTH	Flushed	
Moore	S20614	1/8/2007	500	Blockage	HTH	Flushed	
Moore	S20614	1/9/2007	500	Blockage	HTH	Flushed	
Moore	S20614	12/22/2006	500	Blockage	HTH	Flushed	
Moore	S20614	4/20/2006	500	Blockage	HTH	Flushed	
Moore	S20614	9/28/2005	500	Debris	HTH	Flushed	
Moore	S20614	9/25/2005	500	Blockage	HTH	Flushed	Manhole
Moore	S20614	9/18/2005	500	Blockage	HTH	Flushed	Manhole
Moore	S20614	6/4/2005	500	Blockage	HTH	Flushed	
Moore	S20614	3/22/2005	500	Blockage	HTH	Flushed	
Moore	S20614	3/5/2005	500	Grease	HTH	Flushed	
Moore	S20614	1/14/2005	500	Blockage	HTH	Flushed	

Facility Name	Facility ID	Bypass Date	Amount (Gallons)	Cause	Cleanup[7]	Preventive	Type of Source
Moore	S20614	1/1/2005	500	Blockage	HTH	Flushed	
Moore	S20614	11/8/2004	500	Grease	HTH	Flushed	
Moore	S20614	8/23/2004	500	Blockage	HTH	Flushed	
Moore	S20614	2/29/2004	500	Vandalism	HTH	Flushed	
Moore	S20614	1/23/2004	500	Blockage	HTH	Flushed	Manhole
Moore	S20614	1/8/2004	500	Vandalism	HTH	Sealed manhole	Manhole
Moore	S20614	1/9/2004	500	Vandalism	HTH	Sealed	Manhole
Moore	S20614	12/30/2003	500	Blockage	HTH	Flushed	
Moore	S20614	12/22/2003	500	Blockage	HTH	Flushed	
Moore	S20614	11/30/2003	500	Blockage	HTH	Flushed	
Moore	S20614	11/20/2003	500	Blockage	HTH	Flushed	
Moore	S20614	10/22/2003	500	Blockage	HTH	Flushed	
Moore	S20614	9/5/2003	500	Blockage	HTH	Flushed	
Moore	S20614	9/2/2003	500	Debris	HTH	Flushed	Manhole
Moore	S20614	9/2/2003	500	Rain	HTH	Flushed	
Moore	S20614	4/4/2003	500	Blockage	HTH	Flushed	
Moore	S20614	3/30/2003	500	Blockage	HTH	Flushed	
Moore	S20614	3/3/2003	500	Blockage	HTH	Flushed	
Moore	S20614	1/21/2003	500	Blockage	HTH	Flushed	
Moore	S20614	4/15/2002	500	Collapsed line	HTH	Replace	
Moore	S20614	2/8/2010	400	Blockage	HTH	Flushed	Manhole
Moore	S20614	8/29/2008	400	City pumping error	HTH	Informed crew	
Moore	S20614	11/22/2005	400	Blockage	HTH	Flushed	
Moore	S20614	11/22/2005	400	Blockage	HTH	Flushed	
Moore	S20614	3/15/2004	400	Blockage	C & D	Flushed	Manhole
Moore	S20614	3/25/2005	350	Blockage	HTH	Flushed	
Moore	S20614	6/14/2004	350	Blockage	HTH	Flushed	
Moore	S20614	3/17/2012	300	Blockage	Washed	Flushed	Manhole
Moore	S20614	3/4/2012	300	Blockage	HTH	Flushed	Manhole
Moore	S20614	12/26/2011	300	Blockage in sewer main	HTH & flowed fire hydrant	Flushed sewer main	
Moore	S20614	6/17/2010	300	Blockage	HTH	Flushed	Manhole
Moore	S20614	2/16/2010	300	Blockage	NONE	Flushed	Manhole
Moore	S20614	7/1/2009	300	Blockage	HTH	Flushed	
Moore	S20614	4/4/2009	300	Blockage	HTH	Flushed	
Moore	S20614	6/1/2008	300	Blockage	HTH	Flushed	Manhole
Moore	S20614	7/10/2007	300	Rain			
Moore	S20614	3/21/2007	300	Blockage	HTH	Flushed	
Moore	S20614	3/3/2007	300	Blockage	HTH	Flushed	
Moore	S20614	2/9/2007	300	Blockage	HTH	Flushed	
Moore	S20614	11/11/2004	300	Roots	HTH	Flushed	

Facility Name	Facility ID	Bypass Date	Amount (Gallons)	Cause	Cleanup[7]	Preventive	Type of Source
Moore	S20614	3/13/2004	300		C & D	Jetted	
Moore	S20614	11/8/2000	252	Rain	Flushed		
Moore	S20614	3/19/2012	250	Rain	HTH		Manhole
Moore	S20614	2/16/2011	250	Blockage	HTH	Flushed	Manhole
Moore	S20614	6/14/2008	250	Blockage	HTH	Flushed	
Moore	S20614	5/16/2008	250	Blockage	HTH	Flushed	Manhole
Moore	S20614	4/24/2008	250	Blockage	HTH	Flushed	Manhole
Moore	S20614	7/20/2007	250	Grease	HTH	Flushed	
Moore	S20614	7/20/2007	250	Blockage	HTH	Flushed	
Moore	S20614	1/21/2006	250	Blockage	HTH	Flushed	
Moore	S20614	1/19/2005	250	Blockage	HTH	Flushed	
Moore	S20614	6/15/2004	250	Blockage	HTH	Flushed	
Moore	S20614	6/10/2003	250	Debris	HTH	Flushed	Manhole
Moore	S20614	6/26/2012	200	Blockage	HTH	Flushed	Manhole
Moore	S20614	5/10/2012	200	Blockage	HTH	Flushed	Manhole
Moore	S20614	4/21/2011	200	Blockage	HTH	Flushed	Manhole
Moore	S20614	3/14/2011	200	Blockage	HTH	Flushed	Manhole
Moore	S20614	1/27/2011	200	Blockage	HTH	Flushed	Manhole
Moore	S20614	5/11/2010	200	Debris from storm	Cleaned	Flushed	Manhole
Moore	S20614	3/19/2010	200	Blockage		Flushed	Manhole
Moore	S20614	3/9/2010	200	Blockage		Flushed	Manhole
Moore	S20614	2/22/2010	200	Blockage		Flushed	Manhole
Moore	S20614	11/28/2009	200	Blockage	HTH	Flushed	Manhole
Moore	S20614	6/15/2008	200	Blockage	HTH	Flushed	
Moore	S20614	4/28/2008	200	Blockage	HTH	Flushed	Manhole
Moore	S20614	4/15/2008	200	Blockage	HTH	Flushed	Manhole
Moore	S20614	12/4/2007	200	Blockage	HTH	Flushed	Manhole
Moore	S20614	4/26/2007	200	Blockage	HTH	Flushed	
Moore	S20614	4/12/2007	200	Blockage	HTH	Flushed	
Moore	S20614	2/16/2007	200	Blockage	HTH	Flushed	
Moore	S20614	5/22/2006	200	Blockage	HTH	Flushed	Manhole
Moore	S20614	10/3/2005	200	Blockage	HTH	Flushed	
Moore	S20614	5/1/2005	200	Blockage	HTH	Flushed	
Moore	S20614	3/28/2005	200	Grease & debris	HTH	Flushed	
Moore	S20614	3/1/2005	200	Blockage	HTH	Flushed	
Moore	S20614	1/25/2005	200	Blockage	HTH	Flushed	
Moore	S20614	6/25/2004	200	Main break	HTH	Repair	
Moore	S20614	5/19/2004	200	Blockage	HTH	Flushed	
Moore	S20614	12/23/2003	200	Blockage	HTH	Flushed	
Moore	S20614	11/11/2003	175	Blockage	HTH	Flushed	
Moore	S20614	7/19/2006	160	Line break	HTH	Repaired	

Facility Name	Facility ID	Bypass Date	Amount (Gallons)	Cause	Cleanup[7]	Preventive	Type of Source
Moore	S20614	3/26/2012	150	Stoppage	HTH	Flushed	Manhole
Moore	S20614	12/29/2011	150	Pump failure	C & D	Replaced pumps	
Moore	S20614	12/6/2011	150	Blockage	HTH	Flushed	Manhole
Moore	S20614	10/6/2010	150	Blown fuse & down line	HTH	Replaced fuse & line repairs	Lift station
Moore	S20614	12/21/2009	150	Blockage	HTH	Flushed	Manhole
Moore	S20614	10/15/2009	150	Blockage	HTH	Flushed	
Moore	S20614	11/12/2006	150	Blockage	HTH	Flushed	
Moore	S20614	9/8/2006	150	Collapsed main	HTH	Repaired	
Moore	S20614	12/23/2005	150	Blockage	HTH	Flushed	
Moore	S20614	12/25/2005	150	Blockage	HTH	Flushed	
Moore	S20614	11/5/2005	150	Blockage	HTH	Flushed	
Moore	S20614	2/4/2005	150	Blockage	HTH	Flushed	
Moore	S20614	2/6/2004	150	Blockage	HTH	Flushed	
Moore	S20614	11/28/2003	150	Blockage	HTH	Flushed	
Moore	S20614	7/31/2003	150	Debris	HTH	Flushed	
Moore	S20614	9/27/2002	150	Blockage	HTH	Flushed	
Moore	S20614	9/23/2003	120	Foaming	HTH	Plugged	
Moore	S20614	9/17/2003	105	Blockage	HTH	Flushed	
Moore	S20614	8/1/2012	100	Blockage	HTH	Flushed	Manhole
Moore	S20614	7/11/2012	100	Blockage	HTH	Flushed	Manhole
Moore	S20614	6/28/2012	100	Blockage	HTH	Flushed	Manhole
Moore	S20614	4/11/2012	100	Roots & grease	Washed	Root cut & flushed	Pipe
Moore	S20614	3/29/2012	100	Blockage	HTH	Flushed	Manhole
Moore	S20614	3/26/2012	100	Roots	HTH	Flushed	Manhole
Moore	S20614	3/11/2012	100	Blockage	HTH	Flushed	Manhole
Moore	S20614	3/5/2012	100	Debris	HTH	Flushed	Manhole
Moore	S20614	12/9/2011	100	Blockage	HTH	Flushed	Manhole
Moore	S20614	12/7/2011	100	Blockage	HTH	Flushed	Manhole
Moore	S20614	11/20/2011	100	Blockage	HTH	Flushed	Manhole
Moore	S20614	8/29/2011	100	Blockage	HTH	Flushed	Manhole
Moore	S20614	5/21/2011	100	Blockage	HTH	Flushed	Manhole
Moore	S20614	4/9/2011	100	Blockage	HTH	Flushed	Manhole
Moore	S20614	4/9/2011	100	Blockage	HTH	Flushed	Manhole
Moore	S20614	3/23/2011	100	Broken main	HTH	Repaired	Manhole
Moore	S20614	3/19/2011	100	Blockage	HTH	Flushed	Manhole
Moore	S20614	12/2/2010	100	Blockage	HTH	Flushed	Manhole
Moore	S20614	12/1/2010	100	Blockage	HTH	Flushed	Manhole
Moore	S20614	11/23/2010	100	Blockage	HTH	Flushed	Manhole
Moore	S20614	10/24/2010	100	Blockage	HTH	Flushed	Manhole
Moore	S20614	3/24/2010	100	Blockage	HTH	Flushed	Manhole

Facility Name	Facility ID	Bypass Date	Amount (Gallons)	Cause	Cleanup[7]	Preventive	Type of Source
Moore	S20614	12/19/2009	100	Blockage	HTH	Flushed	Manhole
Moore	S20614	12/19/2009	100	Blockage	HTH	Flushed	Manhole
Moore	S20614	12/21/2009	100	Blockage	HTH	Flushed	Manhole
Moore	S20614	12/1/2009	100	Blockage	HTH	Flushed	Manhole
Moore	S20614	12/19/2008	100	Blockage	HTH	Flushed	
Moore	S20614	4/3/2008	100	Blockage	HTH	Flushed	Manhole
Moore	S20614	2/7/2008	100	Blockage	HTH	Flushed	
Moore	S20614	2/7/2008	100	Blockage	HTH	Flushed	
Moore	S20614	12/6/2007	100	Blockage	HTH	Flushed	
Moore	S20614	11/27/2007	100	Blockage	HTH	Flushed	
Moore	S20614	2/20/2007	100	Blockage	HTH	Flushed	
Moore	S20614	2/20/2007	100	Blockage	HTH	Flushed	
Moore	S20614	2/4/2007	100	Blockage	HTH	Flushed	
Moore	S20614	12/14/2006	100	Blockage	HTH	Flushed	
Moore	S20614	12/7/2006	100	Blockage	HTH	Flushed	
Moore	S20614	10/9/2006	100	Blockage	HTH	Flushed	
Moore	S20614	9/8/2006	100	Blockage	HTH	Flushed	
Moore	S20614	8/11/2006	100	Blockage	HTH	Flushed	
Moore	S20614	8/7/2006	100	Blockage	HTH	Flushed	
Moore	S20614	5/19/2006	100	Blockage	HTH	Flushed	Manhole
Moore	S20614	2/3/2006	100	Blockage	HTH	Flushed	
Moore	S20614	1/3/2006	100	Blockage	HTH	Flushed	
Moore	S20614	1/2/2006	100	Blockage	HTH	Flushed	
Moore	S20614	6/30/2005	100	Blockage	HTH	Flushed	
Moore	S20614	5/30/2005	100	Blockage	HTH	Flushed	Manhole
Moore	S20614	3/19/2005	100	Blockage	HTH	Flushed	
Moore	S20614	2/14/2005	100	Blockage	HTH	Flushed	Manhole
Moore	S20614	8/23/2004	100	Blockage	HTH	Flushed	
Moore	S20614	3/7/2004	100	Blockage	C & S	Flushed	
Moore	S20614	11/30/2003	100	Blockage	HTH	Flushed	
Moore	S20614	11/20/2003	100	Blockage	HTH	Flushed	
Moore	S20614	11/9/2003	100	Blockage	HTH	Flushed	
Moore	S20614	10/14/2003	100	Blockage	HTH	Flushed	
Moore	S20614	7/11/2003	100	Debris	HTH	Flushed	
Moore	S20614	8/16/2002	100	Overflow	C & D	Construction	Lift station
Moore	S20614	5/7/2002	100	Blockage	HTH	List	
Moore	S20614	5/9/2001	100	Line stoppage	Disinfected	Flushed	
Moore	S20614	1/20/2012	75	Blockage	HTH	Flushed	Manhole
Moore	S20614	8/28/2005	75	Blockage	HTH	Flushed	
Moore	S20614	8/2/2012	50	Blockage	HTH	Replaced	Manhole
Moore	S20614	7/12/2012	50	Blockage	HTH	Flushed	Manhole

Facility Name	Facility ID	Bypass Date	Amount (Gallons)	Cause	Cleanup[7]	Preventive	Type of Source
Moore	S20614	7/2/2012	50	Blockage	HTH	Jetted	Manhole
Moore	S20614	5/25/2012	50	Blockage	HTH	Flushed	Manhole
Moore	S20614	4/18/2012	50	Grease	Flowed hydrant	Flushed	Manhole
Moore	S20614	10/29/2011	50	Lift station malfunction	HTH	Control panel repair	Lift station
Moore	S20614	9/7/2011	50	Blockage	HTH	Flushed	Manhole
Moore	S20614	3/16/2010	50	Blockage	HTH	Flushed	Manhole
Moore	S20614	10/3/2009	50	Blockage	HTH	Flushed	Manhole
Moore	S20614	6/29/2009	50	Blockage	HTH	Flushed	Manhole
Moore	S20614	3/19/2009	50	Blockage	HTH	Flushed	
Moore	S20614	4/29/2008	50	Blockage	HTH	Flushed	
Moore	S20614	11/27/2007	50	Grease	HTH	Flushed	Manhole
Moore	S20614	9/9/2007	50	Rain	HTH		
Moore	S20614	9/9/2007	50	Rain	C & S		
Moore	S20614	2/14/2006	50	Blockage	HTH	Flushed	
Moore	S20614	9/13/2005	50	Blockage	HTH	Flushed	Manhole
Moore	S20614	1/18/2005	50	Blockage	HTH	Flushed	
Moore	S20614	8/28/2003	50	Blockage	HTH	Flushed	
Moore	S20614	10/5/2002	50	Grease	HTH	Flushed	
Moore	S20614	8/6/2012	25	Blockage	HTH	Flushed	Pipe
Moore	S20614	7/20/2012	25	Roots	HTH	Flushed	Manhole
Moore	S20614	7/6/2012	25	Blockage	HTH	Flushed	Manhole
Moore	S20614	2/1/2012	25	Roots	Cleaned	Root control	Manhole
Moore	S20614	1/20/2012	25	Blockage	HTH	Flushed	Manhole
Moore	S20614	10/10/2003	25	Blockage	HTH	Flushed	
Moore	S20614	8/13/2007	10	Line blockage	HTH	Flushed	
Moore	S20614	11/16/2003	5	Blockage	HTH	Flushed	

Appendix G

Response to Comments

Response to Public Comments for the Draft Lake Thunderbird Report for Nutrient, Turbidity, and Dissolved Oxygen Total Maximum Daily Loads

November 5, 2013

Comments were received on the Lake Thunderbird Draft TMDL Report from the following:

A Norman Developers Council (Represented by Heiple Law Office, Inc), dated 07/23/2013

B Norman Developers Council (Represented by Heiple Law Office, Inc), Supplemental Comments, dated 07/31/2013

C Sierra Club (Same as transcript from Public Meeting on 07/23/2013), dated 7/31/2013

D City of Norman, dated 07/31/2013

E Satish Dasharathy, email dated 08/01/2013

F Charles & Lyntha Wesner, email dated 08/01/2013

G Joy Hampton, email dated 08/01/2013

A. Comments from Norman Developers Council (prepared by Heiple Law Office – 7/23/13)

A1. Exec. Summary, Pages 1 and 2: The fact that Oklahoma City and Moore contribute more than half of the pollutants going into the lake, but do **NOT** get drinking water from the lake, needs to be apparent to regulators when watershed-specific control actions and management measures are being considered, in order to insure that those cities are **REQUIRED** to take the same actions that Norman will be undertaking (essentially) voluntarily.

Response: *Cities using the lake for a drinking water source are identified in several locations throughout the report. The additional TMDL requirements for Municipal Separate Storm Sewer Systems (MS4) Permits, construction stormwater permits and industrial stormwater permits apply equally to all three cities in the Lake Thunderbird Watershed. No changes were made as a result of this comment.*

A2. Exec. Summary, Page 2: There are ways to increase the volume of water in the lake. The critically important need is for ODEQ to **promptly develop standards for waste water treated by cities in Oklahoma to be eligible for discharge into water sources like Lake Thunderbird.** With the contemplated improvement in its waste water treatment plant (which currently discharges 10-12 MGD into the South Canadian), Norman could divert much of its treated waste water to Lake Thunderbird. Also, additional water could be discharged from those Norman wells currently off-line because of arsenic levels, flowing through creeks (including wetlands that could be developed) into Lake Thunderbird.

Response: *Analysis of potential future discharges to the Lake Thunderbird Watershed was not within the scope of this study, and the court-imposed schedule for development of the report did not allow for any expansion of the scope. While there have been some conceptual discussions of such discharge scenarios, there are currently no active, concrete proposals to discharge treated wastewater into Sensitive Water Supply (SWS) lakes[1], like Lake Thunderbird. The Oklahoma Water Resources Board (OWRB) is the agency responsible for*

[1] For information about SWS lakes, refer to Oklahoma's Water Quality Standards (WQS) [Appendix A.5 (for Lake Thunderbird) of Title 785, Chapter 45 of the Oklahoma Administrative Code; 785:45-5-25(c)(4)(A) and 785:45-3-2(c)].

proposing changes to the Water Quality Standards. DEQ is not aware of any proposal to make such a change to Water Quality Standards (WQS). This TMDL report is based on the current Water Quality Standards. If any authorization for such a discharge is requested in the future, this TMDL would have to be revised to accommodate the additional pollutant loading. Also, please see the response to comment A.9. No changes were made as a result of this comment.

A3. Exec. Summary, Page 3: Utilizing data that covers only one 12-month period seems insufficient. It appears there was ample opportunity to have collected data for additional years.

Response: *The study plan for Lake Thunderbird included a special stream monitoring program conducted by the Oklahoma Conservation Commission (OCC) in 2008-2009. OCC was responsible for collection of streamflow and water quality data at five stations in the Watershed. OWRB, in conjunction with the Central Oklahoma Master Conservancy District (COMCD), collected water quality data at eight stations in the Lake during the same time period. The monitoring program implemented for the Watershed and Lake was designed to provide the observed data needed to support development of the TMDLs for Lake Thunderbird. A special monitoring program was needed because historical flow and water quality observations did not exist for the Little River Watershed.*

Based on annual precipitation data from the Mesonet[2] *Norman station, the Lake Thunderbird Watershed area experienced annual precipitation of 36.0 inches in 2008 and 35.7 inches in 2009. The annual precipitation in 2008-2009 is very close to the 30-year long-term average of 37.4 inches for the area. The data suggests that, during the model calibration period of 2008-2009, pollutant loadings from the Watershed to the Lake can be considered to represent "average" hydrologic conditions. The data used for this study were more than adequate for model calibration and TMDL development. No changes were made as a result of this comment.*

A4. Sec. 1.1: Note that the federal government says **States** have the obligation and the right to develop and implement controls. If Oklahoma would promptly adopt standards to allow treated waste water to be discharged into sources of drinking water, we could avoid the possibility of federal EPA intervention. Oklahomans are best qualified to address threats to our drinking water.

Response: *Please see the responses to comments A.2 and A.9. No changes were made as a result of this comment.*

A5. Sec. 1.1: It seems an extraordinary waste of talent, as well as an unnecessary burden on the *"stakeholders who live and work in the watersheds"*, if this report by ODEQ does not at least compile a list of various "*watershed-specific control actions and management measures"* that could be utilized to address specific problems described in the "*public Comment"* report.

Response: *This TMDL Report sets the maximum daily loads, reduction goals, and various requirements for permit holders in the Watershed. Additional permit provisions are described in Appendix E along with descriptions and reported efficiencies of various Best Management Practices (BMPs) and references to the technical literature regarding BMP selection and*

2 "Mesonet" is a combination of the words "mesoscale" and "network". In meteorology, "mesoscale" refers to weather events that range in size from about one mile to about 150 miles. Mesoscale events last from several minutes to several hours. A "network" is an interconnected system. Thus, the Oklahoma Mesonet is a system designed to measure the environment at the size and duration of mesoscale weather events.

implementation. Other recommendations may be found in Section 5.6, including requirements for Section 404 Permits. Flexibility is allowed for the communities in the Watershed to tailor their own programs and determine their implementation strategy to achieve the required load reduction goals and to meet the required wasteload allocations (WLA). No changes were made as a result of this comment.

A6. Sec. 1.2: As stated before, the use of only one 12-month period seems shallow. Would not the impact of years of high and low rainfall (such as the more than 55" in 2007) allow for the better analysis and understanding of whether diverting and discharging addition water into Thunderbird would alleviate some of the identified problems?

Response: *Please refer to the responses to comments A.2and A.3. No changes were made as a result of this comment.*

A7. Table 1-2: Is it correct that decomposing leaves from trees comprise the biggest source of phosphorous and/or nitrogen in Lake Thunderbird?

Response: *No, it is not correct. There are ten land use categories used in the Lake Thunderbird Watershed Model. The land area in acres, the Total Phosphorus (TP) & Total Nitrogen (TN) unit loadings in pounds per acre per year, and the total pollutant loading in pounds per year for each land use category are summarized in the following table. As can be seen, total pollutant loadings from urban areas exceed those from forest areas by one to two orders of magnitude. Even the loadings from just the commercial areas of the watershed far exceed the loadings from the forested areas. While there is a large portion of the Watershed which is forested, the unit loadings from forested areas are smaller than any other land use category, which leads to a smaller total loading. Therefore, TN and TP loadings from leaves are NOT major sources of pollutants although the area of forest land is a significant portion of the total watershed area. For clarification, the table below along with explanatory text was added to the report in Section 3.3.6. as Table 3-9.*

Table 3-9. Nutrient Loading for Each Land Use Category

Land Use Category	Land Area (acres)	TN (lb/ac/yr)	TN (lbs/yr)	TP (lb/ac/yr)	TP (lbs/yr)
Forest Deciduous	55,010	0.189	10,397	0.009	495
Forest Evergreen	351	0.183	64	0.009	3
Total Forest			**10,461**		**498**
Wetland	8	0.324	3	0.046	0
Rangeland	59,765	3.074	183,718	0.607	36,277
Pasture	5,452	4.043	22,042	0.611	3,331
Agriculture	3,341	3.413	11,403	0.913	3,050
Low Density Urban	6,769	9.019	61,050	1.886	12,766
Medium Density Urban	3,102	9.089	28,194	1.895	5,878
Commercial	14,661	9.906	145,232	2.024	29,674
High Density Urban	661	10.34	6,835	2.169	1,434
Total Urban			**241,311**		**49,762**

A8. Sec. 1.3: Adding substantial additional water to Lake Thunderbird would obviously impact a TMDL assessment.

Response: *That is correct. Before any substantial additions of water to Lake Thunderbird occur in the future, this TMDL would have to be revised. Also, please refer to the response to comment A2. No changes were made as a result of this comment.*

A9. Sec. 2.1: Has ODEQ provided any information to OWRB regarding standards that would allow treated waste water to be deposited into drinking water sources?

Response: *Discussions between DEQ and OWRB about any potential future wastewater discharge to the Lake Thunderbird Watershed was not a part of the TMDL development. However for information purposes, DEQ is providing the following: DEQ was required by 2012 Senate Bill 1043 to convene a working group to discuss issues related to water reuse. DEQ has convened the working group as required. The group has met and some preliminary discussions have occurred related to possible discharges to Sensitive Water Supplies such as Lake Thunderbird. DEQ and the OWRB have been included in these meetings. This is an ongoing process and - as of the date of this response - no proposals have been developed. No changes were made as a result of this comment.*

A10. Sec. 2.2: In light of the amount of pollution contributed by decomposing leaves and other vegetation, how do you conclude that "**urban development**" is the **primary** cause of excessive nutrient loading from the watershed?

Response: *Please refer to the response to comment A7. No changes were made as a result of this comment.*

A11. Table 3-3: This further supports our belief that cities such Moore and Oklahoma, who do **NOT** get drinking water from Thunderbird, must be subjected to mandatory compliance with regulations designed to protect Thunderbird.

Response: *[Note: Table 3-3 is a summary of sanitary sewer overflows and bypasses.] The additional TMDL requirements for MS4 permits, construction storm water permits, and industrial storm water permits apply equally to all three cities in the watershed. Non-compliance with these permit requirements will be considered a permit violation subject to enforcement actions. No changes were made as a result of this comment.*

A12. Sec. 3.1.3: Moore and Oklahoma City need **more** than simply an allocation of how much waste load they can discharge into the Lake Thunderbird watershed. Just like Norman, they need established and enforceable punishments, if and when either Moore or Oklahoma City exceeds their established allocation.

Response: *Please refer to the response to comment A11. Noncompliance with permit requirements for Norman, Moore, or Oklahoma City would subject them to enforcement actions including possible fines of up to $10,000 per day. No changes were made as a result of this comment.*

A13. Sec. 3.2.1: "For Lake Thunderbird, wet and dry deposition data was estimated as the average of annual data from 208-2009 for… … Dry deposition for phosphorus was estimated using the CASTNET and NADP data for nitrogen with annual average N/P ratio for atmospheric deposition of N and P reported for 6 sites located in Iowa." This does not appear to be sufficient information upon which to contemplate a building moratorium for the Little River Watershed.

Response: *Atmospheric deposition data were available for nitrogen for 2008-2009 from the National Atmospheric Deposition Program (NADP) Kessler Field Station (OK17) and the CASTNET Cherokee station (CHE185) in Oklahoma. The Kessler Field station (OK17) is located about 38 km southeast of the dam*[3] *and the Cherokee station (CHE185) is located about 237 km northeast of the dam*[4]*. These are the nearest atmospheric monitoring sites available. Since phosphate data was not available for these or any other stations in Oklahoma, a literature search identified a comprehensive study of atmospheric deposition data for nitrogen and phosphorus at six locations in Iowa. Estimates of phosphate deposition for Lake Thunderbird were based on the Oklahoma nitrogen deposition rate and the N/P ratio of the data from the Iowa stations. National-scale maps of atmospheric deposition of nitrogen for 2008-2009 from the NADP (http://nadp.sws.uiuc.edu/) show that nitrogen deposition rates in the Central Plains states, including Iowa, are comparable to the nitrogen deposition rates measured at the Oklahoma stations. The nitrogen and phosphorus deposition data and the N/P ratio derived from the study in Iowa are, therefore, considered to be representative of the Central Plains region where Lake Thunderbird is located. Section 4.4 of the report and Tables 4-1 and 4-2 provide data characterizing the contributions of each source of nutrients to the lake model. The contributions of the sources of phosphorus from the watershed, atmospheric deposition and internal sediment flux are given in Table 4-1 and the percentage of each source is given in Table 4-2. Atmospheric deposition accounts for only 0.4% of the total phosphorus loading to the Lake, a negligible contribution to the total phosphorus loading to Lake Thunderbird.*

The report does not mention any contemplation of a building moratorium for the Little River watershed. No changes were made as a result of this comment.

A14. Sec. 4.7: Norman **must** get on board, because Lake Thunderbird provides its drinking water. Unless the mitigating measures are made **mandatory** for Moore and Oklahoma City, **with significant fines for non-compliance,** any proposed regulatory action is worthless.

Response: *Please refer to the responses to comments A11 and A12. No changes were made as a result of this comment.*

B. Supplemental Comments from Norman Developers Council (prepared by Heiple Law Office - 7/31/2013)

B1. Newspaper accounts of that meeting raised concerns on our part. The following quote is taken from the story, beginning on page 1 and continued on page 3, in the July 24, 2013 edition of ***The Norman Transcript:***

> *"Under the proposal, construction sites would have to maintain a 100-foot vegetative buffer for all streams, put in sediment basins (detention ponds) for sites five acres and larger, submit to weekly inspections, plant vegetation quickly and test the soil before using fertilizer."*

The newspaper quote appears to conflict with the following statement in the June 13, 2013 draft of the Lake Thunderbird TMDL Report:

> ***Exec. Summary, Page 1:*** *"This report does not identify specific control actions (regulatory controls) or management measures (voluntary best management practices) necessary to reduce pollutant loading from the watershed. Watershed-specific control actions and management measures will be identified, selected, and implemented under a separate process involving stakeholders who live and work in the watershed, along with local, state, and federal government agencies."*

[3] Latitude: 34.98 and Longitude -97.5214
[4] Latitude: 35.7507 and Longitude -94.67

Response: *Please refer to the response to comment A5. No changes were made as a result of this comment.*

B2. Our first concern is that an ODEQ Report that suggests a ***single*** management practice that applies to ***all*** lands (*e.g., 100-FOOT VEGETATIVE BUFFER FOR ALL STREAMS*) could result in an EPA pronouncement that ***mandates*** such a single solution for ***all*** lands in the Little River watershed**.** Compare the experience of the City of Norman.

More than two years ago, following months of study and deliberations by a large committee of City officials and citizens, the City of Norman adopted Ordinance O-1011-52, which include the following standard:

"Sec. 19-411. Water Quality Protection Zone design standards.

A. The Water Quality Protection Zone (WQPZ) for a stream system shall consist of a vegetated strip of land, preferably undisturbed and natural, extending along both sides of a stream and its adjacent wetlands, floodplains, or slopes. The width shall be adjusted to include contiguous sensitive areas, such as steep slopes, where development or disturbance may adversely affect water quality, streams, wetlands, or other water bodies.

B. The required base width for all WQPZs shall be equal to:

1. The greater of the following:

a. One hundred (100) feet in width, measured from the top of the bank, on either side of the stream; or

b. The designated Stream Planning Corridor as delineated on Exhibit 4-4 to the Storm Water Master Plan, dated October 2009, and accepted by City Council on November 10, 2009, and as available on the appropriate scale through the Public Works Department, or as indicated by the applicant's independent engineering analysis; or

c. The FEMA floodplain; or

*2. An alternative width equal to twenty-five (25) feet in width, measured from the top of the bank, on either side of the stream when a reduction in nitrogen of at least seventy-five (75) percent and a reduction in phosphorus of at least fifty-eight (58) percent is achieved through the use of an engineered process that is certified by a licensed Professional Engineer. A development plan using an alternative width less than the SPC shall also document protection against flooding and bank erosion that would be anticipated during the one-percent-chance flood event in any given year assuming full build-out watershed conditions in those areas with forty (40) or more acres of drainage area in the Lake Thunderbird watershed. For the purpose of determining the applicable reduction in the base width of the buffer, the table below (**not included in this excerpt,** but see next page**)** may be utilized to determine pollutant removal for a particular structural control, as long as such control is constructed in accordance with the specifications for said control contained in Wichita/Sedgwick County Stormwater Manual…"*

The alternative provided in Section B.(2) is the recognition by the City of Norman, its officials and its citizens, that ***a "One-Size-Fits-All" standard is NOT the most effective way to treat the edges of all streams.***

Response: *The stream buffer is ONE additional requirement for construction storm water permits, but is not the SINGLE management practice that applies to these permits. All additional permit provisions are discussed in Appendix E of the report. Oklahoma's permit for construction storm water discharges allows for alternatives to the buffer zone where site conditions preclude the establishment of a buffer, similar to the Norman ordinance. This is noted on page 7 of Appendix E. No changes were made as a result of this comment.*

B3. A second concern is that an ODEQ Report that suggests a ***single*** management practice that applies to ***all*** sites five acres and larger could result in an EPA pronouncement that ***mandates*** a sediment basin (detention pond) in the Little River watershed for ***all*** sites five acres and larger.

Many years ago, the City of Norman mandated that, in **rural** East and West Norman, a single-family residence could be built **only** on a tract of **ten acres or larger.** In the past two years, there have been examples of how imposition of the requirements of the new Norman ***WATER QUALITY PROTECTION ZONE*** ordinance, on tracts no larger than ten acres, would render such tracts essentially useless. (***SUGGESTION: Limit TMDL report to tracts of 40 acres or more***.)

Response: *The sediment basin is ONE additional requirement for construction storm water permits, but is not the SINGLE management practice that applies to these permits. All additional permit provisions are discussed in Appendix E of the report. Limiting the TMDL requirements to tracts of 40 acres or more is not practical since there are very few construction projects of that magnitude. Pollutant loading from construction sites of 5 – 40 acres would be substantial. It is not likely that the reduction targets could be met under those circumstances. No changes were made as a result of this comment.*

B4. For a third point, we suggest that, rather than have any EPA-approved TMDL Report on Lake Thunderbird mandate particular Management Practices to be utilized in the Little River watershed, regulators could implement Pollutant Removal percentages required for different Structural Controls for specified pollutants, such as the following table from Section 19-411 of Norman City Code:

Table of Design Pollutant Removal Efficiencies for Stormwater Controls (%)

Structural Control	Total Suspended Solids	Total Phosphorus	Total Nitrogen	Metals
Stormwater Pond	80	55	30	50
Dry Extended Detention Pond	60	35	25	25
Enhanced Dry Swales	90	50	50	40
Grass Channel	50	25	20	30
Infiltration Trench	90	60	60	90
Soaking Trench	90	60	60	90
Vegetative Filter Strips	50	20	20	40
Surface Sand Filters	80	50	30	50

In closing, Norman developers are ready, willing and able to support, and help implement, a reasonable and flexible plan for improving the water quality of Lake Thunderbird. We appreciate the opportunity for input.

Response: *EPA recommends, and DEQ agrees, that the permitting approach for storm water discharges should be based on appropriate BMPs rather than numeric effluent limits in terms of concentration, mass or percent reductions as the Developers recommend. Vegetative buffers and sediment basins are among the most effective and reliable sediment and nutrient control BMPs for construction sites. Without these requirements for construction storm water permits, it is not likely that the overall load reduction goals for the Lake Thunderbird watershed will be achieved. The need for any additional controls or numeric limits will be re-evaluated in the future as implementation plans are developed. No changes were made as a result of this comment.*

C. Comments from Sierra Club (7/24/2013)

C1. The report requires more background information on other major pollutant runoff that is not phosphate and nitrate based such as chemicals, cleaning products, or petroleum based pollutants swept into storm water drains and waterways after being deposited on streets, driveways, and parking lots.

Response: *The scope of this report is limited to documented water quality impairments. Water quality constituents that relate to the impairments of Lake Thunderbird are suspended sediment, phosphorus, nitrogen, and carbonaceous biochemical oxygen demand (CBOD). Section 303(d) of the Clean Water Act requires that TMDLs be determined for the pollutants that are related to the impairments identified for Lake Thunderbird. There are no known impairments for Lake Thunderbird related to chemicals, cleaning products or petroleum based pollutants. No changes were made as a result of this comment.*

C2. Section 5, page 7, makes an assumption of 35% removal and not a higher percentage. Why have scenarios for a higher removal percentage not been included including their temporal/time impact on reducing water pollution in Lake Thunderbird?

Response: *Removal percentages higher than 35% were considered and simulated for the modeling study. As discussed in Section 4.5 on page 4-7 and 4-8 of the report, the calibrated lake model was used to evaluate the water quality response to reductions in watershed loading of sediment, nutrients and CBOD. Load reduction scenario simulation runs were performed to determine if water quality targets for turbidity, chlorophyll and dissolved oxygen could be attained with watershed-based load reductions of 25%, 35%, 50%, and 75%. Based on an evaluation of the load reduction scenario results the 35% removal alternative was selected for a detailed "spin-up" analysis of the long-term water quality response of the Lake to changes in watershed loads. The 35% removal scenario was then used to simulate eight years of sequential "spin-up" runs to evaluate the long-term response of water quality conditions in the lake to the 35% removal change in external loads from the watershed. The modeling results indicate that water quality standards should be attained within a reasonable time if pollutant loads are reduced by 35%. Larger removal rates are not required to attain the standards. No changes were made as a result of this comment.*

C3. In Section 5, page 9, the report needs to include other sources of water pollution including: urban storm water runoff, impermeable surfaces, construction areas, erosion control, of stream banks, destruction of in-stream and riparian habitat, and sewer runoffs.

Response: *With the exception of destruction of in-stream and riparian habitat, all the other sources noted in the comment, including an explicit representation of urban stormwater runoff and impermeable surfaces, are incorporated in the pollutant loading rates for sediment and nutrients that are assigned to each land use in the watershed model. Existing land management practices, including pollutant reducing best management practices for different land uses, are implicitly simulated in the watershed model. The calibrated pollutant loading rates used in the watershed model are considered to be reasonable representations of the pollutants generated for each land use category because the watershed model results are shown to be in good agreement with observed water quality data for sediment and nutrients. Destruction of in-stream and riparian habitat is not considered to be a pollution source within the context of a TMDL. No changes were made as a result of this comment.*

C4. Section, page 10 needs to include cattle, agriculture, and failing septic systems as primary non-source pollution sources.

Response: *Agricultural land uses and appropriate nonpoint source pollutant loading rates for sediments and nutrients are considered in the watershed model. Existing land management practices, including pollutant reducing best management practices for agricultural land uses, are implicitly simulated in the watershed model. Although inventories of cattle and failing septic systems in the watershed were not explicitly included in the watershed model, the land use-dependent pollutant loading rates that were simulated did result in a good calibration of the watershed model in comparison to observed sediment and nutrient data. Failing septic systems were not likely to be a significant factor in this watershed due to the low density of septic systems. No changes were made as a result of this comment.*

C5. Section 5, pages 10-11—an additional source of non-point source pollution that needs to be added to the report is non-existent or weak local government regulations. Just one example of this among manu *(sic)* including those documented in numbers 6-9 below is the exemption by the City of Norman of on August 12, 2012 of Milligan Trucking of pollutant discharges into the Little River that flows into Lake Thunderbird, see also: http://normantranscript.com/local/x1301511255/Dirt-flies-at-city-hall/print

Response: *The presence or absence of local regulations is not considered a pollutant source within the context of a TMDL. The purpose of the TMDL is to establish wasteload allocations and load reduction goals for the cities so that the water quality in Lake Thunderbird can be restored. The TMDL report also establishes additional requirements for State issued MS4 permits, construction permits and MSGP permits in Lake Thunderbird watershed. The Plan or strategy for each city to achieve the WLAs is beyond the scope of this TMDL report. Flexibility is allowed for the Cities to decide what measures to take and what local ordinances/regulations will work best for the community. Progress in meeting the pollutant reduction goals must be documented. No changes were made as a result of this comment.*

C6. In Norman, Lake Thunderbird pollution control efforts includes a storm water master plan with a 100 foot buffer or a 25 foot engineered buffer zone around waterways and numerous platted property adjacent to waterways exempt from Norman storm water master plan regulations. The 25 foot buffer allows for significant phosphate and nitrate and runoff (Appendix A)[5]. In addition the Norman storm water master plan has a grandfather clause that allows already platted properties to be exempt from the storm water master plan. There are numerous examples of this (Appendix B)[6]. Neither the engineered 25 foot buffer zone nor the grandfathered platted property meet current requirements and standards for a vigorous removal of nitrate and phosphate pollution. This needs to be noted in the report.

Response: *Please refer to the response to comment C5. No changes were made as a result of this comment.*

C7. Norman also has adopted a purported street sweeping program that is not based on best practices (Appendix C)[7] and http://normantranscript.com/government-beat/x1100993249/Norman-streets-aren-tbeing-swept-at-the-moment/print [sic][8] by not using

[5] This references an appendix to their comments. "Appendix A" refers to Sec. 19-411 (Water Quality Protection Zone" that was outlined in B2's comment.

[6] "Appendix B" is a map from City of Norman (entitled LakeThunderbirdDrainage_FBF.pdf), March 31, 2011 of platted properties in exempt from the Norman stormwater ordinance.

[7] "Appendix C" is a reference to one of the appendices to their comments. In this case, the commenter was referencing: "*Evaluation of Street Sweeping as a Stormwater-Quality-Management Tool in Three Residential Basins in Madison, Wisconsin*" by William R. Selbig and Roger T. Bannerman.

[8] Bad link. DEQ notified the commenter who responded with the correct link which is: http://normantranscript.com/headlines/x1100993249/Norman-streets-aren-t-being-swept-at-the-moment/

air vacuum street sweepers at least once a week on major roads in the spring, summer, and fall and at least once a month on secondary roads. This effort should not be credited as a scientifically certified and viable approach for phosphate and nitrate removal. This needs to be noted in the report.

Response: *All three cities within the watershed will be required to develop an implementation plan designed to achieve the reduction goals and WLAs. Flexibility is allowed in choosing the particular measures to be included in those plans but progress toward achieving the reduction goals must be demonstrated. Also, please refer to the response to comment C5. No changes were made as a result of this comment.*

C8. Norman also has adopted (Appendix D) a phosphate ban ordinance that is weak and is primarily voluntary and education oriented rather than bans phosphates in fertilizers. This effort should not be credited as a scientifically certified and viable approach for phosphate and nitrate removal. This needs to be noted in the report.

Response: *Please refer to the responses to comments C5 and C7. No changes were made as a result of this comment.*

C9. In Moore and OKC the report should note there are no water quality ordinances related to Lake Thunderbird other than anti-soil erosion requirements.

Response: *Both Oklahoma City and Moore are currently required to implement various programs to reduce pollutants from storm water discharges, including necessary ordinances. Also, please refer to responses to comments C5 and C7. No changes were made as a result of this comment.*

D. Comments from the City of Norman (7/31/2013)

D1. The report primarily targets Norman, Oklahoma City, and Moore as the largest contributors of storm water runoff to Lake Thunderbird. Table ES-1 in the Executive Summary provides the loading contributions of Moore, Norman, Oklahoma City, and Other Areas for nitrogen, phosphorus, oxygen demand and sediment (as measured from April 2008 – April 2009). Table 5-4 allocates the waste load allocations among the cities based on loading contribution measured during April 2008 – April 2009. The City is concerned that setting waste load allocations based on the loadings measured in 2008 and 2009 without consideration of expected future development won't encourage an equitable level of effort and investment by the cities over the long term. Will the waste load allocations be re-evaluated throughout the time period in which the TMDL is effective?

Response: *There are no specific plans at this time to re-evaluate the waste load allocations and there are no requirements to do so. If conditions change or other new discharges are proposed, the TMDL may need to be revised in the future. For example, see the responses to comments A2 and A8. No changes were made as a result of this comment.*

D2. The TMDL proposes to set Waste Load Allocations based on the total existing watershed load as estimated by the loads contributed by each MS4 city during collection of the 2008-2009 data. Moore makes up about 8% of the Lake Thunderbird watershed by land area, yet Moore was responsible for 25% of the total nitrogen, 28% of the total phosphorus, 31% of the COBD, and 21% of the suspended solids based on the data collected in 2008-2009. Do the WLA's proposed by the TMDL account for the relative contribution of each pollutant by each city or by its size as it relates to the total watershed?

Response: *The proposed WLAs are based on the percentage of the existing loadings generated from each city, not by the size of the city relative to the watershed. No changes were made as a result of this comment.*

D3. The TMDL study indicates that long-term modeling indicates that compliance with water quality criteria for turbidity, dissolved oxygen, and chlorophyll could be met within a reasonable time frame. Will updates be made periodically by DEQ and in what time frame will the updates be made (every 10 years)?

Response: *Lake Thunderbird will be monitored to see if the water quality of the lake is improving. However, there is no specific plan to update TMDLs at this time. Also please see the response to comment D1. No changes were made as a result of this comment.*

D4. Appendix E (II)(2) of the TMDL requires that each MS4 Stormwater Permittee develop or participate in a Pollutant Monitoring and Tracking Program. The City believes a coordinated water sampling program between Norman, Oklahoma City, and Moore is important to achieving this mandate and asks that such coordination be required in the TMDL.

Response: *DEQ recognizes that there could be advantages and efficiencies with a coordinated regional monitoring program and that approach is allowed as an option. The decision whether to participate in a regional monitoring program is left to the individual communities and therefore is not a requirement of the TMDL. No changes were made as a result of this comment.*

D5. The TMDL Study states that "to ensure compliance with the TMDL requirements under the permit, MS4 permittees must develop strategies designed to achieve progress toward meeting the reduction goals established in the TMDL." The Study goes on to encourage the permittees to use Best Management Practices (BMPs) to meet the reduction goals. The City of Norman has already undertaken several of the suggested BMPs found in Appendix E to the TMDL study. We believed the programs that the City proactively instituted should be considered by ODEQ when it evaluates the City for compliance and efforts as outlined in the TMDL

Response: *Each community will be required to develop a comprehensive TMDL Compliance Plan, as described in Appendix E of the report. Continuing existing programs and considering enhancement and/or expansion of those programs, as well as new programs, could be part of the Plan. The ultimate goal is to achieve the loading reductions and restore the water quality of Lake Thunderbird. Each community is given the flexibility to design a Plan that best suits the community's needs and results in progress toward those goals. No changes were made as a result of this comment.*

D6. The City of Norman has undertaken a study to determine potential water sources to supply Norman's water needs for the next 50 years. Paralleling Norman's study, COMCD (Central Oklahoma Master Conservancy District) has also completed a study to determine the viability of augmenting Lake Thunderbird with highly treated wastewater effluent (reuse) to be a viable option. We realize that augmenting Lake Thunderbird with reuse water was not a part of the current TMDL, but strongly believe reuse to be realistic and valuable option for the future. We would like to TMDL to acknowledge best management plans, future monitoring and future TMDL's may include reuse as a water source for augmenting Lake Thunderbird.

Response: *Please see the responses to comments A2, A8 and A9. No changes were made as a result of this comment.*

E. Comments from Satish Dasharathy (08/01/2013)

E1. Appendix D, Page 64; Figure D-2 OWRB Water Quality Monitoring Stations for Streams in Lake Thunderbird Watershed; Samples were collected by Oklahoma Conservation Commission and analyzed by DEQ lab.

Response: *The caption of Figure D-2 was revised. "OWRB" was changed to "OCC".*

E2. It would be helpful to include stream flow data for the six stations.

Response: *The stream flow data for the five stations was not included in the report due to size considerations since the data comprise about 290 pages. All of the stream flow data will be made available as an appendix to the report under "Appendix H".*

E3. See attached data for Station L17 from Appendix D; It appears that data is incomplete for more than 3 months of the reported 1 year period for this particular station. I am not sure why another sampling station downstream in this segment of the watershed was not additionally selected to provide water quality data confirmation for Station L17. Allocating almost 30 percent of the proposed 35% reduction in the waste load from Moore based on less than 9 months of data from this area may not be sufficient to confirm the existing conditions in this area of the watershed. It would have been much more helpful to have included the stakeholders early on in the study to provide input in selecting the stream sampling stations.

Response: *The missing data at station L17 were added in Appendix D. Figures A-41 through A-46 in Appendix A were also updated. Due to some database issues, some of the collected data were not displayed in the Appendices and figures. However, a full year of data was collected and all data were used in the HSPF model calibration. Also, please see the response to comment A3.*

F. Comments from Charles & Lyntha Wesner (08/01/2013)

F1. There is a need for political boundaries to be clearly shown in order to help the general public understand where pollutants originate. Specifically, on the two shaded maps which show where pollutants originate, it would be very useful to overlay individual city boundaries for Moore, Norman and Oklahoma City.

Response: *City boundaries for Moore, Norman and Oklahoma City were overlaid to the loading maps (Figure 3-10 – 3-14).*

F2. There is a need for a definite schedule to determine progress in cleaning up our drinking water supply. Please state the definite timeline at which each city's preliminary plan is ready for review by DEQ, when review will be completed, when revisions, if needed, should be completed, reviewed, implemented and progress measured. Then a time when measured progress should be checked by DEQ to determine if progress is actually being accomplished. If progress is not being made, a timeline should be established for plan revision, review by DEQ, implementation with measuring, and again review to determine progress or suggest changes by DEQ.

Response: *As detailed in Appendix E, the initial TMDL Compliance Plans are to be submitted to DEQ within 24 months of EPA approval of the TMDL. To address the tracking of progress toward achieving reduction goals, the following new provision was added as Section 4 of Part II in Appendix E, Specific Requirements for MS4 Stormwater Permits:*

4. Evaluating Progress

Compliance with this TMDL and progress toward achieving the wasteload allocations and load reduction goals will be evaluated at each renewal of the MS4 permit for each entity, generally every five years. Consideration will be given to:

- *Water quality data and results from the pollutant monitoring and tracking program*
- *The status of achieving milestones and accomplishing items in the current compliance plan*
- *Any revisions that have been made to or proposed for the compliance plan*
- *Any proposed enhancements to the compliance plan for the next permit term*

If sufficient progress is not demonstrated, an updated compliance plan and implementation schedule will be required to be submitted within six months. Noncompliance may subject the permittee to enforcement action.

G. Comments from Joy Hampton (08/01/2013)

G1. The map showing hot zones for high loads of pollution did NOT include boundaries of where those areas were Moore, OKC or Norman. I think it is vital that people know if some of the worst pollution is coming from some other entities such as Moore and what enforcement efforts will be made.

Response: *Figure 3-10 through Figure 3-14 were updated to included City boundaries for Moore, Norman and Oklahoma City. Regarding enforcement, please the responses to comments A11 and A12.*

G2. Norman's drinking water is at stake so Norman is invested. I am concerned, particularly considering tornado damage and rebuilding, if we have heavy pollution from Moore and South OKC... they can rebuild and we can be supportive, but they also need to be held to the standards for keeping our drinking water safe. Norman residents have a right to know how much of our lake's pollution is coming from other entities including both sediment and nutrients.

Response: *Table ES-1 shows the percentage of TP, TN, BOD and Sediments from Moore, Norman and Oklahoma City to Lake Thunderbird. Table 5-5 shows the wasteload allocation for each City. Moore, Norman and Oklahoma City are all required to develop plans (please see requirements in Appendix E) to meet these wasteload allocations. These requirements apply equally to all three cities. No changes were made as a result of this comment.*

G3. Please send me maps with the city boundaries included on the hot zones lists for those pollutants. I believe sediment and nutrients were mapped separately

Response: *The requested maps were emailed.*