Attachment B

CITY OF NORMAN
STORMWATER MANAGEMENT PROGRAM
FOR PHASE II MS4 COMPLIANCE
2016 TO 2020

Prepared by:
City of Norman
Public Works Department
Stormwater Division

March 17, 2017

Authorization No. OKR040015
Permit Term 2016-2020

_______________________________ ____________
Signature Date
Steve Lewis, City Manager

Executive Summary

In 2001, the EPA promulgated the Phase II stormwater rule which expanded the existing stormwater program to include cities under 100,000 population and constructions sited of between one and five acres. This rule applied to the City of Norman and 44 other municipalities and non-traditional entities in the State of Oklahoma. The rule required permittees to develop a Stormwater Management Program (SMP) to reduce pollutants in stormwater runoff from the municipal separate sewer systems (MS4s).

The Oklahoma Department of Environmental Quality (ODEQ) issued the OKR04 General Permit for Stormwater Discharges from MS4s on February 8, 2005. The City of Norman submitted a Notice of Intent, SMP, and other required permit documents and received authorization under the permit on November 29, 2005. This permit expired February 9, 2010, but was administratively continued pending re-issuance. On October 1, 2015, the ODEQ reissued permit OKR04 with an effective date of November 1, 2015. Existing permittees were required to submit a permit application for the permit by February, 1, 2016.

In compliance with Permit OKR04, the City of Norman has developed this SMP to reduce the discharge of pollutants from the City's MS4 to the maximum extent practicable. The SMP presented here has been reviewed and updated as required by the Permit. All minimum control measures (MCMs) and their associated best management practices (BMPs) were reviewed, with changes made where appropriate and necessary for permit compliance. Those BMPs from the previous permit term which are to be continued with minor modifications will be implemented by February 1, 2016. New BMPs and updates to the SMP will be implemented by November 1, 2016, as required by the Permit. This SMP has also incorporated the requirements of the ODEQ Lake Thunderbird TMDL Study and the Lake Thunderbird Compliance Plan and Monitoring Plans produced by the City of Norman.

The SMP must address these six MCMs, as follows:

- Public Education and Outreach Program
- Public Participation and Involvement
- Illicit Discharge Detection and Elimination
- Construction Site Stormwater Runoff Control
- Post-Construction Management in New Development and Redevelopment
- Pollution Prevention/Good Housekeeping for MS4 Operations

Major Program enhancements for the 2016-2020 permit term include the addition of a street sweeper for increased street sweeping, a camera and crew for better storm sewer inspection and illicit discharge investigations, and addition of an inspector for increased inspection and enforcement on construction sites, including those in the Lake Thunderbird watershed.

Acronyms and Abbreviations

BMP	Best Management Practice(s)
CFR	U.S. Code of Federal Regulations
CWA	Clean Water Act
DMR	Discharge Monitoring Report
ECAB	City of Norman Environmental Control Advisory Board
EPA	Environmental Protection Agency
MCM	Minimum Control Measure(s)
MEP	Maximum Extent Practicable
MS4	Municipal Separate Storm Sewer System
NOI	Notice of Intent
NOV	Notice of Violation
NPDES	National Pollutant Discharge Elimination System
OAC	Oklahoma Administrative Code
O&M	Operation and Maintenance
ODEQ	Oklahoma Department of Environmental Quality
OPDES	Oklahoma Pollutant Discharge Elimination System
SMP	Stormwater Management Program
TMDL	Total Maximum Daily Load
TSS	Total Suspended Solids
USFWS	U.S Fish and Wildlife Service

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1.0 CITY BACKGROUND

1.1 REGULATORY BACKGROUND

In 1972, Congress amended the Federal Water Pollution Control Act (commonly referred to as the Clean Water Act [CWA]) to prohibit the discharge of any pollutant to *Waters of the United States* from a point source unless the discharge is authorized by a National Pollutant Discharge Elimination System (NPDES) permit. The NPDES program is designed to track point sources and requires the implementation of controls necessary to minimize the discharge of pollutants.

In 1987, Congress amended the CWA to require implementation, in two phases, of a comprehensive national program for addressing stormwater discharges. The first phase of the program, commonly referred to as “Phase I”, was promulgated by the Environmental Protection Agency (EPA) on November 16, 1990 (*Federal Register*, Volume 55, Page 47,990 [55 FR 47990]). Phase I requires NPDES permits for stormwater discharge from a large number of priority sources, including municipal separate storm sewer systems (MS4) generally serving populations of 100,000 or more and several categories of industrial activity, including construction sites that disturb five or more acres of land.

EPA promulgated the second phase of the stormwater regulatory program, commonly referred to as “Phase II,” on December 8, 1999 (64 FR 68722). Phase II regulations address stormwater discharges from certain MS4’s serving populations of less than 100,000 people (called “small MS4’s”). EPA has delegated authority to issue MS4 stormwater discharge permits to the State of Oklahoma. Under the authority of Clean Water Act (CWA), the Oklahoma Department of Environmental Quality (DEQ) is the regulatory body responsible for issuing permits to discharge waste pollutants in stormwater runoff from small MS4 systems to waters of the state.

The DEQ issued a general permit for the discharge of stormwater from small MS4’s, General Permit OKR04, on February 8, 2005. Permit requirements are based on the Clean Water Act (33 U.S.C. 1251, et seq.), and OPDES regulations OAC 252:606-1-3(b)(3) adopting and incorporating by reference 40 CFR122.26, as amended.

As a regulated small MS4 operator, the City of Norman obtained permit coverage under OKR04 from the DEQ for the discharge of pollutants in stormwater runoff on November 29, 2005. Coverage expired at midnight on February 7, 2010, but by rule continues under the existing permit until the DEQ grants coverage to the City under the current permit which became effective on November 1, 2015.

In summary, the permit requires the City to comply with a number of administrative and legal requirements and to develop, implement, and enforce a stormwater management program designed to reduce the discharge of pollutants from the MS4 to the maximum extent practicable to protect water quality. The SMP must address six areas, called

“Minimum Control Measures” (MCMs), as follows:

- Public Education and Outreach Program
- Public Participation and Involvement
- Illicit Discharge Detection and Elimination
- Construction Site Stormwater Runoff Control
- Post-Construction Management in New Development and Redevelopment
- Pollution Prevention/Good Housekeeping for MS4 Operations

General Permit OKR04 for small MS4’s, dated November 1, 2015, authorizes discharges of stormwater and certain non-stormwater discharges from small MS4’s (Appendix A). The submittal date of NOI for stormwater discharges from small MS4’s as required by General permit OKR04 is February 1, 2015.

For each MCM, the City must:

- Select appropriate Best Management Practices (BMP), which are various methods of reducing pollutants in stormwater runoff.
- Define measurable goals for each BMP.
- Establish an implementation schedule.
- Assign a responsible person or persons for implementing all activities.

1.2 THE PURPOSE OF THIS DOCUMENT

This document serves as an update to the City’s SMP and will be submitted to the DEQ by the City on or before the application deadline of February 1, 2016. In order to receive authorization to discharge stormwater from its small MS4, the City must submit a description of the SMP. It includes all selected BMPs for each of the six MCMs, measurable goals for each BMP, an implementation schedule, and a listing of the person(s) responsible for implementation of all activities. The purpose of this update to the plan is to renew the City’s permit with DEQ.

This document provides a clear road map for implementing stormwater quality management activities to improve runoff quality and to maintain permit compliance.

1.3 ORGANIZATION OF THIS DOCUMENT

This document is organized into various sections as follows:

Section 1 – Introduction: This section provides background information on the stormwater regulatory program, defines the purpose of this document, and describes document organization.

Section 2 – City Background: This section provides general information about the city, including setting and character, surface water quality concerns, development conditions, construction schedules, form of government, and legal authority.

Section 3 – Public Education and Outreach: This section describes the regulatory requirements, permit requirements, current city programs, selected BMPs, measurable goals, implementation schedule, and responsible parties pertaining to MCM-1.

Section 4 – Public Participation and Involvement: This section describes the regulatory requirements, permit requirements, current city programs, selected BMPs, measurable goals, implementation schedule, and responsible parties pertaining to MCM-2.

Section 5 – Illicit Discharge Detection and Elimination: This section describes the regulatory requirements, permit requirements, current city programs, selected BMPs, measurable goals, implementation schedule, and responsible parties pertaining to MCM-3.

Section 6 – Construction Storm Water Runoff Control: This section describes the regulatory requirements, permit requirements, current city programs, selected BMPs, measurable goals, implementation schedule, and responsible parties pertaining to MCM-4.

Section 7 – Post-Construction Stormwater Management in New Development and Redevelopment: This section describes the regulatory requirements, permit requirements, current city programs, selected BMPs, measurable goals, implementation schedule, and responsible parties pertaining to MCM-5.

Section 8 – Pollution Prevention/Good Housekeeping for Municipal Operations: This section describes the regulatory requirements, permit requirements, current city programs, selected BMPs, measurable goals, implementation schedule, and responsible parties pertaining to MCM-6.

Section 9 – Reviews, Updates, Record Keeping, and Reporting: This section describes the annual reporting requirements of the permit.

2.0 CITY BACKGROUND

2.1 SETTING AND CHARACTER

The City of Norman is the seat of Cleveland County and is located 17 miles south of the state capital, Oklahoma City. The City's economic base is mainly in education, manufacturing, and governmental agencies. The City of Norman encompasses approximately 190 square miles, with about 40 square miles, or 25,000 acres, being in the urbanized area. Existing land use in the urbanized area is approximately 22,000 acres residential, 1,400 acres commercial, 925 acres industrial, and 670 acres parklands. Three-fifths of Norman's total land area is undeveloped rural land in far eastern Norman.

2.2 NRCS SOIL DATA

The major soils in each map unit located in the city limits of Norman are summarized below.

S. No.	*Map Unit No.*	*Name of the Soil Complex*	*Percent Slopes*
1	3	Grainola-Ashport	0-8
2	4	Gracemore- Gaddy	0-1
3	6	Grainola-Ironmound	5-12
4	9	Kingfisher-Ironmound	1-5
5	11	Dougherty-Konawa	3-8
6	13	Derby loamy fine sand	3-15
7	18	Gracemore loamy fine sand	0-1
8	19	Goodnight loamy fine sand	5-20
9	32	Lomill silty clay	0-1
10	33	Norge-Ashport	0-8
11	39	Asher silt loam	0-1
12	40	Asher silty clay loam	0-1
13	41	Asher silty clay loam	0-1
14	49	Kirkland-Urban land-Pawhuska	0-3
15	50	Kirkland silt loam	0-1
16	51	Kirkland-Pawhuska complex	0-1
17	53	Kirkland-Pawhuska complex	0-3
18	57	Teller-Urban land	3-8
19	58	Teller-Urban land	3-8
20	59	Bethany-Urban land	0-3
21	65	Renfrow-Huska	3-5
22	66	Renfrow-Huska	3-5
23	69	Renfrow- Urban land-Huska	1-5
24	70	Slaughterville fine sandy loam	1-3
25	72	Slaughterville fine sandy loam	5-8
26	74	Vanoss-Urban land-Norge	0-3
27	77	Teller fine sandy loam	1-3
28	78	Teller fine sandy loam	3-5
29	81	Norge silt loam	1-3
30	82	Norge silt loam	3-5
31	84	Grant-Huska	1-5
32	86	Norge-Urban land	3-8
33	88	Grant-Urban land-Huska	1-5

2.3 RECEIVING WATERSHEDS

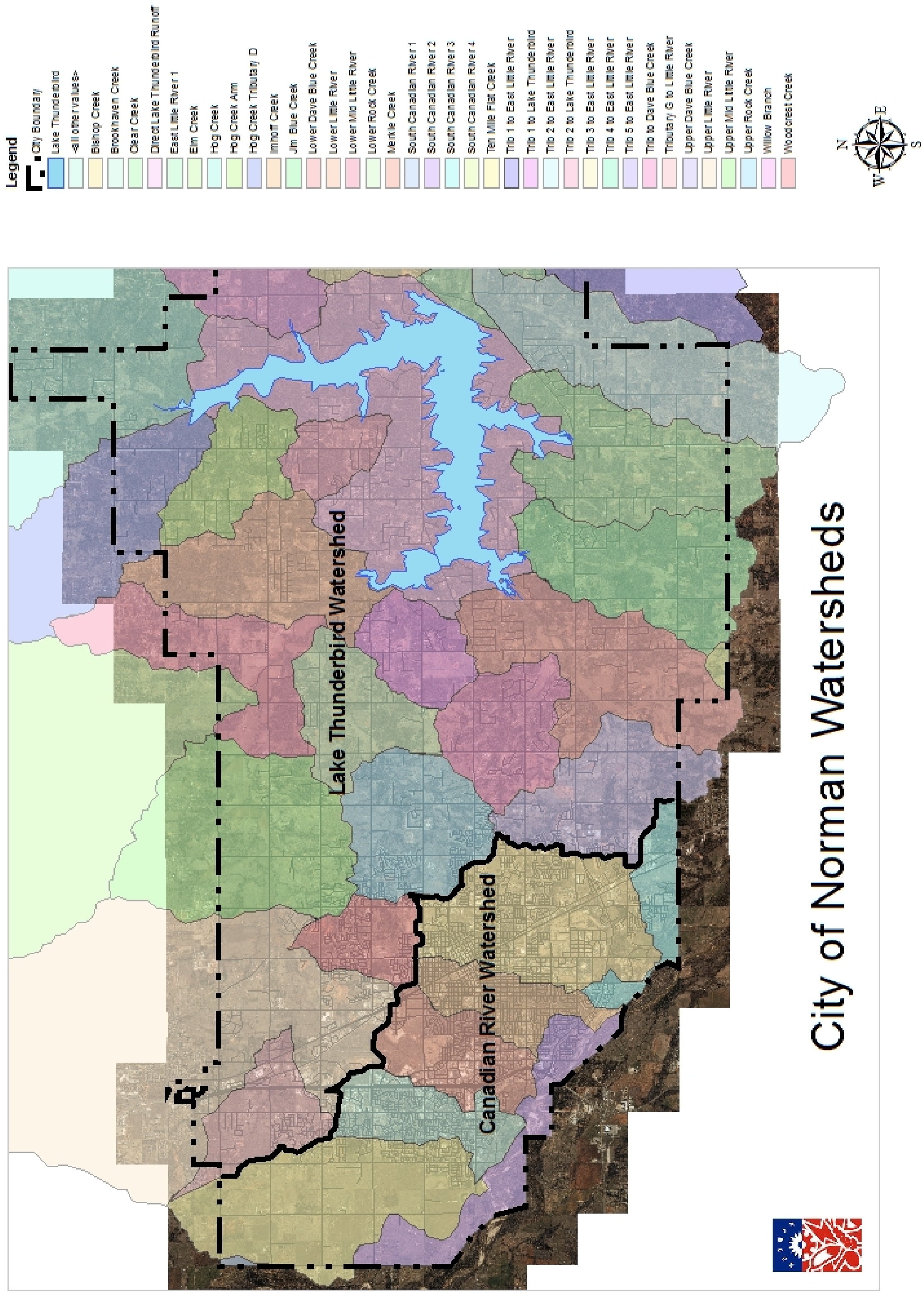
Stormwater runoff from the urbanized area is contained in two major drainage basins; The Canadian River watershed and the Lake Thunderbird watershed. Six creeks and their associated sub-watersheds drain into the Canadian River, which flows along the south edge of the urbanized area. Little River and its tributaries as well as Dave Blue Creek and Rock Creek drain to Lake Thunderbird. The majority of the urbanized area drains to the Canadian River; however, development is increasing in the Lake Thunderbird watershed.

To plan for future development, the City of Norman has developed the Norman 2025 Land Use and Transportation Plan (Appendix F). The plan is intended to guide development in the city-based available public services and environmental suitability. Goals of the plan include greenbelt development and water quality protection.

Basin	Area (acres)	Perimeter (feet)	Drainage
Little River	40,000	393,000	Lake Thunderbird
Rock Creek	7,000	106,000	Lake Thunderbird
Dave Blue	11,000	154,000	Lake Thunderbird
Woodcrest	2,010	41,000	Little River
Ten Mile	7,290	76,000	Canadian River
Brookhaven	2,660	51,000	Canadian River
Merkle	2,470	49,000	Canadian River
Imhoff	2,320	58,000	Canadian River
Bishop	5,700	77,000	Canadian River
Canadian	3,700	130,000	Canadian River

Table 2-2 Receiving Waterbodies

Figure 1: Watershed Map



2.3.1 Impaired Water Bodies

Lake Thunderbird is located in rural east Norman and is the major water supply source. According to the Oklahoma Water Quality Standards, beneficial uses listed are: warm water aquatic community, agriculture, public and private water supply, primary body contact recreation, and aesthetics. It is also listed as a Sensitive Water Supply. DEQ issued a TMDL study for the lake in November 2013 due to non-attainment of water quality standards for turbidity, chlorophyll-a and dissolved oxygen. The City of Norman submitted a TMDL monitoring & compliance plan in November 2015 and incorporated the requirements of these plans in the SMP. The TMDL is further discussed in Section 2.3.4

The **Canadian River** flows along the south border of the Norman city limits and receives the majority of stormwater runoff from the urbanized area. According to the Oklahoma Water Quality Standards, beneficial uses listed are: warm water aquatic community, agriculture, municipal and industrial water supply, primary body contact recreation, and aesthetics. Total Dissolved Solids and Enterococcus bacteria are listed as causes of water quality impairment for the Canadian River according to the 2014 Oklahoma Integrated Water Quality Assessment 303(d) list. The Canadian River is also listed as an Aquatic Resource of Concern due to the presence of a threatened species, the Arkansas River shiner (*Notropis girardi*).

Bishop Creek is located in east Norman and flows south into the Canadian River. Listed beneficial uses include warm water aquatic community and primary body contact recreation. The creek is listed on the 303(d) list as impaired due to Chlorpyrifos.

Merkle Creek is located in the central Norman urbanized area and also flows south to the Canadian River. It was added to the 2014 303(d) list for Microinvertebrate and Fishes Bioassessment impairment.

2.3.2 Water Quality Standards

Water Quality Standards for the beneficial uses listed in Section 2.3.1 above can be found in OAC 785:45-5-10 (Public and Private Water Supplies), 785:45-5-12 (Fish and Wildlife Propagation), OAC 785:45-5-13 (Agriculture: Livestock and Irrigation), OAC 785:45-5-17 (Secondary Body Contact Recreation), and OAC 785:45-5-19 (Aesthetics).

2.3.3 Discharges to Impaired Water Bodies

Potential sources of these pollutants are stormwater runoff from the urbanized area of Norman from application of lawn care chemicals and fertilizers, construction activity, pet waste and other impervious surfaces. The primary means of control of discharges containing pesticides and nutrients to the MS4 will be by a public education/involvement program to inform the public about adverse environmental impacts from overuse and misuse of these chemicals. Information on the proper use, reduction, and safe alternatives for these chemicals will also be distributed to the community. The main effort to control the discharge of organic pollutants to the MS4 will be through the detection and elimination of illicit domestic sewage discharges to the MS4.

2.3.4 TMDL's

Lake Thunderbird: The Oklahoma Department of Environmental Quality (ODEQ) issued a Total Maximum Daily Load (TMDL) study for the lake in November 2013 due to non-attainment of water quality standards for turbidity, chlorophyll-a and dissolved oxygen. Cities affected by the TMDL include Norman, Oklahoma City, and Moore. The City of Norman contracted with Olsson & Associates for assistance in developing the TMDL Compliance and Monitoring Plans. Additionally, the City of Norman initiated and hosted joint meetings with representatives from each of the affected cities to discuss each city's response to the TMDL. The City of Norman submitted TMDL Compliance and Monitoring Plans on November 5, 2015. DEQ approved these plans on September 21, 2016, and was adopted by City Council on October 25, 2016. Requirements of the Lake Thunderbird TMDL will be incorporated into the SMP and appropriate MCMs.

2.3.5 Endangered Species

The Canadian River is habitat for the Arkansas River shiner, which is listed as threatened by the USFWS. The USFWS Final Rule (DOCIDfr23no98-24) states the primary threat facing the Arkansas River shiner is destruction and modification of habitat by stream channelization, reservoir construction, stream flow alteration and depletion, and, to a lesser extent, water quality degradation. The implementation of BMPs to reduce the discharge of pollutants into the MS4 is expected to improve the quality of stormwater flows to the Canadian River and have no impact on in-stream flows.

2.4 FORM OF GOVERNMENT

The municipal government provided by the City's Charter is known as a "Council-City Manager" form of government. Pursuant to its provisions and subject only to the limitations imposed by the state constitution and by its Charter, all powers of the city are vested in the Mayor and the eight City Council members, who enact local legislation, adopt budgets, and determine policies. All powers of the city are exercised in the manner prescribed by the City's Charter, or if not prescribed, then as may be prescribed by City Ordinance.

2.5 LEGAL AUTHORITY

The City is a Home-Rule municipality.

2.6 CONSTRUCTION AND DEVELOPMENT

Ample undeveloped land remains distributed throughout the city. Continued development and growth are anticipated within the city throughout the duration of this SMP. The City typically reviews about 400-500 residential permits per year for home construction.

2.7 EXISTING PROGRAMS

Existing stormwater management programs are primarily implemented by the Department of Public Works Engineering Division, Stormwater Quality Section. These departments perform a variety of duties, including development and community planning, construction permitting and review, capital engineering, and construction and maintenance.

2.8 STORM WATER MASTER PLAN

In the summer of 2007, the City of Norman selected the firm of Post, Buckley, Schuh & Jernigan, Inc. (PBS&J), an engineering, planning and architecture firm, to study and develop a plan for stormwater management and planning. In addition to traditional drainage issues, the plan addressed water quality issues in local watersheds, greenbelt/trails and riparian corridor planning, Phase II/City of Norman MS4 permitting, development regulations, and development of funding mechanisms for a stormwater utility fee. The Storm Water Master Plan Final Report was adopted by City Council Resolution R-1011-120 on June 28th, 2011. Action items in the Plan which have been implemented include the Water Quality Protection Zone Ordinance and the Manufactured Fertilizer Ordinance.

2.9 RATIONALE STATEMENT FOR SMP

During the development of this SMP, the City considered BMPs that would protect water quality, comply with the Phase II stormwater regulations, and ensure program costs that would not create undue hardship on city residents and businesses. Established Phase I stormwater programs, as well as proposed Phase II programs for other MS4 operators, were reviewed and evaluated. A variety of BMPs for each minimum control measure were considered and compared. BMPs were ultimately selected based on an evaluation of overall effectiveness, affordability, and suitability to the City. The program will allow continual adjustment and refinement through City implementation experience and feedback from all sectors of the residential and business community.

3.0 MCM-1 PUBLIC EDUCATION AND OUTREACH

The following section describes permit requirements and selected BMPs. Additional details for each MCM, including measurable goals, implementation dates, associated BMPs and responsible parties are found in Appendix B, Table 1.

Part IV.C.1 of Permit OKR04 requires the City of Norman to revise and update the existing public education and outreach program. The revision of the program shall be completed within the first year after effective date of this Permit. The City must continue to implement a public education and outreach program to distribute information and educational materials to the community or conduct equivalent outreach activities to promote behavior change by the public to reduce pollutants in stormwater runoff and eliminate illicit discharges. The public education or equivalent outreach activities shall be tailored, using a mix of locally appropriate strategies, to target specific audiences and communities. Individual MCM requirements and associated BMPs to meet the requirement are presented below.

3.1 PERMIT REQUIREMENT: Include Education and Outreach Efforts for the General Public

3.1.1 Utility Bill Stormwater Pollution Prevention Informational Inserts

Stormwater pollution prevention informational pamphlets will be distributed in City utility bills annually. This BMP target goal has been increased from 50% of all utility customers to 75% of all utility customers. There are approximately 35,000 City of Norman utility accounts and this will increase distribution from 17,500 to 26,250 pamphlets.

3.1.2 Stormwater Website

Stormwater program information is posted on the City of Norman website, http://www.normanok.gov/content/storm-water-quality, along with a link for the public to submit questions and comments. Additionally, the website, GreenNorman.org, has been created to promote the City environmental programs and environmental awareness. Content of these websites will be reviewed and updated at least annually. This BMP is unchanged from the previous permit cycle.

3.1.3 Action Center Hotline

The Action Center hotline operated by the City Clerk's office allows citizens to easily report pollution concerns to personnel in the city who can take appropriate action to address stormwater pollution issues. The Action Center may be contacted by phone at (405) 366-5396 or by email at, *Action.Center@NormanOK.gov*. A log of all referred stormwater pollution complaints will be maintained by the Engineering Division. This BMP target goal to receive and respond to citizen complaints has been increased from 50% response to 90% response.

3.1.4 Earth Day Public Education Event

An Earth Day booth will continue to be set up every year in the month of April in cooperation with the Environmental Services Division and the Parks & Recreation Department. It will continue to encourage public participation in a learning day about environmental and natural resources issues and will continue to raise environmental awareness in the general public. The event will continue to improve natural resources and promote the maintenance of a productive and healthy environment. This BMP is unchanged from the previous permit cycle.

3.1.5 Stormwater Education for Schools

The City will continue to work with local schools to provide promotional items and educational materials for elementary school children about the impacts of stormwater pollution to two schools annually. The City will also present stormwater educational information annually at selected schools as part of National Public Works Week as an improvement to this BMP.

3.1.6 Newspaper Advertisement

Newspaper advertisements will inform the general public informed about various methods to reduce to reduce stormwater pollution. The target goal for this BMP has been increased from 2 to 4 ads published annually.

3.1.7 Fertilizer Use Brochure

Educational materials on proper fertilizer use, including retail location signage and bi-lingual printed material, were developed in the previous permit cycle to provide information to the public and businesses on proper selection and application of fertilizer, soil testing, and environmental impacts of improper fertilizer use. These materials also contain information on the requirements of the City of Norman Manufactured Fertilizer Ordinance O-1213-34 which was adopted on February 26, 2013, and regulates the use and application of manufactured fertilizers by commercial applicators and the public. This ordinance also requires commercial fertilizer applicators to register with the City. This is a new BMP for the 2016-2020 permit term.

3.1.8 Multi-lingual Educational Materials

This practice seeks to increase the effectiveness of the Public Education MCM by developing educational material for citizens whose primary language is not English. Spanish language lawn care and fertilizer use materials were developed in the previous permit cycle. Additional educational materials will be evaluated annually for translation. This is a new BMP for the 2016-2020 permit term.

3.1.9 TMDL Educational Materials

Educational materials regarding the Lake Thunderbird TMDL and watershed protection will be developed and incorporated into the existing Public Education MCM. These materials will be distributed through existing Public Education BMPs and constitute a new BMP for the 2016-2020 permit term.

3.2 PERMIT REQUIREMENT:
Establish or Revise Measurable Goals

This MCM and associated BMPs has been reviewed, and appropriate revisions or additions have been made. Target milestones, BMP frequency, and persons responsible for implementation are shown in Appendix B.

3.3 PERMIT REQUIREMENT:
Assess Your Education and Outreach Program Annually.

This MCM and associated BMPS will be reviewed annually by the permit authorization date. Any required revisions will be made in accordance with the requirements in Permit OKR04.

4.0 MCM-2 PUBLIC PARTICIPATION AND INVOLVEMENT

The following section describes permit requirements and selected BMPs. Additional details for each MCM, including measurable goals, implementation dates, associated BMPs and responsible parties are found in Appendix B, Table 2.

Part IV.C.2 of Permit OKR04 requires the City of Norman public participation and involvement program be reviewed and updated within the first year after the effective date of this Permit, then reviewed annually and revised, if necessary. The program must encourage public involvement and participation in the development and implementation of the SMP.

4.1 PERMIT REQUIREMENT: Include a Process by Which Public Comments on the Program Are Received

4.1.1 Website Link for Receipt of E-mails

An email link is posted on the Engineering Division and Stormwater Division which allows the public to directly contact staff regarding the SMP and stormwater issues in general. Citizens may report complaints, spills, and other related issues to: http://www.normanok.gov/content/storm-water-quality. This BMP was implemented during the previous permit term and will be continued for the 2016-2020 permit term. This BMP target goal to receive and respond to citizen email inquiries has been increased from 25% response to 90% response

4.1.2 Environmental Control Advisory Board

The City of Norman Environmental Control Advisory Board (ECAB) is made up of citizens appointed by the Mayor. ECAB investigates, prepares plans for, and recommends programs regarding the preservation and enhancement of the environment. A representative of the Public Works Department will coordinate with the ECAB on a quarterly basis to provide two-way information flow regarding stormwater pollution issues. This is a new BMP for the 2016-2020 permit term.

4.1.3 Action Center Hotline

The Action Center hotline operated by the City Clerk's office allows citizens to easily report pollution concerns to personnel in the city who can take appropriate action to address stormwater pollution issues. The Action Center may be contacted by phone at (405) 366-5396 or by email at, *Action.Center@NormanOK.gov* . A log of all referred stormwater pollution complaints will be maintained by the Engineering Division. This BMP target goal to receive and respond to citizen complaints has been increased from 50% response to 90% response.

4.1.4 Stormwater Public Meetings

Public meetings that sought public input were completed during the previous permit term. Additional meetings will be scheduled as needed to address any future stormwater issues. Discussion of the Lake Thunderbird TMDL Study and the City of Norman TMDL Compliance and Monitoring Plans will also be incorporated into these meetings and the Public Involvement MCM in general. At least one meeting will be held annually. The addition of TMDL information constitutes a change for this BMP in the 2016-2020 permit cycle.

4.1.5 Earth Day Public Education Event

An Earth Day booth will continue to be set up every year in the month of April in cooperation with the Environmental Services Division and the Parks & Recreation Department. It will continue to encourage public participation in a learning day about environmental and natural resources issues and will continue to raise environmental awareness in the general public. The event will continue to improve natural resources and promote the maintenance of a productive and healthy environment. This BMP is unchanged from the previous permit cycle.

4.1.6 Blue Thumb Partnership

A working relationship with the Oklahoma Conservation Commission's Blue Thumb organization and Cleveland County Conservation District has been developed. The City will continue to work with these organizations to distribute educational materials and plan public events. This BMP is unchanged from the previous permit cycle.

4.2 PERMIT REQUIREMENT: Comply with State and Local Public Notice Requirements

Formal legal notice will be provided by the City when taking any action requiring it to do so by law. Informing the public and other stakeholders in the implementation of the SMP is essential for effective Public Education and Public Involvement in the process. The content to be published will be prepared by City staff and published by the City Clerk's office.

4.3 PERMIT REQUIREMENT: Establish or Revise Measurable Goals

This MCM and associated BMPs have been reviewed and appropriate revisions and additions have been made. Target milestones, BMP frequency and persons responsible for implementation are shown in Appendix B.

4.4 PERMIT REQUIREMENT: Assess Your Public Participation and Involvement Program Annually

This MCM and associated BMPS will be reviewed annually. Any required revisions will be made in accordance with the requirements in Permit OKR04.

5.0 MCM-3 ILLICIT DISCHARGE DETECTION ELIMINATION

The following section describes permit requirements and selected BMPs. Additional details for each MCM, including measurable goals, associated BMPs, and responsible parties are found in Appendix B, Table 3.

Part IV.C.3 of Permit OKR04 requires the City to revise its existing illicit discharge detection and elimination program, as necessary. The revision of this program shall be completed within the first year after the effective date of this Permit, then as needed. New elements shall be developed, as necessary, and the City will continue to implement and enforce the program to detect and eliminate illicit discharges into its small MS4, including a dry weather field screening program to identify non-stormwater flows.

5.1 PERMIT REQUIREMENT: Enforce Ordinances to Prohibit Illicit Discharges to Your MS4

5.1.1 Ordinance Prohibiting Discharging and Dumping

City of Norman Ordinance O-0506-76, adopting the Engineering Design Criteria (EDC) was adopted by the City Council in the previous permit term. Section 6000 of the EDC prohibits discharging and dumping of pollutants, and illicit discharges into the MS4. Section 6000 also establishes enforcement actions and penalties for violations of that section. The EDC may be found on the web at:
http://www.normanok.gov/city/public-works-engineering

5.1.2 Enforcement Actions

Referrals, spill reports, inspections and sampling may be used to identify violations of City stormwater regulations. Responsible parties identified as violating City stormwater regulations will be notified verbally and in writing. A course of action and time schedule to correct the violation will be developed, and the responsible party will be informed of actions to be taken and possible consequences of non-compliance. In development of a course of action, consideration will be given to the nature and amount of the illicit discharge. If the discharge is determined to cause an unacceptable health or environmental risk, the City may issue an immediate Cease and Desist Order and/or take action to eliminate the discharge. Failure to comply may result in further enforcement action, including fines, suspension of permit issuance, or criminal prosecution.

5.2 REQUIREMENT: Implement Dry Weather Field Screening for Illicit Discharges

5.2.1 Outfall Dry Weather Screening

The outfall screening program will provide visual inspection of outfalls to assess condition and detect illicit discharges, including illegal dumping and connections to the MS4. If an illicit discharge of unknown source is found, samples will be collected to attempt to characterize the pollutant. A combination of sampling, inspections and use of storm sewer maps will then be used to trace the discharge upstream to its source. A storm sewer system map was completed during the previous permit term. This BMP target goal has been increased from 25% of outfall screening points annually to 90% of outfall screening points annually. Current procedures will be reviewed and updated by January 2017 to ensure compliance with Permit OKR04.

5.2.2 Illicit Discharge Investigations

In addition to identifying illicit discharges, the City will perform inspections of the MS4 to detect illicit connections. These inspections will be done by visually inspecting creeks, channels, manholes, and other accessible parts of the MS4. Smoke testing and dye testing may also be used to aid in investigations. The City of Norman also plans to acquire video camera equipment by the third year of the permit cycle to improve inspection capabilities. This is a new BMP for the 2016-2020 permit term.

5.3 REQUIREMENT:
Develop, Maintain and Update a Map of the MS4

5.3.1 MS4 Mapping

A map of the MS4 system was created by the City of Norman GIS Section during the previous term. The map is updated annually.

5.4 REQUIREMENT:
Prohibit Non-Stormwater Discharges to the MS4

5.4.1 Engineering Design Criteria

An ordinance prohibiting discharging, dumping, and illicit discharges into MS4 conveyances and that establishes enforcement procedures s was completed during the previous permit term and is found in The City of Norman Engineering Design Criteria, Section 6000. The Engineering Design Criteria is incorporated by reference into the City Code of Ordinances.

5.5 REQUIREMENT:
Implement a Plan to Detect Non-Stormwater Discharges and Illegal Dumping

5.5.1 Outfall Visual Screening

The outfall screening program will provide visual inspection of outfalls to detect illicit discharges including illegal dumping and connections to the MS4 and record those results. If an illicit discharge of unknown source is found, samples will be collected to attempt to characterize the pollutant. A combination of sampling, inspections and use of storm sewer maps will then be used to trace the discharge upstream to its source. A storm sewer system map was completed during the previous permit term. This BMP target goal has been increased from 25% of outfall screening points annually to 90% of outfall screening points annually.

5.5.2 MS4 Inspection

An MS4 inspection program will be implemented in conjunction with dry weather field screening and impoundment inspections. The MS4 will be surveyed for any evidence of illicit discharges and needed repairs or maintenance. Open channels will be visually inspected while enclosed conveyances will be inspected by remote camera. 10% of the MS4 system will be inspected each year. This is a new BMP for the 2016-2020 permit term.

5.5.3 Action Center Hotline

The existing Action Center Hotline/Website Link discussed in Section 3 allows the public to report pollution concerns including illicit discharges and dumping to the MS4. Any illicit discharges noted by citizens may be reported to the Action Center call line. This information is then sent to the Public Works Department for investigation and follow-up. A log of all referred illicit discharge complaints will be maintained by the Engineering Division. This BMP target goal to receive and respond to citizen calls has been increased from 50% response to 90% response.

5.6 REQUIREMENT: Inform Employees, Businesses and the Public on the Hazards of Illicit Discharges

5.6.1 Hazardous Waste Public Education

Educational materials regarding proper use and disposal of hazardous wastes will be incorporated into MCM3 Public Education and Outreach.

5.6.2 Household Hazardous Waste Collection Event

The annual household hazardous waste collection coordinated by the Utilities Department Environmental Services Division gives residents a legal and cost-free way to dispose of unwanted household chemicals that cannot be disposed of in the regular trash. This helps prevent dumping of unwanted wastes into the MS4. This event also allows for interaction and education of the public on proper use and disposal of household hazardous wastes.

5.7 REQUIREMENT: Maintain a List of Allowable Non-Stormwater Discharges to the MS4

5.7.1 Engineering Design Criteria

A list of allowable non-stormwater discharges is found in The City of Norman Engineering Design Criteria, Section 6000 and Appendix I of the SMP. City of Norman Ordinance O-0506-76, adopting the Engineering Design Criteria (EDC) was adopted by the City Council in the previous permit term.

5.8 REQUIREMENT: Establish or Revise Measurable Goals

This MCM and associated BMPs have been reviewed and appropriate revisions and additions have been made. Target milestones, BMP frequency and persons responsible for implementation are shown in Appendix B.

5.9 REQUIREMENT: Assess Your Illicit Discharge Detection and Elimination Program Annually

This MCM and associated BMPS will be reviewed annually. Any required revisions will be made in accordance with the requirements in Permit OKR04.

6.0 MCM-4 CONSTRUCTION STORMWATER RUNOFF CONTROL

The following section describes permit requirements and selected BMPs. Additional details for each MCM, including measurable goals, associated BMPs and responsible parties are found in Appendix B, Table 4.

Part IV.C.4 of Permit OKR04 requires the City of Norman to review and revise its existing construction site stormwater runoff control program, as necessary. The revision shall be completed within the first year after the effective date of this Permit, then as needed. The City must develop new elements, as necessary, and continue to implement and enforce the program to reduce pollutants in any stormwater runoff to your MS4 from construction activities that result in a land disturbance of greater than or equal to one acre. Reduction of stormwater discharges from construction activity disturbing less than one acre must be included in your program if that construction activity is part of a larger common plan of development or sale that would disturb one acre or more.

6.1 PERMIT REQUIREMENT: Develop, Implement and Enforce an Ordinance for Erosion and Sediment Control

City of Norman Ordinance O-0506-76, adopting the Engineering Design Criteria (EDC) was adopted by the City Council in the previous permit term. Section 5000 of the EDC contains requirements for erosion and sediment control from construction activities, permitting requirements and enforcement options. The EDC may be found on the City of Norman website at: http://www.normanok.gov/city/public-works-engineering

6.2 PERMIT REQUIREMENT: Develop, Implement and Enforce Requirements for Construction Site Operators to Implement BMPs for Erosion and Sediment Control

6.2.1 City of Norman Erosion and Sedimentation Control Requirements

Section 5000 of the EDC contains requirements for BMP installation and maintenance on construction sites including erosion and sedimentation control plans. All construction sites with an earth disturbance area of one acre or larger, or part of a larger common plan of development of one acre or more, are required to obtain a City of Norman Earth Change Permit. The City inspects construction sites issued an Earth Change Permit within 30 days of permit issuance. Problems with construction on residential lots may be referred by City code enforcement, City inspectors and any other City staff for further inspection by the Engineering Division Stormwater Staff.

6.2.2 Earth Change Permit

Earth disturbing activities including developing, grading, land filling and berming are required to obtain a City of Norman Earth Change Permit prior to commencing activity. The Earth Change

Permit allows initial clearing and grading necessary to complete installation of required erosion and sedimentation control BMPs. Ninety percent of sites issued an Earth Change Permit will be inspected within 30 days of permit issuance. This BMP target goal to inspect construction sites within thirty days of permit issuance has increased from 75% of permitted sites to 90% of permitted sites.

6.3 PERMIT REQUIREMENT:

Develop, Implement and Enforce Requirements for Construction Site Operators to Implement Control Measures to Reduce or Eliminate Impacts to Receiving Waters and Control Waste On Site.

6.3.1 City of Norman Construction Stormwater Control Requirements

Section 5000 of the EDC contains requirements for BMP to reduce or eliminate pollutants in stormwater runoff from construction sites. Stormwater management considerations, locations for drainage features and water bodies on and near the construction site must also be submitted before permit issuance.

6.3.2 Site Inspection and Enforcement Procedures

Inspections and referrals for construction sites will be made by Engineering Division Staff with assistance from construction inspectors and code enforcement staff. Inspections will also be conducted in response to citizen complaints. Complaints may be called in to the City via the Action Center line, directly to the Stormwater Pollution Control Staff, or to Code Enforcement. Training for city inspectors will be coordinated through the Municipal Good Housekeeping MCM. The Public Education MCM will provide information on construction site runoff regulations to the public.

Responsible parties identified as violating the provisions of the EDC Section 5000 and/or Section 6000 will be notified verbally. A course of action and time schedule to correct the violation will be developed, and the responsible party will be informed of actions to be taken and possible consequences of non-compliance. In development of a course of action, consideration will be given to the severity of the discharge. If the violation is not resolved within the set time, a Notice of Violation (NOV) will be issued by certified mail listing the violation(s) and setting a time for correction and/or notifying the responsible party to contact the City to discuss correction of the violations. Failure to comply after issuance of an NOV may result in further enforcement action, including fines, water service severance, suspension of permit issuance and city services, or criminal prosecution. If the discharge is determined to cause an unacceptable health or environmental risk, the City may issue an immediate Cease and Desist Order and/or take action to eliminate the discharge. Enforcement procedures, site inspection checklists, inspection control, and the record keeping system were completed in the previous permit term. The Public Works Department policy for enforcement of Sections 5000 and 6000 of the EDC related to construction site erosion control, stormwater runoff and illicit discharges is detailed in the Enforcement

Procedure Guidance Document (Appendix G).

6.4 PERMIT REQUIRMENT:
Develop, Implement and Enforce Procedures for Site Plan Review

6.4.1 City of Norman Earth Change Permit Requirements

Section 5000 of the EDC requires submittal, review and approval of an erosion and sedimentation control plan prior to Earth Change Permit issuance for all construction sites with an earth disturbance area of one acre or larger, or those sites part of a larger common plan of development of one acre or more. The required plan must include a project description, existing site conditions, a description of the area to include structures and natural features, stormwater management considerations and BMP descriptions.

6.5 PERMIT REQUIREMENT:
Implement and Enforce Procedures for Receipt and Consideration of Information Submitted by the Public

6.5.1 Action Center Hotline

The existing Action Center Hotline/Website Link discussed in Section 3 allows the public to report pollution concerns including stormwater runoff or erosion and sedimentation control from construction sites. Any stormwater pollution issues on construction sites noted by citizens may be reported to the Action Center call line. This information is then sent to the Public Works Department for investigation and follow-up. A log of all referred illicit discharge complaints will be maintained by the Engineering Division. This BMP target goal to receive and respond to citizen calls has been increased from 50% response to 90% response.

6.5.2 Construction Educational Event

An educational event will be held annually to present stormwater pollution prevention information related to construction site runoff, the City of Norman Earth Change Permit requirements and construction inspection procedures. This event will also allow for public input. This BMP target goal has increased from one educational event annually to two events annually.

6.6 PERMIT REQUIREMENT:
Develop, Implement and Enforce Procedures for Site Inspection and Enforcement of Control Measures

6.6.1 Construction Site Inspection

All active permitted construction sites will be inspected within thirty days of Earth Change Permit issuance and every thirty days thereafter. Records of the permitting and inspection of each site will be maintained and permit violations will be recorded and referred for corrective action. This

BMP target goal to inspect permitted construction sites at least monthly has increased from 75% of permitted sites to 90% of permitted sites.

6.7 PERMIT REQUIREMENT: Establish or Revise Measurable Goals

This MCM and associated BMPs have been reviewed and appropriate revisions and additions have been made. Target milestones, BMP frequency and persons responsible for implementation are shown in Appendix B.

6.8 PERMIT REQUIREMENT: Evaluate Appropriateness of BMPs for this MCM

This MCM will be reviewed annually and the effectiveness of associated BMPS evaluated. Any required revisions will be made in accordance with the requirements in Permit OKR04.

6.9 ADDITIONAL BMPs

6.9.1 Water Quality Protection Zone Ordinance

An ordinance to establish water quality protection zones was adopted in 2011. The ordinance (0-1011-52) requires natural vegetative buffers or a combination of buffers and other BMPs be maintained to protect water quality during and after construction. This is a new BMP for the 2016-2020 permit terms.

6.9.2 TMDL Workshop

An annual workshop will be held to educate the building and development community on the impact of the Lake Thunderbird TMDL on their operations. The workshop will include appropriate methods and BMPs for protection of the Lake Thunderbird watershed. This is a new BMP for the 2016-2020 permit term.

6.9.3 Enhanced Construction Inspection

The City of Norman plans to increase the frequency of construction site inspections by the addition of one additional inspector by FYE 2017. This will allow the City greater oversight and compliance with construction site stormwater requirements with an emphasis being placed on construction sites in the Lake Thunderbird TMDL Study area.

7.0 MCM-5 POST-CONSTRUCTION STORMWATER MANAGEMENT IN NEW DEVELOPMENT AND REDEVELOPMENT

The following section describes permit requirements and selected BMPs. Additional details for each MCM, including measurable goals, associated BMPs and responsible parties are found in Appendix B, Table 5.

Part IV.C.4 of Permit OKR04 requires the City to revise its existing new development and redevelopment post-construction management program, as necessary. The revision shall be completed within the first year after the effective date of this Permit, then as needed. The City must develop new elements, as necessary, and continue to implement and enforce a program to address stormwater runoff from new development and redevelopment projects that disturb greater than or equal to one acre, including projects less than one (1) acre that are part of a larger common plan of development or sale, that discharge into the small MS4. The program must attempt to maintain pre-development runoff conditions and ensure that controls are in place that would prevent or minimize water quality impacts.

7.1 PERMIT REQUIREMENT: Develop, Implement and Enforce Strategies for Structural and Non-Structural BMPs

7.1.1 City of Norman BMPs and LID

Section 5000 of the Engineering Design Criteria (EDC) contains requirements for operation and maintenance of the MS4 system including drainage, detention and stormwater runoff from pre and post-development activity. The EDC will be reviewed within the first two years of the permit term to identify needed changes or additions. The City of Norman also adopted Ordinance O-1011-52 which establishes a Water Quality Protection Zone (WQPZ) and other post-construction BMPs along streams in the Lake Thunderbird watershed. The ordinance establishes the Wichita/Sedgwick County Stormwater Manual as a guidance document for any structural BMPs implemented.

7.2 PERMIT REQUIREMENT: Develop, Implement and Enforce an Ordinance to Address Post-Construction Runoff

7.2.1 Water Quality Protection Zone Ordinance (WQPZ)

Ordinance O-1011-52 was adopted by the City of Norman Council in 2011. The ordinance stablishes standards and requirements for a designated water quality protection zone within the Lake Thunderbird watershed. The WQPZ shall consist of a vegetated buffer strip of land along both sides of a stream and its adjacent wetlands. The buffer width may be modified if structural BMPs are used to achieve an equivalent pollutant removal rate. Implementation of the WQPZ Ordinance is a new BMP for the 2016-2020 permit term.

7.2.2 Manufactured Fertilizer Ordinance

To help protect local surface waters and our drinking water supply, the City of Norman has adopted Ordinance O-1213-34 regulating the use of manufactured fertilizers in 2013. The ordinance is a proactive effort to preserve and protect water bodies within the City of Norman limits including our municipal water supply, Lake Thunderbird. The ordinance limits the use of phosphorus-containing fertilizer and establishes rules for the application of all fertilizers. It also requires commercial applicators to register with the City and provide their customers with information about proper fertilizer use. Implementation of the Manufactured Fertilizer Ordinance is a new BMP for the 2016-2020 permit term.

7.3 PERMIT REQUIREMENT: Review Ordinances and Regulations to Remove Barriers to LID

7.3.1 City of Norman Review of Rules and Regulations Regarding LID

The Engineering Design Criteria (EDC) and other selected City rules will be reviewed within the first two years of the permit term to identify any barriers to implementing low impact development practices. Any identified barriers will be selected for review, amendment or removal. This is a new BMP for the 2016-2020 permit term.

7.4 PERMIT REQUIREMENT: Develop, Implement and Enforce Procedures for Long-term Operation and Maintenance of BMPs

7.4.1 Permanent Stormwater BMP Inspections

Inspection of stormwater detention/retention ponds will be performed to ensure proper function and maintenance, and to screen for illicit discharges. Future BMPs may include installing stormwater treatment devices and incorporation of infiltration and/or filter structures in commercial development and parking lots. O&M of structural BMPs will be the responsibility of property owners or the City, depending on the size and location of the facility. Either the City or the operator of the permanent BMP will conduct inspections at least annually to verify proper operations and maintenance of the structural stormwater quality controls. This BMP is unchanged from the previous permit cycle.

7.5 PERMIT REQUIREMENT: Participate in an Education Program for Developers and The Public About Project Designs That Protect Water Quality and Include LID Strategies

7.5.1 Post-Construction Workshop

An annual workshop will be held to educate the building and development community, as well as the public on the benefits of LID, City of Norman LID requirements and highlight any LID projects within the City of Norman. This is a new BMP for the 2016-2020 permit term.

7.6 PERMIT REQUIREMENT: Establish or Revise Measurable Goals

This MCM and associated BMPs have been reviewed and appropriate revisions and additions have been made. Target milestones, BMP frequency and persons responsible for implementation are shown in Appendix B.

7.7 PERMIT REQUIREMENT: Evaluate the Appropriateness of Identified BMPs

This MCM will be reviewed annually and the effectiveness of associated BMPS evaluated. Any required revisions will be made in accordance with the requirements in Permit OKR04.

8.0 MCM-6 POLLUTION PREVENTION/GOOD HOUSEKEEPING FOR MUNICIPAL OPERATIONS

The following section describes permit requirements and selected BMPs. Additional details for each MCM, including measurable goals, associated BMPs and responsible parties are found in Appendix B, Table 6.

Part IV.C.5 of Permit OKR04 requires the City to review and revise its existing pollution prevention and good housekeeping program, as necessary. The revision shall be completed within the first year after the effective date of this Permit, then as needed. The City must develop new elements, as necessary, and continue to implement and enforce the operation and maintenance program that includes a training component and has the ultimate goal of preventing or reducing pollutant runoff from MS4 operations

8.1 PERMIT REQUIREMENT: Use Training Materials for Your Employee Training Program

8.1.1 Employee Training Materials

Materials for employee municipal stormwater management were developed or obtained during the previous permit cycle. These materials will be updated as required. Training will include identification, reduction, and elimination of pollutant sources from municipal operations. Training materials will include BMPs for construction site erosion control, identifying safer substitutes for materials currently in use and preventing stormwater pollution in runoff from City facilities and activities

8.2 PERMIT REQUIREMENT: Implement a Municipal Employee Training Program to Prevent and Reduce Stormwater Pollution from City Operations

8.2.1 Employee Training Sessions

Employees whose duties include maintenance, repairs and construction will attend one training session annually. This BMP target goal to provide one training session annually has increased from 50% of targeted employees to 75% of targeted employees.

8.2.2 Employee Newsletter

The City of Norman employee newsletter is distributed monthly to all City Employees electronically and in print. The newsletter will be used as part of the employee training program to provide information to all City employees regarding the City SMP. Information provided will cover stormwater pollution prevention related to City operations and the general public. This is a new BMP for the 2016-2020 permit term.

8.3 PERMIT REQUIREMENT:
Maintain a List of City-Owned Industrial Facilities subject to the ODEQ Multi-Sector General Permit or OPDES or NPDES Permits

A list of all City facilities which have the potential to contribute polluted stormwater runoff will be compiled and maintained. Facilities which are subject to the ODEQ Multi-sector General Permit, or OPDES or NPDES Individual Permits will be identified.

8.4 PERMIT REQUIREMENT:
Implement Procedures for Controlling, Reducing or Eliminating the Discharge of Pollutants from City-Owned Paved Surfaces and Outdoor Storage Areas

8.4.1 City Facility Inspection

Inspection and inventory of City facilities will identify operations that contribute to stormwater pollution and develop operational BMPs to reduce or eliminate sources. Procedures and BMPs will be implemented and revised as needed to meet the intent of the General Permit OKR04. This BMP is unchanged from the previous permit cycle.

8.4.2 City Facility Storm Sewer Mapping

As part of the City Facility Inspection Program the storm sewer systems at City facilities will be mapped and all outfalls identified. This BMP will help control and prevent any discharges or spills of pollutants to the MS4 and surface waters. Mapping will begin in permit year 2 and be completed by the end of the permit term. This is a new BMP for the 2016-2020 permit term.

8.5 PERMIT REQUIREMENT:
Implement Procedures to Ensure Flood Management Projects are Assessed for Water Quality Impacts

The City of Norman Engineering Design Criteria and other pertinent rules will be reviews and revised if necessary to ensure that water quality impacts are considered in all flood management projects.

8.6 PERMIT REQUIREMENT:
Implement Inspection and Maintenance for Structural and Non-Structural BMPs to Control Pollutants and Floatables

8.6.1 MS4 Inspection

The City of Norman MS4 inspection program will provide inspection of storm sewer system to assess condition, identify needed maintenance and detect illicit discharges, including illegal dumping and connections to the MS4. A storm sewer system map was completed during the previous permit term. Open channels will be visually inspected while enclosed conveyances will be inspected by remote camera. 10% of the MS4 system will be inspected each year. This is a new BMP for the 2016-2020 permit term

8.6.2 Detention/Retention Pond Inspection

Inspection of stormwater detention/retention ponds will be performed to ensure proper function and maintenance, and to screen for illicit discharges. Future BMPs may include installing stormwater treatment devices and incorporation of infiltration and/or filter structures in commercial development and parking lots. O&M of structural BMPs will be the responsibility of property owners or the City, depending on the size and location of the facility. Either the City or the operator of the permanent BMP will conduct inspections at least annually to verify proper operations and maintenance of the structural stormwater quality controls. This BMP is unchanged from the previous permit cycle.

8.7 PERMIT REQUIREMENT: List and Define the BMPs Implemented for this MCM

8.7.1 BMPs for City Operations

Selected BMPs for City operations including facility maintenance, parks and landscape maintenance, water and sewer line maintenance, and MS4 maintenance will be implemented. The goal of these BMPs will be to reduce or eliminate sediment, fertilizers and other pollutants caused by City operation in stormwater runoff to the MS4. Additional details for each MCM, including measurable goals, associated BMPs and responsible parties are found in Appendix B.

8.7.2 Street Sweeping

Street sweeping will prevent debris and sediments from blocking storm drains. The existing program consists of two operators and two sweepers. At least one additional sweeper will be added during the permit term. This is a new BMP for this permit term.

8.7.3 Emergency Response Spill Kits

Emergency response spill kits will be furnished at City facilities and provided in vehicles with a spill risk. This measure will help ensure that spills are properly contained and mitigated.

8.7.4 Employee TMDL Education

Educational materials regarding the Lake Thunderbird TMDL will be incorporated into City employee educational materials and training sessions.

8.8 PERMIT REQUIREMENT: Establish or Revise Measurable Goals

This MCM and associated BMPs have been reviewed and appropriate revisions and additions have been made. Target milestones, BMP frequency and persons responsible for implementation are shown in Appendix B.

8.9 PERMIT REQUIREMENT: Evaluate the Appropriateness of Identified BMPs

This MCM will be reviewed annually and the effectiveness of associated BMPS evaluated. Any required revisions will be made in accordance with the requirements in Permit OKR04.

9.0 MONITORING RECORDKEEPING AND REPORTING

The City of Norman will develop new elements as needed and continue to implement its SMP to reduce the discharge of pollutants to the MS4. A Review of this document has been completed with revisions and updates incorporated. This review process will be repeated as needed to ensure compliance with General Permit OKR04 and the CWA.

9.1 PERMIT REQUIREMENTS

9.1.1 Stormwater Management Program Review

The City of Norman will conduct an annual review of the SMP in conjunction with preparation of the annual report required under PART V.C. of the permit.

9.1.2 Stormwater Management Program Update

The City of Norman may change the SMP during the life of the permit in accordance with the following procedures:

a. Changes adding (but not subtracting or replacing) components, controls, or requirements to the SMP may be made at any time upon written notification to the Director.

b. Changes replacing an ineffective or unfeasible BMP specifically identified in the SMP with one or more alternate BMP may be requested at any time. Unless denied by the Director, changes proposed in accordance with the criteria below shall be deemed approved and may be implemented 60 days from submittal of the request. If your request is denied, the Director will send you a written response giving a reason for the decision. Your modification requests must include the following:

(1) An analysis of why the BMP is ineffective or infeasible (including cost prohibitive)

(2) Expectations on the effectiveness of the replacement BMP

(3) An analysis of why the replacement BMP is expected to achieve the goals of the BMP to be replaced.

9.1.3 Retain Records of All Monitoring Information

The City of Norman must include all calibration and maintenance records and all original strip chart recordings for continuous monitoring instrumentation, copies of all reports required by this permit, copies of Discharge Monitoring Reports ("DMR"), a copy of the OPDES permit, and records of all data used to complete the NOI for this permit, for a period of at least three years from the date of the sample, measurement, report or application, or for the term of this permit, whichever is longer. This period may be extended by request of the Director at any time.

9.1.4 Submit Records

The City of Norman must mail the completed DMR reports, if required, to the DEQ along with the annual report. The City must retain a description of the SMP required by this permit (including a copy of the permit language) at a location accessible to the Director. The City must make records, including the NOI and the description of the SMP, available to the public.

9.1.5 Annual Reports

The City of Norman must submit an annual report for each permit year to the Director of the DEQ. Mail the report to the address specified in PART II.C of the permit. The annual report must be received within 90 days of the end of the fiscal year; September 1. Each report must contain information regarding activities of the previous permit year. Each report must include:

a. The status of compliance with permit conditions, an assessment of the appropriateness of the identified best management practices, progress toward achieving the statutory goal of reducing the discharge of pollutants to the Maximum Extent Practicable ("MEP"), and progress toward achieving the measurable goals for each of the minimum control measures.

b. Results of information collected and analyzed, if any, during the reporting period, including monitoring data used to assess the success of the program at reducing the discharge of pollutants to the MEP.

c. A summary of the stormwater activities the MS4 Operator plans to undertake during the next reporting cycle (including an implementation schedule).

d. Proposed changes to the SMP, including changes to any BMPs or any identified measurable goals that apply to the program elements.

e. Description and schedule for implementation of any additional BMPs or monitoring that may be necessary to ensure compliance with any applicable TMDL.

f. Notice that the MS4 Operator is relying on another government entity to satisfy some permit obligations (if applicable) and a copy of the agreement with that entity.

The City of Norman has opted not to utilize the optional permit requirements for municipal construction activities.

10.0 REFERENCES

City of Norman, 2006. *MS4 Phase II Annual Report*. Public Works, Norman, OK.

City of Norman, 2005. *Phase II Stormwater Pollution Management Plan*. Public Works, Norman, OK.

Oklahoma Administrative Code and Register Online, *252:606-1-3. Adoption of U.S. EPA regulations by reference.* Accessed from:http://www.oar.state.ok.us/oar/codedoc02.nsf/frmMain?OpenFrameSet&Frame=Main&Src=_75tnm2shfcdnm8pb4dthj0chedppmcbq8dtmmak31ctijujrgcln50ob7ckj42tbkdt374obdcli00_. February 2008.

Oklahoma Department of Environmental Quality, 2005. *General Permit OKR04 Phase II Small Municipal Separate Storm Sewer System Discharges within the State of Oklahoma*. Oklahoma City, OK, February 8.

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National Resources Conservation Service, 1987. *Soil Survey of Cleveland County*, Oklahoma, Accessed from: http://websoilsurvey.nrcs.usda.gov/app/ in November 2007.

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CITY OF NORMAN
STORMWATER MANAGEMENT PROGRAM
FOR PHASE II MS4 COMPLIANCE
2016 TO 2020

Appendix A

Oklahoma Department of Environmental Quality Water Quality Division

General Permit OKR04

Phase II Small Municipal Separate Storm Sewer System Discharges Within the State of Oklahoma

November 1, 2015

General Permit for Stormwater Discharges Associated with Municipal Separate Storm Sewer Systems in Small Cities, Urbanized Areas, and Other County Areas in the State of Oklahoma

AUTHORIZATION TO DISCHARGE UNDER THE

OKLAHOMA POLLUTANT DISCHARGE ELIMINATION SYSTEM

In compliance with the provisions of the Clean Water Act, as amended, (33 U.S.C. 1251 et. seq.) as required under Section 122.34(d)(2) of the Stormwater Phase II Rule, and with the provisions under the Oklahoma Pollutant Discharge Elimination System, OAC 252:606-1-3(b)(3) incorporated by reference 40 CFR §122.26 and 122.30 through 122.35, operators of Small Municipal Separate Storm Sewer Systems (MS4s) are authorized to discharge in accordance with the conditions and requirements set forth herein. The Phase II regulations issued by the EPA can be found in FR Vol. 64 No. 235, December 8, 1999, beginning on page 68722, and became effective on February 7, 2000.

This Permit is a reissuance by the Department of Environmental Quality (DEQ) and shall become effective on November 1, 2015. This Permit and the authorization to discharge shall expire at midnight on October 31, 2020. As provided in this Permit, operators of Small MS4s, located in areas specified herein and who submit Notices of Intent (NOI) and descriptions of their Stormwater Management Programs (SWMPs) in accordance with PART IV of this Permit are authorized to discharge pollutants to waters of the State in accordance with the conditions and requirements set forth herein.

Signed and issued this 1st day of October, 2015.

Shellie Chard-McClary, Director
Water Quality Division

Michael B. Moe, P.E., Engineering Manager
Wastewater Group,
Water Quality Division

Table of Contents

PART I: COVERAGE UNDER THIS PERMIT

I. A Eligibility

This Permit authorizes discharges of stormwater and certain non-stormwater discharges from small Municipal Separate Storm Sewer Systems (MS4s), as defined in 40 CFR §122.26(b)(16), adopted and incorporated by reference in Oklahoma Administrative Code (OAC) 252:606-1-3(b)(3). This includes MS4s designated under 40 CFR §122.32(a)(1) and 40 CFR §122.32(a)(2) that describe the referenced area with a population of at least 10,000 but not exceeding 100,000, and small MS4s located in urbanized areas (UA). Operators of small MS4s located outside of an UA may be designated as a regulated MS4. Stormwater discharges associated with construction activities are allowed within the boundaries of your local authority in compliance with Part VIII.

You are authorized to discharge under the terms and conditions of this General Permit if you operate a small MS4 within the permit area described below:

1. Are not a “large” or “medium” MS4 pursuant to 40 CFR §122.26(b)(4) and (b)(7) or designated under 40 CFR §122.26(a)(1)(v).
2. Submit a Notice of Intent (NOI) in accordance with Part II of this Permit, submit a description of your Stormwater Management Program (SWMP), and obtain authorization.
3. Are located fully or partially within an urbanized area as determined by the latest Decennial Census by the U.S. Bureau of Census, or are designated for permit coverage by the Department of Environmental Quality (DEQ) pursuant to OAC 252.606 1-3(b)(3) adopted and incorporated by reference 40 CFR §122.32.

I. B Types of Authorized Discharges

1. Stormwater Discharges: This Permit authorizes discharges from small MS4s to waters of the State except as listed in Part I.C.

2. Authorized Non-Stormwater Discharges: You are authorized to discharge the following non-stormwater sources provided you have not determined these sources to be substantial contributors of pollutants to your small MS4. Your list of allowable non-stormwater discharges and determination documentation must be included in your SWMP:

   a. Water line flushing;
   b. Landscape irrigation;
   c. Diverted stream flows;
   d. Rising ground waters;
   e. Residential building wash water without detergents;
   f. Uncontaminated pumped ground water;
   g. Uncontaminated ground water infiltration;

h. Discharges from potable water sources;

i. Foundation drains;

j. Air conditioning condensate;

k. Irrigation water;

l. Springs;

m. Water from crawl space pumps;

n. Footing drains;

o. Lawn watering;

p. Individual residential car washing;

q. De-chlorinated swimming pool discharges;

r. Street wash water;

s. Fire hydrant flushing;

t. Non-commercial or charity car washes;

u. Discharges from riparian areas and wetlands;

v. Discharges in compliance with a separate Oklahoma Pollutant Discharge Elimination System (OPDES) or National Pollutant Discharge Elimination System (NPDES) permit;

w. Unless otherwise permitted or regulated by DEQ discharges of gray water from municipal splash pads (aka, spray parks or spray grounds) as defined in Oklahoma Statutes §27A-2-6-107 provided the discharges comply with all applicable municipal or county ordinances enacted pursuant to law, Discharges from recirculating systems shall be de-chlorinated prior to discharge; and

x. Discharges or flows from emergency firefighting activities provided procedures are in place for the Incident Commander, Fire Chief, or other on-scene firefighting official in charge to make an evaluation regarding potential releases of pollutants from the scene. Measures must be taken to reduce any such pollutant releases to the maximum extent practicable subject to all appropriate actions necessary to ensure public health and safety. These procedures must be documented in your SWMP. Discharges or flows from firefighting training activities are not authorized by this Permit.

I. C Limitations on Coverage

This Permit does not authorize:

1. Discharges Mixed with Non-Stormwater Unless Such Discharges are:

    a. In compliance with a separate OPDES or NPDES permit, or

    b. Determined not to be a substantial contributor of pollutants to waters of the State in accordance with Parts I.B.2 of this Permit.

2. Stormwater Discharges Associated with Industrial Activity as defined in OAC 252.606-1-3(b)(3) adopted and incorporated by reference 40 CFR §122.26(b)(14)(i)-(ix) and (xi).

3. Stormwater Discharges Associated with Construction Activity as defined in OAC 252.606-1-3(b)(3) adopted and incorporated by reference 40 CFR §122.26(b)(14)(x) or 40 CFR §122.26(b)(15), except as provided by Part VIII.

4. Stormwater Discharges Currently Covered under another Permit.

5. Discharges Exceeding Water Quality Standards: Your SWMP must include a description of all necessary Best Management Practices (BMPs) and other measures that you will be using to ensure that discharges, or future discharges, will not cause, have the reasonable potential to cause, or contribute to an exceedance of water quality standards. DEQ may require corrective action or an application for an individual permit or alternative general permit if a small MS4 is determined to cause, have the reasonable potential to cause, or contribute to an exceedance of water quality standards.

6. Discharges not consistent with a Total Maximum Daily Load (TMDL): Discharge of a pollutant into any water for which a TMDL, or watershed plan in lieu of a TMDL, for that pollutant has been either established or approved by DEQ or U.S. Environmental Protection Agency (EPA) is prohibited, unless your discharge is consistent with that TMDL, or watershed plan. You must incorporate into your SWMP any conditions necessary to ensure discharges are consistent with the assumptions and requirements of any such TMDL, or watershed plan. This eligibility condition and compliance with Part III.B applies at the time you submit a Notice of Intent (NOI) (see Exhibit 2) for coverage.

   If conditions change after you have permit coverage, you may remain covered by the permit provided you comply with the applicable requirements of Part III. For discharges not eligible for coverage under this Permit, you must apply for and receive an individual or other applicable general OPDES permit.

7. Discharges Originating on Indian Country Lands: Stormwater discharges from MS4s or construction activities occurring on Indian Country lands (as defined in 18 US Code Section 1151) are not under the authority of DEQ and are not eligible for coverage under this Permit. If discharges of stormwater require authorization under federal NPDES regulations, a permit for these discharges must be obtained from the EPA.

I. D Historic Preservation

The Oklahoma DEQ's OPDES permitting activities are not Federal undertakings and, therefore, are not subject to review under Section 106 of the National Historic Preservation Act. However, applicants and permittees must comply with the Oklahoma State Register of Historic Places Act (53 O.S. § 361), where applicable, and the Burial Disturbance Law [21 Oklahoma Statutes (O.S.) §§ 1168.0-1168.6)], as well as with any applicable local laws concerning the identification and protection of historic properties.

Applicants and permittees who may receive Federal funding or other Federal assistance in the completion of their projects must be aware that compliance with Section 106 of the

Historic Preservation Act may apply. For information about the Section 106 review process in Oklahoma, Oklahoma properties listed on or eligible for the National Register of Historic Places, and related topics, contact**:**

State Historic Preservation Office
Oklahoma Historical Society
Oklahoma History Center
800 Nazih Zuhdi Drive
Oklahoma City, OK 73105
Tel: (405) 521-6249
To identify historic properties, go to the following website at
http://www.okhistory.org/index

Oklahoma Archeological Survey
111 East Chesapeake
Norman, OK 73019
Tel: (405) 325-7211
To identify archeological sites go to the following website at:
http://www.ou.edu/cas/archsur/

I. E Meeting Eligibility Criteria for Endangered Species

1. Eligibility Criteria

   a. Activities authorized by this Permit must avoid unacceptable effects to Federal and State listed endangered or threatened ("listed") species or designated critical habitats. Direct and indirect effects must be considered. Coverage under this Permit is available only if your stormwater discharges, allowable non-stormwater discharges, and discharge related activities are not likely to:

      (1) Jeopardize the continued existence of any listed species or result in the adverse modification or destruction of critical habitat; or

      (2) Cause a prohibited "take" of endangered or threatened species [as defined under Section 3 of the Endangered Species Act (ESA) and 50 CFR § 17.3], unless such takes are authorized under Sections 7 or 10 of the ESA.

   b. "Discharge-related activities" include: activities which cause, contribute to, or result in stormwater point source pollutant discharges; and measures to control stormwater discharges. These include the construction and operation of BMPs to control, reduce, or prevent stormwater pollution.

2. Eligibility Certification

   a. You must certify that you have met eligibility criteria for protection of threatened or endangered species and their critical habitat. Your signed NOI will constitute your certification of eligibility. If the eligibility requirements cannot be met, you may seek coverage under a DEQ individual permit. This eligibility must be evaluated before the NOI is submitted. DEQ strongly recommends that you conduct this evaluation at the earliest possible stage to ensure that measures to protect listed species are incorporated early in the planning process.

b. You must state on the NOI which of the criteria listed in Part I.E.2.d that you are relying upon for meeting the Endangered Species eligibility.

c. Refer to Exhibit 1 for the map and list of *Aquatic Resources of Concern* for this Permit. The shaded regions of the map are considered to be *Aquatic Resources of Concern*.

d. You must meet one or more of the criteria below for the entire term of coverage under this Permit. If you are located partially or wholly in a shaded region of the map or in an area described in Exhibit 1, then you must meet criterion B, C, D, or E for the term of this Permit. If you are not located in the shaded area or watersheds listed in Exhibit 1, then you meet the terms of criterion A. The information used to make the eligibility determination must be documented and included as part of the SWMP.

Criterion A: No endangered or threatened species or critical habitats are in proximity to the small MS4. The point where authorized discharges reach waters of the State is not located within an area shown as an *Aquatic Resource of Concern*.

Criterion B: In the course of a separate federal action involving the small MS4, formal or informal consultation with the U.S. Fish and Wildlife Service (FWS) under Section 7 of the ESA has been concluded and that consultation:

(1) Addressed the effects of the stormwater discharges, allowable non-stormwater discharges, and discharge related activities on listed species and critical habitat; and

(2) The consultation resulted in either a no jeopardy opinion or a written concurrence by the FWS on a finding that the stormwater discharges, allowable non-stormwater discharges, and discharge related activities are not likely to adversely affect listed species or critical habitat. You must submit a copy of the FWS Determination with your NOI.

Criterion C: The activities of the small MS4 are authorized under Section 10 of the ESA and that authorization addresses the effects of the stormwater discharges, allowable non-stormwater discharges, and discharge related activities on listed species and critical habitat. You must submit a copy of the Authorization with your NOI.

Criterion D: The applicant has evaluated, using best judgment and available scientific and commercial data, the effects of the stormwater discharges, allowable non-stormwater discharges, and discharge related activities on listed species and critical habitat. Based on the evaluation, the permittee has determined that there is no reason to believe the discharge and discharge related activities are likely to adversely affect any listed species or result in the adverse modification or destruction of critical habitat. Any measures necessary to maintain eligibility under this criterion must be documented in the SWMP.

Criterion E: The stormwater discharges, allowable non-stormwater discharges, and discharge related activities were already addressed in another operator's certification of eligibility under Part I.E which includes the small MS4 activities. By certifying eligibility under this criterion, the applicant agrees to comply with any measures or controls upon which the other operator's certification was based. Your SWMP must identify the operator upon whom you are relying.

I. F Obtaining Authorization

1. Submit a Notice of Intent: To receive authorization to discharge stormwater from a small MS4, you must submit an official NOI (see Exhibit 2) and a description of your SWMP in accordance with the schedule in Part II. A.

2. Use of an Official Notice of Intent: An official NOI can be obtained from the DEQ web site at: http://www.deq.state.ok.us/wqdnew/stormwater/index.html or you can request a form from the DEQ Water Quality Division at 405-702-8100. The NOI you submit must be complete with all required information according to Part II.B.

3. Authorized Start Date: Dischargers who submit a NOI in accordance with the requirements of this Permit are not authorized to discharge stormwater from MS4s under the terms and conditions of this Permit until an authorization is received from DEQ.

   Upon receipt of your properly completed NOI and application/permit fees, DEQ will process the information and notify you by return mail with an authorization certificate accompanied by a letter of notification.

4. Application and Annual Permit Fees: There is an annual permit fee and an application fee for a renewal or new NOI. For new permittees, the first year's permit fee will be prorated and will cover the period beginning the issuance date of your authorization and ending June 30th of the coinciding fiscal year. The fee schedule is in Section 252:606-3-4(d) of Title 252, Chapter 606 (http://www.deq.state.ok.us/rules/606.pdf).

   An invoice will be sent upon receipt of the NOI. The authorization will not be processed until the fee is paid.

5. Certification of the NOI: Your NOI must be signed and certified in accordance with Part VI.H of this Permit.

6. Change of Operator: Where the operator changes, or where a new operator is added after submittal of a NOI under Part II, a new NOI must be submitted in accordance with Part II prior to the change or addition.

PART II: NOTICE OF INTENT (NOI) REQUIREMENTS

II. A Deadlines for Notification

1. Application Deadline

   a. Renewal Permittees: You must submit a new NOI (see Exhibit 2), a summary status of your current Stormwater Management Program (SWMP) within the previous permit term, and an updated description of your current SWMP or apply for an individual permit within 90 days of the effective date of this Permit. Authorization under the 2005 Permit will be administratively extended for a period not to exceed 90 days from the effective date of this Permit.

   You must include a list of current measurable goals for all six (6) or seven (7) Minimum Control Measures (MCMs) and summary of all Best Management Practice (BMP) activities actually accomplished in the summary status of your current SWMP. Also you must include the changes to any BMPs or any measurable goals that apply to your current SWMP.

   You must update your existing SWMP according to this Permit and provide a description of your updated SWMP to DEQ. This description shall include a list of BMPs with measurable goals for each of the six (6) or seven (7) MCMs proposed for the new permit term under this Permit (see Part IV.C).

   b. Newly Regulated Small MS4s: You must submit a NOI and a description of your SWMP within 180 days of the effective date of this Permit.

   You must develop and implement a SWMP according to this Permit and provide a description of your SWMP. Your description shall include a list of the BMPs associated with measurable goals for each of the six MCMs. You are required to implement the SWMP during the first five (5) year permit term (see Part IV).

   c. Small MS4 Newly Designated after the Date of Permit Issuance: If you are designated to obtain permit coverage by DEQ after the date of permit issuance, then you are required to submit a NOI and a description of your SWMP to DEQ within 180 days of being notified by DEQ that you operate a regulated small MS4 unless the notice specifies a different deadline.

2. Submitting a Late NOI: You are not prohibited from submitting a NOI after the dates provided above. If a late NOI is submitted, your authorization is only for discharges that occur after permit coverage is granted. The Director reserves the right to take appropriate enforcement actions for any unpermitted discharges.

II. B Contents of the Notice of Intent

The Notice of Intent must be signed in accordance with Part VI.H of this Permit and must include the following information:

1. Information about the Permittee

a. The name of your MS4, the mailing address, telephone number, and the name and title of your Stormwater Program Manager.

b**.** An indication of whether you are a federal, state, or other public entity.

2. Information on the Municipal Separate Storm Sewer System (MS4)

   a. The Urbanized Area (UA) or Core Municipality (if you are not located in a UA) where your system is located; county(ies) where your MS4 is located; and the latitude and longitude of your City Hall or the approximate center of your MS4.

   b. A description or map that defines the boundaries or extent of your MS4 jurisdiction. For those MS4 cities not located entirely within an UA, your jurisdiction shall cover the entire area within the corporate boundaries of the municipality.

   c. The name(s) of the major receiving water(s) and an indication of whether any of your receiving waters are on the latest Clean Water Act (CWA or The Act) §303(d) list of impaired waters, or are designated as Outstanding Resource Water (ORWs), or have a TMDL either established or approved by the DEQ or EPA. If you discharge into impaired waters on the 303(d) list, an ORW, or water with a TMDL, you must certify that your SWMP complies with the requirements of Part III.

   d. Supporting documentation addressing the special conditions of this Permit required by Part III.B and C, if applicable.

   e. Indication of your decision to implement the optional permit requirements for municipal construction activities in Part VIII. If you choose to develop this optional measure, provide a description of the optional permit requirements or an outline of your MS4's stormwater pollution prevention plan (SWP3).

   f. Indication of which criterion you are relying upon for your small MS4 to meet the endangered species eligibility requirements listed in Part I.E.2.

3. Relying on another Government Entity: Indicate if you are relying on another government entity already regulated under the stormwater regulations (40 CFR § 122.26 and 122.23) to satisfy one or more of your obligations. Identify that entity and the element(s) of the SWMP they will be implementing on your behalf (see Part IV.A.5).

4. Best Management Practices (BMPs): Provide information on your chosen BMPs and the measurable goals for each of the stormwater MCMs in Part IV.C of this Permit. For each of the six MCMs, include:

   a. A description of BMPs that will be implemented for compliance with each MCM.

   b. An implementation schedule for each BMP including months and years that you will undertake required actions.

   c. Measurable goals for each BMP including, as appropriate, interim milestones and frequency of occurrence.

d. The name of the person or persons responsible for implementing or coordinating your SWMP.

II. C Where to Submit Your NOI

Submit your NOI, signed in accordance with the signatory requirements of Part VI.H of this Permit, along with supporting materials to DEQ at the following address:

Oklahoma Department of Environmental Quality, Water Quality Division, PO Box 1677, Oklahoma City, OK 73101-1677

II. D Co-Permittees

You may partner with other MS4s to develop and implement your SWMP. Each co-permittee must complete the NOI form. The description of your SWMP must clearly describe which permittees are responsible for implementing each of the control measures.

II. E Terminating Coverage

1. A permittee may terminate coverage under this Permit by submitting a notice of termination (NOT) (see Exhibit 3). Authorization to discharge terminates at midnight on the day the NOT is signed.

2. A permittee must submit a NOT to DEQ within 30 days after the permittee:

   a. Ceases discharging stormwater from the MS4.

   b. Ceases operations at the MS4.

   c. Transfers ownership or responsibility for the MS4 to another operator.

3. The NOT will consist of a letter to DEQ and must include the following information:

   a. Name, mailing address, and location of the MS4 for which the notification is submitted.

   b. The name, address, and telephone number of the operator addressed by the NOT.

   c. The OPDES small MS4 permit number for the MS4.

   d. An indication of whether another operator has assumed responsibility for the MS4, the discharger has ceased operations at the MS4, or the stormwater discharges have been eliminated.

   e. The following certification:

      I certify under penalty of law that all stormwater discharges from the identified MS4 that are authorized by an OPDES general permit have been eliminated, or that I am no longer the operator of the MS4, or that I have ceased operations at the MS4. I understand that by submitting this Notice of Termination I am no longer authorized to discharge stormwater under this general permit, and that discharging pollutants in stormwater to waters of the State is unlawful under the Clean Water Act and OAC 252:606-1-3(b)(3) where the discharge is not authorized by an OPDES *permit. I also understand that the submission of this Notice of Termination does not release an operator from liability for any violations of this Permit, the Clean Water Act, and the Oklahoma Pollution Discharge Elimination Act.*

4. The NOT must be signed in accordance with Part VI.H of this Permit and must be submitted to the address listed in Part II.C.

PART III: SPECIAL CONDITIONS

III. A Compliance with Water Quality Standards

Operators seeking coverage under this Permit shall not be causing or have the reasonable potential to cause or contribute to a violation of a water quality standard. If you have discharges to receiving waters included on the latest CWA §303(d) list of impaired waters, you must document in your SWMP how you will comply with the following requirements:

1. If you discharge to waters identified on the latest CWA § 303(d) list of impaired waters, you must include all necessary BMPs that will ensure that the impairment caused by identified pollutants (e.g., nitrogen, phosphorus, bacteria) in your receiving waters will, not cause, have the reasonable potential to cause, or contribute to an in-stream exceedance of water quality standards. You must include the following in development or revision of your SWMP:

    a. You must develop a plan which lists the BMPs you have implemented or will implement to reduce the pollutants of concern and describe how you expect the selected controls to reduce the pollutants of concern.

    b. Your outreach programs must be directed toward targeted groups of commercial, industrial and institutional entities likely to have significant stormwater impacts on your impaired waters.

    c. You must identify any non-stormwater discharges that contribute significant pollutants to your impaired waters.

    d. You must locate those areas likely to have illicit discharges and conduct inspections based on the priority areas in the watershed of your 303(d) listed waterbodies.

    e. You must include any operation and maintenance procedures for structural and non-structural stormwater controls to reduce pollutants discharged into your impaired water. You must ensure that new flood management projects assess the impacts on water quality and examine existing projects to determine if incorporating additional water quality protection devices and practices are necessary.

    f. You must choose BMPs from EPA's menu or select others that can be used for managing the identified pollutants (e.g., nitrogen, phosphorus, bacteria) in your discharges. The details of the BMPs can be viewed from EPA's website at: http://water.epa.gov/polwaste/npdes/swbmp/index.cfm .

    g. If the pollutant of concern is bacteria, you must include a list of identified BMPs addressing the below areas, as applicable, in the SWMP and implement as appropriate. You may not exclude BMPs associated with the minimum control measures required under this Permit (see Part IV.C). The proposed BMPs will be required to be submitted to ODEQ for review.

        The BMPs shall, as appropriate, address the following:

        1) Sanitary Sewer Systems
            (a) Make improvements to sanitary sewers;

(b) Address lift station inadequacies;
(c) Improve reporting of violations; and
(d) Strengthen controls.

2) On-site Sewage Facilities (for entities with appropriate jurisdiction)

(a) Identify and address failing systems; and
(b) Address inadequate maintenance of On-Site Sewage Facilities.

3) Illicit Discharges and Dumping

Place additional effort to reduce waste sources of bacteria; for example, from septic systems, grease traps, and grit traps;

4) Animal Sources

Expand existing management programs to identify and target animal sources such as zoos, pet waste, horse stables, and livestock sale barns.

5) Resident Education

Increase focus to educate residents on:

(a) Bacteria discharging from a residential site either during runoff events or directly;
(b) Fats, oils and grease clogging sanitary sewer lines and resulting overflows;
(c) Decorative ponds; and
(d) Pet waste.

2. Where a discharge is already authorized under this Permit and is later determined to cause, have the reasonable potential to cause, or contribute to the in-stream exceedance of an applicable water quality standard, DEQ will notify you. You must take all necessary actions to ensure that future discharges do not cause, have the reasonable potential to cause, or contribute to in-stream exceedance of a water quality standard and must document these actions in the SWMP. If an exceedance remains or recurs, the coverage under this Permit may be terminated by DEQ, and DEQ may require an application for coverage under an alternative general permit or an individual permit.

3. Compliance with this requirement does not preclude any enforcement activity as provided by the Clean Water Act for the underlying violation.

III. B Established Total Maximum Daily Load Allocations

1. If a TMDL or watershed plan in lieu of a TMDL is established for any waterbody into which a MS4 discharges prior to the date that the MS4 submits a NOI, and if that TMDL includes a wasteload allocation (WLA) or load allocation (LA) for a parameter likely to be discharged by the MS4, the MS4's discharges must meet any limitations, conditions, or other requirements of the implementation plan associated with that WLA, LA and/or TMDL within any timeframes established in the TMDL or watershed plan. Monitoring and reporting of the discharges may also be required as appropriate to ensure compliance with the TMDL, or watershed plan. The MS4 must adopt any

WLAs assigned to its discharges specified in the TMDL, or similar targets in the watershed plan, as measurable goals in the SWMP. If the TMDL or watershed plan relies on a BMP-based approach, effective implementation of additional TMDL or watershed plan-related BMPs will be sufficient to implement applicable WLAs. This BMP-based approach is consistent with EPA memoranda dated November 22, 2012[1] (EPA 2002) and November 26, 2014[2] (EPA 2014). If the TMDL or watershed plan specifies additional requirements, the MS4 must also meet these additional requirements.

2. If a TMDL or watershed plan in lieu of a TMDL is approved for any waterbody into which a MS4 discharges after the date that the MS4 submits a NOI, the MS4 must incorporate any limitations, conditions, and requirements applicable to the discharges into its SWMP to ensure that the requirements of the implementation plan associated with the WLA, LA, and/or the TMDL will be met within any timeframes established in the TMDL or watershed plan. Monitoring and reporting of the discharges may also be required as appropriate to ensure compliance with the TMDL or watershed plan. The MS4 must adopt any WLAs assigned to its discharges specified in the TMDL, or similar targets in the watershed plan, as measurable goals in the SWMP. If the TMDL or watershed plan relies on a BMP-based approach, effective implementation of additional TMDL or watershed plan-related BMPs will be sufficient to implement applicable WLAs. This BMP-based approach is consistent with EPA memoranda dated November 22, 2002[1] and November 26, 2014[2]. If the TMDL or watershed plan specifies additional requirements, the MS4 must also meet these additional requirements.

III. C Discharges to Outstanding Resource Waters

Except for discharges of stormwater from temporary construction activities, new discharges located within the watershed of any waterbody designated Outstanding Resource Water (ORW) in Oklahoma's Water Quality Standards are not allowed and are not authorized by this Permit. Discharges to ORW waters from MS4s existing as of June 25, 1992 are allowed but such stormwater discharges are prohibited from increased load of any pollutant. If any part of your MS4 discharges to an ORW waterbody, you must document in your SWMP how you will comply with this prohibition.

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1 Robert H. Wayland, III, Director, Office of Wetlands, Oceans and Watersheds and James A. Hanlon, Director, Office of Wastewater Management, 'Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs,' November 22, 2002.

2 Andrew D. Sawyers, Director, Office of Wastewater Management and Benita Best-Wong, Director, Office of Wetlands, Oceans and Watersheds, 'Revisions to the November 22, 2002 Memorandum "Establishing Total Maximum Daily Load (TMDL) Wasteload Allocations (WLAs) for Storm Water Sources and NPDES Permit Requirements Based on Those WLAs,"' November 26, 2014.

III. D Site Specific Requirements (Reserved)

PART IV: STORMWATER MANAGEMENT PROGRAM (SWMP)

IV. A Requirements

You must develop new elements, as needed, and continue to implement, and enforce a written SWMP designed to reduce the discharge of pollutants from your MS4 to the maximum extent practicable (MEP), to protect water quality, and to satisfy the appropriate water quality requirements of the CWA. The SWMP should include BMPs, control techniques and system, design and engineering methods, an enforcement component and such other provisions as the Director determines appropriate for the control of such pollutants.

1. Renewal Permittees: You must review the SWMP you developed under the 2005 Small MS4 General Permit, revise and update existing, and/or develop new BMPs and measurable goals in your SWMP, as needed, to meet the requirements of this Permit, or as required by the Director to ensure compliance with the CWA. Modifications and updates shall be reflected in your SWMP and implemented within one (1) year of the effective date of this Permit, then as needed. You are required to keep the SWMP document up to date during the term of the Permit. Compliance deadlines are not extended for small MS4s required to have obtained coverage under the 2005 Small MS4 General Permit.

2. Newly Regulated Small MS4s: You must develop a written SWMP according to this part and include all six (6) Minimum Control Measure (MCM) requirements. You must define and list the BMPs that you or another entity will implement for each of the minimum control measures listed in Part IV.C. You must provide program development, implementation and enforcement schedules for full implementation of the complete SWMP as soon as practicable, but no later than five (5) years from the effective date of this Permit. Credible interim progress in developing and implementing SWMP elements must be made over the term of the Permit.

3. Small MS4s Newly Designated after the Date of Permit Issuance: You must develop a written SWMP according to this part, and you must comply with the following:

   a. Include all six (6) minimum control measure requirements (MCMs);

   b. Define and list the BMPs that you or another entity will implement for each of the MCMs listed in Part IV.C;

   c. Provide program development, implementation and enforcement schedules for full implementation of the complete SWMP as soon as practicable, but no later than five (5) years from the effective date of this Permit or according to the schedule that the Director specifies in the DEQ notification; and

   d. Make credible interim progress in developing and implementing SWMP elements over the term of this Permit.

4. Measurable Goals for BMPs: You must list and define the BMPs that you or another entity are or will be implementing for each of the stormwater MCMs listed in Part IV.C. For each BMP, you must:

   a. Include measurable goals;

b. Include the months and years in which you will undertake required actions, including interim milestones and the frequencies of the actions; and

c. Identify who will be responsible for implementing or coordinating the BMPs for your SWMP.

You may use EPA's "*Measurable Goals Guidance for Phase II Small MS4s*" to develop new measurable goals or revise current ones. The guidance can be downloaded from EPA's website at http://www.epa.gov/npdes/pubs/measurablegoals.pdf. You must provide a rationale for how and why you selected each of the BMPs and measurable goals for your SWMP. The information required for such a rationale is given in Part IV.C for each minimum measure.

5. Sharing Responsibility: Implementation of one or more of your stormwater MCMs may be shared with another government entity or may be fully implemented by another government entity. You may rely on another government entity only if:

   a. The other government entity implements the control measure;

   b. The particular control measure, or component of that measure, is as least as stringent as the corresponding permit requirement; and

   c. The other government entity agrees to implement the control measure on your behalf. Written acceptance of this obligation is required. This obligation must be maintained as part of the description of your SWMP. If the other government entity agrees to report on the minimum measure, you must supply the other government entity with the reporting requirements contained in Part V.C. If the other government entity fails to implement the control measure on your behalf, then you remain responsible for compliance with permit obligations. You must modify your SWMP within one (1) year and comply with permit requirements.

IV. B Required SWMP Updates

DEQ may notify you that changes to your SWMP are necessary to:

1. Address adverse impacts on receiving water quality that discharges from your MS4 are or may have the reasonable potential to cause or contribute to;

2. Include more stringent requirements necessary to comply with new Federal statutory or regulatory requirements;

3. Include other conditions deemed necessary by the Director to comply with the goals and requirements of the Clean Water Act, including TMDL requirements;

   Or

4. Include any permit requirements that the Director determines that your SWMP does not meet.

Changes requested by the Director must be made in writing, set forth the time schedule for you to develop the changes, and offer you the opportunity to propose alternative SWMP changes to meet the objective of the requested modification. Within the time schedule provided, you must submit a copy of the revisions made to the SWMP.

IV. C Minimum Control Measures (MCMs)

The six (6) Minimum Control Measures (MCMs) that must be included in your SWMP are listed below. A seventh optional Control Measure is described in Part VIII. Each MCM must comply with the items included in the “Permit Requirements” section. You are encouraged to consider the information included in “Recommendations” and incorporate them as appropriate, but "Recommendations" are not permit requirements. You must continue to implement your SWMP and revise it according to Part IV.D. If you are a newly regulated small MS4 or MS4 newly designated after the date of this Permit issuance, you are required to develop and implement and enforce a SWMP that specifically addresses each of the six (6) MCMs, as soon as practicable, but no later than five (5) years from the effective date of this Permit, or utilize the schedule that DEQ provides to you.

1. Public Education and Outreach Program

a. Permit Requirements

You must revise and update your existing public education and outreach program. The revision of the program shall be completed within the first year after effective date of this Permit. You must continue to implement a public education and outreach program to distribute information and educational materials to the community or conduct equivalent outreach activities to promote behavior change by the public to reduce pollutants in stormwater runoff and eliminate illicit discharges. The public education or equivalent outreach activities shall be tailored, using a mix of locally appropriate strategies, to target specific audiences and communities. You must:

(1) Include education and outreach efforts for the following audiences:

(a) Traditional municipalities such as cities, counties, etc. must address the general public being served by the MS4;

(b) Non-traditional municipalities such as universities, hospital complexes, prisons, special districts, etc. and federal facilities must address the community served by the MS4. For example, at a university it would be the faculty, other staff, students, and visitors, while at a military base, it would include military personnel (and dependents) contractors, employees, tenants, visitors, etc.; and

(c) Departments of transportation must address the community working on or served by the transportation network within the MS4 including employees, contractors, and the general public.

(2) Establish or revise (as necessary) measurable goals for each BMP, including target milestones (month and year), frequency of action(s) and identify responsible persons.

(3) Assess your education and outreach program annually as required by Part V.C of this Permit.

b. Recommendations

(1) Use stormwater educational materials locally developed or provided by the EPA, States, MS4s and other organizations;

(2) Contact the Blue Thumb Program for assistance with your public education and outreach program, including storm drain marking, assistance with newsletters and brochures, planning of civic events, and borrowing Blue Thumb educational tools for local events. Their contact info is:

Oklahoma Conservation Commission, Statewide Blue Thumb Program,
128 East 3rd Ave.
Bristow, OK 74010

Telephone: (918) 398-1804 or E-mail: Cheryl.Cheadle@conservation.ok.gov

The details of the Blue Thumb Program can be found at: http://www.ok.gov/conservation/Agency_Divisions/Water_Quality_Division/Blue_Thumb/index.html

(3) Distribute stormwater messages to the public by using locally available methods, such as brochures/factsheets, pamphlets, booklets, educational displays, bill inserts, promotional giveaways, workshops, and local cable access channels in TV;

(4) Provide information to homeowners on stormwater pollution prevention, topics such as trash and recycling, landscaping and lawn care, pest control, pet waste management, disposal of household hazardous wastes, residential car washing and water conservation;

(5) Provide information to businesses on stormwater pollution prevention topics such as automobile maintenance, chemical storage and disposal, illicit discharges and erosion/sediment controls, as well as promoting *Low Impact Development* (LID); and

(6) Evaluate the effectiveness of the education program by using methods tied to the identified measureable goals of the program and the overall objective of changes in behavior and knowledge. One method of evaluation of the education program may be an evaluation of audience knowledge prior to commencement of the educational message followed by an evaluation after delivery of the message, such as a survey.

2. Public Participation and Involvement

The public can provide valuable input and assistance to a regulated small MS4's SWMP, so the public should be given opportunities to play an active role in both the development and implementation of the SWMP. An active and involved community is crucial to the success of a SWMP.

a. Permit requirements: Your public participation and involvement program must be reviewed and updated within the first year after the effective date of this Permit, then reviewed annually and revised, if necessary. This program must encourage public involvement and participation in the development and implementation of your SWMP. This must:

(1) Include a process by which public comments on the SWMP are received and reviewed by the person(s) responsible for the SWMP;

(2) Comply with State and local public notice requirements when implementing your public participation and involvement program.

(3) Establish or revise (as necessary) measurable goals for each BMP, including target milestones (month and year), frequency of action(s) and identify responsible persons; and

(4) Assess your public participation and involvement program annually as required by Part V.C of this Permit.

b. Recommendations: In the first minimum control measure, *Public Education and Outreach*, the goal of that element of your SWMP was to inform your community about reducing pollutants in stormwater runoff. The public, in that measure, is passively receiving information. But in the *Public Participation and Involvement* element of your SWMP, the goal is to get members of your community participating in activities that reduce pollutants in stormwater runoff. Community members are actively involved in working toward this goal. There are a variety of practices that could be incorporated into a public participation and involvement program. For example, you can:

(1) Establish a citizen advisory group or utilize existing citizen organizations to participate in the development, implementation and revision of your SWMP. Make an effort to reach out and engage all economic and ethnic groups by involving them with public activities in your SWMP;

(2) Conduct public meetings/citizen panels to allow citizens to discuss various viewpoints and provide input concerning appropriate stormwater management policies and BMPs;

(3) Create opportunities for the public to participate in the implementation of stormwater controls. Examples of ways to include the public include:

(a) Encourage individuals or groups to conduct storm drain marking and/or participate in community programs such as “Adopt-A-Storm Drain”. In this program, citizens keep storm drains free of debris and monitor what is entering local waterways through storm drains. These are important and simple activities that concerned citizens, especially students, can do;

(b) Organize community clean-ups along local waterbodies;

(c) Train citizen watch groups to aid local enforcement authorities in the identification of polluters; and

(d) Develop a volunteer monitoring program. Volunteer water quality monitoring gives citizens first-hand knowledge of the quality of local waterbodies and provides a cost-effective means of collecting water quality data. Contact Blue Thumb for assistance with your volunteer monitoring program.

(4) Evaluate the effectiveness of the public participation and involvement program by using methods tied to the identified measureable goals of the program and the overall objective of changes in behavior and knowledge.

3. Illicit Discharge Detection and Elimination

a. Permit Requirements

You must review and revise your existing illicit discharge detection and elimination program, as necessary. The revision of this program shall be completed within the first year after the effective date of this Permit, then as needed. You must develop new elements, as necessary, and continue to implement and enforce the program to detect and eliminate illicit discharges into your small MS4, including a dry weather field screening program to identify non-stormwater flows. You must:

(1) Enforce ordinances or other regulatory mechanisms that you utilize to effectively prohibit illicit discharges into your small MS4. If your ordinance or regulatory mechanism is already developed, include a copy of the relevant sections with your illicit discharge detection and elimination program.

(2) Continue to implement a dry weather field screening plan to detect, investigate, and eliminate illicit discharges. Rely on visual indicators and simple field test kits for most work where you are looking for indications of a problem. Laboratory methods can be reserved for situations where you have identified a problem and need to enforce on a suspected illicit discharger. Your field screening program must address the following, at a minimum:

(a) Procedures for locating priority areas within your MS4 likely to have illicit discharges (e.g., areas with older sanitary sewer lines), or ambient sampling to locate impacted reaches;

(b) Procedures to address on-site sewage disposal systems that may flow into your storm drainage system;

(c) Procedures for tracing the source of an illicit discharge, including the specific techniques you will use to detect the location of the source;

(d) Procedures for removing the source of the illicit discharge; and

(e) Procedures for illicit discharge detection and elimination program evaluation and assessment.

(3) Develop (if necessary), maintain and regularly update a storm sewer system map, showing the location of all outfalls and the names and location of all waters of the State that receive discharges from those outfalls.

(4) To the extent allowable under State or local law, effectively prohibit, through ordinance or other regulatory mechanism, non-stormwater discharges into

your storm sewer system and implement appropriate enforcement procedures and actions. If you lack legal authority for direct enforcement action, you must include procedures to notify DEQ when a party fails to comply with the requirements. You may rely on DEQ for assistance in enforcement of this provision of the permit in these cases.

(5) Develop (if necessary) and implement a plan to detect and address non-stormwater discharges, including illegal dumping to your system.

(6) Inform public employees, businesses, and the general public of hazards associated with illegal discharges and improper disposal of waste. Promote, publicize and facilitate the reporting of illicit discharges.

(7) Maintain a list of occasional incidental non-stormwater discharges or flows as allowed in Part I - B2 that will not be addressed as illicit discharges. These non-stormwater discharges must not be reasonably expected (based on information available to you) to be significant sources of pollutants to the small MS4, because of either the nature of the discharges or conditions you have established for allowing these discharges to your small MS4 (e.g., a charity car wash with appropriate controls on frequency, proximity to sensitive waterbodies, BMPs on the wash water, etc.). You must document in your SWMP any local controls or conditions placed on the discharges. You must include a provision prohibiting any individual non-stormwater discharge that is determined to be contributing significant amounts of pollutants to your MS4.

(8) Establish or revise (as necessary) measurable goals for each BMP, including target milestones (month and year), frequency of action(s) and identify responsible persons.

(9) Evaluate the appropriateness of your identified BMPs for this minimum control measure. Your evaluation shall verify compliance with permit requirements and more importantly, document that efforts have been made towards achieving your identified measurable goals and reducing the impacts of stormwater runoff from the small MS4. Document the evaluation of your illicit discharge detection and elimination program annually as required by Part V.C of this Permit.

b. <u>Recommendations</u>

(1) Develop and implement a written spill response and prevention plan to ensure the appropriate actions that will take place when a spill occurs within your small MS4.

(2) Expand your plan to detect and address illicit discharges to your system, including illegal dumping control, sanitary sewer overflows, on-site sewage disposal, a used oil recycling program, trash and debris management. You may use EPA's illicit discharge detection and elimination manual to develop or revise your plan. You can download the document from EPA's website at http://cfpub.epa.gov/npdes/stormwater/idde.cfm.

(3) Identify priority areas which includes areas with higher likelihood of illicit connections (e.g., areas with older sanitary sewer lines or with a history of

sewer overflows or cross-connections; areas with older infrastructure that are more likely to have illicit connections; areas of industrial, commercial, or mixed use; areas with a history of past illicit discharges; areas with a history of illegal dumping; areas with onsite sewage disposal systems, and areas of *Aquatic Resources of Concern*). Update this priority area list to reflect changing priorities annually.

(4) Educate and train the general public, employees, and businesses about the hazards associated with illegal discharges and improper disposal of waste. Set up a hotline for citizens to report violations. Coordinate the program with your public education MCM and your pollution prevention/good housekeeping MCM programs.

(5) Educate employees that have been working in the field, such as maintenance workers, building inspectors etc., to identify and report stormwater illicit discharges.

4. <u>Construction Site Stormwater Runoff Control</u>

a. <u>Permit Requirements</u>

You must review and revise your existing construction site stormwater runoff control program, as necessary. The revision shall be completed within the first year after the effective date of this Permit, then as needed. You must develop new elements, as necessary, and continue to implement and enforce the program to reduce pollutants in any stormwater runoff to your MS4 from construction activities that result in a land disturbance of greater than or equal to one acre. Reduction of stormwater discharges from construction activity disturbing less than one acre must be included in your program if that construction activity is part of a larger common plan of development or sale that would disturb one acre or more. You must:

(1) Develop (if necessary), implement and enforce an ordinance or other regulatory mechanism to require erosion and sediment controls, as well as sanctions to ensure compliance, to the extent allowable under State or local law. Review and revise your existing ordinance to meet the permit requirements. If you lack legal authority for direct enforcement action, you must include procedures to notify DEQ if a construction site operator fails to comply with your construction site stormwater runoff control program. You may rely on DEQ for assistance in enforcement of this provision of the permit in these cases;

(2) Develop (if necessary), implement and enforce requirements for construction site operators to implement appropriate BMPs for erosion and sediment control;

(3) Develop (if necessary), implement and enforce requirements for construction site operators to select and implement appropriate erosion and sediment control measures to reduce or eliminate the impacts to receiving waters, and control waste at the construction site that may cause adverse impacts to water quality such as discarded building materials, concrete truck washout, chemicals, litter, and sanitary waste;

(4) Develop (if necessary), implement and enforce procedures for site plan review which incorporate consideration of potential water quality impacts including erosion and sediment controls, controls of other wastes, and any other impacts that must be examined according to the requirements of the local ordinance or other regulatory mechanism;

(5) Develop (if necessary), implement and enforce procedures for receipt and consideration of information submitted by the public;

(6) Develop (if necessary), implement and enforce procedures for site inspection and enforcement of control measures including enforcement escalation procedures for recalcitrant or repeat offenders. Document inspection findings and take all necessary follow-up actions (i.e., re-inspection, enforcement) to ensure site compliance;

(7) Establish or revise (as necessary) measurable goals for each BMP, including target milestones (month and year), frequency of action(s) and identify responsible persons; and

(8) Evaluate the appropriateness of your identified BMPs for this MCM. Your evaluation shall verify compliance with permit requirements and more importantly, documents that efforts have been made towards achieving your identified measurable goals and reducing the impacts of stormwater runoff from the small MS4 (as required by Part V.C of this Permit).

b. <u>Recommendations</u>

(1) Use sanctions and enforcement mechanisms, including non-monetary penalties (such as stop work orders), fines, bonding requirements, legal action, and/or permit denials for non-compliance.

(2) Implement an outreach program for the local development community. Coordinate with your public education MCM and your pollution prevention and good housekeeping MCM programs.

(3) Conduct a staff training to address requirements for inspection and enforcement of erosion and sediment control measures once construction begins.

(4) Offer incentives for “green developers”, such as expedited permit review, reduced application fees, and public recognition.

(5) Expand your procedures for site plan review, site inspection and enforcement to smaller sites.

5. <u>Post-Construction Management in New Development and Redevelopment</u>

a. <u>Permit Requirements</u>

You must review and revise your existing new development and redevelopment post-construction management program, as necessary. The revision shall be completed within the first year after the effective date of this Permit, then as needed. You must develop new elements, as necessary, and continue to implement and enforce a program to address stormwater runoff from new development and redevelopment projects that disturb greater than or equal to one acre, including projects less than one (1) acre that are part of a larger common plan of development or sale, that discharge into your small MS4. Your program must attempt to maintain pre-development runoff conditions and ensure that controls are in place that would prevent or minimize water quality impacts. You must:

(1) Develop (if necessary), implement and enforce strategies which include a combination of structural and/or non-structural BMPs appropriate for your community;

(2) Develop (if necessary), implement and enforce an ordinance or other regulatory mechanism to address post-construction runoff from new development and redevelopment projects to the extent allowable under State or local law;

(3) Review local ordinances and regulations, and identify any legal/regulatory barriers to Low Impact Development (LID). Develop a schedule to remove those barriers that prohibit LID practices selected by the MS4, or provide a justification for each barrier not removed;

(4) Develop (if necessary), implement and enforce procedures to ensure adequate long-term operation and maintenance of BMPs that are installed during and left in place after the completion of a construction project, including inspections of each BMP;

(5) Participate in an education program for developers and the public about project designs that minimize water quality impacts, including LID strategies. This would coordinate with your public education MCM and your pollution prevention and good housekeeping MCM programs;

(6) Establish or revise (as necessary) measurable goals for each BMP, including target milestones (month and year), frequency of action(s) and identify responsible persons; and

(7) Evaluate the appropriateness of your identified BMPs for this MCM. Your evaluation shall verify compliance with permit requirements and, more importantly, document that efforts have been made towards achieving your identified measurable goals and reducing the impacts of stormwater runoff from the small MS4 (as required by Part V.C of this Permit).

b. <u>Recommendations</u>

(1) Promote non-structural/structural BMPs which are appropriate for the local community, minimize water quality impacts and attempt to maintain pre-development runoff conditions in your new development and redevelopment post-construction management program. These BMPs include post-construction plan review, green roofs, green parking, narrower residential streets, open space design, protection of natural features, riparian/forested buffer, street design and patterns, grassed swales, infiltration basin/trench, porous pavement, bioretention/rain gardens, catch basin inserts, vegetated filters, and stormwater wetland/wet ponds.

(2) Consider requirements and standards to direct growth to identified areas, protect sensitive areas such as wetlands and riparian areas, maintain and/or increase open space (including a dedicated funding source for open space acquisition). Provide buffers along sensitive waterbodies, minimize impervious surfaces, and minimize disturbance of soils and vegetation. Encourage infill development in higher density urban areas, and areas with existing storm sewer infrastructure. Consider adopting and implementing low impact development (LID) practices through an ordinance or other regulatory mechanism.

(3) Assess current street design and parking lot guidelines and requirements that affect the creation of impervious cover. Determine if changes in standards for streets and parking lots can be modified to support LID design options.

(4) Complete an inventory of impervious areas (such as conventional pavements, sidewalks, driveways, roadways, parking lots and rooftops), and directly connected impervious areas (portion of impervious area with a direct hydraulic connection to the receiving waters via continuous paved surfaces, gutters, pipes and other impervious features). Based on the results of the inventory, determine the areas that may have the potential to be retrofitted with BMPs (such as LID) designed to reduce the frequency, volume and peak intensity of stormwater runoff to and from your MS4.

(5) Use measures such as minimization of the percentage of impervious area after development, minimization of directly connected impervious areas, and source control measures often thought of as good housekeeping, preventive maintenance and spill prevention.

(6) Use structural BMPs, including, as appropriate:

(a) Storage practices such as wet ponds and extended-detention outlet structures.

(b) Filtration practices such as grassed swales, bioretention cells, sand filters and filter strips.

(c) Infiltration practices such as infiltration basins and infiltration trenches.

(7) Within your required long-term operation and maintenance (O&M) program, consider including the following: pre-construction review of BMP designs, inspection during construction to verify BMPs are built as designed, and penalty provisions for noncompliance. Options to help ensure that future O&M responsibilities are clearly identified include an agreement between you and another party such as the post-development landowners or regional authorities.

(8) Use incentives to encourage interest in LID, such as increased densities, reduced review time/expedited review, tax incentive, reduced application fees, public recognition, dedicated review team, flexibility in design restrictions, adjustments to the required parking, lower stormwater fees, new fee structure, reduced conventional stormwater requirements.

6. Pollution Prevention/Good Housekeeping For MS4 Operations

a. Permit Requirements

You must review and revise your existing pollution prevention and good housekeeping program, as necessary. The revision shall be completed within the first year after the effective date of this Permit, then as needed. You must develop new elements, as necessary, and continue to implement and enforce the operation and maintenance program that includes a training component and has the ultimate goal of preventing or reducing pollutant runoff from MS4 operations. You must:

(1) Use training materials that you develop or that are available from EPA, DEQ, or other reputable organizations. Your pollution prevention and good housekeeping program must include employee training to prevent and reduce stormwater pollution from activities such as park and open space maintenance, fleet and building maintenance, new construction and land disturbances, and stormwater system maintenance;

(2) Implement a municipal employee training and education program that you will use to prevent and reduce stormwater pollution from MS4 activities. Describe any existing, available materials you plan to use. Describe how this training program will be coordinated with the outreach programs developed for the public information minimum measure and the illicit discharge MCM;

(3) Maintain a list of industrial facilities you own or operate that are subject to the DEQ Multi-Sector General Permit or individual OPDES or NPDES permits for discharges of stormwater associated with industrial activity that ultimately discharge to your small MS4. Include the authorization number or a copy of the Industrial NOI form for each facility. You must review this inventory annually and update as necessary;

(4) Implement procedures for controlling, reducing or eliminating the discharge of pollutants from streets, roads, highways, parking lots, maintenance and storage yards, waste transfer stations, fleet or maintenance shops with outdoor storage areas, and salt/sand storage locations and snow disposal areas you operate;

(5) Implement procedures to ensure that new flood management projects are assessed for impacts on water quality;

(6) Implement inspection/maintenance for structural and non-structural BMPs, including maintenance activities, maintenance schedules and long term inspection procedures for controls to reduce floatables and other pollutants discharged to your small MS4;

(7) List and define the BMPs that you or another entity will implement in the pollution prevention and good housekeeping program. You must include, as appropriate, the months and years in which you will undertake required actions, including interim milestones and the frequency of the action. Also you must identify who will be responsible for implementing or coordinating the BMPs in this program;

(8) Establish or revise (as necessary) measurable goals for each BMP, including target milestones (month and year), frequency of action(s) and identify responsible persons; and

(9) Evaluate the appropriateness of your identified BMPs for this MCM. Your evaluation shall verify compliance with permit requirements and more importantly, document that efforts have been made towards achieving your identified measurable goals and reducing the impacts of stormwater runoff from the small MS4 (as required by Part V.C of this Permit).

b. <u>Recommendations</u>

(1) Develop an inventory of all your MS4 operations that are impacted by this program. Review this inventory annually and update as necessary.

(2) Establish procedures for proper use, storage, and disposal of both petroleum and non-petroleum products at schools, town offices, police and fire stations, pools, parking garages and other permittee-owned or operated buildings or utilities. Develop or continue to implement a Spill Response and Prevention Plan to ensure that appropriate actions will take place when a spill occurs within your small MS4.

(3) Establish procedures for the proper storage of permittee-owned vehicles and equipment, including fueling areas. Ensure that vehicle wash waters are not discharged to the small MS4. (4) Establish procedures for catch basin inspections, cleaning and repairs, and sweeping streets, sidewalks, and permittee-owned parking lots within your small MS4.

IV. D Reviewing and Updating the SWMP

1. <u>SWMP Review</u>: You must conduct an annual review of your SWMP in conjunction with preparation of the annual report required under Part V.C.

2. <u>SWMP Update</u>: Your SWMP shall be modified as needed during the life of this Permit in accordance with the following procedures:

a. Changes to comply with new requirements of this Permit.

b. Changes adding (but not subtracting or replacing) components, controls, or requirements to the SWMP may be made at any time upon written notification to the Director.

c. Changes replacing an ineffective or infeasible BMP specifically identified in the SWMP with one or more alternate BMP(s) may be requested at any time. Unless denied by the Director, changes proposed in accordance with the criteria below shall be deemed approved and may be implemented 60 days from submittal of the request. If your request is denied, the Director will send you a written response giving a reason for the decision. Your modification requests must include the following:

(1) An analysis of why the BMP is ineffective or infeasible (including cost prohibitive);

(2) Expectations on the effectiveness of the replacement BMP; and

(3) An analysis of why the replacement BMP is expected to achieve the goals of the BMP to be replaced.

d. Change requests or notifications must be made in writing and signed in accordance with Part VI.H.

IV. E Transfer of Ownership or Operational Authority

The entity responsible for SWMP implementation must implement the SWMP for all new areas added to your portion of the MS4 (or for which you become responsible for implementation of stormwater quality controls) as expeditiously as practicable, but not later than one year from addition of the new areas. Implementation may be accomplished in a phased manner to allow additional time for controls that cannot be implemented immediately.

Within 90 days of a transfer of ownership, operational authority, or responsibility for SWMP implementation, you must have a plan for implementing your SWMP on all affected areas. The plan may include schedules for implementation. Information on all new annexed areas and any resulting updates required to the SWMP must be included in the annual report.

IV. F Minor Permit Modification

Only those portions of the SWMP specifically required as permit conditions shall be subject to the modification requirements of OAC 252:606-1-3(b)(4) adopted and incorporated by reference 40 CFR §124.5. Addition of components, controls, or requirements by the permittee(s) and replacement of an ineffective or infeasible BMP implementing a required component of the SWMP with an alternative BMP expected to achieve the goals of the original BMP shall be considered minor changes to the SWMP and not modifications to this Permit.

PART V: MONITORING, RECORD KEEPING, AND REPORTING

V. A Monitoring

1. Designing Your Monitoring Program: You must evaluate SWMP compliance, the appropriateness of identified BMPs, and progress toward achieving identified measurable goals. If you discharge to a water of the State for which a TMDL has been approved, you may have additional monitoring requirements under Part III of this Permit.

2. Conducting Monitoring: If you plan to conduct monitoring, you are required to comply with the following:

a. Representative monitoring: Samples and measurements taken for the purpose of monitoring shall be representative of the monitored activity.

b. Laboratory Methods

If laboratory analysis is conducted it must be conducted according to test procedures approved under 40 CFR part 136.

3. Records of Monitoring Information: Monitoring records must include:

a. The date, exact place, and time of sampling or measurements;

b. The names(s) of the individual(s) who performed the sampling or measurements;

c. The date(s) analysis were performed;

d. The names of the individuals who performed the analyses;

e. The analytical techniques or methods used; and

f. The results or observations of such analyses.

4. Discharge Monitoring Report (DMR): The reporting of monitoring results may be required, by the Director, to be submitted on a Discharge Monitoring Report.

V. B Recordkeeping

1. **Retain Records of All Monitoring Information**: Include all calibration and maintenance records and all original strip chart recordings for continuous monitoring instrumentation, copies of all reports required by this Permit, copies of DMRs, a copy of the OPDES permit, and records of all data used to complete the NOI for this Permit, for a period of at least three (3) years from the date of the sample, measurement, report or application, or for the term of this Permit, whichever is longer. This period may be extended by request of the Director at any time.

2. Submit Your Records: Mail your completed DMR reports, if required, to DEQ along with your annual report. You must retain a description of the SWMP required by this Permit (including a copy of the permit language) at a location accessible to the Director.

You must make your records, including the NOI and the description of the SWMP, available to the public.

V. C Annual Reports

1. You must submit an annual report for each permit year to the Director of DEQ. If you implement your SWMP on a calendar year basis (from January 1st through December 31st), you must submit your annual report to ODEQ by March 1st of the calendar year, beginning in 2016 for existing permittees or 2017 for new permittees. If you implement your SWMP on a fiscal year basis (from July 1st through June 30th), you must submit your annual report by September 1st of the fiscal year, beginning in 2016 for existing permittees or 2017 for new permittees. Mail your report to the address specified in PART II.C or e-mail to DEQ electronically. Each report must contain information regarding activities of the previous permit year. Each report must include:

   a. The status of your 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 Maximum Extent Practicable (MEP), and progress toward achieving the measurable goals for each of the MCMs;

   b. 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;

   c. A summary of the stormwater activities you plan to undertake during the next reporting cycle (including an implementation schedule);

   d. Proposed changes to your SWMP, including changes to any BMPs or any identified measurable goals that apply to the SWMP elements;

   e. Description and schedule for implementation of any additional BMPs or monitoring that may be necessary to reduce/eliminate the discharges of the pollutant of concern into impaired waters on the 303(d) list;

   f. Description and schedule for implementation of any additional BMPs or monitoring that may be necessary to ensure compliance with any applicable TMDL or watershed plan in lieu of a TMDL; and

   g. 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.

2. If the optional permit requirement for construction activities is elected you must also include in your Annual Report a progress report concerning the elected optional permit requirements. At a minimum this must include:

   a. The number of your active construction sites that are currently covered under the elected optional permit requirement;

   b. The number of construction projects that were started during the reporting period;

c. The number of construction projects that were completed during the reporting period; and

d. The number of construction sites that were covered under the elected optional permit requirement that have reached final stabilization.

PART VI: STANDARD PERMIT CONDITIONS

VI. A Duty to Comply

You must comply with all conditions of this Permit insofar as those conditions are applicable to each permittee, either individually or jointly. Any violation of this Permit constitutes a violation of the Oklahoma Pollutant Discharge Elimination System Act, 27A O.S. § 2-6-206 et seq., and the Clean Water Act, and regulations promulgated thereto; and is grounds for the issuance of an enforcement action; for permit termination, revocation and reissuance, or modification; and/or for denial of a permit renewal application.

The OPDES Act and Clean Water Act also provide that any violation of this Permit may subject the permittee to:

1. Administrative penalties may be assessed up to $10,000 per day per violation for each day during which the violations continue with a $125,000 per violation maximum;

2. Civil penalties may be assessed up to $10,000 per day per violation;

3. Criminal penalties may range from the minimum of $2,500 to the maximum of $2,000,000 with a maximum jail time of 30 years in the state penitentiary; and

4. Penalties for permit fraud are subject to a maximum of $20,000 and a maximum of 4 years in prison.

VI. B Duty to Re-Apply

If you wish to continue an activity regulated by this Permit after the expiration date of this Permit, you must apply for and obtain a new permit.

VI. C Continuation of the Expired General Permit

If this Permit is not reissued or replaced prior to the expiration date, it will be administratively continued in accordance with the Administrative Procedures Act and remain in force and effect. Any permittee who was granted permit coverage prior to the expiration date will automatically remain covered by the continued permit until the earlier of:

1. Reissuance or replacement of this Permit, at which time you must comply with the Notice of Intent (NOI) conditions of the new permit to maintain authorization to discharge; or

2. Issuance of an individual permit for your discharges; or

3. A formal permit decision by the permitting authority not to reissue this Permit, at which time you must seek coverage under an alternative general permit or individual permit.

VI. D Need to Halt or Reduce Activity is not a Defense

It shall not be a defense for you in an enforcement action that it would have been necessary to halt or reduce the permitted activity in order to maintain compliance with the conditions of this Permit.

VI. E Duty to Mitigate

You must take all reasonable steps to minimize or prevent any discharge in violation of this Permit that has a reasonable likelihood of adversely affecting human health or the environment.

VI. F Duty to Provide Information

You must furnish to the Director, within a reasonable time, any information which the Director may request to determine whether cause exists for modifying, revoking, and reissuing, or terminating this Permit or to determine compliance with this Permit. You must also furnish to the Director, upon request, copies of records required to be kept by this Permit.

VI. G Other Information

If you become aware that you have failed to submit any relevant facts in your Notice of Intent (NOI) or submitted incorrect information in the NOI or in any other report to the Director, you must promptly submit or correct such facts or information.

VI. H Signatory Requirements

1. Notices of Intent: All Notices of Intent must be signed and certified as follows:

a. For a corporation, the NOI must be signed and certified by a *responsible corporate officer*. For the purpose of this Part, a *responsible corporate officer* means:

(1) A president, secretary, treasurer, or vice-president of the corporation in charge of a principal business function, or any other person that performs similar policy decision making functions for the corporation, or

(2) The manager of one or more manufacturing, production, or operating facilities, provided the manager is authorized to make management decisions which govern the operation of the regulated facility, including having the explicit or implicit duty of making major capital investment recommendations, and initiating and directing other comprehensive measures to assure long term environmental compliance with environmental laws and regulations; the manager can ensure that the necessary systems are established or actions taken to gather complete and accurate information for permit application requirements; and where authority to sign documents has been assigned or delegated to the manager in accordance with corporate procedures.

b. For a partnership or sole proprietorship, the NOI must be signed and certified by a general partner or the proprietor, respectively.

c. For a municipality, State, Federal, or other public agency, the NOI must be signed and certified by either a *principal executive officer* or ranking elected official. For purposes of this Part, a *principal executive officer* of a Federal agency includes:

(1) The chief executive officer of the agency, or

(2) A senior executive officer having responsibility for the overall operations of a principal geographic unit of the agency (e.g., Regional Administrator of EPA).

2. Reports and Other Information: All NOTs, SWMPs, SWP3s, reports, certifications or other information required by this Permit and other information requested by the Director or authorized representative of the Director shall be signed by a person described in Part VI.H.1 or by a duly authorized representative of that person. A person is a duly authorized representative if:

a. The authorization is made in writing by a person described in Part VI.H.1, and submitted to the Director.

b. The authorization specifies either an individual or a position having responsibility for the overall operation of the regulated facility or activity, such as the position of manager, operator, superintendent, or position of equivalent responsibility for environmental matters for the regulated entity.

c. The signed and dated written authorization is included in the SWMP. A copy must be submitted to the Director.

3. Changes to Authorization: If an authorization is no longer accurate because a different operator has the responsibility for the overall operation of the MS4, a new authorization satisfying the requirement of Part VI.H.2 above must be submitted to the Director prior to or together with any reports, information, or notices of termination to be signed by an authorized representative.

4. Certification: Any person signing documents under terms of this Permit shall make the following certification:

> *"I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."*

VI. I Property Rights

The issuance of this Permit does not convey any property rights of any sort, or any exclusive privilege, nor does it authorize any injury to private property nor any invasion of personal rights, nor any infringement of Federal, State or local laws or regulations.

VI. J Proper Operation and Maintenance

You must at all times properly operate and maintain all facilities and systems of treatment and control (and related appurtenances) which are installed or used by you to achieve compliance with the conditions of this Permit and with the conditions of your SWMP. Proper operation and maintenance also includes adequate laboratory controls and appropriate quality assurance procedures. Proper operation and maintenance requires the operation of backup or auxiliary facilities or similar systems, installed by you only when the operation is necessary to achieve compliance with the conditions of the permit.

VI. K Inspection and Entry

You must allow the Director or an authorized representative (including an authorized contractor acting as a representative of the Director) upon the presentation of credentials and other documents as may be required by law, to do any of the following:

1. Enter the premises where a regulated facility or activity is located or conducted or where records must be kept under the conditions of this Permit.

2. Have access to and copy at reasonable times, any records that must be kept under the conditions of this Permit.

3. Inspect at reasonable times any facilities or equipment (including monitoring and control equipment) practices, or operations regulated or required under this Permit.

4. Sample or monitor any substances or parameters at any location at reasonable times for the purposes of assuring permit compliance or as otherwise authorized by the CWA.

VI. L Permit Actions

This Permit may be modified, revoked and reissued, or terminated for cause. Your filing of a request for a permit modification, revocation and reissuance, or termination, or a notification of planned changes or anticipated noncompliance does not stay any permit condition.

VI. M Permit Transfers

This Permit is not transferable to any person except after notice to the Director. The Director may require modification or revocation and reissuance of the Permit to change the name of the permittee and incorporate such other requirements as may be necessary under the Act.

VI. N Anticipated Noncompliance

You must give advance notice to the Director of any planned changes in the permitted small MS4 or activity that may result in noncompliance with this Permit.

VI. O State Environmental Laws

1. Nothing in this Permit shall be construed to preclude the institution of any legal action or relieve you from any responsibilities, liabilities, or penalties established pursuant to any applicable State law or regulation under the authority preserved by Section 510 of the Act.
2. No condition of this Permit releases you from any responsibility or requirements under other environmental statutes or regulations.

VI. P Severability

The provisions of this Permit are severable, and if any provision of this Permit or the application of any provision of this Permit to any circumstance is held invalid, the application of such provision to other circumstances, and the remainder of this Permit shall not be affected thereby.

VI. Q Procedures for Modification or Revocation

Permit modification or revocation will be conducted according to OAC 252.606-1-3(b)(3) and (4) adopted and incorporated by reference 40 CFR § 122.62, 122.63, 122.64, and 124.5.

VI. R Requiring an Individual Permit or Alternative General Permit

1. Request by Director

DEQ may require any person seeking authority under or authorized by this Permit to apply for and/or obtain either an individual OPDES permit or an alternative OPDES general permit. Any interested person may petition DEQ to take action under this paragraph. Where DEQ requires you to apply for an individual OPDES permit, DEQ will notify you in writing that a permit application is required. This notification shall include a brief statement of the reasons for this decision, an application form, a statement setting a deadline for you to file the application, and a statement that on the effective date of issuance or denial of the individual OPDES permit or the alternative general permit as it applies to the individual permittee, coverage under this general permit shall automatically terminate. DEQ may grant additional time to submit the application upon request of the applicant. If you fail to submit an individual OPDES permit application in a timely manner as required by DEQ under this paragraph, then the applicability of this general permit to you is automatically terminated at the end of the day specified by DEQ for application submittal. This paragraph does not apply to any person whom the Director determines was never eligible under Part I.A. The Director may also require a discharger to file for an individual permit prior to submission of a NOI.

2. Request by Permittee

Any discharger authorized by this Permit may request to be excluded from the coverage of this Permit by applying for an individual permit. In such cases, you must submit an individual application in accordance with the requirements of 40 CFR §122.33(b)(2), with reasons supporting the request, to the Director of DEQ. The request may be granted by issuance of any individual permit or an alternative general permit if the reasons cited by you are adequate to support the request.

3. General Permit Termination

When an individual OPDES permit is issued to a discharger otherwise subject to this Permit, or you are authorized to discharge under an alternative OPDES general permit, the applicability of this Permit to the individual OPDES permittee is automatically terminated on the effective date of the individual permit or the date of authorization of coverage under the alternative general permit, whichever the case may be. When an individual OPDES permit is denied to an operator otherwise subject to this Permit, or the operator is denied coverage under an alternative OPDES general permit, the applicability of this Permit to the individual OPDES permittee is automatically terminated on the date of such denial, unless otherwise specified by the Director.

VI. S Compliance Schedules

Reports of compliance or noncompliance with, or any progress reports on, interim and final requirements contained in any compliance schedule of this Permit shall be submitted no later than 14 days following each schedule date.

VI. T Twenty-Four (24) Hour Reporting

1. You shall report any noncompliance which may endanger health or the environment. Any information shall be provided orally within 24 hours from the time you become aware of the circumstances. A written submission shall also be provided within 5 days of the time you become aware of the circumstances. The written submission shall contain a description of the noncompliance and its cause; the period of noncompliance, including exact dates and times, and if the noncompliance has not been corrected, the anticipated time it is expected to continue; and steps taken or planned to reduce, eliminate, and prevent reoccurrence of the noncompliance;
2. The following shall be included as information which must be reported within 24 hours: 1) Any unanticipated bypass which exceeds any effluent limitation in the permit; 2) Any upset which exceeds any effluent limitation in the permit; and 3) Violation of a maximum daily discharge limitation for any of the pollutants listed by the DEQ in the permit to be reported within 24 hours; and
3. DEQ may waive the written report on a case-by-case basis for reports if the oral report has been received within 24 hours.

PART VII: DEFINITIONS

All definitions contained in Section 502 of The Act and 40 CFR §122 shall apply to this Permit and are incorporated herein by reference. For convenience, simplified explanations of some regulatory/statutory definitions have been provided, but in the event of a conflict, the definition found in the Statute or Regulation takes precedence.

Best Management Practices (BMPs) means schedules of activities, prohibitions of practices, maintenance procedures, and other management practices to prevent or reduce the pollution of waters of the State. BMPs also include treatment requirements, operating procedures, and practices to control runoff, spillage or leaks, sludge or waste disposal, or drainage from raw material storage.

Construction Site Operator means the party or parties that meet one or more of the following descriptions:

1. Has operational control over construction plans and specifications, including the ability to make modifications to those plans and specifications or

2. Has day-to-day operational control of those activities at a project that are necessary to ensure compliance with a Stormwater Pollution Prevention Plan (SWP3) for the site or other permit conditions (e.g., they are authorized to direct workers at a site to carry out activities required by the SWP3 or comply with other permit conditions).

In addition, "owner" refers to the party that owns the structure being built. Ownership of the land where construction is occurring does not necessarily imply the property owner is an operator (e.g., a landowner whose property is being disturbed by construction of a gas pipeline or a landowner who allows a mining company to remove dirt, shale, clay, sand, gravel, etc. form a portion of his property).

This definition is provided to inform permittees of DEQ's interpretation of how the regulatory definitions of "operator" are applied to discharges of stormwater associated with construction activity.

Control Measure as used in this Permit, refers to any Best Management Practice (BMP) or other method used to prevent or reduce the discharge of pollutants to waters of the State.

CWA or The Act means the Clean Water Act (formerly referred to as the Federal Water Pollution Control Act or Federal Water Pollution Control Act Amendments of 1972) Pub.L. 92-500, as amended Pub. L. 95-217, Pub. L. 95-576, Pub. L. 96-483 and Pub. L. 97-117, 33 U.S.C. 1251 et.seq.

Director means the Executive Director or chief administrator of the Department of Environmental Quality or an authorized representative.

Discharge, when used without a qualifier, refers to “discharge of a pollutant” as defined at 40 CFR §122.2.

Impaired Water (or Water Quality Impaired Water) is identified by a State, or EPA pursuant to Section 303(d) or the Clean Water Act as not meeting applicable State water quality standards. Impaired waters include both waters with approved or established TMDLs, and those for which a TMDL has not yet been approved or established.

Illicit Discharge is defined at 40 CFR §122.26(b)(2) and refers to any discharge to a municipal separate storm sewer that is not entirely composed of stormwater, except discharges authorized under an OPDES or NPDES permit (other than the OPDES permit for discharges from the MS4) and discharges resulting from firefighting activities.

LID is an acronym for "Low Impact Development," an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible. LID employs principles such as preserving and recreating natural landscape features, minimizing effective imperviousness to create functional and appealing site drainage that treats stormwater as a resource rather than a waste product.

MEP is an acronym for "Maximum Extent Practicable," the technology-based discharge standard for Municipal Separate Storm Sewer Systems (MS4s) to reduce pollutants in stormwater discharges that was established by CWA §402(p). A discussion of MEP as it applies to MS4s is found at 40 CFR § 122.34.

MS4 is an acronym for "Municipal Separate Storm Sewer System" and is used to refer to a either Large, Medium, or Small Municipal Separate Storm Sewer System. The term is used to refer to either the system operated by a single entity or a group of systems within an area that are operated by multiple entities (e.g., the Oklahoma City MS4 includes MS4s operated by Oklahoma City, the Oklahoma Department of Transportation, and others).

Municipal Separate Storm Sewer System is defined at 40 CFR § 122.26(b)(8) and means a conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains):

1. Owned or operated by a state, city, town, borough, county, parish, district, association, or other public body (created by or pursuant to State law) having jurisdiction over disposal of sewage, industrial wastes, stormwater, or other wastes, including special districts under State law such as a sewer district, flood control district or drainage district, or similar entity, or an Indian tribe or an authorized Indian tribal organization, or a designated and approved management agency under section 208 of the CWA that discharges to waters of the United States;

2. Designed or used for collecting or conveying stormwater;

3. Which is not a combined sewer; and

4. Which is not part of a Publicly Owned Treatment Works (POTW) as defined at 40 CFR §122.2.

Newly Regulated Small MS4 refers to a small MS4 newly designated as a result of 2010 US census data or other new information, and required to be covered under an OPDES permit.

NOI is an acronym for "Notice of Intent" to be covered by this Permit and is the mechanism used to "register" for coverage under a general permit.

Non-traditional MS4 means state and federal prisons, office complexes, hospitals, state transportation agencies, universities, public housing authorities, schools and other special districts.

Outstanding Resource Waters means those waters of the State which are designated as such in Oklahoma's Water Quality Standards OAC 785:45.

Small Municipal Separate Storm Sewer System is defined at 40 CFR §122.26(b)(16) and refers to all separate storm sewers that are owned or operated by the United States, a state, city, town, county, district, association, or other public body (created by or pursuant to State law) having jurisdiction over disposal of sewage, industrial wastes, stormwater, or other wastes, including special districts under State law such as a sewer district, flood control district or drainage district, or similar entity, or a designated and approved management agency under section 208 of the CWA that discharges to waters of the State, but is not defined as a "large"' or "medium" municipal separate storm sewer system. This term includes systems similar to separate storm sewer systems in municipalities, such as systems at military bases, large hospital or prison complexes, and highways and other thoroughfares. The term does not include separate storm sewers in very discrete areas, such as individual buildings.

Small MS4 Newly Designated after the Date of Permit Issuance refers a small MS4 newly designated by EPA or DEQ after the date of this Permit issuance.

Stabilization is the process of covering exposed ground surfaces with vegetative or non-vegetative practices that reduce erosion and prevent sediment discharge from occurring.

- "**Temporary stabilization**" refers to the stabilization of exposed portions of the site in order to provide temporary cover (1) during the establishment and growth of vegetation, and/or (2) in areas where earth-disturbing activities will occur again in the future.

- "**Final stabilization**" refers to the stabilization of exposed portions of the site using practices that provide permanent cover and qualify the permittee for permit termination.

All soil disturbing activities at the site have been completed and either of the two following criteria is met:

1. A uniform (e.g., evenly distributed, without large bare areas) perennial vegetative cover with a density of 70% of the native background cover for the area has been established on all unpaved areas and areas not covered by permanent structures, or

2. Equivalent permanent stabilization measures (such as the use of riprap, gabions, or geotextiles) have been employed.

When background native vegetation covers less than 100% of the ground (e.g., arid areas, and beaches), establishing at least 70% of the natural cover of the native vegetation meets the vegetative cover criteria for final stabilization (e.g., if the native vegetation covers 50% of the ground, 70% of 50% would require 35% total cover for final stabilization. On a beach with no natural vegetation, no vegetation is required.

Stormwater is defined at 40 CFR §122.26(b)(13) and means stormwater runoff, snow melt runoff, and surface runoff and drainage.

Stormwater Management Program (SWMP) refers to a comprehensive program to manage the quality of stormwater discharged from the municipal separate storm sewer system (MS4).

SWMP is an acronym for "Stormwater Management Program."

Total Maximum Daily Load or TMDL means the sum of the individual wasteload allocations (WLAs) for point sources, safety, reserves, and loads from nonpoint sources and natural background.

"You" and "Your" as used in this Permit is intended to refer to the permittee, the operator, or the discharger as the context indicates and that party's responsibilities (e.g., the city, the county, the flood control district, the U.S. Air Force, etc.).

Waters of the State means all streams, lakes, ponds, marshes, watercourses, waterways, wells, springs, irrigation systems, drainage systems, storm sewers and all other bodies or accumulations of water, surface and underground, natural or artificial, public or private, which are contained within, flow through, or border upon this state or any portion thereof, and shall include under all circumstances the waters of the United States which are contained within the boundaries of, flow through, or border upon this state or any portion thereof. Provided waste treatment systems, including treatment ponds or lagoons designed to meet federal and state requirement other than cooling ponds as defined in the Clean Water Act or rules promulgated thereto, and prior converted cropland are not waters of the State. (27A O.S. §1-1-201).

PART VIII: OPTIONAL PERMIT REQUIREMENTS FOR MUNICIPAL CONSTRUCTION ACTIVITIES

VIII. A Optional for Small MS4s Seeking Coverage For Municipal Construction Activities Under This Permit

The development of this optional provision for municipal construction activities is an alternative for the small MS4 operator seeking coverage under this Permit. This provision does not apply to Oklahoma Turnpike Authority (OTA) or Oklahoma Department of Transportation (ODOT), who are small MS4 operators. Additionally, contractors working for the small MS4 operator are not required to obtain separate authorization as long as the contractor does not meet the definition of “construction site operator”, but does remain compliant with the conditions of this Permit. Small MS4s that choose to develop this option will be authorized by this Permit to discharge stormwater and certain non-stormwater from construction activities where the small MS4s are the “construction site operators”. For small MS4s that choose to develop this measure, it shall be part of the SWMP submitted with the initial NOI. You must comply with the requirements in Part VIII.B.

If you choose not to develop this optional measure, then you must submit a NOI and seek coverage under the DEQ general permit (OKR10) for stormwater discharges from construction activities.

If this optional provision requirement is elected you must include the following in your SWMP:

1. Description of how construction activities will generally be conducted by the small MS4. Local conditions and other site specific considerations must be included in the description;
2. Description of how the small MS4 will implement the technology-based requirements to comply with Effluent Limitation Guidelines and Standards for the Construction and Development Point Source Category (ELGs) under Part 450 of 40 C.F.R., Effective February 1, 2010, in Part VIII.B.3 of this Permit;
3. Description of how the small MS4 will ensure that the SWP3 requirements are properly implemented and maintained at the construction site; or how the small MS4 will ensure that the contractors obtain a separate authorization for stormwater discharges from DEQ for each project; and
4. General Stormwater Pollution Prevention Plan (SWP3) conditions and a procedure to include site specific BMPs to account for local considerations.

VIII. B Optional Permit Requirements for Municipal Construction Activities

1. **<u>Eligibility</u>**

   a. This optional provision authorizes small Ms4s to discharge pollutants in stormwater runoff associated with municipal construction activities as defined in 40 CFR (Code of Federal Regulations) 122.26 (b)(14)(x) for construction sites of five or more acres, CFR 122.26 (b)(15)(i) for construction sites of more than one acre but less than five acres**,** and those construction site discharges designated by the Director as needing a stormwater permit under 122.26 (a)(1)(v), or under 122.26 (a)(9) and

122.26 (g)(1)(i). Any discharge authorized by a different OPDES or NPDES permit may be commingled with discharges authorized by this Permit.

b. This provision also authorizes stormwater discharges from support activities[1] (e.g., concrete batch plants, equipment staging yards, material storage areas, excavated material disposal areas, borrow areas) provided:

(1) Concrete batch plant activity is not located in the watershed of an Outstanding Resource Water[2] as defined in the Oklahoma Water Quality Standards.

(2) The support activity is directly related to a construction site that is required to have OPDES permit coverage for discharges of stormwater associated with construction activity.

(3) The support activity is not a commercial operation serving multiple unrelated construction projects by different operators, and does not operate beyond the completion of the construction activity at the last construction project it supports.

(4) Appropriate controls and measures are identified in a SWP3 covering the discharges from the support activity areas.

2. <u>Authorized Non-Stormwater Discharges</u>

The following non-stormwater discharges from active construction sites are authorized by this provision:

a. Waters used to wash vehicles where detergents are not used;

b. Water used to control dust;

c. Routine external building wash down which does not use detergents;

d. Pavement wash waters where spills or leaks of toxic or hazardous materials have not occurred (unless all spilled material has been removed) and where detergents are not used; and

e. Uncontaminated flows from excavation dewatering activities will be allowed if operational and structural controls are used to reduce any pollutant releases in order to avoid or minimize the impacts on water quality. These controls must be included in your SWP3.

3. <u>Non-Numeric Technology Based Effluent Limitations</u>

The stormwater control requirements in this part are the technology-based effluent limitations that apply to all discharges from construction sites eligible for coverage under this provision. These requirements apply the national effluent limitations guidelines and new source performance standards found at 40 CFR Part 450.

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1 Discharges subject to a numeric effluent limitation guideline for Asphalt Batch Plants are not covered under this Permit and required to apply for permit coverage under stormwater multi-sector general permit OKR05.

2 See Part VII Definitions for details

a. Erosion and Sediment Control Requirements

You must design, install and maintain erosion and sediment that minimize the discharge of pollutants from earth-disturbing activities. You are required to minimize the amount of soil exposed during construction activities and also subject to the deadlines for temporarily and/or permanently stabilizing exposed portions of your site pursuant to Part VIII.B.3.b. You must account for the following factors in designing your stormwater controls:

- The expected amount, frequency, intensity, and duration of precipitation.
- The nature of stormwater runoff and run-on at the site, including factors such as expected flow from impervious surfaces, slopes, and site drainage features. If any stormwater flow will be channelized at your site, you must design stormwater controls to control both peak flowrates and total stormwater volume to minimize erosion at outlets and to minimize downstream channel and streambank erosion.
- The range of soil particle sizes expected to be present on the site.

You must direct discharges from your stormwater controls to vegetated areas of your site to increase sediment removal and maximize stormwater infiltration, including any natural buffers established under Parts VIII.B.3.a.(1) and VIII.B.5, unless infeasible. Use velocity dissipation devices if necessary to prevent erosion when directing stormwater to vegetated areas.

(1) Protection of surface water

In order to minimize sediment discharges, if any water of the State are located on or immediately adjacent to the site, you must maintain at least fifty (50) feet of natural buffer zone, as measured from the top of the bank to disturbed portions of your site, from any named or unnamed receiving streams, creeks, rivers, lakes or other waterbodies unless 100 feet of natural buffer is required by Part VIII.B.4.b and VIII.B.5. There are exceptions from this requirement for water crossings, limited water access, and stream restoration authorized under a CWA Section 404 permit. Where no natural buffer exists due to preexisting development disturbances (e.g., structures, impervious surfaces) that occurred prior to the initiation of planning for the current development of the site, you are not required to comply with the requirements in this part, unless you will remove portions of the preexisting development. Where some natural buffer exists but portions of the area within 50 feet of the surface water are occupied by preexisting development disturbances, you may refer to Exhibit 4 (Buffer Guidance) for sediment control alternatives. Additionally, this requirement is not intended to interfere with any other ordinance, or regulation, statute or other provision of law.

(2) Install perimeter controls

You must install sediment controls along those perimeter areas of your site that will receive stormwater from earth-disturbing activities. For linear projects with rights-of-way that restrict or prevent the use of such perimeter controls, you must maximize the use of these controls where practicable and document in your SWP3 why it is impracticable in other areas of the project. You must remove sediment before it has accumulated to one (1)-half of the above-ground height of any perimeter control.

(3) Minimize sediment track-out

You must minimize the track-out of sediment onto off-site streets, other paved areas, and sidewalks from vehicles exiting your construction site. To comply with this requirement, you must:

(a). Restrict vehicle use to properly designated exit points.

(b). Use appropriate stabilization techniques at all points that exit onto paved roads so that sediment removal occurs prior to vehicle exit.

(c). Where necessary, use additional controls to remove sediment from vehicle tires prior to exit.

(d). Where sediment has been tracked-out from your site onto the surface of off-site streets, other paved areas, and sidewalks, you must remove the deposited sediment by the end of the same work day in which the track-out occurs or by the end of the next work day if track-out occurs on a non-work day. You must remove the track-out by sweeping, shoveling, or vacuuming these surfaces, or by using other similarly effective means of sediment removal. You are prohibited from hosing or sweeping tracked-out sediment into any stormwater conveyance (unless it is connected to a sediment basin, sediment trap, or similarly effective control), storm drain inlet, or surface water.

(4) Control discharges from stockpiled sediment or soil

For any stockpiles or land clearing debris composed, in whole or in part, of sediment or soil, you must comply with the following requirements:

(a). Locate the piles outside of any natural buffers established under Parts VIII.B.3.a.(1) or VIII.B.4.b and physically separated from other stormwater controls implemented in accordance with Part VIII.B.3.a.

(b). Protect from contact with stormwater (including run-on) using a temporary perimeter sediment barrier.

(c). Where practicable, provide cover or appropriate temporary stabilization to avoid direct contact with precipitation or to minimize sediment discharge.

(d). Do not hose down or sweep soil or sediment accumulated on pavement or other impervious surfaces into any stormwater conveyance (unless connected to a sediment basin, sediment trap, or similarly effective control), storm drain inlet, or surface water.

(e). Unless infeasible, contain and securely protect from wind.

(5) Minimize Dust

In order to avoid pollutants from being discharged into surface waters, to the extent feasible, you must minimize the generation of dust through the appropriate application of water or other dust suppression techniques.

(6) Minimize the Disturbance of Steep Slopes

You must minimize the disturbance of steep slopes (i.e., slopes of 40% or greater). If it is not feasible to avoid disturbance of steep slopes, you must:

(a). Divert concentrated or channelized flows of stormwater away from and around areas of disturbance on steep slopes.

(b). Use specialized erosion and sediment controls for steep slopes, such as temporary and permanent seeding with soil binders, erosion control blankets, surface roughening, reducing the continuous slope length with terracing or diversions, gradient terraces, interceptor dikes and swales, grass-lined channels, pipe slope drains, subsurface drains, level spreaders, check dams, seep berms, and triangular silt dikes.

(c). Use stabilization practices designed to be used on steep slopes. You must comply with the stabilization requirements as required in Part VIII.B.3.b.

(7) Preserve Topsoil

You must preserve native topsoil on your site, unless infeasible; you should stockpile and reuse it in areas that will be stabilized with vegetation if applicable.

(8) Minimize Soil Compaction

In areas of your site where final vegetative stabilization will occur or where infiltration practices will be installed, you must either restrict vehicle and equipment use in these locations to avoid soil compaction, or use techniques that condition the soils to support vegetative growth if necessary, prior to seeding or planting areas of exposed soil that have been compacted.

(9) Protect Storm Drain Inlets

If you discharge to any storm drain inlet that carries stormwater flow from your site directly to surface water (and it is not first directed to a sediment basin, sediment trap, or similarly effective control), and you have the authority to access the storm drain inlet, you must install inlet protection measures that remove sediment from your discharge prior to entry into the storm drain inlet. You must clean, or remove and replace the protection measures as sediment accumulates, the filter becomes clogged, and/or performance is compromised. Where there is evidence of sediment accumulation adjacent to the inlet protection measure, you must remove the deposited sediment by the end of the same work day in which it is found or by the end of the following work day if removal by the same work day is not feasible.

(10) Constructed Stormwater Conveyance Channels

You must design channels to avoid unstabilized areas on the site and to reduce erosion, unless infeasible. Minimize erosion of channels and their embankments, outlets, adjacent streambanks, slopes, and downstream waters during discharge conditions through the use of erosion controls and velocity dissipation devices within and along the length of any constructed stormwater conveyance channel, and at any outlet to provide a non-erosive flow velocity.

(11) Sediment Basins

If you install a sediment basin, you must comply with the following:

(a). Design requirements. Provide storage for either the calculated volume of runoff from a 2-year, 24-hour storm, or 3,600 cubic feet per acre drained.

(b). When discharging from the sediment basin, utilize outlet structures that withdraw water from the surface in order to minimize the discharge of pollutants, unless infeasible.

(c). Prevent erosion of the sediment basin using stabilization controls (e.g., erosion control blankets), and the inlet/outlet using erosion controls and velocity dissipation devices.

(d). Sediment basins must be situated outside of surface waters and any natural buffers established under Parts VIII.B.3.a.(1) and VIII.B.4.b.

(12) Dewatering Practices

You are prohibited from discharging groundwater or accumulated stormwater that is removed from excavations, trenches, foundations, vaults, or other similar points of accumulation associated with a construction activity, unless such waters are first effectively managed by appropriate controls. Uncontaminated dewatering water can be discharged without being routed to a control. You must also meet the following requirements for dewatering activities:

(a). Do not discharge visible floating solids or foam.

(b). Use an oil-water separator or suitable filtration device (such as a cartridge filter) that is designed to remove oil, grease, or other products if dewatering wastewater is found to contain these materials.

(c). To the extent feasible, utilize vegetated, upland areas of the site to infiltrate dewatering water before discharge. In no case will surface waters be considered part of the treatment area.

(d). At all points where dewatering water is discharged, comply with the velocity dissipation requirements of Part VIII.B.3.a.(10).

(e). With backwash water, either haul away for disposal or return it to the beginning of the treatment process.

(f). Replace and clean the filter media used in dewatering devices when the pressure differential equals or exceeds the manufacturer's specifications.

b. Stabilization Requirements

You are required to stabilize exposed portions of your site in accordance with the following requirements:

(1) Deadlines for Initiating and Completing Stabilization

You must initiate stabilization measures immediately[3] 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. As soon as practicable, but no later than 14 calendar days after the initiation of soil stabilization measures, you are required to have completed:

(a). For vegetative stabilization, all activities necessary to initially seed or plant the area to be stabilized; and/or

(b). For non-vegetative stabilization, the installation or application of all such non-vegetative measures.

If you discharge to an impaired water, or Outstanding Resource Water (ORW), or Aquatic Resource of Concern (ARC), you are required to complete the stabilization activities within seven (7) calendar days after the temporary or permanent cessation of earth-disturbing activities.

(2) Criteria for Stabilization

To be considered adequately stabilized, you must meet the criteria below depending on the type of cover you are using, either vegetative or non-vegetative.

(a). For both temporary and final stabilization[4], if you are using vegetative cover to stabilize an exposed portion of your site, you must comply with one of the criteria:

(b). Provide an established uniform perennial vegetative cover (e.g., evenly distributed without large bare areas), which covers 70% or more of the density of coverage that was provided by vegetation prior to commencing earth-disturbing activities. When background vegetation covered less than 100% of the ground prior to commencing earth-disturbing activities, the 70% coverage criteria is adjusted as in following example:

3 The term "immediately" is used to define the deadline for initiating stabilization measures. In the context of this provision, "immediately" means as soon as practicable, but no later than the end of the next work day, following the day when the earth-disturbing activities have temporarily or permanently ceased.

4 Temporary and final stabilization in Part VII Definitions

If vegetation covered 50% of the ground prior to construction, then the requirement would be to provide a total vegetative cover at final stabilization of 70% of 50% (0.70 X 0.50 = 0.35), or 35% of the site.

(c). Immediately after seeding or planting the area to be vegetative stabilized, to the extent necessary to prevent erosion on the seeded or planted area, you must select, design, and install non-vegetative erosion controls that provide cover (e.g., mulch, rolled erosion control products) to the area while vegetation is becoming established.

(d). If you are using non-vegetative controls (e.g., hydromulch, erosion control blankets, riprap, geotextiles, and gabions) to stabilize exposed portions of your site, or if you are using such controls to temporarily protect areas that are being vegetatively stabilized, you must provide effective non-vegetative cover to stabilize any such exposed portions of your site.

c. Pollution Prevention Requirements

You are required to design, install, implement and maintain effective pollution prevention measures in order to minimize or prevent the discharge of pollutants. To meet this requirement, you are required to:

- Eliminate certain pollutant discharges from your site [see Part VIII.B.3.c.(1)].
- Properly maintain all pollution prevention controls [see Part VIII.B.3.c.(2)].
- Comply with pollution prevention standards for pollutant-generating activities that occur at your site [see Part VIII.B.3.c.(3)].

(1) Prohibited discharges

You are prohibited from discharging the following from your construction site:

(a) Wastewater from the washout of concrete, unless managed by an appropriate control as described in Part VIII.B.3.c.(2).(d).
(b) Wastewater from the washout and cleanout of stucco, paint, from release oils, curing compounds and other construction materials, unless managed by an appropriate control as described in Part VIII.B.3.c.(2).(d).
(c) Fuels, oils, or other pollutants used in vehicle and equipment operation and maintenance.
(d) Soaps, detergents or solvents used in vehicle and equipment washing.
(e) Toxic or hazardous substances from a spill or other release.

(2) Maintenance requirements

You must ensure that all pollution prevention controls installed in accordance with this Part remain in effective operating condition and are protected from activities that would reduce their effectiveness. You must inspect all pollutant-generating activities and pollution prevention controls in accordance with your inspection frequency requirements in Part VIII.B.7.m.(2) and document your findings in accordance with Part VIII.B.7.m.(5) if you find that controls need to be replaced, repaired, or maintained, you must make the necessary repairs or modifications in accordance with the following:

(a). <u>General Maintenance Requirements</u>: You must initiate work to fix the problem immediately after discovering the problem, and complete such work by the close of the next work day, if the problem does not require significant repair or replacement, or if the problem can be corrected through routine maintenance.

(b). <u>Washing of Equipment or Vehicles</u>: You must provide an effective means of minimizing the discharge of pollutants from equipment and vehicle washing, wheel wash water, and other types of washing. To comply with the prohibition in Part VIII.B.3.c.(1) for storage of soaps, detergents, or solvents, you must provide either cover (e.g., plastic sheeting or temporary roofs) to prevent these detergents from coming into contact with rainwater, or a similarly effective means designed to prevent the discharge of pollutants from these areas.

(c) <u>Storage, Handling, and Disposal of Construction Products, Materials and Wastes</u>: You must minimize the exposure to stormwater of any of the products, materials, or wastes specified below that are present at your site by complying with the requirements in this Part. To ensure you meet this requirement, you must do the following:

i. For building products in storage areas, you must provide either cover (e.g., plastic sheeting or temporary roofs) to prevent these products from coming into contact with rainwater, or a similarly effective means designed to prevent the discharge of pollutants from these areas.

ii. For pesticides, herbicides, insecticides, fertilizers, and landscape materials in storage areas, you must provide either cover (e.g., plastic sheeting or temporary roofs) to prevent these chemicals from coming into contact with rainwater, or a similarly effective means designed to prevent the discharge of pollutants from these areas; and comply with all application and disposal requirements included on the registered pesticide, herbicide, insecticide, and fertilizer label.

iii. For diesel fuel, oil, hydraulic fluids, other petroleum products, and other chemicals to comply with the prohibition in Part VIII.B.3.c.(1), you must store chemicals in water-tight containers, and provide either cover (e.g., plastic sheeting or temporary roofs) to prevent these containers from coming into contact with rainwater, or a similarly effective means designed to prevent the discharge of pollutants from these areas (e.g., spill kits), or provide secondary containment (e.g., spill berms, decks, spill containment pallets); and clean up spills immediately, using dry clean-up methods where possible, and dispose of used materials properly. Do not clean surfaces or spills by hosing the area down. Eliminate the source of the spill to prevent a discharge or a continuation of an ongoing discharge.

iv. For hazardous or toxic waste (e.g., paints, solvents, petroleum-based products, wood preservatives, additives, curing compounds, acids), you must:

- Separate hazardous or toxic waste from construction and domestic waste, store waste in sealed containers, which are constructed of suitable materials to prevent leakage and corrosion, and which are labeled in accordance with applicable Resource Conservation and Recovery Act (RCRA) requirements and all other applicable federal, state, or local requirements,
- Store all containers that will be stored outside within appropriately-sized secondary containment (e.g., spill berms, decks, spill containment pallets) to prevent spills from being discharged, or provide a similarly effective means designed to prevent the discharge of pollutants from these areas (e.g., storing chemicals in covered areas or having a spill kit available on site),
- Dispose of hazardous or toxic waste in accordance with the manufacturer's recommended methods of disposal and in compliance with federal, state, and local requirements.
- Clean up spills immediately, using dry clean-up methods where possible, and dispose of used materials properly. Do not clean surfaces or spills by hosing the area down. Eliminate the source of the spill to prevent a discharge or a furtherance of an ongoing discharge.

v. For construction and domestic waste (e.g., packaging materials, scrap construction materials, masonry products, timber, pipe and electrical cuttings, plastics, Styrofoam, concrete, and other trash or building materials), you must provide waste containers (e.g., dumpster or trash receptacle) of sufficient size and number to contain construction and domestic wastes. In addition, you must clean up and dispose of waste in designated waste containers on work days; and clean up immediately if containers overflow.

vi. For sanitary waste, you must position portable toilets so that they are secure and cannot be tipped or knocked over.

(d). <u>Washing of Applicators and Containers Used for Paint, Concrete, or Other Materials</u>

To comply with the prohibition in Parts VIII.B.3.c.(1) and (2), you must provide an effective means of eliminating the discharge of water from the washout and cleanout of stucco, paint, concrete, form release oils, curing compounds, and other construction materials. To comply with this requirement, you must:

i. Direct all washwater into a leak-proof container or leak-proof pit. The container or pit must be designed so that no overflows can occur due to inadequate sizing or precipitation.

ii. Handle washout or cleanout wastes as follows:

- Do not dump liquid wastes in storm sewers,
- Dispose of liquid wastes in accordance with applicable requirements in Part VIII.B.3.c.(2).(c).
- Remove and dispose of hardened concrete waste consistent with your handling of other construction wastes in Part VIII.B.3.c.(2).(c).
- Locate any washout or cleanout activities as far away as possible from surface waters and stormwater inlets or conveyances, and,
- To the extent practicable, designate areas to be used for these activities and conduct such activities only in these areas.

(3) Emergency Spill Notification

You are prohibited from discharging toxic or hazardous substances from a spill or other release, consistent with Part VIII.B.3.c.(1).(e). Where a leak, spill, or other release containing a hazardous substance or oil in an amount equal to or in excess of a reportable quantity established under either 40 CFR Part 110, 40 CFR Part 117, or 40 CFR Part 302 occurs during a 24-hour period, you must notify the National Response Center (NRC) at (800) 424-8802 or, in the areas of Oklahoma, call (800) 522-0206 as soon as you have knowledge of the discharge. You must also, within seven (7) calendar days of knowledge of the release, provide a description of the release, the circumstances leading to the release, and the date of the release. Local requirements may necessitate additional reporting of spills or discharges to local emergency response, public health, or drinking water supply agencies.

(4) Fertilizer Discharge Restrictions

You are required to minimize discharges of fertilizers containing nitrogen or phosphorus. To meet this requirement, you must comply with the following requirements:

(a). Apply at a rate and in amounts consistent with manufacturer's specifications, or document departures from the manufacturer specifications.

(b). Apply at the appropriate time of year for your location, and preferably timed to coincide as closely as possible to the period of maximum vegetation uptake and growth.

(c). Avoid applying before heavy rains that could cause excess nutrients to be discharged.

(d). Never apply to frozen ground.

(e). Never apply to stormwater conveyance channels with flowing water.

(f). Follow all other federal, state, tribal and local requirements regarding fertilizer application.

4. **Water Quality Based Effluent Limitations**

Your stormwater discharges must be controlled as necessary to meet applicable water quality standards. Operators seeking coverage under this Permit shall not be causing or have the reasonable potential to cause or contribute to a violation of a water quality standard. Where a discharge is already authorized under this Permit and is later determined to cause or have the reasonable potential to cause or contribute to the violation of an applicable water quality standard, the Director will notify the operator of such violation(s). The permittee shall take all necessary actions to ensure future discharges do not cause or contribute to the violation of a water quality standard and document these actions in the SWP3. If violations remain or re-occur, then coverage under this Permit may be terminated by the Director, and an alternative general permit or individual permit may be issued. Compliance with this requirement does not preclude any enforcement activity as provided by the Clean Water Act (CWA) for the underlying violation. If such violation is determined, the Director may require you to:

- Develop a supplemental BMP action plan describing SWP3 modifications to address adequately the identified water quality concerns;
- Submit valid and verifiable data and information that are representative of ambient conditions and indicate that the receiving water is attaining water quality standards; or
- Cease discharges of pollutants from construction activity and submit an alternative general permit or individual permit application.

a. Discharges to Waters Identified as Impaired Waters

If you discharge to impaired water that is impaired for sediment within one (1) stream mile, you are required to comply with the additional requirement in this part.

(1) Identify if you discharge to impaired waters: If you discharge to impaired waters, you must comply with the following requirements in Part VIII.B.4.a.(2), (3), and (4).

(2) Site inspection requirements: You must conduct site inspections once every seven (7) calendar days at a minimum, and within 24 hours of a storm event of 0.5 inches or greater or within 24 hours of a discharge caused by snowmelt.

(3) Corrective actions: If the inspection or visual examination results indicate any permit violations, you must implement the corrective actions required in Part VIII.B.7.n. However, a violation would result if you fail to implement the required corrective actions.

(4) Stabilization requirements: You are required to comply with the following modified stabilization requirements as specified in Part VIII.3.b within seven (7) calendar days after the temporary or permanent cessation of earth-disturbing activities.

b. Discharges to Waters Identified as an Outstanding Resource Water (ORW) or Aquatic Resource of Concern (ARC)

If you discharge to water identified as ORW or your sites are located within areas identified as an ARC you must implement inspection, corrective actions and stabilization requirements provided in Part VIII.B.3.b. Also you must comply with the following additional requirements:

(1) In order to minimize sediment discharges, if any ORW or ARC is located on or immediately adjacent to your site, you must ensure that a vegetated buffer zone of at least 100 feet is retained or successfully established/planted between the area disturbed and all perennial or intermittent streams. A vegetated buffer zone of at least 50 feet must be retained or successfully established/planted between the areas disturbed during construction and all ephemeral streams or drainages. If the nature of the construction activity or the construction site makes a buffer impossible, you must provide equivalent controls. Use Exhibit 4 (Buffer Guidance) for information to assist you in developing equivalent controls. There are exceptions from this requirement for water crossings, limited water access, and stream restoration authorized under a CWA Section 404 permit.

(2) For drainage locations serving five (5) or more acres disturbed at one time, a temporary (or permanent) sediment basin and/or sediment traps shall be used to minimize sediment discharges within the areas of the ORW or ARC. You may use the information in Part VIII.B.3.a.(11) and VIII.B.7.j.(3) to assist you in complying with this requirement.

(3) For any portion of the site that discharges to an ORW or ARC, instead of the inspection frequency specified in Part VIII.B.7.m.(2), you must conduct

inspections within seven (7) calendar days and within 24 hours of the occurrence of a storm event of 0.5 inches or greater.

(4) For initiating and completing stabilization, you are required to complete the stabilization activities within seven (7) calendar days after the temporary or permanent cessation of earth-disturbing activities.

5. **Endangered Species**

a. Determine whether the project area drains to ARC for construction activities

(1) Refer to Exhibit 1, a map, and a list of all the waters of Oklahoma which the U.S. Fish and Wildlife Service and the Oklahoma Department of Wildlife Conservation consider to be sensitive for construction activities, because they harbor populations of federal or State listed species or their designated critical habitat.

(2) If the proposed construction site is not located within any of these areas, the proposed construction stormwater discharge or stormwater discharge related activities are not likely to significantly affect endangered and threatened species.

(3) If the proposed construction site is located within the corridor of any ARC, you must comply with Part VIII.B.5.

b. Implementation of stormwater control measures to protect endangered and threatened species in ARC

(1) Applicants whose proposed construction site is located within an ARC must incorporate the following measures into the SWP3 for this site unless permit coverage is allowed under Parts I.E.2.d Criteria C, D and E. Other pollutants such as, but not limited to, oil, grease, solid waste (i.e. building material scrap, and trash), and human and hazardous waste, (e.g., paint and solvents), are not authorized for discharge under this Permit. These potential pollutants must be properly managed and their contact with stormwater minimized or eliminated to the greatest extent practicable.

(a). Consistent with Part VIII.B.3, sediment must be retained on site to the greatest extent practicable; all sediment, solid waste, and human waste control measures must be properly installed and maintained at all times; and off-site accumulations of any escaped sediment must be removed.

(b). A vegetated buffer zone of at least 100 feet must be retained or successfully established/planted between the area disturbed during construction and all perennial or intermittent streams on or adjacent to the construction site. A vegetated buffer zone at least 50 feet wide must be retained or successfully established/planted between the areas disturbed during construction and all ephemeral streams or drainages. Buffer zones shall be measured from the top of the first defined bank of the stream and shown on the site map.

If characteristics of the site or the project make it impossible to maintain the required buffer, refer to Exhibit 4 (Buffer Guidance) for information to assist you in developing equivalent sediment controls. You must maintain the buffer or selected alternative throughout your period of coverage under this Permit and no construction activities may be conducted in this area. All discharges through the buffer must be non-channelized or non-concentrated, and must first be treated by the site's sediment and erosion controls.

(c). Document in your SWP3 the following:

i. If the buffer is less than 100 or 50 feet, the width of the buffer vegetation to be retained.

ii. Information you relied on to comply with the requirement to achieve the equivalent sediment load reduction as an undisturbed naturally vegetated 100- or 50-foot buffer.

(d). For any disturbances within the required 100 or 50-foot buffer area, you must comply with the following stabilization requirements, which replace the corresponding requirements in Part VIII.B.3.b:

i. You must immediately initiate stabilization in any exposed areas of the buffer where earth-disturbing activities have permanently or temporarily ceased, and will not resume for a period exceeding seven (7) calendar days. For the purposes of this Permit, earth-disturbing activities have temporarily ceased when clearing, grading, and excavation within any area of your construction site will not resume for a period of 14 or more days, and earth-disturbing activities have permanently ceased when clearing and excavation within any area of your construction site has been completed, and final grade has been reached.

ii. Within seven (7) calendar days of initiating stabilization, you are required to have completed all soil conditioning, seeding, watering, mulching, and any other required activities related to the planting and establishment of vegetation for vegetative cover; and/or the installation or application of all non-vegetative measures for non-vegetative cover.

(e). You are not required to comply with this buffer requirement for the following types of construction projects, provided that you limit the area of disturbance to the minimum needed to complete the construction and to access the site, and that you retain the natural vegetation in the buffer outside this area:

i. Construction of water crossings authorized under a CWA Section 404 permit (where required) for water lines, sewer lines, utility lines, and roadways.

ii. Construction of water-dependent structures and water access areas (piers, boat ramps, etc.) approved under a CWA Section 404 permit (where required) or

iii. Development of a site where no naturally vegetated buffer area exists due to prior disturbances.

(f). You must conduct inspections within 7 calendar days and within 24 hours of a storm event of 0.5 inches or greater instead of the inspection frequency specified in Part VIII.B.7.m.(2).

(g). You must meet any local requirements affecting construction in the buffer.

(2) Consistent with Parts VIII.B.3.b and VIII.B.4.b, an implementation schedule must be included which describes the stabilization practices that will be used to control erosion during construction and when construction has permanently ceased. The preservation of mature vegetation on-site is preferred.

(3) Consistent with Parts VIII.B.3.a and VIII.B.7.j, structural BMPs must be successfully implemented to divert uphill stormwater flows from crossing disturbed areas, to store flows (e.g., retention ponds) or to otherwise control runoff from disturbed areas during construction. At a minimum this must include silt fencing and vegetated buffer strips on all down slope boundaries of the area disturbed during construction. The construction of temporary or permanent stormwater detention or retention structures (e.g., ponds) is preferred, but these should not be constructed within intermittent or perennial stream channels or within floodplains.

(4) Consistent with Part VIII.B.3.a.(10) and VIII.B.7.j.(3).(c), velocity dissipation devices must be incorporated into the design of outfall channels and discharge locations. Outfalls must be screened to prevent the discharge of solid materials with stormwater runoff.

(5) Hazardous construction materials and waste must be stored in a manner that minimizes their contact with stormwater. An emergency response plan must be included which addresses the handling of accidental spills (see Part VIII.B.3.c).

(6) The applicant must comply with any terms and conditions imposed under the eligibility requirements of Part I.E.2 to ensure that its stormwater discharges and stormwater discharge-related activities are protective of listed species and/or critical habitat. Such terms and conditions must be incorporated in the project's SWP3. If the eligibility requirements of Part I.E.2 cannot be met, the applicant may seek relief from the appropriate service in the form of an approved take. As an alternative, the applicant may seek coverage under a DEQ individual permit.

6. **Stormwater Pollution Prevention Plans (SWP3s)**

a. You must develop a preliminary SWP3 template for all construction projects or sites covered by this provision. This SWP3 template represents both controls under common site conditions and needs for unique water quality prevention. You shall use or modify this SWP3 template based on individual sites when it starts a project which is covered under this provision.

b. The SWP3s shall be prepared in accordance with good engineering practices. Use of a licensed professional engineer (PE) for SWP3 preparation is not required by this provision. However, if any part of the SWP3 involves the practice of engineering[5] then those engineering practices and designs are required to be prepared by a licensed professional engineer. The SWP3 shall identify potential sources of pollution that may reasonably be expected to affect the quality of stormwater discharges from the construction site. The SWP3 shall describe and ensure the implementation of practices that will be used to reduce the pollutants in stormwater discharges associated with construction activity at the construction site and assure compliance with the terms and conditions of this provision.

c. When developing SWP3s, small MS4s must determine whether listed endangered or threatened species or critical habitat would be affected by your stormwater discharges or stormwater discharge-related activities. Any information on whether listed species or critical habitats are found in proximity to the construction site must be included in the SWP3. Any terms or conditions that are imposed under Part VIII.B.5 of this provision to protect listed species or critical habitat from stormwater discharges or stormwater discharge-related activity must be incorporated into the SWP3. Small MS4s must implement the applicable requirements of the SWP3 required under this provision. A list and map of "Oklahoma Sensitive Waters and Watersheds Harboring Endangered and Threatened Species and their Critical Habitat of Concern" has been included in Exhibit 1. This information can also be obtained from the DEQ's GIS mapping and Data Viewer at http://maps.deq.ok.gov/deq_wq/MapFrame.asp.

d. If your construction site discharges into a receiving water which has been listed on the Clean Water Act 303(d) list of impaired waters, and your discharges contain the pollutant(s) for which the waterbody is impaired, you must document in your SWP3 how the BMPs and other controls selected for your site will control the discharge of the pollutant(s) of concern. If Part VIII.B.4.a applies to your discharge you must include in your SWP3 the additional requirements specified in that part.

e. Keeping Plans Current! The small MS4s must amend the SWP3 whenever:

5 Statutes and Rules of Oklahoma State Board of Licensure for Professional Engineers & Land Surveyors, Section 472.2 "Definitions" states that the practice of engineering means, "*Any service or creative work, the adequate performance of which requires engineering education, training and experience in the application of special knowledge of the mathematical, physical and engineering sciences to such services or creative work as consultation, investigation, evaluation, planning and design of engineering works and systems, planning the engineering use of land and water, teaching of advanced engineering subjects or courses related thereto, engineering research, engineering surveys, engineering studies, and the inspection or review of construction for the purposes of assuring compliance with drawings and specifications; any of which embraces such services or work, either public or private, in connection with any utilities, structures, buildings, machines, equipment, processes, work systems, projects, and industrial or consumer products or equipment of a mechanical, electrical, chemical, environmental, hydraulic, pneumatic or thermal nature, insofar as they involve safeguarding life, health or property, and including such other professional services as may be necessary to the design review and integration of a multidiscipline work, planning, progress and completion of any engineering services.*"

(1) There is a change in design, construction, operation, or maintenance that has a significant effect on the discharge of pollutants to the waters of the State that has not been addressed in the SWP3 or

(2) Inspections or investigations by site operators, local, State or Federal officials indicate the SWP3 is proving ineffective in eliminating or significantly minimizing pollutants from sources identified under Part VIII.B.7.e, or is otherwise not achieving the general objectives of controlling pollutants in stormwater discharges associated with construction activity.

7. **Contents of SWP3**

The SWP3 shall include the following items:

a. Stormwater Team

Small MS4 must assemble a "stormwater team," which is responsible for overseeing the development of the SWP3, any later modifications to it, and for compliance with the requirements in this Permit. The SWP3 must identify the personnel (by name or position) that are part of the stormwater team, as well as their individual responsibilities. Each member of the stormwater team must have ready access to an electronic or paper copy of applicable portions of this Permit, the most updated copy of your SWP3, and other relevant documents or information that must be kept with the SWP3.

b. Nature of Construction Activities

The SWP3 must describe the nature of the construction activity, including the size of the property (in acres), the total area expected to be disturbed by the construction activities (in acres), construction support activity covered by this Permit, and the maximum area expected to be disturbed at any one time.

c. Sequence and Estimated Dates of Construction Activities

The SWP3 must include a description of the intended sequence of major construction activities, including a schedule of the estimated start dates and the duration of the activity, for the following activities:

(1) Installation of stormwater control measures, and when they will be made operational, including an explanation of how the sequence and schedule for installation of stormwater control measures complies with Part VIII.B.3.a and of any departures from manufacturer specifications.

(2) Commencement and duration of earth-disturbing activities, including clearing and grubbing, mass grading, site preparation (i.e., excavating, cutting and filling), final grading, and creation of soil and vegetation stockpiles requiring stabilization.

(3) Cessation, temporarily or permanently, of construction activities on the site, or in designated portions of the site.

(4) Final or temporary stabilization of areas of exposed soil. The dates for stabilization must reflect the applicable deadlines to which you are subject in Parts VIII.B.3.b and VIII.B.4.b and

(5) Removal of temporary stormwater conveyances/channels and other stormwater control measures, removal of construction equipment and vehicles, and cessation of any pollutant-generating activities.

d. Site Map

The SWP3 must contain a legible site map or series of maps showing the following features of the project:

(1) Boundaries of the property and of the locations where construction activities will occur, including:

(a). Locations where earth-disturbing activities will occur, noting any phasing of construction activities.

(b). Approximate slopes before and after major grading activities. Note areas of steep slopes (i.e., greater than 40%).

(c). Locations where sediment, soil, or other construction materials will be stockpiled.

(d). Locations of any crossings of surface waters.

(e). Designated points on the site where vehicles will exit onto paved roads.

(f). Locations of structures and other impervious surfaces upon completion of construction.

(g). Locations of construction support activity areas covered by this Permit.

(2) Locations of all waters of the State within one mile of the site, including wetlands that exist within or in the immediate vicinity of your site. Indicate which waterbodies are listed as impaired for sediment, and which are identified by the State as ARC or ORW.

(3) The boundary lines of any natural buffers (i.e., either the 100 foot or 50-foot buffer or other buffer areas retained on site) consistent with Parts VIII.B.3.a.(1), and VIII.B.4.b.

(4) Topography of the site, existing vegetative cover (e.g., forest, pasture, pavement, structures)**,** and drainage pattern(s) of stormwater and authorized non-stormwater flow onto, over, and from the site property before and after major grading activities.

(5) Stormwater and allowable non-stormwater discharge locations, including:

(a). Locations of any storm drain inlets on the site and in the immediate vicinity of the site.

(b). Locations where stormwater or allowable non-stormwater will be discharged to waters of the State on or near the site.

(6) Locations of all potential pollutant-generating activities identified in Part VIII.B.7.e.(1) below.

(7) Locations of stormwater control measures.

e. Construction Site Pollutants

The SWP3 must identify all pollutants that you expect to be found at your site and that could be discharge from the site. The SWP3 must also list and describe the activities that are expected to generate these pollutants (or "pollutant-generating activities"). You must provide the following documentation in order to demonstrate your compliance with the permit requirements:

(1) Pollutant-generating activities at the site

The SWP3 must include a list and description of all the pollutant-generating activities on your site. Examples of pollutant-generating activities include, but are not limited to: paving operations; concrete; paint; stucco washout & waste disposal; solid waste storage & disposal; and dewatering operations.

(2) Pollutants

For each pollutant-generating activity, an inventory of pollutants or pollutant constituents (e.g., sediment, paints, solvents, fuels) associated with that activity, which could be exposed to rainfall, snowmelt, and could be discharged from your construction site. You must take into account where potential spills and leaks could occur that contribute pollutants to stormwater discharges. You must also document any departures form the manufacturer’s specifications for applying fertilizers containing nitrogen and phosphorus as required in Part VIII.B.3.c.(4).

f. A copy of this Permit must be included in your SWP3

You may keep this Permit copy electronically and do not submit it to DEQ if you are required to submit your SWP3 for DEQ review.

g. Documentation of Measures to Protect Endangered or Threatened Species

The SWP3 must include information on whether listed endangered or threatened species, or critical habitat, are found in proximity to the construction activity and whether such species may be affected by the small MS4 stormwater discharges or stormwater discharge-related construction activities. You must describe and implement the measures necessary to protect theses endangered species and threatened habitat in the SWP3, including any equivalent sediment controls specified in Exhibit 4 Buffer Guidance or others.

h. Documentation of Federal, State or Local Historic Preservation Laws

The SWP3 must include information on whether stormwater discharges or stormwater discharge-related activities would have an effect on a property that is protected by Federal, State or local historic preservation laws along with any written agreements reached with the State services to mitigate those effects in Part I.D.

i. Documentation of Water Quality Impaired Waters

The SWP3 must include information on whether stormwater discharges or stormwater discharge-related activities would have an effect on water quality impaired receiving waters. The permittee must describe how the BMPs and other controls selected for the site will reduce and avoid the discharges of pollutants of concern into any 303(d) impaired waters, including requirements of Part VIII.B.4.a. The permittee must describe and implement any measures necessary to meet the requirements of an approved TMDL or watershed plan and/or associated implementation schedule established in the TMDL or watershed plan. Monitoring and reporting of discharge quality may also be required if necessary to ensure compliance with an approved TMDL or watershed plan.

j. Stormwater Control Measures

Each SWP3 shall include a description of appropriate control measures (i.e., BMPs) that will be implemented as part of the construction activity to control pollutants in stormwater discharges. The SWP3 must clearly describe for each major activity identified in Part VIII.B.6 appropriate control measures and the general timing (or sequence) during the construction process that the measures will be implemented.

(1) Control Measures to be used during construction activity

You may utilize a national BMP menu to select appropriate control measures for your site. The national menu of Stormwater Best Management Practices can be found on EPA's website at:
http://water.epa.gov/polwaste/npdes/swbmp/index.cfm

(a). The construction-phase erosion and sediment controls should be designed to retain sediment on site to the extent practicable.

(b). All control measures must be properly selected, installed, and maintained in accordance with the manufacturer's specifications and good engineering practices. If periodic inspections or other information indicates a control has been used inappropriately, or incorrectly, the small MS4 must replace or modify the control for site situations.

(c). If sediment escapes the construction site, off-site accumulations of sediment must be removed at a frequency sufficient to minimize offsite impact (e.g., fugitive sediment in street could be washed into storm sewers by the next rain and/or pose a safety hazard to users of public streets).

(d). Sediment must be removed from sediment traps or sedimentation ponds when design capacity has been reduced by 50%.

(e). Litter, construction debris, and construction chemicals exposed to stormwater shall be prevented from becoming a pollutant source for stormwater discharges (e.g., screening outfalls, picked up daily).

(f). Offsite material storage areas (also including overburden and stockpiles of dirt, borrow areas, etc.) used solely by the permitted project are considered a part of the project and shall be addressed in the SWP3.

(g). Many applications of straw and hay bales for erosion and sediment control are proving ineffective, maintenance-intensive and expensive. Therefore, straw or hay bales as BMP controls within the State are not allowed. Alternatives to straw or hay bales can be found on EPA's website at: http://water.epa.gov/polwaste/npdes/swbmp/Straw-or-Hay-Bales.cfm

(2) Stabilization Practice

The SWP3 must describe the specific vegetative and/or non-vegetative stabilization practices that will be used to achieve temporary and final stabilization on the exposed portions of your site as required in Part VIII.B.3.b.

(3) Structural Practices

The SWP3 must include a description of structural practices to divert flows from exposed soils, store flows, or otherwise limit runoff and the discharge of pollutants from exposed areas of the site to the degree attainable. Structural practices may include but are not limited to: silt fences, earth dikes, drainage swales, sediment traps, check dams, subsurface drains, pipe slope drains, level spreaders, storm drain inlet protection, rock outlet protection, reinforced soil retaining systems, gabions, and temporary or permanent sediment basins. Placement of structural practices in floodplains should be avoided to the degree attainable. The installation of these devices may be subject to Section 404 of the CWA.

(a). For common drainage locations that serve an area with ten (10) or more acres disturbed at one time (or 5 acres if required by Part VIII.B.4.b), a temporary (or permanent) sediment basin that provides storage for a calculated volume of runoff from a 2-year, 24-hour storm from each disturbed acre drained, or equivalent control measures, shall be provided where attainable until final stabilization of the site. Where no such calculation has been performed, a temporary (or permanent) sediment basin providing 3,600 cubic feet of storage per acre drained, or equivalent control measures, shall be provided where attainable until final stabilization of the site. When computing the number of acres draining into a common location it is not necessary to include flows from offsite areas and flows from onsite areas that are either undisturbed or have undergone final stabilization where such flows are diverted around both the disturbed area and the sediment basin.

In determining whether installing a sediment basin is attainable, the small MS4s may consider factors such as site soils, slope, available area on site, etc. In any event, the small MS4s must consider public safety, especially as it relates to children, as a design factor for the sediment basin and alternative sediment controls shall be used where site limitations would preclude a safe design. For drainage locations that serve ten (10) or more disturbed acres at one time and where a temporary sediment basin or equivalent controls is not attainable, smaller sediment basins and/or sediment traps should be used. Where neither the sediment basin nor equivalent controls are attainable due to site limitations, silt fences, vegetative buffer strips, or equivalent sediment controls are required for all down slope boundaries of the construction area and for those side slope boundaries deemed appropriate as dictated by individual site conditions. DEQ encourages the use of a combination of sediment and erosion control measures in order to achieve maximum pollutant removal.

(b). For drainage locations serving less than 10 acres, smaller sediment basins and/or sediment traps should be used. At a minimum, silt fences, vegetative buffer strips, or equivalent sediment controls are required for all down slope boundaries (and for those side slope boundaries deemed appropriate as dictated by individual site conditions) of the construction area unless a sediment basin providing storage for a calculated volume of runoff from a 2-year, 24-hour storm or 3,600 cubic feet of storage per acre drained is provided. DEQ encourages the use of a combination of sediment and erosion control measures in order to achieve maximum pollutant removal.

(c). Velocity dissipation devices shall be placed at discharge locations and along the length of any outfall channel when necessary to provide a non-erosive flow velocity from the structure to a water course so that the natural physical and biological characteristics and functions are maintained and protected (e.g. no significant changes in the hydrological regime of the receiving water).

k. Pollution Prevention

(1) Spill Prevention and Response

The SWP3 must describe procedures that you will follow to prevent and respond to spills and leaks, including:

(a). Procedures for expeditiously stopping, containing, and cleaning up spills, leaks, and other releases. Identify the name or position of the employee(s) responsible for the detection and response to spills or leaks.

(b). Procedures for notification of appropriate facility personnel, emergency response agencies, and regulatory agencies where a leak, spill, or other release containing a hazardous substance or oil in an amount equal to or in excess of a reportable quantity consistent with Part 3.2 and established under either 40 CFR Part 110, 40 CFR Part 117, or 40 CFR Part 302, occurs during a 24-hour period. Contact information must be in locations that are readily accessible and available.

You may also reference the existence of Spill Prevention Control and Countermeasure (SPCC) plans developed for the construction activity under Part 311 of the CWA, or spill control programs otherwise required by an OPDES permit for the construction activity, provided that you keep a copy of that other plan onsite.

(2) Waste Management

The SWP3 must describe procedures for how you will handle and dispose of all wastes generated at your site, including, but not limited to, clearing and demolition debris, sediment removed from the site, construction and domestic waste, hazardous or toxic waste, and sanitary waste.

l. Maintenance

All erosion and sediment control measures and other protective measures identified in the SWP3 must be maintained in effective operating condition. If site inspections required by Part VIII.B.7.m identify BMPs that are not operating effectively, maintenance shall be performed before the next anticipated storm event, or as necessary to maintain the continued effectiveness of stormwater controls. If maintenance prior to the next anticipated storm event is impracticable, maintenance must be scheduled and accomplished as soon as practicable.

m. Inspections

(1) Person(s) responsible for Inspecting Site

The person(s) inspecting your site may be a person on your staff or a third party you hire to conduct such inspections. You are responsible for ensuring that the person who conducts inspections is a "qualified person[6]. An inspection form shall be developed and included in your SWP3.

(2) Frequency of Inspections

At a minimum, you must conduct a site inspection once every 14 calendar days and within 24 hours of the end of a storm event of 0.5 inches or greater and within 24 hours of a discharge generated by snowmelt, unless you are subject to Parts VIII.B.4.a or b. If a storm event of 0.5 inches or greater, or snowmelt, causes your site to discharge, within 24 hours of the end of the storm event or the beginning of the snowmelt discharge you must conduct a site inspection when the discharge is occurring and comply with the requirements of Part VIII.B.7.m.(4).

(3) Reductions in Inspection frequency

You may reduce the frequency of inspections to once per month in areas of your site where you have initiated vegetative stabilization that meets the criteria in Part VIII.B.3.b, once you have completed the initial seeding or planting, and provided protection with non-vegetative cover pursuant to Part VIII.B.3.b.(2).(b), or you have installed temporary, non-vegetative stabilization that meet the criteria in Part VIII.B.3.b.(2).(d). If construction

6 A “qualified person” is a person knowledgeable in the principles and practice of erosion and sediment controls and pollution prevention, who possesses the skills to assess conditions at the construction site that could impact stormwater quality, and the skills to assess the effectiveness of any stormwater controls selected and installed to meet the requirements of this Permit.

activity resumes at a later date, the inspection frequency shall immediately increase to that is required in Part VIII.B.7.m.(2).

(4) Requirements for Inspections

(a). Areas that need to be inspected

During your site inspection, you must at a minimum inspect the following areas of your site:

i. All areas that have been cleared, graded, or excavated and that have not yet completed stabilization consistent with Part VIII.B.3.b.

ii. All stormwater controls installed at the site to comply with this provision.

iii. Material/waste/borrow/equipment storage and maintenance areas that are covered by this Permit.

iv. All areas where stormwater typically flows within the site, including drainage ways designed to divert/convey/treat stormwater.

v. All points of discharge from the site.

vi. All locations where stabilization measures have been implemented.

(b). Inspection requirements

During your site inspection, you must:

i. Check whether all erosion and sediment controls and pollution prevention controls are installed, appear to be operational, and are working as intended to minimize pollutants discharges. Determine if any controls need to be replaced, repaired, or maintained in accordance with Part VIII.B.7.n.

ii. Check for the presence of conditions that could lead to spills, leaks, or other accumulations of pollutants on the site.

iii. Identify any locations where new or modified stormwater controls are necessary to meet the requirements of Part VIII.B.3.

iv. At point of discharge and, if applicable, the banks of any surface waters flowing within your property boundaries or immediately adjacent to your property, check for signs of visible erosion and sedimentation (i.e., sediment deposits) that have occurred and are attributable to your discharge. If not accessible, nearby downstream locations must be inspected to the extent practicable.

v. Identify any incidents of noncompliance observed.

vi. If a discharge is occurring during your inspection, you are required to identify all points of the property from which there is a discharge, and observe and document the visual quality of the discharge, and take note of the characteristics of the stormwater discharge, including color, odor, floating, settled, or suspended solids, foam, oil sheen, and other obvious indicators of stormwater pollutants.

Also you are required to document whether your stormwater controls are operating effectively, and describe any such controls that are clearly not operating as intended or are in need of maintenance.

vii. Based on the results of your inspection, you must initiate corrective action under Part VIII.B.7.n.

(5) Inspection Report

(a). You must complete an inspection report within 24-hours of completing any site inspection. Each inspection report must include the following:

i. The inspection date.

ii. Names and titles of personnel making the inspection.

iii. A summary of your inspection finding, covering at a minimum the observations you made in accordance with Part VIII.B.7.m.(4).

iv. If you are inspecting your site at the frequency specified in Parts VIII.B.7.m.(2) and VIII.B.4.a.(2) and conducted an inspection because of rainfall measuring 0.5 inches or greater, you must include the applicable rain gauge or weather station readings that triggered the inspection.

v. If you have determined that it is unsafe to inspect a portion of your site, you must describe the reason you found it to be unsafe and specify the locations that this condition applied to.

(b). Signature Requirements: Each inspection record must be signed in accordance with Part VI.H.

(c). Recordkeeping Requirements: You are required to keep a current, copy of all inspection reports at the site or at an easily accessible location, so that it can be made available at the time of an onsite inspection or upon request by DEQ.

n. Corrective Actions[7]

(1) Requirements for Taking Corrective Action

You must complete the following corrective actions in accordance with the deadlines specified in this part. In all circumstances, you must immediately take all reasonable steps to minimize or prevent the discharge of pollutants until a permanent solution is installed and made operational, including cleaning up any contaminated surfaces so that the material will not discharge in subsequent storm events.

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7 Corrective actions are actions you take in compliance with this Part to (1) repair, modify, or replace any stormwater control used at the site; (2) clean up and dispose of spills, releases, or other deposits; or (3) remedy a permit violation.

(a). For any of the following conditions on your site, you must install a new or modified control and make it operational, or complete the repair, by no later than seven (7) calendar days from the time of discovery. If it is infeasible to complete the installation or repair within seven (7) calendar days, you must document in your records why it is infeasible to complete the installation or repair within the seven (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.

i. A required stormwater control was never installed, was installed incorrectly or not in accordance with the requirements in Parts VIII.B.3 and/or VIII.B.6; or

ii. You become aware that the stormwater controls you have installed and are maintaining are not effective enough for the discharge to meet applicable water quality standards or applicable requirements in Part VIII.B.4; and

iii. One of the prohibited discharges in Parts I.C and VIII.B.3.c is occurring or has occurred.

(b). Where your corrective actions result in changes to any of the stormwater controls or procedures documented in your SWP3, you must modify your SWP3 accordingly within seven (7) calendar days of completing corrective action work.

(2) Corrective Action Records

For each corrective action taken in accordance with this Part, you must complete a corrective action report, which includes the applicable information in this part.

(a). Within 24 hours of discovering the occurrence of one of the triggering conditions in Part VIII.B.7.n.(1).(a) at your site, you must provide a record of the following:

i. Which condition was identified at your site?

ii. The nature of the condition identified.

iii. The date and time of the condition identified and how it was identified.

(b). Within seven (7) days of discovering the occurrence of one of the triggering conditions in Part VIII.B.7.n.(1).(a) at your site, you must complete a record of the following:

i. Any follow-up actions taken to review the design, installation, and maintenance of stormwater controls, including the dates such actions occurred.

ii. A summary of stormwater control modifications taken or to be taken, including a schedule of activities necessary to implement changes, and the date the modifications are completed or expected to be completed.

iii. Notice of whether SWP3 modifications are required as a result of the condition identified or corrective action.

(3) Recordkeeping Requirements

You are required to keep a current copy of all corrective action reports at the site or at an easily accessible location, so that it can be made available at the time of an onsite inspection or upon request by DEQ.

o. Non-Stormwater Discharges

Sources of non-stormwater listed in Parts I.B.2 and VIII.B.2 of this Permit that are combined with stormwater discharges associated with construction activity must be identified in the SWP3. The SWP3 shall identify and ensure the implementation of appropriate pollution prevention measures for the non-stormwater component(s) of the discharge.

EXHIBIT 1: ENDANGERED AND THREATENED SPECIES AND THEIR CRITICAL HABITAT OF CONCERN

A. Aquatic Resources of Concern (ARC) for Federally Listed Species, as Identified by the U.S. Fish & Wildlife Service for the DEQ Municipal Separate Storm Sewer Systems (MS4s) Stormwater General Permit

Grand (Neosho) River: A two-mile corridor (one mile from each bank) of the main stem of the Grand (Neosho) River above its confluence with Tar Creek. This corridor includes portions of Craig and Ottawa counties.

Cimarron River: A two-mile corridor (one mile from each bank) of the main stem of the Cimarron River from the US Hwy-77 Bridge in Logan County upstream to and including Beaver County. This corridor includes river segments in Beaver, Harper, Kingfisher, Logan, Major, Woods, and Woodward counties.

South Canadian River: A two-mile corridor (one mile from each bank) of the main stem from the Eufaula Reservoir flood pool upstream to the northern border of Custer County. This corridor includes river segments in Blaine, Caddo, Canadian, Cleveland, Custer, Grady, Hughes, McClain, McIntosh, Pittsburg, Pontotoc, Pottawatomie, and Seminole counties.

Muddy Boggy River: A two-mile corridor (one mile from each bank) of the main stem of the Muddy Boggy River includes portions of Atoka, Choctaw, and Coal counties.

Kiamichi River: The **watershed** of the Kiamichi River is upstream from the Hugo Reservoir. This watershed includes portions of Atoka, Latimer, Leflore, Pittsburg, and Pushmataha counties.

Little River: The **watershed** of the Little River includes portions of LeFlore, McCurtain, and Pushmataha counties.

Glover River: The **watershed** of the Glover River includes portions of McCurtain and Pushmataha counties.

Mountain Fork River: The **watershed** of the Mountain Fork River is above the Broken Bow Reservoir and includes portions of Leflore and McCurtain counties.

Northeast HUC-11 Watersheds: These **watersheds** are identified by the following 11-digit Hydrologic Unit Codes (HUC): 1107020206030, 11070206060, 11070207190, 11070208070, 11070209020, 11070209030, 11070209040, 11070209050, 11070209060*, 11070209070, 11070209100, 11070209110 and 11070209120. These watersheds include portions of Ottawa, Craig, Delaware, and Mayes Counties.

Elk River: A two-mile corridor (one mile from each bank) of the Elk River includes portions of Delaware and Ottawa counties.

Spring River: A two-mile corridor (one mile from each bank) of the Spring River includes portions of Ottawa County.

Verdigris River: A two-mile corridor of the main stem from the dam of Lake Oologah to the confluence of the Arkansas River. This corridor includes river segments in Rogers, Wagoner, and Muskogee counties.

B. ARC for State Listed Species, as Identified by the Oklahoma Department of Wildlife Conservation for the DEQ Municipal Separate Storm Sewer Systems (MS4s) Stormwater General Permit.

Illinois River – A **ten-mile** corridor (five miles from each bank within the watershed) of the main stem of the Illinois River begins above the Tenkiller Reservoir. This corridor includes portions of Cherokee, Delaware, and Mayes counties.

Lee and Little Lee Creeks: The **watershed** of Lee Creek and Little Lee Creek includes portions of Adair and Sequoyah counties.

Note: No stormwater discharge-sensitive endangered or threatened species occur in the following counties: Alfalfa, Beckham, Carter, Cimarron, Comanche, Garfield, Garvin, Grant, Greer, Johnston, Kiowa, Lincoln, Murray, Nowata, Okfuskee, Oklahoma, Okmulgee, Rogers, Stephens, Texas, Washington, or Washita.

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* This HUC does not contain a known Ozark cavefish cave. It was included because it is entirely surrounded by 11 digit HUCs with known Ozark cavefish caves. Therefore, we assume that Ozark cavefishes likely occupy this portion of the aquifer.

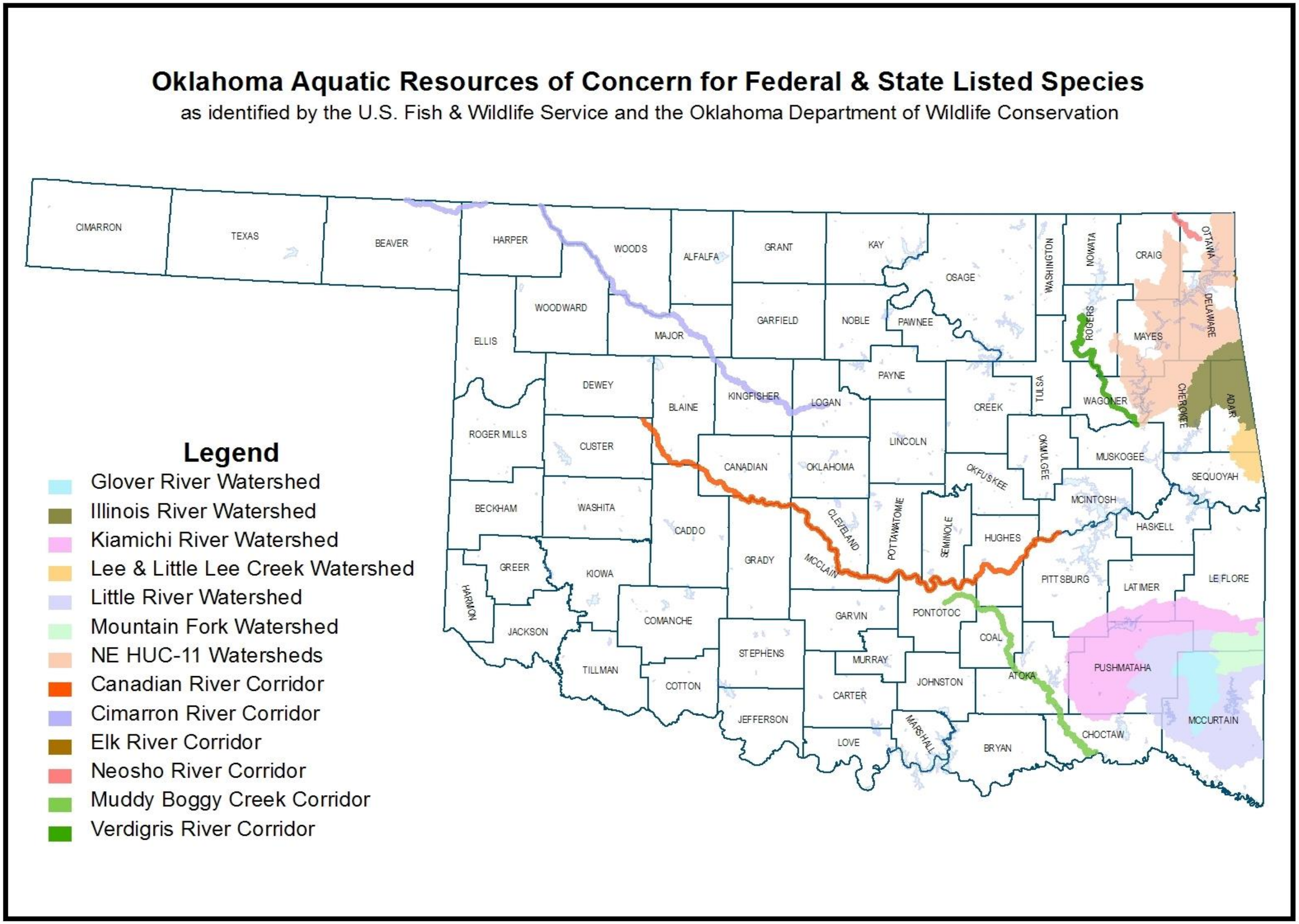

Oklahoma Aquatic Resources of Concern for Federal & State Listed Species
as identified by the U.S. Fish & Wildlife Service and the Oklahoma Department of Wildlife Conservation
Legend
Glover River Watershed
Illinois River Watershed
Kiamichi River Watershed
Lee & Little Lee Creek Watershed
Little River Watershed
Mountain Fork Watershed
NE HUC-11 Watersheds
Canadian River Corridor
Cimarron River Corridor
Elk River Corridor
Neosho River Corridor
Muddy Boggy Creek Corridor
Verdigris River Corridor
CIMARRON
TEXAS
BEAVER
HARPER
WOODS
ALFALFA
GRANT
KAY
OSAGE
WASHINGTON
NOWATA
CRAIG
OTTAWA
WOODWARD
ELLIS
MAJOR
GARFIELD
NOBLE
PAWNEE
ROGERS
MAYES
DELAWARE
DEWEY
KINGFISHER
LOGAN
PAYNE
CREEK
TULSA
WAGONER
CHEROKEE
ADAIR
BLAINE
ROGER MILLS
CUSTER
CANADIAN
OKLAHOMA
LINCOLN
OKMULGEE
MUSKOGEE
SEQUOYAH
OKFUSKEE
BECKHAM
WASHITA
CADDO
CLEVELAND
POTTAWATOMIE
SEMINOLE
MCINTOSH
HUGHES
HASKELL
GRADY
MCCLAIN
GREER
KIOWA
HARMON
PITTSBURG
LATIMER
LE FLORE
JACKSON
COMANCHE
GARVIN
PONTOTOC
COAL
PUSHMATAHA
STEPHENS
MURRAY
TILLMAN
COTTON
JOHNSTON
ATOKA
CARTER
MCCURTAIN
JEFFERSON
MARSHALL
CHOCTAW
LOVE
BRYAN

EXHIBIT 2: NOTICE OF INTENT

DEQ FORM 605-R04 November 1, 2015	OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY	**Oklahoma Department of Environmental Quality** **Notice of Intent (NOI) for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems (MS4s) Under OPDES General Permit OKR04**

Please print or type: All items should be completed as accurately as possible and in their entirety. Please refer to Part 4 of the permit OKR04 for information about the required items. An original signature of the applicant is required according to PART VI.H in the permit OKR04. Use additional pages to fully describe your responses.

Note: Municipality is defined as a federal, state, city, town, county, district, association, or other public body (created by or pursuant to Oklahoma or Federal law), including special districts under State law such as a storm sewer district, flood control or drainage district, or similar entity, or a designated and approved management agency under Section 208 of the CWA.

1. **Name and address of the permit applicant and local contact:**

Name of the small MS4: ____________________

Address: ____________________

City: ____________________

County: ____________________ State: __________

Circle the appropriate letter to indicate the legal status of the operator of the facility: **F** = Federal; **S** = State; **M** = Municipal (public other than Federal or State, i.e. as city, county); **P** = Private

F S M P

ZIP Code: __________+________

Telephone Number: (_____)______________ E-mail Address: ____________________

Name and Title of Stormwater Management Program Manager: ____________________

2. **Co-permittee:** Are you co-permitting with another entity? **Yes** ☐ **No** ☐ **If yes**, complete the following:

____________________ ____________________

Name of the Co-permittee Name and Title of Stormwater Management Program Manager

____________________ ______________ ______________

Mailing Address City ZIP

Telephone Number: (_____)______________ E-mail Address:____________________

Circle the letter for type of facility: **F**ederal, **S**tate, **M**unicipal, **P**rivate **F S M P**

Certification by the co-permittee is required in Section 9.

Latitude: ______________ Longitude: ______________

3. **Facility/Site Location:** Attach a map showing your MS4 boundaries. Your MS4 jurisdiction shall cover the entire area within the corporate boundaries of the municipality if your city is not located entirely within an Urbanized Area.

Name of the small MS4: ____________________ County: ______________

Street Address: ____________________ City: ____________________

Latitude: ____________/Longitude:______________ Approximate area of the MS4:__________ square miles

Latitude/Longitude: If you do not have this information, go to the DEQ Flexviewer at http://gis.deq.ok.gov/flexviewer/.

4. **Will another entity provide services to perform some portion or all of the Best Management Practices (BMPs) for the six minimum control measures** (PART IV.C) **or TMDL supplemental conditions** (PART III.B)**?**

Yes ☐ No ☐ **If yes**, attach a statement listing their name and the service they will be providing.

5. **Receiving waters for discharges of stormwater from your MS4:** Use additional pages if needed.

Name of Waterbodies	**Impaired?**	**Impairment**	**Source of Impairment**
______________________	Yes No	__________	______________________
______________________	Yes No	__________	______________________
______________________	Yes No	__________	______________________

Do you discharge into waterbodies on the Oklahoma 303(d) list of impaired waters? Yes ☐ No ☐

If yes, you must ensure that impairment caused by identified pollutants in your receiving waters will, in future discharges, not cause, have the reasonable potential to cause, or contribute to an in-stream exceedance of WQ standards and comply with PART III.A.1

Do you discharge into receiving waterbodies with an established TMDL or watershed plan? Yes ☐ No ☐

If yes, you must adopt any Wasteload Allocation (WLA) assigned to your discharges specified in the TMDL as measurable goals and include any limitations, conditions, monitoring, and other requirements associated with a TMDL implementation plan within specified timeframes.

Do you discharge into an Outstanding Resource Water (ORW)? Yes ☐ No ☐

If yes, you must document in your SWMP how you will comply with WQ standard prohibitions (PART III.C).

6. **Outline of Measurable Goals and BMPs**

Attach an updated description of your Stormwater Management Program (SWMP). You shall include details of BMPs that will be implemented and the measurable goals for each of the six stormwater minimum control measures, the month and year in which the MS4 operator will start and fully implement each of the control measures or the frequency of the action, and the name of the person(s) responsible for implementing or coordinating the SWMP.

7. **Endangered Species**

Based on the requirements of Part I. E and Exhibit 1, does your municipality discharge into an Aquatic Resource of Concern?

Yes ☐ No ☐ **If yes**, which criterion listed in Part I.E is your municipality using to meet eligibility requirements?

Criterion ____________________

Certification of this NOI will constitute your certification of compliance with the endangered species requirements of this Permit.

8. **Construction by the Permitted Municipality**

You have the option to develop permit requirements (PART VIII) that allow the municipality to cover all municipalities owned and operated construction sites under this Permit rather than filing a separate OKR10 NOI with the DEQ for each such project.

Will the municipality include the optional permit requirements into your SWMP and permit? Yes ☐ No ☐

9. **Certification of Permittee**

"I certify, under penalty of law, that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who manage the system or those persons directly responsible for gathering the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations."

______________________	______________________
Signature of Applicant	Date Signed
______________________	______________________
Name (printed)	Title

Certification of Co-Permittee (if applicable)

______________________	______________________
Signature of Co-Permittee	Date Signed
______________________	______________________
Name (printed)	Title

EXHIBIT 3: NOTICE OF TERMINATION

DEQ FORM 605-R04B November 1, 2015	OKLAHOMA DEPARTMENT OF ENVIRONMENTAL QUALITY	**Oklahoma Department of Environmental QualityNotice of Termination (NOT) for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems (MS4s) Under OPDES General Permit OKR04**

Submission of this Notice of Termination constitutes notice that the party identified in Section I of this form is no longer authorized to discharge stormwater from the small MS4 under the OPDES program.

All Requested Information Must Be Provided On This Form. See Instructions On The Back of Form.

Permit Information: OPDES Stormwater General Permit Number: OKR04____________________________	**Check here if the stormwater MS4 discharge(s) is being terminated:** ☐	**Check here if the facility is changing ownership or the operator has ceased operations at the small MS4:** ☐

I. Facility Operator Information:

Name: ____ Phone______________________

Address:____

City: ____________________________ County:________________ Zip Code____________

Email: ____

II. Facility/Site Location:

Name: ____ Phone______________________

Address:____

City: ____________________________ County:________________ Zip Code____________

Latitude: ________________ Longitude: ________________

III. Certification:

I certify under penalty of law that all stormwater discharges from the identified MS4 that are authorized by an OPDES general permit have been eliminated, or that I am no longer the operator of the MS4, or that I have ceased operations at the MS4. I understand that by submitting this Notice of Termination I am no longer authorized to discharge stormwater under this Permit, and that discharging pollutants in stormwater to waters of the State is unlawful under the Clean Water Act and OAC 252:606-1-3(b)(3) where the discharge is not authorized by an OPDES permit. I also understand that the submission of this Notice of Termination does not release an operator from liability for any violations of this Permit, the Clean Water Act, and the Oklahoma Pollution Discharge Elimination Act.

Print Name: ____Date:____________________

Signature:____ Title__________________________

Instructions for Completing Notice of Termination (NOT) for Stormwater Discharges from Small MS4s Under OPDES General Permit OKR04

When To File NOT Form:

Permittees who are presently covered under an issued OPDES general permit for stormwater discharges from a Phase II MS4 must submit a **Notice of Termination (NOT)** to DEQ within 30 days when the permittee:

- Ceases discharging stormwater from the MS4,
- Ceases operations at the MS4, or
- Transfers ownership or responsibility for the facility to another operator.

An NOT terminates coverage under the general permit and must include the following information:

- Name, mailing address, and location of the MS4 for which the notification is submitted.
- The name, address, telephone number and email of the operator addressed by the NOT.
- The OPDES permit number for the Phase II MS4.
- An indication of whether another operator has assumed responsibility for the MS4, the discharger has ceased operations at the MS4, or the stormwater discharges have been eliminated.
- The NOT must be signed in accordance with PART VI.H of this Permit

Authorization to discharge terminates at midnight on the day the NOT is signed.

If you need assistance or have questions, contact the Watershed Planning and Stormwater Permitting Section of DEQ's Water Quality Division at (405) 702-8100.

Section I: Permit Information

Enter the existing OPDES General Stormwater Permit authorization number assigned to the facility or site identified in Section II.

Section II: Facility Operator Information

Give the legal name of the person, firm, public organization or any other entity that operates the MS4. The operator of the MS4 is the legal entity that controls the MS4's operation.

Section III: Facility/Site Location Information

Enter the MS4's official or legal name and complete address. This must include the MS4's city, county, and ZIP code. Indicate the latitude and longitude of the MS4's City Hall or approximately the geographical center of the MS4. For lat/long information, go to the DEQ Flexviewer at http://gis.deq.ok.gov/flexviewer/.

Section IV: Certification

The NOT form must be signed by a responsible party. For a municipality, State, Federal, or other public agency, a responsible party is either a principal executive officer or ranking elected official. For purposes of this Section, a principal executive officer of a Federal agency includes (i) the chief executive officer of the agency, or (ii) a senior executive officer having responsibility for the overall operations of a principal geographic unit of the agency (e.g., Regional Administrator of EPA).

Where to File a NOT form:

NOTs must be submitted to DEQ using one of the following methods:

Mailing address:

DEQ - Water Quality Division
P.O. Box 1677
Oklahoma City, Oklahoma 73101-1677

FAX:

405-702-8101
c/o Water Quality Division
Stormwater Permitting

Bring it physically to DEQ:

707 North Robinson
Oklahoma City
Ask for Stormwater in the
Water Quality Division

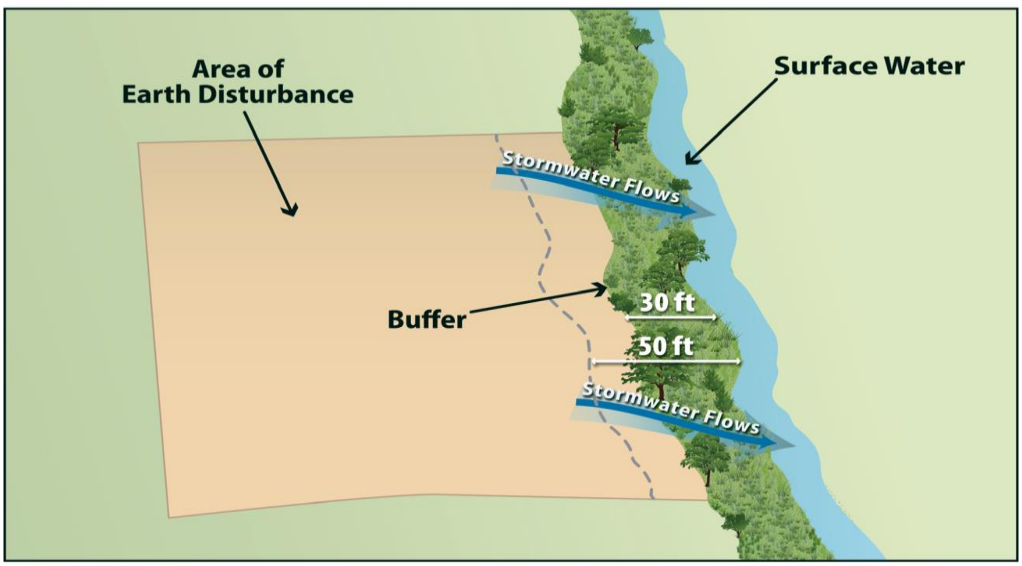
EXHIBIT 4: BUFFER GUIDANCE

The purpose of this guidance is to assist you in complying with the requirements in Parts VIII.B.3.a.(1) and VIII.B.4.b.(1) of this Permit regarding the establishment of natural buffers or equivalent sediment controls.

Step 1 - Determine Whether 100 Feet or 50 Feet of Natural Buffer Is Required

If your land disturbing activities will occur within the Aquatic Resources of Concern which are identified by USFWS and ODWC, a vegetated buffer of at least 100 feet is required between the area disturbed and all perennial or intermittent streams on or adjacent to the construction site, or a vegetated buffer of at least 50 feet is required between the area disturbed and all ephemeral streams. If your disturbing activities will be adjacent to the waters of the State, a vegetated buffer of at least 50 feet is required. Figure 4.1 illustrates when a site would be required to comply with the requirements in Part VIII.B.3.a.(1) due to their proximity to surface waters. If the surface water is not located within 50 feet of the earth-disturbing activities, Part VIII.B.3.a.(1) does not apply. If you determine that the buffer requirements apply to your site and those buffer requirements cannot be met, you may continue on to Step 2.

Figure 4.1: Example of Earth-Disturbing Activities within 50 feet of a Surface Water



Step 2 - Determine Compliance Alternatives to the Buffer Requirements

You have three compliance alternatives from which you can choose:

Alternative 1: Provide and maintain a 100-foot or 50-foot undisturbed natural buffer; or

Alternative 2: Provide and maintain an undisturbed natural buffer that is less than 100-feet or 50-feet and is supplemented by additional erosion and sediment controls, which in combination achieves the sediment load reduction equivalent to a 100-foot or 50-foot undisturbed natural buffer; or

Alternative 3: If it is infeasible to provide and maintain an undisturbed natural buffer of any size, you must implement erosion and sediment controls that achieve the sediment load reduction equivalent to a 100-foot or 50-foot undisturbed natural buffer.

The compliance alternative selected above must be maintained throughout the duration of permit coverage. The following provides detailed guidance for how you can comply with each of the compliance alternatives. Part 1 below provides guidance on how to provide and maintain natural buffers consistent with the Alternatives 1 and 2. Part 2 below provides guidance on how to comply with the requirement to provide a 100-foot or 50-foot buffer equivalent through erosion and sediment controls consistent with Alternative 2 and 3.

1. Guidance for Providing and Maintaining Natural Buffers

The following guidance is intended to assist you in complying with the requirements to provide and maintain a natural buffer during construction. This part of the guidance applies to you if you choose either Alternative 1 (100-foot or 50-foot buffer) or Alternative 2 (a buffer of < 100 feet or < 50 feet supplemented by additional erosion and sediment controls that achieve the equivalent sediment load reduction as the 100-foot or 50-foot buffer).

a. Buffer Width Measurement

Where you are retaining a buffer of any size, the buffer should be measured perpendicularly from any of the following points, whichever is further landward from the water:

(1) The ordinary high water mark of the waterbodyy, defined as the line on the shore established by fluctuations of water and indicated by physical characteristics such as a clear, natural line impressed on the bank, shelving, changes in the character of soil, destruction of terrestrial vegetation, and/or the presence of litter and debris; or

(2) The edge of the stream or river bank, bluff, or cliff, whichever is applicable.

Refer to Figure 4.2 and Figure 4.3. You may find that specifically measuring these points is challenging if the flow path of the surface water changes frequently, thereby causing the measurement line for the buffer to fluctuate continuously along the path of the waterbody. Where this is the case, DEQ suggests that rather than measuring each change or deviation along the water’s edge, it may be easier to select regular intervals from which to conduct your measurement. For instance, you may elect to conduct your buffer measurement every 5 to 10 feet along the length of the water.

b. Limits to Disturbance within the Buffer

You are considered to be in compliance with this requirement if you retain and protect from construction activities the natural buffer that existed prior to the commencement of construction. If the buffer area contains no vegetation prior to the commencement of construction (e.g., sand or rocky surface), you are not required to plant any additional vegetation. As noted above, any preexisting structures or impervious surfaces are allowed in the buffer provided you retain and protect from disturbance the vegetation in the buffer outside the preexisting disturbance.

To ensure that the water quality protection benefits of the buffer are retained during construction, you are prohibited from conducting any earth-disturbing activities within the buffer during permit coverage.

Figure 4.2

This image shows buffer measurement from the ordinary high water mark of the waterbody, as indicated by a clear natural line impressed on the bank, shelving, changes in the character of the soil, destruction of terrestrial vegetation, and/or the presence of litter/debris.

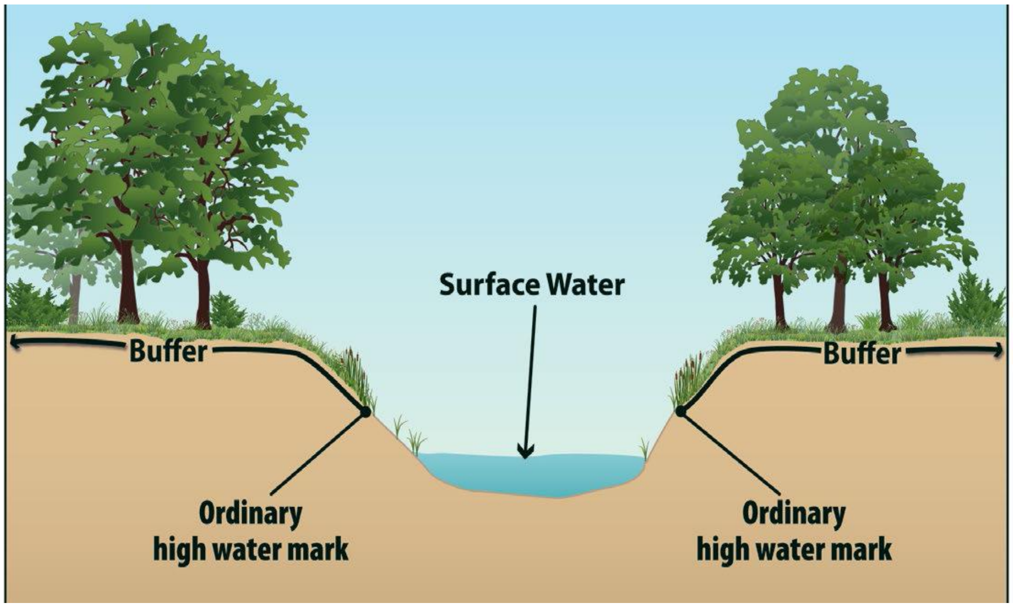
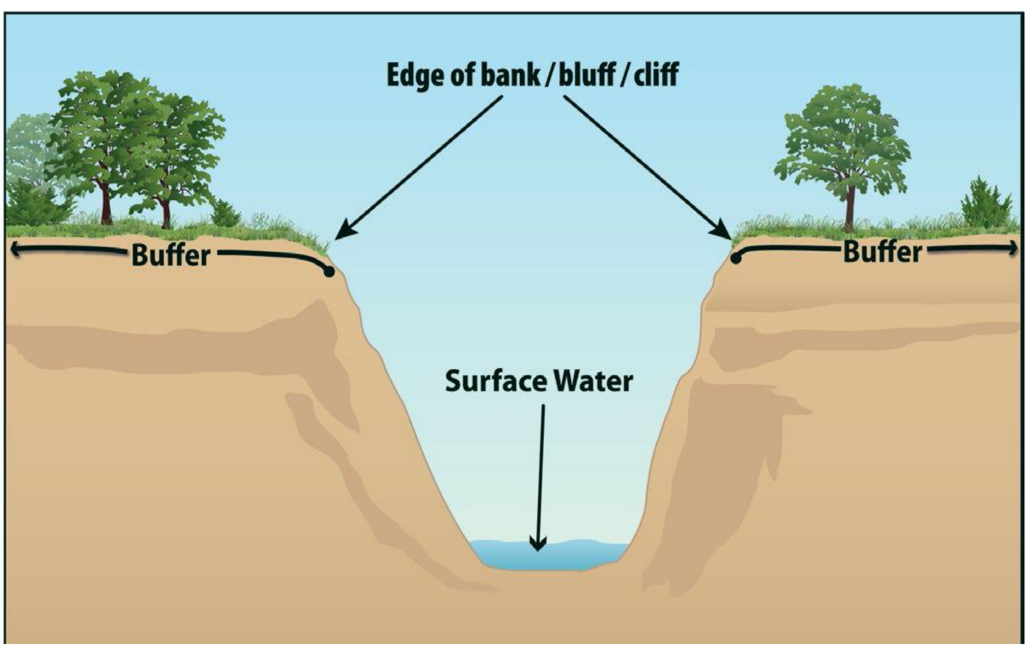


Figure 4.3

This image shows buffer measurement from the edge of the bank, bluff, or cliff, whichever is applicable.



c. Discharges to the Buffer: You must ensure that all discharges from the area of earth disturbance to the natural buffer are first treated by the site's erosion and sediment controls (*for example, you must comply with the Part VIII.B.3.a.(6).(b) requirement to establish sediment controls around the downslope perimeter of your site disturbances*), and if necessary to prevent erosion caused by stormwater flows within the buffer, you must use velocity dissipation devices.

d. SWP3 Documentation: You must document the reduced width of the buffer you will be retaining and you must also describe the erosion and sediment controls you will use to achieve an equivalent sediment reduction, as described in Part 2 below. Note that you must also show any buffers on your site plan in your SWP3. Additionally, if any disturbances related to the exceptions in Part VIII.B.3.a.(1) occur within the buffer area, you must document this in the SWP3.

2. Guidance for Providing the Equivalent Sediment Reduction as the 100-foot or 50-foot Buffer

If you are selecting Alternative 2 (provide and maintain a buffer that is less than 100feet or 50 feet that is supplemented by additional erosion and sediment controls that, together, achieve the equivalent sediment load reduction as the 100-foot or 50-foot buffer) or Alternative 3 (implement erosion and sediment controls that achieve the equivalent sediment load reduction as the 100-foot or 50-foot buffer), the following guidance is intended to assist you in demonstrating that you will achieve the equivalent sediment reduction as the 100-foot or 50-foot buffer.

a. <u>Determine Whether It Is Feasible to Provide a Reduced Buffer</u>

DEQ recognizes that there will be a number of situations in which it will be infeasible to provide and maintain a buffer of any width. While some of these situations may exempt you from the buffer requirement entirely (See Part VIII.B.3.a.(1), if you do not qualify for one of these exemptions, there still may be conditions or circumstances at your site that make it infeasible to provide a natural buffer. For example, there may be sites where a significant portion of the property on which the earth-disturbing activities will occur is located within the buffer area, thereby precluding the retention of natural buffer areas. DEQ believes there are likely to be other examples of situations that make it infeasible to provide any buffer area.

Therefore, in choosing between the 2 different compliance alternatives (Alternative 2 or 3), you should only elect to comply with Alternative 2 if it is feasible for you to retain any natural buffer on your site. (Note: For any buffer width retained, you are required to comply with the requirements in Part 1, above, concerning the retention of vegetation and restricting earth disturbances.) Similarly, if you determine that it is infeasible to provide a natural buffer of any size during construction, you should elect to comply with Alternative 3. After making this determination, you should proceed to Part 2 to determine how to provide controls that, together with any buffer areas that is being retained, if applicable, will achieve an equivalent sediment load reduction as the 100-foot or 50-foot buffer. You must describe why it is infeasible to provide and maintain an undisturbed natural buffer of any size in the SWP3.

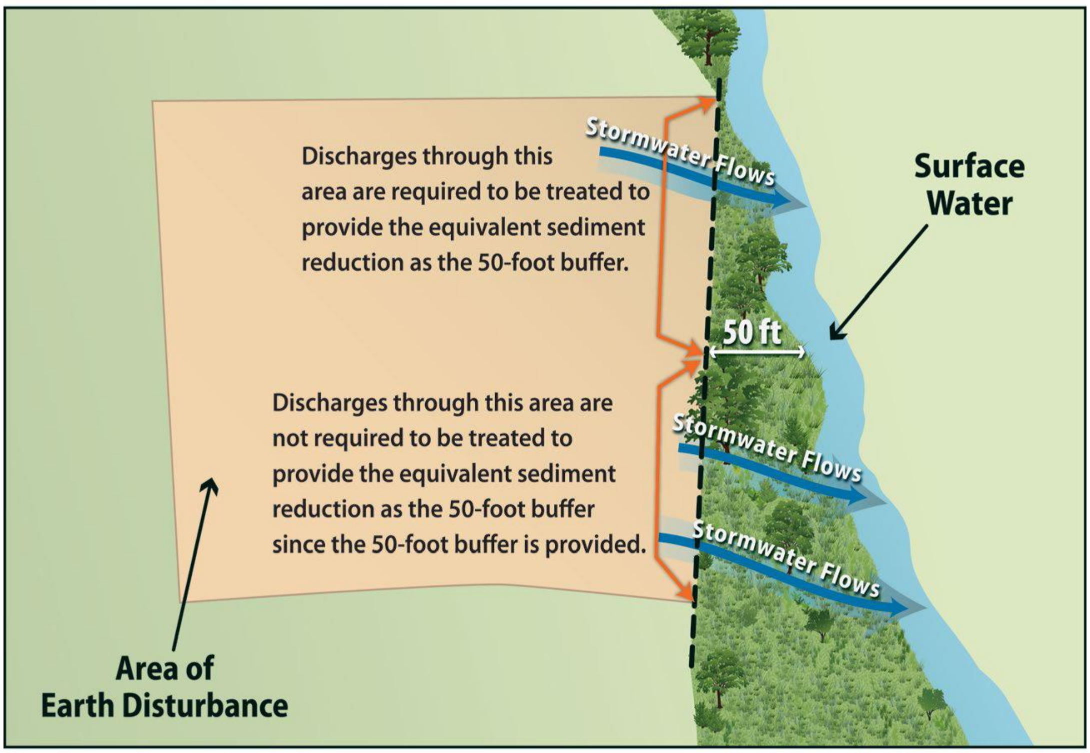
b. Design Controls That Provide Equivalent Sediment Reduction as 100-foot or 50-foot Buffer

You must next determine what additional controls must be implemented on your site alone or in combination with any retained natural buffer, to achieve a reduction in sediment equivalent to that achieved by a 100-foot or 50-foot buffer.

Note that if only a portion of the natural buffer is less than 50 feet, you are only required to implement erosion and sediment controls that achieve the sediment load reduction equivalent to the 100-foot or 50-foot buffer for discharges through that area. You would not be required to provide treatment of stormwater discharges that flow through 100 feet 50 feet or more of natural buffer. See Figure 4.4.

Figure 4.4

Example of how to comply with the requirement to provide the equivalent sediment reduction when only a portion of your earth-disturbances discharge to a buffer of less than 100 feet or 50 feet



Guidelines to help you work through these requirements are provided below:

Step 1: Estimate the Sediment Reduction from Your Site if You Had Retained a 100-foot or 50-foot Natural Buffer

In order to design controls that match the sediment removal efficiency of a 100-foot or 50- foot buffer, you first need to know what this efficiency is for your site. The sediment removal efficiencies of natural buffers vary according to a number of site-specific factors, including precipitation, soil type, land cover, slope length, width, steepness, and the types of sediment controls used to reduce the discharge of sediment prior to the buffer. DEQ has simplified this calculation by developing buffer performance tables covering a range of vegetation and soil types for the areas covered by the permit. See Attachment 1, Tables 4.1 through 4.4.

Note: buffer performance values in Tables 4.1 through 4.4 represent the percent of sediment captured through the use of perimeter controls (e.g., silt fences) and 100-foot or 50-foot buffers at disturbed sites of fixed proportions and slopes. Using Tables 4.1 through 4.4 (see Attachment 1), you can determine the sediment removal efficiency of a 100-foot or 50-foot buffer for your geographic area by matching the vegetative cover type and the type of soils that predominate at your site. For example, if your site is located in Oklahoma City (see Table 4.1), and your buffer vegetation corresponds most closely with that of fescue grass, and the soil type at your site is best typified as sand, your site's sediment removal efficiency would be 90 percent.

In this step, you should choose the vegetation type in the tables that most closely matches the vegetation that would exist naturally in the buffer area on your site regardless of the condition of the buffer. However, because you are not required to plant any additional vegetation in the buffer area, in determining what controls are necessary to meet this sediment removal equivalency in Step 2 below, you will be able to take credit for this area as a fully vegetated "natural buffer."

Similarly, if a portion of the buffer area adjacent to the surface water is owned by another party and is not under your control, you can treat the area of land not under control as having the equivalent vegetative cover and soil type that predominates on the portion of the property on which your construction activities are occurring. *For example, if your earth-disturbances occur within 50 feet of a surface water, but the 10 feet of land immediately adjacent to the surface water is owned by a different party than the land on which your construction activities are taking place and you do not have control over that land, you can treat the 10 foot area adjacent to the stream as having the equivalent soil and vegetation type as predominates in the 40 foot area under your control. You would then make the same assumption in Step 2 for purposes of determining the equivalent sediment removal.*

Alternatively, you may do your own calculation of the effectiveness of the 50-foot buffer based upon your site-specific conditions, and may use this number as your sediment removal equivalency standard to meet instead of using Tables 4.1 through 4.4. This calculation must be documented in your SWP3.

Step 2: Design Controls That Match the Sediment Removal Efficiency of the 100-foot or 50-foot Buffer

Once you have determined the estimated sediment removal efficiency of a 100-foot or 50-foot buffer for your site in Step 1, you will be required to select stormwater controls that will provide an equivalent sediment load reductions.

To make the determination that your controls and/or buffer area achieve an equivalent sediment load reduction as the 100-foot or 50-foot buffer, you may use stormwater controls listed in Tables 4.1 through 4.4 to select a single designed control, such as 12” or 6” waddle, roll material, silt fence or straw mulch (see Attachment 1), or you will need to use a model or other type of calculator. There are a variety of models available that can be used to support your calculation, including USDA’s RUSLE-series programs and the WEPP erosion model, SEDCAD, SEDIMOT, or other models.

Alternatively, you may elect to install a combination of stormwater controls and to retain some amount of a buffer. Whichever control(s) you select, you must demonstrate in your SWP3 that the controls will provide at a minimum the same sediment removal capabilities as the 100-foot or 50-foot buffer (Step 1). You are allowed to take credit for the removal efficiencies of your required perimeter controls in your calculation of equivalency, because these were included in calculating the buffer removal efficiencies in Tables 4.1 through 4.4. (Note: You are reminded that the controls must be kept in effective operating condition until you have completed final stabilization on the disturbed portions of the site discharging to the surface water.)

If you are retaining a buffer of less than 100 feet or 50 feet, you may take credit for the removal that will occur from the reduced buffer and only need to provide additional controls to make up the difference between the removal efficiency of a 100-foot or 50-foot buffer and the removal efficiency of the narrower buffer. For example, if you are retaining a 30 foot buffer, you can account for the sediment removal provided by the 30-foot buffer retained, and you will only need to design controls to make up for the additional removal provided by the 20-foot of buffer that is not being provided. To do this, you would plug the width of the buffer that is retained into RUSLE or another model, along with other stormwater controls that will together achieve a sediment reduction equivalent to a natural 50-foot buffer.

As described in Step 1 above, you can take credit for the area you have retained as a “natural buffer” as being fully vegetated, regardless of the condition of the buffer area. *For example, if your earth-disturbances occur 30 feet from a surface water, but the 10 feet of land immediately adjacent to the surface water is owned by a different party than the land on which your construction activities are taking place and you do not have control over that land, you can treat the 10-foot area as a natural buffer, regardless of the activities that are taking place in the area. Therefore, you can assume (for purposes of your equivalency calculation) that your site is providing the sediment removal equivalent of a 30-foot buffer, and you will only need to design controls to make up for the additional removal provided by the 20- foot of buffer that is not being provided.*

Step 3: Document How Site-Specific Controls Will Achieve the Sediment Removal Efficiency of the 100-foot or 50-foot Buffer

In Steps 1 and 2, you determined both the expected sediment removal efficiency of a 100-foot or 50-foot buffer at your site, and you used this number as a performance standard to design controls to be installed at your site, which alone or in combination with any retained natural buffer, achieves the expected sediment removal efficiency of a 100-foot or 50-foot buffer at your site. The final step is to document in your SWP3 the information you relied on to calculate the equivalent sediment reduction as an undisturbed natural buffer. DEQ will consider your documentation to be sufficient if it generally meets the following:

For Step 1: Refer to the Table in Attachment 1 that you used to derive your estimated 100-foot or 50-foot buffer sediment removal efficiency performance. Include information about the buffer vegetation and soil type that predominate at your site, which you used to select the sediment load reduction value in Tables 4.1 through 4.4. Or, if you conducted a site-specific calculation for sediment removal efficiency, provide the specific removal efficiency, and the information you relied on to make your site-specific calculation.

For Step 2: (1) Specify a single designed stormwater control (see Table 4.1 thru 4.4) or other stormwater controls that you used to estimate sediment load reductions from your site. Specify a model or other type of calculator that you used to support your calculation if any.

(2) The results of calculations showing how your controls will meet or exceed the sediment removal efficiency from Step 1. If you choose Alternative 3, you must also include in your SWP3 a description of why it is infeasible for you to provide and maintain an undisturbed natural buffer of any size.

ATTACHMENT 1

Sediment Removal Efficiency Tables: Percent of sediment removal was calculated for a 200-foot runoff area with a 100-foot buffer, and a 100-foot runoff area with a 50-foot buffer. DEQ recognizes that very high removal efficiencies, even where theoretically achievable by a 50-foot or 100-foot buffer, may be very difficult to achieve in practice using alternative controls. Therefore in the tables below, DEQ has limited the removal efficiencies to a maximum of 90%. Efficiencies that were calculated at greater than 90% are shown as 90%, and this is the minimum percent removal that must be achieved by alternative controls.

Best Management Practices Defined

- Fescue: Buffer strip (100 feet or 50 feet) at the end of the overland flow path of Fescue grass, the area has not been grazed
- Grama Grass: Buffer strip (100 feet or 50 feet) at the end of the overland flow path of Grama grass, at least the third year after seeding
- Range Grass: Buffer zone (100 feet or 50 feet) at the end of the overland flow path of a generic low production range grass
- Switchgrass: Buffer zone (100 feet or 50 feet) at the end of the overland flow path of Switchgrass growth
- Weeds: Buffer zone (100 feet or 50 feet) at the end of the overland flow path of at least 5 years of growth of generic weeds started from volunteer germination
- 12” Waddle: 12 inch straw sock or wattle installed at the base of the runoff area
- 6” Waddle: 6 inch straw sock or wattle installed at the end of the overland flow path
- Roll Material: Erosion control blanket placed over the disturbed area
- Silt Fence: Full retardance fabric silt fence installed at the end of the overland flow path
- Straw Mulch: Straw mulch applied over the disturbed area, 4000 lbs/acre

Soils Defined

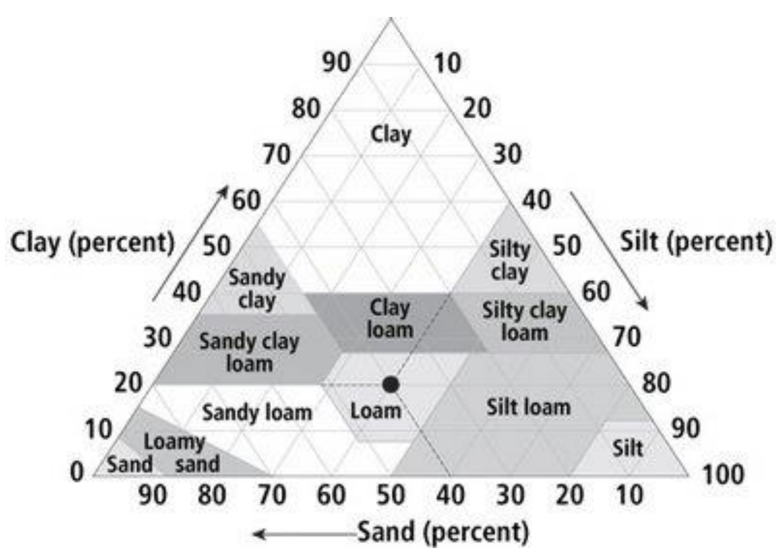


Table 4.1: Estimated Buffer Performance of Blade Fill in OKC, Oklahoma *

Best Management Practices**	Estimated % Sediment Removal										
	Clay	Silty Clay	Silty Clay Loam	Clay Loam	Silt Loam	Loam	Sandy Loam	Silt	Sandy Clay Loam	Loamy Sand	Sand
Fescue (100' Buffer)	90	90	90	90	90	90	90	90	90	90	90
Fescue (50' Buffer)	90	90	90	90	90	90	90	90	90	90	90
Grama Grass (100' Buffer)	74	79	79	79	78	78	78	76	78	74	71
Grama Grass (50' Buffer)	65	77	78	78	78	78	77	76	74	67	50
Range Grass (100' Buffer)	89	90	92	90	90	90	90	90	90	90	90
Range Grass (50' Buffer)	89	90	90	90	90	90	90	90	90	90	89
Switchgrass (100' Buffer)	90	90	90	90	90	90	90	90	90	90	90
Switchgrass (50' Buffer)	90	90	90	90	90	90	90	90	90	90	90
Weeds (100' Buffer)	47	49	48	50	48	49	50	46	50	50	48
Weeds (50' Buffer)	42	47	47	48	47	49	48	46	48	45	41
12" Waddle	86	74	72	84	56	72	82	27	86	90	90
6" Waddle	38	58	56	67	45	62	69	20	62	55	24
Roll Material	90	90	90	90	90	90	90	90	90	90	90
Silt Fence	86	77	80	90	70	83	89	43	90	90	90
Straw Mulch	85	87	87	86	88	87	83	90	87	89	89

Table 4.2: Estimated Buffer Performance of Blade Cut in OKC, Oklahoma *

Best Management Practices**	Estimated % Sediment Removal										
	Clay	Silty Clay	Silty Clay Loam	Clay Loam	Silt Loam	Loam	Sandy Loam	Silt	Sandy Clay Loam	Loamy Sand	Sand
Fescue (100' Buffer)	88	90	90	90	90	90	90	90	90	90	88
Fescue (50' Buffer)	87	88	90	90	90	90	90	90	90	89	84
Grama Grass (100' Buffer)	24	52	70	63	74	72	70	71	48	33	11
Grama Grass (50' Buffer)	24	39	65	54	71	70	60	70	39	15	10
Range Grass (100' Buffer)	78	85	89	90	90	90	90	89	88	84	24
Range Grass (50' Buffer)	77	83	89	89	90	90	90	89	85	80	68
Switchgrass (100' Buffer)	86	89	90	90	90	90	90	90	90	90	85
Switchgrass (50' Buffer)	85	88	90	90	90	90	90	90	90	88	81
Weeds (100' Buffer)	18	26	33	31	33	34	35	28	26	22	15
Weeds (50' Buffer)	23	22	32	31	31	35	31	28	22	15	14
12" Waddle	80	72	71	81	55	70	80	25	84	83	73
6" Waddle	9	11	47	35	43	57	51	19	17	0	1
Roll Material	90	90	90	90	90	90	90	90	90	90	90
Silt Fence	86	76	80	90	69	82	88	40	90	90	90
Straw Mulch	90	90	90	90	90	90	90	90	90	90	90

Table 4.3: Estimated Buffer Performance of Blade Fill Tulsa, Oklahoma *

Best Management Practices**	Estimated % Sediment Removal										
	Clay	Silty Clay	Silty Clay Loam	Clay Loam	Silt Loam	Loam	Sandy Loam	Silt	Sandy Clay Loam	Loamy Sand	Sand
Fescue (100' Buffer)	90	90	90	90	90	90	90	90	90	90	90
Fescue (50' Buffer)	90	90	90	90	90	90	90	90	90	90	90
Grama Grass (100' Buffer)	74	80	79	79	78	78	77	76	79	76	69
Grama Grass (50' Buffer)	65	76	79	79	78	77	77	75	76	67	52
Range Grass (100' Buffer)	90	90	90	90	90	90	90	90	90	90	90
Range Grass (50' Buffer)	89	89	90	90	90	90	90	90	90	90	90
Switchgrass (100' Buffer)	90	90	90	90	90	90	90	90	90	90	90
Switchgrass (50' Buffer)	90	90	90	90	90	90	90	90	90	90	90
Weeds (100' Buffer)	50	50	48	51	50	50	49	47	51	51	48
Weeds (50' Buffer)	43	48	47	49	48	47	49	45	49	44	40
12" Waddle	86	74	71	83	55	70	81	24	86	90	90
6" Waddle	39	60	55	67	44	59	69	18	65	53	25
Roll Material	90	90	90	90	90	90	90	90	90	90	90
Silt Fence	86	76	79	90	69	82	89	41	90	90	90
Straw Mulch	84	86	87	86	87	86	86	89	86	87	88

Table 4.4 Estimated Buffer Performance of Blade Cut in Tulsa, Oklahoma *

Best Management Practices**	Estimated % Sediment Removal										
	Clay	Silty Clay	Silty Clay Loam	Clay Loam	Silt Loam	Loam	Sandy Loam	Silt	Sandy Clay Loam	Loamy Sand	Sand
Fescue (100' Buffer)	88	90	90	90	90	90	90	90	90	90	87
Fescue (50' Buffer)	87	89	90	90	90	90	90	90	90	90	83
Grama Grass (100' Buffer)	29	52	73	62	75	74	70	70	52	33	9
Grama Grass (50' Buffer)	18	45	64	57	73	72	63	70	38	25	10
Range Grass (100' Buffer)	79	85	89	90	90	90	90	87	89	85	72
Range Grass (50' Buffer)	76	84	88	90	90	90	90	88	86	81	69
Switchgrass (100' Buffer)	86	89	90	90	90	90	90	90	90	90	85
Switchgrass (50' Buffer)	84	88	90	90	90	90	90	90	90	89	81
Weeds (100' Buffer)	21	30	33	32	34	35	34	26	30	24	15
Weeds (50' Buffer)	19	27	31	30	33	34	32	28	24	19	14
12" Waddle	79	74	69	80	55	70	80	26	84	84	73
6" Waddle	0	18	46	37	43	58	54	19	14	6	0
Roll Material	90	90	90	90	90	90	90	90	90	90	90
Silt Fence	86	77	79	89	68	81	88	39	90	90	90
Straw Mulch	90	90	90	90	90	90	90	90	90	90	90

* Applicable for sites less than nine percent slope

** Characterization focuses on the under-story vegetation

CITY OF NORMAN
STORMWATER MANAGEMENT PROGRAM
FOR PHASE II MS4 COMPLIANCE
2016 TO 2020

Appendix B

MCM - 1 Public Education

City of Norman Stormwater Management Program

BMP	Goal	Implementation Date	Frequency
Distribute informational brochure with utility bills	One brochure to 75% of all utility accounts	1-Feb-16	Annually
Add storm water pollution prevention information to city web site	Information posted	1-Feb-16	Annual review/update
Operate Action Center Hotline	Receive and respond to 90% of legitimate complaints	1-Feb-16	Annually
Public stormwater education event	Coordinate with Environmental Services for Earth Day event	1-Feb-16	Annually
Educational event & materials for schools	Supply material to 2 elementary schools annually and participate in Public Works Week event at local school	1-Feb-16	Annually
Newspaper ads	Quarterly ads in local paper with water quality, pollution prevention or watershed protection information	1-Feb-16	Annually
Develop SWPP brochure for fertilizer use	Distribute to 75% of all utility accounts	1-Jul-16	Once
Develop Spanish language SWPP brochure	Develop Spanish language storm water pollution prevention informational materials	1-Jul-16	Once
Develop educational materials on the Lake Thunderbird TMDL	Provide educational material to the public about water quality impairments in Lake Thunderbird and the Lake Thunderbird TMDL	1-Jul-16	Annually

Responsible Person(s) for performance of these BMPs:	Carrie Evenson Stormwater Engineer

MCM - 2 Public Participation and Involvement

City of Norman Stormwater Management Program

BMP	Goal	Implementation	Frequency
Establish web site link for receipt of email regarding storm water issues	Respond to 90% of all emails received	1-Feb-16	Annually
Environmental Control Advisory Board	A storm water quality representative will meet with ECAB quarterly to provide information on storm water pollution issues.	1-Feb-16	Annually
Operate Action Center Hotline	Receive and respond to 90% of legitimate complaints	1-Feb-16	Annually
Public meeting for storm water issues	Hold one public meeting annually	1-Feb-16	Annually
Public Storm Water Education Event	Coordinate with Environmental Services for one event annually	1-Feb-16	Annually
Blue Thumb/Oklahoma Conservation Commission Partnership	Maintain working relationship with Blue Thumb and coordinate for one for onestorm water public education event annually	1-Feb-16	Annually
Lake Thunderbird TMDL public meeting	Hold one public meeting annually for education and discussion of the Lake Thunderbird TMDL	1-Jul-16	Annually

Responsible Person(s) for performance of these BMPs:	Carrie Evenson Stormwater Engineer

MCM - 3 Illicit Discharge Detection and Elimination

City of Norman Stormwater Management Program

BMP	Goal	Implementation Date	Frequency
Operate Action Center Hotline	Receive and respond to 90% of complaints received.	1-Feb-16	Annually
Household Hazardous Waste Collection Day	Provide annual event for the public to drop off unwanted household waste and report amount of waste collected	1-Feb-16	Annually
Dry Weather Field Screening	90% of visual screening points inspected each year	1-Feb-16	Annually
Illicit Discharge Investigations	Perform source investigation on all identified illicit discharges and connections	1-Feb-16	Annually
Enforcement Actions	Take enforcement actions as allowed by City regulations where responsible parties for illicit discharges are identified	1-Feb-16	Annually
Inspect MS4 System	Visually inspect open channels and camera enclosed conduits. Inspect 10% of system each year.	1-Jul-18	Annually

Responsible Person(s) for performance of these BMPs:	Carrie Evenson Stormwater Engineer

MCM - 4 Construction Stormwater Runoff Control

City of Norman Stormwater Management Program

BMP	Goal	Implementation Date	Frequency
Earth Change Permit	Permit 90% of all earth disturbing operations over 1 acre in size within 30 days of permit issuance	1-Feb-16	Annually
Construction site inspection	Inspect 90% of sites within 30 days of permit issuance and at least monthly. Perform enforcement actions as needed	1-Feb-16	Annually
Education event for construction/development	Hold two events for developers, constuction crews, utility contractors and engineering companies	1-Feb-16	Annually
Water Quality Protection Zone Ordinance	Implement requirements of the Water Quality Protection Zone Ordinance including establishment and maintenance of streamside buffers	1-Feb-16	Annually
Lake Thunderbird TMDL building/development workshop	Hold annual workshop for the building and development community on the Lake Thunderbird TMDL compliance requirements and Lake Thunderbird watershed protection	1-Jan-17	Annually

Responsible Person(s) for performance of these BMPs:	Carrie Evenson Stormwater Engineer

MCM - 5 Post-Construction Stormwater in New/Redevelopment

City of Norman Stormwater Management Program

BMP	Goal	Implementation Date	Frequency
Review/ammend City engineering and development regulations	Remove any barriers to Low Impact Development (LID)	1-Jul-17	Review every 5 years
Implement Water Quality Protection Zone (WQPZ) ordinance	Establish water quality protection zones in riparian areas	1-Jul-16	Annually
Fertilizer Ordinance	Implement the Manufactured Fertilizer Ordinance to educate the public and commercial fertilizer applicators on proper fertilizer use	1-Jul-16	Annually
Storm water impoundment inspection	Inspect 50% of storm water impoundments	1-Jul-16	Annually
Post-Construction Events	Include information on post-construction BMPs in construction/development events listed for MCM 4	1-Jul-16	Annually

Responsible Person(s) for performance of these BMPs:	Carrie Evenson Stormwater Engineer

MCM - 6 Good-Housekeeping for Municipal Operations   City of Norman Stormwater Managemet Program

BMP	Goal	Implementation Date	Frequency
Develop employee training program	Provide one training session for75% of targeted employees	1-Jan-17	Annually
Street Sweeping	Sweep at least 2500 curb miles annually to prevent sediment, debris and pollutants from entering	1-Jul-16	Annually
City facility storm water inspections	Inspect half of all facilites identified as potential sources of storm water pollution	1-Jul-16	Annually
Map City facility storm sewer systems	Locate all SS inlets and outfalls at two City facilites every year	1-Jan-17	2 facilities annually until complete
Spill Kits	Provide spill containment kits to 25% of City vehicles	1-Jul-16	Annually
Employee Newsletter	Distribute storm water pollution prevention information to City Employees through the newsletter once each quarter	1-Feb-16	Annually
Employee education on Lake Thunderbird TMDL	Incorporate Lake Thunderbird TMDL requirements into City employee training events.	1-Jul-16	Annually
Implement BMPs for City Operations	Implement BMPs for parks and landscape maintenance, water and sewer line maintenance, and MS4 maintenance	1-Jan-17	Annually

Responsible Person(s) for performance of these BMPs:	Carrie Evenson Stormwater Engineer

CITY OF NORMAN
STORMWATER MANAGEMENT PROGRAM
FOR PHASE II MS4 COMPLIANCE
2016 TO 2020

Appendix C

FINAL

STORM WATER MASTER
NORMAN, OKLA

PBS&J
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Document No. 080238
PBS&J Job No. 441941

NORMAN

FINAL REPORT

STORM WATER MASTER PLAN
NORMAN, OKLAHOMA

REGISTERED PROFESSIONAL ENGINEER
DUKE GALEN ALTMAN
19039
OKLAHOMA

Duke G. Altman
10/9/09

Prepared for:

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Norman, Oklahoma 73072-7267

October 2009

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Acronyms and Abbreviations

°F	degrees Fahrenheit
µg/l	micrograms per liter
ac-ft	acre-feet
BMP	best management practice
BNSF	Burlington Northern and Santa Fe Railroad
cfs	cubic feet per second
CIP	Capital Improvement Projects
City	City of Norman, Oklahoma
CLOMR	Conditional Letter of Map Revision
CMP	corrugated metal pipe
COMCD	Central Oklahoma Master Conservancy District
DO	dissolved oxygen
EPA	U.S. Environmental Protection Agency
ERU	equivalent runoff/residential unit
ESU	equivalent storm water unit
FC	fecal coliform
FEMA	Federal Emergency Management Agency
FIS	Flood Insurance Study
ft	feet/foot
FY	fiscal year, October 1 through September 30
GIS	Geographic Information System
GO	general obligation
H:V	horizontal to vertical side slope ratio
HEC	U.S. Army Corps of Engineers Hydrologic Engineering Center
HEC-RAS	USACE HEC's River Analysis System
IH	Interstate Highway
LIDAR	light detection/distance and ranging
LOMR	Letter of Map Revision
MCM	minimum control measures
MS4	municipal storm water separate storm sewer systems
MSE	mechanically stabilized earth
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service
NSQD	National Stormwater Quality Database
O&M	operations and maintenance
OCARTS	Oklahoma City Area Regional Transportation Study
OCC	Oklahoma Conservation Commission
ODEQ	Oklahoma Department of Environmental Quality
OPDES	Oklahoma Pollutant Discharge Elimination System
OWRB	Oklahoma Water Resources Board
PBCR	primary body contact recreation
POA	Property Owner Association

Project Identification Numbers (for flood-related and stream erosion problems identified within Norman, Oklahoma)	BC	Bishop Creek
	BHC	Brookhaven Creek
	CC	Clear Creek
	CR	Canadian River
	DBC	Dave Blue Creek
	IC	Imhoff Creek
	LR	Little River Mainstem
	TGLR	Little River, Tributary G
	WC	Little River, Woodcrest Creek
	MC	Merkle Creek
	RC	Rock Creek
	TMF	Ten Mile Flat

RCB	reinforced box culvert
RFD	Rapid Floodplain Delineation
ROW	right of way
SH	State Highway
SPC	stream planning corridor
sq ft	square feet
SSO	sanitary sewer overflow
SSURGO	Soil Survey Geographic Database
State	State of Oklahoma
SWAT	Soil Water Assessment Tool
SWMP	Storm Water Master Plan
SWS	sensitive water supply
TMDL	Total Maximum Daily Load
T-P	total phosphorus
TSS	total suspended solids
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
WPA	Work Projects Administration
WQS	Water Quality Standards

Acknowledgements

This Storm Water Master Plan was developed by the City of Norman's Public Works and Planning Departments with technical and professional assistance from PBS&J, Halff Associates, Inc., and Vieux, Inc. A great number of Norman residents have dedicated their time and effort to provide input and guidance as part of this master planning undertaking. A special thanks go to these individuals listed below.

City of Norman, City Council

Cindy S. Rosenthal	Mayor
Bob Thompson (ended 2009)	Ward 1
Alan Atkins (began 2009)	Ward 1
Tom Kovach	Ward 2
Hal Ezzell	Ward 3
Carol Dillingham	Ward 4
Rachel Butler	Ward 5
James Griffith	Ward 6
Doug Cubberley	Ward 7
Dan Quinn	Ward 8

City of Norman Staff

Steve Lewis	City Manager
Shawn O'Leary	Public Works Director
Bob Hanger	City Engineer
Patrick Copeland	Development Services Manager
Aaron Milligan	Storm Water Pollution Specialist
Cody Whittenburg	Storm Water Pollution Inspector
Julie Shelton	Administrative support

Norman Stormwater Task Force Members

Trey Bates	Norman Developers Council
Geoff Canty	ECAB Board Member/Norman Area Land Conservancy Board Member

Norman Stormwater Task Force Members, cont'd

Ellen Censky	Sam Noble Museum of Natural History
Russ Dutnell	Geomorphologist/Sole Proprietor – Riverman Engineering
Jane Ingels	Greenbelt Commission
Jim Gasaway	Planning Commissioner
Joan Goth	Parks Board Member
Chris Lewis	Board of Directors – Summit Lakes Homeowners Association
Curtis McCarty	Planning Commission/Home Builders Association President
Richard McKown	Greenbelt Commission/Norman Developers Council Chairman
Richard Ryan	University of Oklahoma
Lyntha Wesner	Greenbelt Commission, Imagine Norman, Parks Advocate

Advisory Committee

Trey Bates	Norman Developers Council
Geoff Canty	Environmental Control Advisory Board
Joan Goth	Parks Board
Curtis McCarty	Planning Commission
Joyce Pitchlynn	Tree Board
Duane Winegardner	Central Oklahoma Master Conservancy District

Technical Committee

Glen Brown	Geologist
Dan Butler	Oklahoma Conservation Commission
Alan Haws	Planning Commission
Tom McCaleb	SMC Consulting Engineers
Sarah Peterson	University of Oklahoma
Richard Ryan	University of Oklahoma
Jean Vieux	Vieux and Associates, Inc.

EXECUTIVE SUMMARY

As the county seat of Cleveland County and home of the University of Oklahoma, the City of Norman is a large and diverse community that is proactive on a wide range of issues, including its land and water environments. The City encompasses almost 190 square miles, including almost 30 square miles that has been developed to accommodate its current population of approximately 112,000. As Norman has grown in population and further urbanized many of its watersheds, the resulting impacts on flooding, water quality, and erosion have increased significantly. Of particular concern, Lake Thunderbird's water quality has deteriorated significantly, which is a condition that could directly impact all of Norman's citizens. At the same time, the recreational opportunities offered by the City's waterways have become increasingly apparent and desirable. Given these and other related factors, the City initiated development of a Storm Water Master Plan (SWMP) in late 2005 with its primary goals aimed at reducing flooding dangers, protecting water quality, enhancing the environment, and advancing recreational opportunities. Development of the present SWMP project began in August 2007 and includes all City watersheds. The SWMP incorporates "quality of life" elements for Norman's citizens by outlining measures to manage creek corridors and floodplains in an environmentally sound manner while offering opportunities for increased recreational activities. A Greenway Master Plan is being developed by the City (Halff Associates, Inc. [Halff], 2009) in parallel with the SWMP and is also nearing completion. This greenway plan is being produced in a separate report although opportunities and constraints were shared between the two studies.

The overall approach to development of the SWMP involved the use of existing information and data to the extent possible, building on that base with new information and data, and performing the analyses needed to meet the SWMP goals. Realizing that local public input was a critical component in fulfilling the goals of the SWMP, a Storm Water Task Force was formed to coordinate ongoing project issues and provide guidance on local perspectives. Several meetings with City Council members, the SWMP Task Force, and City staff as well as three public meetings were held to review ongoing study efforts, discuss project progress, and coordinate the SWMP work flow. Additional City Council workshops, public meetings, and numerous other related meetings are being held throughout 2009.

STUDY LEVELS

In order to focus on the primary stream systems and provide detailed evaluations in the areas having the worst problems, analyses associated with watershed/stream assessments, stream flooding, and stream erosion were performed at different "levels" of study detail based on the needs of the City. Generally, Levels 1 and 2 were studied in detail and Levels 3 and 4 were more generally studied. All watersheds in the City were studied in some capacity, but depending on needs some were analyzed in detail while others were considered using more general methods. Exhibit ES-1 identifies the level of study undertaken for respective streams throughout the City. In consideration of the amount of future urbanization projected to occur in the City, data and other useful information were obtained from the Norman 2025 Plan. **In this report, any reference to this plan should be considered to mean the "Norman 2025 Plan and subsequent updates to this comprehensive plan as adopted by the City Council."**

WATERSHED AND STREAM ASSESSMENTS

Assessments were developed for 36 watersheds that carry storm water into, through, and/or within the City of Norman. Although most of the watersheds are located in the City of Norman, several also originate north of the City, flow into the Little River, and ultimately discharge into Lake Thunderbird. Exhibit ES-1 outlines boundaries of the 15 major watersheds that were further subdivided into the 36 assessed watersheds by separating out larger tributaries or simply separating the watersheds into upper, middle, and lower divisions. In order to quantify and spatially locate certain physiographic characteristics within a watershed, GIS datasets collected from various sources were analyzed and used to develop watershed-specific tables and presentation maps that outline descriptive information such as land use, hydrologic soil groups, floodplains, and impervious cover. Stream corridor environments were similarly analyzed to identify conditions such as erosion problem areas, channel type, floodplain vegetation, Federal Emergency Management Agency (FEMA) flood zone type, and number of storm water outfalls.

HYDROLOGIC AND HYDRAULIC MODELING

Three complementary hydrologic and hydraulic modeling approaches were used in the development of design flows for the master plan. The most detailed of the three methods utilized either the USACE HEC-1 (existing models) or HEC-HMS (some existing and all new models) software. The second approach, used for the development of flows for the Stream Planning Corridors, utilized a USGS regression equation. The third approach, used in limited cases for site-specific drainage issues, was the Rational Method per the City of Norman design criteria. Hydrologic analyses were performed for 307 square miles of drainage area that includes the City's 190 square miles within its boundaries. Hydraulic analyses and floodplain mapping were developed for almost 400 stream miles, which included 59 miles along detailed (Level 1 and 2) streams and 333 miles along general (Level 3 and 4) streams.

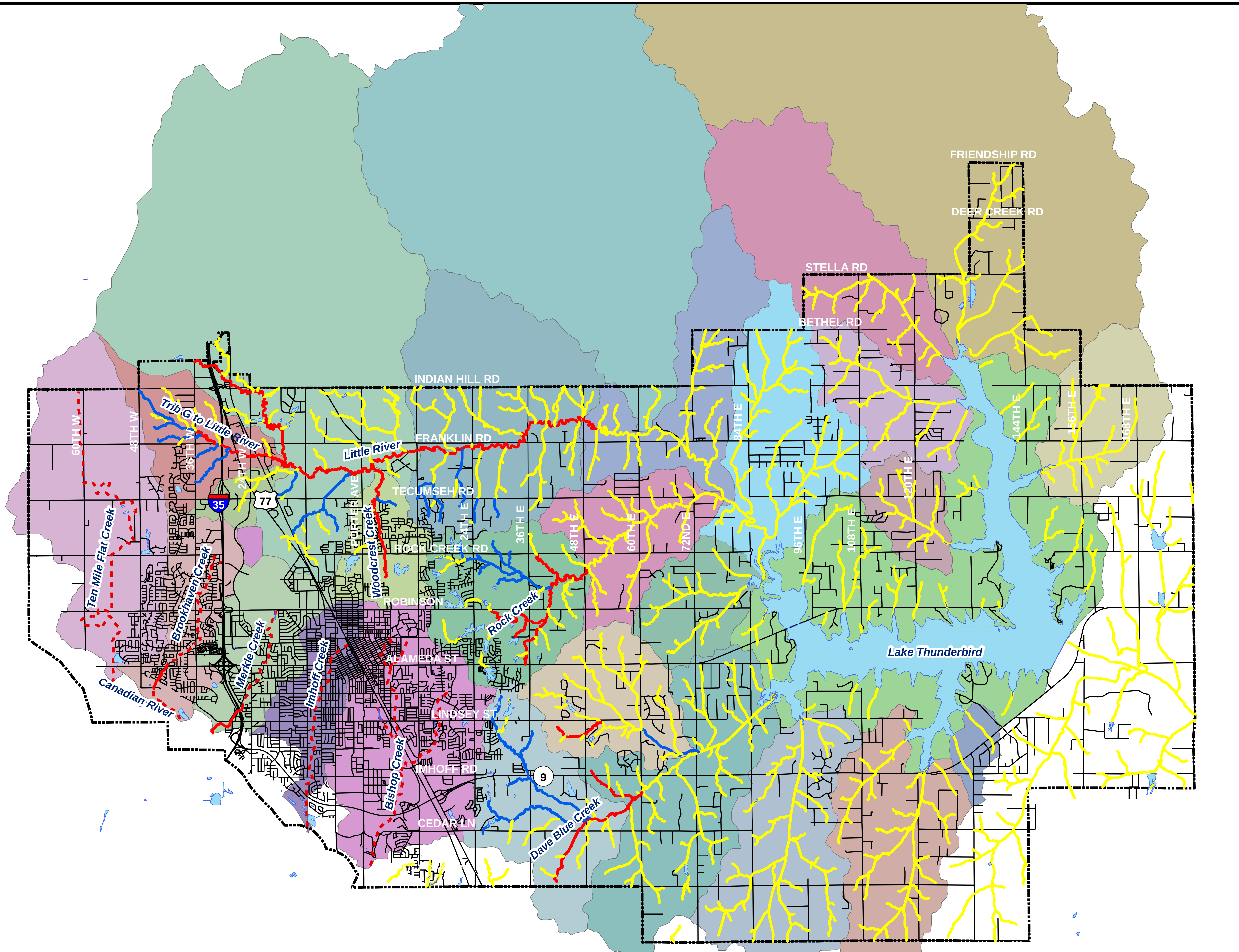
STORM WATER PROBLEMS AND SOLUTIONS

Storm water problem identification and solution development for the detailed study areas were grouped into stream flooding, stream erosion, water quality, and local drainage to assist in understanding the overall magnitude of such problem types in the City. The identification of problems was accomplished through a variety of means including the review and evaluation of items such as: the City's GIS data; past water quality studies; hydrologic and hydraulic modeling and mapping; watershed and stream assessments; input obtained from the City, various committees, and the SWMP Task Force; and input received from the general public as provided through the City staff and during public meetings. Although existing conditions were reviewed and considered, the identification and evaluation of flooding along major streams primarily focused on future (baseline) full buildout watershed conditions that reflect projected development levels in the City's 2025 Plan and subsequent updates to this comprehensive plan as adopted by the City Council. The identification of stream erosion problems was primarily based on existing conditions consistent with the watershed and stream assessments.

Norman Storm Water Master Plan
Exhibit ES-1
Study Areas

City of Norman
201 West Gray, Bldg. A
Norman, OK 73069

PBSJ



Legend

- Lake
- New Models-Detailed (Level 1)
- Existing Models-Detailed (Level 2)
- Future Detailed (Level 3)
- New General (Level 4)
- Road Centerline

City Watersheds

- Bishop Creek
- Brookhaven Creek
- Direct Lake Thunderbird Runoff
- Imhoff Creek
- Lower Dave Blue Creek
- Lower Little River
- Lower Mid Little River
- Lower Rock Creek
- Merkle Creek
- Ten Mile Flat Creek
- Trib to Dave Blue Creek
- Tributary G to Little River
- Upper Dave Blue Creek
- Upper Rock Creek
- Woodcrest Creek

Note: Level 3 and Level 4 are Stream Planning Corridors

N

0 4,500 9,000 Feet

In developing solutions, considerations were made to incorporate items such as improving and/or protecting stream environmental integrity by using bio-engineering and natural channel design techniques, preserving the historical character of an existing solution type such as the WPA-constructed channels found in the upper Imhoff and Bishop Creek watersheds, improving water quality, and identifying greenway opportunities. Solutions were developed in a way to recognize and respect the conditions and character of the respective watershed in which the problem exists. In addition to considering the opportunities for preserving or enhancing environmental and recreational conditions, the solution development process included the consideration of various possible alternatives or options and review of preliminary findings with City staff as well as the project Task Force to obtain their feedback and guidance.

Due to their “non-point source” nature, the identification of water quality problems and related solutions development were evaluated on a citywide scale consistent with procedures used for similarly sized cities throughout the country. This citywide approach to addressing water quality involves a programmatic approach which is now ongoing through the City’s MS4 Program with the potential for expansion due to Canadian River TMDL concerns as well as the Oklahoma Department of Environmental Quality (ODEQ) Watershed Plan that is being developed for the 256-square-mile basin area draining to Lake Thunderbird which includes a large part of Norman.

In addition to identifying existing water quality problems and related solutions through the City’s MS4 Program, one of several major concerns involves the threat of further water quality degradation throughout Norman’s waterways, especially as it relates to Lake Thunderbird’s water quality, due to future urbanization. The State of Oklahoma has designated Lake Thunderbird as a sensitive water supply lake (ODEQ, 2002). Lake Thunderbird has been added to the State of Oklahoma’s 303(d) list of impaired waterbodies due to high levels of chlorophyll-a, an accepted measure of algal content, which has caused non-attainment of designated uses in the lake. A major component of this SWMP is to provide further understanding and awareness of the critically important need to protect Lake Thunderbird’s water quality and to recommend measures that will assist in accomplishing the needed protection. As land development progresses in the Lake Thunderbird Watershed, further degradation of the lake’s water quality can be expected as reported in a recent report developed by Vieux, Inc., entitled “Lake Thunderbird Watershed Analysis and Water Quality Evaluation” for the Oklahoma Conservation Commission (Vieux, 2007). This 2007 study assessed and quantified the impact of future land development on storm water non-point nutrient and sediment loadings to the lake as well as analyzed the potential effectiveness of management practices in preserving and protecting the lake’s water quality.

Modeling reported in the Vieux report (Vieux, 2007) generated results of water quality conditions associated with baseline (2000) and build-out (2030) conditions which clearly point out that watershed nutrient loadings to the lake are high and will increase (phosphorus more than doubling) with future urbanization. As explained in some detail in this 2007 report, these nutrient loadings and especially those from phosphorus have already contributed significantly to algal growth in the lake. Additionally in 2000, the Central Oklahoma Master Conservancy District (COMCD) and the Oklahoma Water Resources Board (OWRB) in cooperation with the cities of Norman, Del City, and Midwest City, set an upper limit goal of 20 µg/L of chlorophyll-a, a pigment or molecule commonly used to indicate algal content, for open water sites during the growing season (OWRB, 2001). The 20 µg/L concentration goal for chlorophyll-a is regarded as the boundary between eutrophic (high) and hypereutrophic (excessive) algal growth.

Using projected phosphorus loadings and an in-lake relationship between phosphorus and chlorophyll-a, estimates of potential algal growth (i.e., in-lake chlorophyll-a concentrations) in the lake were made for baseline and build-out watershed conditions. As the projected nutrient loading and associated chlorophyll-a results clearly show, the increased nutrient loadings projected to occur with future urbanization without sufficient mitigating measures will further exacerbate the algal growth in the lake significantly above the in-lake level set as the goal (i.e., the 20 µg/L chlorophyll-a concentration). Modeling in the Vieux report reveals that chlorophyll-a concentrations currently exceed the existing water quality goal of 20 µg/L for the lake, averaging 30.8 µg/L for baseline conditions. For the build-out conditions, the average chlorophyll-a concentration is projected to be as high as 44 µg/L, which is an increase of 43% above existing conditions and well above the water quality goal set for the lake. This increase in potential algal growth greatly increases the threat of toxins being produced in the lake from the algal masses, exacerbates taste and odor problems, as well as decreases recreational potential. It is clear that the City of Norman is confronted with the significant potential for an ever worsening unclean, unhealthy, and unsafe water supply.

The Vieux analyses further present that implementation of multiple management practices (structural and non-structural water quality controls) for both existing and build-out conditions such as statutory fertilizer reductions, existing wetlands protection, and structural controls (e.g., detention basins, retention or sedimentation basins, constructed wetlands, and bioretention filter basins) can result in significant reductions of phosphorus loading and chlorophyll-a concentrations within the lake. Combinations of several management practices throughout the entire Lake Thunderbird Watershed were shown to reduce the lake’s total phosphorus load to a level where the chlorophyll-a concentration in the lake would remain close to the set water quality goals. However, limiting the application of management practices within the limits of the City of Norman alone would not meet the water quality goals set for the lake. If statutory fertilizer reduction, wetlands, and structural controls are applied only to the area within the City of Norman under baseline conditions, the modeled chlorophyll-a concentration in the lake was estimated to be 24 µg/L which is still above the goal of 20 µg/L. For the build-out condition and management practices applied only in Norman, the chlorophyll-a concentration in the lake equated to 36 µg/L principally due to watershed loadings from outside of Norman’s city limits. This indicates significant hyper-eutrophic water quality conditions and still well above the 20 µg/L water quality goal.

While implementing non-structural and structural controls for previously developed areas would be difficult, the implementation of such controls including stream buffers or related floodplain dedications (e.g., Stream Planning Corridors) as well as water quality facilities (e.g., extended detention) in future developments will greatly assist Norman in improving the water quality in Lake Thunderbird. According to the Environmental Protection Agency (EPA), the use of stream buffers has the potential to control nutrient loadings by reducing loadings to streams by 30–40% (EPA, 1993). Fisher and Fischenich (2000) reported literature values for phosphorus removal due to “buffer zones and corridors for water quality considerations” as high as approximately 80%. Extended detention, an often used structural water quality control, has been reported to reduce phosphorus loadings by approximately 50% (Vieux, 2007).

Along with several other studies, reports, and programs (e.g., requirements of the City’s MS4 Program) as documented in Sections 5, 6, and 7 of this SWMP report, results of the Vieux (2007) analyses and report were strongly considered when selecting and recommending structural and non-structural controls for areas that could potentially undergo future development within the City of Norman. These results were also considered when making our recommendation to coordinate storm water protection initiatives with the cities of Moore and Oklahoma City which also have areas that drain to Lake Thunderbird and contribute to the water quality problems therein. It is also recognized that in certain circumstances these water quality controls may also be implemented in previously developed areas depending on the conditions and applicability.

The 2007 Vieux report clearly reveals that a combination of controls will be needed to protect Lake Thunderbird's water quality. The SWMP recommendations and implementation plan subsequently presented in this executive summary serve to provide an outline of recommended storm water management practices or controls for the Lake Thunderbird Watershed that, among other items, include Stream Planning Corridors (SPCs), structural controls (dry extended detention basins), fertilizer use education, fertilizer use controls, a continuation of present development density controls, and the encouraged use of effective low impact development measures. Recommendations of these particular controls are being made since they have demonstrated in numerous locations that they have the ability to significantly assist in protecting water quality and are recognized by EPA as viable management practices or controls. If implemented properly, these management practices will significantly assist in preserving and protecting Lake Thunderbird's water quality and the City's primary water source which, in turn, will protect the health, safety, and welfare of Norman's citizenry.

As the largest municipal area draining into Lake Thunderbird, the City of Norman should take affirmative steps to address water quality issues. In order to assure the continued viability of the City's primary water source, it is recommended that the City implement the key non-structural and structural water quality controls selected herein in areas of future development and work to ameliorate conditions in existing developments that are reported to be contributing to the degradation of water quality.

Fifty-nine problem areas including those characterized by stream flooding, stream erosion and local drainage were identified within the City from the many investigations and evaluations performed. The problems are spread over a large part of the City but all are located along, or west of, 48th Avenue East. Adding to their magnitude, a vast majority of the problems occur on property lacking sufficient drainage easements or rights-of-way requiring that solution costs include the purchase of such easements/rights-of-way. Table ES-1 provides the number of each problem areas in the respective Level 1 and 2 watersheds.

As indicated in Table ES-1, a variety of conceptual solutions were developed for the 59 flood/drainage-related and stream erosion problems. The estimated costs for each solution were developed and totaled by the respective watersheds and for the City as a whole. Approximately 84% of the problems were located in the urban watersheds of Bishop Creek, Brookhaven Creek, Imhoff Creek, Merkle Creek, and Woodcrest Creek with their solution costs amounting to almost 90% of the City's $82.6 million total costs. Stream flooding occurs in several locations in these watersheds with stream erosion also destabilizing the mid and lower reaches of the streams traversing these same watersheds with the exception of Merkle Creek. Certain solutions address overlapping problems, such as stream flooding and stream erosion. The level of protection for most stream flooding solutions varied somewhat although

Table ES-1
Summary of Proposed Storm Water Projects

	Stream Flooding		Stream Stabilization		Local Drainage			
Watershed	No.	Costs	No.	Costs	No.	Costs	Watershed Total Cost	Percent of City Total
Bishop Creek	6	$5,347,808	6	$1,817,248	5	$4,720,055	$11,885,111	14.4
Brookhaven Creek	4	$2,613,904	4	$2,106,735	3	$1,278,962	$5,999,601	7.3
Clear Creek	---	---	---	---	1	$1,794,023	$1,794,023	2.2
Canadian River	---	---	---	---	1	$400,645	$400,645	0.5
Dave Blue Creek	2	$1,786,733	---	---	---	---	$1,786,733	2.2
Imhoff Creek	9	$24,439,559	2	$6,816,509	1	$12,461,087	$43,717,155	53.0
Little River	1	$305,233	1	$123,682	---	---	$428,915	0.5
Tributary G to Little River	1	$992,182	---	---	---	---	$992,182	1.2
Woodcrest Creek	3	$3,167,165	1	$110,965	---	---	$3,278,130	4.0
Merkle Creek	4	$8,856,558	---	---	---	---	$8,856,558	10.7
Rock Creek	3	$3,136,111	---	---	---	---	$3,136,111	3.8
Ten Mile Flat Creek	---	---	---	---	1	$255,326	$255,326	0.3
Citywide Totals	33	$50,645,253	14	$10,975,139	12	$20,910,098	$82,530,490	100.0

improvements associated with channel capacity and roadway bridge openings used projected 100-year baseline (future) peak discharges while roadway culvert openings used projected 50-year peak flows. Exceptions were made in special cases where 10-year protection was judged to be preferred due to limited space and the costs associated with larger improvements. Such cases included channel improvements and certain roadway crossings along Imhoff Creek, the west-central Imhoff Creek watershed area (including the Lindsey Street-McGee Drive intersection flooding problem), and a few others.

The 59 solutions developed offer resolution and/or mitigation to the problems identified with the following benefits:

- 34 (58% of all solutions) instances of stream flooding mitigation.
  - 26 of the 34 target structure or building flooding.
    - 652 of 830 structures removed from the 100-year baseline floodplain.
  - 29 of the 34 include upgrades to flooded (overtopped) road crossings.
    - 36 out of 36 flood prone road crossings protected to design levels.
  - 12 of the 34 have a structure/parcel buyout component.
    - 62 properties identified as possible buyouts.
- 14 (24% of all solutions) involve stream erosion stabilization.
  - 10,050 ft of eroding streams stabilized.
- 12 (20% of all solutions) represent resolutions of local drainage problems.

Another important aspect of developing solutions for the many problems identified involved prioritization of the solutions. These prioritizations allow for identification of the most critical projects to address the storm water needs in Norman. Further, prioritizations represent an important tool for the City to use along with other information, such as individual project costs, in determining the order that solutions might be implemented or how they might be financed. The prioritization system developed evaluates, scores, and ranks each solution or project in terms of its ability to: solve the problem being considered, provide for public safety, provide sustainability, utilize funding advantages, impart positive impacts on affected neighborhoods and the environment, assist in other important issues like transportation, and present its economic costs versus benefits relationship. Using the evaluation scores, solution (project) rankings were established and organized according to the respective watersheds and ward(s) in which the projects reside as well as within the City as a whole.

KEY ISSUES

During development of the SWMP, several key issues emerged that warranted a considerable amount of attention due to their complexity and the need to have various stakeholder groups offer their guidance on how best to resolve the issues. Numerous discussions with City Council members, the SWMP Task Force, City staff, and other stakeholders produced a variety of approaches and ideas about how to resolve these various issues. As reflected in this executive summary and Section 9 of this report, recommendations on these key issues have been made to assist the City in moving forward toward meeting their storm water management goals. However, it is understood that additional discussion will follow to work out the associated details and exceptions/variances. These key issues are:

- incorporating floodplain or “Stream Planning Corridors” dedications in new developments,
- utilizing structural and non-structural water quality controls in new developments including low impact development techniques,
- providing enhanced maintenance of creeks and storm water detention facilities in existing and new developments,
- acquiring drainage easements and rights-of-way in new and existing developments, and
- providing dam safety throughout the City.

FINANCIAL ANALYSES

Financial analyses were performed to meet the funding needs for the programs and activities associated with this SWMP. The funding needs developed primarily include operations and maintenance costs to meet the City’s current MS4 storm water permit requirements, the upcoming expansion of MS4 permit requirements, the storm water capital improvement program costs, trail construction, and the purchase of critical drainage easements/rights-of-way. Guidance on critical financing decisions was obtained from the mayor and City Council, the SWMP Task Force, City staff, and other stakeholders throughout the process. Key analyses investigated the background and legislative history of storm water utilities, revenue requirements, funding potential associated with a storm water utility as well as general obligation (GO) bonding, and utility rate establishment methods. The proposed utility rate structure developed ensures that: a public purpose will be served, a reasonable relationship exists between the amount of service rendered and the amount of charge to be levied, the rates will not be arbitrary, and the rates will be equally and fairly applied.

The amount of revenue required for the proposed storm water management activities and improvements outlined in the SWMP can be broken down into needs for operation and maintenance, cash (or storm water fee) financed capital, debt service, and reserve creation less any non-operating revenues such as interest earnings. In addition to a storm water utility, the City decided to propose funding a portion of the storm water capital improvements with general obligation (GO) bonds in order to more quickly provide needed projects in areas of critical storm water needs. Three rate options were developed to fund the storm water capital improvements using the split between GO bonding and storm water utility rates over a 20-year program as defined by the City. As shown in Table ES-2 and consistent with the CIP costs for proposed solutions, the total 20-year capital improvement program needs in 2008–2009 dollars were estimated to be approximately $83 million. To cover these costs, three options for financing this program were developed with varying amounts of general obligation (GO) bonding and storm water utility user fees.

Table ES-2
Three Rate Options – FY 2008–2009 Dollars (Uninflated)

Line No.	Item	Option 1	Option 2	Option 3
1	Capital Improvement Program (20-Year Period)	$83,000,000	$83,000,000	$83,000,000
2	Funding Source			
3	General Obligation Bonds	$30,000,000	$38,500,000	$40,000,000
4	Storm Water User Rates (Pay-go) Financing	$53,000,000	$44,500,000	$43,000,000
5	Total	$83,000,000	$83,000,000	$83,000,000
6	Program Period	20	20	20
7	Capital Improvement Projects per Year Funded by Rates	$2,650,000	$2,225,000	$2,150,000

The total storm water revenue requirements were established by incorporating the costs developed during the SWMP project for pertinent items, specifically the eight items listed in Table ES-3 (excluding items on lines 5, 10, and 11). Table ES-3 shows the storm water revenue requirement assumed for the first 5-year period, FY 2009–2010 through FY 2013–2014, under the three rate options. The City chose to implement one rate for the next 5 years and therefore FY 2011–2012 (the midyear in this 5-year period) is used to set rates for this 5-year period. As indicated in line 7 of Table ES-3, the capital improvements program is equivalent to line 7 in Table ES-2 with the exception that the ES-3 values have been adjusted for inflation to reflect FY 2011–2012 dollars, which is the middle year in the 5-year planning period.

Establishment of the utility rates in the proposed storm water utility system will be based on impervious cover of the property owners in Norman, which was developed from data provided by the City of Norman. Table ES-4 displays the impervious cover data in five user classes. The City Council decided to include all impervious parcels as billable parcels after first assessing the impact to rates if exempt parcels (including the University of Oklahoma, churches, schools, Indian land, county, state and federal land, and non-profit land) were excluded.

Table ES-3
Storm Water Utility Revenue Requirement (FY 2011–2012) Dollars

Line No.	Storm Water Revenue Requirement, FY 2011–2012	Option 1	Option 2	Option 3
1	Operation and Maintenance	$459,799	$459,799	$459,799
2	Shared City Services	$129,465	$129,465	$129,465
3	Minimum Control Measures	$748,616	$748,616	$748,616
4	Reserve Funding	$265,000	$265,000	$265,000
5	Subtotal	$1,602,880	$1,602,880	$1,602,880
6	Enhanced Maintenance (Trails, Detention Ponds, Creeks)	$1,273,080	$1,273,080	$1,273,080
7	Capital Improvements Program	$2,866,240	$2,406,560	$2,325,440
8	Trail Construction	$1,081,600	$1,081,600	$1,081,600
9	Easements and Rights- of- Way	$265,225	$265,225	$265,225
10	Less Interest on Cash Accounts	$(25,758)	$(25,758)	$(25,758)
11	Total Revenue Requirement	$7,063,267	$6,603,587	$6,522,467

Table ES-4
Impervious Data Analysis Results

All Parcels	(A)	(B)	(C)	(D)	(E)	(F)
User Class	**Parcel Count**	**Total Area Sq Ft**	**Imp. Area Sq Ft**	**% of Total Impervious Area**	**Avg Impervious Area Sq Ft**	**% of Total Area that is Impervious**
Single Family	26,078	636,195,726	94,245,445	32%	3,614	15%
Multi-family	6,626	193,751,640	42,293,081	15%	6,383	22%
Comm/Indust/Office	2,314	222,531,361	59,935,187	21%	25,901	27%
Agriculture	4,616	3,854,345,991	72,687,230	25%	15,747	2%
University of Oklahoma	199	76,314,671	15,637,104	5%	78,578	20%
Miscellaneous	18	17,709,556	6,827,420	2%	379,301	39%
Total	**39,851**	**5,000,848,945**	**291,625,467**	**100%**		

The storm water rate, in dollars per square feet (sq ft) of impervious area, was then developed as shown in Table ES-5. The corresponding billing amounts for user classes for each parcel were then determined as shown in Table ES-6 for the first 5-year period and in Table ES-7 for subsequent 5-year periods, assuming Option 1. Table ES-6 also shows the average impervious area and average yearly bill under each of the three options for the three different user classes as well as the University of Oklahoma.

Table ES-5
Storm Water Rate Calculation for FY 2009–2010 through 2013–2014

	Option 1	Option 2	Option 3
Revenue Requirement	$7,063,267	$6,603,587	$6,522,467
Total Impervious Sq Ft	291,625,467	291,625,467	291,625,467
Yearly Rate ($/Sq Ft)	$0.024	$0.023	$0.022
Monthly Rate ($/Sq Ft)	$0.0018	$0.0017	$0.0017

Table ES-6
Average Bill for Each User Class (Based on Mid-Year, 2011–2012, of 2009–2014 Planning Period)

		Option 1		Option 2		Option 3	
User Class	Average Impervious Surface (Sq Ft)	Average Yearly Bill ($)	Average Monthly Bill ($)	Average Yearly Bill ($)	Average Monthly Bill ($)	Average Yearly Bill ($)	Average Monthly Bill ($)
Single Family	3,614	87.53	7.29	81.84	6.82	80.83	6.74
Multi-family	6,383	154.60	12.88	144.54	12.04	142.76	11.90
Commercial/Industrial/Office	25,901	627.33	52.28	586.50	48.88	579.30	48.27
Agriculture	15,747	381.40	31.78	356.58	29.71	352.20	29.35
University of Oklahoma	78,578	1,903.19	158.60	1,779.33	148.28	1,757.47	146.46

Table ES-7
Storm Water Rates for the Subsequent 5-Year Planning Periods (Option 1)

	5-Year Planning Period		
	FY 14/15 to 18/19	FY 19/20 to 23/24	FY 24/25 to 28/29
Revenue Requirement	$9,596,914	$11,117,910	$13,228,877
Total Impervious Sq Ft	291,625,467	291,625,467	291,625,467
Yearly Rate ($/Sq Ft)	$0.0329	$0.0381	$0.0454
Monthly Rate ($/Sq Ft)	$0.0027	$0.0032	$0.0038
Average Yearly Single Family Bill	$118.93	$137.78	$163.94
Average Monthly Single Family Bill	$9.91	$11.48	$13.66

As rates were being considered, a nationwide survey was performed to help the City ascertain whether it was common to exempt universities from storm water fees. The results indicated that most universities are not exempt from storm water charges. The City eventually decided to bill all impervious surfaces, both universities and other exempt properties, within the City. The survey taken indicated that in cities which claimed that their fees were fully adequate to fund the storm water utility, monthly utility fees averaged $9.95 (in 2008 dollars). This compares quite favorably for the City of Norman's anticipated average fee of approximately $6.74 to $7.29 in FY 2011–2012 dollars. As a final output, a long-range financial plan was developed that mapped the financial health of the storm water utility over the 20-year study period.

Table ES-8 shows various bills in 2011–2012 dollars for various impervious cover deciles (i.e., groups of equal frequency). As indicated, approximately 40% of single-family customers have 2,800 square feet of impervious surface or less, which would result in 40% of Norman's single-family property owners receiving maximum monthly bills of $5.65, $5.28, or $5.22 (probably less depending on each property's actual impervious amount) for Options 1, 2, and 3, respectively. The median single-family impervious square footage is approximately 3,100 square feet and implies a maximum monthly bill of $6.26, $5.85, or $5.78 (probably less depending on each property's actual impervious amount) under Options 1, 2, and 3, respectively.

Table ES-8
Bill for Various Impervious Surface Deciles

		Option 1		Option 2		Option 3	
Single-Family Impervious Surface (sq ft)	Decile – % Properties ≤ sq ft Given	Average Yearly Bill ($)	Average Monthly Bill ($)	Average Yearly Bill ($)	Average Monthly Bill ($)	Average Yearly Bill ($)	Average Monthly Bill ($)
2,500	30	60.55	5.05	56.61	4.72	55.91	4.66
2,800	40	67.82	5.65	63.40	5.28	62.62	5.22
3,100	50	75.08	6.26	70.20	5.85	69.33	5.78
3,400	60	82.35	6.86	76.90	6.42	76.04	6.34
3,800	70	92.04	7.67	86.05	7.17	84.99	7.08
4,400	80	106.57	8.88	99.63	8.30	98.41	8.20

RECOMMENDATIONS/IMPLEMENTATION PLAN

Recommendations were developed to cover the range of topics analyzed and evaluated as part of the SWMP development. In certain instances, the recommendations presented should be viewed with the understanding that further meetings, discussions, and considerations will be required. These recommendations covered general items, watershed and stream assessments, hydrologic and hydraulic modeling, drainage criteria manual updates, storm water problems and solutions, key issues, and storm water financing. An overview of the recommendations includes:

Future Meetings and Coordination

- Continue to involve stakeholders in all aspects of the SWMP including implementation.
- Refine storm water and watershed protection goals and needs in the future based on continued public involvement and new studies.
- Develop a formal public outreach campaign or program to further educate citizens about the City's storm water needs, the importance of obtaining adequate funding to meet those needs, and the general support needed to sustain a viable storm water program throughout the City.

Key Issues

- Stream Planning Corridors and 100-year full buildout floodplain dedications as well as structural and non-structural storm water quality controls.
  - Dedicate Stream Planning Corridors (SPCs) and/or the 100-year full buildout floodplains to the City of Norman by easement or title for streams located in the Lake Thunderbird watershed that have a drainage area greater than 40 acres.
    - Prohibit development or significant land disturbance in the SPCs and/or 100-year full buildout floodplain. Exemptions should include items such as, but not limited to, maintenance activities, greenway trails, road crossings, utilities, and stream stabilization measures.
    - Require additional stream-side buffers of 15 feet to each side of steams with drainage areas greater than 40 acres that are located in the Lake Thunderbird watershed and also in Suburban Residential and Country Residential areas as defined in the Norman 2025 Plan including subsequent updates to the comprehensive plan as adopted by the City Council.
  - Require that water quality facilities be constructed to capture and treat runoff from all proposed developments in the City of Norman that exceed 1 acre (or some other size selected by the City) in size. The runoff "capture and treatment volume" should be set to 0.5 inch of runoff from the development area unless specified otherwise for a special condition.
    - Allow very small developments less than 1 acre in size or some other size limit to pay into a regional detention/water quality program in lieu of building very small water quality structures. The City's present regional detention program should be broadened to include this water quality fee in lieu process.
    - Allow and encourage low impact development techniques such as rain gardens and biofilters to provide a portion or all of their storm water quality control requirements subject to the developer providing sufficient technical justification for the techniques.
    - For developments that do not dedicate the SPC or full buildout 100-year floodplain by virtue of obtaining a variance, the runoff capture and treatment volume for their development area should be increased to 0.7 inch of runoff.
  - Allow limited variances for special conditions/situations that would utilize alternative approaches that could be shown to achieve similar water quality, flood control, and recreational opportunity. In situations where there is a clearly defined riparian corridor of environmental significance and/or flood prone soils, it should be relatively more difficult to obtain such a variance. However, obtaining such variances should be less difficult in situations where a riparian corridor does not exist and the subject waterway flows through an area that has experienced significant past disturbance or change from natural conditions (such as past agricultural activities and/or activities associated with residential, commercial, transportation, or industrial uses).
  - Implement nonstructural storm water quality controls in addition to SPCs, including a program to educate the public on fertilizer use, a program to control the overuse of fertilizers, a procedure to ensure proper septic system installation and operation, and a continuation of present development density (and impervious cover) limitations in the Lake Thunderbird watershed.
  - Require the following compliance measures if development or significant land disturbance occurs within the stream banks of a stream in the City:
    - USACE's 404 permitting documentation and proof of permit to be submitted to the City prior to plat approval,
    - Riparian stream corridor mitigation will be required (tree replacement, re-vegetation, stream stabilization using bio-engineering techniques, etc.), and
    - Inlet and outlet structures will be provided as needed to incorporate erosion protection.
  - Continually assess water quality conditions in Lake Thunderbird and update or modify activities and controls to protect this important water supply.

- Acquisition of drainage easements and rights-of-way along streams and detention facility areas.
  - Develop a plan and begin to obtain drainage easements and/or rights-of-way (as needed) in Level 1 and 2 streams and for storm water detention facilities where access is needed for continuous/routine maintenance activities. For streams, the amount of easement or right-of-way would be as needed based on specific site conditions but, in general, would include a width of stream extending bank to bank plus 10 feet on each side of the stream channel. This can include those areas where storm water CIP projects have been identified if the maintenance need justifies obtaining the easements in advance of designing and constructing the proposed CIP project.
- Enhanced maintenance of creeks and storm water detention facilities.
  - A citywide stream maintenance program should be implemented over the next 2 or 3 years consistent with the acquisition of easements, rights-of-way, rights-of-way, rights-of-entry, and reaches of "no action," depending on the situation/conditions. Maintenance should focus on those stream reaches and/or detention facility areas where capital improvements are constructed in order to protect those investments. The City should also consider outsourcing some, or all, of the maintenance activities if it is advantageous, especially while a City's program is ramping up. The City should also focus on detention facilities in which dam maintenance may become a safety issue.
- Dam safety issues.
  - The City should investigate and identify, to the extent possible, the responsible parties for the inspection, maintenance, and overall safety of dams that are judged to be a potential safety hazard. This work should be undertaken beginning with the dams judged to have the greatest public safety risk. An inventory and prioritization method should be developed at the beginning of the investigative work.
  - While stopping short of taking over dam ownership, liability, and routine maintenance from Property Owner Associations (POAs) or other owners, on a case by case basis the City should take over the inspection and maintenance of dams that pose significant safety concerns. POAs should maintain the general/routine mowing and small scale maintenance responsibilities while the City undertakes the more critical inspection and maintenance responsibilities.
  - For any dam for which the City considers taking over certain inspection and maintenance responsibilities, it is recommended that the City first study and determine the prevailing conditions for such dam and its appurtenances. Should the City take over inspection, maintenance, and upgrade responsibilities for the structures, it should first be determined what actions they or the present owners might have to take to bring such structures into state dam safety compliance. Such actions could include determining whether the dam structures, including emergency spillways, require modifications to strengthen them against failure or breach. Another important aspect is whether any of the dams need an emergency action plan to reduce the risk to lives and property that can result from dam failure.

Policy, Ordinances, and Criteria

- Use watershed full buildout peak discharges for new developments and make necessary changes to City policy, the subdivision regulations, and drainage criteria manual.
- Retain the low density development policies outlined in the Norman 2025 plan for the Ten Mile Flat Creek watershed and the areas generally east of the urban core draining to Lake Thunderbird.
- Update the City's Drainage Criteria Manual in all aspects, including the rainfall and runoff methods established in the SWMP as well as a reassessment of the adequacy of the fee-in-lieu of on-site detention criteria.
- Develop a Storm Water Quality Criteria Manual with SWMP findings and recommendations.
- Develop an Erosion Control Manual aimed at preventing erosion problems associated with construction.

General Storm Water Quantity and Quality Management

- To facilitate SWMP improvements implementation, develop a CIP program with staff dedicated to managing the associated design and construction activities. This staff can balance their cyclic work load by using consulting firms and other professionals.
- Inspect and monitor the stream erosion areas identified on a regular schedule (e.g., every 1 or 2 years) until streams are stabilized with adequate improvements.
- Monitor and document conditions associated with the problems identified in the SWMP until CIP improvements solve or mitigate them.
- Incorporate any new problems and possible solutions on a continuing basis.
- Review and update solution prioritizations every few years.
- Continually explore ways to integrate solutions to address multiple problem types and incorporate greenway opportunities.
- Develop collaborative agency partnerships to assist in project funding and cooperation.
- Maintain awareness and knowledge of all water quality monitoring being carried out in watersheds that originate in, or flow through, the City of Norman.
- Meet with the cities of Moore and Oklahoma City to explore ways to improve water quality and preserve Lake Thunderbird's water quality.
- Meet with the Oklahoma Department of Environmental Quality (ODEQ) and get updates on the Lake Thunderbird Watershed Management Plan development and the Canadian River TMDL status. Assign a City coordinator to follow the progress and status of these two programs as well as the MS4 program as compliance activities associated with these three programs will impact water quality in Norman for the foreseeable future.
- Assure compliance with requirements of the City's MS4 OPDES storm water permit, the recently developed Canadian River Bacteria TMDL, and the ODEQ Lake Thunderbird Watershed Management Plan development.

Hydrologic and Hydraulic Modeling

- Update hydrologic and hydraulic models consistent with up-to-date priorities using the data, methods, and findings of the SWMP.

- Develop a hydrologic and hydraulic model management system using an internal City server or a web server to improve user access to the models, facilitate City maintenance and distribution of the models, and to track legitimate updates.
- Submit Letters of Map Revision (LOMRs) to FEMA for the Level 1 streams studied during the SWMP development. When other streams are studied or updated in detail, those studies/updates should be submitted as FEMA LOMRs at that time.

Funding

- Establish long-range funding sources for storm water management such as general obligation bonding and the establishment of a storm water utility.
  - Develop and carry out a strategic work plan for a citizen vote on the proposed storm water utility as described in Section 8. The City must also decide whether establishment of the master account file and other key billing logistics will be worked out before or after the citizen vote (assuming it passes). Regardless, preliminary discussions on billing and administration requirements should begin.
  - Develop and carry out a strategic work plan for a citizen vote on the proposed general obligation bond program as described in Section 8.

SUMMARY STATEMENT

With the results of this SWMP as a solid foundation, the City of Norman will be able to:

- Satisfy their regulatory requirements including the mandated OPDES MS4 storm water quality permitting program.
- Meet the challenges facing the community, including identifying problems and solutions associated with stream flooding, stream erosion, local drainage problems, and water quality.
- Enhance recreational opportunities and protect the environment.
- Obtain input from all stakeholders, receive public input, provide public education on important issues, and maintain public support into the future.

7.0 KEY ISSUES

During development of the SWMP, several key issues emerged that warranted a considerable amount of time due to their complexity and the need to have various stakeholder groups offer their guidance on how best to resolve the issues. Numerous discussions with City Council members, the SWMP Task Force, City staff, and other stakeholders produced a variety of good ideas about the various issues. Although recommendations are included in this report (this section and Section 9), consideration will be needed to resolve details on moving forward with several of these recommendations. Therefore, this section provides pertinent background on the issues, discussion topics considered in the stakeholder meetings, and recommendations on how the City should move forward in the future on each of the issues. Several of these issues came up as the consultant team brought suggestions forward specifically targeting certain City goals established for the SWMP. A breakdown of the major issues into "considerations" is presented below along with options, respective discussions, and recommended actions. It is anticipated that the recommended actions will allow the City to ultimately reach a consensus or understanding on the best approach to follow in the future on each respective issue.

Several possible concepts were considered in an effort to meet certain City's SWMP goals of providing public safety from flooding, protecting water quality including Lake Thunderbird, meeting OPDES permitting requirements, protecting stream corridor environments, capitalizing on greenway and open space expanding opportunities, and generally improving the "quality of life" in Norman. These concepts included:

- incorporating floodplain dedications and/or "Stream Planning Corridors" in new developments,
- utilizing structural (e.g., sediment trapping basins, wet ponds, porous pavement, grass swales) and non-structural (e.g., stream buffers or floodplain dedications, fertilizer application controls, development density limitations, street sweeping) water quality controls in new developments, including low impact development,
- providing enhanced maintenance of creeks and storm water detention facilities in existing and new developments,
- ensuring that existing and any new policies are followed in obtaining drainage easements and rights-of-way in new developments,
- acquiring drainage easements and rights-of-way, as needed, in existing developments, and
- providing dam safety throughout the City.

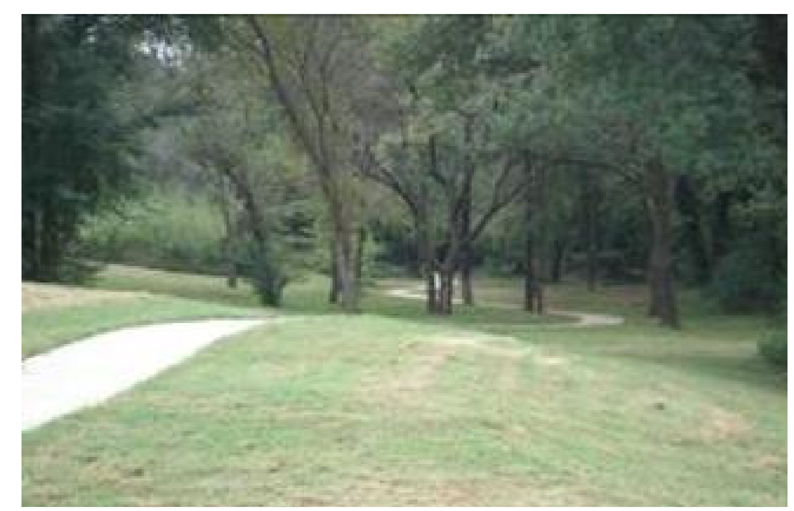
The City Council and SWMP Task Force assisted the consultant team and City staff in the consideration and discussion of these storm water-related elements.

7.1 STREAM PLANNING CORRIDORS

One particular element considered to help meet the City's SWMP goals involved the dedication of floodplain areas and/or stream corridors in new developments. Numerous municipalities (e.g., City of Austin, Texas; City of Stow, Ohio; Burke County, North Carolina; and Cobb County, Georgia) throughout the country presently utilize this environmentally sensitive approach to:

- protect water quality by removing sediments, nutrients, and other contaminants from runoff,
- infiltrate runoff and store floodwaters, thereby providing for public safety and reducing property damage,
- reduce channel bottom degradation and stream bank erosion,
- maintain habitat for fish and other aquatic organisms,
- provide terrestrial habitat,
- improve aesthetics, possibly improving property values,
- maintain base flow in streams, and
- offer opportunities for greenway development.

The appropriateness of dedicating floodplain areas or "Stream Planning Corridors" received considerable discussion during development of the SWMP. A great many discussions were held with the City Council in work session, the SWMP Task Force, City staff, and other stakeholders (including City Council presentations) in an effort to obtain input as well as reach a consensus about using such a method to meet some of the City's water quality, environmental, flood control, and recreational goals. A very wide range of opinions was received with some stakeholders enthusiastically favoring the corridors and others totally against them.



Stream Planning Corridors and Greenways

It is proposed that Stream Planning Corridors (SPCs) be defined as the area of land along both sides of a stream or natural drainage corridor that encompasses the area projected to be inundated by the 1% chance flood event (i.e., the 100-year floodplain) in any given year assuming full buildout watershed conditions plus possibly including an additional buffer width or strip. This additional buffer strip, if added, would aid in further filtering runoff as well as expanding opportunities for incorporating greenbelts/recreational trails within land areas being developed. SPCs without any added buffer strip have been developed for those areas with 40 or more acres of drainage area for Level 3 and 4 streams as shown in Exhibit 4-4. Projected ultimate buildout development conditions consistent with the Norman 2025 Plan, as well as future projected growth for areas that drain into Norman, were used to develop the peak flow rates used to delineate the 1% or 100-year floodplains and SPCs. FEMA floodplains were considered but not used since they were not available when the analysis was performed, were not developed assuming ultimate development conditions, and in many locations were not based on the recent 2007 LIDAR-based topography at the time of the analysis. The SPCs reflect full buildout development flow rates in order to respect conditions expected in the future rather than the present or past.

The use of floodplains or SPC dedications in the headwaters areas of watersheds (up to the 40-acre drainage area size) is important as SPCs have the greatest potential to provide water quality protection in these areas. In these headwater areas, the flows are relatively small and dispersed (shallow flow) in any one location and therefore offer the best opportunity to filter runoff and infiltrate it into the ground surface. SPCs or buffer strips adjacent to larger streams with large drainage areas also help filter runoff and provide many other environmental functions and recreational opportunities but once the runoff is into these larger stream reaches, the chance for filtration through vegetation, absorption, and infiltration decreases as a factor due to the larger flows and resulting velocities in downstream reaches. These processes relate to streams left in their natural state as such benefits are significantly reduced in most rectified channels, especially in concrete-lined or piped systems.

Establishing SPCs provide a means of approximating the floodplain areas along unstudied streams for possible dedication and/or other storm water planning purposes. The floodplains for Level 1 and 2 streams can, and should, be used in the same manner when considering floodplain dedications. The main difference is that the Level 1 and 2 floodplains were developed with more comprehensive and detailed methods. Revisions to these Level 1 and 2 stream floodplains for future land development conditions could be allowed if a delineation problem was discovered during the land development process. In Level 3 and 4 streams, revisions to the SPCs should be allowed if superior floodplain information is presented but the SPCs as provided in the SWMP should provide a reasonable approximation of the floodplain for the 1% flood in most locations. It is anticipated and expected that refined floodplain delineations will be developed by engineers as parcels are developed and compliance with subdivision regulations is achieved. Land developers can, at a minimum, use these SPCs as a planning tool when laying out their respective developments and City staff can use them in their review of development plans and other planning activities.

7.1.1 Key Questions, Options, and Recommended Actions

Question 1: Does the City want future land developments to dedicate the ultimate development condition 1% chance (100-year) floodplain extending well upstream of a 1-square-mile area as an SPC to provide water quality protection, capitalize on greenbelt and open space expansion opportunities, protect stream corridor environments, and generally increase the “quality of life” in Norman?

Discussion: In general, requiring the dedications would be a positive step toward meeting the City’s goals for the SWMP. Floodplain dedications can provide for significant water quality protection, more stream base flow, improved neighborhood recreational opportunities, as well as a more sound and viable environment for wildlife and native vegetation. This will be a change from the way developments are presently planned in Norman so some will not want to make any significant change in the status quo. Some developers may feel that such a program is unfair and not needed. They may also believe that they can develop solutions that would be equivalent to the natural system in terms of flood control, water quality, and recreation. Some may embrace such dedications as long as exceptions or variances could be considered. To the degree that variances are allowed, the City must develop criteria to judge the adequacy of alternative approaches in lieu of the SPC dedications. One approach to consider would be to allow alternative approaches, including low-impact development techniques, but require studies to show that at least flood control and water quality are equivalent to that obtained through using the floodplain dedications. Alternative approaches should include requirements for developers to provide the City with documentation that the U.S. Army Corps of Engineers (USACE) was notified and a Section 404 permit was obtained when natural waterways are altered as part of the development.

Requiring these dedications could also potentially add a significant amount of additional area that the City might have to maintain to some degree, regardless of whether such dedications were in some sort of drainage, utility, or conservation easement. While these areas would require funding to maintain, if they were left natural, maintenance could be minimized.

The City must ultimately decide to require these dedications in a uniform manner throughout the City or apply them differently for areas draining directly to the Canadian River versus areas that drain into Lake Thunderbird. The City could also chose to vary the application of the dedications depending on whether the development was located in the current urban service area, the future urban service area, suburban residential area, and country residential area according to the Norman 2025 Plan.

Options:

1) Require such dedications up to the 40-acre drainage area limit for all new developments.
2) Require such dedications but only up to some other drainage area cut-off limit such as 80 acres, 160 acres, etc.
3) Select 1 or 2 above but apply the dedications differently depending on the development location within the City such as whether or not the area drains to Lake Thunderbird or directly to the Canadian River. Another process that could be used would be to vary the requirements or ability to obtain a variance based on whether a stream being considered has mapped flood prone soils by the Natural Resources Conservation Service. If such soils exist, the stream would be viewed as having an increased need for floodplain/SPC dedications.
4) Make no changes to the present land development regulations, requirements, and processes.

Recommended Actions: In order to meet the goals of protecting the water quality of Lake Thunderbird and its contributing waterways, Option 3 is recommended, which requires that floodplain and/or Stream Planning Corridor dedications extend into the headwater (upstream areas) of Lake Thunderbird watersheds. Option 4 is certainly not recommended given the worsening water quality conditions in Lake Thunderbird. For purposes of this Option 3 recommendation, the City should extend such dedications requirements to the 40-acre drainage area limit for all watershed areas that drain to Lake Thunderbird. Such dedications are not recommended for other portions of the city outside of the Lake Thunderbird watershed since, with the exception of the Ten Mile Flat Creek watershed, these watersheds have relatively small amounts of undeveloped area. Extending the requirement to the 40-acre drainage area size maximizes the water quality benefits afforded by the overland flow, increased infiltration, and vegetative filtering of runoff in these headwater areas. A review of Exhibit 4-4 provides visual observation of the relative areal coverage of the SPC areas versus those areas outside of the SPCs in these headwater areas. It is recognized that further discussions will be held on this subject and the City may eventually decide to select a larger (greater than 40 acres) drainage area limit.

In making this recommendation, it is realized that certain legal and political considerations may require discussion and resolution in the future. The resolution of any legal and political considerations will need to be made in conjunction with the public safety and environmental concerns that are facing the City presently and in the future. The SPC recommendation made here focuses on the actions needed to provide water quality, flood, and environmental corridor protection as well as increasing recreational opportunities. Lake Thunderbird's water quality constitutes the overriding concern since there is considerable evidence that the lake is already degraded (as discussed in Section 5) even though many areas and streams in the lake's watershed are presently in a natural or undeveloped condition. When development occurs in these areas and along the many local streams, it will be very hard to "hold the line" on water quality conditions and prevent further degradation of water quality in the lake as well as in the Canadian River. The challenge to protect water quality in all of the City's steams and especially those contributing to the lake is enormous and will not be met unless significant controls are put in place to counter the impacts of future urbanization.

In an effort to better understand what other local governments throughout the country have done in similar situations, numerous floodplain and/or riparian buffer ordinances across the country were reviewed. While these ordinances have similarities and differences, they provided supportive approaches and information. In Austin, Texas there are requirements to provide "Critical Water Quality Zones" that extend out to the full buildout 100-year floodplain along streams with drainage areas greater than 64 acres in water supply watersheds. These water supply watersheds are similar to those that contribute to Lake Thunderbird in Norman, such as the Little River, Rock Creek, and Dave Blue Creek watersheds. There is also a further requirement in Austin to provide a "Water Quality Transition Zone" that extends from 100 to 300 ft beyond the Critical Water Quality Zone depending on the size of a stream's drainage area at any particular point. Development is all but eliminated in the Critical Water Quality Zone and severely limited in the Water Quality Transition Zone (City of Austin Code, 2009). In Stow, Ohio riparian setbacks from the banks of streams are 50 ft for areas as small as 32 acres and 30 ft for streams smaller than 32 acres (Chagrin River Watershed Partners, Inc., 2006). Douglas County, Georgia requires stream buffers in their water supply basins that extend 100 ft from the stream bank plus an additional 250-foot setback on "small tributaries" in which housing density is limited to one house per acre (Wenger and Fowler, 2000). Lastly, Platte County, Missouri (1992) (part of the Kansas City Metropolitan Area) designates "stream corridor buffer zones" of various total widths depending on drainage area sizes, including 100 ft for areas between 25 and 40 acres; 150 ft for areas between 40 and 160 acres; 250 ft for areas between 160 and 5,000 acres; and 300 ft for areas greater than 5,000 acres.

For those watershed areas that do not drain to Lake Thunderbird but drain more directly to the Canadian River, the recommendation is for the City to forego these dedications altogether instead of extending floodplain/SPC dedications to a larger drainage area limit such as 80 acres. A cursory review of developable land in areas that drain directly to the Canadian River reveals that these dedications would not impact a significant amount of area or stream length and would provide limited water quality benefit due to the existing disturbed nature of the area overall and stream corridors. However, as recommended later in this section, water quality structural and nonstructural water quality controls should be used in this area for future development activities. In terms of flooding in this more urban portion of the city, existing and herein proposed drainage/storm water regulations should provide adequate protection. It is further felt that variance requests could be difficult to judge in these areas creating administrative problems. The Ten Mile Flat Watershed may be an exception to the above discussions since it does have a significant amount of undeveloped area, but existing housing density regulations and other drainage/storm water regulations should provide ample protection for this area.

It is also recommended that the City consider allowing justifiable variances to this requirement that would allow alternative approaches that could be shown to achieve similar water quality, flood control, and recreational opportunity. In situations where a clearly defined riparian corridor of environmental significance and/or flood prone soils exist, it should be relatively more difficult to obtain such a variance. However, obtaining such variances should be less difficult in situations where a riparian corridor does not exist and the subject waterway flows through an area that has experienced significant past disturbance or change from natural conditions (such as past agricultural activities and/or activities associated with residential, commercial, transportation, or industrial uses).

Question 2: Does the City want to add an extra buffer width or strip to the 1% chance floodplain? If yes, how much extra width?

Discussion: Adding an extra buffer width basically has the same type of considerations that were presented above for the first issue. The benefit primarily relates to adding a "safety factor" to help protect the stability, water quality, and environmental integrity of the City's streams. Adding an extra buffer strip would also provide more opportunity for greenbelts and trails although most trails could be included within an SPC. From a water quality standpoint, adding buffer width is important in areas where water quality degradation is occurring or is expected to occur such as is happening to Lake Thunderbird. Adding buffer width might make more sense in the City areas that are to subject to relatively less dense urban development such as the suburban residential areas and the country residential areas, especially those areas draining into Lake Thunderbird. In the current urban service area and the future urban service area, the Norman 2025 Plan discusses the need to provide for more dense development. In these more densely developing areas, it may be impractical and inconsistent to add buffer width.

Options:

1) Add an extra buffer width of 15 ft or some other amount to increase water quality protection.
2) Vary the buffer width with drainage area size, such as:
   a. 40 acres – 640 acres: none
   b. 640 acres – 5 square miles: 20 ft on each side of the creek
   c. >5 square miles: 30 ft on each side of the creek
3) Vary the width based on the development location within the City (see discussion above).
4) Do not add any buffer width.

Recommended Actions: It is recommended that additional buffers of 15 ft be added to each side of all waterways with 40 acres or greater drainage area in addition to, or beyond, all Stream Planning Corridors and/or ultimate buildout 100-year (1%) floodplains areas in those areas that are included in the Norman 2025 Plan as Suburban Residential Areas and Country Residential Areas. No additional buffer is recommended in other City areas. Variance provisions should be considered and allowed if similar water quality protection can be conclusively demonstrated, including provisions for future operations and maintenance.

When the City moves forward with changes to their ordinances and regulations related to floodplain/Stream Planning Corridor dedications and structural/nonstructural water quality controls (discussed subsequently below), the following ordinance considerations have been developed to initiate thoughts about the regulatory changes that might apply.

7.2 STRUCTURAL AND NONSTRUCTURAL STORM WATER QUALITY CONTROLS

As discussed in Section 6.2, programmatic water quality solutions are presently being implemented in Norman's "urbanized areas" as part of the City's compliance with ODEQ's Oklahoma Pollutant Discharge Elimination System (OPDES) "MS4" program. Additional future water quality compliance will also be required as part of the previously mentioned TMDL requirements for Bishop Creek and ODEQ's future watershed management plan development for Lake Thunderbird. As a supplement to the MS4 program, the upcoming ODEQ watershed management plan, and/or the Bishop Creek TMDL as well as to meet certain SWMP water quality goals, the City will need to require new developments to incorporate certain structural and/or nonstructural water quality controls. Structural and non-structural storm water quality controls have the ability to help protect the water quality in Norman's streams and Lake Thunderbird. Typical structural controls include extended detention (sediment trapping) basins, wet ponds or retention basins, filtration basins, porous pavement, and grassed swales. Nonstructural controls include stream buffers, floodplain dedications, fertilizer application controls, street sweeping, and development density limitations. These types of structural and nonstructural controls (BMPs, or best management practices) are an integral part of the City's MS4 program. Discussions on this topic during the SWMP development have been much less involved compared to other issues such as stream planning corridor dedications and drainage easement/ROW needs.

Combination water quality and flood control facility

7.2.1 Key Questions, Options, and Recommended Actions

Question: Should the City of Norman adopt structural and nonstructural storm water quality controls in its development standards and require new developments to provide these controls?

Discussion: First, a discussion of local conditions and ongoing programs underway or in various development stages is provided. This discussion is then followed by an overview of structural and nonstructural water quality controls, or BMPs, that could be used in Norman. In many instances the City will lead the efforts to provide nonstructural controls while developers will provide the structural controls as part of their development drainage infrastructure.

Storm water runoff quality is affected by human activities, land use changes, and the alteration of natural drainage patterns. These urban conditions and activities add pollutants to rivers, lakes, and streams. Urban runoff has been shown to be a significant source of water pollution in locations throughout the country, causing declines in water quality and impairment of waterbodies as is the case for Lake Thunderbird. Examination of national storm water quality data and local studies reveals that nutrients and total suspended solids (as well as other water quality parameters), runoff volumes, and flow rates increase with urbanization and impervious surfaces, thusly impacting Lake Thunderbird inflows and discharges to local streams and the Canadian River.

Though a limited dataset, a local study entitled "Rock Creek Watershed Analysis and Water Quality Evaluation" (COMCD, 2006), in the Rock Creek tributary to Lake Thunderbird showed that total phosphorus, total nitrogen and total suspended solids concentrations were several times higher than National Storm Water Quality Database values. This modeling and analysis study for the Central Oklahoma Water Conservancy District (COMCD, 2006) focused on estimating the impact of urban storm water on nutrient and sediment loading into Lake Thunderbird, the water supply reservoir for the cities of Norman, Midwest City, and Del City. For the majority of events, the most highly developed areas in Rock Creek had the highest modeled constituent concentration of suspended solids, nitrogen and phosphorus. As urban development results in conversion of land use from open areas to residential or commercial classifications, the impervious area and urban activities will increase and result in higher nutrient and total suspended solids concentrations of nutrients and annual loading in storm water to the lake. Increased nutrient loading has the potential to increase algal growth in the lake which, in turn, can cause significant taste and odor problems in the lake's finished drinking water as well as cause the waterbody to be in non-compliance with the set water quality goal for chlorophyll *a* (an indication of lake eutrophication).

In a subsequent study for the Oklahoma Conservation Commission (OCC) entitled "Lake Thunderbird Watershed Analysis and Water Quality Evaluation" (OCC, 2007), an evaluation of structural and nonstructural storm water controls were evaluated in terms of their ability to reduce nutrient and sediment loadings to the lake. Nonstructural controls included voluntary and statutory urban nutrient management while structural controls included grassed swales, constructed wetlands, extended detention – enhanced, retention basins, and bio-retention filters. Modeling indicated that use of all of these controls throughout the lake's watershed reduced total phosphorus loadings to the lake by more than 80% for full buildout development conditions. Although it may be impractical to assume that all of these controls would be implemented as part of any plan, it does show that it is possible to reduce loadings substantially.

ODEQ is concerned that urban development, without appropriate mitigation of its environmental impact, will exacerbate the water quality problems currently experienced by the lake. The watershed management plan being established by ODEQ will identify implementation of management practices in the Lake Thunderbird watershed to help achieve beneficial uses of water in the lake. This watershed management plan could require that the City of Norman develop a program and/or modifications to its land development policies and ordinances to reduce pollutant loadings commonly associated with urban development. Other cities, agencies, and entities that make land use changes within the lake's basin area will also have to follow requirements of the watershed management plan. Norman should increase its efforts to work cooperatively with the cities of Moore and Oklahoma City to improve water quality and protect Lake Thunderbird.

Under the TMDL process for the Canadian River, ODEQ has also identified Norman and the University of Oklahoma as contributors to non-attainment for fecal coliform in Bishop Creek, a local tributary to the Canadian River. Bishop Creek failed to support the designated water use due to fecal coliform concentrations, and thus actions must be taken to meet the water quality standard. Where the TMDL has been developed, additional sampling becomes part of the implementation requirements for regulated MS4 discharges such as those from the City of Norman. Significant monitoring and reporting of water quality and implementation of BMPs are expected to result.

Structural and Nonstructural Storm Water Quality Controls. Both structural and nonstructural solutions have been implemented in areas across the United States, ranging from site-specific engineering solutions to watershed solutions. **Structural controls** constitute engineering solutions designed to reduce pollution in surface water runoff primarily through three basic mechanisms: infiltration, filtration, and detention (EPA, 1993). In effect, these systems attempt to counteract the opposite tendencies of decreased infiltration, filtration, and detention which urbanization imposes upon the land. This section discusses the advantages and disadvantages of the major options available, detailing both design and general cost constraints.

The many BMP options offer varying capabilities in terms of type and extent of pollutant removal, size of upland basin appropriate to the structure and general comparisons. These BMPs have been developed for use across the United States and are generally suitable for the Norman area. This section presents comparative information for several structural BMP options. Tables 7-1 through 7-3 provide a considerable amount of information on (1) pollutant removal efficiencies, (2) siting restrictions, and (3) general cost information, where available.

Nonstructural controls include a wide variety of pollution prevention measures. Whereas structural BMPs require the design, installation and maintenance of actual control facilities/infrastructure, nonstructural BMPs rely on the proper management of existing resources and adherence to common-sense materials management practices to maintain water quality. As such, nonstructural controls are generally less expensive to implement and maintain than structural controls. By anticipating potential problems and by acting to limit contaminants at the source, a substantial savings can be realized compared with a program which solely reacts to pollution once it has occurred. The latter approach involves relatively costly containment, mitigation, cleanup and treatment methods while the former involves techniques such as public education, pollutant source reduction, improved development site design, and protection of environmentally critical areas. Ultimately both strategies are necessary as some entry of pollutants into waterways must be anticipated. However, inexpensive preventative methods can enable end-of-the-pipe structural solutions to be both less expensive and more effective.

Buffer Zones/Protection of Existing Vegetation. Vegetation inherently addresses the hydrologic goals of many structural BMPs with minimal cost and maintenance: tree canopies intercept and diminish the erosive force of rainfall; ground cover by plants and organic matter slows runoff velocities, increases infiltration rates, and inhibits contaminants from entering waterways; and root growth holds and protects the soil from channel and gully erosion. Wetlands serve many of the same functions, effectively acting as natural pollution control systems as well as critical habitat areas. When considered on the large scale of the Lake Thunderbird watershed, proper maintenance of existing vegetative resources becomes an imperative from both cost-effective and pollutant removal standpoints. Through advanced planning, important woodland and wetland areas can be identified and protected. Such strategies have been used nationwide as a highly practical and achievable pollution control measure; significant habitat protection benefits can also be achieved. Table 7-4 presents very general information on the relative costs and benefits of forest and wetland protection.

Buffer zones are nonstructural BMPs that maintain existing or establish new vegetation in critical areas to, among other things, assist in controlling storm water pollution. They are widely accepted as a means of protecting streambanks, wetlands, and other environmentally important areas. Table 7-4 shows the relative costs and benefits of stream, wetland, and expanded buffers. These zones are often employed in areas which are already unsuitable for development, such as within floodplains or federally protected wetlands. These steeper gradients are more susceptible to erosion, especially with increases in impervious cover in nearby areas following development. Buffer zones in

Table 7-1

Structural BMPs: Description, Advantages, and Disadvantages

Management Practice	Advantages	Disadvantages
Extended Detention (ED) Dry Pond Designed to trap a specific percentage of total runoff from upstream drainage basin. Upper chamber traps sediment for easy disposal; lower chamber detains the water for controlled, extended detention. Increased holding time allows suspended particulates and other associated pollutants to drop out prior to release. Performance depends upon the size of the structure (e.g. the percentage of the "first flush" contained) and the length of detention time. Particulate pollutants (e.g. sediments) more effectively removed than soluble forms (e.g. nutrients) (see Table 7-2). Detention design of 24 hours minimum "to achieve maximum removal of most pollutants" (Schueler, 1987). Rates vary with site-specific conditions (e.g. soil types). Fine-grained clays/silts require longer detention times than heavier, coarser sand particles.	• Can provide peak flow control, reducing runoff flows, erosion and flooding downstream • Possible to provide good particulate removal • Can serve large development or area • Requires less capital cost and land area when compared to wet pond • Does not generally release warm or anoxic water downstream • Provides excellent protection for downstream channel erosion • Can create valuable wetland and meadow habitat when properly landscaped • Lowest cost alternative in size range	• Removal rates for soluble pollutants are quite low • Generally not economical for drainage area less than 10 acres • If not adequately maintained, can be an eyesore, breed mosquitoes, and create undesirable odors
Extended Detention (ED) Wet Pond Same as ED dry pond except designed to maintain a permanent pool. Pool vegetation enhances nutrient uptake.	• Can provide peak flow control, reducing runoff floors, erosion and flooding downstream • Can serve large developments or area; most cost-effective for larger, more intensively developed sites • Enhances aesthetics and provides recreational benefits • Permanent pool in wet ponds helps to prevent scour and resuspension of sediments • Provides better nutrient removal when compared to wet pond • Significant soluble nutrient capability added with marginal additional cost over dry ED pond • Can create valuable wetland and meadow habitat when properly landscaped	• Generally not economical for drainage area less than 10 acres • Potential safety hazards if not properly maintained • If not adequately maintained, can be an eyesore, breed mosquitoes, and create undesirable odors • Requires considerable space, which limits use in densely urbanized areas with expensive land and property values • Not suitable for hydrologic soil groups "A" and "B" (SCS classification) • ·With possible oxygen depletion, may severely impact downstream aquatic life
Wet Pond Pond design features pollutant removal through sedimentation (via holding times) and biological uptake (via established plants). Similar to ED ponds, while wetland plant growth captures soluble nutrients, etc. Often have two chambers like ED ponds; upper bay traps sediments for easy maintenance, limiting their entry into pool. Use of native wetland plant species enhances BMP performance, reduces maintenance.	• Can provide peak flow control, reducing runoff flows, erosion and flooding downstream • Can serve large developments; most cost-effective for larger, more intensively developed sites • Enhances aesthetics with proper design • Little groundwater discharge • Permanent pool in wet ponds helps to prevent scour and resuspension of sediments • Provides moderate to high removal of both particulate and soluble urban stormwater pollutants • Can create valuable aquatic habitat when properly maintained	• Generally not economical for drainage area less than 10 acres • Potential safety hazards if not properly maintained • If not adequately maintained, can be an eyesore, breed mosquitoes, and create undesirable odors • Requires considerable space, which limits use in densely urbanized areas with expensive land and property values • Not suitable for hydrologic soil groups "A" and "B" (SCS classification) • With possible oxygen depletion, may severely impact downstream aquatic life
Constructed Stormwater Wetland Constructed to simulate their natural wetland counterparts. Offer a high degree of nutrient uptake and sediment removal, and provide habitat and aesthetic benefits. Often designed with an upper chamber to trap sediments. Careful designs must judge adequate flow rates, microtopography, species diversity, and sediment volume; material excavation must be anticipated for long-term maintenance.	• Can serve large developments or areas; most cost-effective for larger, more intensively developed sites • Provides peak flow control, reducing runoff flows, erosion and flooding downstream • Enhances aesthetics and provides recreational benefits • The marsh fringe also protects shoreline from erosion • Permanent pool in wet ponds helps to prevent scour and resuspension of sediments • Has high pollutant removal capability • Can create valuable aquatic habitat when properly maintained	• Generally not economical for drainage area less than 10 acres • Potential safety hazards if not properly maintained • If not adequately maintained can be an eyesore, breed mosquitoes, and create undesirable odors • Requires considerable space, which limits use in densely urbanized areas with expensive land and property values • With possible oxygen depletion, may severely impact downstream aquatic life • May contribute to nutrient loadings during die-down periods of vegetation
Filtration Basin First flush of rainfall diverted into a sand-filled impoundment. Sediments and associated pollutants strained by sand; water returned via perforated, subsurface pipes to receiving waters. Removal can be enhanced with an additional layer of peat, limestone, and/or topsoil. Soluble pollutants not reliably removed.	• Ability to accommodate medium-size development (3–80 acres) • Flexibility to provide or not provide groundwater recharge • Can provide peak volume control	• Requires pretreatment of storm water through sedimentation to prevent filter media from prematurely clogging • Minimal nutrient removal

Table 7-1, cont'd

Management Practice	Advantages	Disadvantages
Infiltration Basin Impoundments detain runoff, allowing it to recharge over a design period. Improved designs remove coarse sediments before they enter and clog the infiltration capacity of the basin. Full and partial exfiltration options available, depending upon the percentageof runoff desired to treat. Water quality versions treat only the first flush (Schueler, 1987).	• Provides groundwater recharge • Can serve large developments • High removal capability for particulate pollutants and moderate removal for soluble pollutants • When basin works, it can replicate predevelopment hydrology more closely than other BMP options • Basins provide more habitat value than other infiltration systems • Construction cost moderate	• Possible risk of contaminating ground water • Only feasible where soil is permeable and there is sufficient depth to rock and water table • Fairly high failure rate • If not adequately maintained, can be an eyesore, breed mosquitoes, and create undesirable odors • Regular maintenance activities cannot prevent rapid clogging of infiltration basins • Rehabilitation costs potentially high
Infiltration Trench Trench filled with rock to form easily recharged underground reservoirs for runoff. Improved designs incorporate mechanisms to remove sediment and oil before entry into trench. Generally serves drainage areas of less than 10 acres where ponds cannot be used. Full/partial exfiltration and water quality designs possible (Schueler, 1987).	• Provides groundwater recharge • Can serve small drainage areas • Can fit into medians, perimeters, and other unused areas of a development site • Helps replicate predevelopment hydrology, increases dry weather baseflow, and reduces bankful flooding frequency • Cost-effective for smaller sites	• Possible risk of contaminating ground water • Only feasible where soil is permeable and there is sufficient depth to rock and water table • Since not as visible as other BMPs, less likely to be maintained by residents • Requires significant maintenance • Rehabilitation costs potentially considerable
Porous Pavement Porous asphalt design infiltrates runoff into underground rock-filled reservoir for recharge. Often ineffective due to cloggage by fine, clayey soils; recommended only select circumstances. Full/partial exfiltration and water quality designs possible (Schueler, 1987).	• Provides groundwater recharge • Provides water quality control without additional consumption of land • Can provide peak flow control • High removal rates for sediment, nutrients, organic matter, and trace metals • When operating properly can replicate predevelopment hydrology • Eliminates the need for stormwater drainage, conveyance, and treatment systems off-site • Cost-effective compared to conventional asphalt when working properly	• Requires regular maintenance • Possible risk of contaminating ground water • Only feasible where soil is permeable, there is sufficient depth to rock and water table, and there are gentle slopes • Not suitable for areas with high traffic volume • Need extensive feasibility tests, inspections, and very high level of construction workmanship • High failure rate due to clogging • Not suitable to serve large off-site pervious areas
Concrete Grid Pavement Honeycomb grid of concrete blocks filled with pervious materials (e.g. gravel, sand, grass). Proper design bears vehicular traffic while still allowing infiltration.	• Can provide peak flow control • Provides groundwater recharge • Provides water quality control without additional consumption of land	• Requires regular maintenance • Not suitable for area with high traffic volume • Possible risk of contaminating ground water • Only feasible where soil is permeable, there is sufficient depth to rock and water table, and there are gentle slopes
Grassed Swales Check dams may be installed along swale to increase infiltration (Schueler, 1987). May be substituted for more expensive curb and gutter systems for storm water pollution reduction in certain areas.	• Requires minimal land area • Can be used as part of the runoff conveyance system to provide pretreatment • Can provide sufficient runoff control to replace curb and gutter in single-family residential subdivisions and on highway medians • Economical; low cost compared to curb and gutter	• Low pollutant removal rates • Leaching from culverts and fertilized lawns may actually increase the presence of trace metals and nutrients • Low cost compared to curb and gutter

Source: Modified and expanded from EPA, 1993.

Table 7-2
Structural BMPs: Effectiveness in Water Quality Control

Management Practice	Removal Efficiency (%) TSS	TP	TN	COD	Pb	Zn	Factors
Extended Detention (ED) Dry Pond							
Average:	45	25	30	20	50	20	– Storage volume
Reported Range:	5–90	10–55	20–60	0–40	25–65	(-40)–65	– Detention time
Probable Range:[d]	70–90	10–60	20–60	30–40	20–60	40–60	– Pond shape
No. Values Considered:	6	6	4	5	4	5	
Extended Detention (ED) Wet Pond							
Average:	80	65	55	NA	40	20	– Pool volume
Reported Range:	50–100	50–80	55	NA	40	20	– Pond shape
Probable Range:	50–95	50–90	10–90	10–90	10–95	20–95	– Detention time
No. Values Considered:	3	3	1	0	1	1	
Wet Pond							
Average:	60	45	35	40	75	60	– Pool volume
Reported Range:	(-30)–91	10–85	5–85	5–90	10–95	10–95	– Pond shape
Probable Range:	50–90	20–90	10–90	10–90	10–95	20–95	
No. Values Considered:	18	18	9	7	13	13	
Constructed Stormwater Wetland							
Average:	65	25	20	50	65	35	– Storage volume
Reported Range:	(-20)–100	(-120)–100	(-15)–40	20–80	30–95	(-30)–80	– Detention time
Probable Range[e]:	50–90	(-5)–80	0–40	---	30–95	---	– Pool shape
No. Values Considered:	23	24	8	2	10	8	– Wetland's biota – Seasonal variation
Filtration Basin							
Average:	80	50	35	55	60	65	– Treatment volume
Reported Range:	60–95	0–90	20–40	45–70	30–90	50–80	– Filtration media
Probable Range:	60–90	0–80	20–40	40–70	40–80	40–80	
Number of References:	10	6	7	3	5	5	
Infiltration Basin							
Average:	75	65	60	65	65	65	– Soil percolation rates
Reported Range:	45–100	45–100	45–100	45–100	45–100	45–100	– Basin surface area
Probable Range:[a]							– Storage volume
SCS Soil Group A	60–100	60–100	60–100	60–100	60–100	60–100	
SCS Soil Group B	50–80	50–80	50–80	50–80	50–80	50–80	
No. Values Considered:	7	7	7	4	4	4	
Infiltration Trench							
Average:	75	60	55	65	65	65	– Soil percolation rates
Reported Range:	45–100	40–100	(-10)–100	45–100	45–100	45–100	– Trench surface area
Probable Range:[b]							– Storage volume
SCS Soil Group A	60–100	60–100	60–100	60–100	60–100	60–100	
SCS Soil Group B	50–90	50–90	50–90	50–90	50–90	50–90	
No. Values Considered:	9	9	9	4	4	4	
Porous Pavement							
Average:	90	65	85	80	100	100	– Percolation rates
Reported Range:	80–95	65	80–85	80	100	100	– Storage volume
Probable Range:	60–90	60–90	60–90	60–90	60–90	60–90	
No. Values Considered:	2	2	2	2	2	2	

Table 7-2, concluded

Management Practice	Removal Efficiency (%) TSS	TP	TN	COD	Pb	Zn	Factors
Concrete Grid Pavement							
Average:	90	90	90	90	90	90	– Percolation rates
Reported Range:	65–100	65–100	65–100	65–100	65–100	65–100	
Probable Range:	60–90	60–90	60–90	60–90	60–90	60–90	
No. Values Considered:	2	2	2	2	2	2	
Grassed Swales							
Average:	60	20	10	25	70	60	– Runoff volume
Reported Range:	0–100	0–100	0–40	25	3–100[f]	50–60[f]	– Slope
Probable Range:[c]	20–40	20–40	10–30	---	10–20	10–20	– Soil infiltration rates
No. Values Considered:	10	8	4	1	10	7	– Vegetative cover – Swale length – Swale geometry

Source: EPA, 1993. All figures are for BMPs from newly developed areas.
NA – Not available.
a Design criteria: storage volume equals 90% avg runoff volume, which completely drains in 72 hours; maximum depth = 8 ft; minimum depth = 2 ft.
b Design criteria: storage volume equals 90% avg runoff volume, which completely drains in 72 hours; maximum depth = 8 ft; minimum depth = 3 ft; storage volume = 40% excavated trench volume.
c Design criteria: low slope and adequate length.
d Design criteria: min. ED time 12 hours.
e Design criteria: minimum area of wetland equal 1% of drainage area.
f Also reported as 90% TSS removed.

Table 7-3
Structural BMPs: Regional, Site-Specific, and Maintenance Considerations

BMP Option	Size of Drainage Area	Site Requirements	Maintenance Burdens	Longevity
Extended Detention Ponds (Dry and Wet)	Moderate to large	Deep soils	Dry ponds have relatively high burdens	High
Wet Ponds	Moderate to large	Deep soils	Low	High
Constructed Storm Water Wetlands	Moderate to large	Poorly drained soils, space may be limiting	Annual harvesting of vegetation	High
Filtration Basins and Sand Filters	Widely applicable	Widely applicable	Moderate	Low to moderate
Infiltration Basins	Moderate to large	Deep permeable soils	High	Low
Infiltration Trenches	Moderate	Deep permeable soils	High	Low
Porous Pavement	Small	Deep permeable soils, low slopes, and restricted traffic	High	Low
Concrete Grid Pavement	Small	Deep permeable soils, low slopes, and restricted traffic	Moderate to high	High
Grassed Swales	Small	Low-density areas with <15% slope	Low	Low if poorly maintained, high if well maintained

Source: Modified from EPA (1993).

Table 7-4
Nonstructural BMPs: Comparison of Relative Costs and Benefits

	Nutrient Control	Sedimentation	Sediment Toxics	Stormwater Control	Maintenance Burdens	Longevity	Cost to Developers	Cost to Local Governments	Difficulty in Local Implementation	Site Data Required
Buffer Zones/Protection of Existing Vegetation										
Forest Protection	○	⊙	○	○	●	●	○	●	⊙	⊙
Wetland Protection	●	●	○	⊙	●	●	⊙	●	●	○
Stream Buffers	⊙	⊙	○	○	●	●	⊙	●	⊙	●
Wetland Buffers	⊙	⊙	○	○	●	●	○	●	●	●
Expanded Buffers	●	●	○	○	●	●	⊙	●	○	○
Floodplain Limits	⊙	○	○	⊙	●	●	⊙	●	⊙	⊙
Steep Soils Limits	○	●	○	⊙	●	●	⊙	●	●	●
Site Planning BMPs										
Septic Limits	⊙	○	○	□	●	●	○	⊙	○	⊙
Minimize Imperviousness	○	○	○	⊙						
Time/Area Disturbance	⊙	⊙	□		●	●	●	⊙	●	⊙
Public Education Programs										
Urban Housekeeping	○	⊙	⊙	□	⊙	○		●	●	●
Fertilizer Control	⊙	□	□	□	○	○		⊙	⊙	⊙
Septic Maintenance	⊙	□	□	□	○	⊙		⊙	⊙	○
Household Hazardous Waste	○	□	●	□	○	○		⊙	⊙	○
	● 0–40% High Level of Control ⊙ 30–40% Mod. Level of Control ○ 0–20% Low Level of Control □ Ineffective	● 60+ High ⊙ 30–60% Moderate ○ 0–30% Low □ Ineffective	● Highly Effective ⊙ Moderately Effective ○ Low Effectiveness □ Ineffective	● Highly Effective ⊙ Moderately Effective ○ Low Effectiveness □ Ineffective	● Low Burden ⊙ Moderate Burden ○ High Burden □ Not Applicable	● Long Lived ⊙ Long Lived w/Maintenance ○ Short Lived □ Not Applicable	● Low ⊙ Moderate ○ High □ Very High	● Low ⊙ Moderate ○ High □ Very High	● Easy ⊙ Moderate ○ Tough □ Very Tough	● Simple ⊙ Moderate ○ Complex □ None

Source: Derived from EPA, 1993.

these areas would provide additional protection. Table 7-4 also gives information on limiting the development of steep slopes. Buffer zones may be incorporated into a development plan as an aesthetic amenity and wildlife habitat area as well as a pollution prevention measure. Excellent examples of buffer zone use can be seen in the Woodlands community near Houston, Texas, where pollution control and aesthetic design have been integrally combined.

Site Planning BMPs. A number of water quality benefits may be relatively easily achieved through the use of careful site planning and design in new developments. Table 7-4 presents general considerations for the nonstructural BMPs discussed in this section. Septic limits refer to guidelines on the proper location of onsite disposal systems (OSDS), including septic systems. If improperly sited and/or installed, OSDS are potentially a large source of pollution. Therefore, many municipalities across the U.S. advise against the placement of such systems near streams and other hydrologically problematic areas. Minimization of imperviousness is also a common strategy to avoid many of the negative effects of increases in paved surfaces. Buildings and associated parking areas may be clustered such that open spaces (pervious areas) are maximized and impervious areas are held to a minimum. Reduction of “effective” (hydraulically connected) impervious cover and structural BMPs such as grassed swales, as well as porous and concrete grid pavement, can be logically included in designs minimizing the extent and relative effects of impermeable surfaces (see Table 7-1). These innovative designs build in relatively low maintenance, or no maintenance, water quality features, reducing the need for costly future BMP retrofitting to offset developmental impacts. Time/area disturbance BMPs are those which intelligently sequence the timing of construction "to limit the amount of disturbed area at any given time" and to discourage the disturbance of areas to be used as buffer zones post-development (EPA, 1993).

Public Education Programs. A wide variety of innovative and effective public education campaigns have been developed throughout the United States to combat storm water pollution. The EPA has compiled several very useful summaries of such programs (EPA, 1993). Table 7-4 presents four basic programs: Urban Housekeeping; Fertilizer Control; Septic Maintenance; and Household Hazardous Waste. Urban housekeeping BMPs seek to educate the public about ways to limit storm water pollution (e.g., litter and pet waste control) and avoid introduction of harmful substances into waterways. Fertilizer control seeks to educate the public about sensible fertilizer selection and application techniques, minimizing nutrient pollution from more soluble forms of fertilizers. Septic maintenance includes a wide array of strategies on proper septic system upkeep ranging from education of homeowners about operation and maintenance procedures to systematically informing OSDS installers and waste haulers with up-to-date information.

Household hazardous waste programs seek to inform the public about the means of properly disposing of common household toxic substances commonly contributing to storm water pollution (e.g., waste motor oil, pesticides, paint thinner, etc.) and the availability and selection of non-toxic alternatives. Additional considerations/topics for storm water public education campaigns include the use of water tolerant, disease-resistant native plant species (e.g., xeriscape strategies, which minimize fertilizer and pesticide use), innovative turf management (e.g., proper use of treated wastewater for golf course irrigation), and education about the connection between storm water pollution and public infrastructure (e.g., keeping waste materials out of the storm sewer system; some cities have stenciled reminders of the destination of the sewer, such as “Rock Creek”) (EPA, 1993).

Options:

1) Continue meetings between the City Council, SWMP Task Force, City staff, and other stakeholders and move forward with discussions to decide whether the City should investigate new structural and/or nonstructural storm water controls (BMPs) in new developments to improve existing water quality conditions and help prevent further degradation. The discussions should also include whether the requirement for such controls be different for areas draining into Lake Thunderbird versus those that drain directly to the Canadian River. Use of these controls would serve to comply with the City’s OPDES permit with ODEQ for minimum control measure number five (discussed above) entitled “Post-Construction Management in New Development and Redevelopment.”

2) Generally, implement structural storm water quality controls in the same manner and locations as storm water detention and consistent with the ordinance considerations provide below this section. Implement non-structural controls associated with the MS4 (minimum control measures), require SPCs and floodplain dedications, educate the public on limiting fertilizer application, develop a program to educate the public on fertilizer overuse, ensure proper septic system operation and maintenance, and maintain present development density limits in the Lake Thunderbird watershed.

3) Forego any changes to development regulations related to storm water structural and nonstructural controls and wait for any new requirements under ODEQ’s Lake Thunderbird’s watershed management plan and/or the OPDES MS4 program.

Recommendation Actions: Option 2 – It is recommended that structural storm water controls be, in general, required in the same manner and locations as required for storm water detention throughout the city. Further elaboration of how storm water quality controls could work is provided below in proposed ordinance enhancements. These structural controls can be built in conjunction with storm water detention facilities in most instances. In most, but not all, cases and due to maintenance costs, public safety, and nuisance (insects, etc.) considerations, the City should encourage the use of dry detention and water quality facilities rather than wet detention/water quality facilities. For nonstructural controls that should be concurrently implemented with structural controls, the City should continue to ensure that the minimum control measures, as part of the OPDES MS4 program, be met. Additionally, the City should require floodplain/SPC dedications, implement a program to educate the public on fertilizer use, develop a program to control the overuse of fertilizers, and ensure proper septic system installation and operation, as well as continue to limit development density (and impervious cover) in the Lake Thunderbird watershed.

Proposed Considerations, including Variances, for Incorporating Stream Planning Corridors (SPCs) and Structural as well as Nonstructural Water Quality Controls into Norman’s Land Development Ordinances

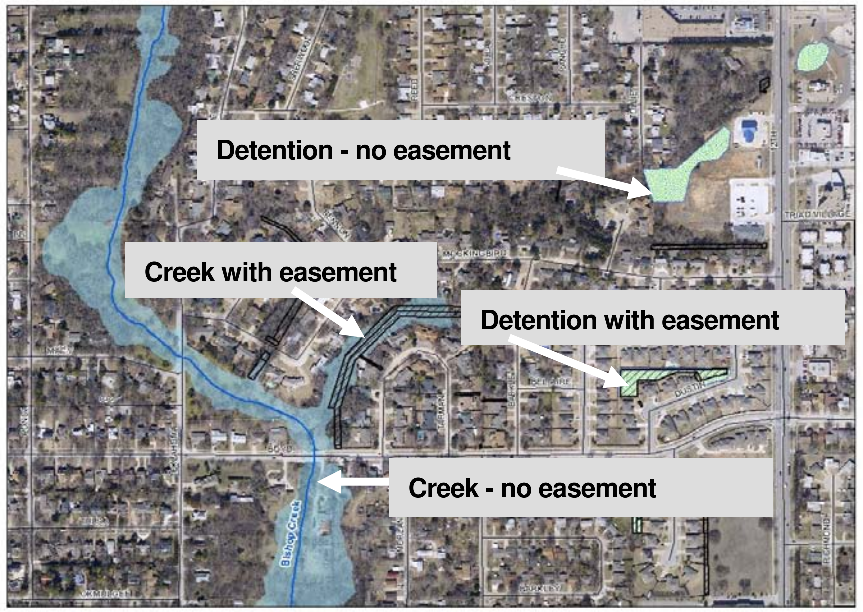
The following generally outlines how SPCs and structural/nonstructural storm water controls could be incorporated into Norman’s ordinances and subdivision regulations. These recommended ordinance additions are presented to illustrate how the dedications of SPCs and utilization of water quality controls can work in tandem to protect Norman’s stream and lake water quality while allowing some flexibility in compliance for the City and developers. These ordinance items would be in addition to other existing or proposed ordinance requirements. Further, it addresses the possible uses of variances for special or atypical circumstances including the compensatory requirements for those that obtain variances.

- Unless stipulated otherwise herein, these considerations would apply to all developments including, but not limited to, single-family residential, multi-family residential, commercial, industrial, and possible institutional developments.
- Dedicate SPCs and/or the 100-year full buildout floodplains to the City of Norman by easement or title for streams located in the Lake Thunderbird watershed that have a drainage area greater than 40 acres.
  - Prohibit development or significant land disturbance in the SPCs and/or 100-year full buildout floodplain. Exemptions should include items such as, but not limited to, maintenance activities, greenway trails, road crossings, utilities, and stream stabilization measures.
  - Additional stream-side buffers of 15 ft to be added to each side of waterways for streams with greater than 40 acres that are located in the Lake Thunderbird watershed and also in Suburban Residential and Country Residential areas as defined in the Norman 2025 Plan.
  - If development per lot storm water fees are ultimately required to help pay for storm water management costs in the City, these fees will not be charged to developments that dedicate SPCs and/or full buildout 100-year floodplains to the City by easement or title for streams that drain more than 40 acres and are located in the Lake Thunderbird watershed.
- Require that water quality facilities be constructed to capture and treat runoff from all proposed developments in the City of Norman that exceed one acre (or some other size selected by the City) in size. The runoff "capture and treatment volume" should be set to 0.5 inch of runoff from the development area unless specified otherwise for a special condition.
  - The City should consider allowing very small developments, say less than one acre or some other limit, to pay into a regional detention/water quality program in lieu of building very small water quality structures. The City's present regional detention program should be broadened to include this water quality fee in lieu process.
  - The City should allow and encourage low impact development techniques such as rain gardens and biofilters to provide a portion or all of their storm water quality control requirements subject to the developer providing sufficient technical justification for the techniques.
  - For developments that do not dedicate the SPC or full buildout 100-year floodplain by virtue of obtaining a variance, the runoff capture and treatment volume for their development area should be increased to 0.7 inch of runoff.
- Require storm water detention facilities to control post-development peak discharges to pre-development peak discharges for the 2-, 5-, 10-, 25-, 50-, and 100-year events assuming full buildout watershed development.
  - Inlet and outlet structures to provide erosion protection and will be constructed of materials that offer sustainability of the structures.
  - Entity with dedicated funding source made responsible for general maintenance (mowing, trash cleanup, etc.).
  - City to assume responsibility of dams and other structures.
- Allow limited variances for special conditions/situations that would utilize alternative approaches that could be shown to achieve similar water quality, flood control, and recreational opportunity. In situations where there is a clearly defined riparian corridor of environmental significance and/or flood prone soils, it should be relatively more difficult to obtain such a variance. However, obtaining such variances should be less difficult in situations where a riparian corridor does not exist and the subject waterway flows through an area that has experienced significant past disturbance or change from natural conditions (such as past agricultural activities and/or activities associated with residential, commercial, transportation, or industrial uses).
- Implement nonstructural storm water quality controls in addition to SPCs, including a program to educate the public on fertilizer use, a program to control the overuse of fertilizers, a procedure to ensure proper septic system installation and operation, and a continuation of development density (and impervious cover) limitations in the Lake Thunderbird watershed.
- Require the following compliance measures if development or significant land disturbance occurs within the stream banks of a stream in the City:
  - USACE's 404 permitting documentation and proof of permit to be submitted to the City prior to plat approval,
  - Riparian stream corridor mitigation will be required (tree replacement, re-vegetation, stream stabilization using bio-engineering techniques, etc.), and
  - Inlet and outlet structures will be provided as needed to incorporate erosion protection.

7.3 ACQUISITION OF DRAINAGE EASEMENTS AND RIGHTS-OF-WAY

Like many other municipalities, the City of Norman periodically needs access to streams/creeks, man-made channels, ditches, drains, storm sewers, and storm water detention ponds, for the purposes of construction, maintenance, repair, and overall management of these storm water systems to aid in their proper function. Unfortunately, investigations carried out in this SWMP project revealed that there is an overwhelming lack of drainage easements or rights-of-way (ROW) along streams, open channels, and storm water detention ponds in Norman. The location of easements/rights-of-way along streams and storm water detention facilities are available in the City's GIS system and are shown in the plan (odd numbered) exhibits in Section 6 for Level 1 and 2 study areas. This information clearly shows that most stream reaches and detention facilities have no easements/ROW at all, others have insufficient amounts, and a few have sufficient easements.

Analyses performed during the SWMP effort revealed that the City would need to acquire, or accept as a donation, easements/ROW on well over a thousand properties to gain the rights and access to major streams (assuming bank to bank plus approximately 10 ft beyond each bank) and storm water detention facilities in its urban area. The number of properties requiring easement/ROW purchases or donations would increase significantly if the City were to obtain the FEMA floodways along these creeks as easement or out right purchase.



Typical easement conditions in Norman

Adding to this overall problem, property owners have built structures, fences, and other flow obstructions adjacent to undersized waterways in the floodplain and even the floodway. These obstructions often block flood flows and increase flooding problems along waterways and contribute to the debris that washes into the streams. Additionally, many property owners have made attempts to "fix" problems such as eroding stream banks or beds by dumping various materials (e.g., concrete rubble, logs, wire mesh, cables, tin, etc.) into the waterways. In doing this, these property owners likely did not understand or contemplate the possible negative impacts that their action may cause to other properties along the stream or to the overall stream environment.

Several discussions on the subject of easement/ROW needs have been held with City Council in work session, the SWMP Task Force, the City staff, and other stakeholders (including City Council sessions). Guidance in a general sense was obtained that basically called for a targeted and controlled acquisition of easements and rights-of-way associated with the City's storm water planning. Easements and/or ROW needed to construct critical stream flood control and/or stream erosion stabilization projects as well as to allow access to streams needing critical maintenance will be targeted for acquisition with those involving project construction receiving the highest priority. It is hopeful that much of the easement/ROW area will be donated to the City although in some instances purchasing the easement may be required. The City has indicated that those that donate easement/ROW area will be looked on favorably when selecting projects to build around the City. Even though the City has indicated how they would like to proceed as stated above, the subject of obtaining easements and/or rights-of-way as considered during the SWMP is presented below.

7.3.1 Key Questions, Options, and Recommended Actions

Question 1: Does the City want to obtain (through donations or purchasing) drainage easements and/or rights-of-way in previously urbanized areas in order to possibly construct needed modifications, provide maintenance, and/or carry out inspections on an as-needed basis?

Discussion: This is an issue that has grown in significance and importance since the inception and initiation of the SWMP project. The lack of drainage easements or drainage-related rights-of-way was not fully understood by many until the SWMP investigations brought attention to the related issues. It is in the best interest (health, safety, maintenance of property values, etc.) of the local citizens to have properly functioning drainage systems. As part of the SWMP, there are apparent needs to construct modifications, clean out clogged and eroding stream reaches, and maintain the stream on a regular basis.

When considering the needs identified by the SWMP, it may be best to obtain rights-of-way or special easements in stream reaches where past structures and/or improvements are located or future structures will be located in order for the City to perform the type of repair, reconstruction, inspection, survey, and/or maintenance work needed in such reaches to keep the system operating properly. It must be very clear that these reaches having significant public investment must be easily accessible to protect those investments. In other stream reaches, it may be acceptable to obtain more or less standard easements primarily for access to maintain the waterway such as cleaning, shaping, seeding, stabilizing, or mowing. Another option on certain stream reaches would be to develop a right-of-entry program such that property owners are asked for "single event" access to a stream area on their property for maintenance or stabilization work. The City can opt to only enter if given the right-of-entry approval or possibly enter regardless if the planned work is for the health and safety of the public at large and inaction would significantly endanger other citizens and property. The City may also want to determine whether it has the legal authority to enter private property for storm water management maintenance or modifications if it would create an unacceptable risk to the health and safety of the public in not taking such action.

Costs of obtaining these rights or properties are also a big consideration especially since preliminary costs to obtain easements (creek area plus 10 ft beyond the top of bank) along all the Level 1 and 2 streams was estimated to exceed \$18 million. Again, the City has decided to be much more selective in purchasing easements/ROW as discussed above. Costs to obtain wider easements such as obtaining the entire floodway along the respective creeks might cost significantly more than the figure given above since numerous buildings and other structures would have to be bought along with a much larger property footprint. Relocations of effected homeowners and businesses would also need to be considered. Some property owners might be willing to donate an easement to the City while others might not. Guidance received from the City indicates that approximately 20–30% might donate drainage easements to the City while 80% would want the easements to be purchased. In most all rights-of-way transfers of property, the owners might want to sell the property to the City rather than donate it although there would be exceptions. One exception might be that land owners along a creek needing improvements could come forward as a group and donate easements or rights-of-way in order to move a project up on the City's priority list which could also reduce costs significantly. Finally, it should be recognized that whatever plan is selected, obtaining easements on a citywide scale would be spread out over a long time period such as 10 to 20 years, if not longer.

In looking at the options below, it is assumed that there will be some storm water management system improvements in the City as a result of the SWMP.

Options:

1) Obtain drainage easements along all streams identified in the SWMP along the Level 1 and 2 stream reaches studied.
2) Obtain drainage easements along only those streams that have a SWMP improvement project implemented or reaches that are judged to have a significant present and/or ongoing maintenance need (likely obtained when the improvement project is constructed or the first maintenance activity is carried out).
3) Obtain a mixture of drainage easements, rights-of-way, rights-of-entry, and reaches of "no action" depending on the situation/conditions. This option possibly offers the best solution as it is very flexible and allows the City to utilize their funds in the most efficient manner. For instance, rights-of-way could be obtained along reaches where substantial structures/improvements are built or will be built. Drainage easements could be obtained in areas that have a need to significant initial and/or ongoing maintenance. Rights-of-entry could be used in areas that will likely need maintenance every few years and/or only if certain things occurred (e.g., large storms or a buildup of debris over, say, five to ten years). Finally, there might be some reaches that are presently being maintained (e.g., mowed often like a lawn) by property owners and these property owners would like to continue doing so. The City could simply let the maintenance of those reaches stay with the property owner as they are doing a good job and want to continue doing so.

Recommended Actions: Option 3 – Obtain a mixture of drainage easements, rights-of-way, rights-of-entry, and reaches of "no action" depending on the situation/conditions. The preferred approach would be to obtain easements or rights-of-way wherever possible unless there are location-specific problems with this approach. However, and while it is preferred to obtain easements or rights-of-way, obtaining rights-of-entry and/or not obtaining any easement ("no action") may be the most prudent action in certain instances. When considering the needs in any specific area, it is recommended that rights-of-way or special easements be obtained in stream reaches where past structures and/or improvements are located or future structures will be located. This is needed to allow the City to perform the type of repair, reconstruction, inspection, survey, and/or maintenance work needed in such reaches to keep the system operating properly. It must be very clear that these reaches having significant public investment and therefore, must be easily accessible to protect those investments. In other stream reaches, it may be acceptable to obtain more or less standard easements primarily for access to maintain the waterway such as cleaning, shaping, seeding, stabilizing, or mowing. On stream reaches where one or more property owner are reluctant to provide easements or rights-of-way, the City should consider obtaining a rights-of-entry to targeted properties. In these instances, property owners are asked for "single event" access to a stream area on their property for maintenance or stabilization work. The City can opt to only enter if given the right-of-entry approval or possibly enter regardless if the planned work is for the health and safety of the public at large and inaction would significantly endanger other citizens and property. The City may also want to determine whether it has the legal authority to enter private property for storm water management maintenance or modifications if it would create an unacceptable risk to the health and safety of the public in not taking such action.

Consideration 2: Does the City want to obtain rights-of-way or easement widths that cover the respective creek channels (bed and banks), possibly going a distance of say 10 ft beyond the bank, or obtain a much larger area such as creek floodway areas.

Discussion: In instances where the City does want to pursue obtaining easements or rights-of-way, then a follow on question becomes how much to obtain. As mentioned above, two ideas have emerged related to the amount of easement/ROW to obtain if that is the direction the City chooses. As for obtaining the creek (bank to bank plus say 10 ft), this would cost the least and would be a much smaller undertaking compared to obtaining the FEMA floodway. Although many property owners might be reluctant to "give up" some of their property or property rights near the creek, they might prefer this to being bought out in the floodway-based easement buyout which would be required on numerous properties that are located in the floodway. FEMA defines the regulatory floodway as the channel of a river or other water course and the adjacent land areas that must be reserved in order to discharge the base (100-year or 1%) flood without cumulatively increasing the water surface elevation more than a designated height (usually 1 foot).

There are many benefits to obtaining the floodway as easement. One primary benefit would be to remove numerous structures from harms way in the floodway. This would also offer a much larger area for greenbelts and open space along waterways, a SWMP priority. Again, the main drawbacks would be the increased costs, the need to relocate many residents to different homes, and to move businesses to new locations. The benefits would be that the stream corridor would be more respected and returned to a more natural state (within limits) which would add to the "quality of life" in those stream areas and restore some lost environmental qualities.

Options:

1) When obtaining easements or rights-of-way, target the area extending from stream bank to stream bank plus 10 ft on each side.
2) When obtaining easements or rights-of-way, target the area that is encompassed by the FEMA floodway along the respective streams.

Recommended Actions: The City should use a combination of Options 1 and 2 and obtain easements/ROW extending bank to bank plus 10 ft (or a somewhat wider amount depending on specific site circumstances) on each side of Level 1 and 2 creeks while allowing that in a few special locations such as Imhoff Creek, a plan be developed to obtain properties in the FEMA floodway over a longer period of time.

7.4 ENHANCED MAINTENANCE OF CREEKS AND STORM WATER DETENTION FACILITIES

There is no formal maintenance program to maintain the many open waterways in the City. The lack of drainage easements along the City's streams has played a major role in the lack of maintenance as access and rights are limited. A large number of steam reaches have not been maintained at all, some have had sporadic maintenance by City workers or landowners, and certain ones appear to have been maintained regularly by landowners. The lack of maintenance has caused "log jams" on creeks such as Imhoff Creek where, in the past, fallen trees and debris have clogged the waterway and built a virtual dam across the stream. In the reaches that are unmaintained, the stream corridor does not appear capable of safely carrying storm flows, detracts from the aesthetic appeal of the creek, presents an environmentally damaged setting, and can subject local citizens to unsafe conditions. However, there are some stream reaches that look well maintained as local residents appear to be maintaining the creek near their properties.

As stated above, the lack of easements/ROW and resulting access limitations has historically played a big role in a significant deficiency in storm water maintenance throughout Norman. Many times property owner associations (POAs) have the responsibility of maintaining the creeks and storm water detention facilities located in their neighborhoods. This has led to poor maintenance or no maintenance in many of these storm water areas. There are some instances where POA maintenance appears to be adequate such as in the Hall Park neighborhood. However, the inadequate and inconsistent maintenance has led to numerous problems that the City Council and City staff feel need to be addressed. If the City of Norman wants to upgrade its maintenance, the acquisition of drainage easements or rights-of-way from existing and new developments must be part of the solution. Discussions with City Council members, the SWMP Task Force, the City staff, and other stakeholders documented the need for future maintenance activities in coordination with the acquisition of selective easements and rights-of-way.

Various cities and counties were contacted to obtain general program costs of maintaining various types of streams. These program costs include the manpower and equipment costs required. Typical costs were developed for each type/condition of a stream from this information. The City's GIS data were used to obtain estimates of stream lengths and storm water detention facility dimensions to provide the quantities of areas requiring maintenance. Estimating general maintenance costs for Levels 1 and 2 streams included delineating three stream types, obtaining lengths of each stream type, estimating unit maintenance costs by type, respectively multiplying stream lengths by unit costs for the three stream types, and totaling all costs for stream maintenance as shown below. Obtaining general maintenance cost estimates for storm water detention facilities included measuring the perimeter length around each storm water detention facility area, totaling the perimeter lengths, obtaining the unit maintenance cost, and multiplying the total perimeter length by the unit cost to arrive at the total cost. When added together, the general estimate of annual maintenance costs for streams and storm water detention facilities totals approximately $1.2 million.

Debris blocking Imhoff Creek

Woody debris in lower Bishop Creek

Stream maintenance is a significant commitment.

7.4.1 Key Questions, Options, and Recommended Actions

Consideration 1: Does the City want to incur the costs and significantly increase the maintenance provided in streams and waterways especially the Level 1 and 2 streams studied?

Discussion: Costs associated with maintaining the Level 1 and 2 stream reaches will be significant and should be considered in future actions. Costs for the Level 1 and 2 streams are discussed below.

Level 1 and 2 Streams:

- Type 1: Natural channels with lots of trees, steep banks, difficult access, debris problems, etc. (Example = lower Imhoff Creek or Brookhaven Creek below 36th Avenue SW or Main Street).
- Type 2: Natural channels that are able to be mowed with few trees, easy access, maybe a concrete low flow channel (Example: Imhoff Creek upstream of the articulated block channel lining near Lindsey Street).
- Type 3: Modified channels with lining such as concrete or articulated block – relatively small and easy. (Example = the WPA channels with mortared rock walls and concrete bottom, such as in upper Imhoff Creek and upper Bishop Creek).
- Unit Costs:
  - Type 1: Assume $12,000/mi/yr. ($24,000/mi for years that inspections are conducted). Assumes maintenance performed once every two years on average.
  - Type 2: Assume $8,000/mi/yr. Maintenance every year (once per year).
  - Type 3: Assume $2,000/mi/yr. Maintenance and/or inspection every year. Expectations would be that in most years only inspections would be performed.
- Total length (miles):
  - Type 1: 42.8
  - Type 2: 3.6
  - Type 3: 11.0
- Total Costs:
  - Type 1: $514,000/yr
  - Type 2: $29,000/yr
  - Type 3: $22,000/yr
- Grand Total Costs: $565,000/yr

Consideration 2: Does the City want to significantly increase the maintenance provided for storm water detention facilities? Does the City want to vary the maintenance based on certain types of detention facilities? Does the City want to share responsibility with property owner associations?

Discussion: Similar to what was discussed above for streams, the costs of maintaining storm water detention facilities will be a significant annual expense. A general cost estimate for the present system of detention facilities in the City (based on the City's GIS system data) is presented below.

Storm Water Detention Facilities:

- Number of detention facilities from City's GIS system = 286
- Total perimeter length around the facilities = 61.4 miles
- Unit Cost per mile: $10,000. Maintenance every year (once per year).
- Total Cost: $614,000

Total Costs for Streams and Storm Water Detention Facilities = $1,179,000 (use $1,200,000)

Recommended Actions for Considerations 1 and 2: A City stream maintenance program, with maintenance schedules as recommended above, should be ramped up over a few years consistent with the acquisition of easements, rights-of-way, rights-of-way, rights-of-entry, and reaches of "no action" depending on the situation/conditions. Maintenance should focus in those stream reaches and/or detention facility areas where capital improvements are constructed in order to protect those investments as well as in areas where serious problems have been identified, such as lower Imhoff Creek, lower Brookhaven Creek, and stream erosion sites along Bishop Creek and its tributaries.

The City should also consider outsourcing some, or all, of the maintenance activities if it is advantageous especially while a City's program is ramping up. The City should also focus on detention facilities in which dam maintenance becomes a safety issue as discussed below.

7.5 DAM SAFETY

A key issue that became a concern during the SWMP project involves dam safety. It is obvious from viewing aerial photos of Norman and viewing the City's drainage systems (see Exhibit 4-4) that the City has a great number of dams of significant height with homes and business located in low lying areas downstream of the dams. Many of these dams impound a significant pool of water and/or have the potential to temporarily store large volumes of storm water during flood events. These conditions pose a dam break public safety concern for those that live, work, drive, recreate, and generally occupy the floodplain area downstream of these impoundment structures. Generally speaking, as the height of a dam increases, risks, danger and public safety become more of a concern.

The Oklahoma National Dam Inventory identified approximately 20 dams in the Norman area as shown in Figure 7-1. Most all of these dams were reported to have been built in the 1960s, which makes them 38 to 48 years old. These 20 dams identified in the national inventory are the more substantial dams and came under the jurisdictional authority of the Oklahoma Water Resources Board pursuant to the enactment of Title 82 of Oklahoma Statutes. Consequently, all of the old (i.e., already in existence) jurisdictional dams in Oklahoma were inventoried and inspected by the USACE in the late 1970s as mandated by The National Dam Inspection Act, Public Law 92-367, 8 August 1972 under the "Phase One Inspection of the National Dam Safety Program."

Two key issues require consideration.

7.5.1 Key Questions, Options, and Recommended Actions

Consideration 1: Should the City investigate and identify, to the extent possible, the responsible parties for the inspection, maintenance, and overall safety of the dams that are judged to be a potential safety hazard?

Discussion: Although OWRB oversees dam safety in Oklahoma, it is unclear whether there is a program in place to systematically evaluate the dam sites in Norman. A dam safety concern involves the apparent limited maintenance of many of the dams located in the City as well as the associated principal spillways, the emergency spillways, and the upstream ponding areas in general. In many instances, it is not known who is responsible for the inspection and maintenance of most of these dams that pose a public safety concern in various areas throughout the City. According to the City and in most instances, property owner associations (POAs) have inherited the responsibility for dam inspection and maintenance. The City could undertake one or more investigative projects to determine ownership of the many dams, say 6 ft or higher, located in the City. The dams with the greatest height, unmaintained condition, and/or most downstream development should receive the highest priority during any such investigations. Once ownership is established, the effort should also include gathering information about the dam and its ponding area such as design drawings, inspection reports, maintenance records, and any other pertinent information.

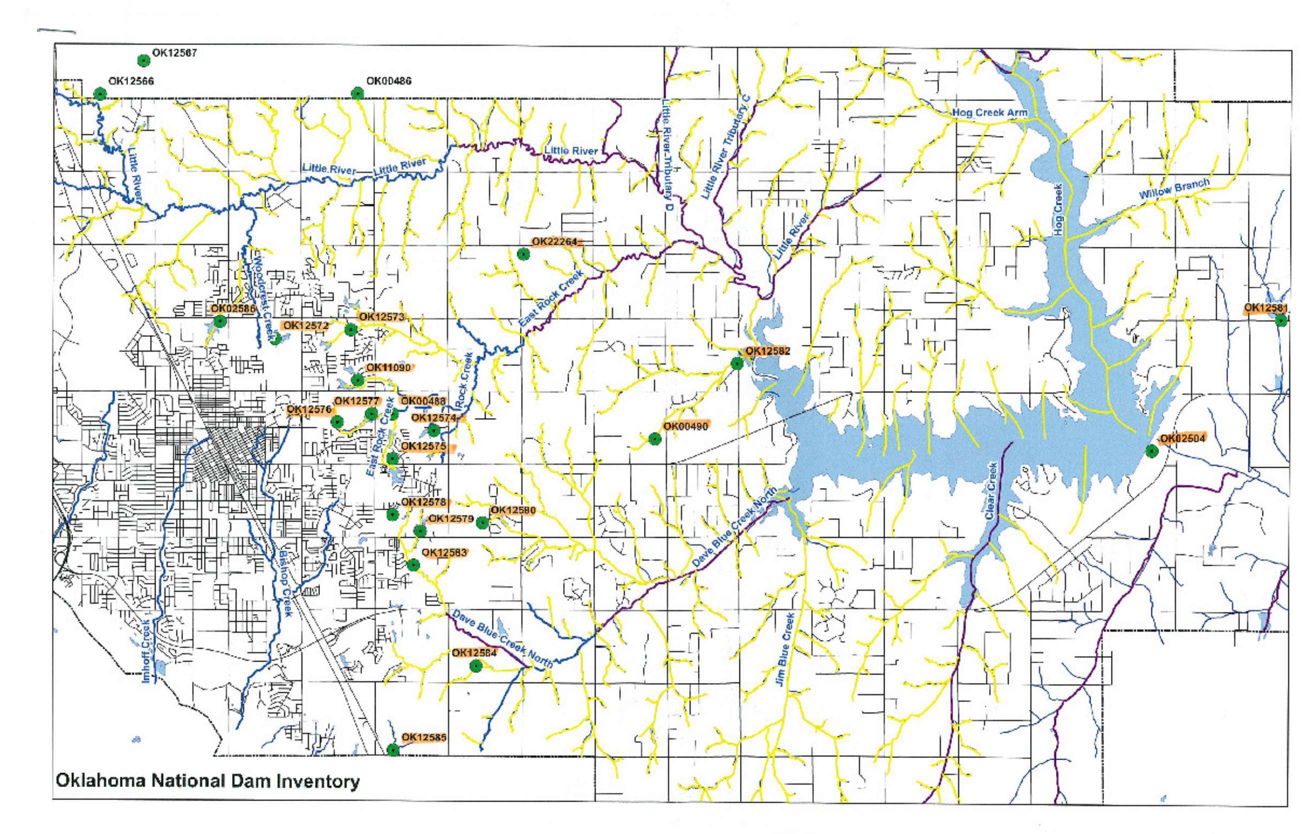


Figure 7-1: Oklahoma National Dam Inventory

Option 1: Undertake one or more investigative projects to determine dam ownership and responsible party for maintenance of the structure and its appurtenances. Collect all available pertinent information about each investigated structure.

Option 2: Forego undertaking any investigative projects.

Recommended Actions: Select Option 1 and undertake the investigative projects beginning with the dams judged to have the greatest public safety risk. An inventory and prioritization method will have to be developed at the beginning of the investigative work.

Consideration 2: Does the City want to take over ownership, liability, and maintenance from POAs or other owners to insure that dams are made safe and properly maintained?

Downstream side of unmaintained dam

Discussion: The City's GIS data indicate that there are almost 290 storm water detention facilities, retention ponds, or other waterbodies in the City. Many of these are likely small and inconsequential from a dam safety standpoint but many warrant public safety concerns.

Recommended Actions: The City should meet with OWRB and obtain their input and insight concerning the dams in Norman and their hazard potential. Considering discussions with City staff and other stakeholders, it is recommended that the City take over the inspection and maintenance for all dams that pose safety concerns or, at least, those that pose the greatest hazards. Further, the POAs should maintain the general mowing and small scale maintenance responsibilities while the City undertakes the more critical dam safety, inspection, and maintenance responsibilities.

It is recommended that the City determine the prevailing conditions for any dam and its appurtenances through an initial investigation prior to taking on any additional responsibilities. Should the City take over inspection, maintenance, and upgrading responsibilities for the structures, it should first be determined what actions they or the present owners might have to take to bring any structures into state dam safety compliance. Such actions could include determining whether the dam structures require modifications to strengthen them against failure or breach. Another important aspect is whether any of the dams need an emergency action plan which is developed to reduce the risk to lives and property that can result from dam failure.

9.0 RECOMMENDATIONS AND IMPLEMENTATION PLAN

The previous eight report sections presented the investigations undertaken and the resultant findings that make up the primary framework for Norman's SWMP. This section expands on several of the key findings to formalize recommendations and provide an "Implementation Plan" (see Section 9.11 below) for future actions that will help improve storm water management in Norman. By necessity, storm water management will always be an ongoing activity at the City and the recommendations made in this report will provide the direction needed to move beyond the SWMP in the future. Some of these recommendations would be best implemented by City staff while others may require the City to obtain assistance from consultants and/or other professionals. Again, these recommendations align with many of the SWMP investigations completed since future actions will be a natural outgrowth of these investigations.

9.1 GENERAL

- Continue to involve stakeholders in all aspects of the SWMP, including implementation.
- Refine storm water and watershed protection goals and needs in the future based on continued public involvement and new studies.
- Develop a formal public outreach campaign or program to continue educating citizens about the City's storm water needs, the importance of obtaining adequate funding to meet those needs, and the general support needed to sustain a viable storm water program at the City level. Some of these primary needs include reliable funding mechanisms such as GO bonding and a storm water utility, MS4 permit compliance requirements, a storm water CIP program, basic operations and maintenance of the storm water system, enhanced maintenance to keep streams clear of debris and trash, enhanced maintenance of detention facilities, acquisition of easements and rights-of-way, and dam safety.

9.2 WATERSHED AND STREAM ASSESSMENTS (SECTION 3)

- Incorporate all of the digital and reference data developed during the SWMP project into the City's GIS and other records. This includes the GIS map overlay system developed to display geo-reference field photo locations taken at strategic creek locations during reconnaissance with the link to view the photos by clicking on the location symbol. Establish a process to systematically update this data and information.
- Update the photo library and GIS layers with new photos of critical areas in the future during maintenance inspections or other field work.
- Inspect and monitor the stream erosion areas identified on a regular schedule (e.g., every 1 or 2 years) until streams are stabilized with adequate improvements.
- Assess the Little River, Rock Creek, and Dave Blue Creek corridors in more detail if significant and contiguous stream access can be obtained.

9.3 HYDROLOGIC MODELING FOR LEVEL 2 AND OTHER STREAMS (SECTION 4)

- Develop modeling for Level 2 (initially) and Level 3 streams that is consistent with the Level 1 modeling performed for the master plan, which used the most up-to-date data and methods. Advances in modeling technology (new versions of HEC-HMS or HEC-RAS) should be integrated as appropriate.
- Continually update modeling needs and change priorities to fit those needs.
- Update drainage area delineations based on the City's 2007 topographic data including resolution of all watershed boundary discrepancies. Update both the GIS layer with the watershed boundaries and the areas in the hydrologic models.
- Update all Level 2 hydrologic models to use HEC-HMS (many are still HEC-1). Also update all HEC-HMS models to version 3.3 (current version at this time) or to the latest version in the future (this should not have any impact on the results of our modeling, which was done with version 3.1.0).
- Update models to include consistent design storm rainfalls (totals and distributions) based on the USGS WRI 99-4232 and the Frequency Storm rainfall distribution (storm centering at 50%).
- Use a standard procedure for design rainfall areal reductions in all modeling of watersheds greater than 9.6 square miles. No areal reduction should be used for smaller watersheds.
- Use standard procedures (NRCS curve numbers) for rainfall loss rate development in all modeling. This includes both the derivation and application of the parameters.
- Use standard procedures for the development of unit hydrograph lag times and update the lag times in the Level 2 and other models as needed.
- Establish standard procedures for hydrograph routing that consider floodplain storage such as the Modified Puls Method. This should be implemented wherever corresponding HEC-RAS models are available.
- Incorporate regional detention facilities into the hydrologic models if an ongoing maintenance program is established (thereby assuring their proper function) and the facilities measurably reduce downstream discharges.

9.4 HYDRAULIC MODELING FOR LEVEL 2 AND OTHER STREAMS (SECTION 4)

- Develop modeling for Level 2 (initially) and Level 3 streams that is consistent with Level 1 modeling (as modified with future advancements) which used the most up-to-date data and methods.
- Continually update modeling needs and change priorities to fit those needs.
- Update flows based on any modifications to the hydrologic models.

- Create updated cross sections based on the City's 2007 topographic data that are fully georeferenced. This will ensure that the latest topography is used and will greatly facilitate accurate floodplain mapping. At a minimum, a georeferenced cross section layer containing all of the cross sections (some locations may have to be estimated if new cross sections are not generated) for each Level 2 model should be created. Fully georeferenced cross section will greatly facilitate floodplain mapping, model updates and the use of the models for development purposes.
- Update roughness coefficients along the streams and in the adjacent overbank areas to better match current existing conditions.
- Review and update bridge/culvert modeling as needed. Structures in models that were converted from HEC-2 should receive special attention.
- Revise the junction modeling for the Brookhaven Creek model. The junctions in the HEC-RAS model received from the City were improperly converted from a previous HEC-2 model yielding slightly conservative water surface elevations.

9.5 CRITERIA MANUAL UPDATES

- Develop a new Drainage Criteria Manual that includes the following:
  - Update design rainfall totals from TP-40/Hydro-35 to USGS WRI 99-4232.
  - Document aerial reduction procedures (most of the City, especially in the urban areas would not need to worry about areal reduction since the watersheds are smaller than 9.6 square miles).
  - Document standard procedure for design rainfall aerial reductions.
  - Document standard procedures for rainfall loss rate development.
  - Document the unit hydrograph methodology standards.
    - Specify the unit hydrograph methodology to be used for modeling – NRCS, Snyder, or either.
    - Document standard procedures used for the development of unit hydrograph lag times.
  - Document standard procedures for hydrograph routing that specify the use of Modified Puls routing where hydraulic models are available.
  - Require full buildout peak discharges for new developments and make necessary changes to City policy, the subdivision regulations, and drainage criteria manual.
- Develop a Storm Water Quality Manual (or incorporate into Drainage Criteria Manual).
- Develop an Erosion Control Manual.

9.6 MODEL MANAGEMENT

- The City of Norman has invested a significant amount in the development of hydrologic and hydraulic models a part of the SWMP. Since the master plan will not directly result in an update of the FEMA floodplains, it will be incumbent upon the City to maintain available and up-to-date copies of these models if they are to be of use to the community as a whole. There are varying levels of solution that can be implemented in order to facilitate the management and distribution of models and supporting data. The following recommendations outline a basic approach that would provide for easy access to the models by City staff and a procedure for tracking updates to these models.
  - Develop an Arc Hydro-compliant stream network and subbasin geodatabase and provide hyperlinks to an associated directory structure built to contain the models for each watershed. Basic tools to store and access the models through these hyperlinks could be adapted from recent systems developed by other entities. There are a variety of options that could be built-on to such an existing system to allow the city to track access to the models, enforce standards, document model changes, etc.).
    - Internal Option – Deploy on an internal server that will allow City staff to store, access and distribute models as needed.
    - External Option – Deploy on a web server and allow the engineering community to access the system and download models for selected stream reaches or watersheds.
  - Include a "metadata" file (can be a simple text or XML file) to document the origin and history/evolution of each hydrologic and hydraulic model.

9.7 FEMA LOMRs

- Submit Letters of Map Revision (LOMRs) to FEMA for the Level 1 streams studied during the SWMP. If other streams are studied or updated, those updates should be submitted as FEMA LOMRs at that time.
- Incorporate regional detention facilities into the hydrologic models if an ongoing maintenance program is established (thereby assuring their proper function) and the facilities measurably reduce downstream discharges.

9.8 STORM WATER PROBLEMS AND SOLUTIONS (SECTIONS 5 AND 6)

- Stream flooding, stream erosion, and local drainage.
  - Continue to monitor and document conditions associated with the problems identified in the SWMP until CIP improvements solve or mitigate them.
  - Review and update solutions prioritization on an annual, two, or five year cycle.
  - Incorporate any new problems and possible solutions on a continuing basis.
  - Continue to explore ways to integrate solutions to address multiple problem types and incorporate greenway opportunities.
  - Develop collaborative agency partnerships to assist in project funding and cooperation.
  - Use stream equilibrium and other geomorphological principals for stream erosion project designs.
  - Any update to the SWMP in the Little River corridor needs to be performed in concert with a roadway planning study as the numerous creek crossings and roadway lengths across the wide Littler River floodplain warrant special consideration in this area.
- Water quality.
  - Maintain awareness and knowledge of all water quality monitoring being carried out in watersheds that originate in, or flow through, the City of Norman.

  - Develop collaborative agency partnerships to assist in project funding and cooperation.
  - Assure compliance with requirements of the MS4 Program and the City's MS4 OPDES storm water permit.
  - Continue to follow and monitor information related to the ODEQ Lake Thunderbird Watershed Management Plan development and provide input when allowed.
  - Comply with recently developed Canadian River Bacteria TMDL requirements as the City may be required to participate in a coordinated monitoring program or develop their own to document the effectiveness of their selected BMPs and to demonstrate progress toward attainment of water quality standards. Reporting requirements include documentation of actions taken by the permittee that affect MS4 storm water discharges to Bishop Creek and the Canadian River.
  - Increase monitoring of erosion controls at construction sites to assure compliance with regulations.
  - See items for Stream Planning Corridors as well as structural and nonstructural storm water controls in Section 9.9 below.

- Capital Improvements Program.
  - Consider developing program staff under the direction of the Director of Public Works to manage the SWMP CIP program and associated projects. These staff can be part of an existing group or make up a new group at the City. If the amount of work is variable, cyclic, or heavy at times, it is recommended that staffing levels target the steady work flow and have consultants assist during times of high work flow.
  - Assuming that funding is available, complete construction the identified CIP projects over a 20- to 25-year period.

9.9 KEY ISSUES (SECTION 7)

- Stream Planning Corridors and 100-year full buildout floodplain dedications as well as structural and nonstructural storm water quality controls.
  - Dedicate Stream Planning Corridors (SPCs) and/or the 100-year full buildout floodplains to the City of Norman by easement or title for streams located in the Lake Thunderbird watershed that have a drainage area greater than 40 acres.
    - Prohibit development or significant land disturbance in the SPCs and/or 100-year full buildout floodplain. Exemptions should include items such as, but not limited to, maintenance activities, greenway trails, road crossings, utilities, and stream stabilization measures.
    - Require additional stream-side buffers of 15 ft to each side of steams with drainage areas greater than 40 acres that are located in the Lake Thunderbird watershed and also in Suburban Residential and Country Residential areas as defined in the Norman 2025 Plan including subsequent updates to the comprehensive plan as adopted by the City Council.
  - Require that water quality facilities be constructed to capture and treat runoff from all proposed developments in the City of Norman that exceed 1 acre (or some other size selected by the City) in size. The runoff "capture and treatment volume" should be set to 0.5 inch of runoff from the development area unless specified otherwise for a special condition.
    - Allow very small developments less than 1 acre in size or some other size limit to pay into a regional detention/water quality program in lieu of building very small water quality structures. The City's present regional detention program should be broadened to include this water quality fee in lieu process.
    - Allow and encourage low impact development techniques such as rain gardens and biofilters to provide a portion or all of their storm water quality control requirements subject to the developer providing sufficient technical justification for the techniques.
    - For developments that do not dedicate the SPC or full buildout 100-year floodplain by virtue of obtaining a variance, the runoff capture and treatment volume for their development area should be increased to 0.7 inch of runoff.
  - Allow limited variances for special conditions/situations that would utilize alternative approaches that could be shown to achieve similar water quality, flood control, and recreational opportunity. In situations where there is a clearly defined riparian corridor of environmental significance and/or flood prone soils, it should be relatively more difficult to obtain such a variance. However, obtaining such variances should be less difficult in situations where a riparian corridor does not exist and the subject waterway flows through an area that has experienced significant past disturbance or change from natural conditions (such as past agricultural activities and/or activities associated with residential, commercial, transportation, or industrial uses).
  - Implement nonstructural storm water quality controls in addition to SPCs, including a program to educate the public on fertilizer use, a program to control the overuse of fertilizers, a procedure to ensure proper septic system installation and operation, and a continuation of development density (and impervious cover) limitations in the Lake Thunderbird watershed.
  - Require the following compliance measures if development or significant land disturbance occurs within the stream banks of a stream in the City:
    - USACE's 404 permitting documentation and proof of permit to be submitted to the City prior to plat approval,
    - Riparian stream corridor mitigation will be required (tree replacement, re-vegetation, stream stabilization using bio-engineering techniques, etc.), and
    - Inlet and outlet structures will be provided as needed to incorporate erosion protection.

- Acquisition of drainage easements and rights-of-way along streams and detention facility areas.
  - Obtain a mixture of drainage easements, rights-of-way, rights-of-entry, and reaches of "no action," depending on the situation/conditions in existing developments.
  - Develop a plan and begin to obtain drainage easements and/or rights-of-way (as needed) in Level 1 and 2 streams and for storm water detention facilities where access is needed for continuous/routine maintenance activities. For streams, the amount of easement or right-of-way would be as needed based on specific site conditions but, in general, would include a width of stream extending bank to bank plus 10 ft on each side of the stream channel. This can include those areas where storm water CIP projects have been identified if the maintenance need justifies obtaining the easements in advance of designing and constructing the proposed CIP project.

- Enhanced maintenance of creeks and storm water detention facilities.
  - Consistent with available funding, a City stream maintenance program should be implemented over the next 2 or 3 years consistent with the acquisition of easements, rights-of-way, rights-of-way, rights-of-entry, and reaches of "no action," depending on the situation/conditions. Maintenance should focus on those stream reaches and/or detention facility areas where capital improvements are constructed in order to protect those investments. The City should also consider outsourcing some, or all, of the maintenance activities if it is advantageous, especially while a City's program is ramping up. The City should also focus on detention facilities in which dam maintenance may become a safety issue.

- Dam safety.
  - The City should investigate and identify, to the extent possible, the responsible parties for the inspection, maintenance, and overall safety of dams that are judged to be a potential safety hazard. This work should be undertaken beginning with the dams judged to have the greatest public safety risk. An inventory and prioritization method should be developed at the beginning of the investigative work.
  - While stopping short of taking over dam ownership, liability, and routine maintenance from Property Owner Associations (POAs) or other owners, on a case by case basis the City should take over the inspection and maintenance of dams that pose significant safety concerns. POAs should maintain the general/routine mowing and small scale maintenance responsibilities while the City undertakes the more critical inspection and maintenance responsibilities.
  - For any dam for which the City considers taking over certain inspection and maintenance responsibilities, it is recommended that the City first study and determine the prevailing conditions for such dam and its appurtenances. Should the City take over inspection, maintenance, and upgrade responsibilities for the structures, it should first be determined what actions they or the present owners might have to take to bring such structures into state dam safety compliance. Such actions could include determining whether the dam structures, including emergency spillways, require modifications to strengthen them against failure or breach. Another important aspect is whether any of the dams need an emergency action plan to reduce the risk to lives and property that can result from dam failure.

9.10 STORM WATER FINANCING (SECTION 8)

- Establish long-range funding options for storm water such as those presented in Section 8.
- Educate the public on the need to have adequate funding or storm water management as described under the general recommendations.

9.11 IMPLEMENTATION PLAN

An implementation plan is presented here that provides the actions that the City of Norman can take to advance the work that was performed to develop the City's Storm Water Master Plan. In some instances, it may overlap or repeat certain aspects of the recommendations provided above, but that is to be expected as these implementation actions reflect the work that was performed as well as the recommendations. These implementation items focus on the immediate future covering the next few months and years although some items may unfold for many years to come.

The successful implementation of the storm water master plan and the associated future actions needed to implement the plan will rely heavily on additional public input and support. Additional meetings with stakeholders, including or such as the Storm Water Task Force, will help greatly in determining the specifics of educating and involving the public about future storm water master plan activities. Without the support of the public and approval of the funding needed, implementation of the master plan will be severely limited.

In listing these key implementation actions below, it is assumed that funding, such as the storm water utility and general obligation bonding described in this SWMP report (Section 8), will eventually become available to allow the City to pursue the actions. Additionally, the implementation actions can be taken out of the order given below as the ultimate order of these actions will depend on many events that have yet to occur.

General

1. Develop a formal public outreach campaign or program to continue educating citizens about the City's storm water needs, the importance of obtaining adequate funding to meet those needs, and the general support needed to sustain a viable storm water program at the City level. Some of these primary needs include reliable funding mechanisms such as GO bonding and a storm water utility, MS4 permit compliance requirements, a storm water CIP program, basic operations and maintenance of the storm water system, enhanced maintenance to keep streams clear of debris and trash, enhanced maintenance of detention facilities, acquisition of easements and rights-of-way, and dam safety.

Financing

2. Develop and carry out a strategic work plan for a citizen vote on the proposed storm water utility as described in Section 8. The City must also decide whether establishment of the master account file and other key billing logistics will be worked out before or after the citizen vote (assuming it passes). Regardless, preliminary discussions on billing and administration requirements should begin.

3. Develop and carry out a strategic work plan for a citizen vote on the proposed general obligation bond program as described in Section 8.

Data Management

4. Incorporate all of the digital and reference data developed during the SWMP project into the City's GIS and other records. This includes the GIS map overlay system developed to display geo-reference field photo locations taken at strategic creek locations during reconnaissance with the link to view the photos by clicking on the location symbol. Establish a process to systematically update this data and information.

Criteria Manuals

5. Update the City's Drainage Criteria Manual with SWMP findings and recommendations.

6. Develop a Storm Water Quality Criteria Manual with SWMP findings and recommendations.

7. Develop an Erosion Control Manual aimed at preventing erosion problems associated with construction.

Hydrology and Hydraulic Analyses

8. Following detailed recommendations in Section 9, develop detailed modeling for Level 2 (existing models used, some becoming outdated) and Level 3 (future detailed) streams consistent with the detailed Level 1 modeling performed for the master plan, which used the most up-to-date topographic and other data as well as hydrologic/hydraulic modeling methods. Advances in modeling technology (new versions of HEC-HMS or HEC-RAS) should be integrated as appropriate. This should be done prior to, or at the beginning of, developing designs for CIP projects.

9. Institute a storm water hydrologic and hydraulic model management system to maintain and facilitate distribution of the latest models to users. This system should be network and/or internet based to minimize the overall effort.

10. Submit Letters of Map Revision (LOMRs) to FEMA for the Level 1 streams studied during the SWMP. If other streams are studied or updated, those updates should be submitted as FEMA LOMRs at that time.

Water Quality

11. Meet with the cities of Moore and Oklahoma City to explore ways to improve water quality and preserve Lake Thunderbird's water quality.

12. Meet with the Oklahoma Department of Environmental Quality (ODEQ) and get updates on the Lake Thunderbird Watershed Management Plan development and the Canadian River TMDL status. Assign a City coordinator to follow the progress and status of these two programs as well as the MS4 program as compliance activities associated with these three programs will impact water quality in Norman for the foreseeable future.

13. Dedicate Stream Planning Corridors (SPCs) and/or the 100-year full buildout floodplains to the City of Norman by easement or title for streams located in the Lake Thunderbird watershed that have a drainage area greater than 40 acres.
    - Prohibit development or significant land disturbance in the SPCs and/or 100-year full buildout floodplain. Exemptions should include items such as, but not limited to, maintenance activities, greenway trails, road crossings, utilities, and stream stabilization measures.
    - Require additional stream-side buffers of 15 ft to each side of steams with drainage areas greater than 40 acres that are located in the Lake Thunderbird watershed and also in Suburban Residential and Country Residential areas as defined in the Norman 2025 Plan including subsequent updates to the comprehensive plan as adopted by the City Council.

14. Require that water quality facilities be constructed to capture and treat runoff from all proposed developments in the City of Norman that exceed 1 acre (or some other size selected by the City) in size. The runoff "capture and treatment volume" should be set to 0.5 inch of runoff from the development area unless specified otherwise for a special condition.
    - Allow very small developments less than 1 acre in size or some other size limit to pay into a regional detention/water quality program in lieu of building very small water quality structures. The City's present regional detention program should be broadened to include this water quality fee in lieu process.
    - Allow and encourage low impact development techniques such as rain gardens and biofilters to provide a portion or all of their storm water quality control requirements subject to the developer providing sufficient technical justification for the techniques.
    - For developments that do not dedicate the SPC or full buildout 100-year floodplain by virtue of obtaining a variance, the runoff capture and treatment volume for their development area should be increased to 0.7 inch of runoff.

15. Allow limited variances for special conditions/situations that would utilize alternative approaches that could be shown to achieve similar water quality, flood control, and recreational opportunity. In situations where there is a clearly defined riparian corridor of environmental significance and/or flood prone soils, it should be relatively more difficult to obtain such a variance. However, obtaining such variances should be less difficult in situations where a riparian corridor does not exist and the subject waterway flows through an area that has experienced significant past disturbance or change from natural conditions (such as past agricultural activities and/or activities associated with residential, commercial, transportation, or industrial uses).

16. Implement nonstructural storm water quality controls in addition to SPCs, including a program to educate the public on fertilizer use, a program to control the overuse of fertilizers, a procedure to ensure proper septic system installation and operation, and a continuation of development density (and impervious cover) limitations in the Lake Thunderbird watershed.

17. Require the following compliance measures if development or significant land disturbance occurs within the stream banks of a stream in the City:
    - USACE's 404 permitting documentation and proof of permit to be submitted to the City prior to plat approval,
    - Riparian stream corridor mitigation will be required (tree replacement, re-vegetation, stream stabilization using bio-engineering techniques, etc.), and
    - Inlet and outlet structures will be provided as needed to incorporate erosion protection.

18. Establish an education outreach program for, and voluntary compliance with, fertilizer application controls in City areas located in the Lake Thunderbird watershed.

19. Continually assess the water quality of Lake Thunderbird and update or modify activities and controls to protect this important water supply.

CIP/Easements/Maintenance

20. Establish an ongoing program activity to inspect and monitor the stream erosion areas identified on a regular schedule (e.g., every 1 or 2 years) until streams are stabilized with adequate improvements.

21. Develop a plan and begin to obtain drainage easements and/or rights-of-way (as needed) in Level 1 and 2 streams and for storm water detention facilities where access is needed for continuous/routine maintenance

activities. For streams, the amount of easement or right-of-way would be as needed based on specific site conditions but, in general, would include a width of stream extending bank to bank plus 10 ft on each side of the stream channel. This can include those areas where storm water CIP projects have been identified if the maintenance need justifies obtaining the easements in advance of designing and constructing the proposed CIP project.

22. Develop an analysis outlining the “pros and cons” of obtaining the FEMA floodway as drainage easement or right-of-way along various reaches of Imhoff Creek as part of a long-term solution to flooding and limited access along this creek.

23. A citywide stream maintenance program should be implemented over the next 2 or 3 years consistent with the acquisition of easements, rights-of-way, rights-of-way, rights-of-entry, and reaches of “no action,” depending on the situation/conditions. Obtaining easements and rights-of-way is the preferred method of gaining routine access to the city’s streams. Maintenance should focus on those stream reaches and/or detention facility areas where capital improvements are constructed in order to protect those investments. The City should also consider outsourcing some, or all, of the maintenance activities if it is advantageous, especially while a City’s program is ramping up. The City should also focus on detention facilities in which dam maintenance may become a safety issue.

24. As funds permit, preliminary designs along with refined construction cost estimates should be developed for the top priority projects.

25. Consider developing program staff under the direction of the Director of Public Works to manage the SWMP CIP program and associated projects. These staff can be part of an existing group or make up a new group at the City. If the amount of work is variable, cyclic, or heavy at times, it is recommended that staffing levels target the steady work flow and have consultants assist during times of high work flow.

26. The CIP projects have been identified, described (functionality/character/costs), and prioritized. In order of their priority, a list should be developed outlining the specific projects (and therefore the total budget outlay) that would be funded through general obligation bonds (options investigated ranged from $30 to $40 million) versus those that would be funded through a storm water utility (financing investigated ranged from $43 to $53 million) over a 20-year period. Preliminary discussions have been held on this issue but it should be finalized.

27. Develop a future roadway improvement plan for Franklin Road east of Interstate Highway 35 that includes a significant drainage or flood prevention study element as this roadway and many of its intersecting roadways are significantly flood prone for several miles of roadway length.

Dams

28. The City should investigate and identify, to the extent possible, the responsible parties for the inspection, maintenance, and overall safety of dams that are judged to be a potential safety hazard. This work should be undertaken beginning with the dams judged to have the greatest public safety risk. An inventory and prioritization method should be developed at the beginning of the investigative work.

29. While stopping short of taking over dam ownership, liability, and routine maintenance from Property Owner Associations (POAs) or other owners, on a case by case basis the City should take over the inspection and maintenance of dams that pose significant safety concerns. POAs should maintain the general/routine mowing and small scale maintenance responsibilities while the City undertakes the more critical inspection and maintenance responsibilities.

30. For any dam for which the City considers taking over certain inspection and maintenance responsibilities, it is recommended that the City first study and determine the prevailing conditions for such dam and its appurtenances. Should the City take over inspection, maintenance, and upgrade responsibilities for the structures, it should first be determined what actions they or the present owners might have to take to bring such structures into state dam safety compliance. Such actions could include determining whether the dam structures, including emergency spillways, require modifications to strengthen them against failure or breach. Another important aspect is whether any of the dams need an emergency action plan to reduce the risk to lives and property that can result from dam failure.

CITY OF NORMAN
STORMWATER MANAGEMENT PROGRAM
FOR PHASE II MS4 COMPLIANCE
2016 TO 2020

Appendix D

FINAL

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

Prepared for
Oklahoma Department of Environmental Quality
Water Quality Division

November 10, 2013

By

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	Nepholometric 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 90^{th} 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

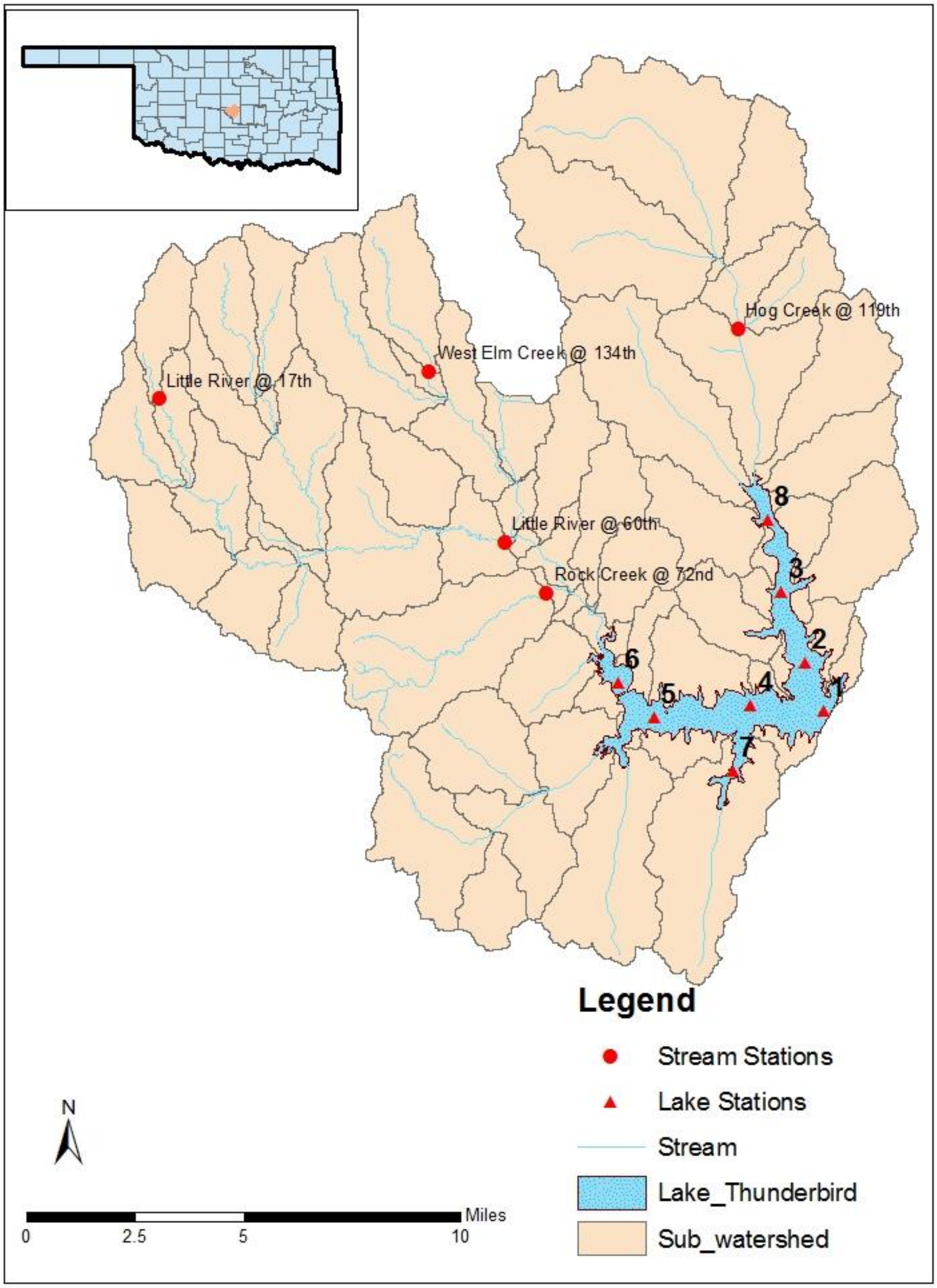


Table 1-1 presents general physical characteristics of Lake Thunderbird. Data sources include the U.S. Army Corps of Engineers, Tulsa District, Bureau of Reclamation, and the Oklahoma Department of Wildlife Conservation (2008).

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

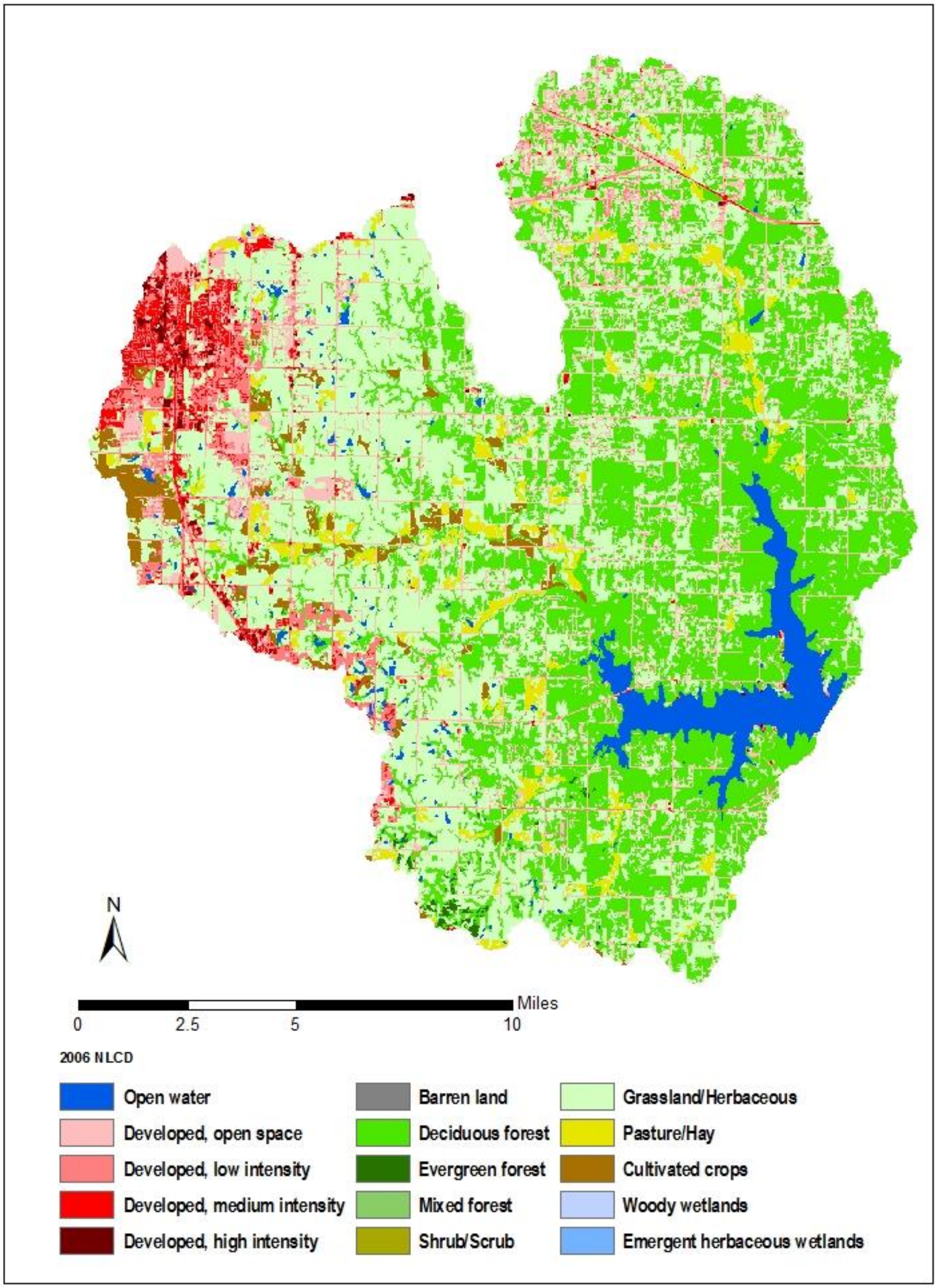


Figure 1-3 Population Density (persons per square mile) based on 2010 Census Tracts within the Lake Thunderbird Watershed

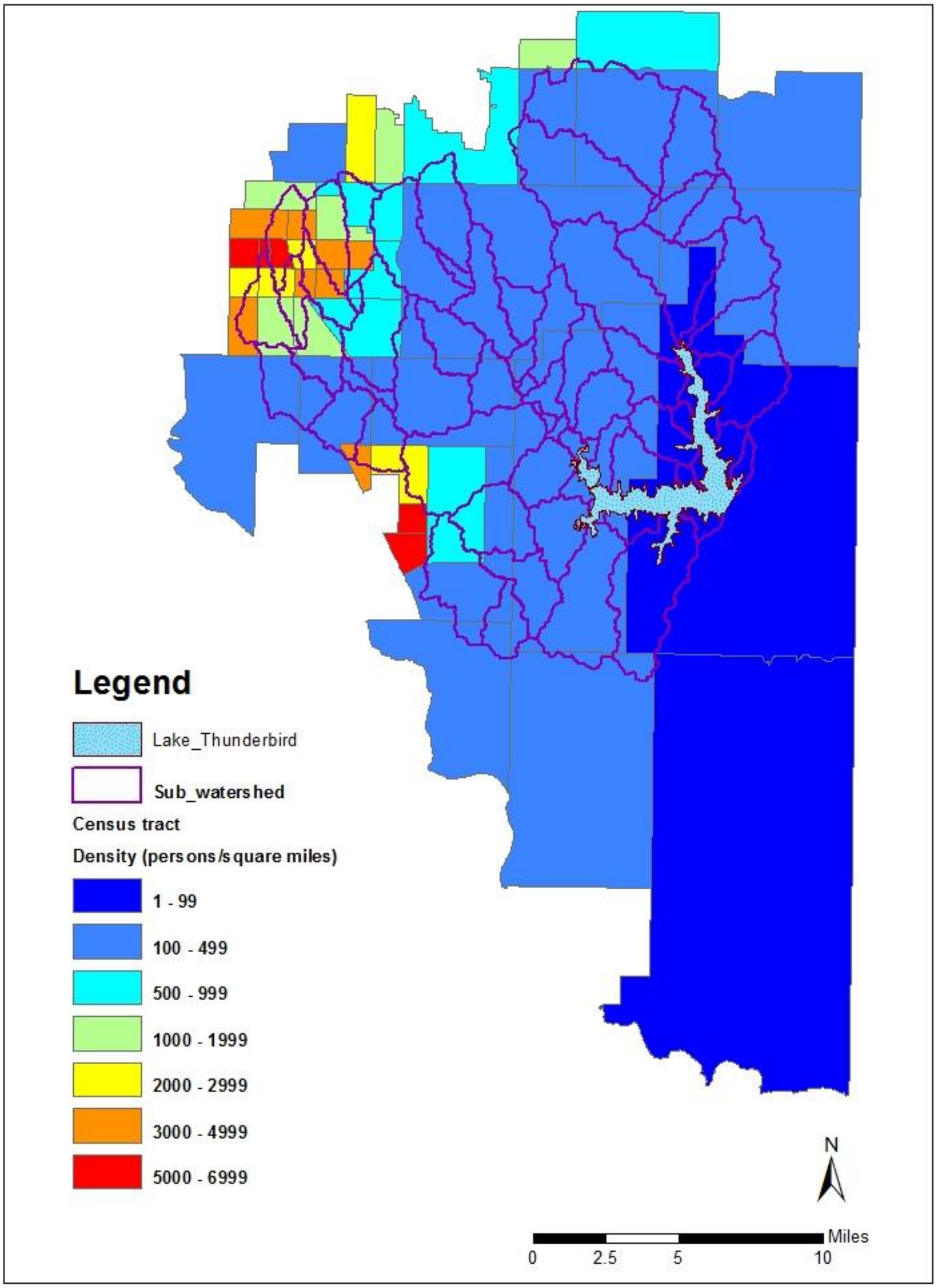
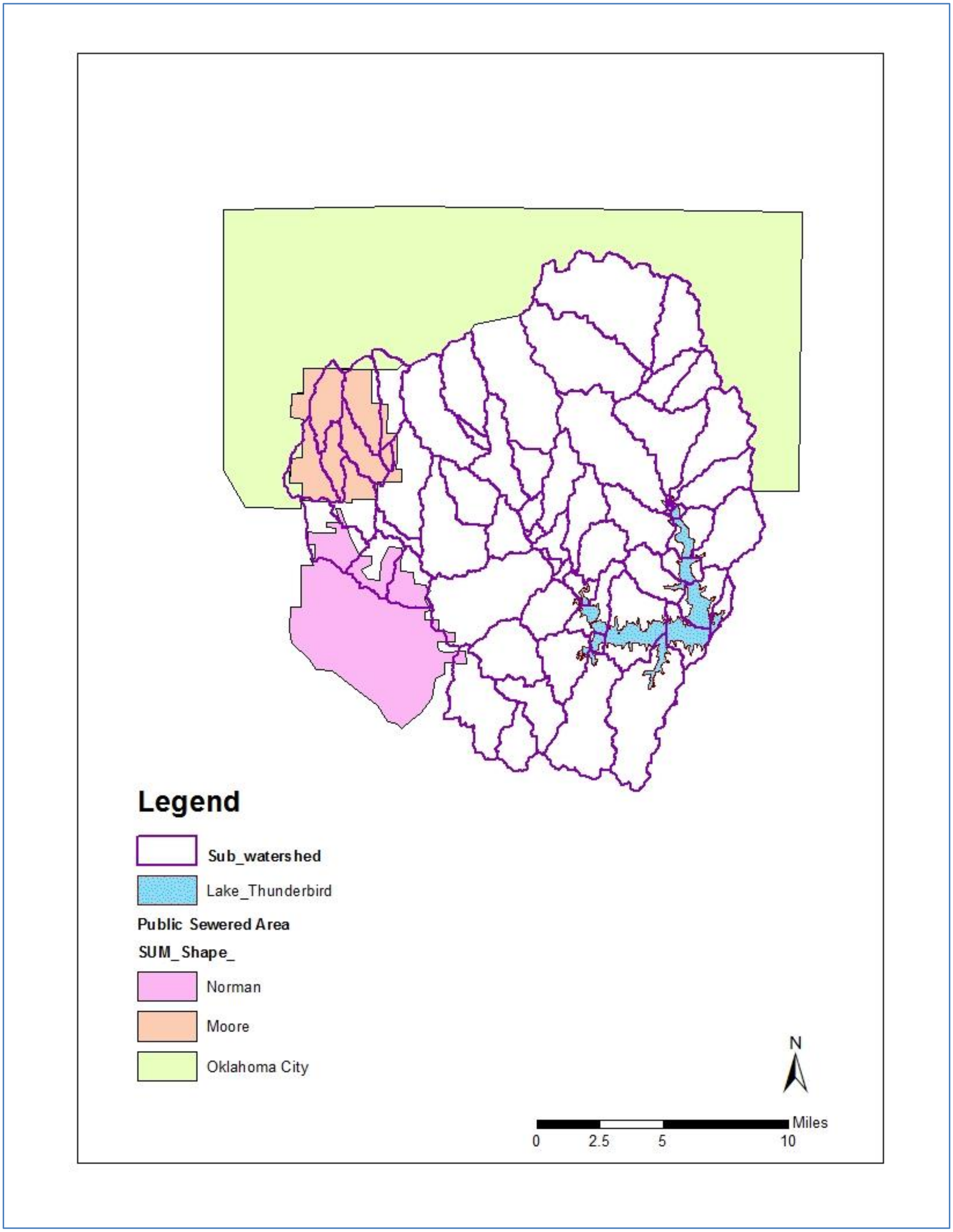


Figure 1-4 Public Sewer System Boundaries within the Lake Thunderbird Watershed



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).

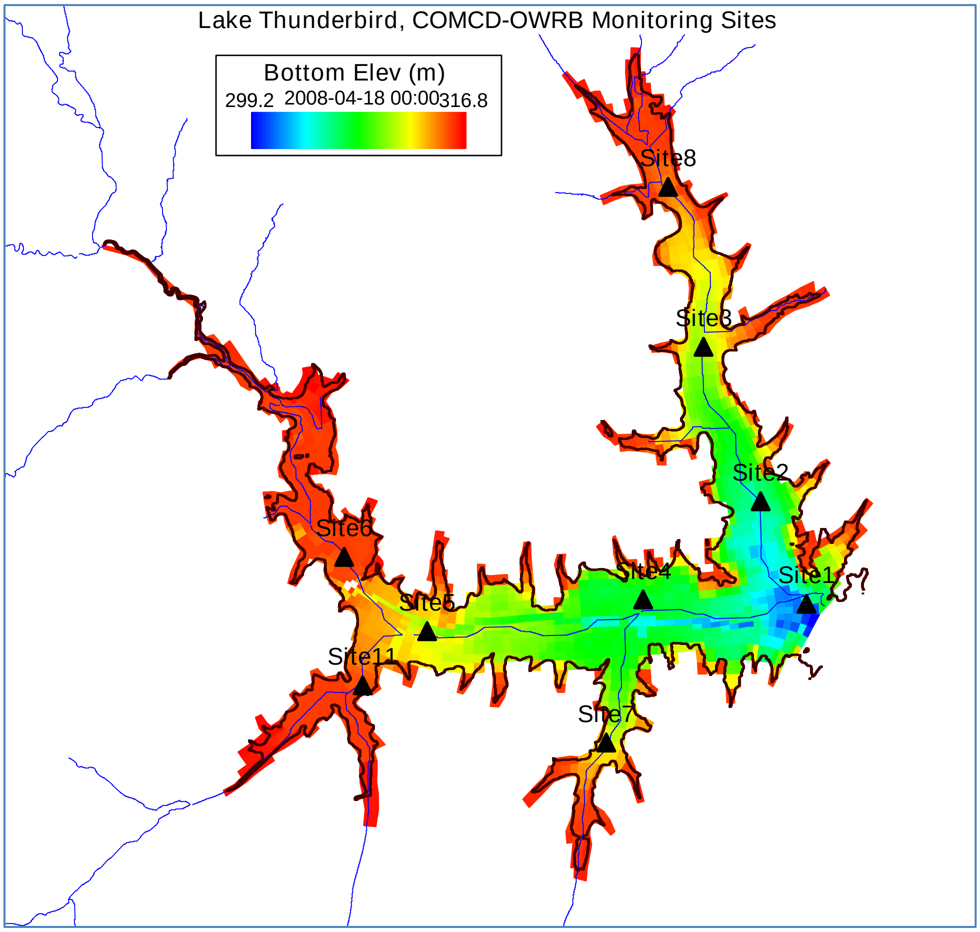
2.2 Overview of Water Quality Problems and Issues

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 520810000020-1-4X 520810000020-1-8X 520810000020-1-12X 520810000020-1bX	35.223333	-97.220833	Dam Site; Lacustrine
2	520810000020-2X 520810000020-2bX	35.238889	-97.228889	Lacustrine
3	520810000020-3X	35.262222	-97.238889	Transition
4	520810000020-4X 520810000020-4bX	35.224444	-97.250833	Lacustrine
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

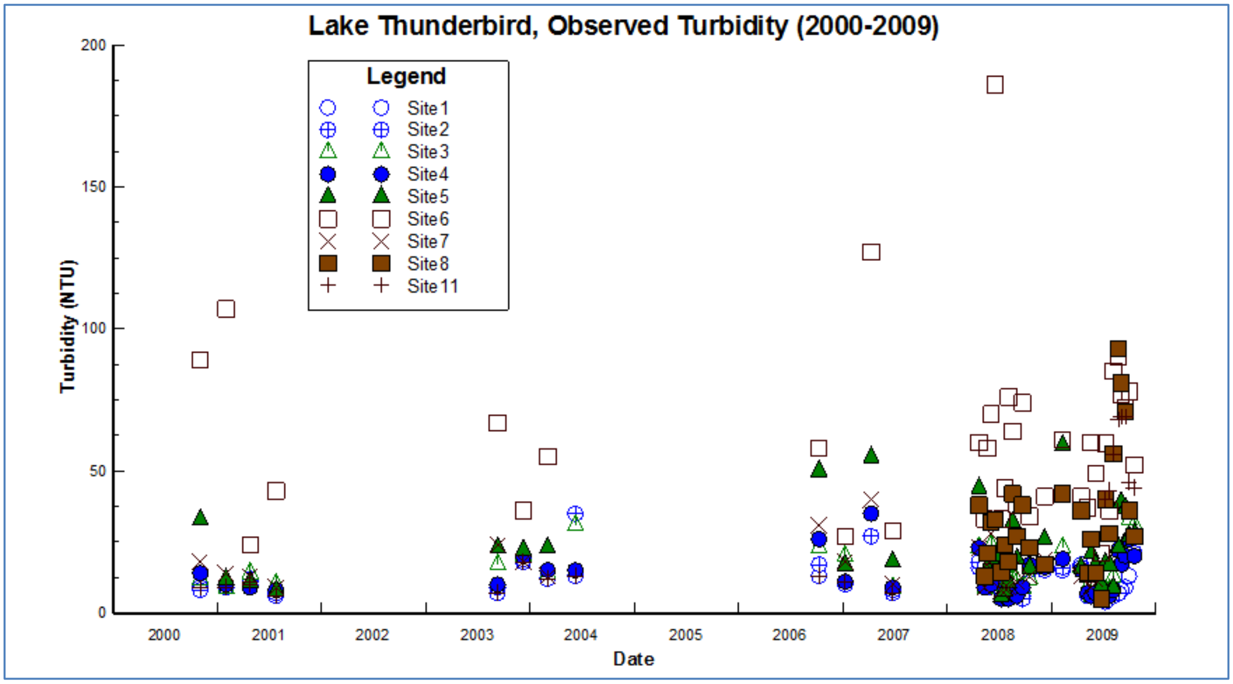
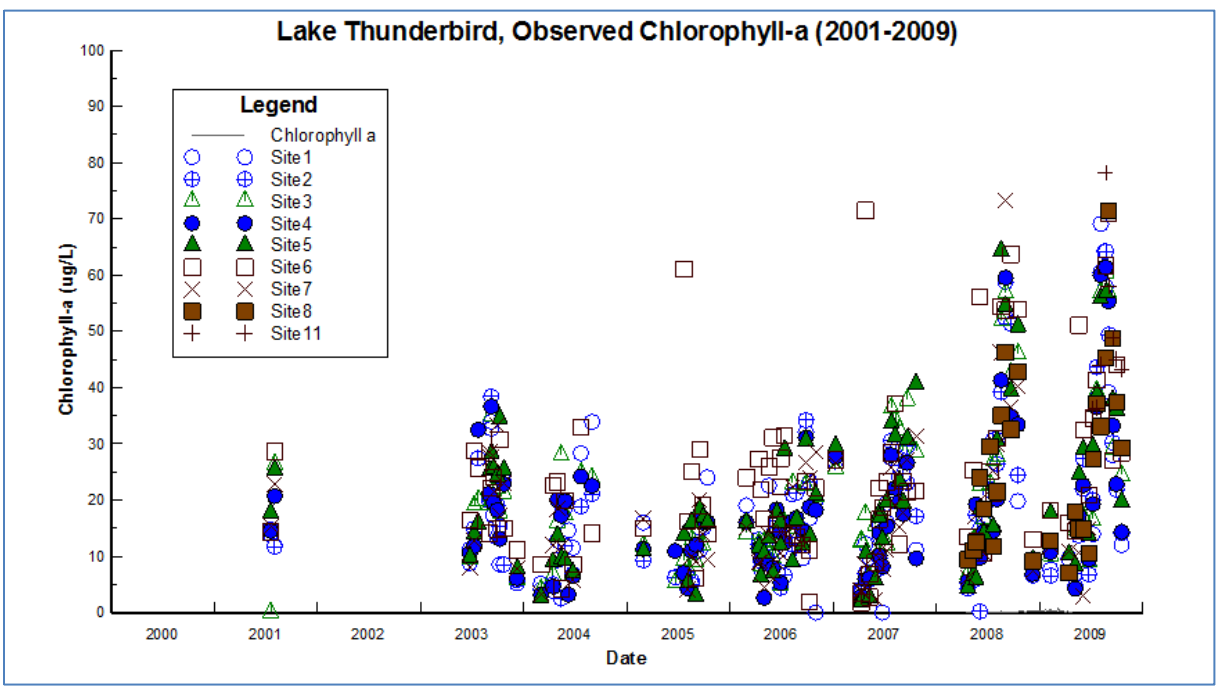


Figure 2-3 Observed Chlorophyll-a in Lake Thunderbird, 2001-2009



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.

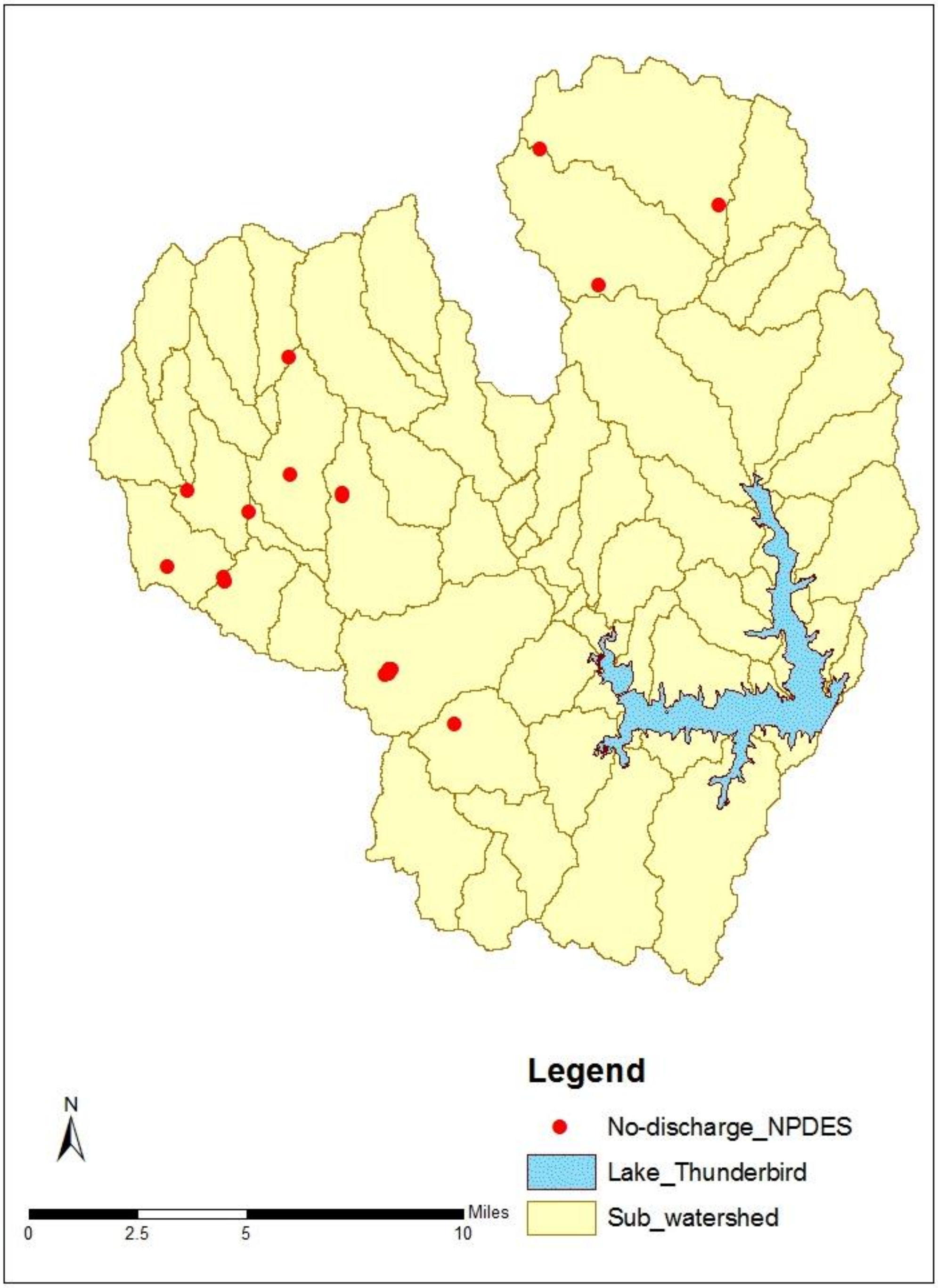
Table 3-1 NPDES No-Discharge Facilities in Lake Thunderbird Watershed

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:

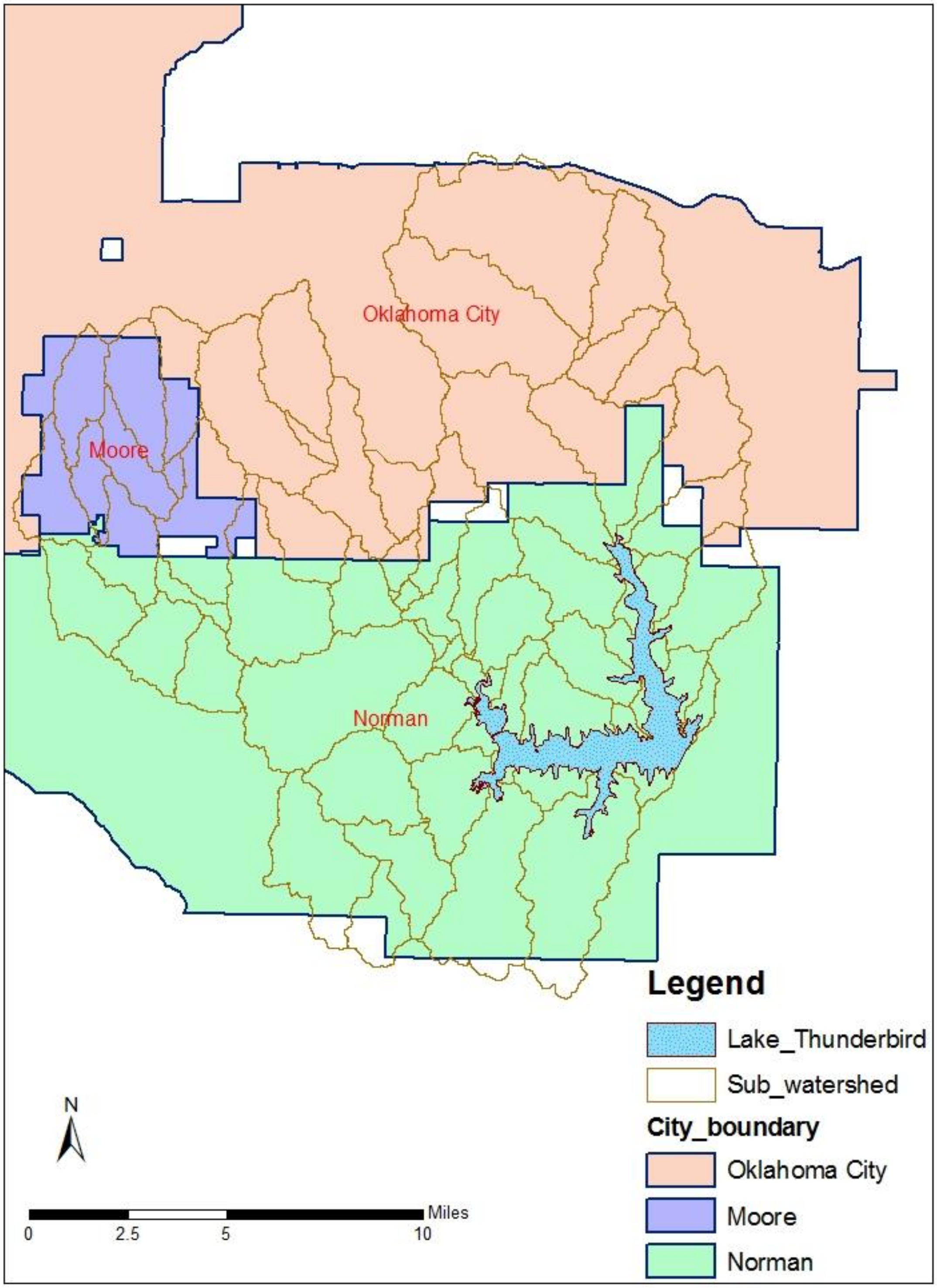
- Public Education and Outreach.
- Public Participation/Involvement.
- Illicit Discharge Detection and Elimination.
- Construction Site Runoff Control.
- Post- Construction Runoff Control.
- Pollution Prevention and Good Housekeeping.

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

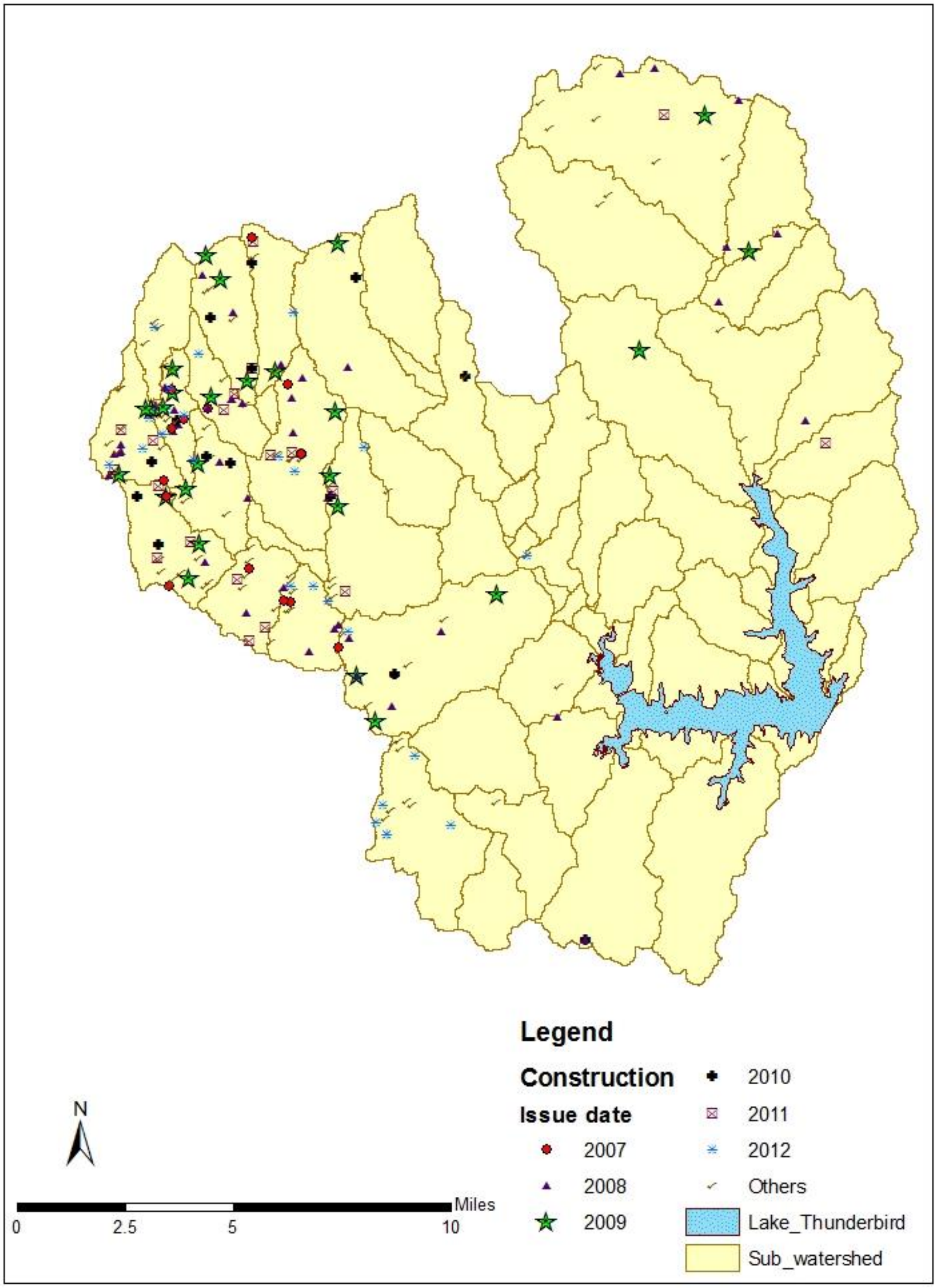
The Oklahoma Department of Environmental Quality (DEQ) has issued the "*General Permit OKR10 for Stormwater Discharges from Construction Activities within the State Of Oklahoma*". Permits are issued for a period of five years for the period from 2007-2012. Permit authorizations are required for construction 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

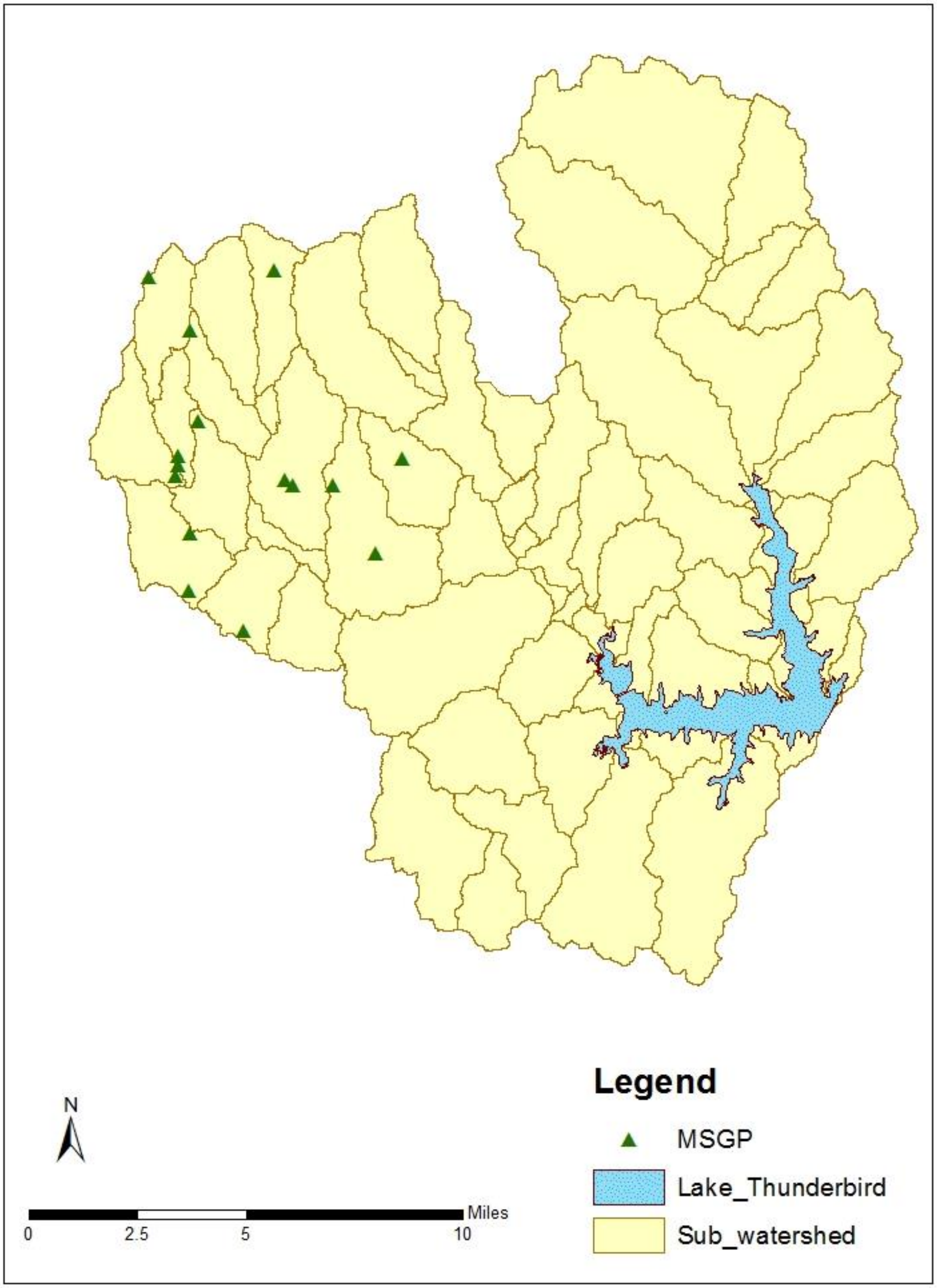
NPDES permit authorizations are required for stormwater discharges from 29 sectors of SIC-coded industrial activities listed in the OKR05 Multi-Sector General Permit (DEQ, 2011). Industrial activities that are on Indian Country Lands or are at oil and gas exploration and production related industry and 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

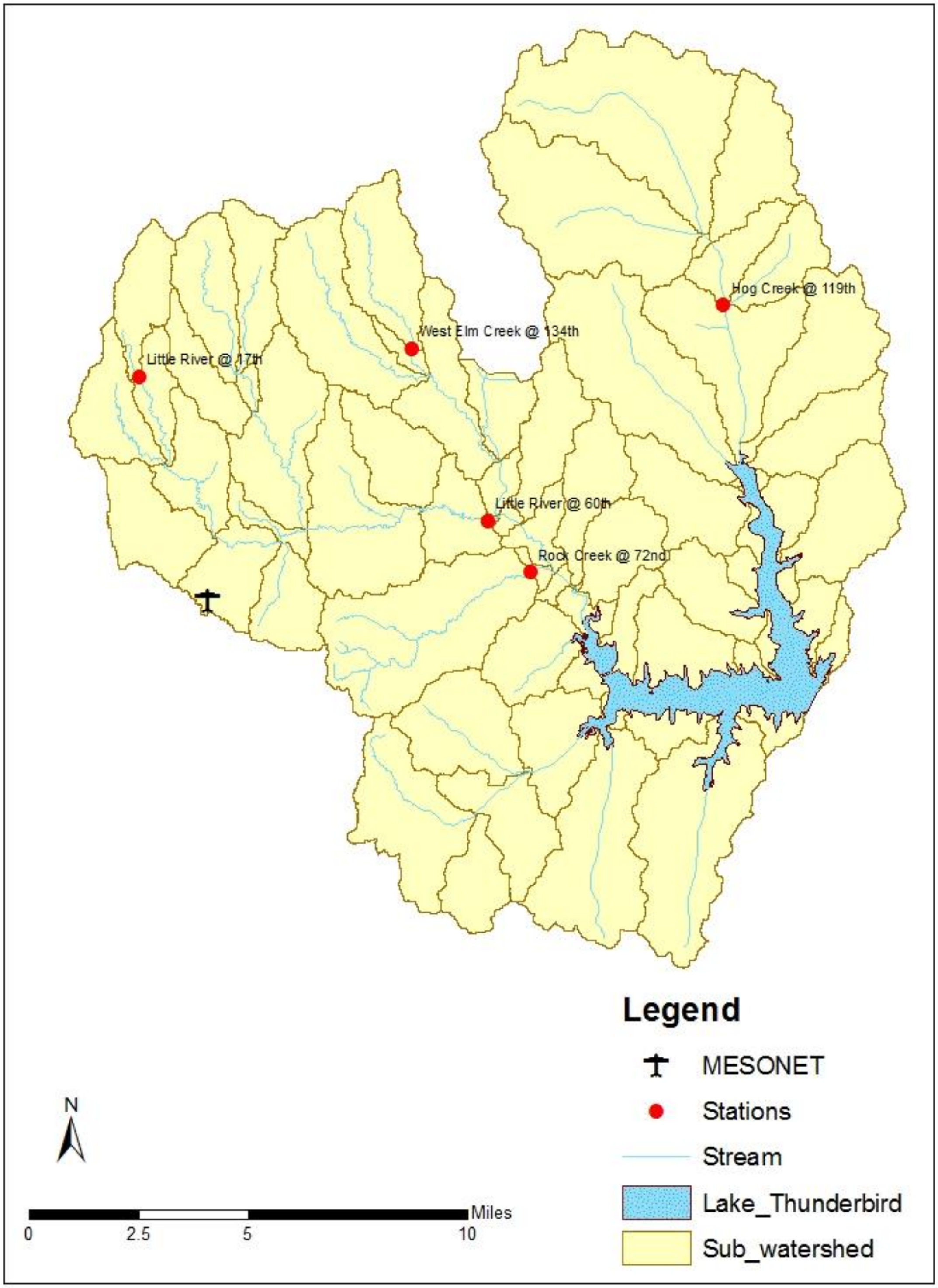
3.3.3 Model domain and discretization for sub-watershed representation

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)

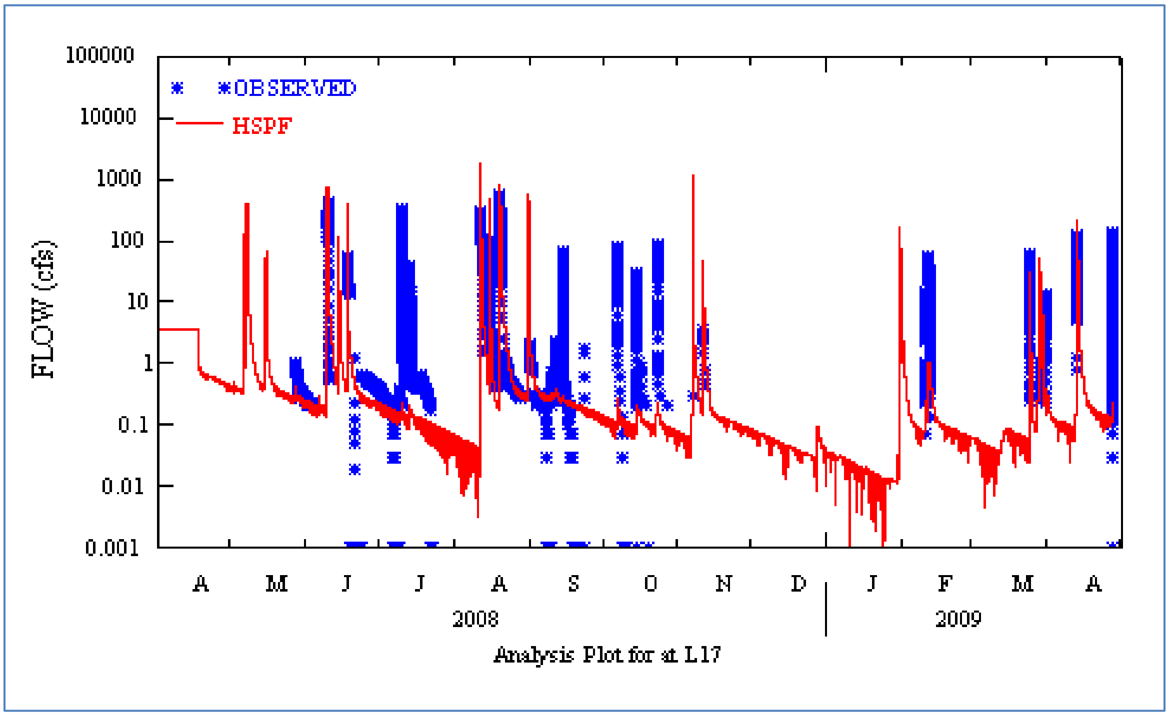


Figure 3-7 Little River at 17th St. (L17) site - Water temperature calibration plot

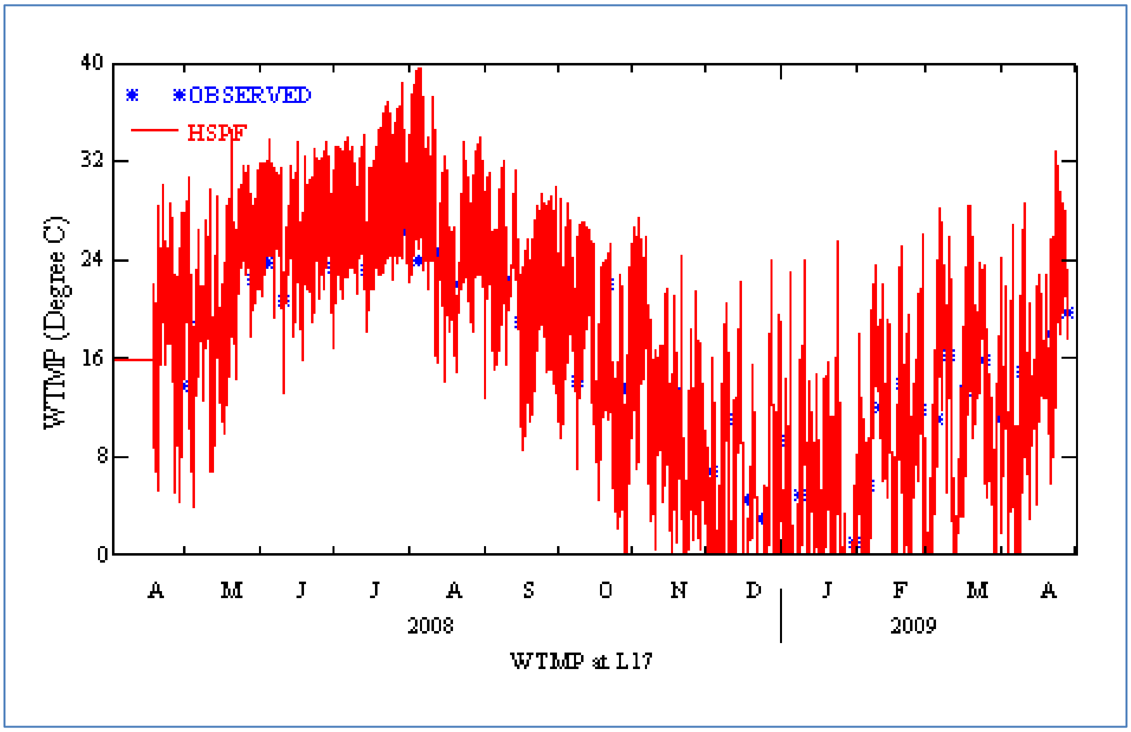


Figure 3-8 DO calibration plot at station L17

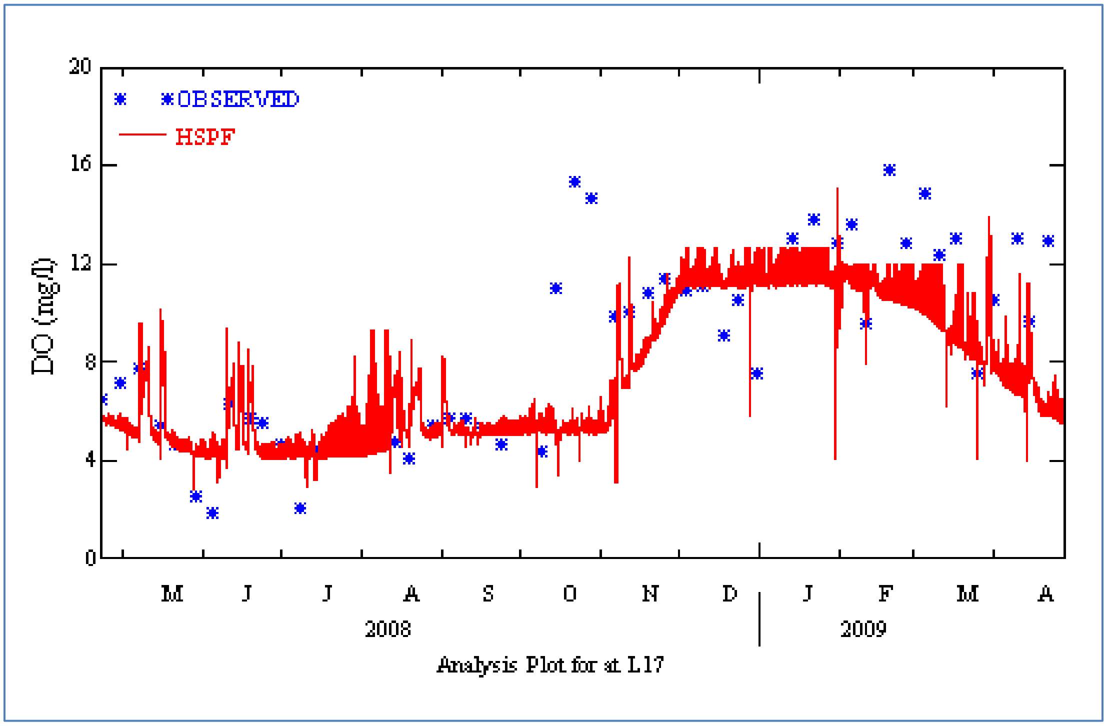
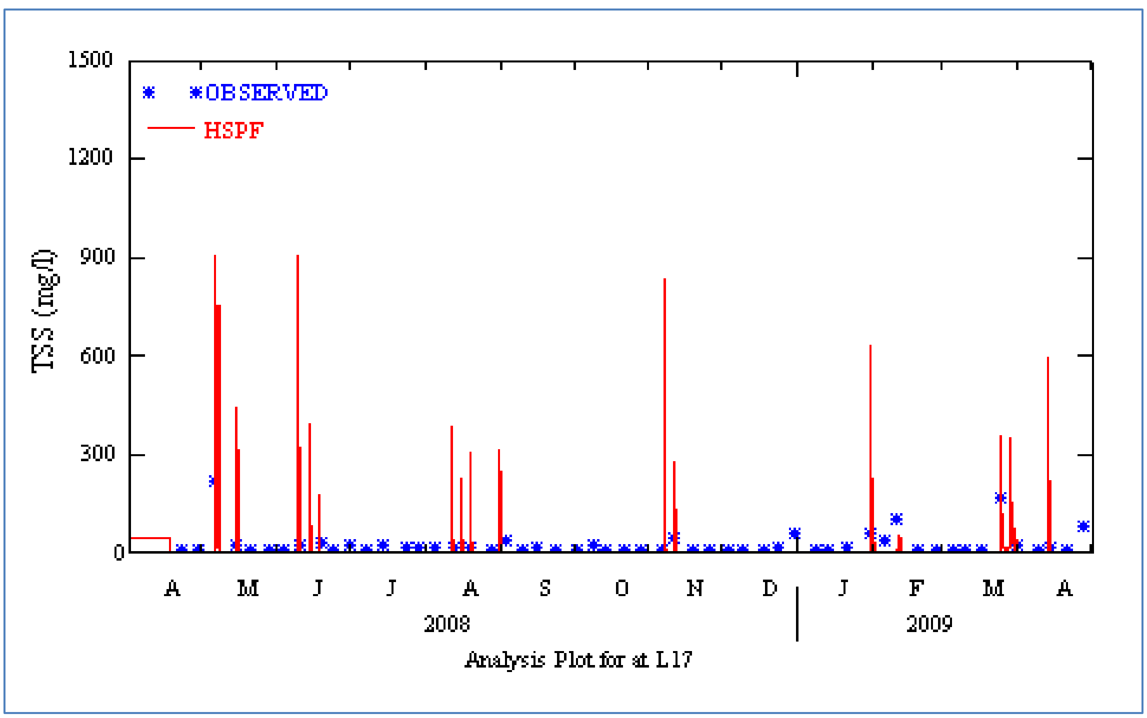


Figure 3-9 TSS calibration plot at station L17



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

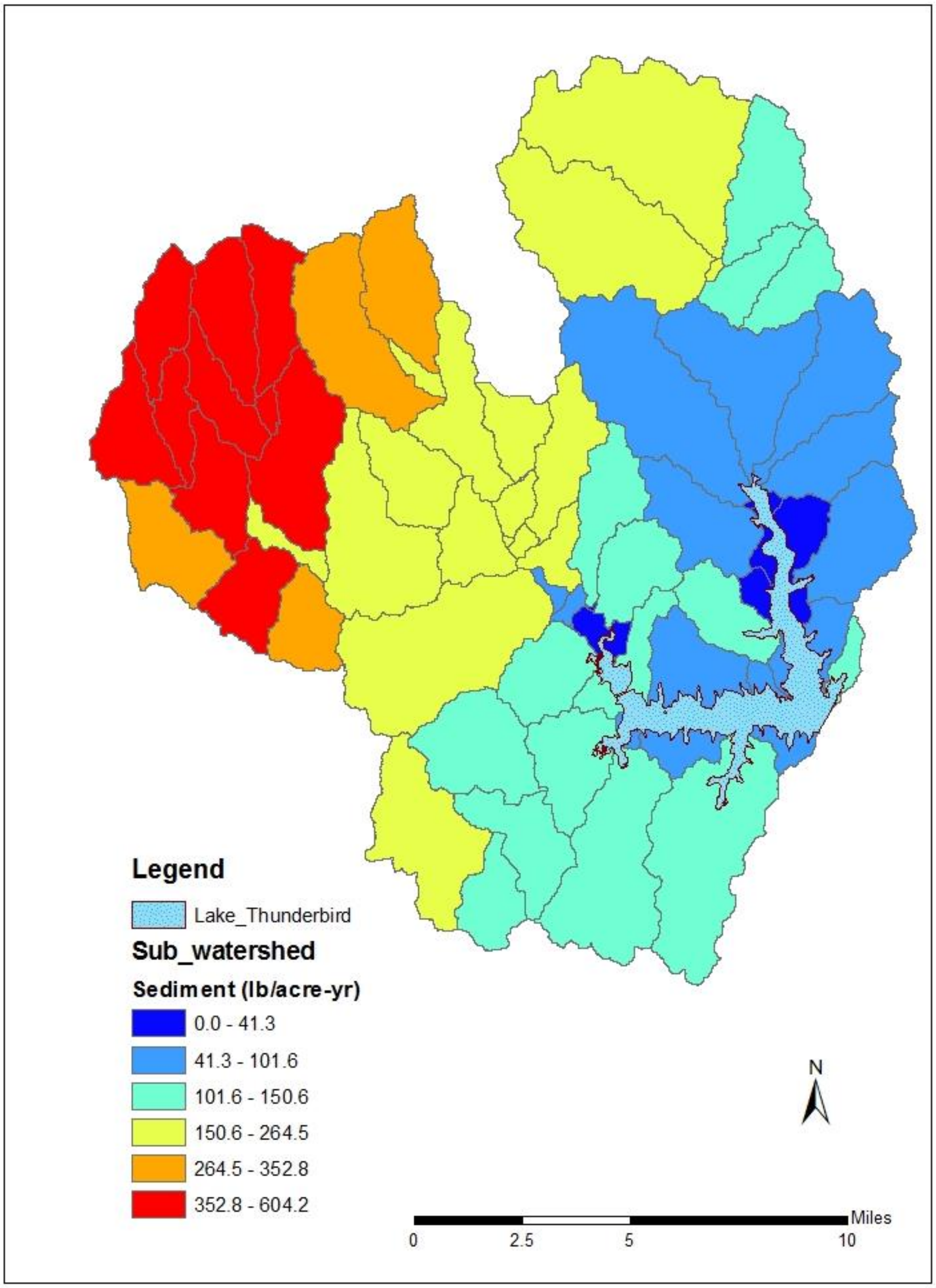


Figure 3-11 Calculated sub-watershed CBOD loadings by HSPF model

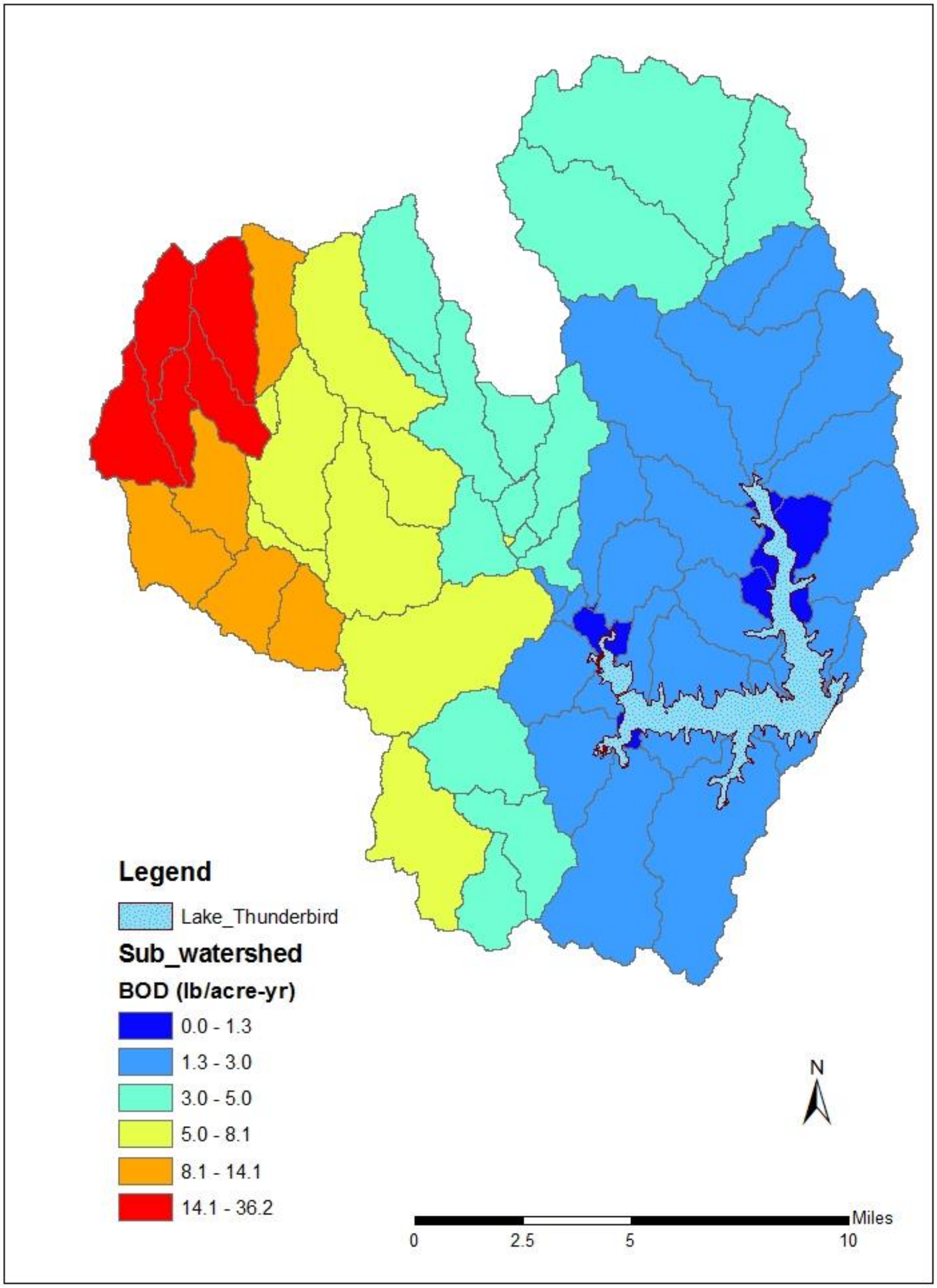


Figure 3-12 Calculated sub-watershed TOC loadings by HSPF model

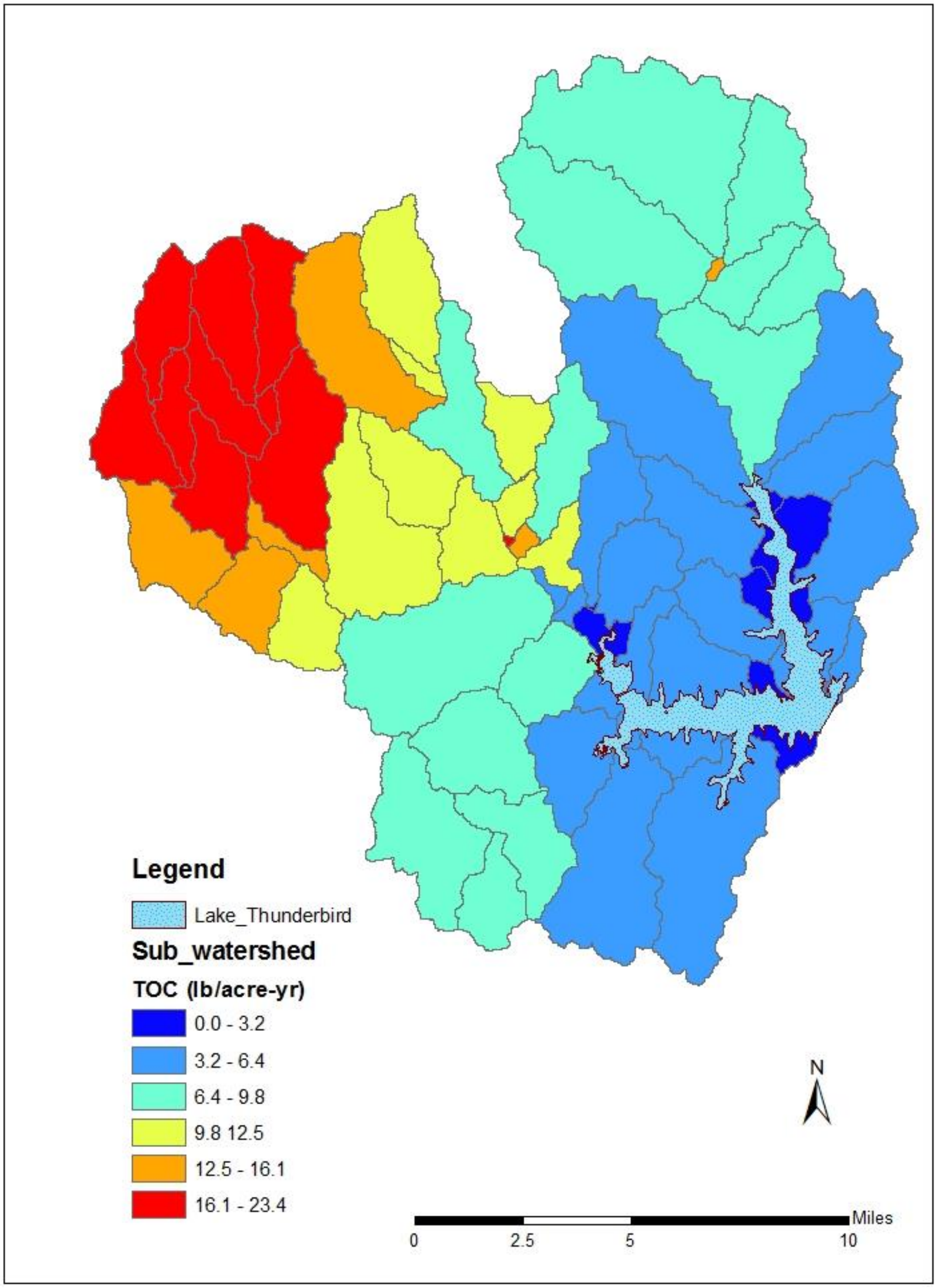


Figure 3-13 Calculated sub-watershed TN loadings by HSPF model

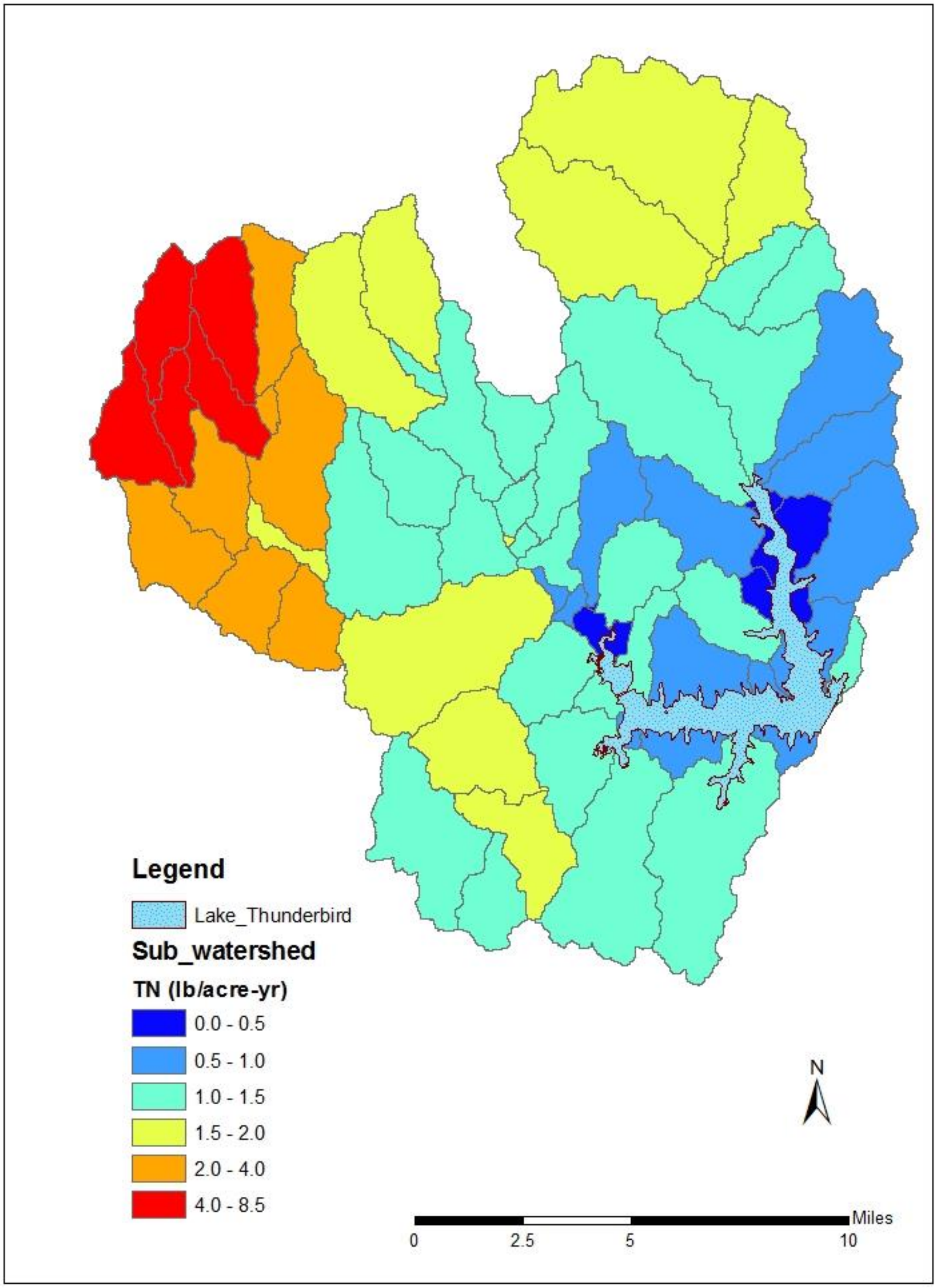
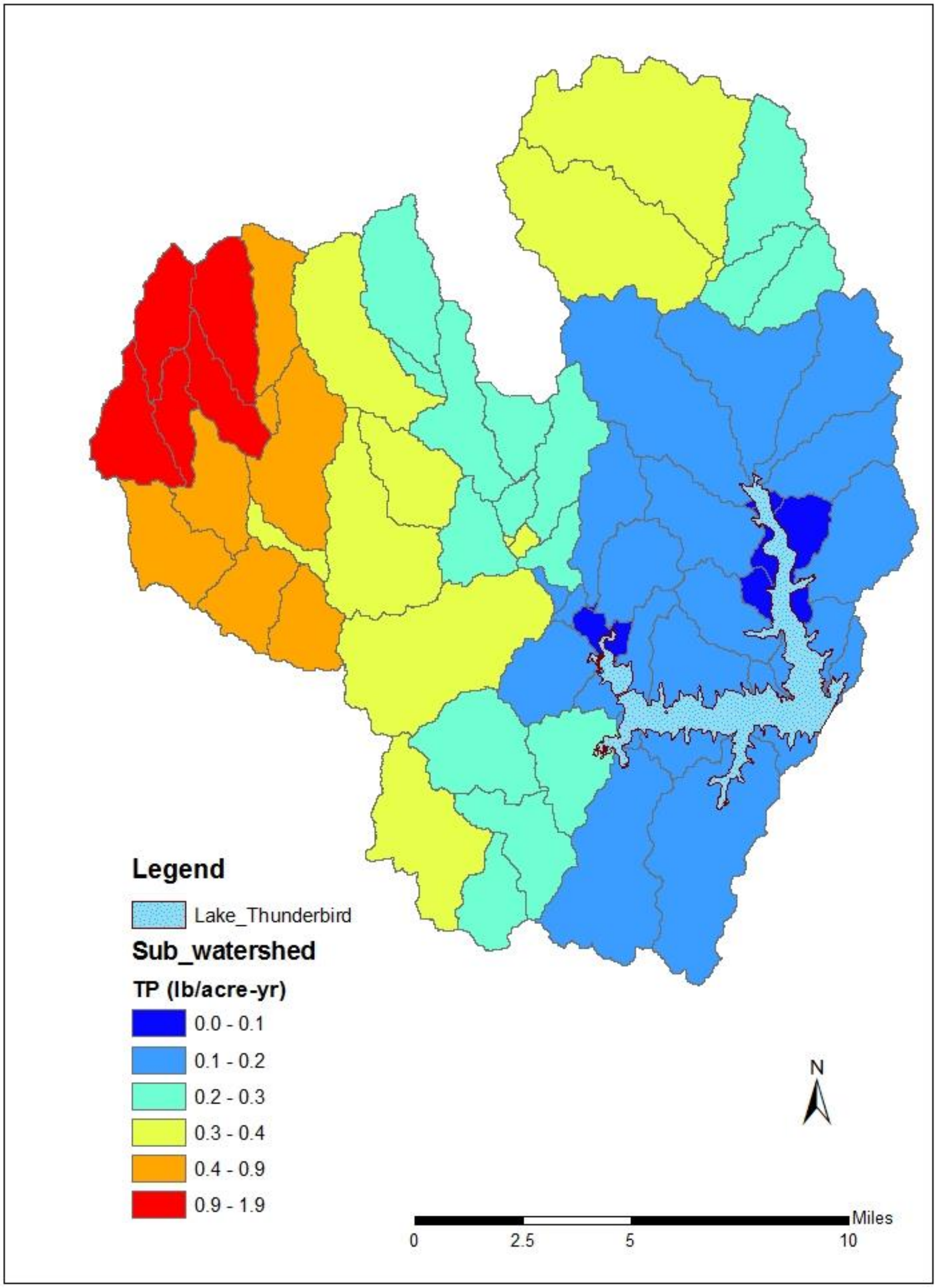


Figure 3-14 Calculated sub-watershed TP loadings by HSPF model



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

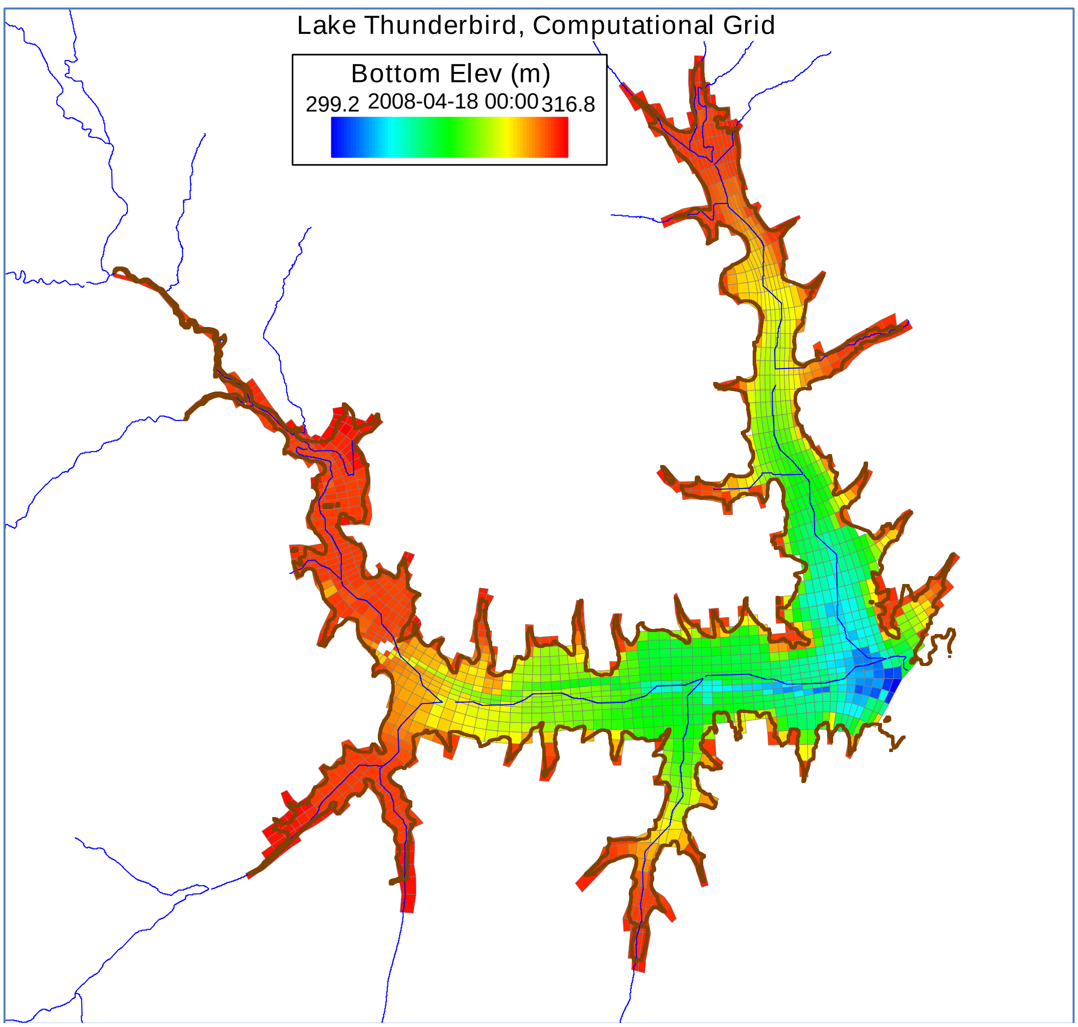
EFDC is an advanced surface water modeling package for simulating three-dimensional (3-D) circulation, salinity, water temperature, sediment transport and biogeochemical processes in surface waters including rivers, lakes, reservoirs, estuaries, and coastal systems. The EFDC model has been supported 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 Nephylometric 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 90th percentile for observed 2008 - 2009 turbidity (29.7 NTU) is seen to exceed the water quality target of 25 NTU. The 90th 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.

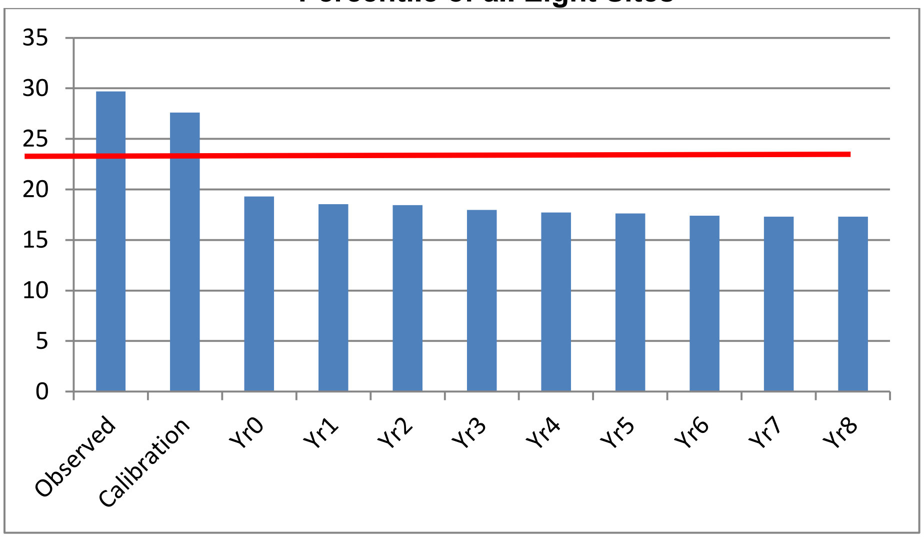
Table 4-3 Summary Statistics for Chlorophyll-*a* and Turbidity for Observed Data, Model Calibration and 8 Years (Year 1 – Year 8) of Spin-Up Runs of the 35% Removal Scenario

[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%

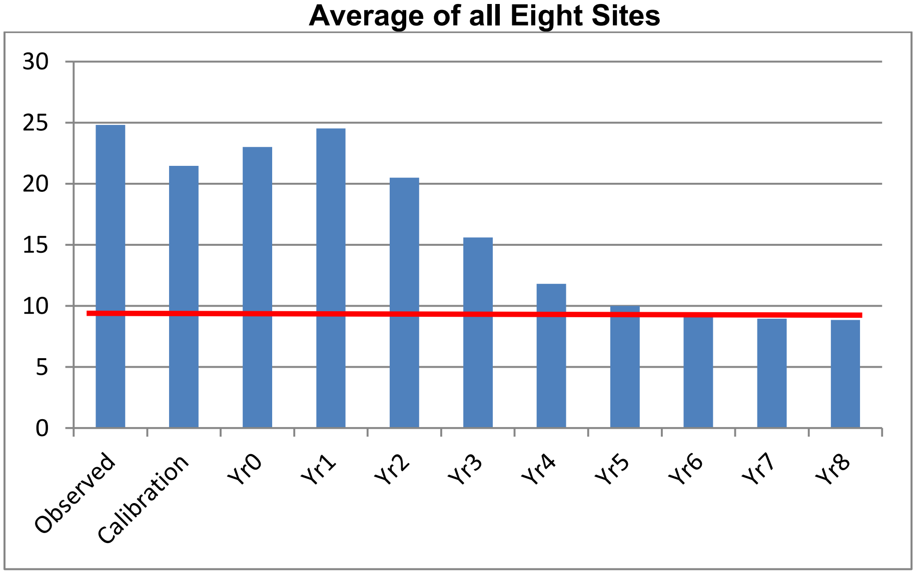
As can be seen in the data presented in Table 4-3, the 90th percentile for observed turbidity (29.7 NTU) exceeds the target of 25 NTU. The calibrated model results for surface turbidity (27.6 NTU) also show non-compliance with the target of 25 NTU. Each of the spin-up runs for the 35% management scenario 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



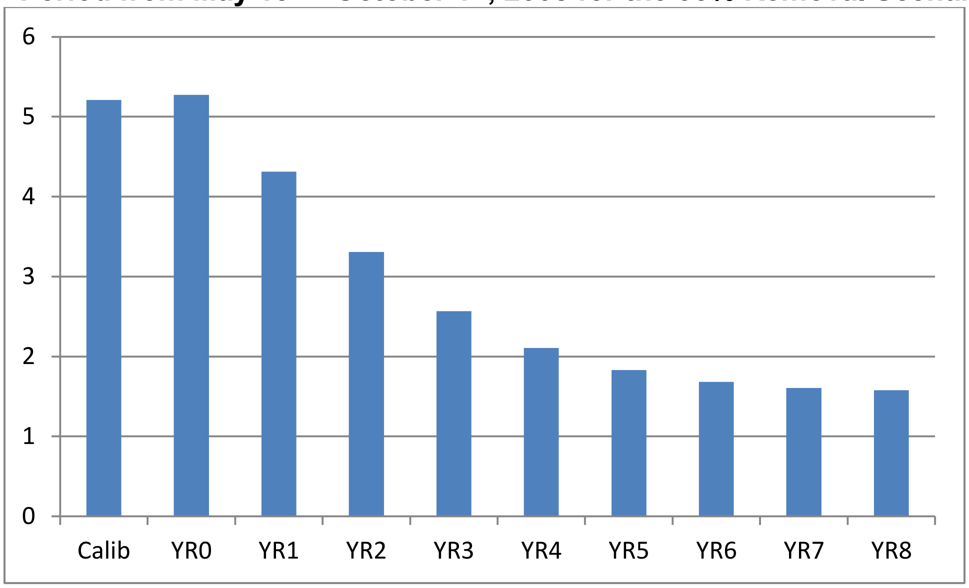
As shown in Table 4-3, the 2008 - 2009 average for observed surface chlorophyll-a (24.8 µg/L) exceeds the target criteria for SWS lakes of 10 µg/L. The calibrated model results for chlorophyll-*a* (21.5 µg/L) also show non-compliance with the SWS target criteria. Figure 4-3 shows the spin-up trend for 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.

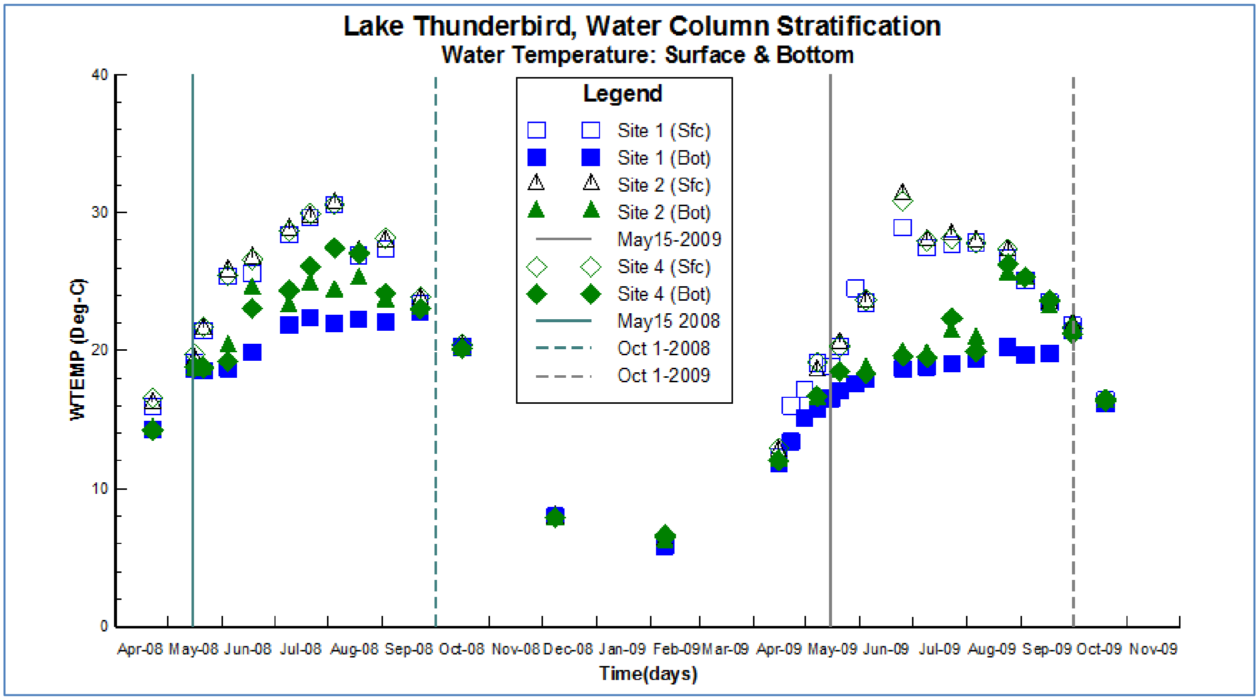
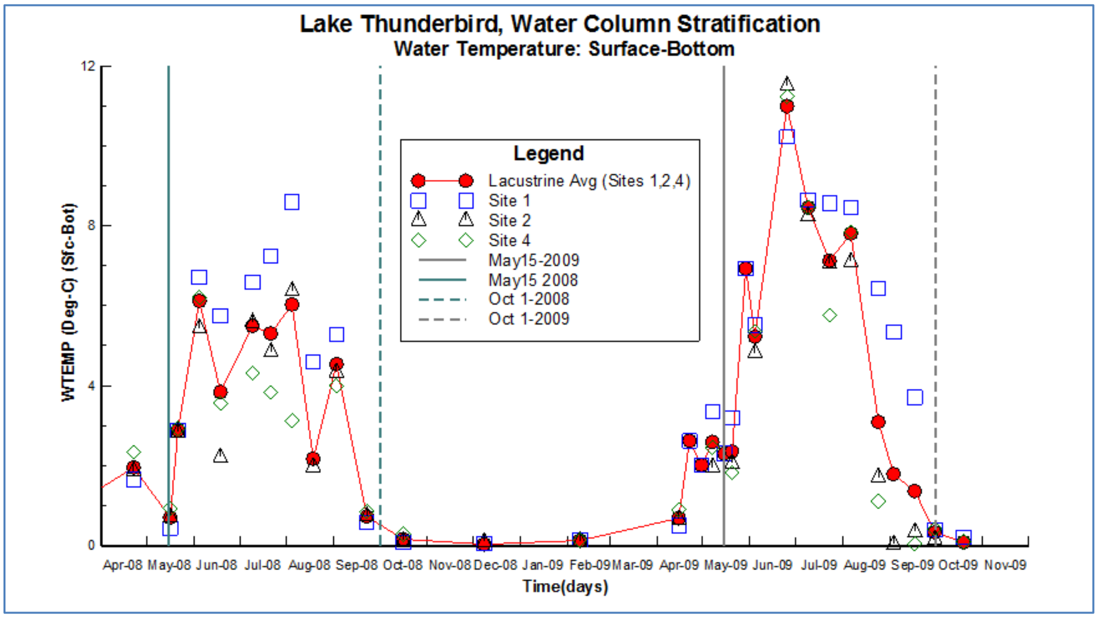


Figure 4-6 shows the difference between surface and bottom temperature for each site and the average of the three sites. May 15 is defined as the date for the onset of stratification when the vertical temperature gradient begins to increase. By October 1, the temperature gradient decreases and remains 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.

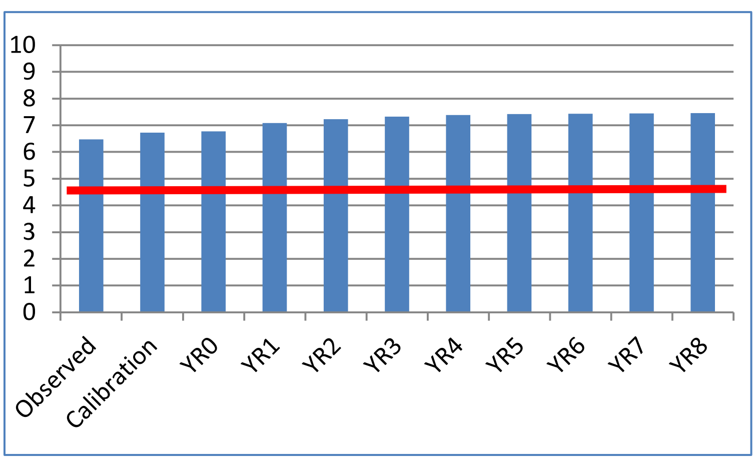
Under the 35% load reduction determined for the TMDL, compliance with the water quality criteria for dissolved oxygen is demonstrated for (a) stratified conditions for the surface layer (epilimnion) and the anoxic volume of lake and (b) the entire water column for the period when the lake is not stratified.

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

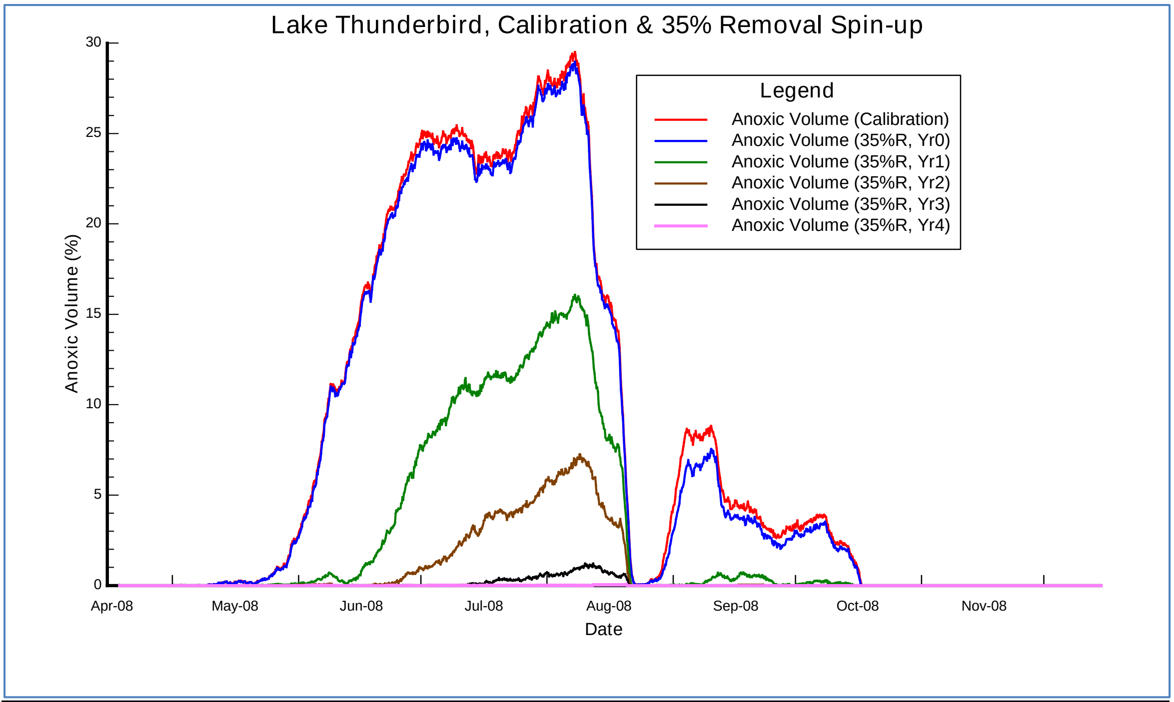


Stratified Period, Anoxic Lake Volume: Water quality criteria require that 50% or less of the lake volume be lower than a 2 mg/L cutoff level of DO during the period of seasonal thermal stratification The results of the computations of anoxic volume, based on a target oxygen level of 2 mg/L, are presented 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.

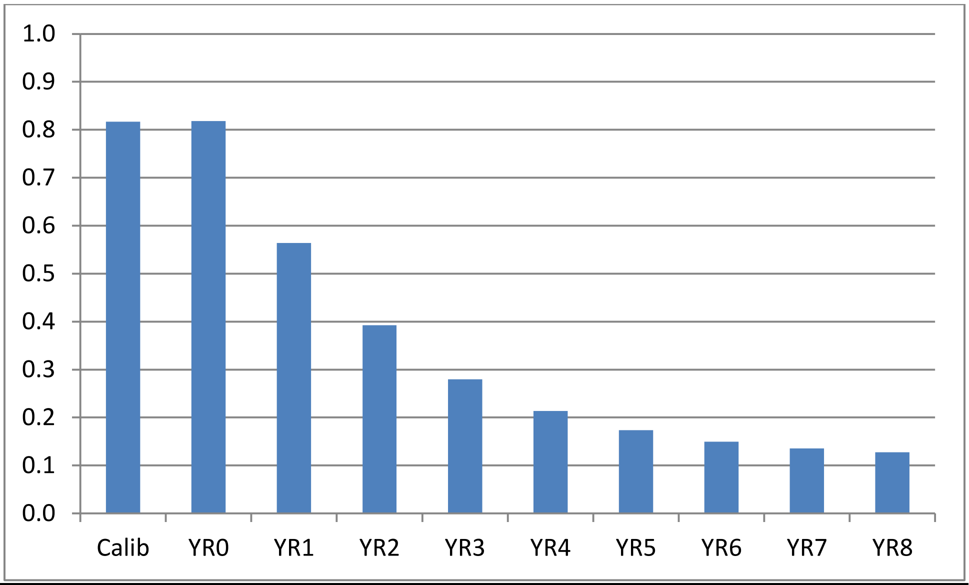
Model Calibration Results are Shown as Red Line. Percentage of Anoxic Volume is Based on Aggregation of All Grid Cells in the Lake. The DO Cutoff Target is 2 Mg/L



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.

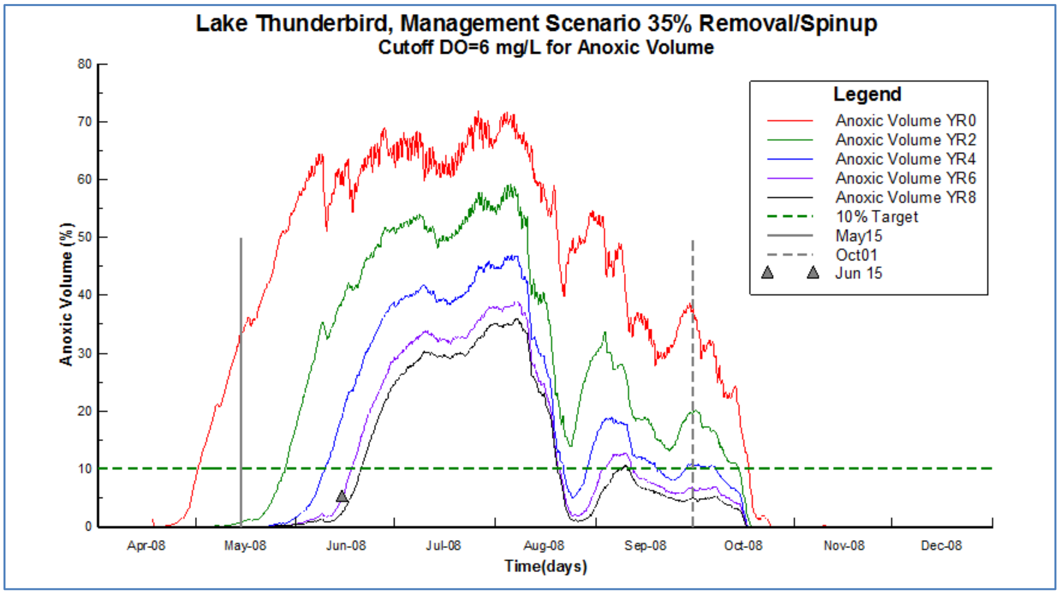
Figure 4-9 Sediment Oxygen Demand (G O_2/M^2-Day), Whole Lake Average for Seasonal Stratified Period from May 15th - October 1st, 2008 for the 35% Removal Scenario



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.

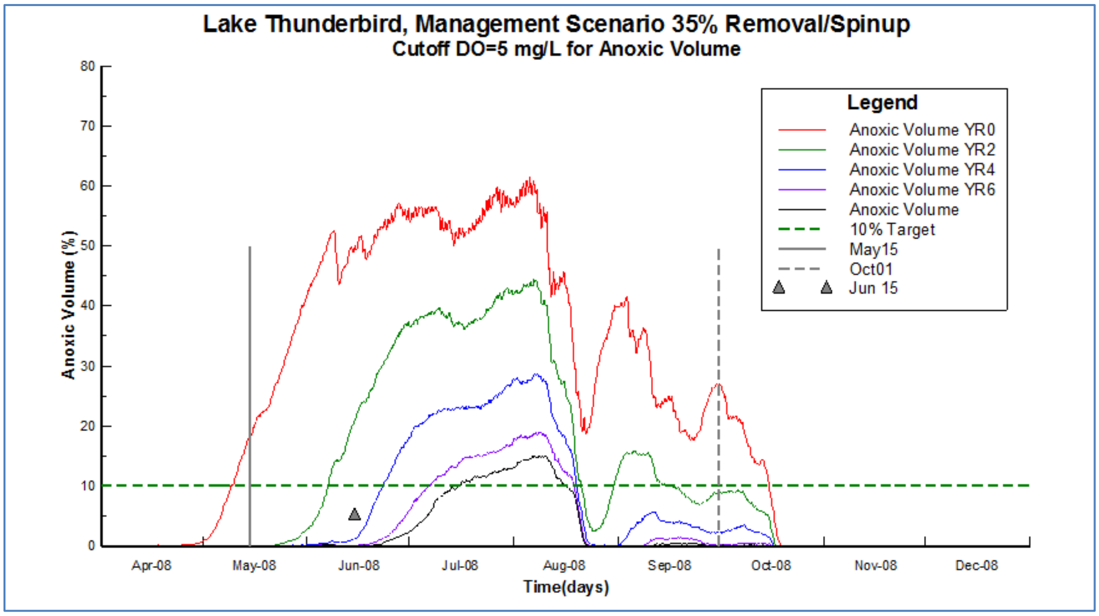
Figure 4-10 Whole Lake Volume Weighted Percentage of Lake Less than Cutoff Concentration of 6 mg/L for Spin-Up Years (Year 0, Year 2, Year 4, Year 6, and Year 8).



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 Source Year 8 Spinup	Annual HSPF %	Annual AtmDep %	Annual SedFlux %	Annual Total %
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:

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

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

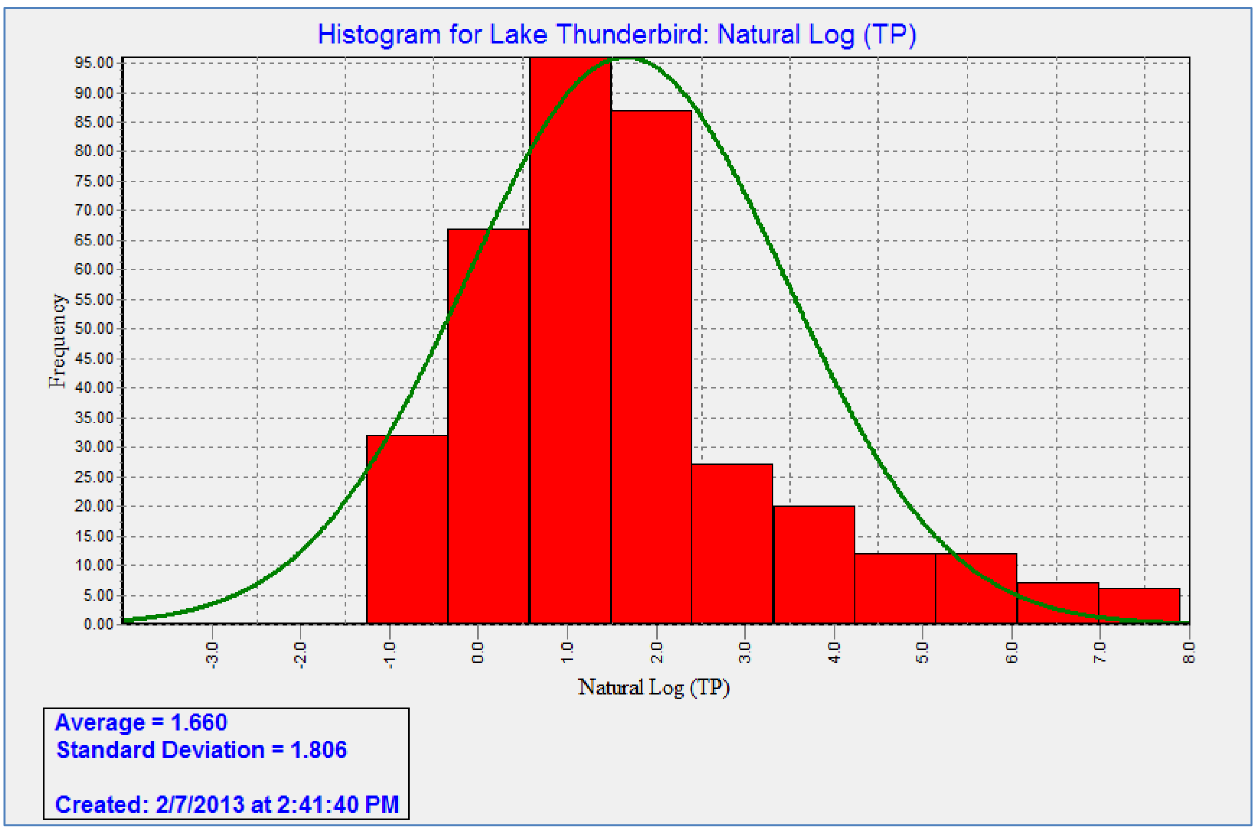
Where:

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.

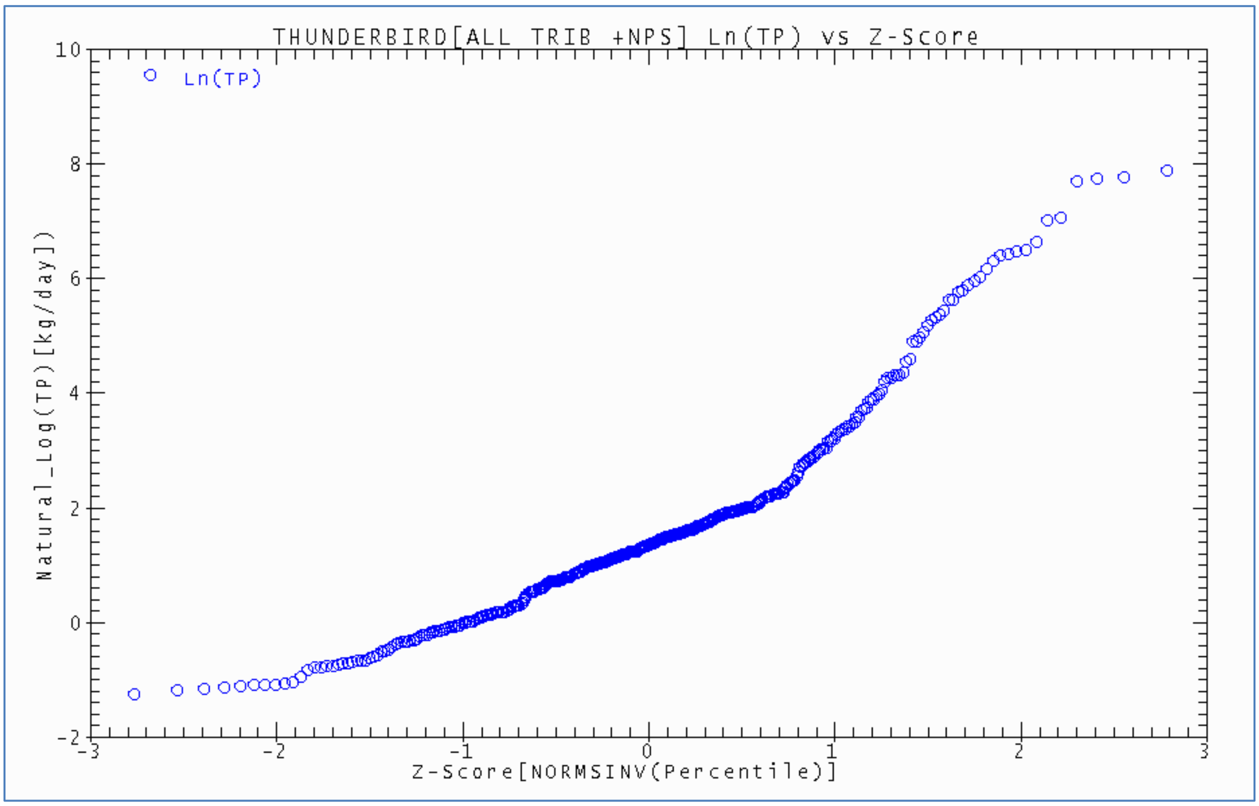
Figure 5-1 Density Distribution of the Log Transformed Total Phosphorus Data



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.

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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

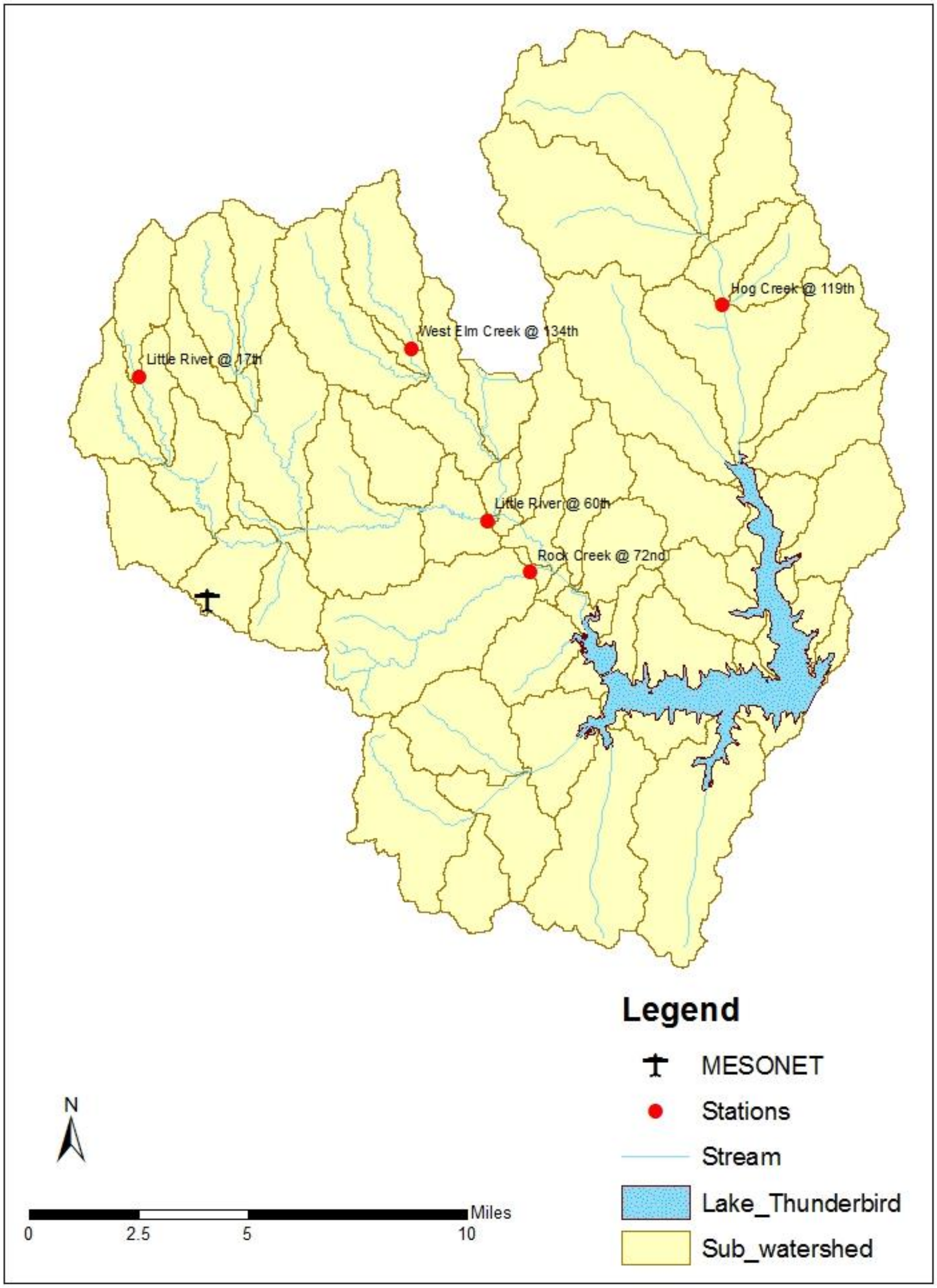
A.2.1 Model domain for watershed representation

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.

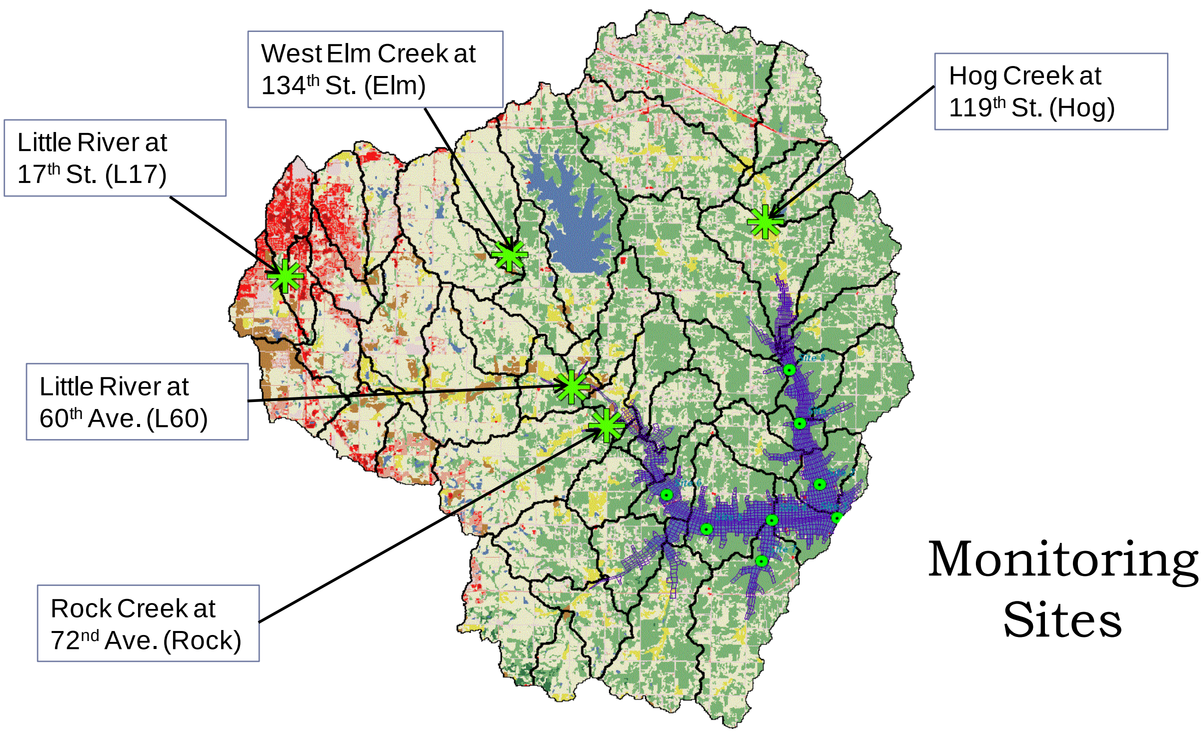
Water quality constituents or pollutants were simulated using HSPF's PQUAL module with simple accumulation and washoff relationships with water and sediment yield (Bicknell et al., 2001). Existing land management practices, including pollutant reducing best management practices for urban and agricultural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

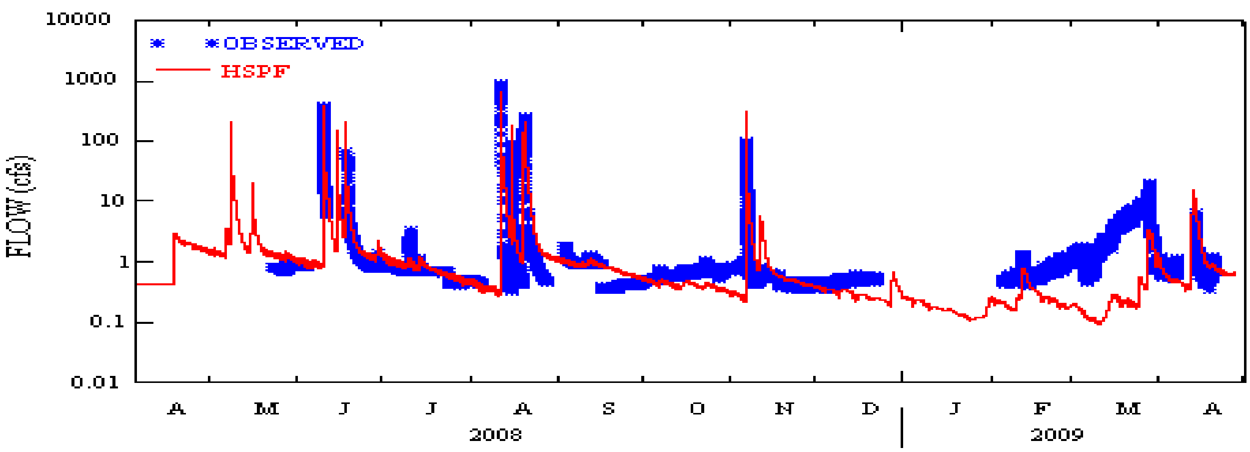


Figure A-4 Little River at 17th St. (L17) site stream discharge plot

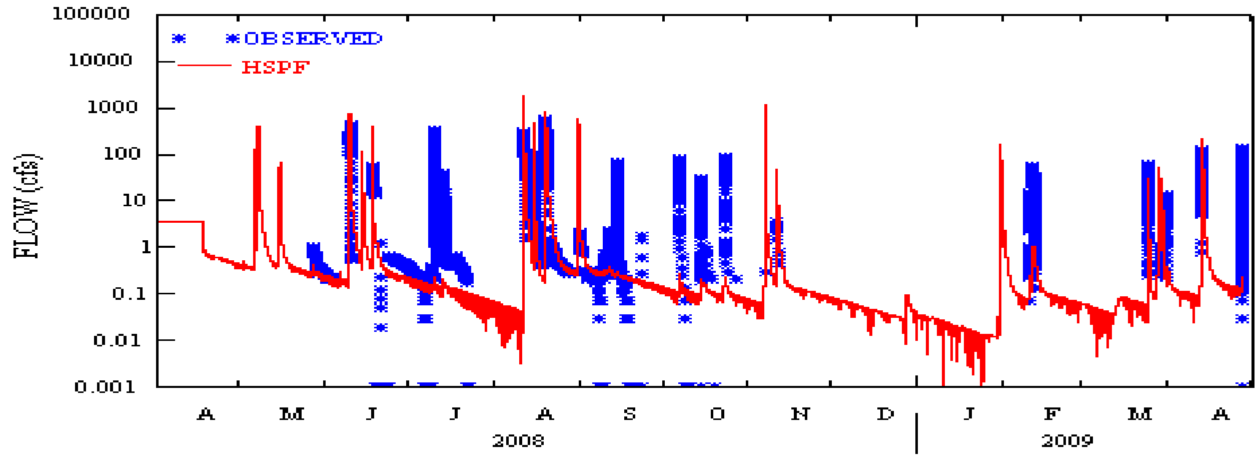


Figure A-5 Little River at 60th Ave. (L60) site stream discharge (Log scale)

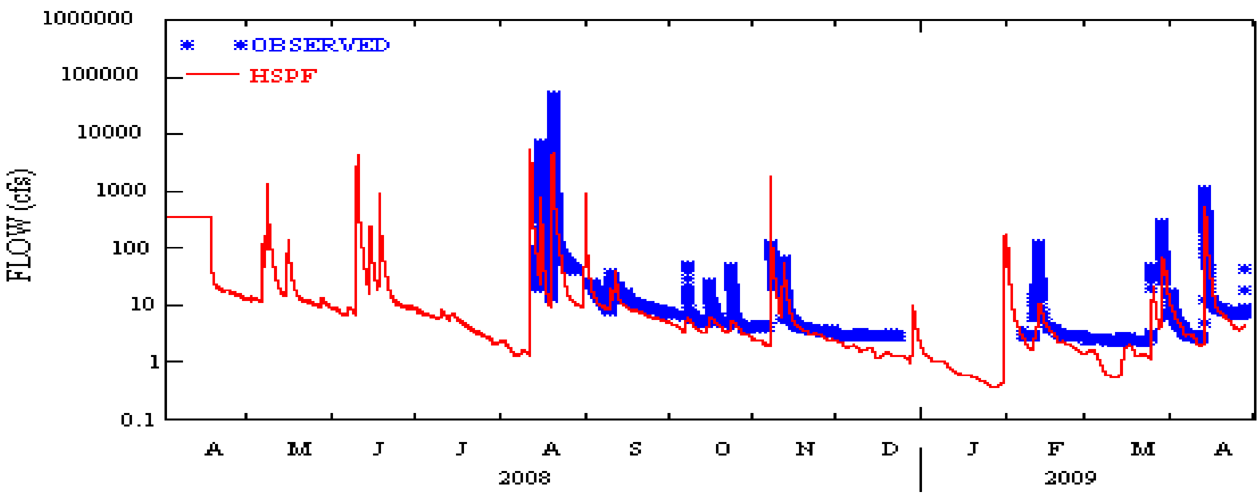


Figure A-6 Rock Creek at 72th Ave. (Rock) site stream discharge (Log scale) plot

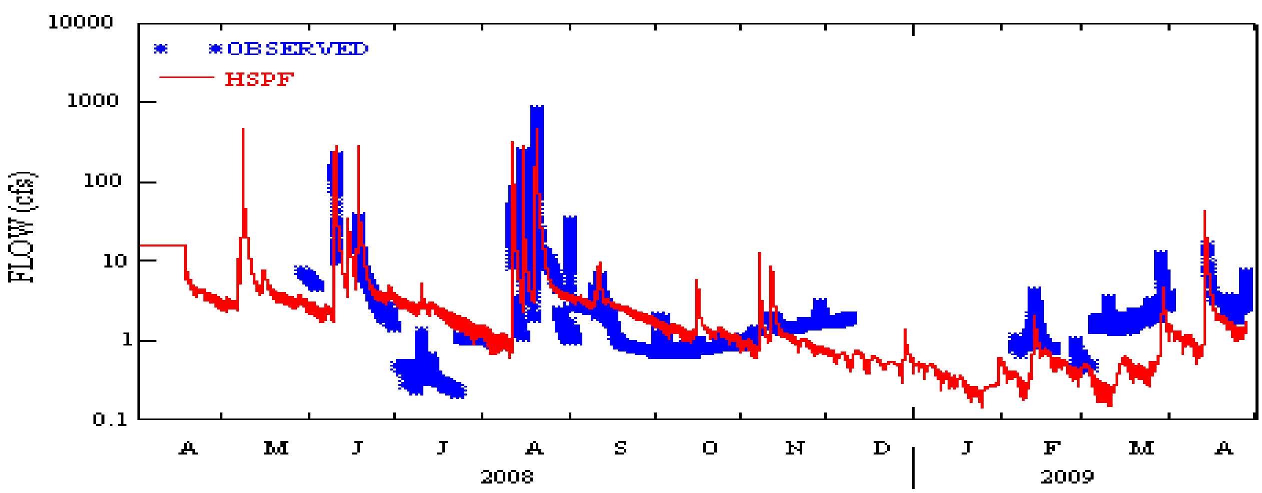


Figure A-7 Hog Creek at 119th St. (Hog) site stream discharge plot (Log scale) plot

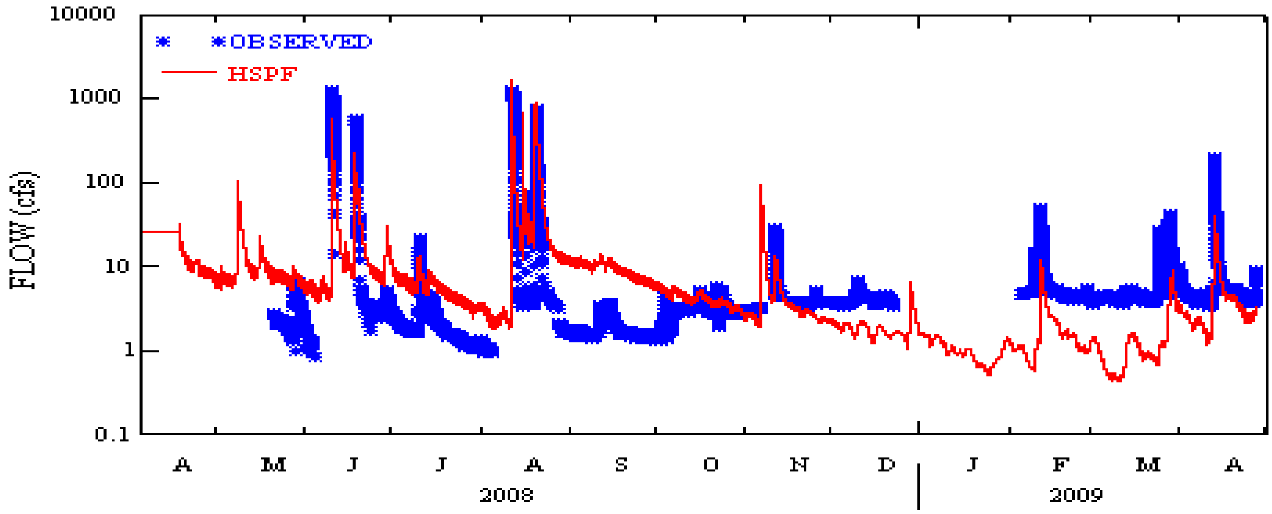


Table A-2 Daily flow statistics of the HSPF model simulation

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.

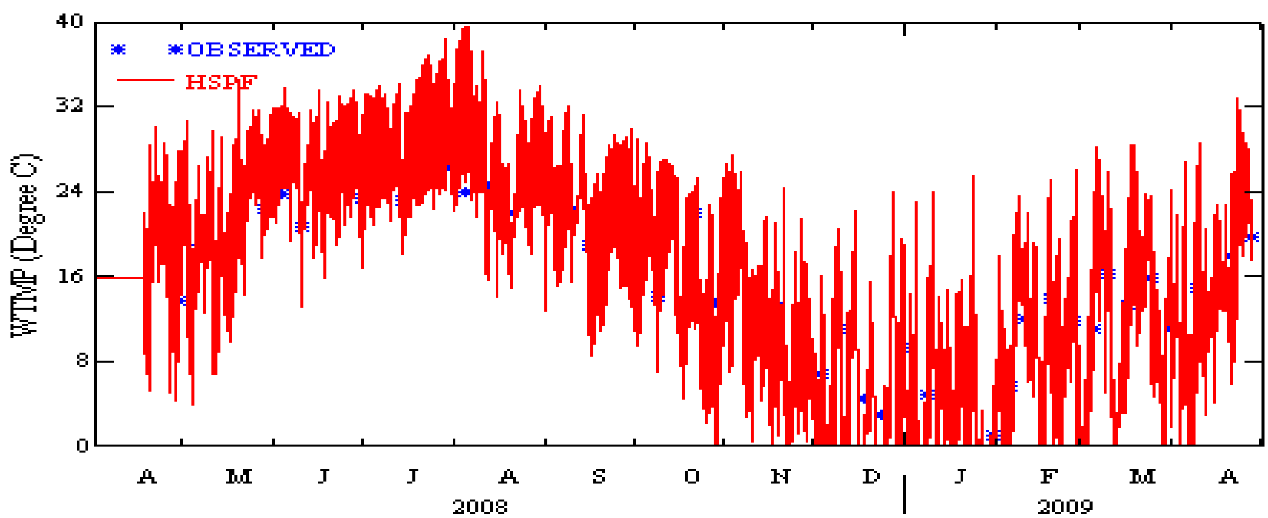


Table A-3 Instantaneous sample statistics of the HSPF model simulation for water temperature

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.

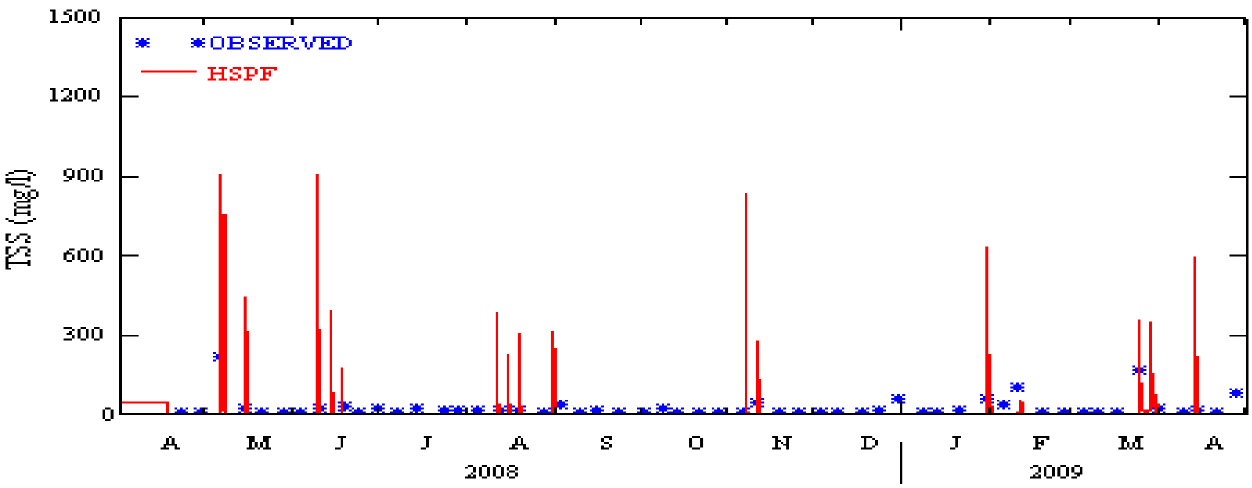


Figure A-10 Little River at 60th Ave. (L60) site total suspended sediment plot.

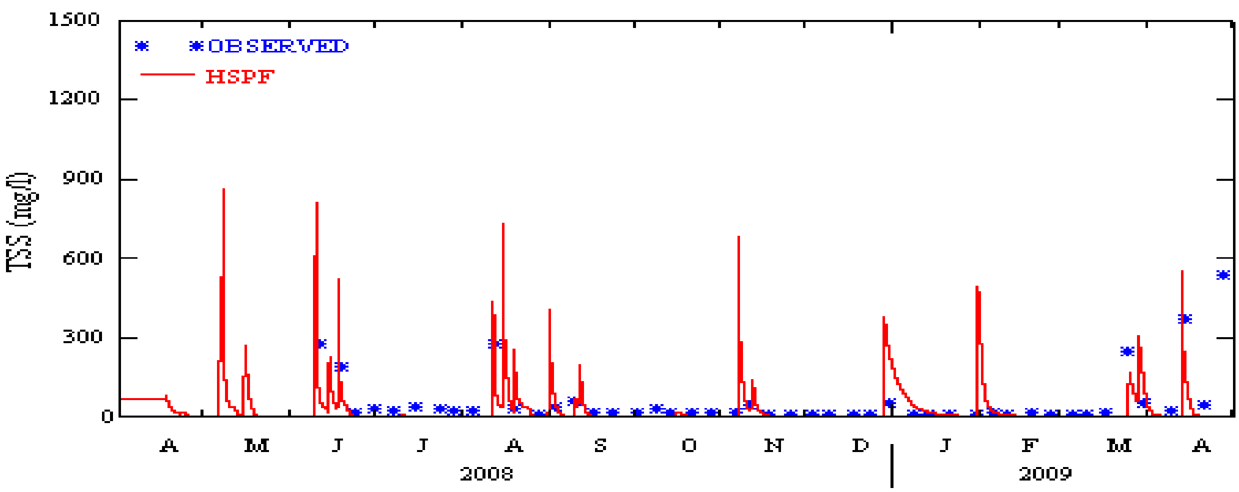


Figure A-11 Hog Creek at 119th St. (Hog) site total suspended sediment plot.

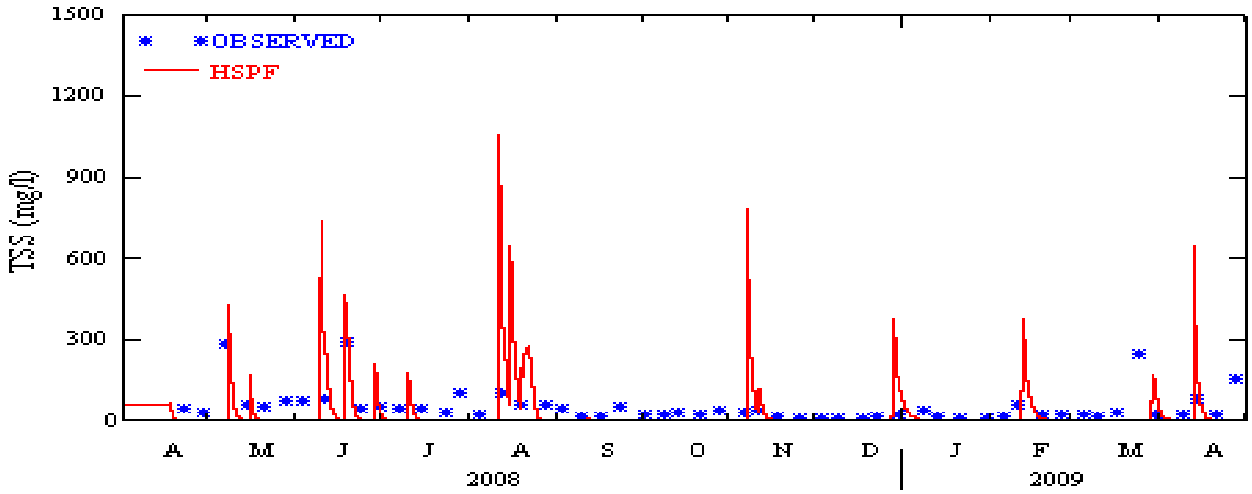


Table A-4 Grab sample statistics of the HSPF model simulation for TSS

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.

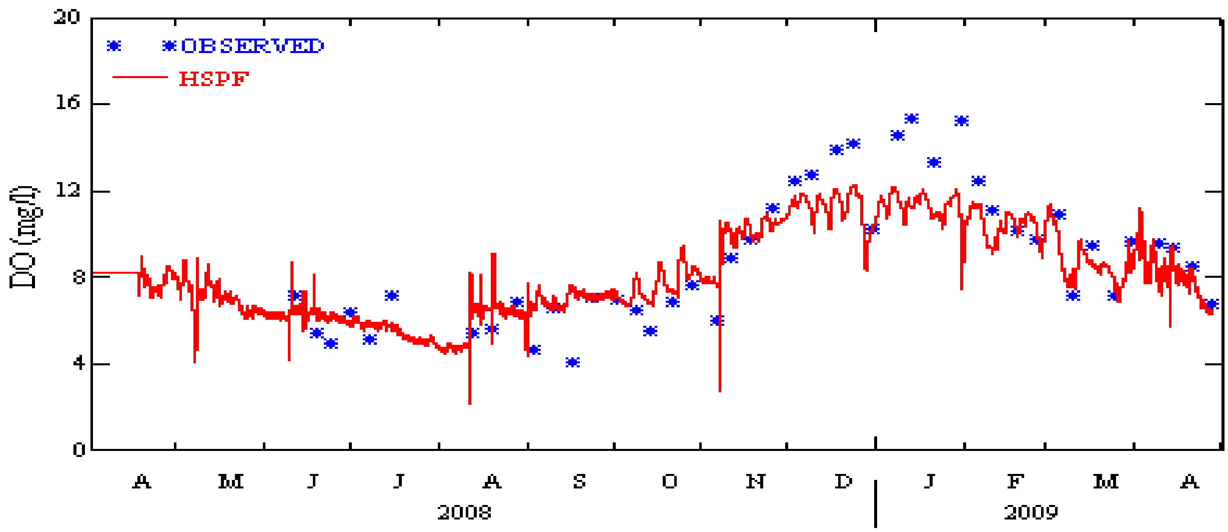


Table A-5 Instantaneous sample statistics of the HSPF model simulation for DO

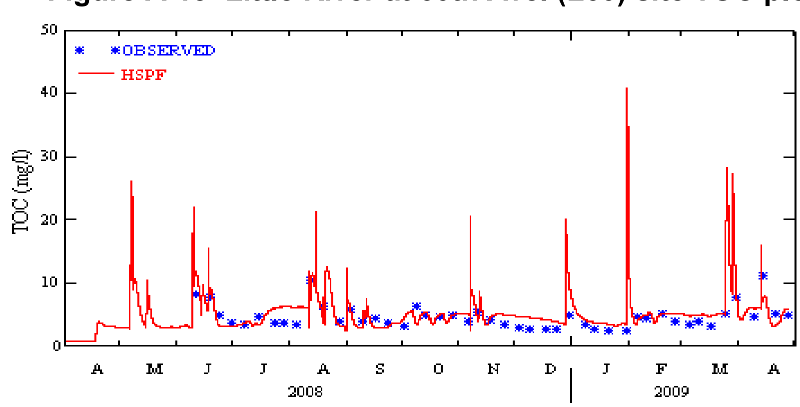
Sites	Sample average (mg/L)	HSPF average (mg/L)	% difference	r^2	Nash-Sutcliffe coefficient
L17	8.5	8.0	-6.2%	0.71	0.71
Elm	8.6	8.4	-3.1%	0.79	0.77
L60	8.6	8.5	-0.1%	0.86	0.77
Rock	7.3	8.5	+16.5%	0.55	0.25
Hog	8.9	8.7	-2.6%	0.84	0.80

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.

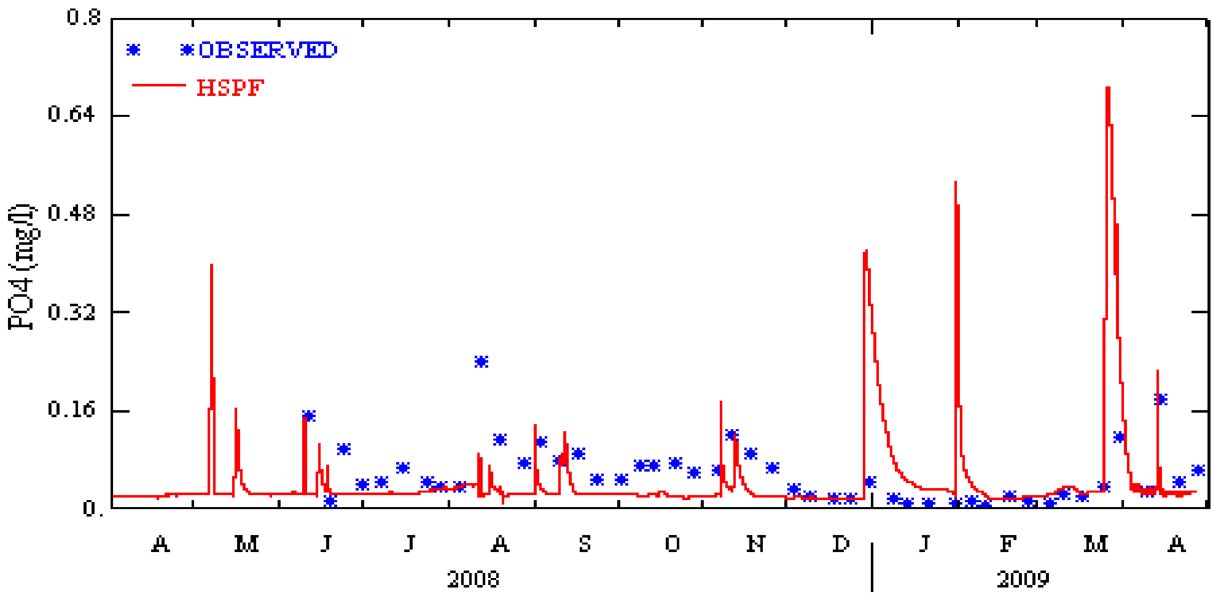
Table A-6 Composite (discharge weighted) sample statistics of the HSPF model simulation for TP

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

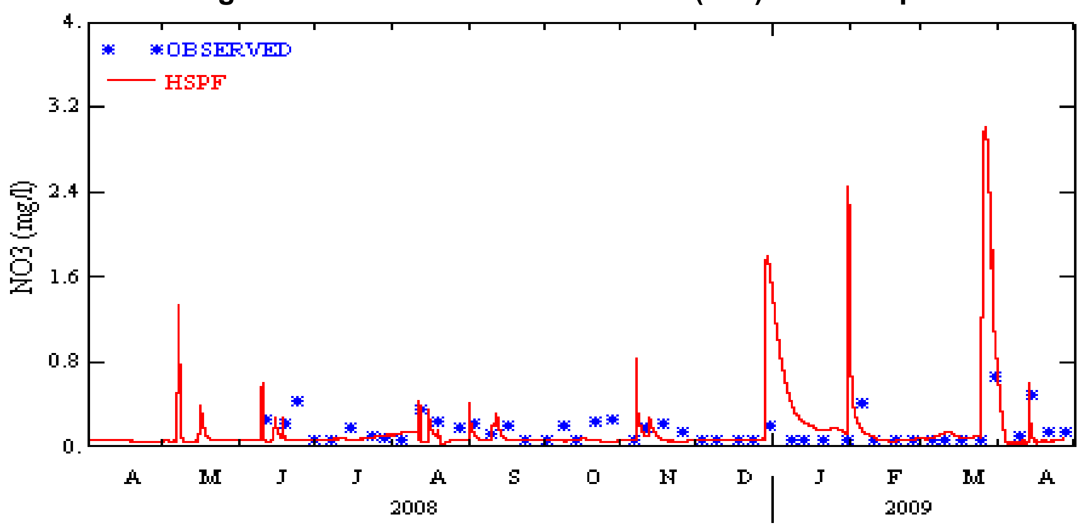
Sites	Sample average (mg/L)	HSPF average (mg/L)	% difference	r^2	Nash-Sutcliffe coefficient
L17	1.35	1.56	9.1%	0.09	-1.56
Elm	0.51	0.52	1.6%	0.79	0.78
L60	1.33	1.11	-16.6%	0.67	0.59
Rock	1.14	1.03	-10.1%	0.19	-0.08
Hog	1.11	0.91	-17.7%	0.65	0.47

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

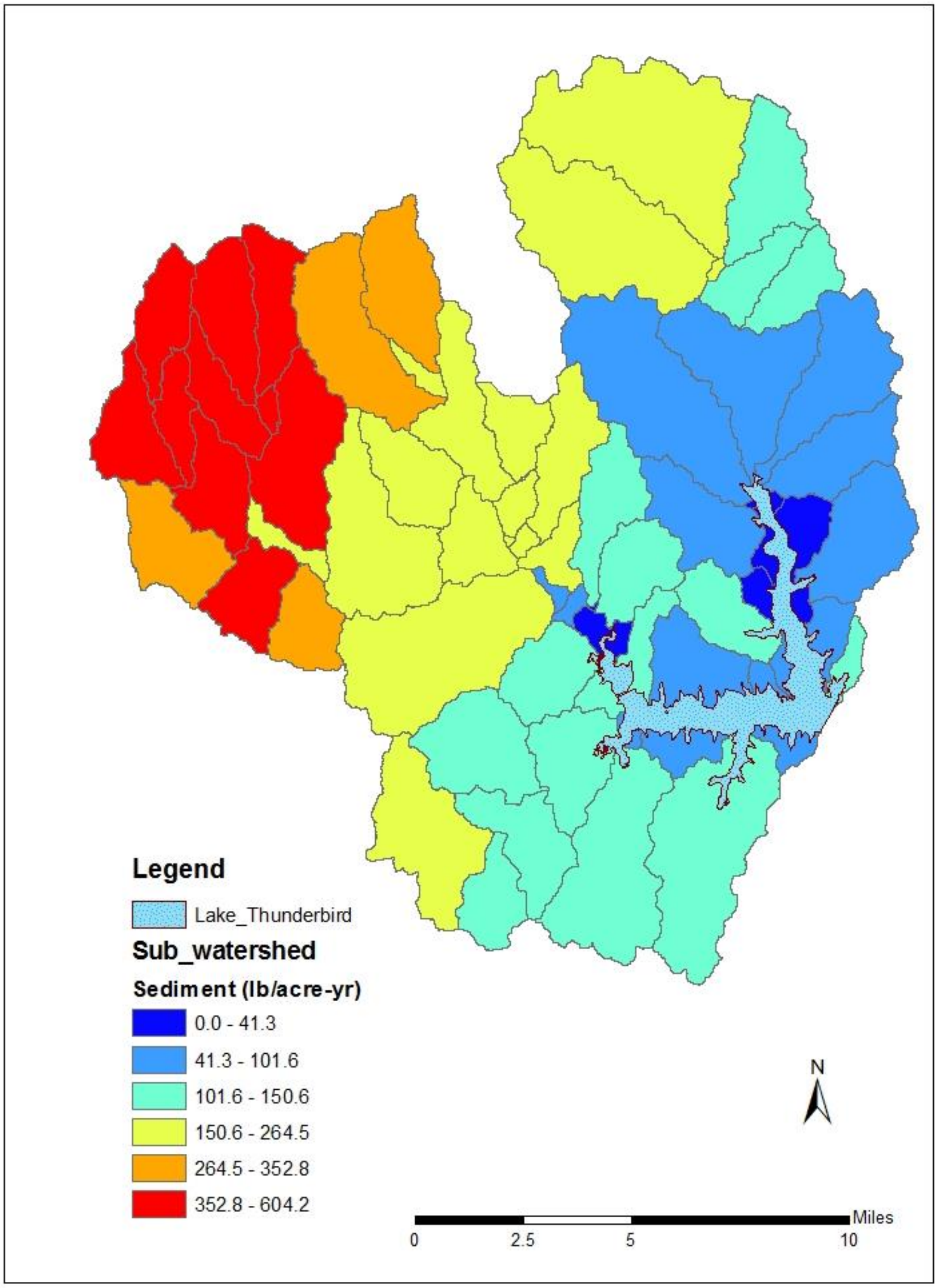


Figure A-17 Calculated sub-watershed BOD loadings by HSPF model

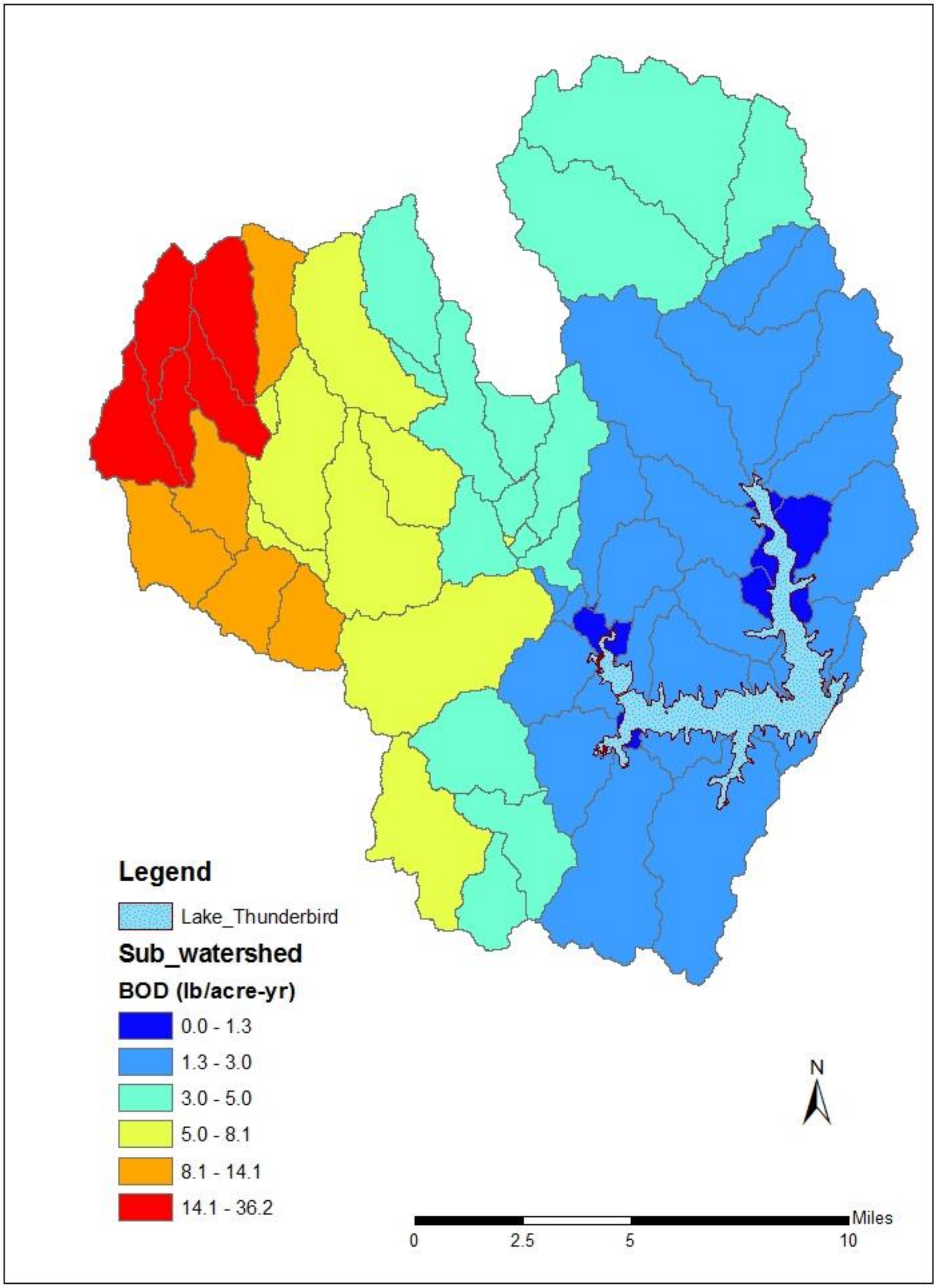


Figure A-18 Calculated sub-watershed TOC loadings by HSPF model

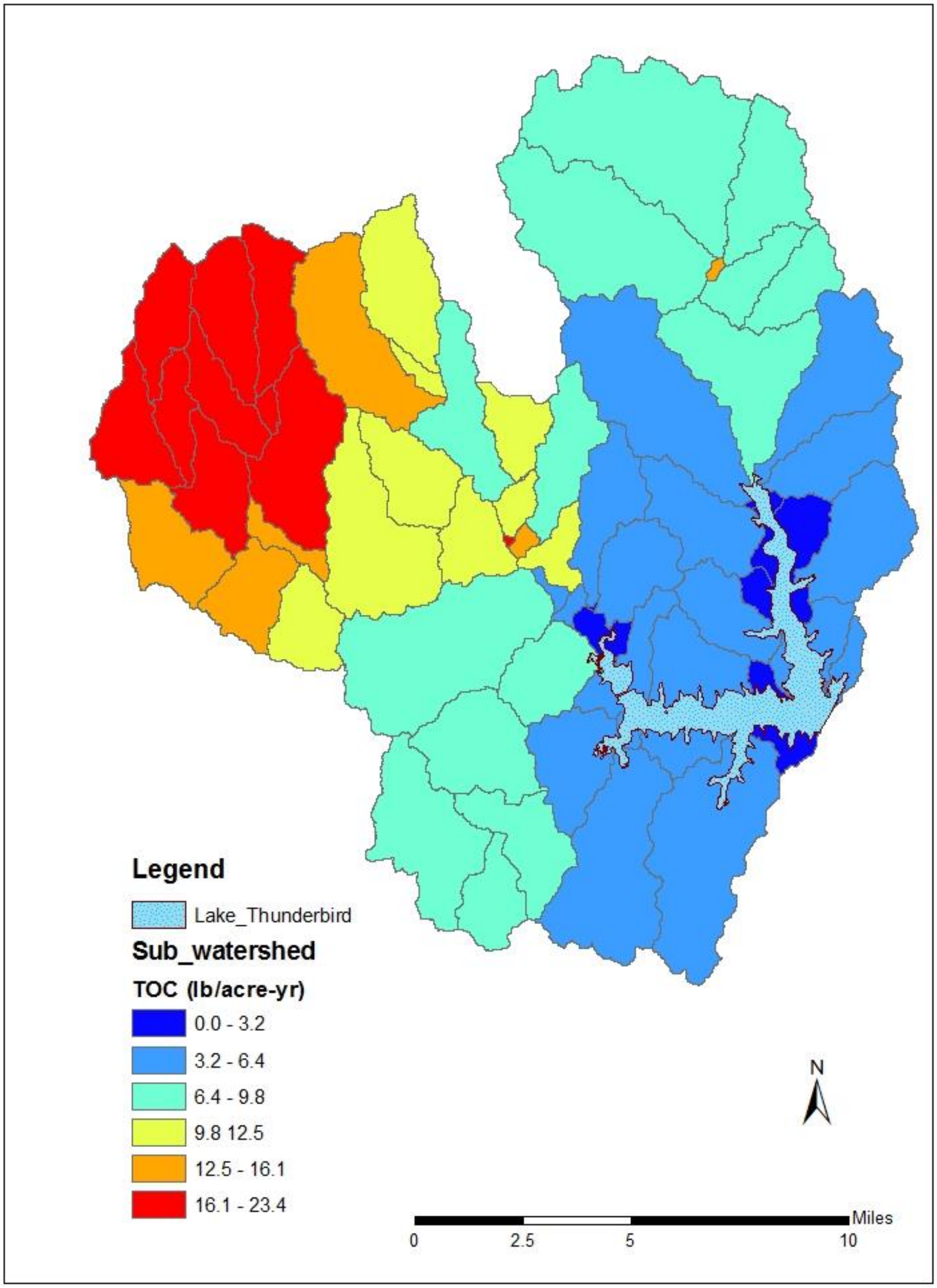


Figure A-19 Calculated sub-watershed TN loadings by HSPF model

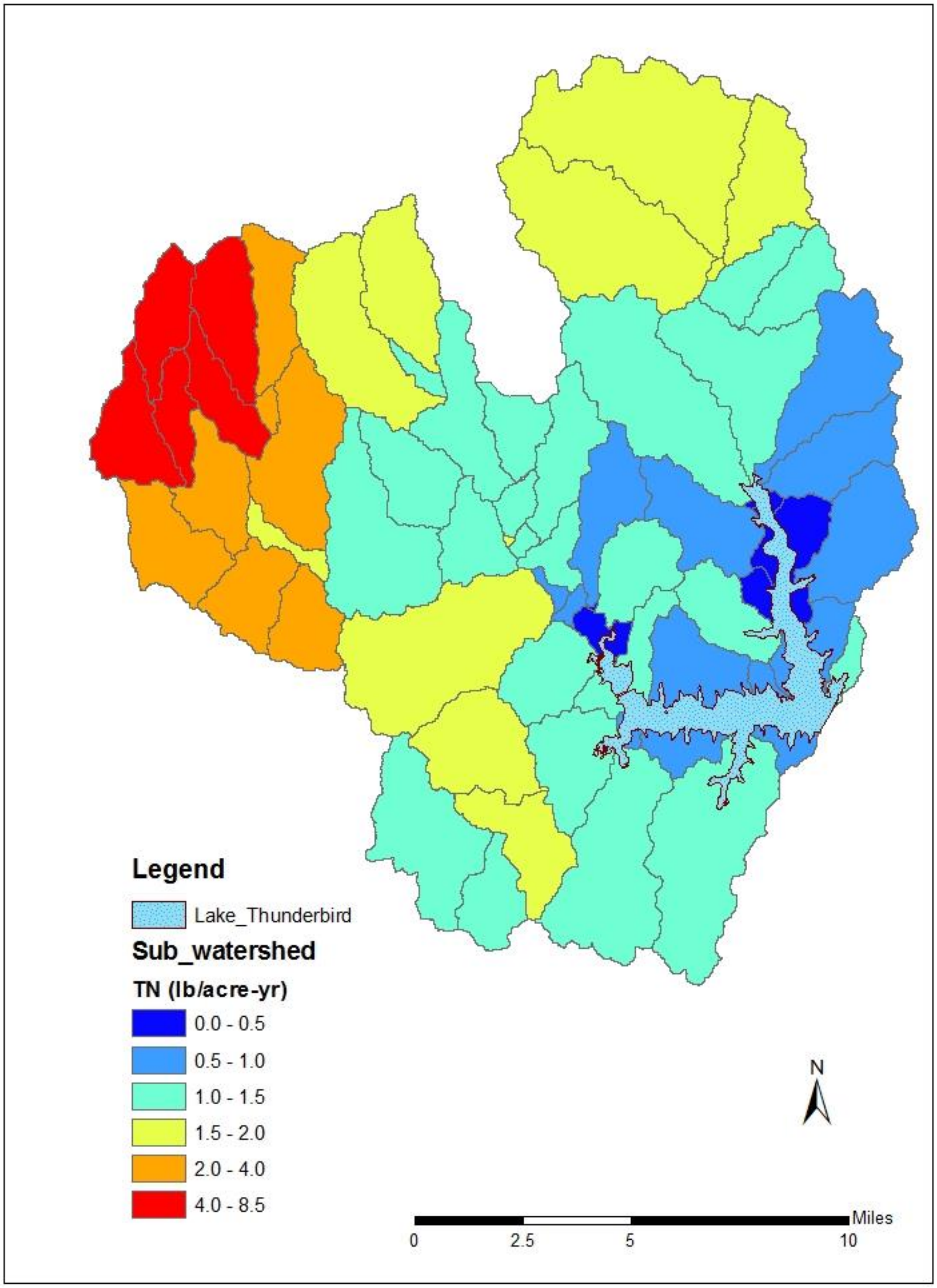
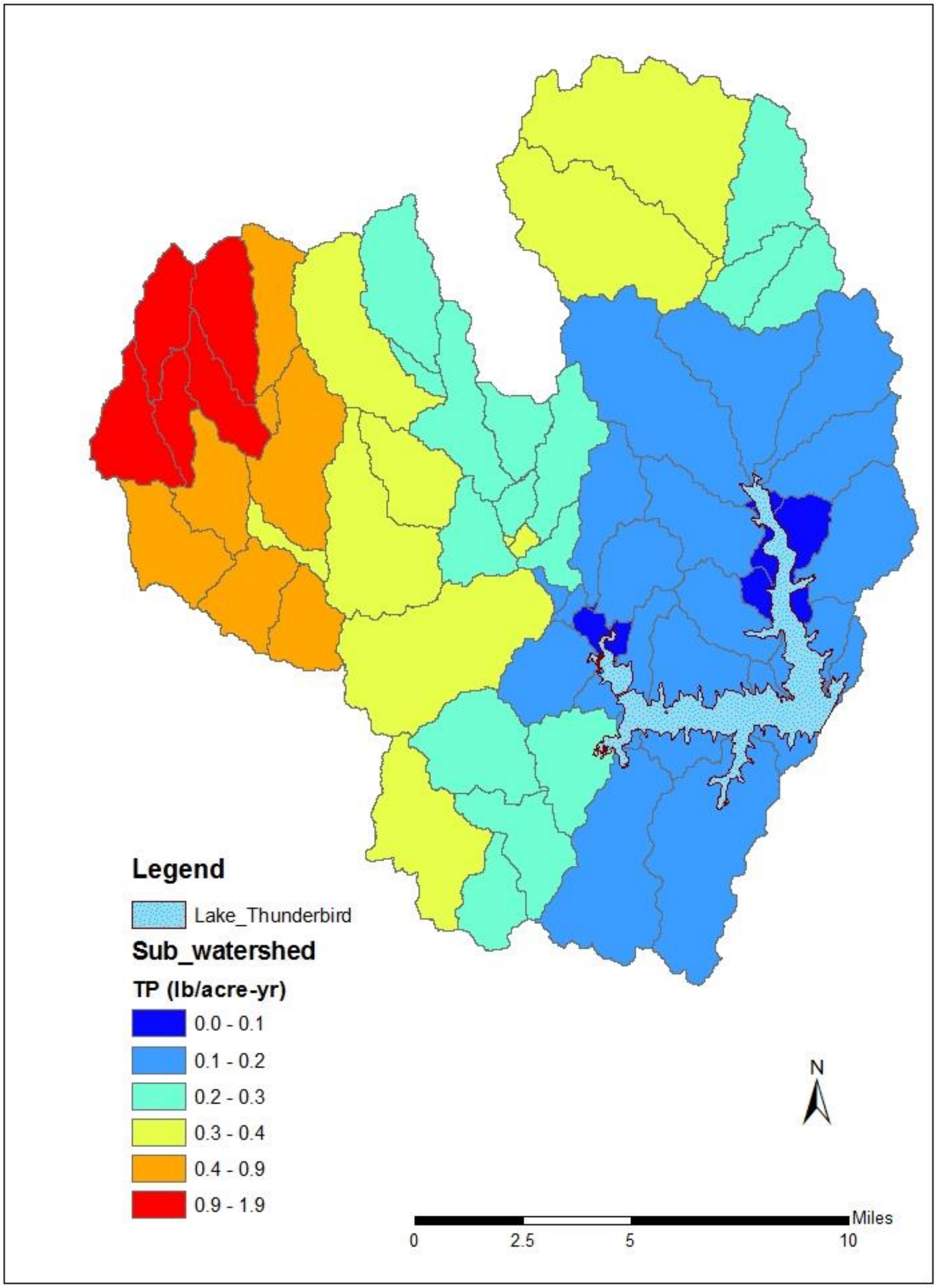


Figure A-20 Calculated sub-watershed TP loadings by HSPF model



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

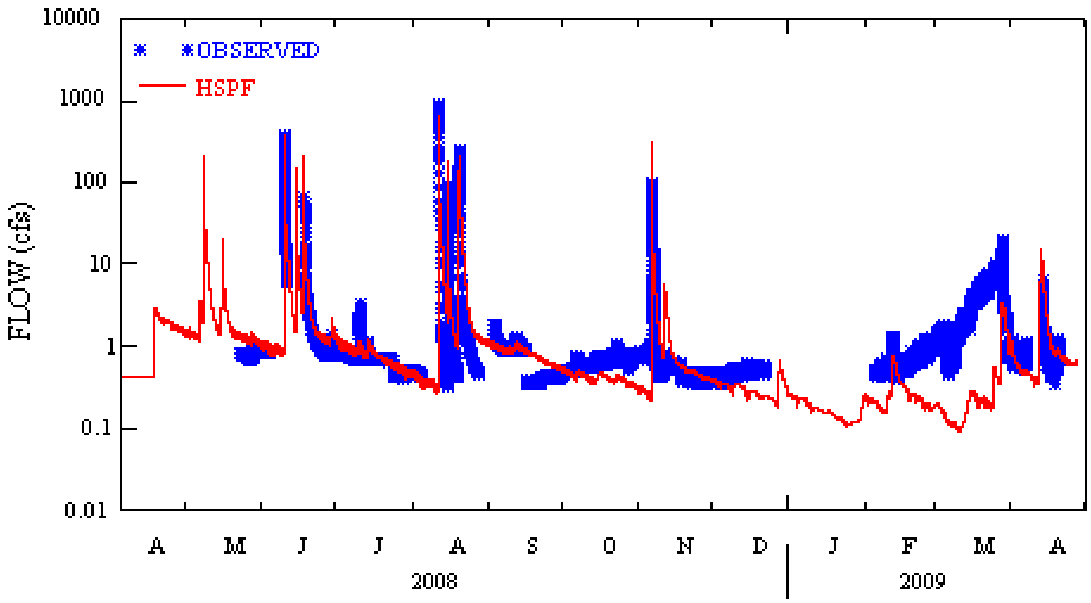


Figure A-22 Comparison of observed and simulated stream flows at Hog station

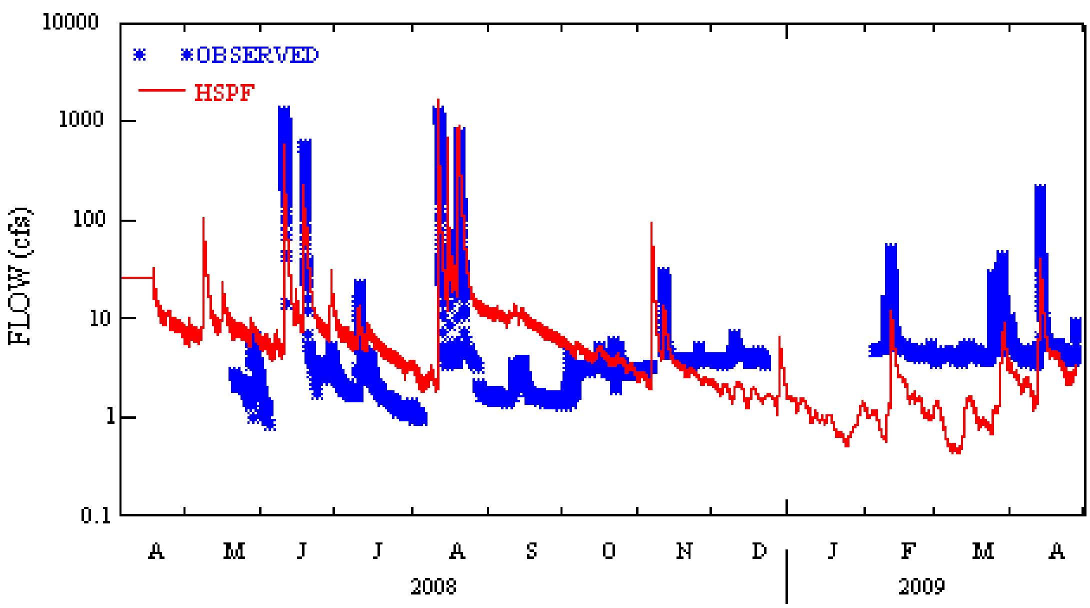


Figure A-23 Comparison of observed and simulated stream flows at L17 station

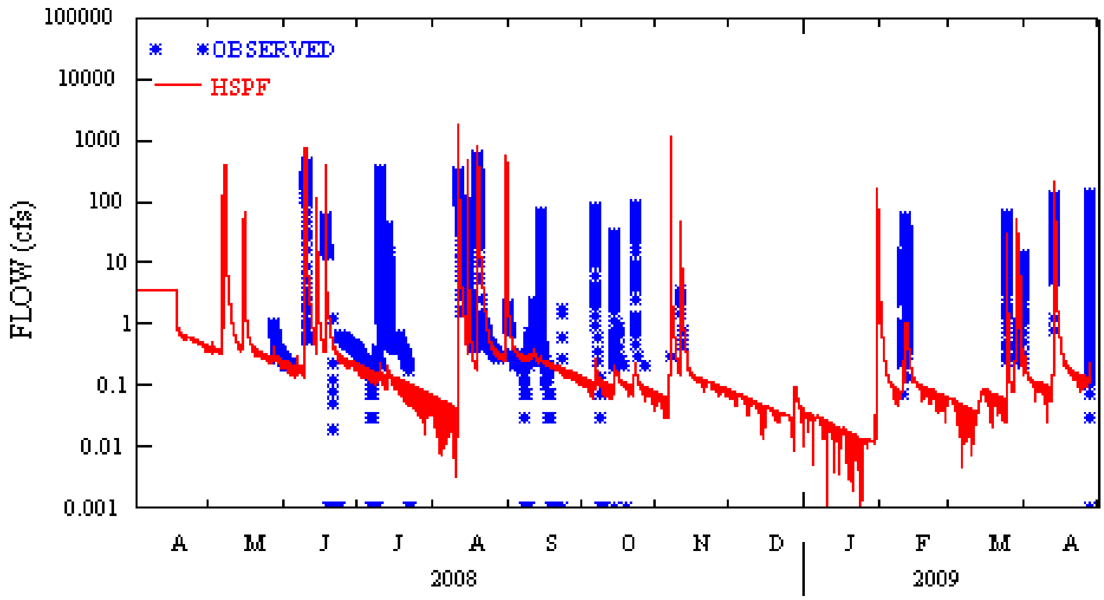


Figure A-24 Comparison of observed and simulated stream flows at L60 station

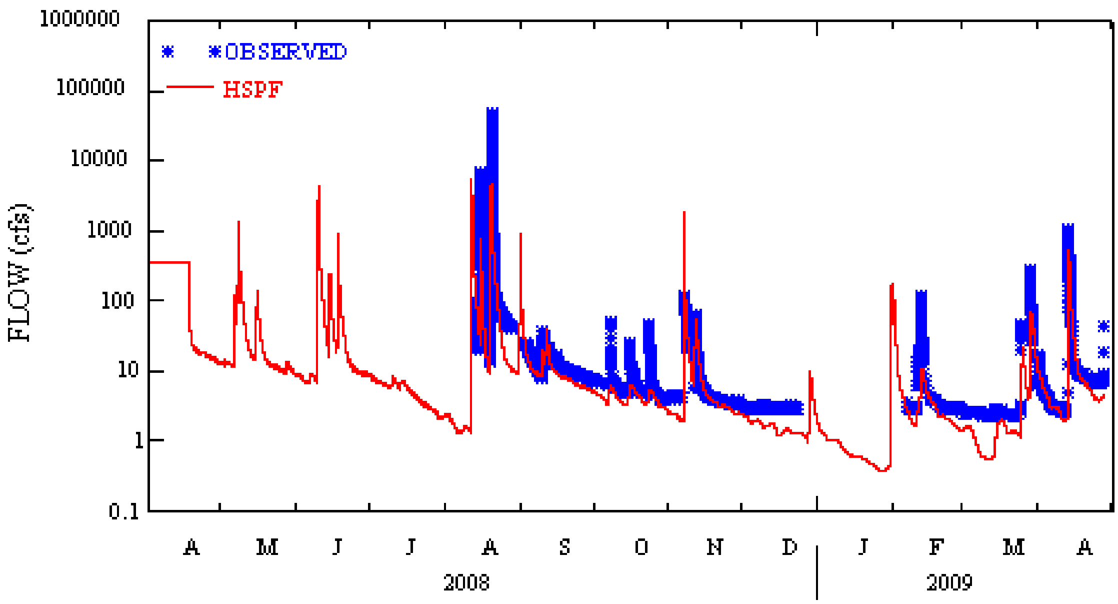


Figure A-25 Comparison of observed and simulated stream flows at Rock station

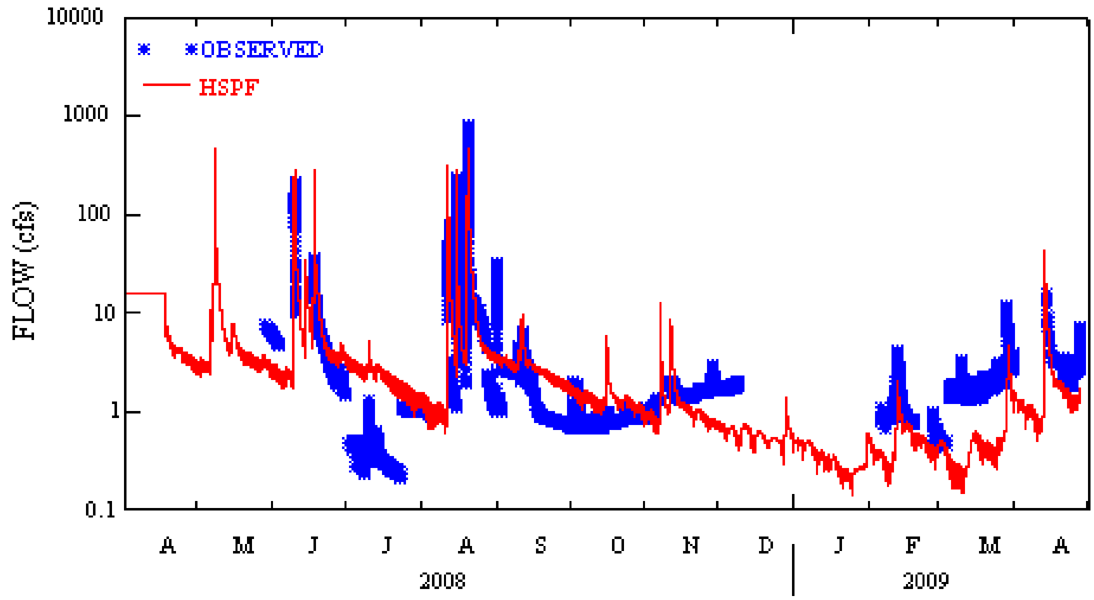


Figure A-26 Comparison of observed and simulated stream temperatures at ELM station

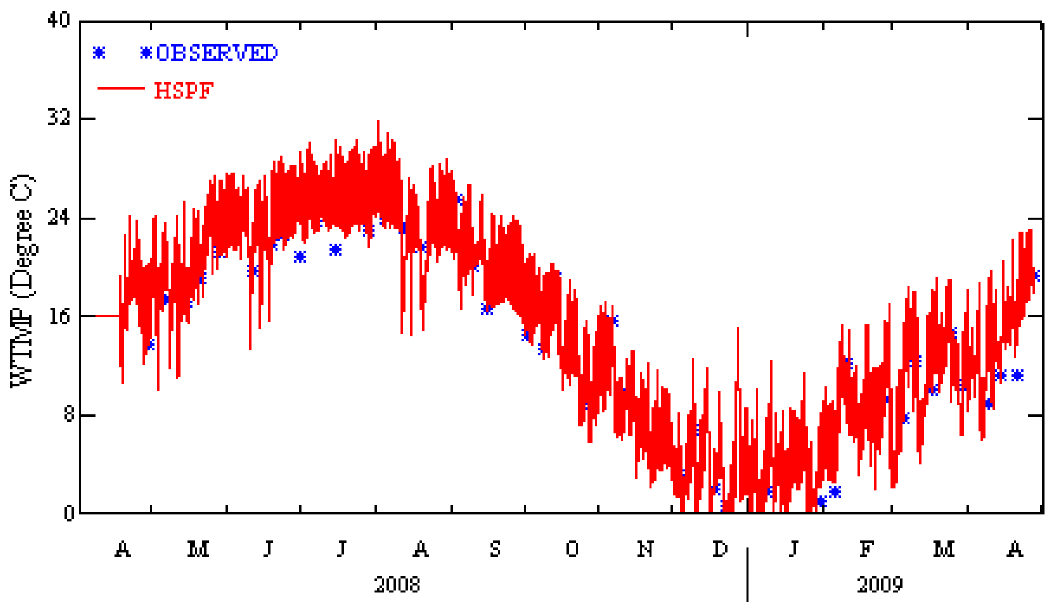


Figure A-27 Comparison of observed and simulated stream temperatures at Hog station

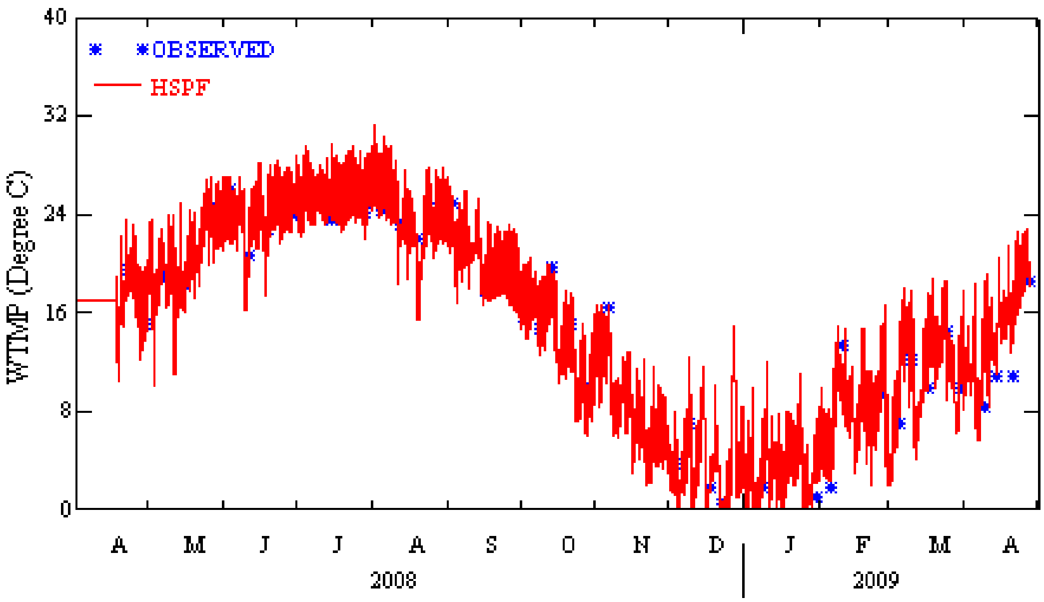


Figure A-28 Comparison of observed and simulated stream temperatures at L17 station

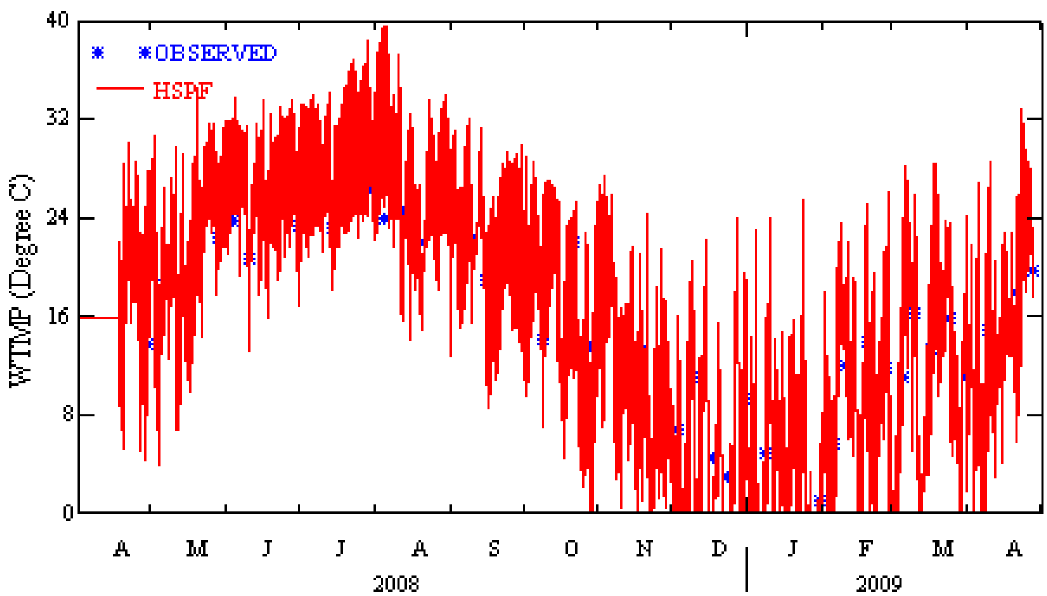


Figure A-29 Comparison of observed and simulated stream temperatures at L60 station

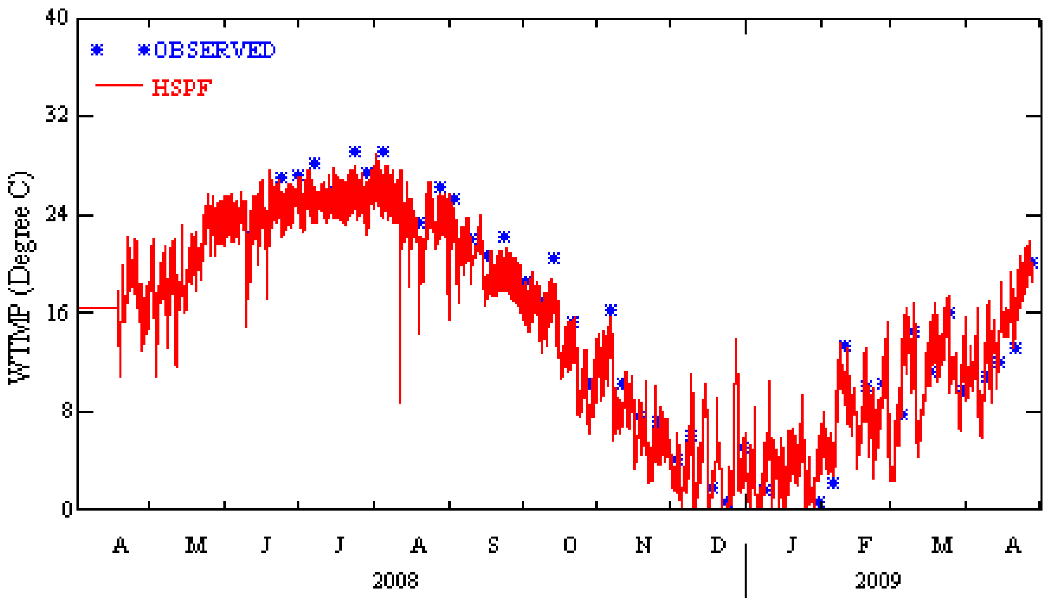


Figure A-30 Comparison of observed and simulated stream temperatures at Rock station

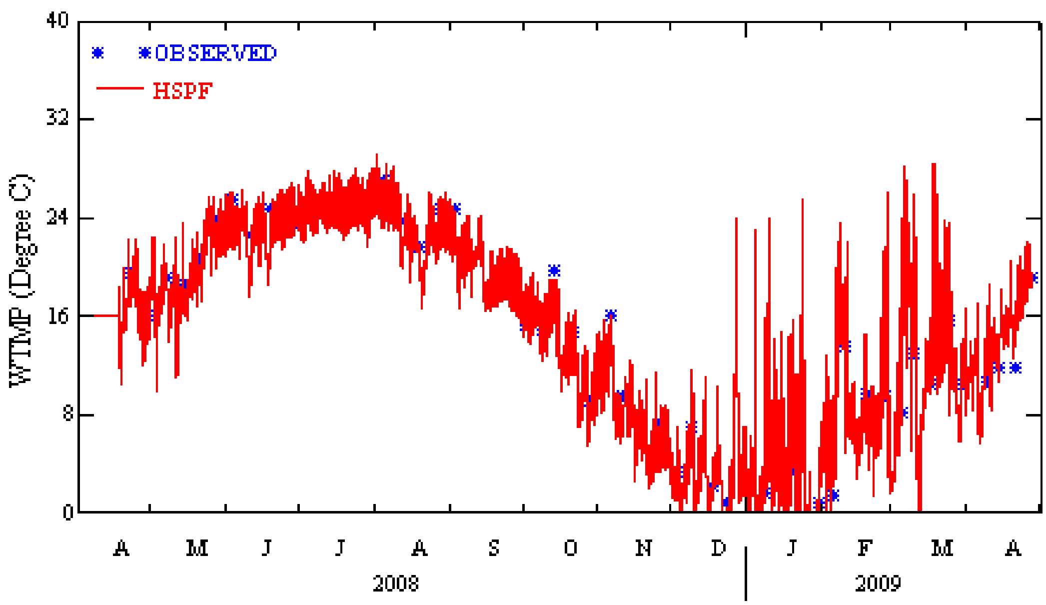


Figure A-31 Comparison of observed and simulated stream TSS concentrations at Elm station

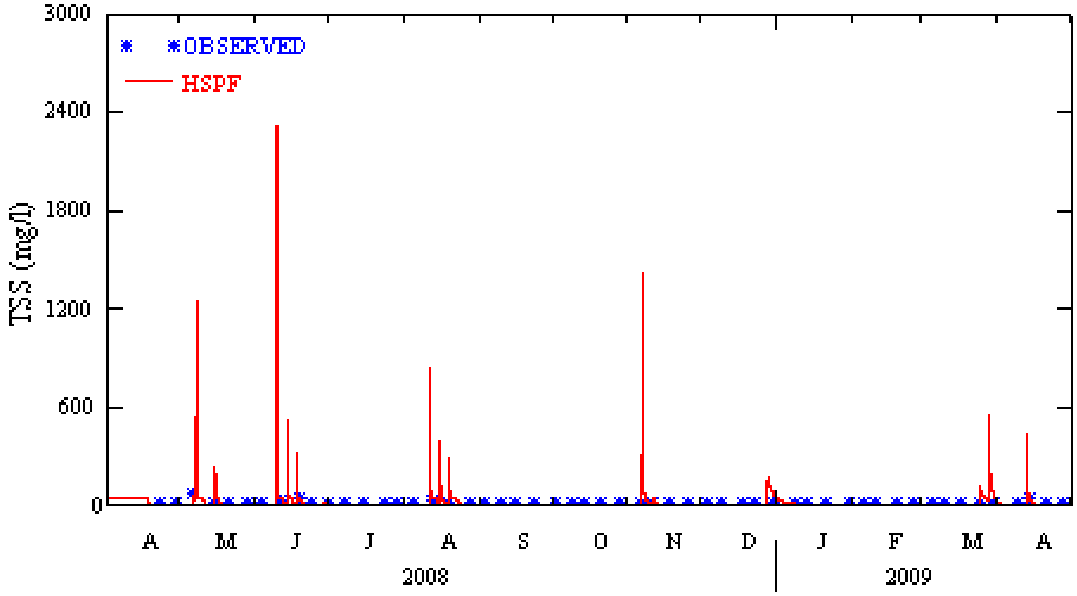


Figure A-32 Comparison of observed and simulated stream TSS concentrations at Hog station

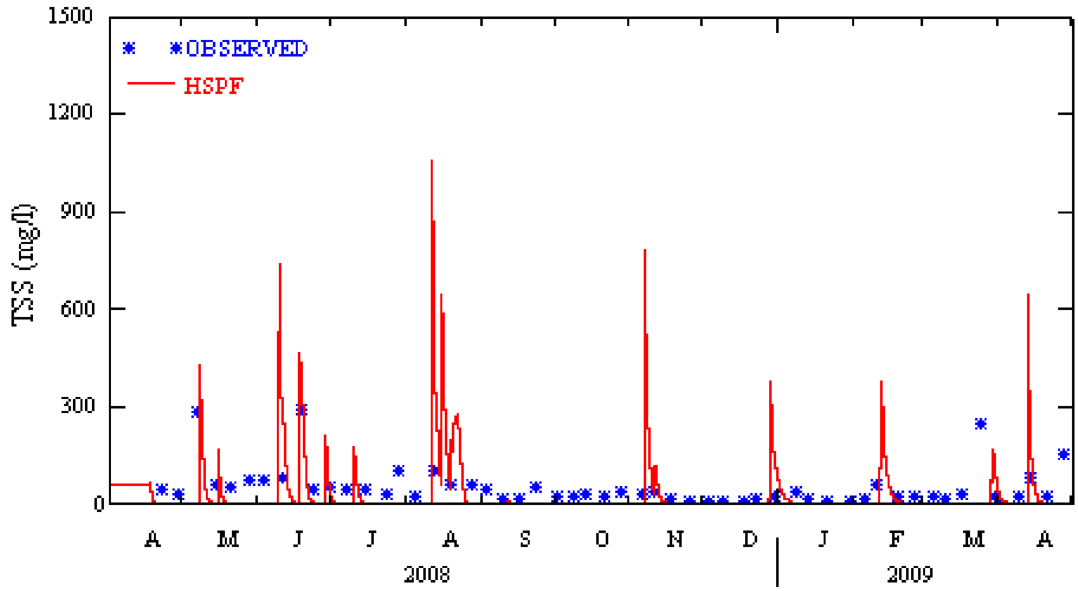


Figure A-33 Comparison of observed and simulated stream TSS concentrations at L17station

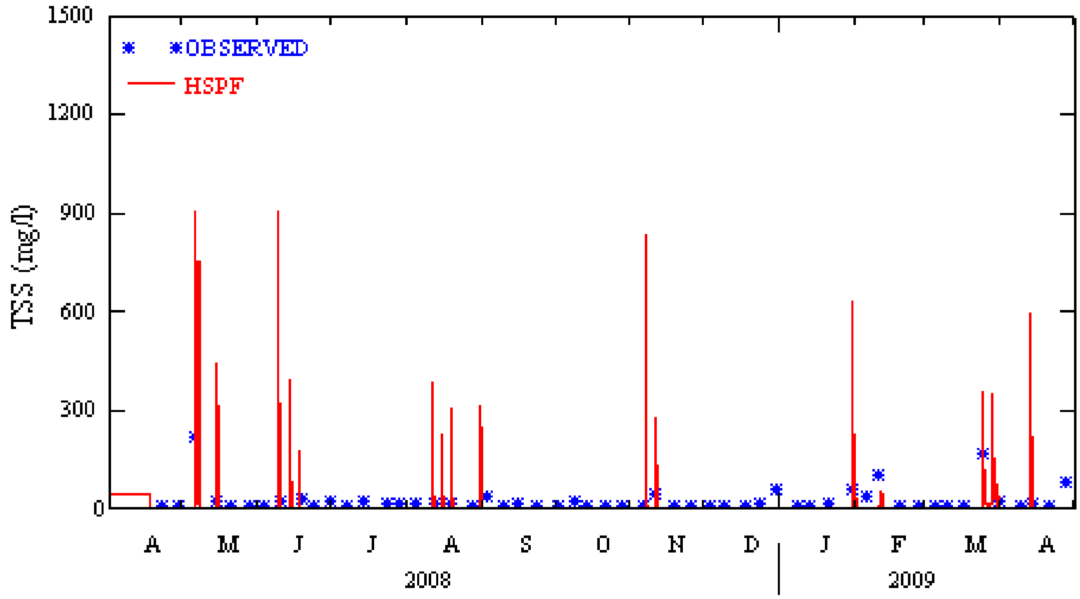


Figure A-34 Comparison of observed and simulated stream TSS concentrations at L60 station

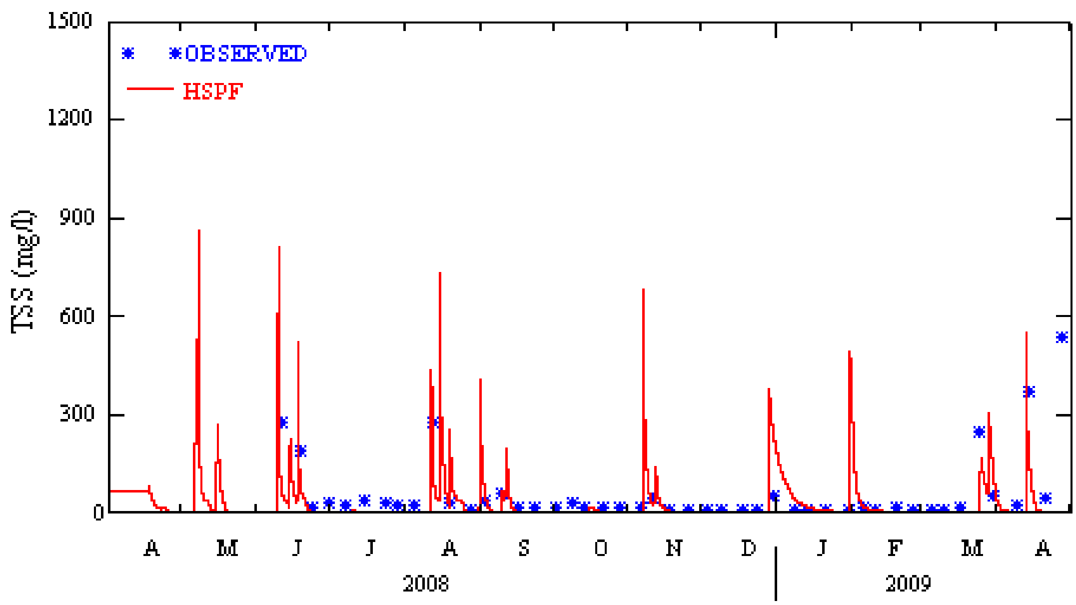


Figure A-35 Comparison of observed and simulated stream TSS concentrations at Rock station

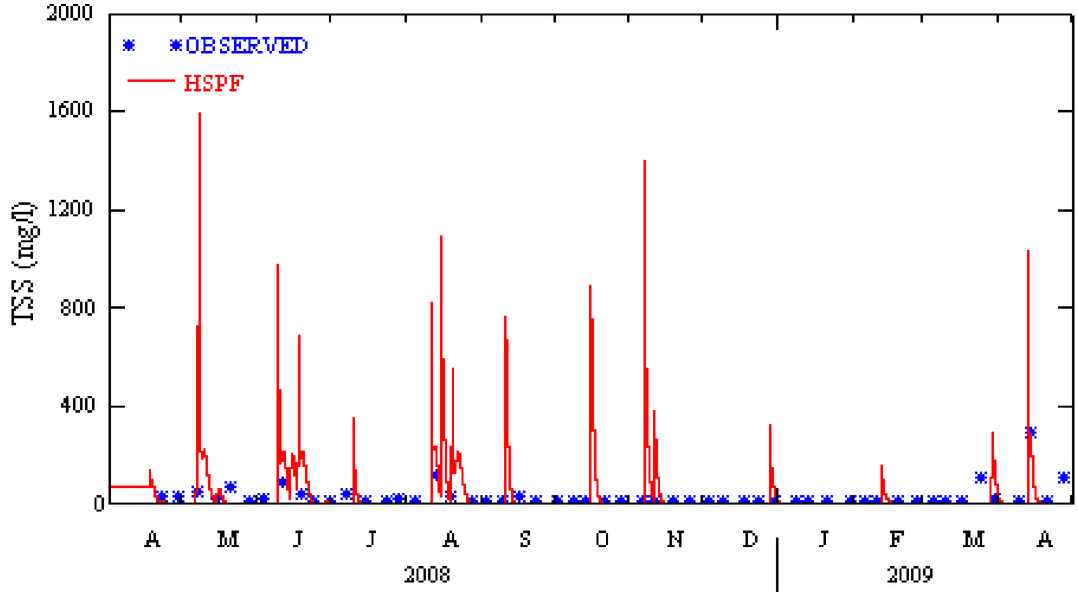


Figure A-36 Comparison of observed and simulated stream DO concentrations at Elm station

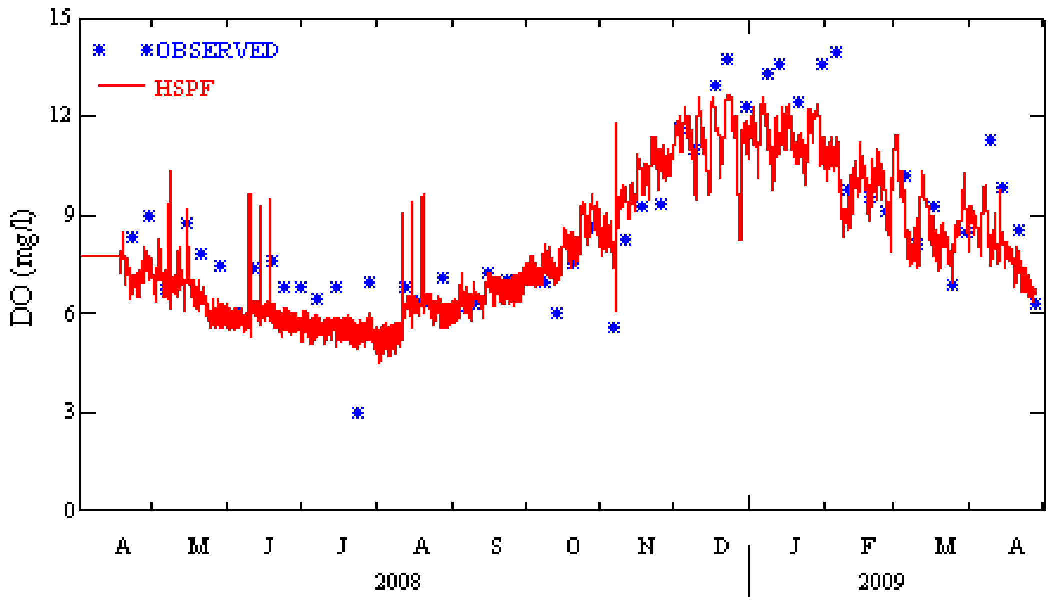


Figure A-37 Comparison of observed and simulated stream DO concentrations at Hog station

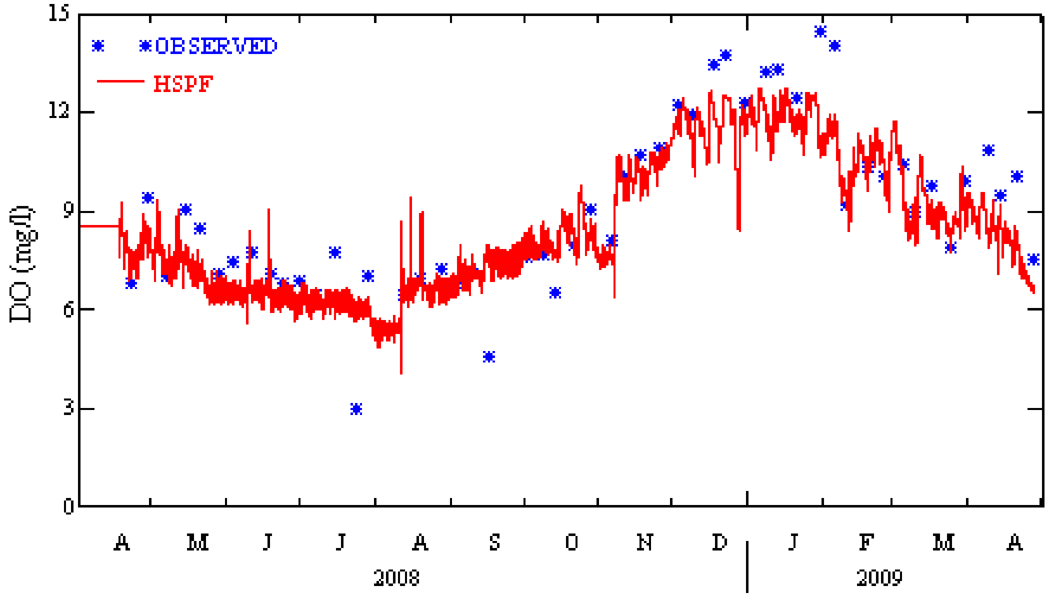


Figure A-38 Comparison of observed and simulated stream DO concentrations at L17 station

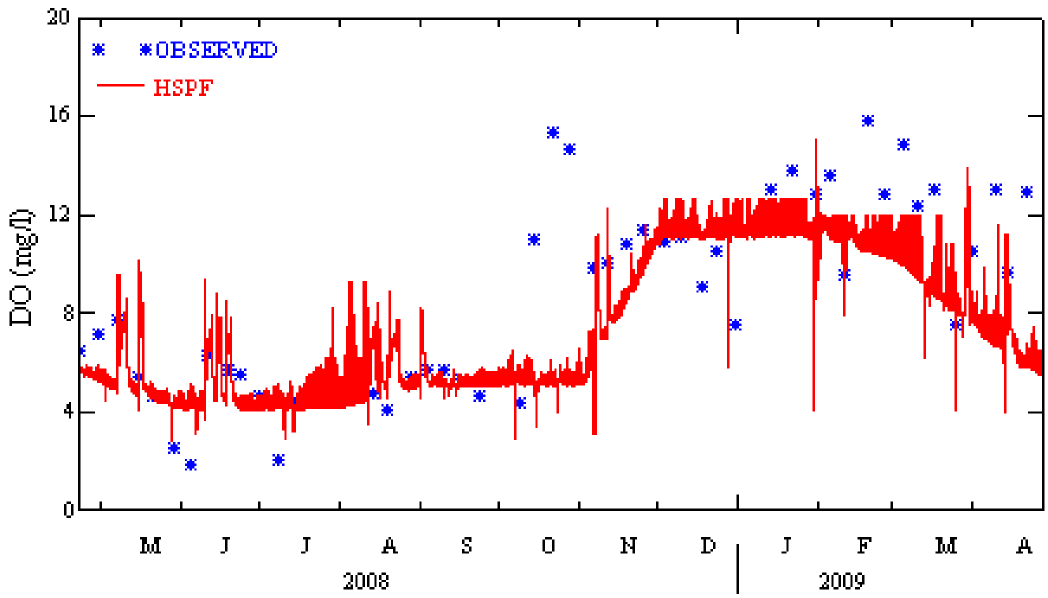


Figure A-39 Comparison of observed and simulated stream DO concentrations at L60 station

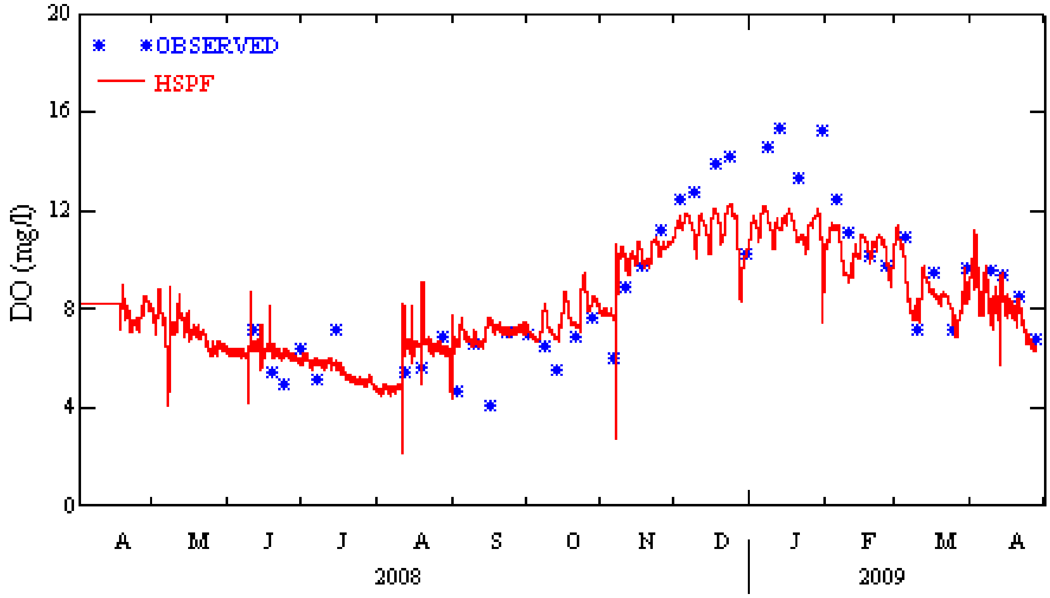


Figure A-40 Comparison of observed and simulated stream DO concentrations at Rock station

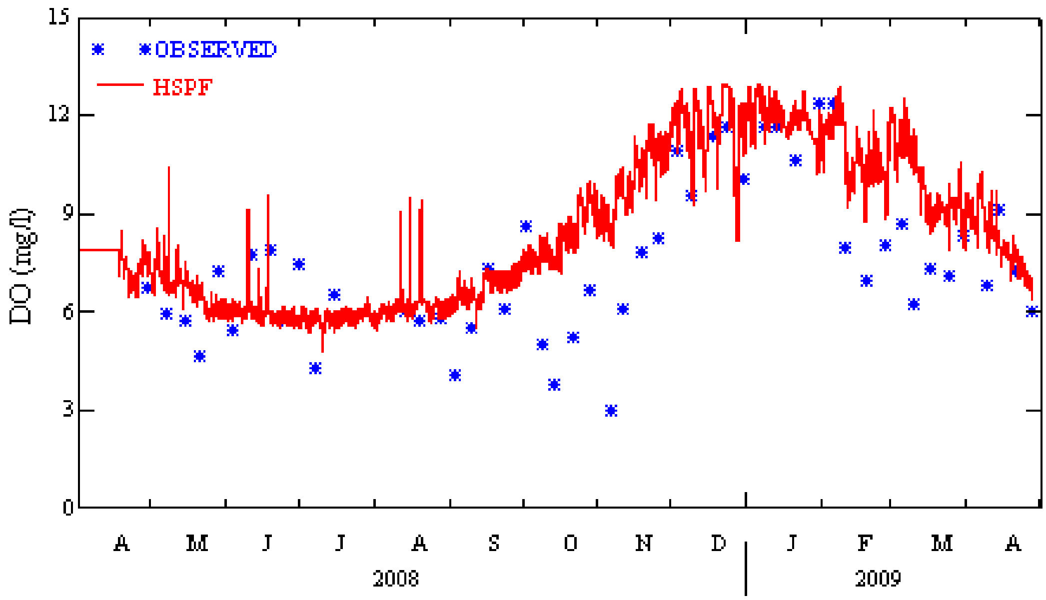


Figure A-41 Comparison of observed and simulated stream TKN concentrations at Elm station

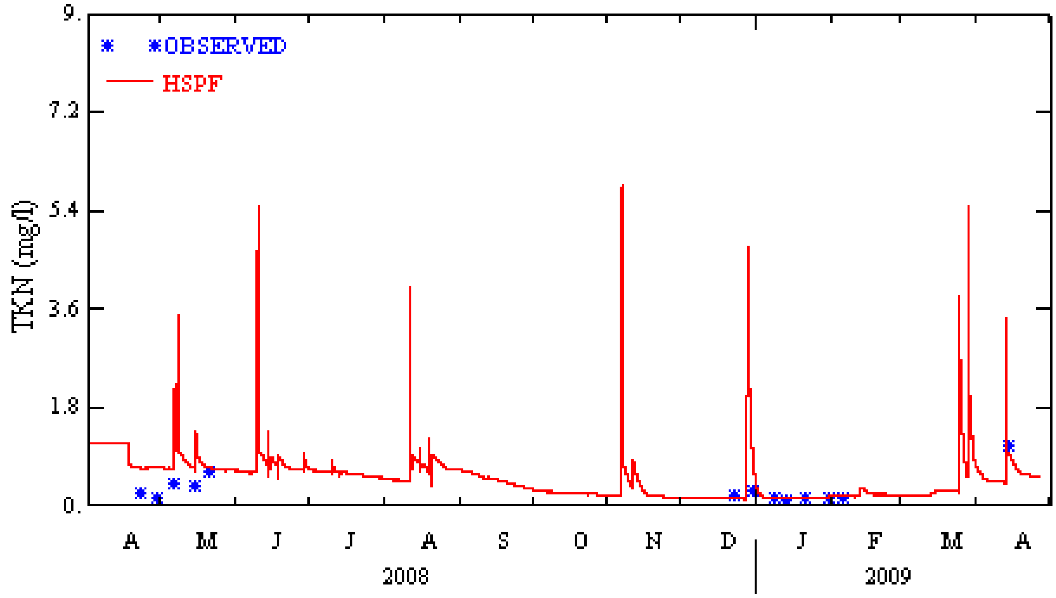


Figure A-42 Comparison of observed and simulated stream TKN concentrations at Hog station

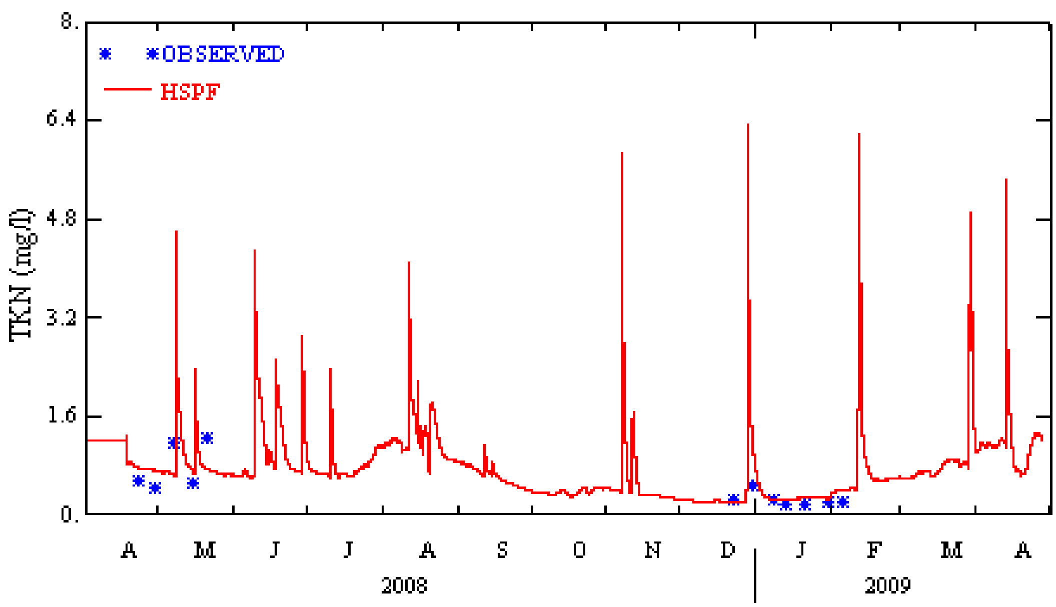


Figure A-43 Comparison of observed and simulated stream TKN concentrations at L17 station

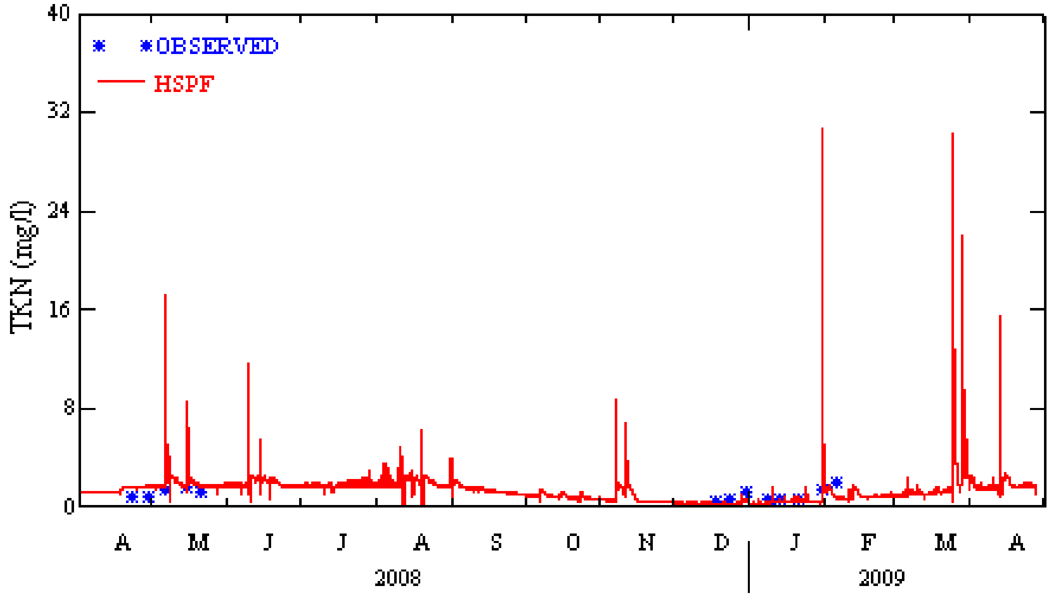


Figure A-44 Comparison of observed and simulated stream TP concentrations at Elm station

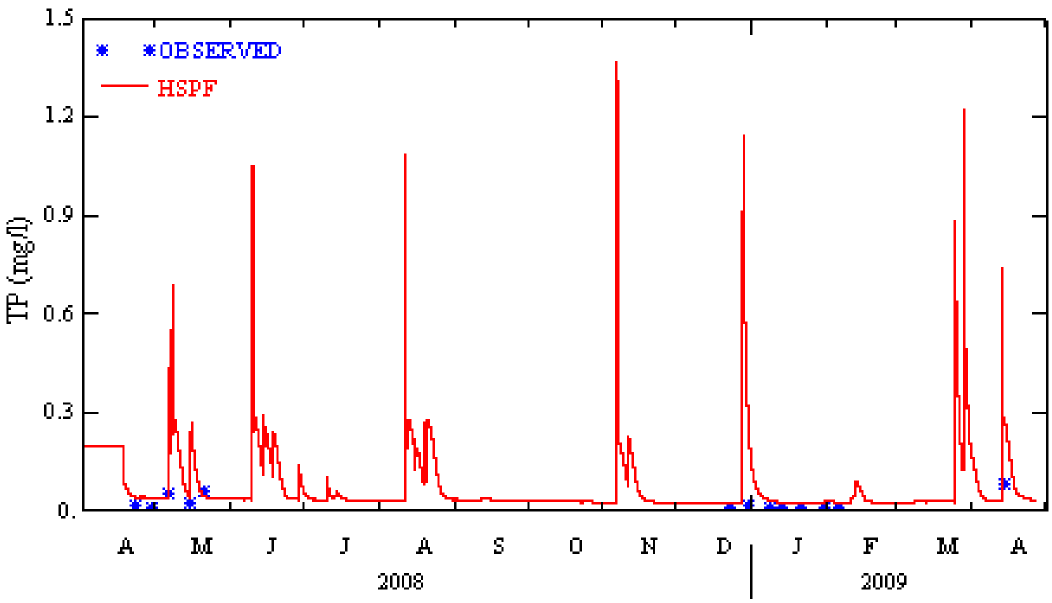


Figure A-45 Comparison of observed and simulated stream TP concentrations at Hog station

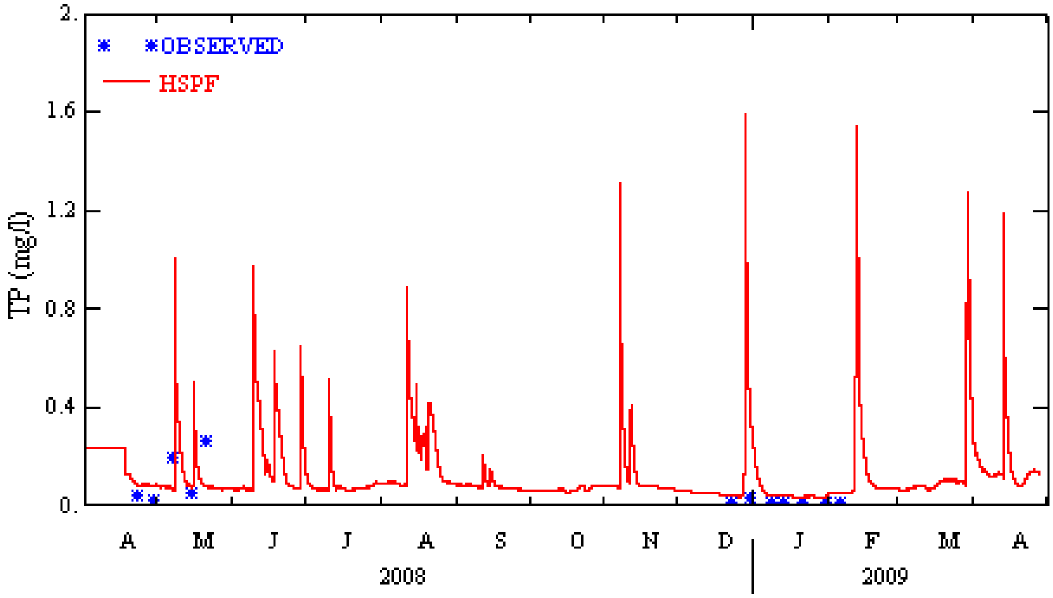
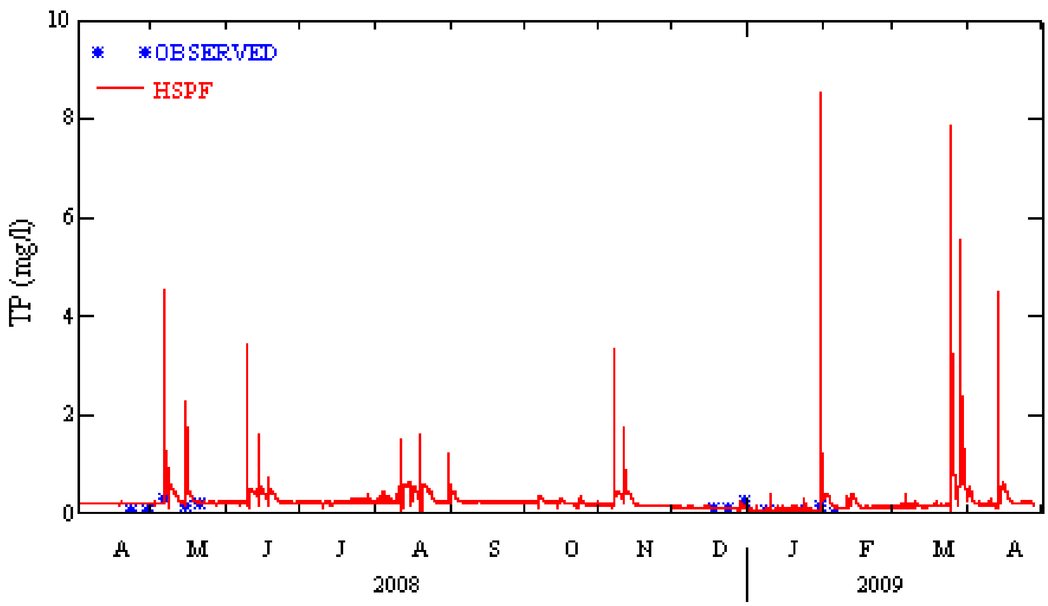


Figure A-46 Comparison of observed and simulated stream TP concentrations at L17 station



A.5 References

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Duda, Paul., J. Kittle, Jr., M. Gray, P. Hummel, R. Dusenbury. An Interactive WindowsInterface to HSPF (WinHSPF). 2001 http://www.epa.gov/waterscience/basins/bsnsdocs.html

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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.

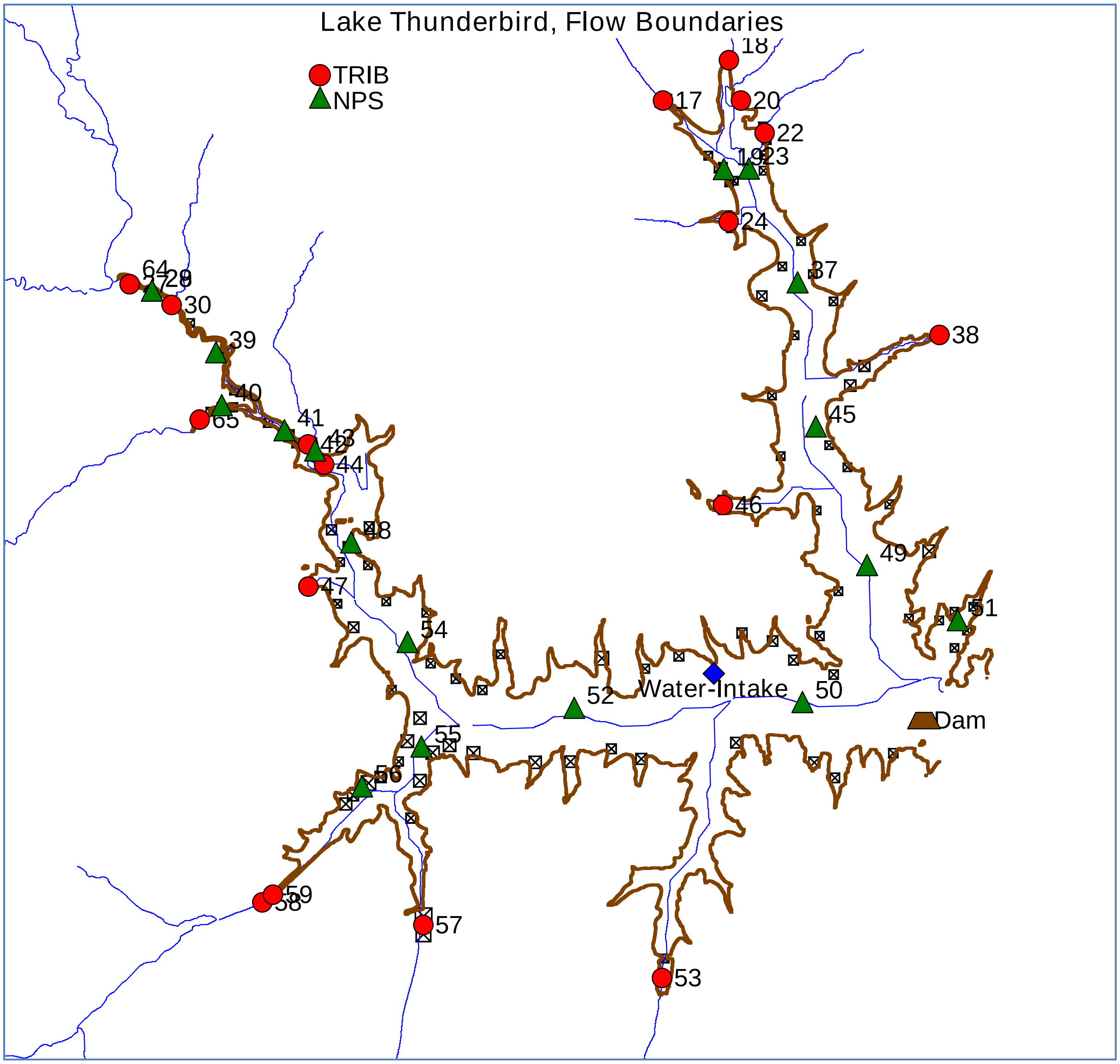
B.2.2 Data Sources - See section 4.2 of the main TMDL report.

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		
Organic-Carbon	C/DW	TOC, POC, DOC	mg C/L
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.

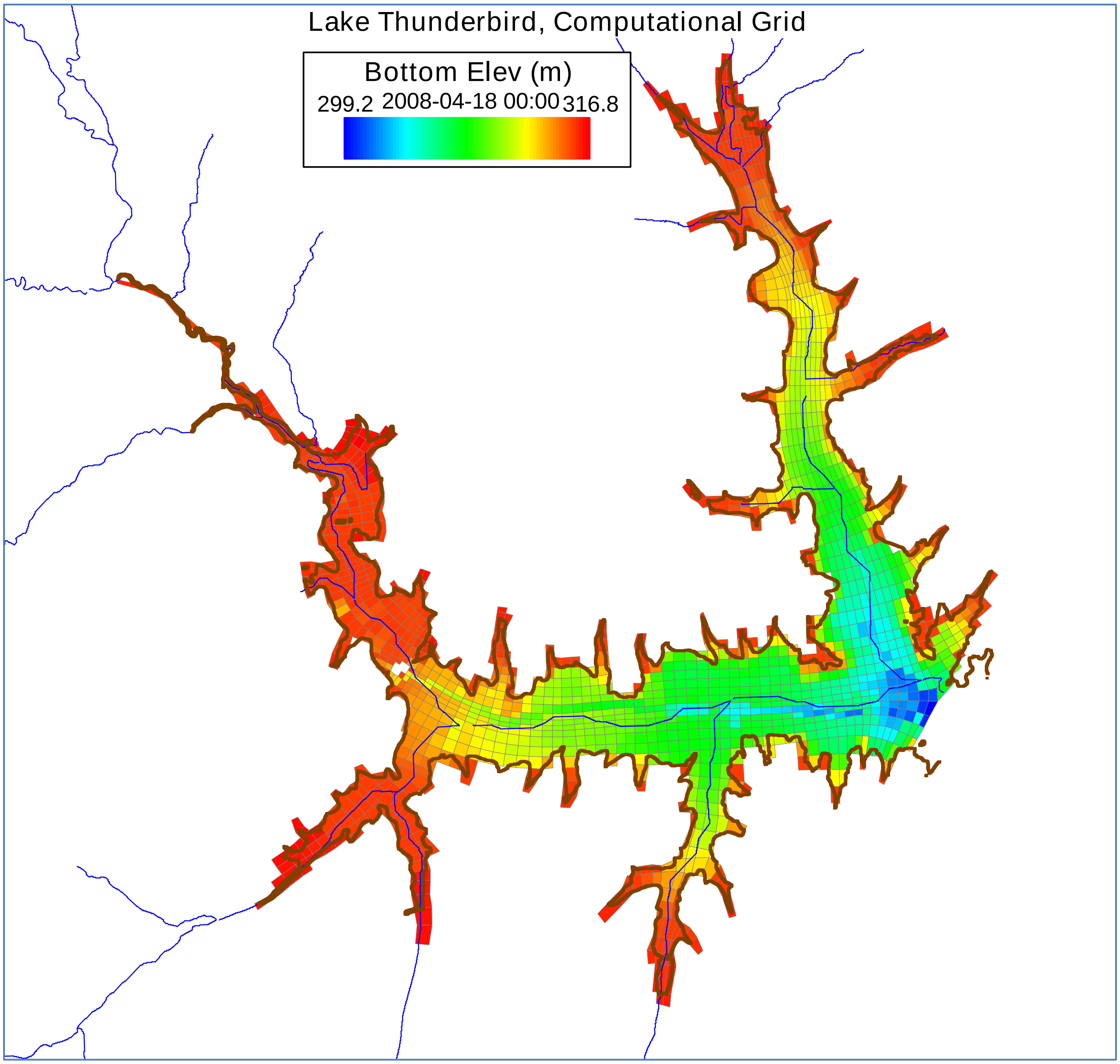
Meteorological Forcing: The EFDC model requires time series data to describe the effect of meteorological forcing and winds on lake circulation processes. Wind speed/direction and meteorological data was obtained from the Oklahoma MESONET database at Station NRMN. Meteorological data needed for the model 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.

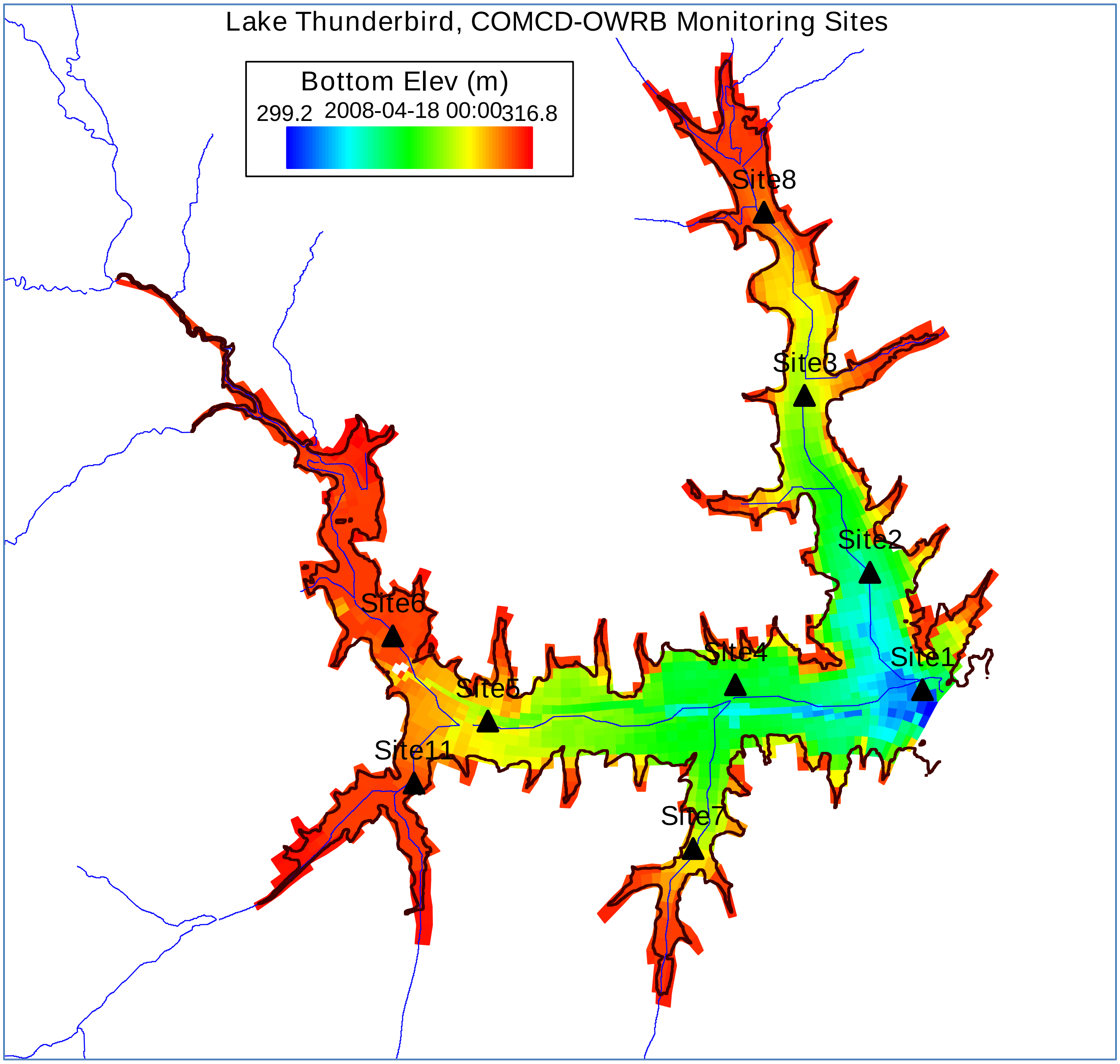
B.3.1 Observed Data

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



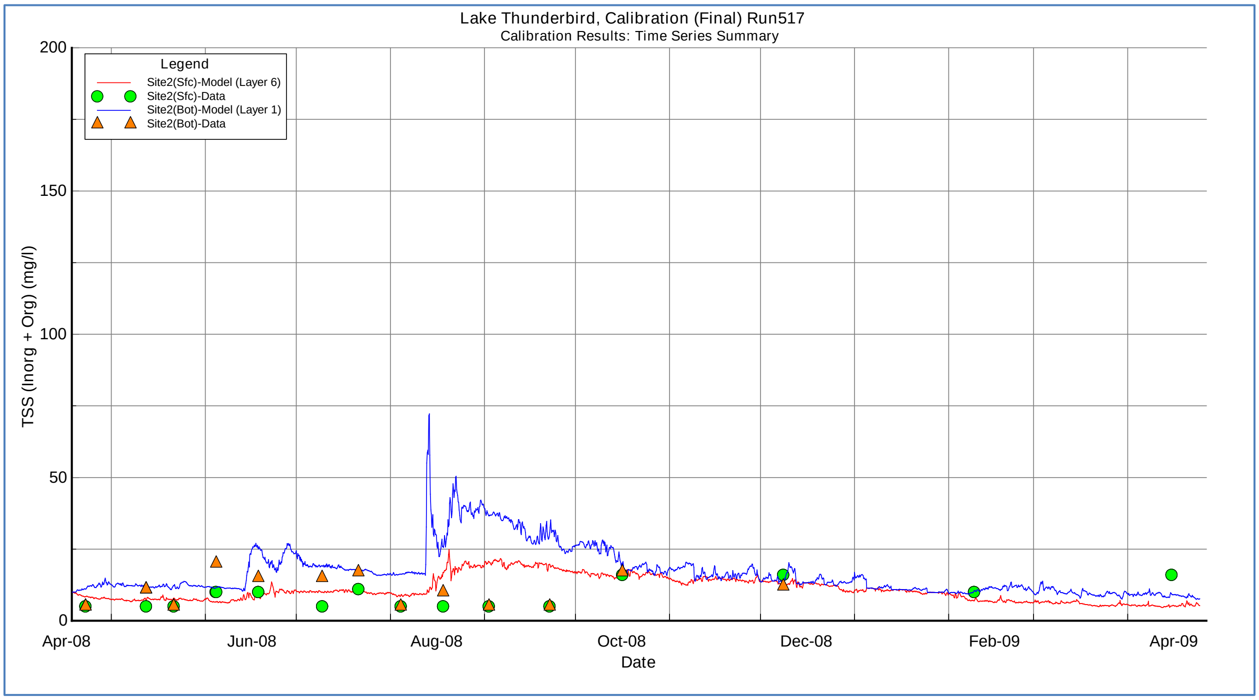
B.3.2 Model Calibration

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

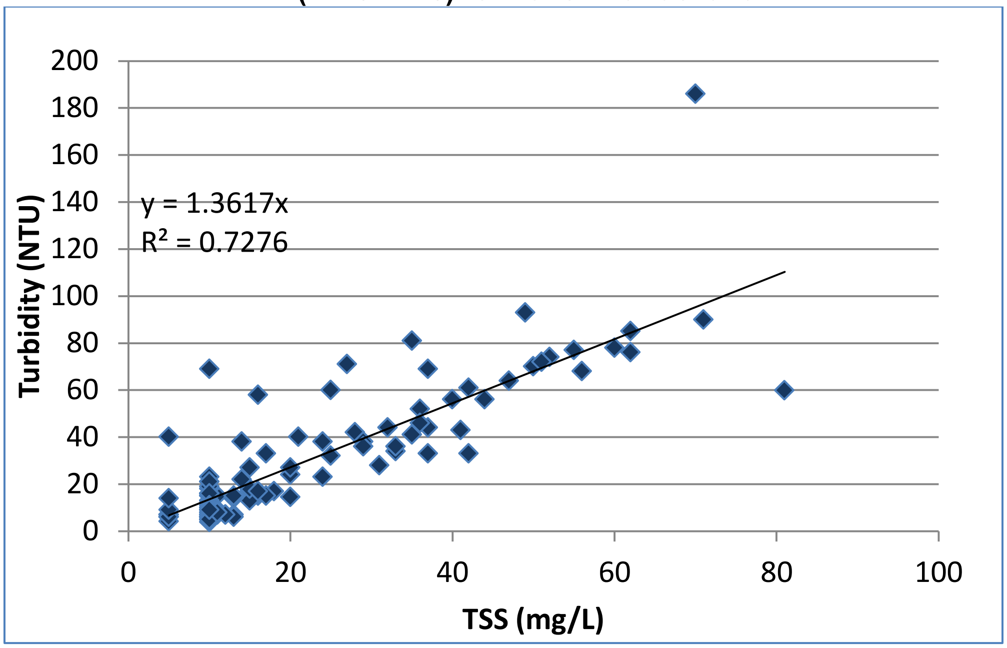
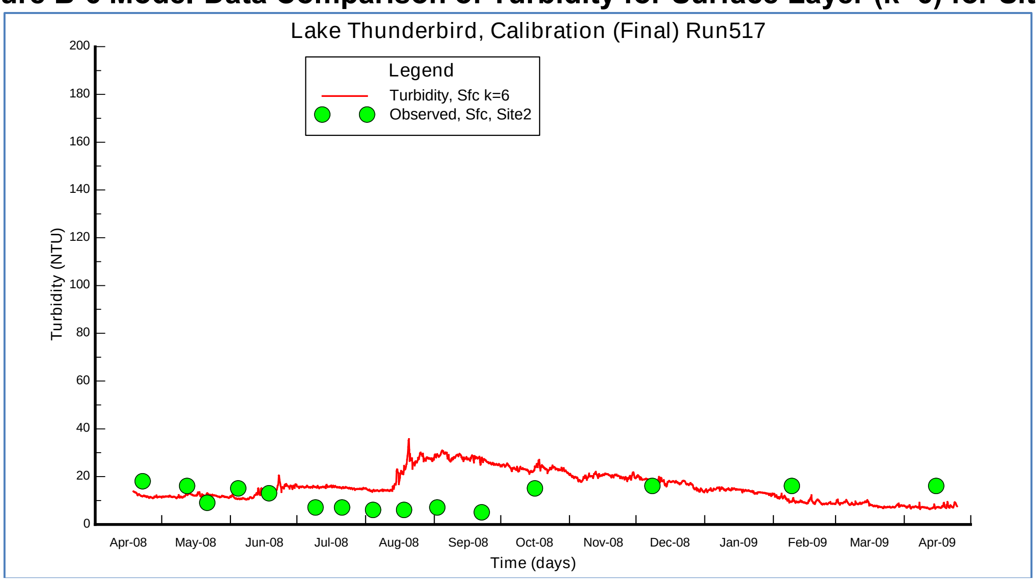
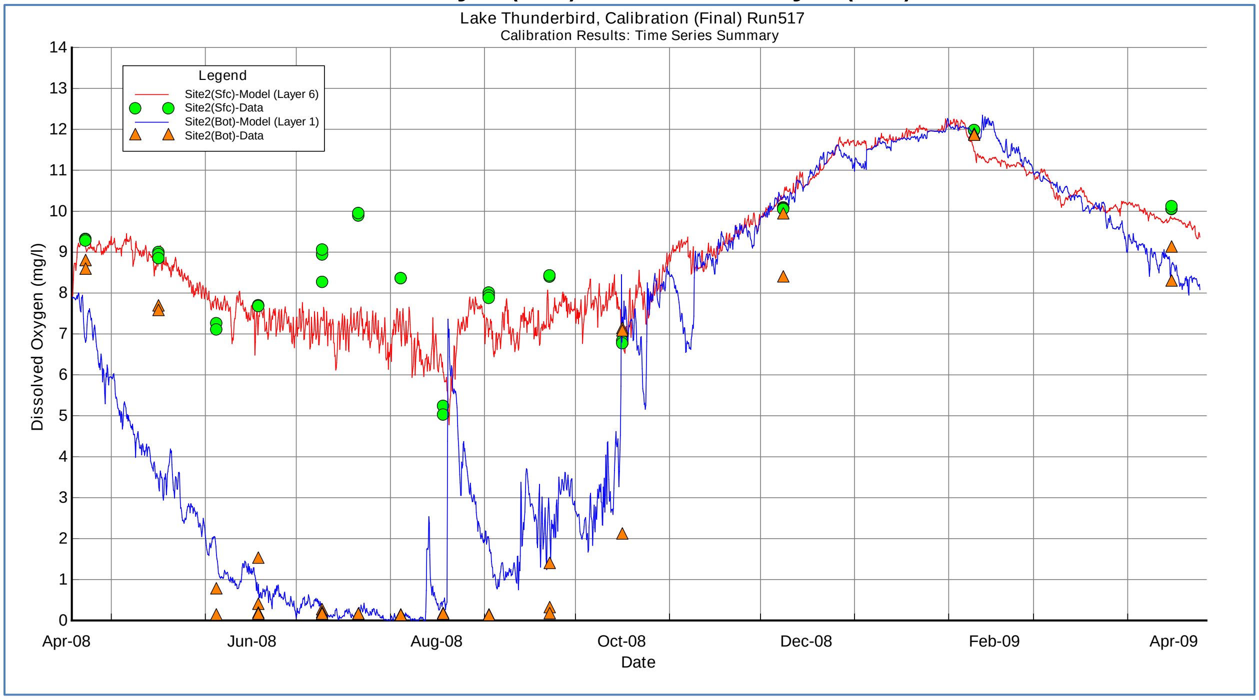


Figure B-6 Model-Data Comparison of Turbidity for Surface Layer (k=6) for Site 2



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%

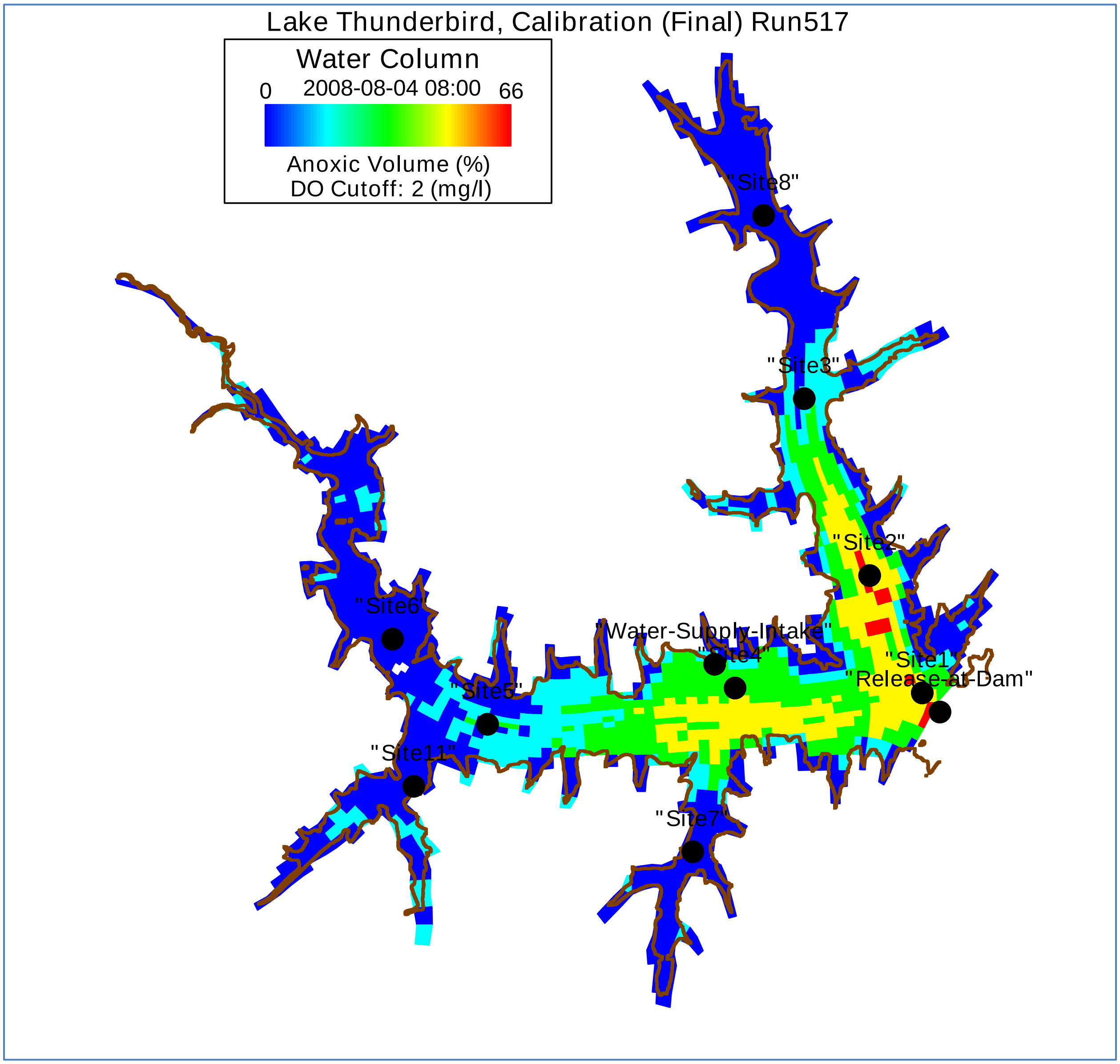


Figure B-9 Time series of anoxic volume of whole lake for model calibration. Percentage of anoxic volume is based on aggregation of all grid cells in the lake.

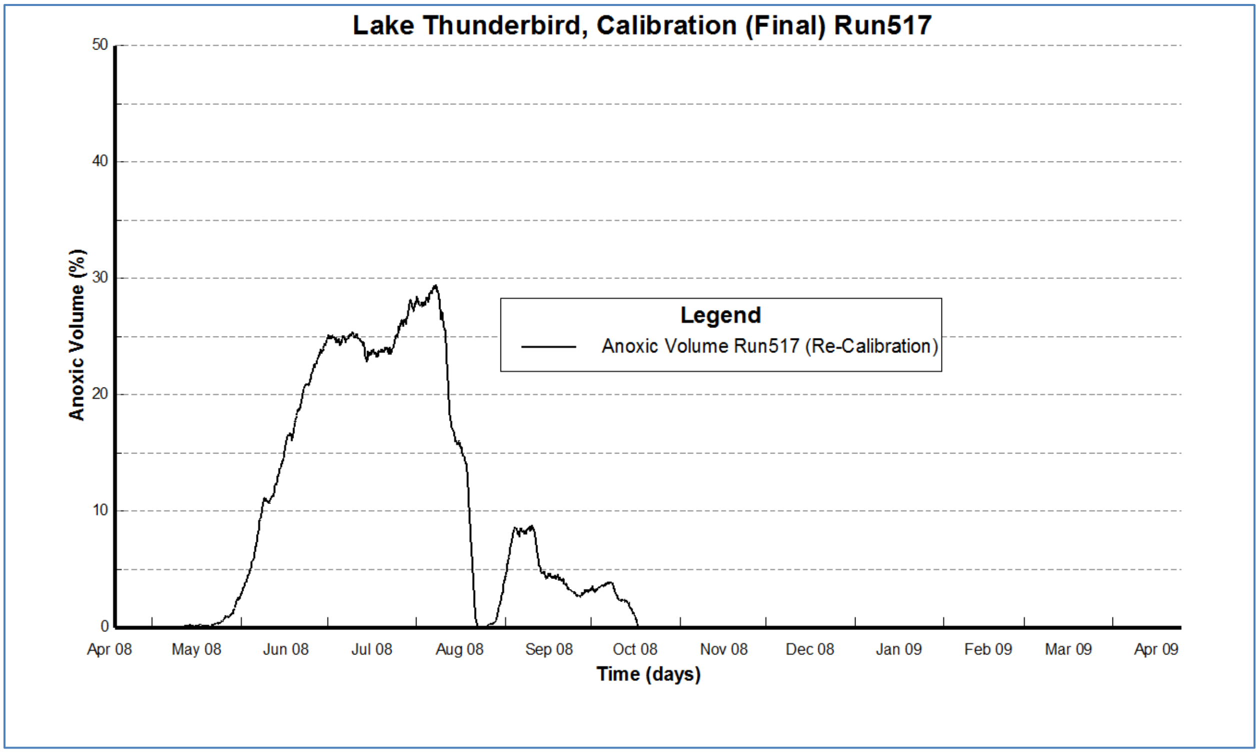
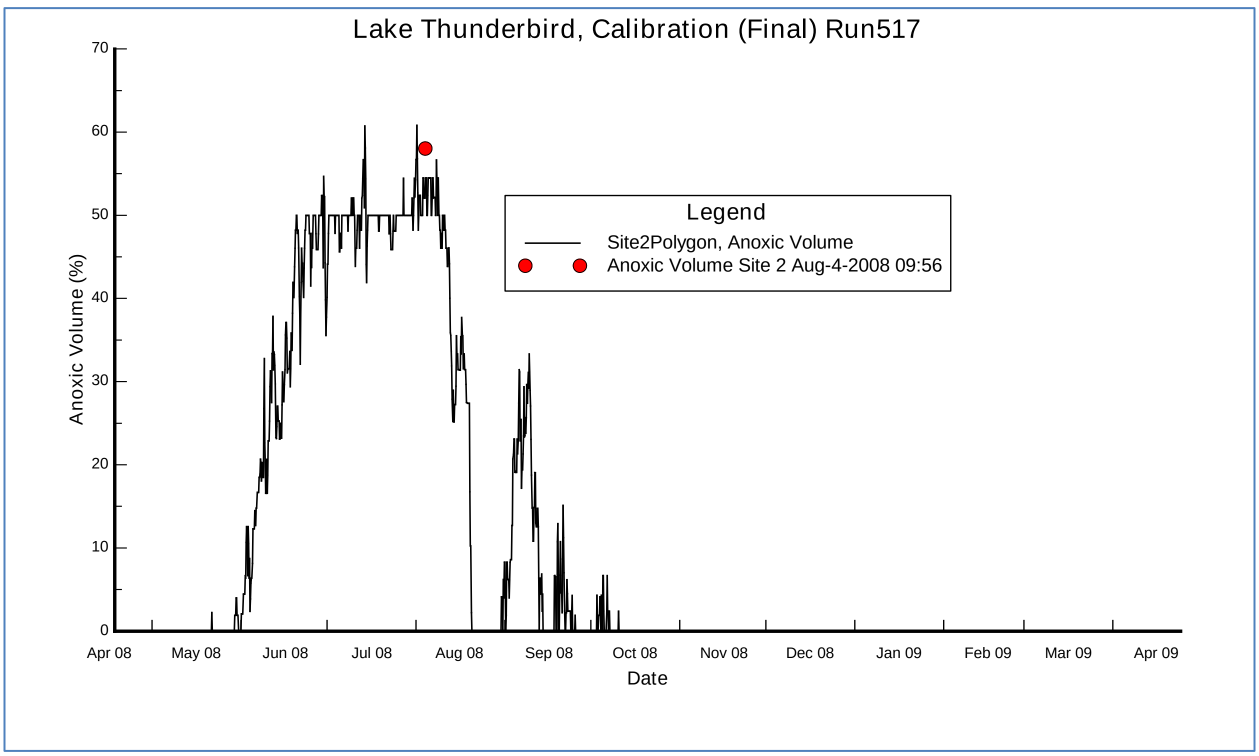


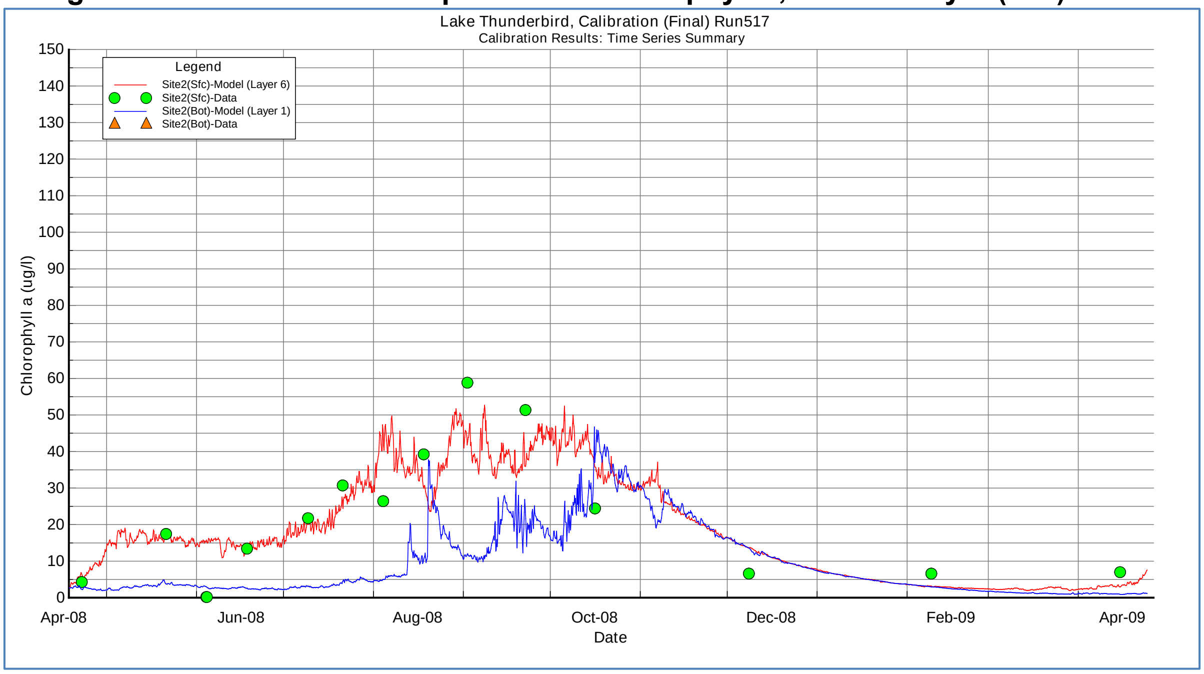
Figure B-10 Time series of anoxic volume of Site 2 for model calibration.

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.

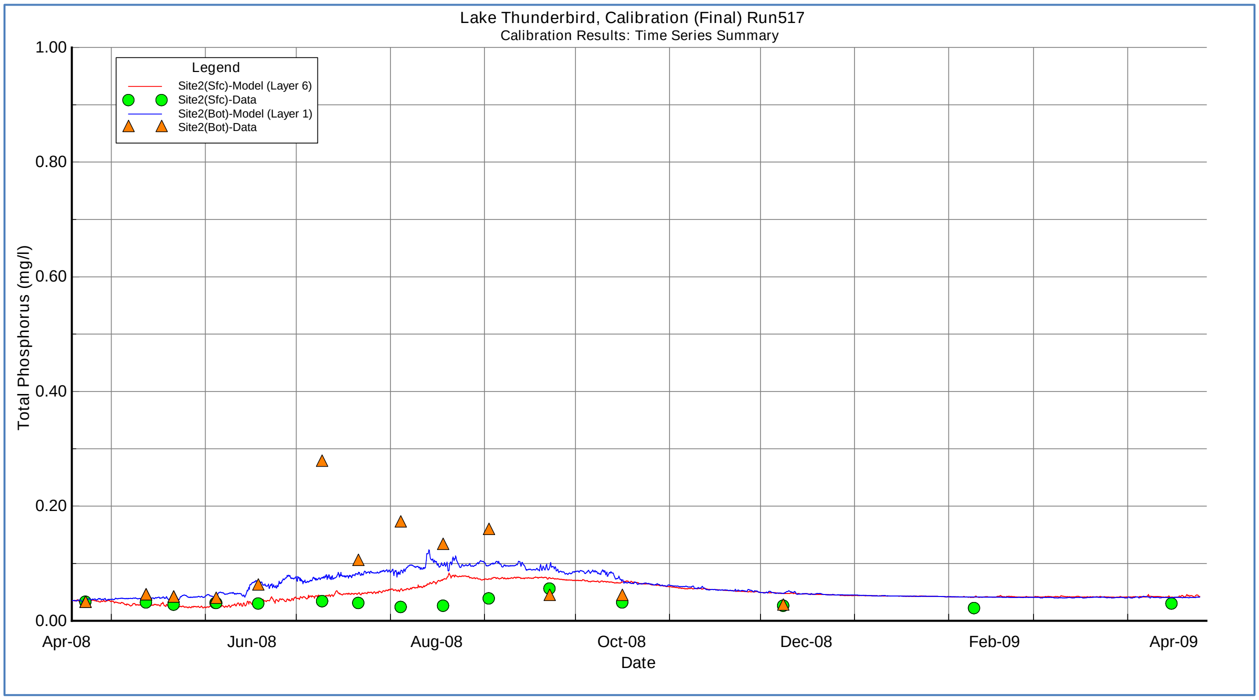
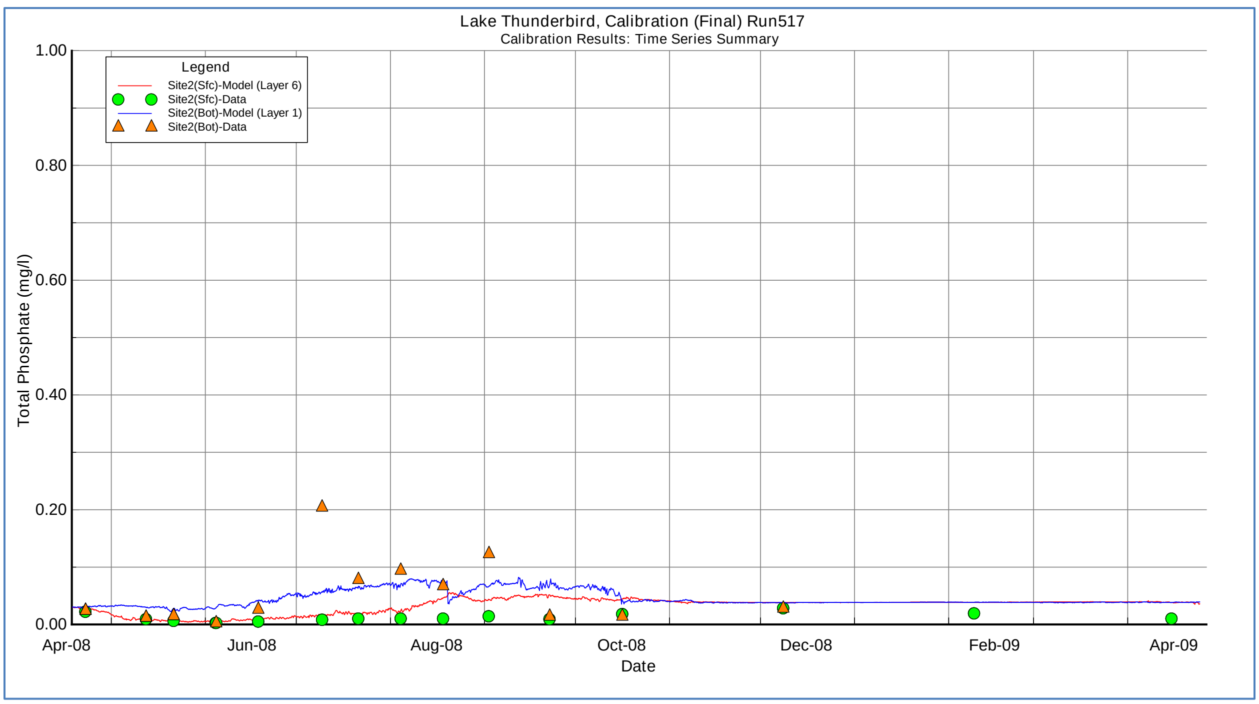


Figure B-13 Model-Data Comparison of Total-Phosphate-P (TPO4) for Surface Layer (k=6) and Bottom Layer (k=1) for Site 2.



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.

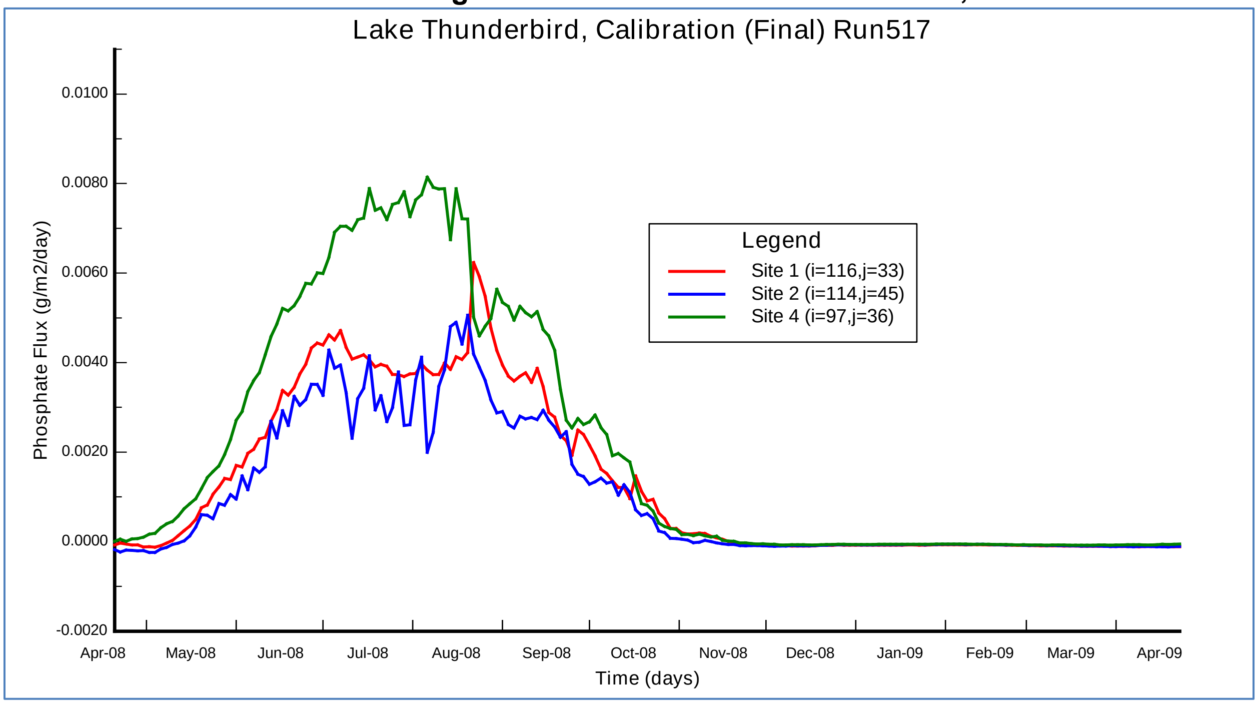
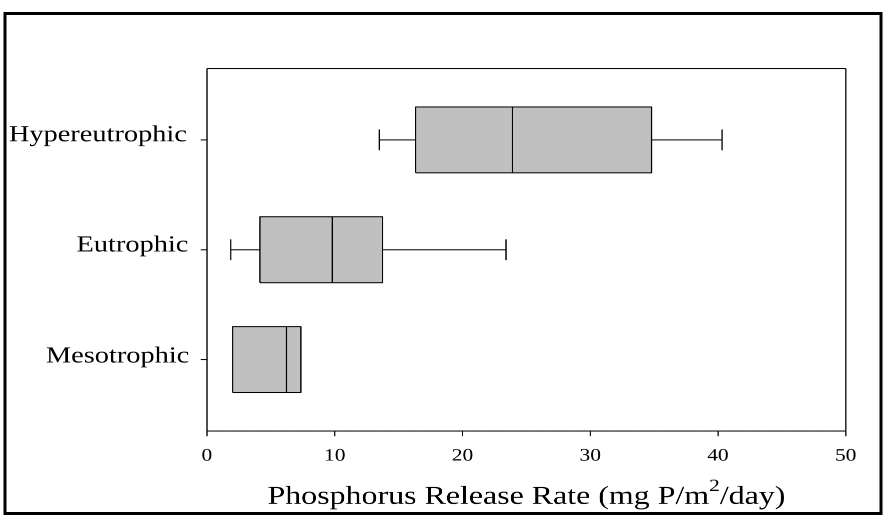


Figure B-15 Comparison of anoxic release rates of phosphorus (as mg P/m^2-day).

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)

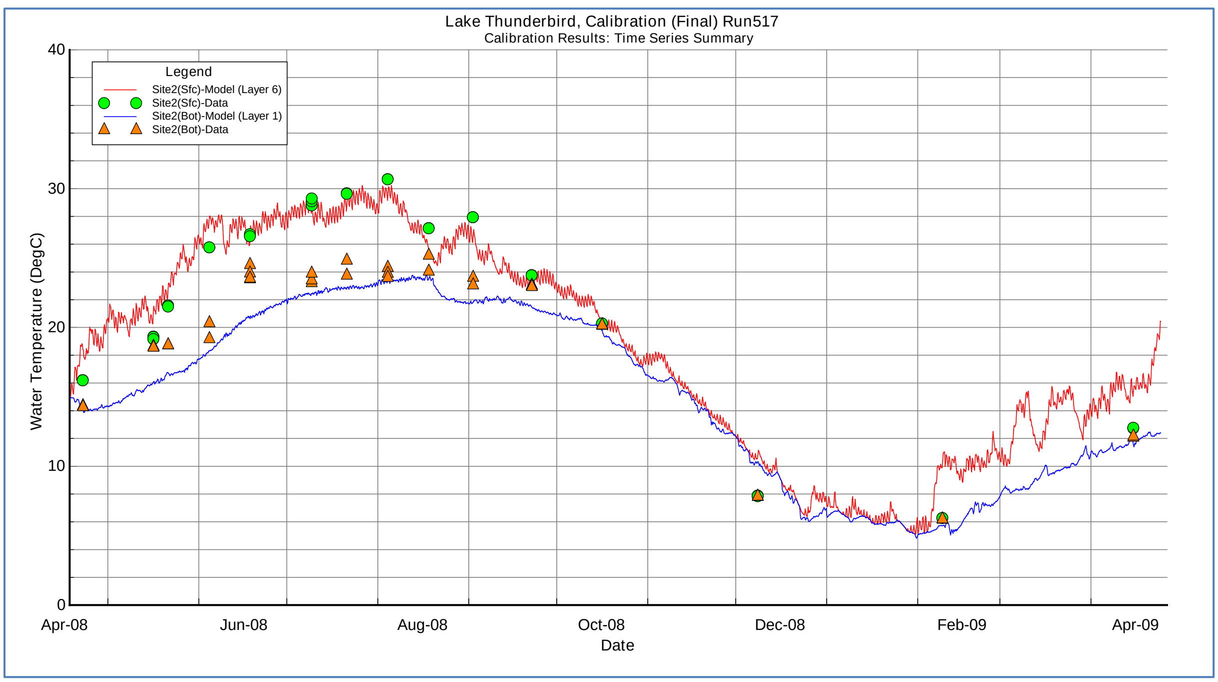


Figure B-17 TS_Cal004_Temp_Site3 (Surface & Bottom)

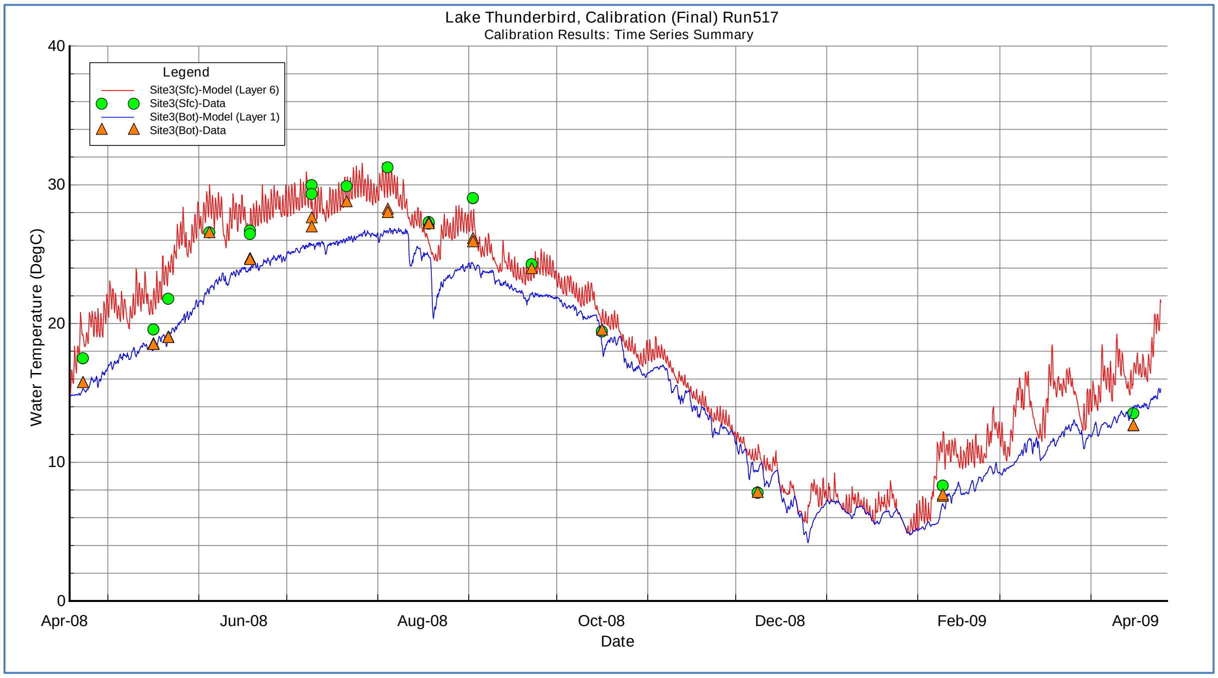


Figure B-18 TS_Cal007_Temp_Site6 (Surface & Bottom)

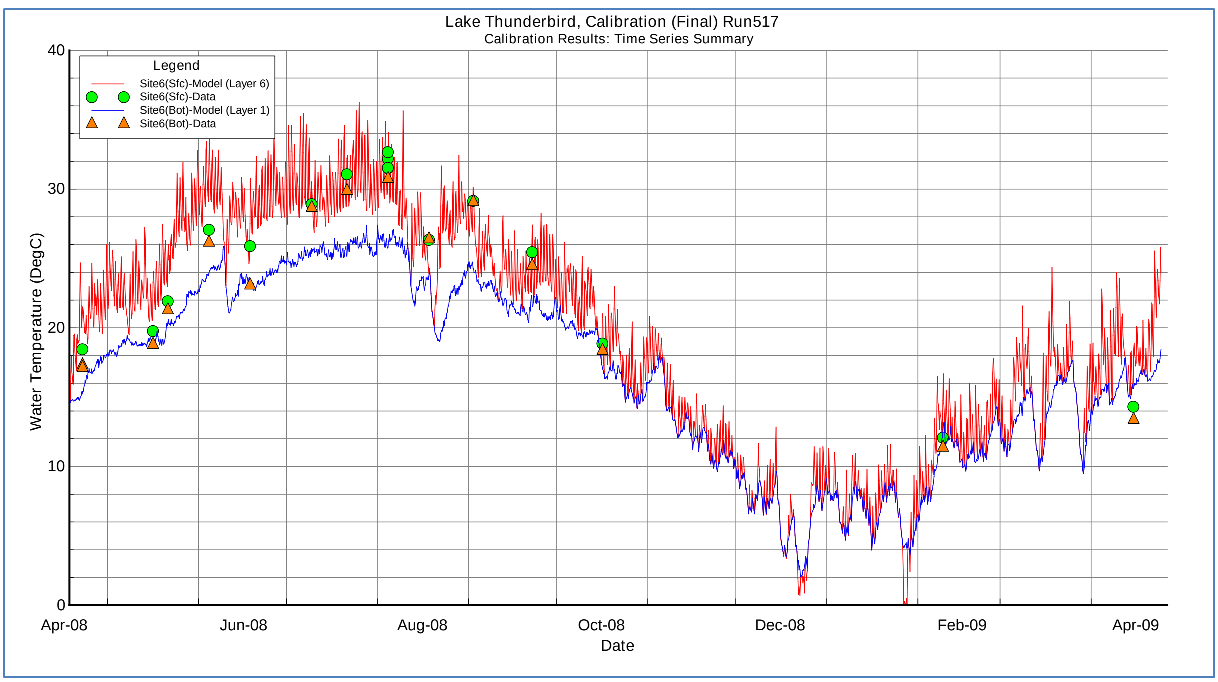


Figure B-19 TS_Cal011_TSS(io)_Site2 (Surface & Bottom)

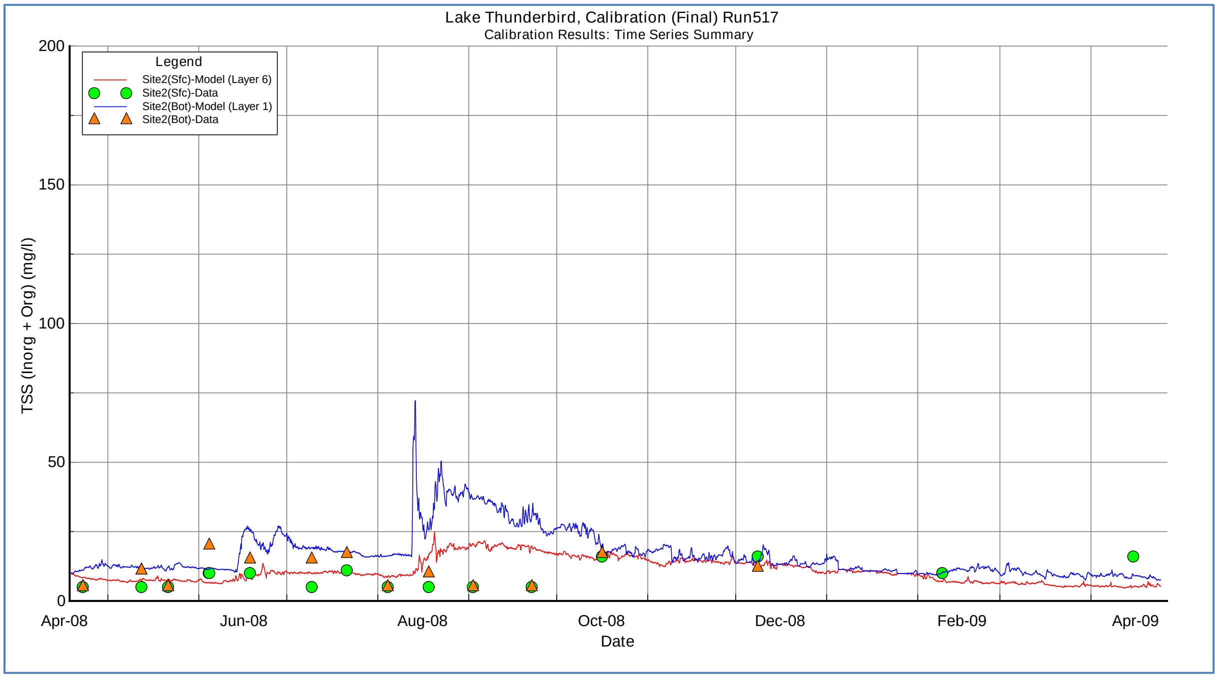


Figure B-20 TS_Cal015_TSS(io)_Site6 (Surface)

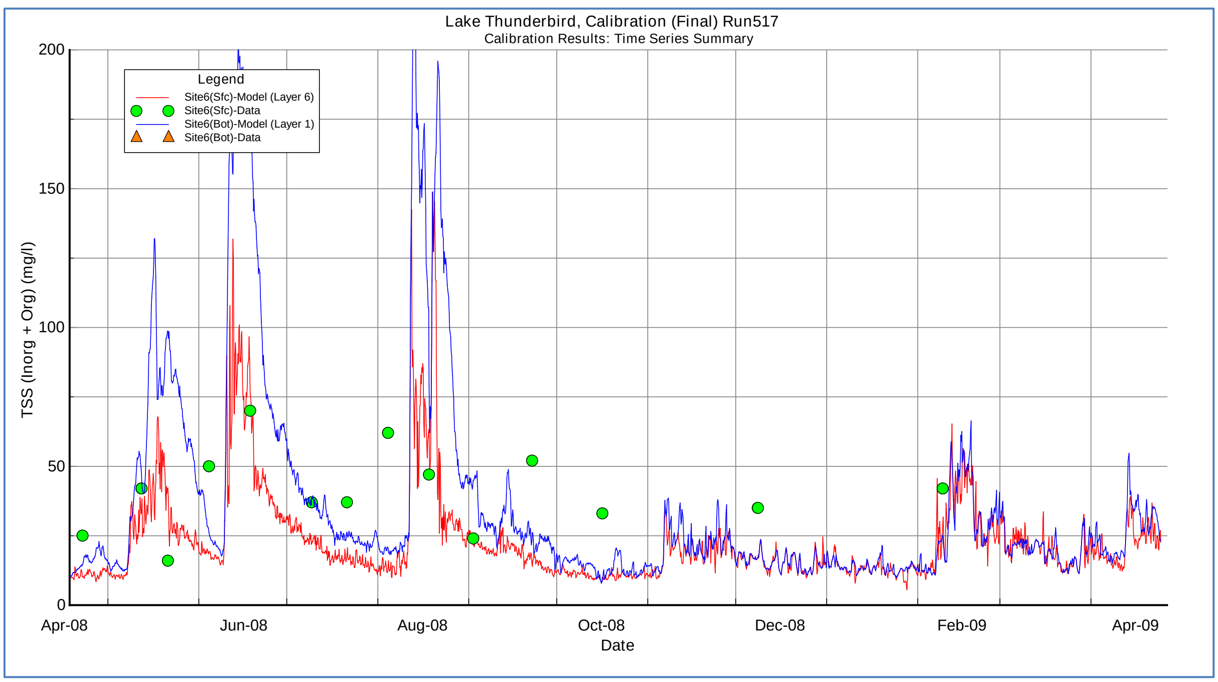


Figure B-21 TS_Cal019_DO_Site2 (Surface & Bottom)

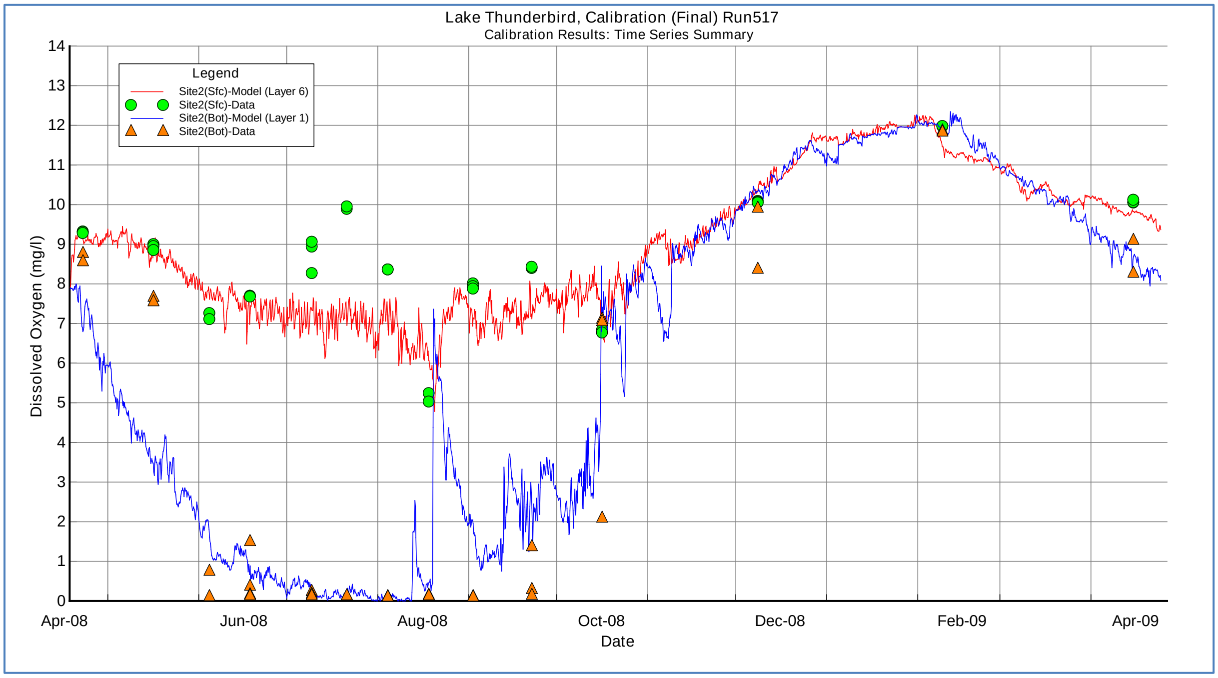


Figure B-22 TS_Cal020_DO_Site3 (Surface & Bottom)

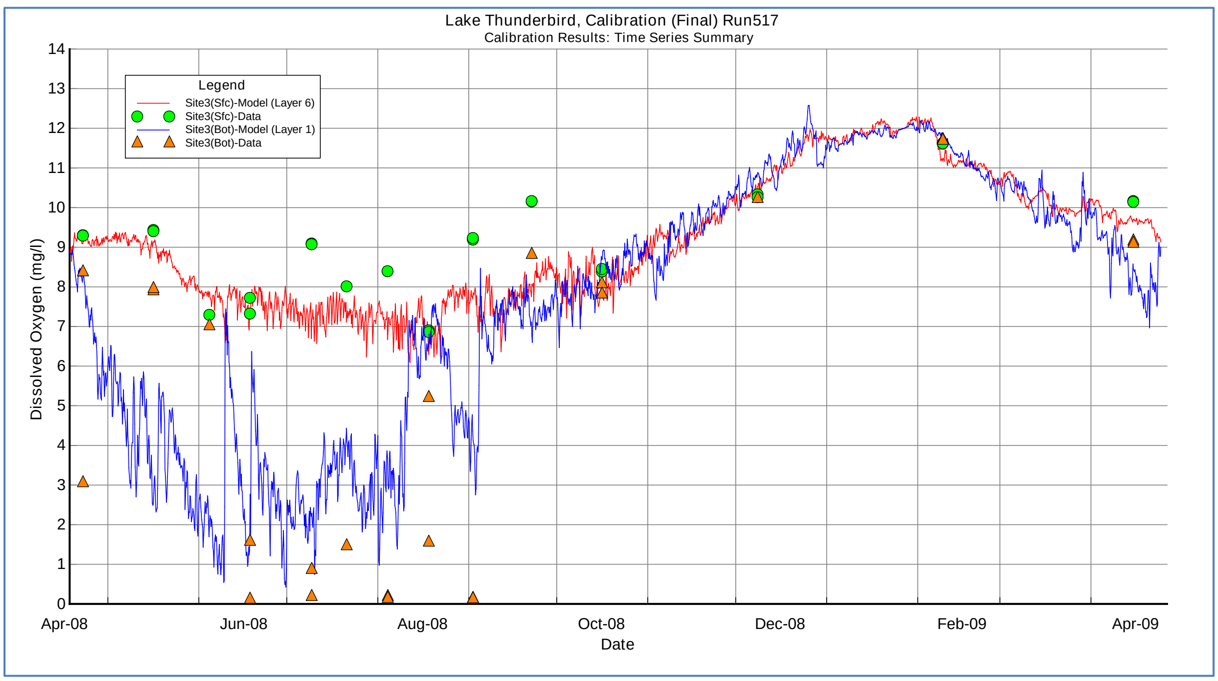


Figure B-23 TS_Cal023_DO_Site6 (Surface & Bottom)

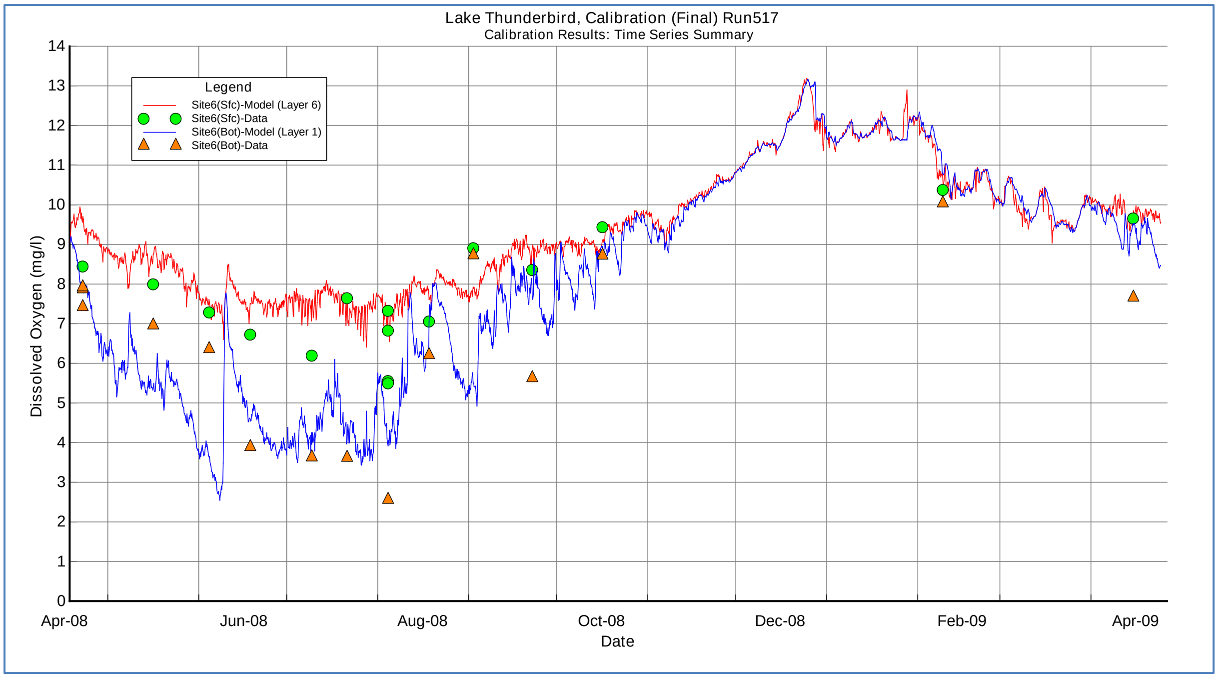


Figure B-24 TS_Cal027_Chl-a_Site2 (Surface)

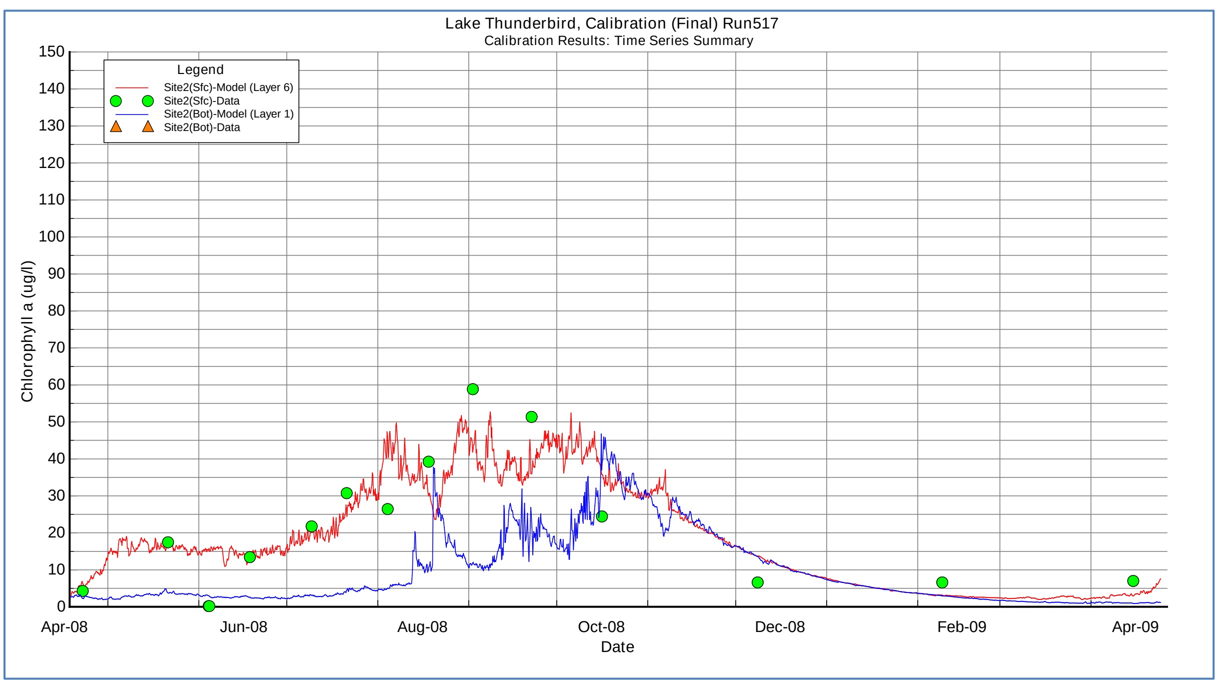


Figure B-25 TS_Cal031_Chl-a_Site6 (Surface)

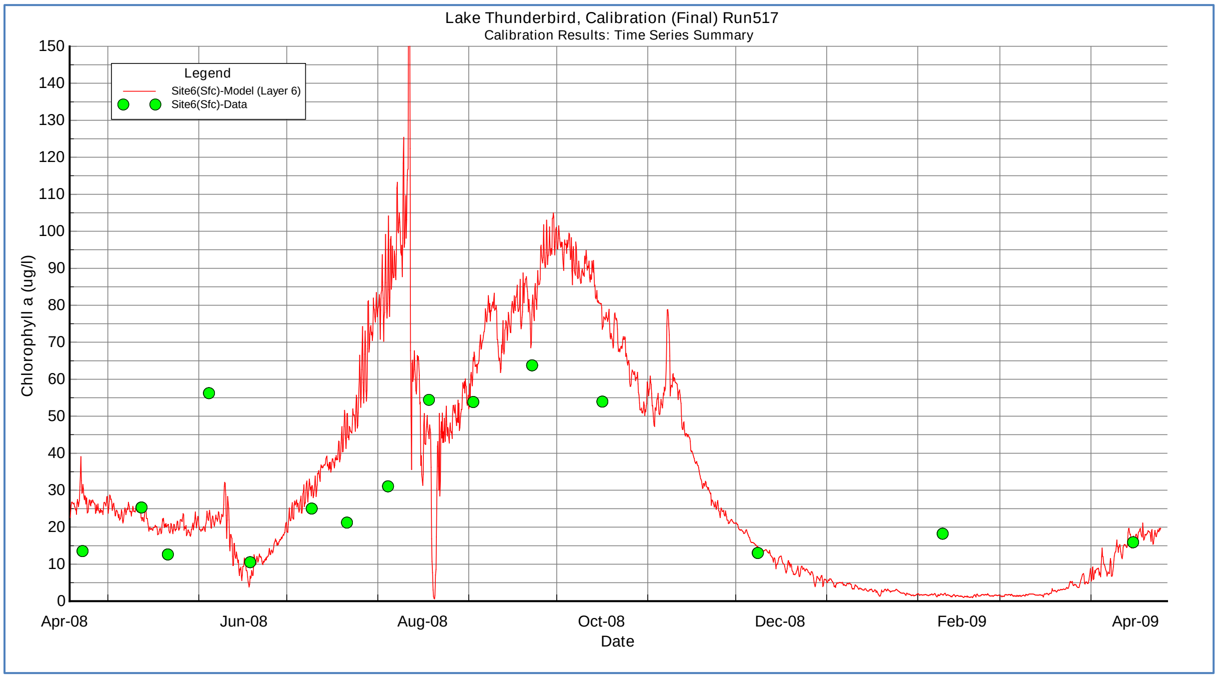


Figure B-26 TS_Cal035_Tot N_Site2 (Surface & Bottom)

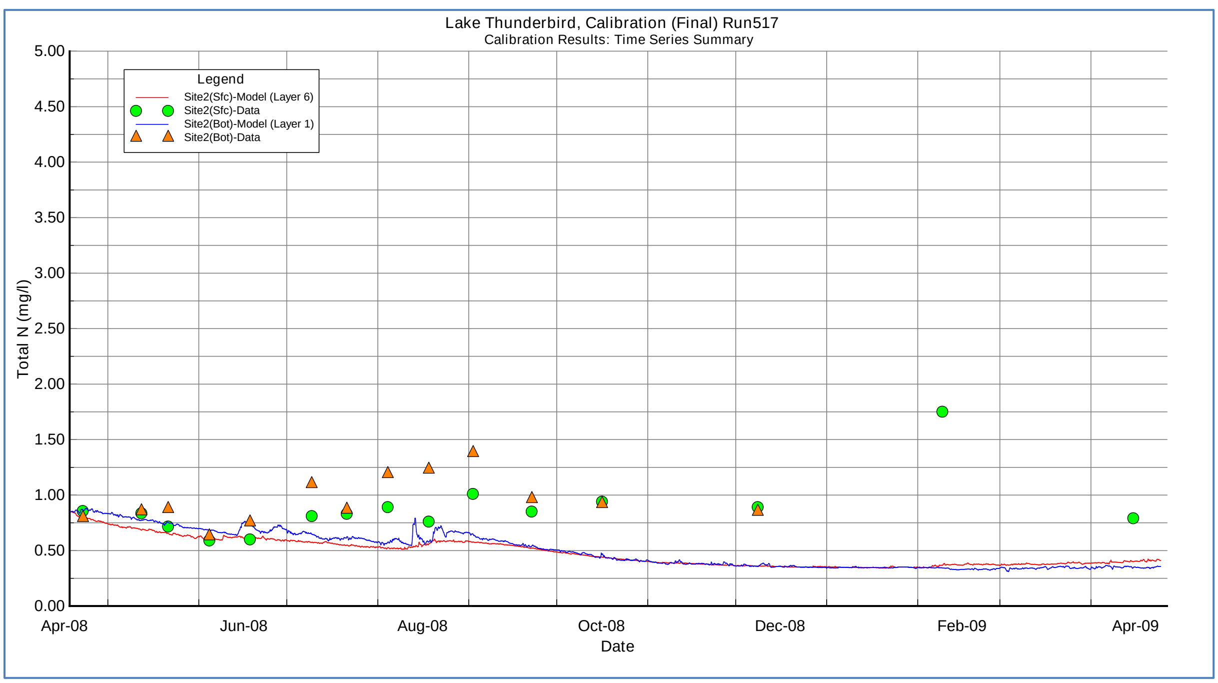


Figure B-27 TS_Cal039_Tot N_Site6 (Surface)

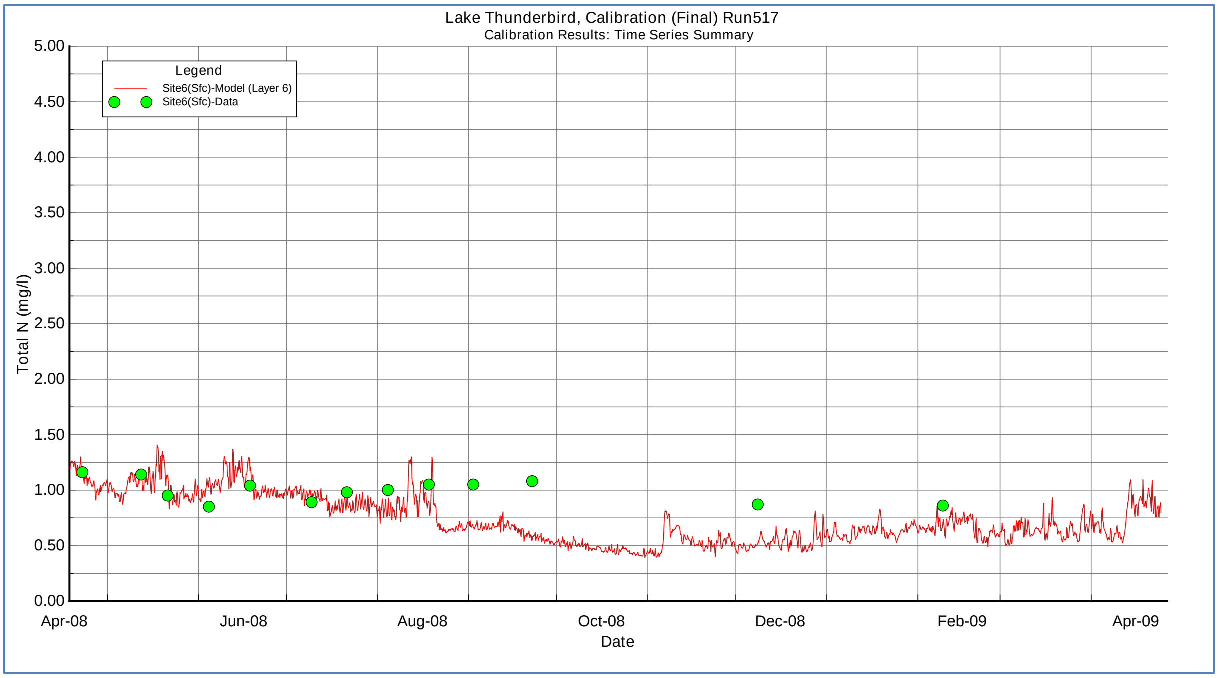


Figure B-28 TS_Cal043_Tot P_Site2 (Surface & Bottom)

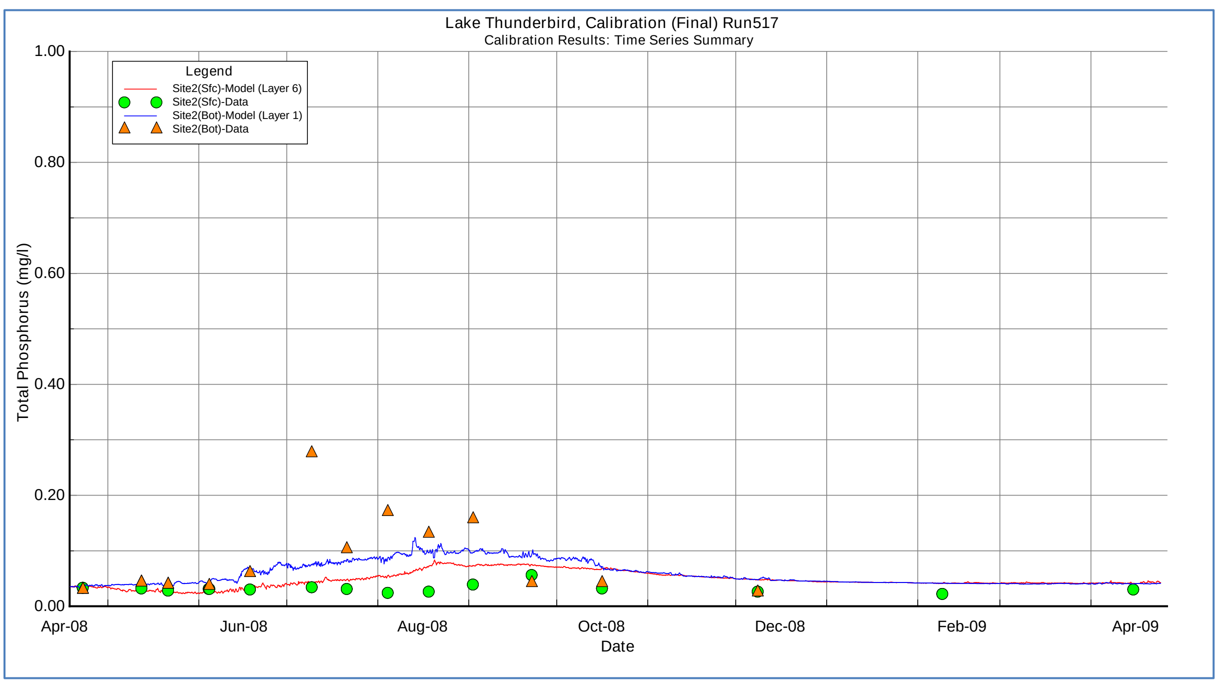


Figure B-29 TS_Cal047_Tot P_Site6 (Surface)

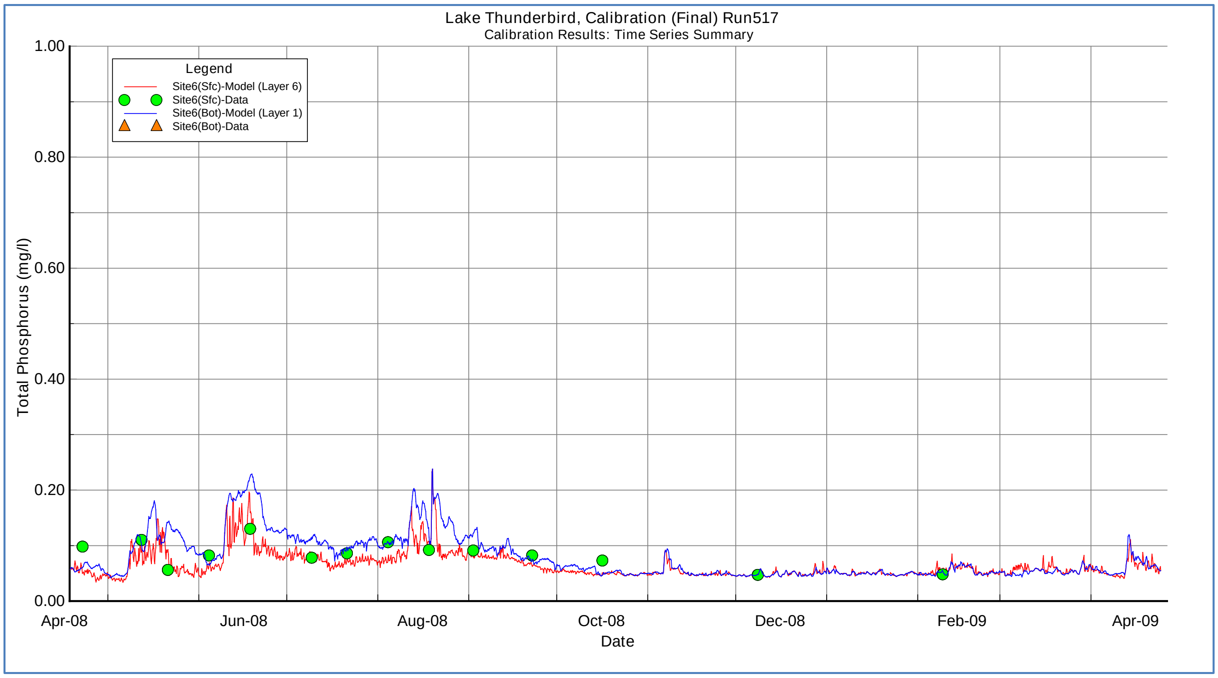


Figure B-30 TS_Cal051_TPO4-P_Site2 (Surface & Bottom)

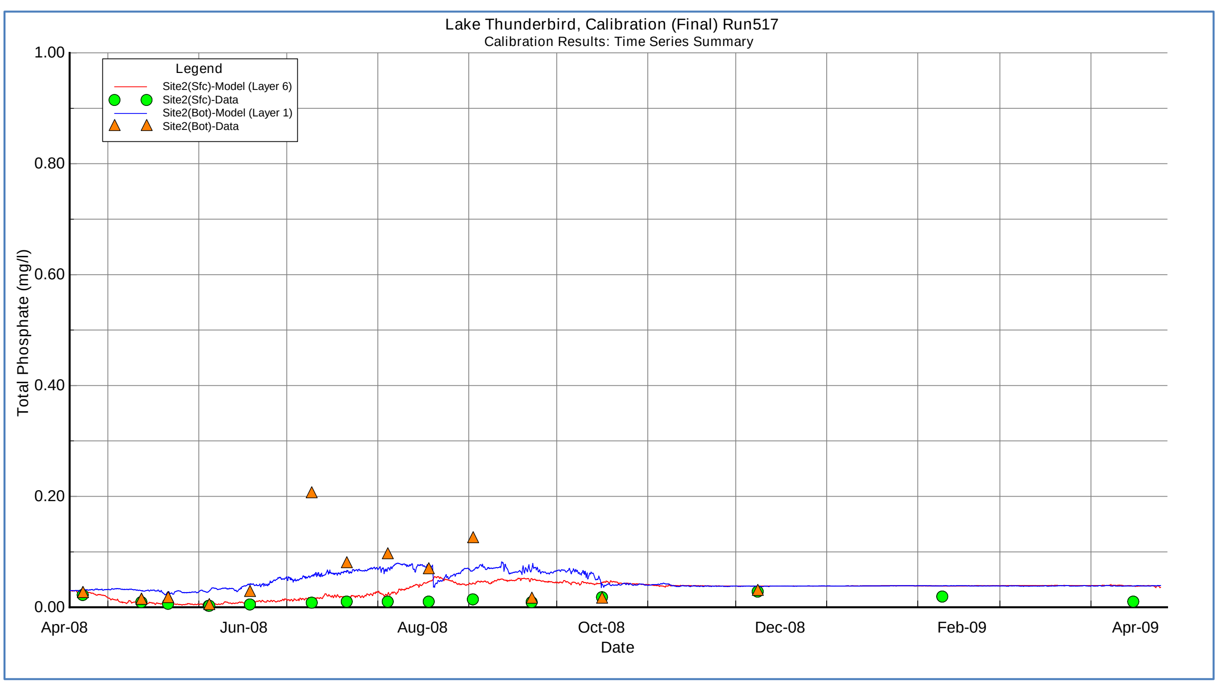


Figure B-31 TS_Cal055_TPO4-P_Site6 (Surface)

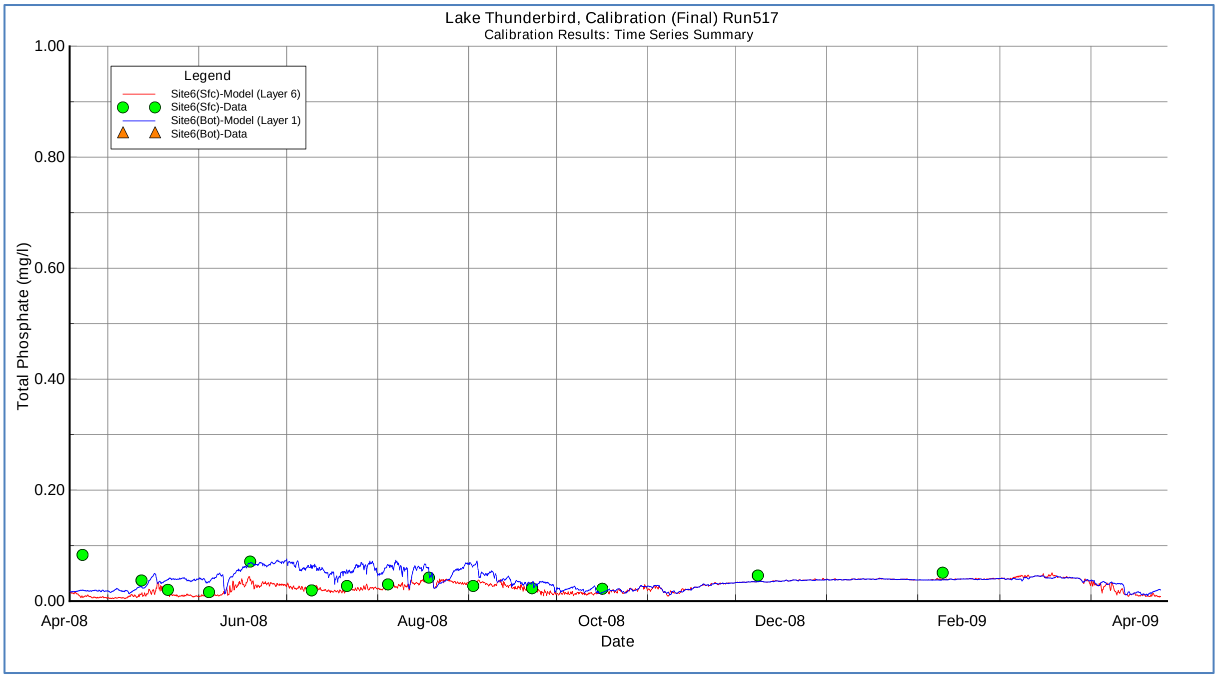


Figure B-32 TS_Cal059_NH4-N_Site2 (Surface & Bottom)

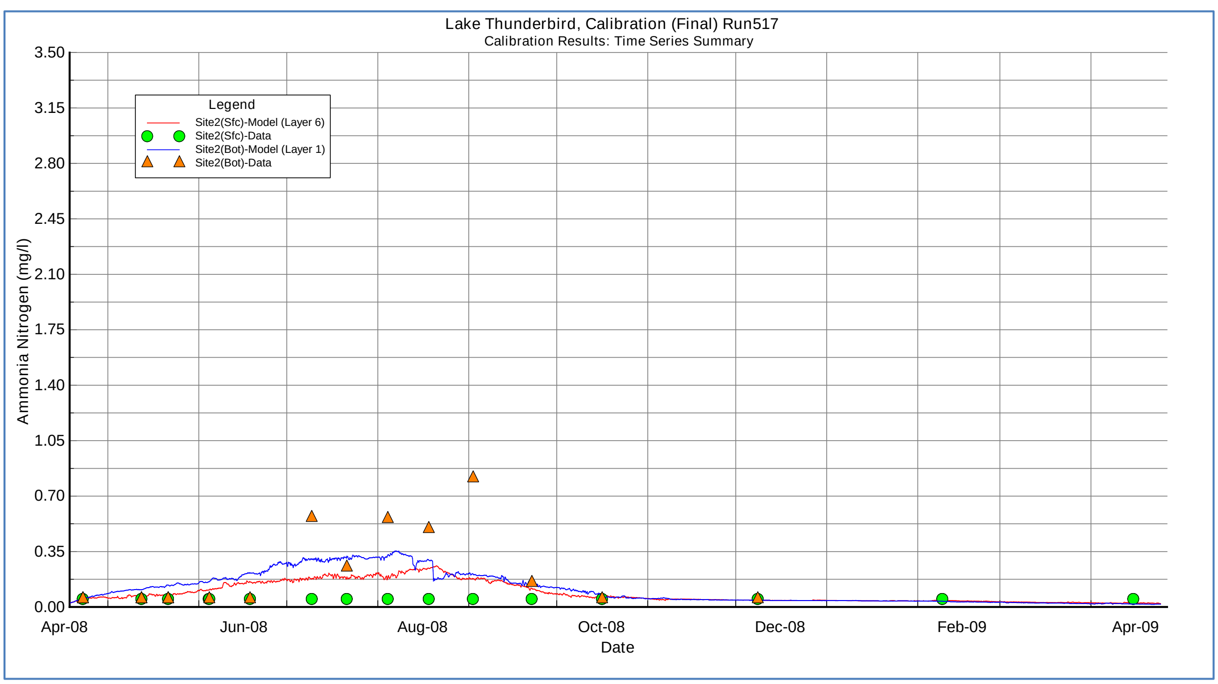


Figure B-33 TS_Cal063_NH4-N_Site6 (Surface)

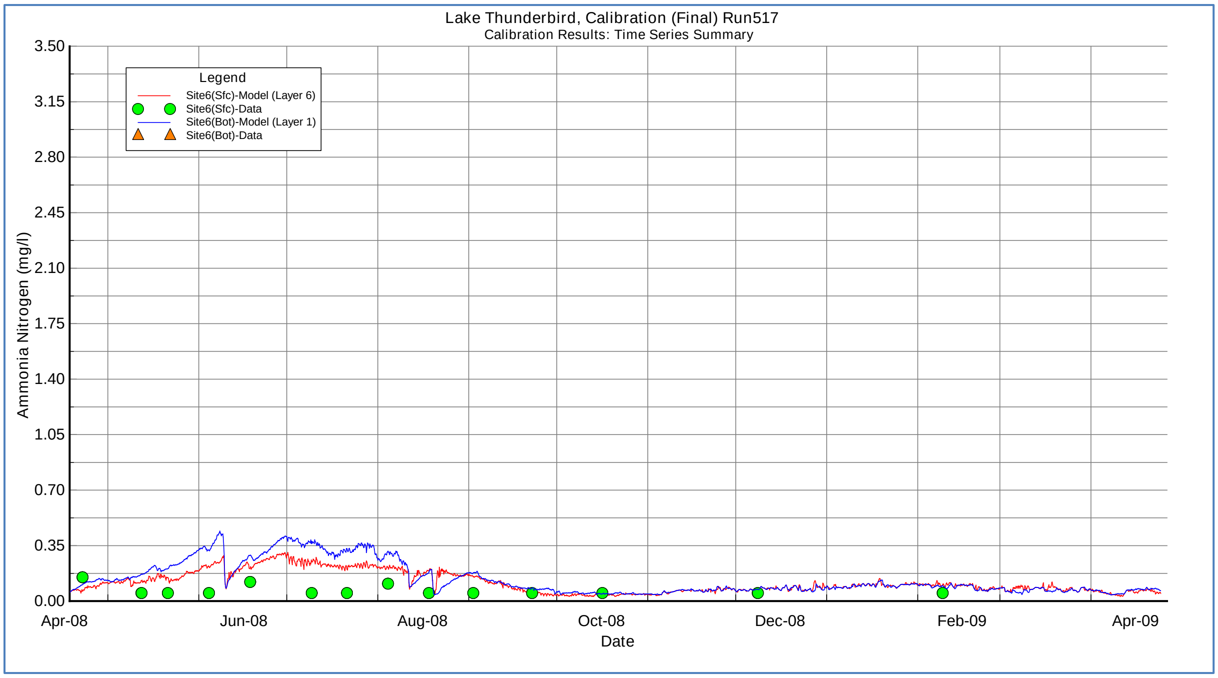


Figure B-34 TS_Cal067_NO3-N_Site2 (Surface & Bottom)

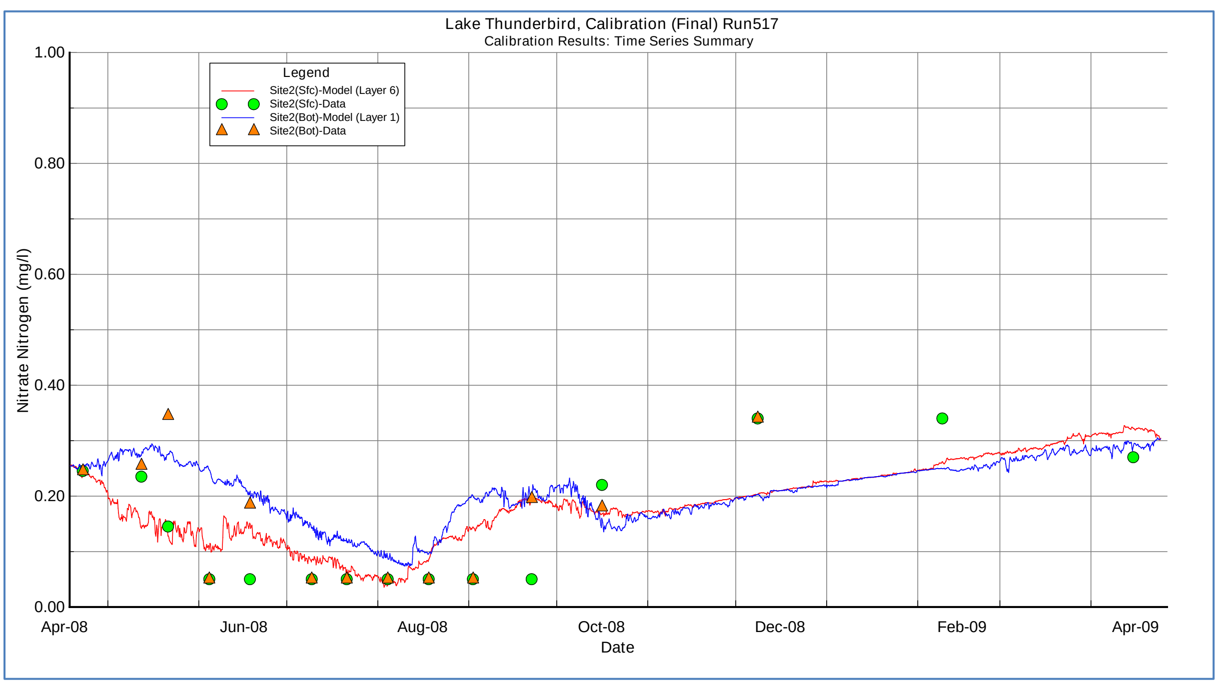
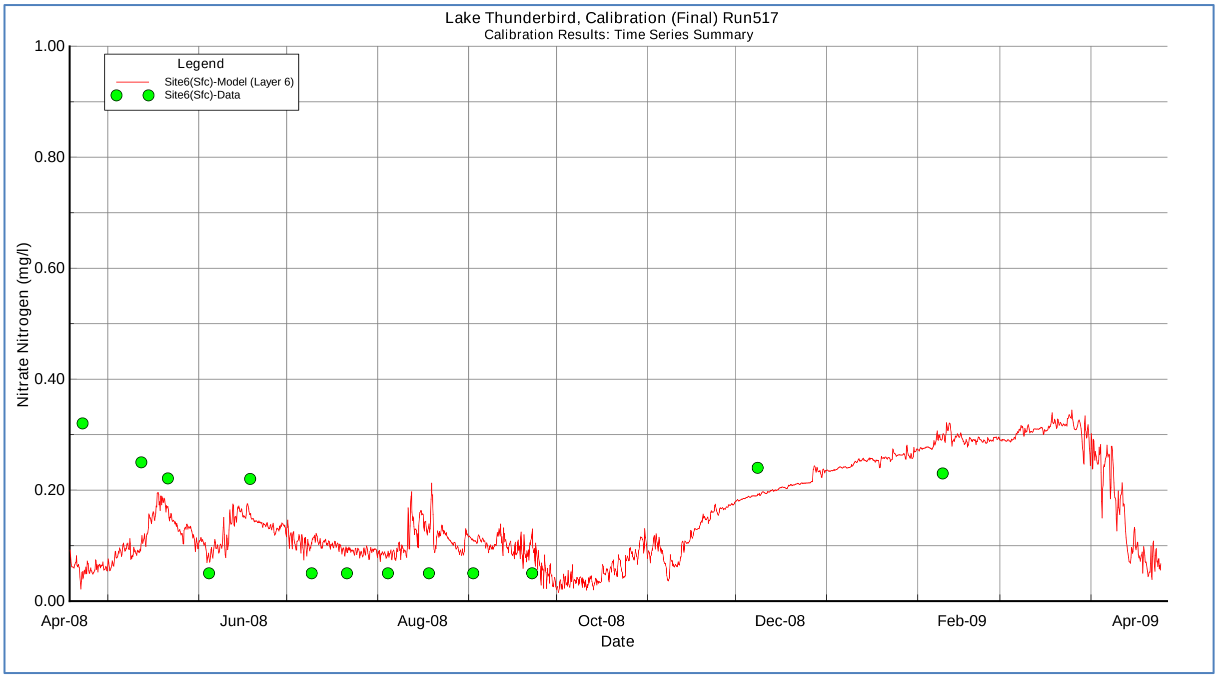


Figure B-35 TS_Cal071_NO3-N_Site6 (Surface)



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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

List of Tables

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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

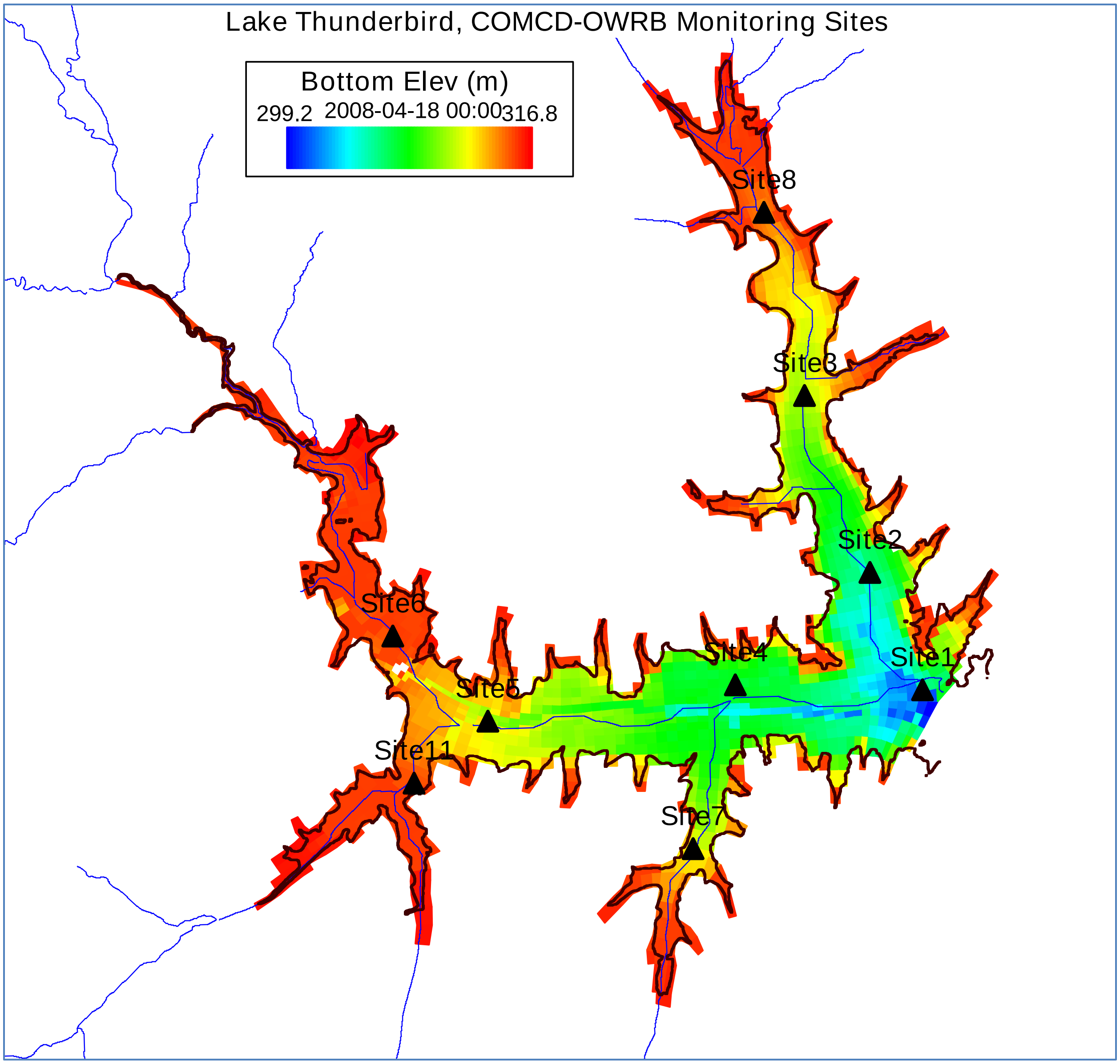

Table D-2 Site 1 HYDROLAB Station Data*

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

* 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	8/24/2009 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 (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	9/22/2008 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 (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
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

* 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	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

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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 (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
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

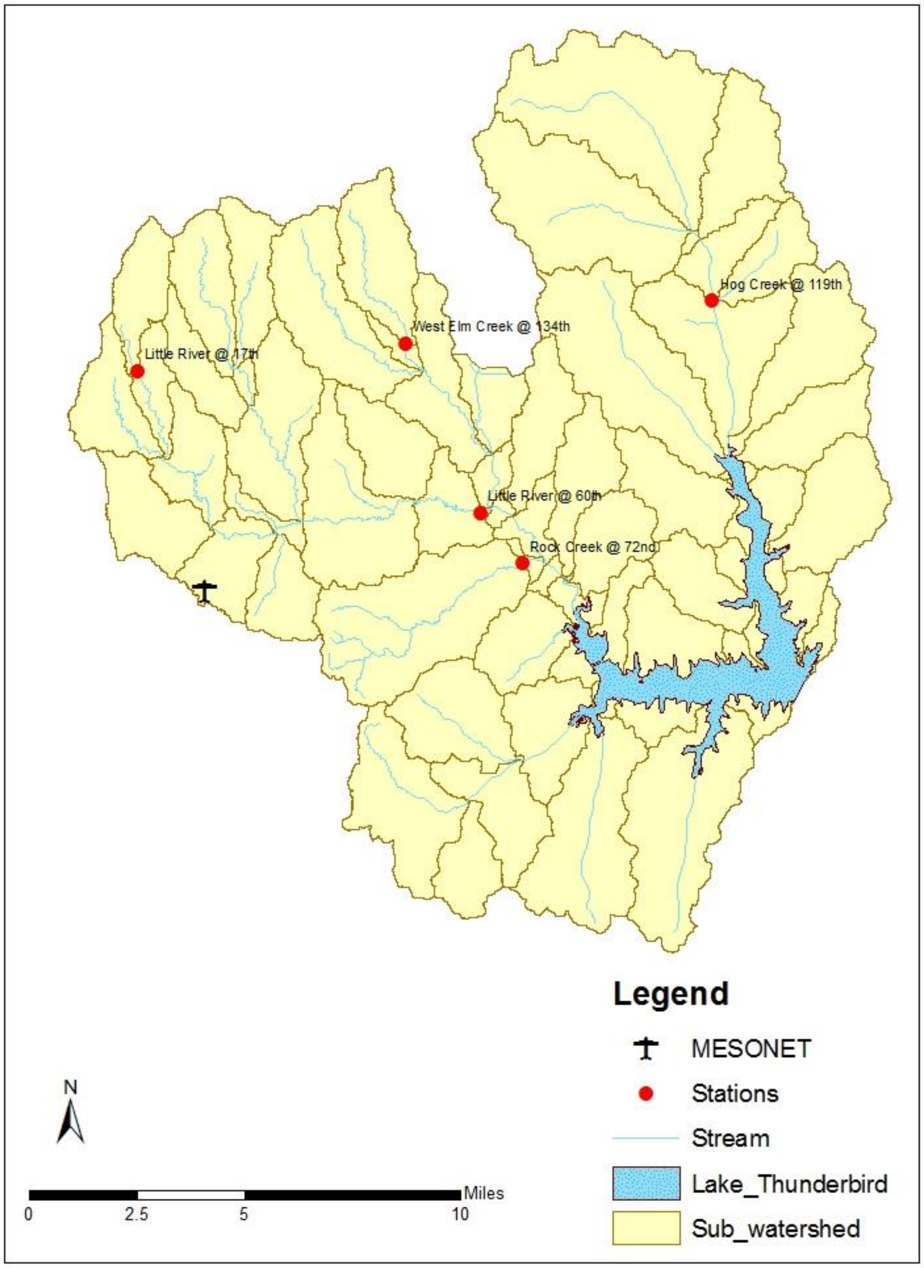

Table D-12 OWRB Water Quality Monitoring Results*

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 = Particulate 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

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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

* 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 = Particulate 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
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

* 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
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.*

CITY OF NORMAN
STORMWATER MANAGEMENT PROGRAM
FOR PHASE II MS4 COMPLIANCE
2016 TO 2020

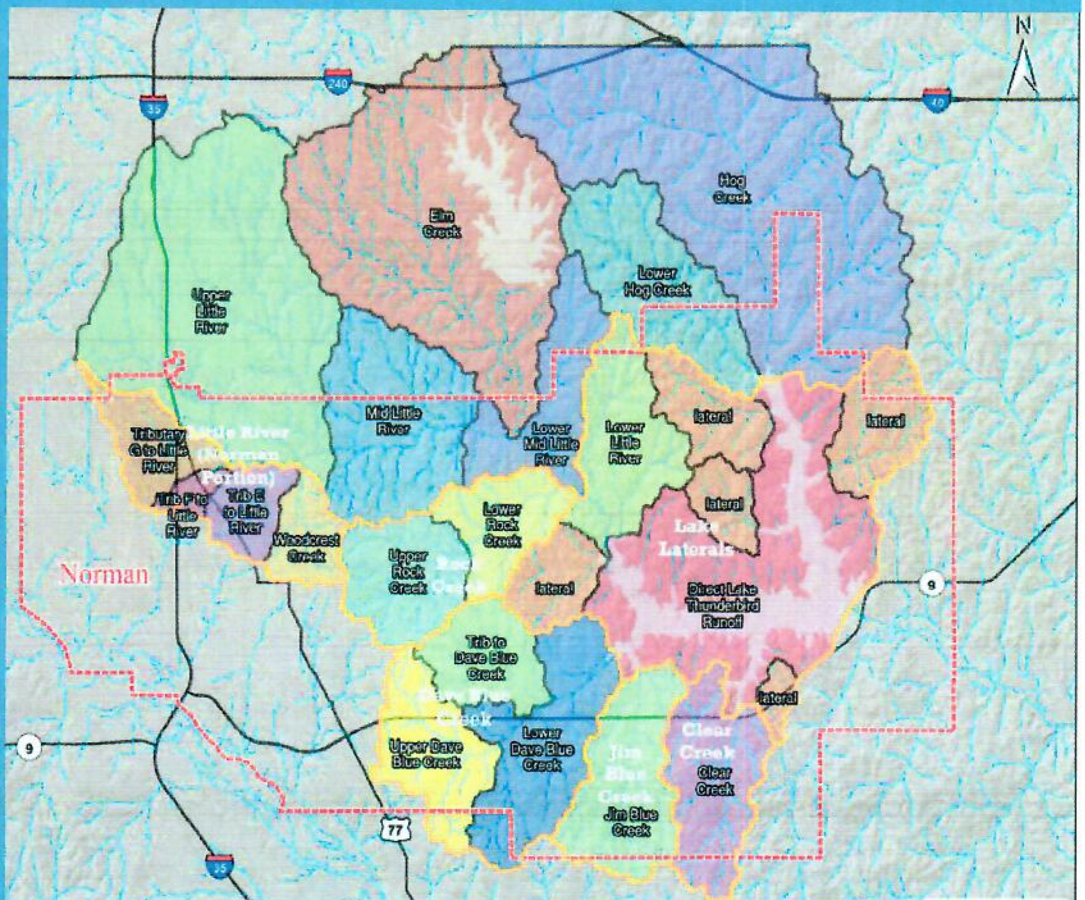
Appendix E

City of Norman

Building an Inclusive Community

Home of the University of Oklahoma

TMDL Compliance Plan
City of Norman, OK



July 15, 2016

GBMc & Associates
Strategic Environmental Services

OLSSON ASSOCIATES

1.0 Introduction

In November 2013 the City of Norman received notification from the Oklahoma Department of Environmental Quality (DEQ) that a Total Maximum Daily Load (TMDL) completed for Lake Thunderbird had been approved by EPA (EPA approval date was 11-13-2013). The DEQ letter required that Norman, as a Phase 2 MS4 Permittee, "incorporate all Total Maximum Daily Load (TMDL) requirements applicable to the storm water discharges into the City's Storm Water Management Program (SWMP)" and that the SWMP be modified within 24 months from the date of EPA approval (of the TMDL). The SWMP is to be modified in accordance with "Appendix E" of the Lake Thunderbird TMDL, which is titled "*MS4 Stormwater Permitting Requirements and Presumptive Best Management Practices (BMP) Approach.*"

Appendix E provides an approach for development of a TMDL Compliance Plan. The Compliance Plan shall include, at a minimum, the following:

1. An evaluation to identify potential significant sources of TSS, nutrients, and organic matter entering the MS4. Following the evaluation of the sources the permittee is to develop and implement a program to reduce those pollutants discharged from its MS4 system.
2. The permittee is to demonstrate understanding of the TMDL requirements and have a strategy to meet the required waste load allocation (WLA). Approaches listed in Appendix E, including BMPs, to be considered in meeting the WLA include the following:
    a. Retrofitting developed areas with structural BMPs.
    b. BMP implementation to prevent additional storm water pollutants in new or re-development areas.
    c. Implementation of non-structural BMPs for source control (fertilizer application restrictions, nutrient testing requirements, stream riparian buffer protections, City ordinances).
    d. Implementation of non-structural BMPs to treat existing loads (street sweeping).
    e. Development and implementation of water quality trading programs.
3. Enhancement of construction site storm water control, compliance inspections, adoption of ordinances.
4. A schedule for achieving the WLA.
5. Implementation and tracking of BMPs including both structural and non-structural using BMP summary sheets that provide sufficient information to document pollutant reduction, efficiency, maintenance, and the necessary calculation processes.
6. Educational programs directed at pollutant reductions.
7. Development of a pollutant monitoring and tracking program (included with this document).

The purpose of this Compliance Plan, prepared for the City of Norman, is to provide the information specified in Appendix E in order to achieve the required WLA in an efficient, science-based manner.

1.1 Approach

To achieve the WLA allocated to the City of Norman MS4 program, and meet the requirements of the TMDL, reductions of sediment, nitrogen and phosphorus are required. A watershed assessment was completed using a combination of GIS land use analysis, watershed modeling and unified stream assessments to help identify watershed issues, sources of pollution and to prioritize problem sub-watersheds. All this information was analyzed first from an overall watershed perspective (all of the Lake Thunderbird Watershed), then the focus was narrowed to examine just the Norman portion of the watershed.

The Hydrologic Simulation Program Fortran (HSPF) modeling completed as the foundation for the TMDL provides pollutant loading on an average annual basis. The TMDL report (Dynamic Solutions, 2013) provides long term average loading in the watershed and then establishes the WLA for each MS4 as a maximum daily load (MDL). The HSPF modeling determined that a 35% reduction in loading was necessary on an average annual basis to comply with the water quality standards. In order to determine the reductions that are required on an average annual basis it was necessary to calculate WLA on an average annual basis. A reduction of 35,881 lbs of nitrogen, 6,765 lbs of phosphorus and 3,644,083 lbs of TSS (sediment) was calculated as the reduction targets for the City of Norman TMDL Compliance Plan based on Long Term Average (LTA) values provided in the TMDL report. BMPs shown in this document were designed to meet the reduction values computed from LTA method. Reduction targets shown in Table 1 are values shown in Table 5-5 of the TMDL document. These values replaced the computed reduction values that were originally placed in this document per request of the regulatory agency during the approval process of this document and will serve as required reduction values.

Table 1. Required Pollutant Reductions for Norman

Pollutant	TMDL Annual Load lb/year[1] (Kg/day)
TN	257,014.47 (319.4)
TP	48,361.21 (60.1)
TSS	25,424,718.15 (31,596.1)

[1]the values shown in Kg/day are the published values on Table 5-5 of the TMDL document.

This TMDL Compliance Plan is largely based on the HSPF modeling completed for the TMDL by Dynamic Solutions using data from 2008 to 2009. Load reductions required to meet Norman's WLA were determined by applying various BMPs to the base HSPF model outputs for different land uses in each of Norman's sub-watersheds. HSPF modeling was used to address mostly structural BMPs applied to urban\suburban and agricultural land. In addition to the HSPF modeling, the Watershed Treatment Model developed by the Center for Watershed Protection (Caraco, 2013) was also used to determine potential reductions from non-structural BMPs.

2.0 Background

Lake Thunderbird, as completed in 1965, is a 6,070 acre reservoir constructed and owned by the U.S. Bureau of Reclamation. Volume of the lake was 119,967 acre-feet as constructed. The lake was created by impounding the Little River and Hog Creek for purposes of providing flood control, water supply, recreation, and fish / wildlife habitat. Lake Thunderbird is located east of Norman in Cleveland County and provides water supply for Norman, Midwest City, and Del City under authority of the Central Oklahoma Master Conservancy District (COMCD). The lake is heavily used for recreation.

2.1 Overview of Previous Studies

Various water quality and modeling studies have been completed for Lake Thunderbird and the Thunderbird Watershed during the past 15 years. The Oklahoma Water Resources Board (OWRB) has completed annual water quality studies of the reservoir beginning in 2000 and continuing through the present time. The reports prepared following these studies generally indicate that the lake has excessive nutrients, algae, and turbidity.

During 2001 the OWRB performed bathymetric mapping of the reservoir. This mapping determined that the surface area of the reservoir had been reduced to 5,439 acres and the volume reduced to 105,838 acre-feet. The OWRB reported that the reservoir sedimentation rate was estimated at 393 acre-feet per year, compared with the Bureau of Reclamation 100-year estimate of 350 acre-feet per year. The observed rate was only 12% higher than the original estimated rate (OWRB, 2002).

The most recent available OWRB report for Lake Thunderbird reflects data collected during 2013. The OWRB report contained information regarding Chlorophyll- α (Chl- α) levels in the lake. Chl- α concentration is used to estimate algal biomass in lakes and other aquatic systems, and the OWRB report suggests that algae may have declined during 2012 and 2013. In the closing remarks section of the report the OWRB states that "the 2012 calendar year represented the first year since 2007 that peak Chl- α had been reduced, and 2013 represented another large reduction in peak Chl- α from 2012. Significant nutrient reduction from the surrounding watershed, particularly in the Little River area is critical to bring Chl- α within Oklahoma Water

Quality Standards of 10 µg/L." (OWRB, 2014). Improvements in the lake are more likely the result of operation of a supersaturated dissolved oxygen system which is designed to oxygenate the lakes hypolimnion that is normally without oxygen during certain periods. This oxygenation serves to preclude the release of sediment phosphorus, which the OWRB noted had been reduced following operation of the supersaturated dissolved oxygen system.

Modeling of the watershed was completed by Vieux (2007) using the Soil and Water Assessment Tool (SWAT) model and by DEQ/Dynamic Solutions, LLC in 2013 using an HSPF model in preparation of the Lake Thunderbird TMDL. Vieux reported that the results of his modeling indicated that the largest phosphorus loads were coming from urbanized areas of Oklahoma City and Moore. The greatest sediment loads were coming from Moore, followed by Norman and then Oklahoma City. Vieux's modeling further estimated that the average phosphorus loads being delivered from the watershed to the lake were between 18,000 kg/yr and 23,000 kg/yr (approximately 39,600 lb/yr to 50,700 lb/yr).

The HSPF modeling completed by DEQ / Dynamic Solutions for the TMDL estimated that the total annual phosphorus load delivered by the watershed in 2008-2009 was 23,087 kg/yr (50,878 lb/yr). Calculated loading rates for sediment, CBOD, TOC, Total Nitrogen, and Total Phosphorus were all highest in the Upper Little River sub-watershed that corresponds to the City of Moore. The TMDL yielded similar results to Vieux's study.

In 2008, the Oklahoma Conservation Commission (OCC) prepared a Watershed Based Plan for the Lake Thunderbird Watershed. The OCC Plan establishes a framework for watershed management for the Lake. Additionally, the OCC contracted with the University of Oklahoma for a demonstration / education project utilizing low impact development building techniques that was completed on a neighborhood scale in 2014.

2.2 Water uality Standards

Lake Thunderbird receives protective Water Quality Standards in accordance with OAC785:45, which contains both designated beneficial uses and criteria necessary to support those uses. Uses designated for the lake include Fish and Wildlife Propagation, Public and Private Water Supply, and Primary Body Contact Recreation. In 2010 the lake was added to EPA 303(d) list and was designated as a sensitive water supply.

The 2014 303(d) list for Oklahoma shows that Lake Thunderbird is not maintaining the designated uses of Fish and Wildlife Propagation – Warm Water Aquatic Use for both Dissolved Oxygen and Turbidity, and Public and Private Water Supply for Chlorophyll-α.

The objective of the Lake Thunderbird TMDL is to reduce loads of nutrients (phosphorus and nitrogen) and sediment such that the waterbody attains all applicable Water Quality Standards designated uses and criteria.

3.0 Watershed Description

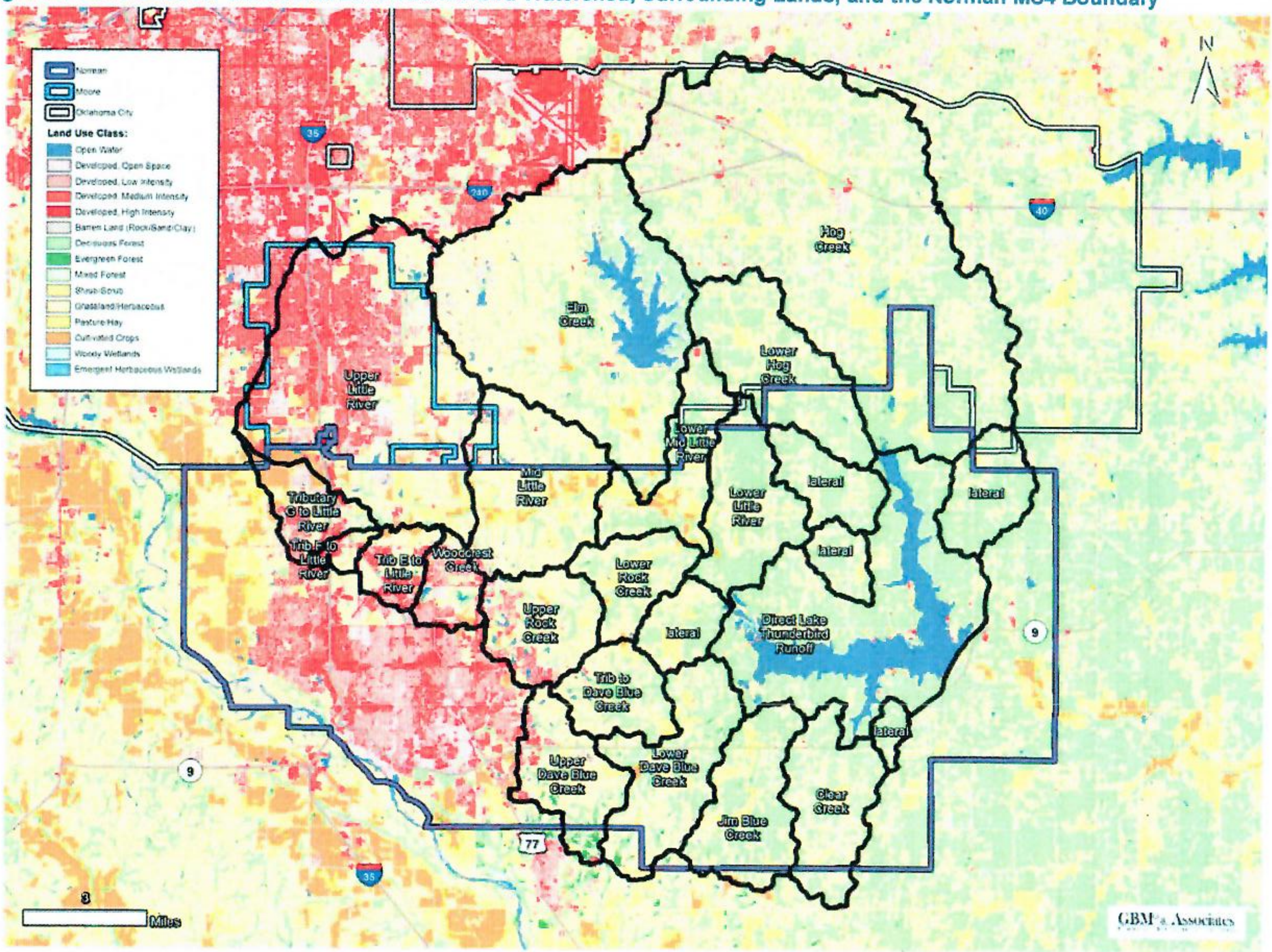
The Lake Thunderbird Watershed is 256 square miles (163,840 acres) in Cleveland and Oklahoma Counties. The watershed contains portions of the cities of Norman, Moore, and Oklahoma City (see Figure 1). Land use reported in the TMDL consists primarily of grassland/herbaceous at 38% and deciduous forest at 35%. Developed urban land use makes up 16% of the watershed. This data was from the 2006 National Land Cover Database (NLCD). More recent Land Use and Land Cover Data was obtained from the Multi-Resolution Land Characteristics Consortium (MRLC) National Land Cover Database (NLCD, 2011). Small changes were present when land cover was examined using more recent NLCD information. The top three land cover percentages were grassland/herbaceous at 37%, deciduous forest at 34% and developed at 18%, showing that both grassland and forest decreased slightly, and developed area increased 2% during the period covered by the 2006 and 2011 NLCD updates. Land cover/use characteristics of the overall watershed from the 2011 NLCD are shown in Table 2.

Table 2. Summary of Lake Thunderbird Watershed Land Use Characteristics.

Land Use	Percentage	Square Miles	Acres
Grassland/Herbaceous	37%	94	60,182
Deciduous Forest	34%	88	56,084
Developed, Open Space	8.9%	23	14,513
Developed, Low Intensity	5.2%	13	8,584
Open Water	4.8%	12	7,812
Developed, Medium Intensity	3.4%	8.6	5,493
Pasture/Hay	3.3%	8.3	5,333
Cultivated Crops	2.0%	5.2	3,325
Developed, High Intensity	0.7%	1.9	1,225
Barren Land (Rock/Sand/Clay)	0.47%	1.2	763
Evergreen Forest	0.20%	0.51	324
Woody Wetlands	0.05%	0.14	89
Emergent Herbaceous Wetlands	0.04%	0.11	72
Shrub/Scrub	0.02%	0.06	40
Totals	100%	256	163,840

Figure 1 shows the land uses for the overall Lake Thunderbird Watershed, surrounding lands, and the Norman MS4 boundary in 2011.

Figure 1. Land Uses for the Overall Lake Thunderbird Watershed, Surrounding Lands, and the Norman MS4 Boundary



3.1 Land Slope

A land slope analysis was also completed for the Lake Thunderbird Watershed, and the results summary is provided in Table 3. Land slope is generally mild; overall 86% of the watershed contains slopes less than 5 degrees. The largest slope category for the watershed is the 3 – 5 degree range which correlates to a 5.2% to 8.8% slope. Slope was derived from U.S. Geological Survey (USGS) National Elevation Dataset (NED) n36w098 1/3 arc-second 2013 using ESRI ArcGIS Spatial Analyst – Slope Tool.
Figure 2 provides the general distribution of land surface slope in the Lake Thunderbird Watershed.

Table 3. Summary of Land Slope Analysis.

Slope Range (Degrees)	Percent of Total Watershed
0 - 1	21
1 - 2	19
2 - 3	18
3 - 5	27
5 - 7	11
7 - 9	2.7
9 - 12	0.78
12 - 17	0.14
17 -52.8	0.02

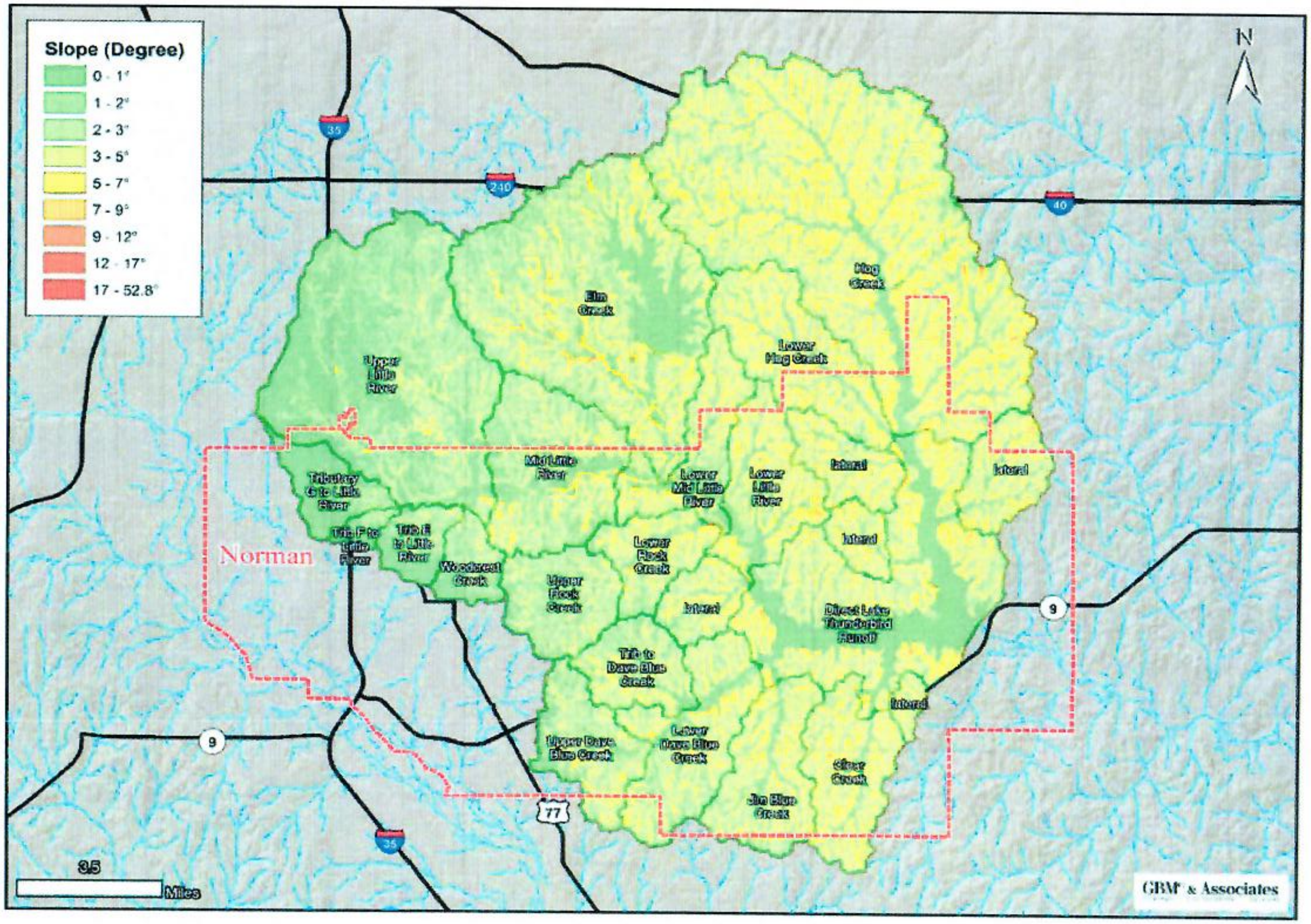


Figure 2. Land Surface Slope in the Lake Thunderbird Watershed.

3.2 Soils

Soils data was obtained from the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Soil Survey Geographic (SSURGO) database for Oklahoma County, Oklahoma (September, 2014) and Soil Survey Geographic (SSURGO) database for Cleveland County, Oklahoma (December, 2013).

Soils on the land surface in the watershed are primarily dominated by the Stephenville-Darsil-Newalla complex, which accounts for 20.1%. Harrah fine sandy loam makes up about 9.3%. The top ten most common soils in the Lake Thunderbird Watershed together comprise approximately 60% of the overall watershed and are shown in Table 4. The distribution of various soil types is shown in Figure 3.

Table 4. Summary of Soils Analysis.

Soil MUNAME	Percent Contribution %
Stephenville-Darsil-Newalla complex, 3 to 8 percent slopes.	20.1
Harrah fine sandy loam, 5 to 8 percent slopes.	9.3
Stephenville-Darsil complex, 1 to 5 percent slopes.	5.4
Renfrow-Huska complex, 3 to 5 percent slopes, eroded.	4.1
Harrah fine sandy loam, 5 to 8 percent slopes, eroded.	3.6
Kingfisher-Ironmound complex, 1 to 5 percent slopes.	3.2
Stephenville-Darsil-Newalla complex, 3 to 8 percent slopes, eroded.	3.1
Grainola-Ashport complex, 0 to 8 percent slopes.	2.8
Grainola-Ironmound complex, 5 to 12 percent slopes.	2.4
Tribbey fine sandy loam, 0 to 1 percent slopes, frequently flooded.	2.3

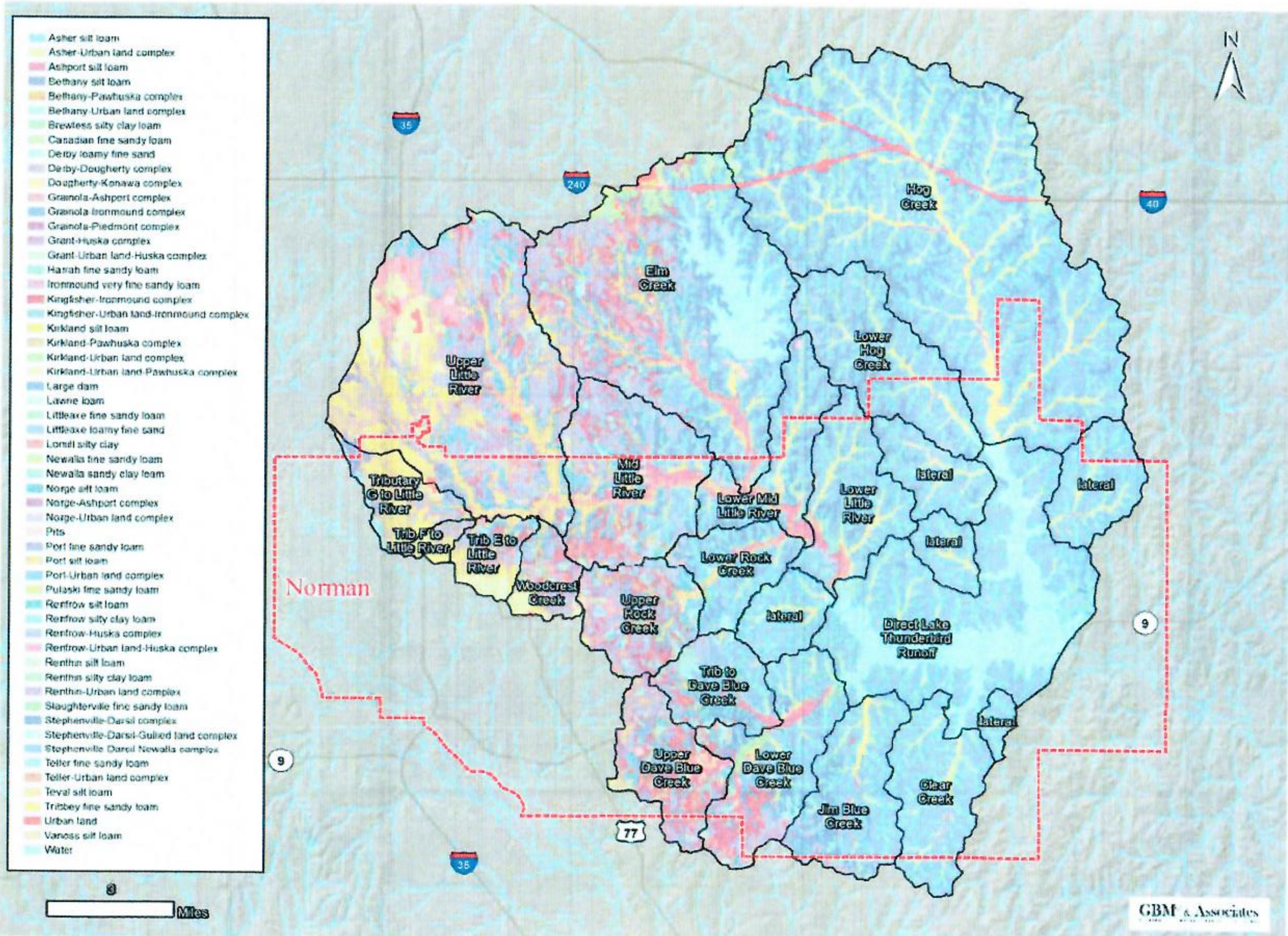


Figure 3. Soil Types in the Lake Thunderbird Watershed.

4.0 Watershed Assessment

An assessment of the Lake Thunderbird Watershed was completed to supplement the information from the TMDL report and the HSPF modeling. The focus of the assessment was to better pin-point which sub-watersheds have potentially been contributing the most sediment and nutrients to Lake Thunderbird and the most probable major sources of those non-point source (NPS) pollutants within each sub-watershed. The assessment utilized GIS resources and field based unified stream assessment (USA) methodologies. The following sections provide a brief description of our assessment methods and summary of our findings. The last sections of this assessment present our specific findings for the City of Norman MS4 portion of the Lake Thunderbird Watershed.

It is important to note that suggested improvements for this compliance document are designated in watersheds that are located entirely within the limits of City of Norman jurisdictional control. The City of Norman will have the option to place BMPs in watersheds that are partially located in the City of Norman Jurisdictional control.

4.1 GIS Non-point Source Assessment

A desktop assessment of the Lake Thunderbird Watershed was completed using GIS resources including soils maps, land use, aerial photographs, etc. The assessment was focused on identifying possible non-point sources of pollutants that could be transported to the stream system during storm runoff events. The entire assessment described in Section 4 was completed on a sub-watershed basis, using the 12-digit HUC watershed delineations (Figure 4). Since the watershed assessment reached beyond the limits of the City of Norman it was necessary to use HUC naming designations for this section (Section 4) of this document. The naming convention in all other sections of this document will follow the City of Norman adopted naming convention for watersheds.

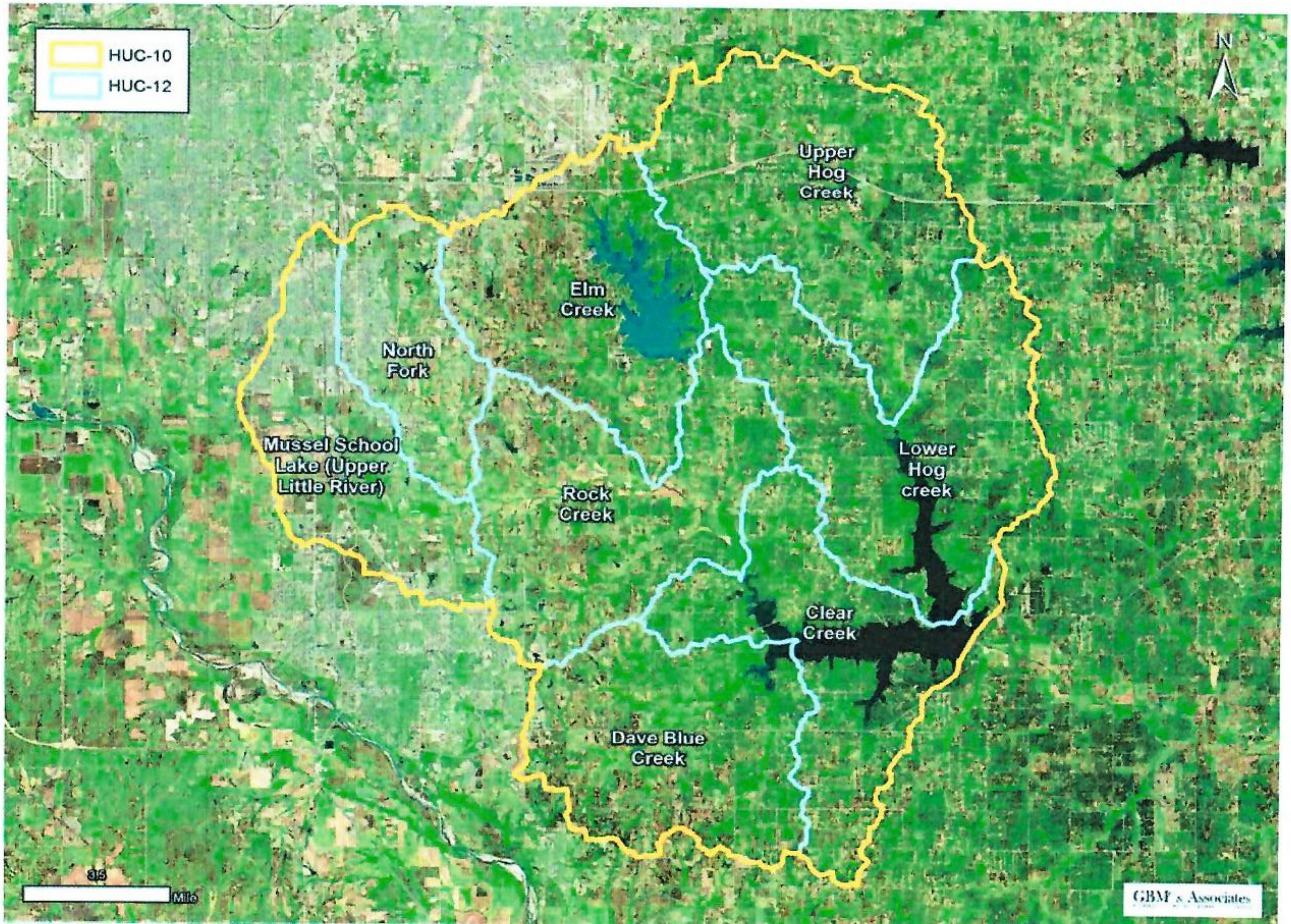


Figure 4. UC-12 Sub-Watersheds Used for Assessment.

4.1.1 Land Use by Sub-watershed

Land use was evaluated using 2006 land-use land cover data (same data used in the 2013 TMDL Report) from the United States Geological Survey (Table 5). Land use is an important attribute in a watershed analysis. The percent of pasture, row crops, and developed (urban) areas were used in this assessment and can provide great insight into a watershed's potential for NPS pollution. The three sub-watersheds that had the most potential impact from agriculture (pasture + row crops) land uses were upper Little River, Rock Creek and North Fork Little River. The three sub-watersheds with the highest potential impacts from urban land uses were the upper Little River, North Fork Little River and upper Hog Creek.

Table 5. Land Use/Cover Shown as Percentages.

Land Cover Type	Dave Blue Creek	North Fork Little River	Little[1] River (upper)	Clear Creek	Rock Creek	Upper og Creek	Lower og Creek	Elm Creek
Open Water	1.81	1.04	1.27	14.03	0.94	0.45	6.26	1.16
Developed, Open Space	7.89	15.42	11.55	6.61	7.43	16.34	6.87	6.58
Developed, Low Intensity	2.01	19.21	22.64	0.68	3.94	3.32	0.34	2.02
Developed, Medium Intensity	0.87	13.85	19.83	0.24	1.28	0.81	0.09	0.74
Developed, High Intensity	0.10	1.40	4.72	0.07	0.07	0.08	0.04	0.31
Total Developed (Urban)	**10.87**	**4 .88**	**58.74**	**7.60**	**12.72**	**20.54**	**7.35**	**.64**
Deciduous Forest	37.02	3.97	3.66	48.19	28.25	40.10	59.47	21.00
Evergreen Forest	1.42	0.00	0.03	0.02	0.00	0.04	0.00	0.02
Shrub/Scrub	0.10	0.00	0.00	0.05	0.00	0.00	0.03	0.00
Rangeland/ Herbaceuous	43.34	38.40	24.26	28.12	48.57	34.69	25.53	63.92
Hay/Pasture	4.62	2.52	3.24	1.59	5.75	4.14	1.34	2.34
Cultivated Crops	0.74	3.98	8.59	0.03	3.73	0.00	0.00	1.82

[1]Little River (upper) is same as Mussel School Lake depicted in Figure 4.

In addition to the traditional land use categories, a special category labeled "developing area" was created and delineated using high resolution aerial photography. This category reflects the area of land surface that had been recently cleared and is undergoing some sort of development (construction activity). It is possible for construction sites to transport large loads of sediment and nutrients even with implementation of some BMPs. This assessment was completed using aerial photography from 2014 (to match current field observations) and for 2008, to match the time frame in which the HSPF model was run for the TMDL. In 2008, during the timeframe the HSPF model was run, the majority of development was occurring in the North Fork Little River, the upper Little River and the Rock Creek sub-watersheds. In 2014, the percent development was lower but still mostly in the same three sub-watersheds. Developing area data determined from aerial photography is provided in Table 6.

Based on field observations in the watershed made during fall 2014 and spring 2015, it was apparent that there was a significant amount of land currently undergoing development of some type. In many cases the areas were large and the soil and erosion control features appeared to be only minimally effective.

Table 6. Developing Area Data Determined from Aerial Photography.

Watershed Name	Total Watershed Area (ac)	Total Developing Area 2008 (ac)	2008 % Watershed Developing	Total Developing Area 2014 (ac)	2014 % Watershed Developing
Clear Creek	20080.2	49.8	0.25	36.3	0.18
Dave Blue Creek	20644.8	147.6	0.72	125.7	0.61
Elm Creek	13339.7	0.0	0.00	17.4	0.13
Lower Hog Creek	26102.7	40.6	0.16	71.0	0.27
Little River (upper)[1]	15830.2	902.6	5.70	691.6	4.37
North Fork Little River	10648.7	701.8	6.59	324.7	3.05
Rock Creek	23221.7	668.6	2.88	237.3	1.02
Upper Hog Creek	27054.7	540.8	2.00	204.9	0.76

[1]Little River (upper) is referred to as Mussel School Lake on Figure 4.

4.2 Unified Stream Assessment

A variation of the USA protocol (Kitchel and Schueler, 2004) was completed on Lake Thunderbird Watershed in each sub-watershed in 2014, with additional information collected from the Norman portion of the watershed in 2015. This visual-based field assessment protocol consists of dividing a stream section into manageable reaches and evaluating, on foot, each reach in its entirety. The evaluation is a screening level tool intended to provide a quick characterization of stream corridor attributes that can be used in determining the most significant problems in each stream reach from a physical, ecological, chemical and hydrologic perspective. General categories of stream corridor characteristics assessed are:

1. Hydrology
2. Channel morphology
3. Substrate
4. Aquatic habitats
5. Land use
6. Riparian buffer
7. Water/sediment observations
8. Stream impacts (non-point source related including bank erosion)
9. Floodplain dynamics
10. Geomorphic attributes
11. Restoration/retrofit opportunities

Figure 5 shows stream reaches where USA data was collected.

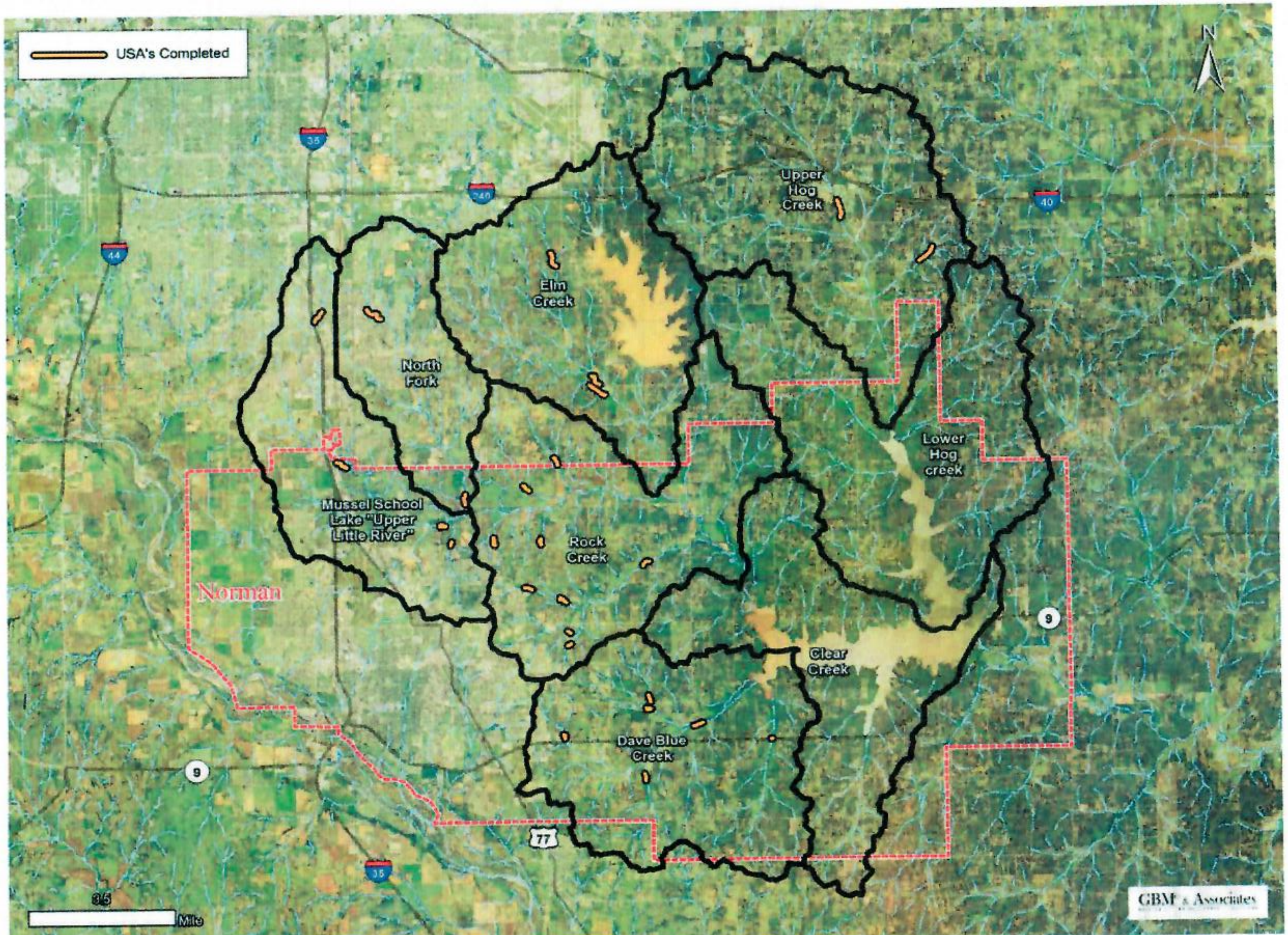


Figure 5. Stream Reaches where USA Data was Collected.

4.2.1 Geomorphology and Channel Stability

Fluvial geomorphology refers to the interrelationship between the land surface (topography, geology and land-use) and stream channel shape (morphology). When the force of running water is exerted on the land surface it can have significant effects on the morphology of stream channels. A stable stream, or one said to be in "equilibrium", is one where water flows do not significantly alter the channel morphology over short periods of time. The most important flow level in defining the shape of a stream is its bankfull flow (or effective discharge) (Rosgen, 1996). Bankfull discharge is the stage at which water first begins to enter the active flood plain. A detailed geomorphic assessment of the entire Lake Thunderbird Watershed was beyond the scope of this project. However, several geomorphic attributes were estimated during the USA's completed during the fall 2014 and spring 2015, and are helpful in assessing channel stability (Rosgen, 1996 and 2006). Table 7 provides a summary of the channel dimensions measured during the USA's as well as key stability issues noted.

Table 7. Summary of Geomorphic Characteristics.

Parameter (approximate/ estimated)	Station Identification						
	Dave Blue Creek	**og Creek**	**Little River (upper)**	**North Fork Little River**	**Rock Creek**	**West Elm Creek**	**Little River (middle)**
Bankfull depth (ft)[1]	1.3	3.1	2.2	4.0	1.4	4.0	2.2
Bankfull width (ft)[1]	17	9.3	23	19	12.5	24	20
Top of bank width (ft)[1]	26.5	14	33	28.5	30	36	35
Substrate size class	silt/clay	silt/clay	silt/clay	silt/clay	silt/clay	silt/clay	silt/clay
Width:Depth ratio	13.1	3.0	10.5	4.8	8.9	6.0	9.1
Entrenchment Ratio	1.6	2.2	1.5	1.5	2.3	1.4	1.8
Overall stream bank erosion hazard	Extreme	High	Very High	Very High+	Extreme	Very High	Extreme
Channel stability issues	Deepening and widening	Channelization	Deepening	Deepening and Bank erosion	Bank erosion	Deepening and Bank erosion	Bank erosion

[1]Dimesions based on approximate measurements made using range finder or tape measure and survey rod.

Channel instability can affect stream dimension in two primary ways, through agradation or degradation (Rosgen, 1996 and 2006). These are frequently manifested as channel widening (bank erosion) and channel entrenchment (deepening) by way of bed erosion (Figure 6). Both of these instability characteristics were observed in the Lake Thunderbird Watershed. Tables 8 and 9 provide an estimate of the potential sediment and nutrient loading (on an annual basis) from each sub-watershed or stream corridor that may be caused by these types of channel instability issues.

Each instance of bank erosion perceived as moderate risk or greater was tagged with a GPS coordinate and the length of the affected bank measured or estimated. The severity of bank erosion was then characterized using a bank erosion hazard index (BEHI) developed by Dave Rosgen (Rosgen, 2006). The BEHI uses several characteristics of the eroded bank (height, vegetated protection, bank angle, soil composition, etc) to calculate an overall score that relates to level of erosion hazard. The possible levels are low, moderate, high, very high, and extremely high.

An estimate of the potential sediment loading from bank erosion was calculated for each sub-watershed based on the BEHI data collected during the USA. The proportion of each USA reach that was experiencing active bank erosion at a moderate or greater level was determined. This proportion was extrapolated to the entire main stream channel in that sub-watershed to arrive at a total length of stream bank affected. Affected stream length was multiplied by average eroding bank height and by a conservative annual bank loss rate of 0.25 feet for each sub-watershed. Volume was then converted to pounds of soil adjusted for gravel content. The nutrient content of the soil was taken from analysis of five stream bank soil samples collected from various drainages in the Lake Thunderbird Watershed (soil data provided in Appendix A) to arrive at loading for nutrients. Stream bed erosion was estimated using a similar procedure substituting bankfull width for bank height.

Stream bank erosion is very prominent in the Lake Thunderbird Watershed (Figure 7). Bank erosion and/or bed erosion are believed to be major sources of sediment and nutrients in each of the sub-watersheds. Several of the sub-watersheds in the Lake Thunderbird Watershed had greater than 20% of their major stream length experiencing active erosion at a moderate level or greater. Active bank erosion can add thousands of tons of sediment and associated nutrients to the stream system during high flow events. These sediment and nutrient loads will ultimately be deposited into Lake Thunderbird.

Figure 6. Entrenched Channel in Little River Watershed.

Table 8. Stream Bank Erosion.

Stream[1]	Sediment/soil (lbs/year)	Nitrogen (lbs/year)	Phosphorus (lbs/year)[2]
Clear Creek	939,204	287	151
Dave Blue Creek	1,640,903	502	265
Little River (middle)[2]	11,672,233	3,572	1,882
Elm Creek	846,819	259	137
Hog Creek	494,353	151	80
Jim Blue Creek	895,716	274	144
Little River (upper)	5,469,170	1,674	882
North Fork Little River	6,664,378	2,039	1,074
Rock Creek	5,134,032	1,571	828
West Branch Hog Creek	273,363	84	44
West Elm Creek	4,774,241	1,461	770

[1] Erosion estimates are presented on a stream by stream basis. Main stem streams were evaluated.
[2] Little River (middle) is in the Rock Creek sub-watershed.
[3] See Figure 5 for location of watersheds.

Table . Stream Bed Erosion (Resulting from Channel Entrenchment).

Stream[1]	Sediment/soil (lbs/year)	Nitrogen (lbs/year)[3]	Phosphorus (lbs/year)[3]
Clear Creek	5,632,275	1,723	908
Dave Blue Creek	9,837,125	3,010	1,586
Little River (middle)[2]	0[3]	0	0
Elm Creek	0	0	0
Hog Creek	3,409,621	1,043	550
Jim Blue Creek	5,369,769	1,643	866
Little River (upper)	25,932,290	7,935	4,180
North Fork Little River	20,189,332	6,178	3,255
Rock Creek	0	0	0
West Branch Hog Creek	1,885,425	577	304
West Elm Creek	35,631,499	10,903	5,744

[1] Erosion estimates are presented on a stream by stream basis. Main stem streams were evaluated.
[2] Little River (middle) is in the Rock Creek sub-watershed.
[3] Streams with a "0" were not substantially entrenched.
[4] See Figure 5 for location of watersheds.

Figure 7. Stream Bank Erosion in the North Fork Little River Drainage (left) and Rock Creek Drainage (right).

In addition to bank and bed erosion, some gully erosion that has the potential for a large amount of sediment transport was observed throughout the watershed (Figure 8). The total amount of sediment loss from a single gully erosion area identified entering Rock Creek was calculated to be approximately 330,000 pounds.

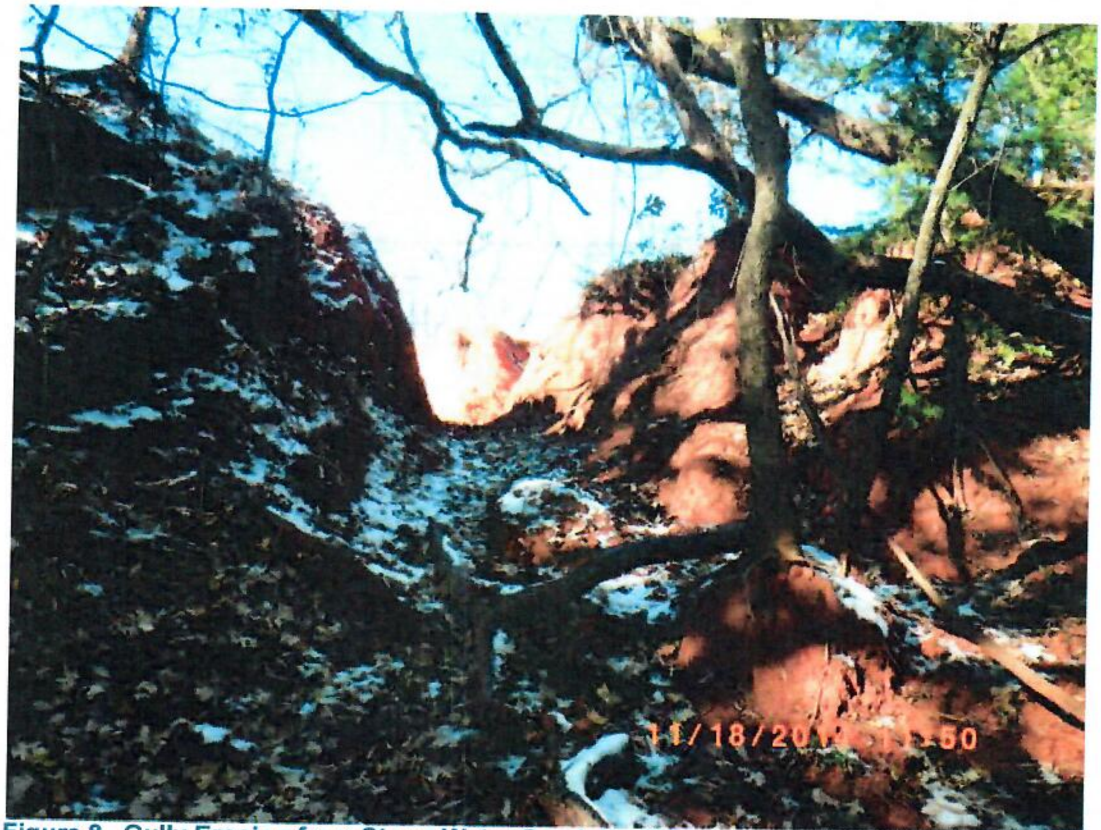


Figure 8. Gully Erosion from Storm Water Conduit off Pasture into Creek.

4.2.2 Riparian Buffer Impacts

Urbanizing areas frequently encroach on stream corridors by stripping riparian vegetation to the edge of the stream bank to make room for buildings and manicured lawns. In addition, row crops and pasture land use can be associated with impact to riparian buffers as nearby stream forest is cleared to create larger fields and pastures, and as cattle grazing encroaches on the stream banks. Impacted riparian buffer from cattle overgrazing or frequent stream access was assessed during the USA's and not found to be a large scale problem in the watershed. However, impacted riparian buffers from urbanization, pasture and row crop creation (and loss of buffer from bank erosion) were commonly observed problems. Therefore, each main stem named stream (identified per National Hydrographic Database) in the associated sub-watershed was examined through aerial photography to determine how many linear feet of stream were affected by loss of riparian buffer. These lengths were then divided by the total length of named stream in that sub-watershed to represent the percent of stream with impacted riparian buffers (Table 10).

Table 10. Riparian Buffer Impacts.

Stream[1]	Total Length (ft)	Impacted Length (ft)	Percent Impacted (%)
Clear Creek	23082.95	2789.41	12.1
Dave Blue Creek	40328.73	3925.58	9.7
East Elm Creek	13386.34	2303.74	17.2
Elm Creek	8342.22	1198.35	14.4
Hog Creek	63588.46	38279.79	60.2
Jim Blue Creek	22014.15	3421.74	15.5
Little River (upper)	125693.99	24171.01	19.2
North Fork Little River	52656.83	19125.29	36.3
Rock Creek	42144.37	1756.92	4.2
West Branch Hog Creek	35162.64	17179.00	48.9
West Elm Creek	47032.21	5809.51	12.4
Willow Branch	17669.20	3728.88	21.1

[1]Riparian buffer estimates are taken from main stem streams in each sub-watershed.

4.2.3 Unpaved Roads

Unpaved roads (gravel or dirt) are common in the Lake Thunderbird Watershed. During storm events these roads can transport significant loads of sediment into adjacent streams. The magnitude of the sediment load varies depending on many factors including: proximity to streams, condition of the road, slope, and the design of the road. Unpaved roads can be designed to include BMPs that reduce erosion and transport of sediment. General observation (and analysis provided for the Norman portion of the watershed in Section 4.5.3) suggests that unpaved roads could be a significant contributor to the sediment load entering Lake Thunderbird.

4.2.4 Other Findings

Other potential sources of sediment and nutrients identified most frequently during the USA were storm water outfalls and stream crossings. Storm water outfalls mostly included culverts entering streams from road side ditches or obvious drainage pathways exiting pastures directly into the creek. Both types of outfalls allow for direct transport of sediment and nutrients into the stream system. Stream crossings were typically ATV or farm trails that can serve as conduits for storm water much like a storm water outfall. Stream crossings also can be sites of active channel erosion due to the crossing of motorized vehicles that impact the stream banks and channel substrates.

4.3 Priority Sub-Watershed Ranking

A priority matrix was developed to aid in determining which sub-watersheds were contributing the most sediment and nutrients to Lake Thunderbird and most in need of being addressed. Each of the major impact assessment categories were considered, including: HSPF sediment loading, HSPF nutrient loading, percent agriculture (pasture+row crops), amount of impacted riparian buffers, amount of bank erosion, amount of stream bed erosion, and percent developing area. HSPF model results from the TMDL report (Dynamic Solutions, 2013) were utilized in the matrix. Model predicted sediment and nutrient loading were evaluated on a sub-watershed basis to arrive at the sub-watershed ranking that appears in the matrix.

Scores were assigned to sub-watersheds based on a ranking of the top five sub-watersheds (Table 11) with the greatest apparent impacts (highest sediment load from bank erosion, worst buffer impacts, highest % urban area, highest sediment load predicted by HSPF, etc.). For our matrix ranking the greatest apparent impact received 5 points, second 4 points, third 3 points, etc. These were then tallied for all 8 assessment parameters. The higher the total score the higher the priority for implementation of BMPs. Table 12 provides a summary of the score totals for each sub-watershed.

Table 11. Matrix Ranking and Scoring of Assessment Parameters.

Sub-watershed	SPF Sediment Loading	SPF Nutrient Loading	% Agriculture	% Developing land area	% Urban	Bank erosion	Bed Erosion	Impacted riparian	Total Score
N. Fork Little River	5	4	3	5	4	4	3	3	31
Little River (upper)[1]	4	5	5	4	5	3	4	2	32
Elm Creek	3	2	1			2	5	1	14
Rock Creek	2	3	4	3	2	5			19
Little River (middle)[2]	1	1	*	*	*	*	*	*	2
Upper Hog Creek	*	*	*	2	3	*	*	5	10
Dave Blue Creek	*	*	2	1	1	1	2	*	7
Clear Creek	*	*	*	*	*	*	1	*	1
Lower Hog Creek	*	*	*	*	*	*	*	4	4

*Not in top 5.
[1] Little River (upper) is also known as Mussel School Lake.
[2] Little River middle is part of the Rock Creek 12-digit HUC in Figure 4. It is separated out in this matrix to reflect contributions upstream of Norman.

Table 12. Total Scores and Matrix Ranking.

Severity Rank	Sub-watershed	Score
1	Little River (upper)	32
2	N. Fork Little River	31
3	Rock Creek	19
4	Elm Creek	14
5	Upper Hog Creek	10
6	Dave Blue Creek	7
7	Lower Hog Creek	4
8	Little River (middle)	2
9	Clear Creek	1

According to the matrix ranking, the five key sub-watersheds of the overall Lake Thunderbird Watershed in most need of source reductions are Upper Little River, North Fork Little River, Rock Creek, Elm Creek and Upper Hog Creek. Of these five, only Rock Creek is under the control of Norman's MS4 program. Section 4.5.4 of this plan will revisit this scoring matrix, focusing on only the sub-watersheds under the influence of the City of Norman's MS4 program.

4.4 istorical Streamflow Analysis at USGS Gauges

The USGS has no permanent gauging stations above Lake Thunderbird. Two temporary stations were installed in or around 2012 by the USGS but neither were operated for more than 6 months, and the data is all considered "preliminary" to this day. Therefore, no long term or short term reliable data exists concerning annual stream flow characteristics or peak flow dynamics in the Lake Thunderbird Watershed.

4.5 Narrowing the Assessment to the Norman MS4

The focus of this more detailed assessment is narrowed down to the Norman portion of the watershed and allows for a more efficient and accurate identification of potential non-point sources and provides information that may allow sub-watersheds to be prioritized for BMP implementation. This narrower focus was accomplished by utilizing the watershed delineations found in the City's Storm Water Master Plan and grouping them into 6 larger sub-watersheds to create watershed sizes that were logical and manageable (Figure 9). The sub-watersheds depicted in Figure 9 are those that Norman has management authority over. Portions of sub-watersheds along the northern boundary of the MS4 are within Normans planning area, but will display water quality influenced greatly by impacts in their upper watershed outside of Norman's control. These areas would be difficult to properly monitor for WLA compliance and are not considered in the analysis.

4.5.1 Land Uses

Land use was evaluated for this more focused analysis using the more recent 2011 MRLC NLCD data (Table 13). The three sub-watersheds that had the most potential impact from rural (pasture + row crops) land uses were Little River (Norman portion), Jim Blue Creek and Rock Creek. The three sub-watersheds with the highest potential impacts from urban (developed) land uses were the Little River (Norman portion), Rock Creek and Dave Blue Creek.

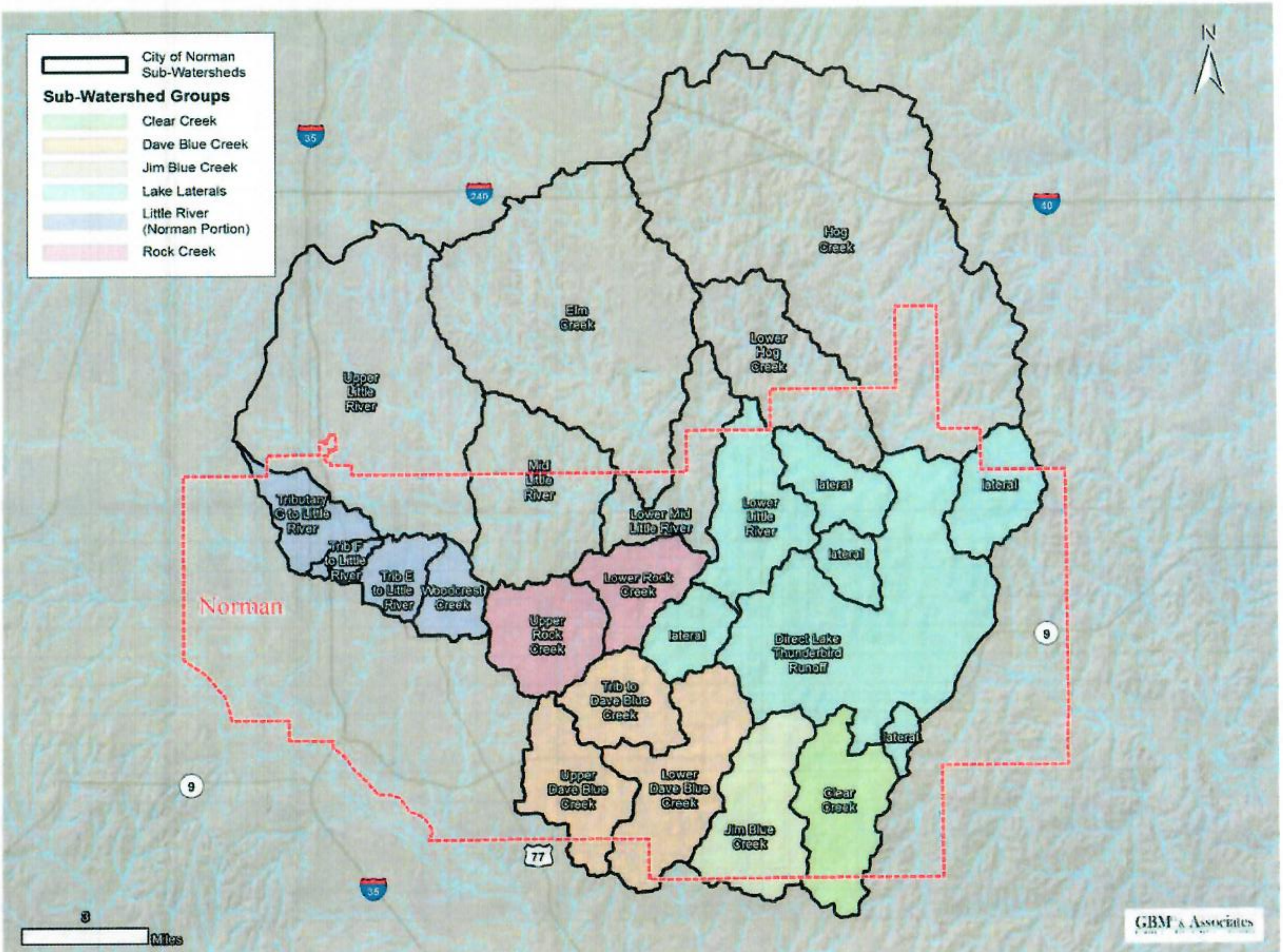


Figure . Norman MS4 Portion of the Lake Thunderbird Watershed and its Associated Sub-Watersheds.

Table 13. Land Use Analysis of Norman MS4 Sub-Watersheds.

Sub-watersheds	Little River					Rock Creek			Dave Blue Creek				Direct Lake Thunderbird Run-off and Laterals							Clear Creek	Jim Blue
LULC	Trib F (2.0)[1]	Woodcrest Creek	Tributary G to Little River	Trib E (31.0)[1]	Overall WS %	Upper Rock Creek (7.0)	Lower Rock Creek	Overall WS %	Trib to Dave Blue Creek	Upper Dave Blue Creek	Lower Dave Blue Creek	Overall WS %	30.0[1]	14.0[1]	11.0[1]	Lake Thunderbird Laterals	20.0[1]	Lower Little River	Overall WS %	Overall WS %	Overall WS %
Open Water	0.6	2.5	1.1	1.2	1.4	3.3	0.5	2.1	1.4	1.2	0.5	1.0	0.0	0.2	0.0	28.8	0.9	0.1	5.0	0.0	0.2
Open Space (developed)	11.2	12.3	13.7	11.1	12.1	9.2	6.4	8.0	8.5	8.5	8.7	8.6	10.5	8.3	6.3	4.6	5.9	7.2	7.1	6.2	5.9
Developed (low-high intensity)	40.6	48.5	31.9	28.2	34.5	18.2	1.0	10.7	1.7	9.8	1.4	4.0	0.9	0.7	0.3	1.0	1.3	0.5	0.8	1.1	0.9
Barren land	0.0	0.1	0.5	0.3	0.3	0.2	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Forest	4.0	7.1	2.9	7.0	5.6	13.7	37.4	24.0	32.6	22.2	39.7	32.7	53.7	62.0	68.1	48.5	43.3	58.6	55.8	50.3	52.1
Grassland	39.8	24.6	29.1	40.1	33.6	51.0	46.4	49.0	50.4	53.7	44.1	48.5	32.2	28.6	24.4	16.6	38.6	31.4	28.6	40.2	33.4
Pasture/Hay	2.4	0.7	1.2	3.3	2.0	2.5	6.5	4.2	4.8	3.4	5.0	4.5	2.6	0.0	0.9	0.0	9.5	1.5	2.4	2.2	6.4
Row Crops	1.3	4.2	19.6	8.8	10.4	1.9	1.7	1.8	0.5	1.0	0.6	0.7	0.0	0.0	0.0	0.0	0.0	0.5	0.1	0.0	1.0
Wetlands	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.5	0.4	0.1	0.2	0.0	0.0
Total Area (acres)	638	1910	2569	3827	8944	4237	3241	7478	3317	4311	6522	14151							31,325	5146	5437

[1]Labeled according to the City of Norman SWMP or label assigned if not specifically named in the SWMP.

4.5.2 Live Stock Numbers

Numbers of agricultural animals were estimated in the watershed from the county agricultural census data for cattle and calves. For cows the number of "all cattle and calves" for Cleveland county was used, along with the number of acres of pasture in each county, to calculate number of cows per acre. Cows were assumed to be evenly spread over the pastures in the counties affected. A cows/acre number was then applied to each sub-watershed using the number of acres of pasture determined through the land use analysis. Cattle estimates are provided in Table 14.

Table 14. Agricultural Animal Estimates per Sub-Watershed.

	Sub-watershed					
	Rock Creek	**Little River (Norman Portion)**	**Dave Blue Creek**	**Jim Blue Creek**	**Clear Creek**	**Lake Laterals**
All Cattle/Calves	321	384	608	234	221	1346

4.5.3 Unpaved Roads

Unpaved roads (gravel and dirt) are common in the Lake Thunderbird Watershed. There are over 100 miles of public and private unpaved roads in the Norman portion of the watershed. The City of Norman will pave majority of public roads and will work with private owners to encourage the stabilization of private drives and roads. During storm events these roads can transport significant loads of sediment into adjacent streams. The magnitude of the sediment load varies depending on many factors including: proximity to streams, condition of the road, slope and the design of the road. Unpaved roads can be designed to include BMPs that reduce erosion and transport of sediment.

Miles of unpaved road were determined from Oklahoma Department of Transportation (ODOT) GIS road layers (Statewide County ODOT Road Network, 2013) for each sub-watershed in the Norman portion of Lake Thunderbird Watershed. A summary of this data is provided in Table 15. Sediment loading for each mile of unpaved road was estimated based on a recent study completed in Pennsylvania by the Center for Dirt and Gravel Road Studies (Bloser, 2012). The Center for Dirt and Gravel Road studies (The Center) is the author of the nationally recognized manual on environmentally sensitive maintenance on dirt and gravel roads (USEPA-PA-2005). This manual is recommended nationwide by the USEPA and the US Forest Service. The Centers study determined the load of sediment transported for several different unpaved road types and conditions that would result from a 0.6 inch rain event occurring over 30 minutes. For purposes of the Lake Thunderbird Watershed assessment an average rate of sediment transport was set at 485 lb/mile of unpaved road per rain event. The 485 lb/mi sediment rate was the average of the runoff rate from roads with average maintenance and traffic levels and roads that had been recently topped with fresh aggregates which produce much lower levels of sediment runoff. These conditions were chosen to provide conservative sediment loading estimates. Six rain events (>1.0 inch) were assumed to occur each year and each rain event would result in 485 lb of sediment per mile of road (Table 15). Sub-watersheds with the highest potential loading of sediment from unpaved roads are Lake Laterals, Rock Creek and Dave Blue Creek.

Table 15. Summary of Unpaved Roads in Lake Thunderbird Watershed[1].

	Rock Creek	Little River (Norman Portion)	Dave Blue Creek	Jim Blue Creek	Clear Creek	Lake Laterals	Total
Unpaved Roads (mi)	24.0	1.0	16.0	8.1	12.2	43.3	104.6
TSS Load Annually (lbs)	69,789	3,020	46,616	23,623	35,606	125,986	304,640

[1]Values provided in this table are rounded to a minimum of 2 significant digits.

4.5.4 Construction Storm Water

The scope of this study did not include site specific evaluation of water quality impacts from construction sites in the Norman area. However, throughout the study period impacts and potential threats to water quality from construction activity were noted. Observations made included large cleared areas left unstabilized or those that had inadequate or unmaintained structural controls. Utility work was also observed numerous times with no best management practices in place, including dewatering efforts which were obviously contributing sediments.

As stated, large unstabilized tracts of land were observed during the study. These tracts were generally associated with the addition and/or expansion of residential neighborhoods. During field study dates in November 2014 to April 2015, these tracts were left with no ongoing construction activity nor any stabilization efforts implemented. A review of historical aerial photography shows that this practice is commonplace and the timeframes are substantial.

Calculations were performed to estimate the increase in storm water discharge and the potential sediment/nutrient loss due to land clearing. The change in runoff coefficient from forest or pastureland to cleared land results in an estimated runoff increase of 2.3 times as much storm water. The associated sediment and nutrient loss with this change in land use is significant.

Soil loss due to erosion was calculated using the Universal Soil Loss Equation and site specific information from the Little River watershed. Calculations showed an estimated annual loss of 5.47 tons/acre/year for a construction site due to surface water erosion assuming no controls are in place. For a 20 acre construction site this correlates to 110 tons of soil, 67 lbs of Nitrogen, and 35 lbs of Phosphorus per year. In contrast, data available from the NRCS (2010) estimated soil losses from Oklahoma farmland at a rate of 2.51 tons/acre/year. Similar evaluation using RUSLE2 Model resulted in a range of values that bracketed 5.47 ton/acre/year. Therefore, the reasonably conservative 5.47 tons/acre/year was utilized for soil loss estimation.

GIS data was utilized to estimate the amount of area currently under development within the Norman portion of the Lake Thunderbird Watershed. According to most recent aerials, Little River watershed has 366 acres under development, Dave Blue watershed has 126 acres, and there are 81 acres under development in the Rock Creek watershed. If left uncontrolled, this represents a potential load of approximately 6,300,000 lbs of sediment, 1,900 lbs of Nitrogen, and 1,000 lbs of Phosphorus per year. A summary of pollutant loading potential from construction storm water is provided in Table 16.

Table 16. Summary of Potential Loading from Uncontrolled Construction Sites[1].

Pollutant	Rock Creek	Little River (Norman Portion)	Dave Blue Creek	Jim Blue Creek	Clear Creek	Lake Laterals	Total
Sediment (lb/year)	885,735	4,002,210	973,215	404,595	229,635	284,310	6,779,700
Nitrogen (lb/year)	271	1225	298	124	70.3	87.0	2,075.3
Phosphorus (lb/year)	143	645	157	65.2	37.0	45.8	1,093

[1]Values in this summary table are rounded to a minimum of two significant digits.

In addition to the soil loss from land use change, the increased run-off also results in higher peak flows in stream channels that cause increased stream bank erosion, contributing more sediment and nutrients to the system. Control of these excess runoff volumes is critical to maintain stream system stability.

4.5.5 Stream Bank Erosion

Additional USA's were completed in the Norman portion of the Lake Thunderbird Watershed to supplement the earlier USAs that were completed watershed wide. Results of the USA and BEHI calculations showed the Little River watershed (Norman portion and middle portion in the MS4 boundary) exhibited the greatest risk for erosion and accompanying sediment/nutrient loads. Stream segments of the Little River and its tributaries showed between 50 to 100% of reach lengths observed were affected by bank erosion. Bank erosion was characterized from high to extreme using the BEHI classification index. Stream reaches observed in this watershed were classified as Entrenched due to the ratio between the bankfull depth and width.

The BEHI procedure showed significant bank erosion within the Rock Creek watershed. Overall, the rankings were lower than the Little River Watershed. However, reaches observed showed a large percentage of affected stream length including one reach with 90% of banks exhibiting Moderate bank erosion. On average, the Rock Creek watershed showed approximately 40% of banks affected with erosion characterized as High. Streams in this watershed were classified as Slightly Entrenched to Moderately Entrenched.

Of the three key Norman MS4 watersheds where USA's were completed, the Dave Blue Watershed showed the least impact due to bank erosion. However, while streams appeared to be in better overall condition compared to other watersheds in the area, there were still areas with significant bank erosion and scour. BEHI calculations showed an average of 17% of the banks evaluated were affected by bank erosion. The erosion hazard was characterized as Very High to Extreme for these stream segments. Streams in the watershed were found to be Moderately Entrenched. Currently, this watershed is the least developed and further urbanization has the potential to increase peak storm flows and erosion in the watershed.

Bank and bed erosion are significant sources of sediment and nutrient load to streams and watersheds. Calculations were completed (as an example) to estimate the loads introduced to the watershed by one 500-ft section of stream with 10-ft high banks. Using a conservative erosion rate of 0.25 ft per year, the amount of sediment loss translates to 1,250 ft^3 or 57.4 tons of sediment per year. Using the average concentrations from samples collected during the study, this amount of nutrient associated with this sediment totals 35.1 lbs of Total Nitrogen and 18.5 lbs of Total Phosphorus for one bank of a 500-ft long stream segment. Considering the amount of affected stream bank within the watershed, this calculation illustrates the necessity to prioritize stabilization and/or remediation of stream banks. A summary of pollutant loading potential from stream bank erosion is provided in Table 17. Explanation of how those estimates were calculated is provided in Section 4.2.1. The HSPF modeling completed for the TMDL (Dynamic Solutions, 2013) uses loading caused by channel scour to account for stream bank erosion. The resulting annual sediment load predicted from HSPF for sour, from the entire Lake Thunderbird Watershed, is approximately 2,000,000 lbs. Based on our calculations (Table 17) this could be a gross underestimation of bank erosion.

Table 17. Summary of Potential Loading from Stream Bank Erosion.

Pollutant	Rock Creek	Little River (Norman Portion)	Dave Blue Creek	Jim Blue Creek	Clear Creek	Lake Laterals[1]	Total
Sediment (lb/year)	3,024,354	7,098,086	2,716,995	895,716	939,204	939,204	15,613,559
Nitrogen (lb/year)[2]	925	2157	831	274	287	287	4,761
Phosphorus (lb/year)[2]	488	1136	438	144	151	151	2,508

[1] No USA data was collected in lake laterals, but these areas are expected to be similar to Clear Creek or Jim Blue Creek.

[2] Nitrogen and phosphorus calculated from average nutrient content of soil samples, 0.00306 lb/lbN and 0.000161 lb/lb P.

4.5.6 Norman MS4 Priority Sub-Watershed Ranking

Many factors play into determining which sub-watersheds should be prioritized and which types of impacts within the sub-watersheds should be addressed first. To aid in this analysis a matrix was developed to consider each of the impact assessment categories including: HSPF sediment loading, HSPF nutrient loading, percent agriculture (pasture+row crops), amount of impacted riparian buffers, amount of bank erosion, amount of unpaved roads, and percent developing area. HSPF model results from the TMDL report (Dynamic Solutions, 2013) were utilized in the matrix. Model-predicted sediment and nutrient loading were evaluated on a sub-watershed basis to arrive at the sub-watershed ranking that appears in the matrix.

Scores were assigned to sub-watersheds (Table 18) based on a ranking of the top five sub-watersheds with the greatest apparent impacts (highest sediment load from bank erosion, worst buffer impacts, highest % urban area, highest sediment load predicted by HSPF, etc.) For this matrix ranking the greatest apparent impact received 5 points, second 4 points, third 3 points, etc. These were then tallied for all 8 assessment parameters. The higher the total score the higher the priority for implementation of BMPs. Table 19 provides a summary of the score totals for each sub-watershed.

Table 18. Matrix Ranking and Scoring of Assessment Parameters.

Sub-watershed	SPF Sediment Loading	SPF Nutrient Loading	% Agriculture	% Developing land area (active construction)	% Urban	Bank erosion	Unpaved Roads	Impacted riparian	Total Score
Rock Creek	4	4	3	3	4	4	4	1	27
Little River (Norman)	5	5	5	5	5	5	0	0	30
Dave Blue Creek	3	3	2	4	3	3	3	5	26
Jim Blue Creek	2	2	4	2	1	1	1	3	16
Clear Creek	1	1	0	0	2	2	2	2	10
Lake Laterals	0	0	1	1	0	1	5	4	12

Table 1 . Total Scores and Matrix Ranking.

Severity Rank	Sub-watershed	Score
1	Little River (Norman portion)	30
2	Rock Creek	27
3	Dave Blue Creek	26
4	Jim Blue Creek	16
5	Lake Laterals	12
6	Clear Creek	10

According to the matrix ranking, the three key sub-watersheds within the Norman portion of the watershed most in need of source reductions are Little River, Rock Creek and Dave Blue Creek. These areas should be the focus of the first round of BMP implementation.

5.0 Pollution Source Assessment

Pollution sources in the Lake Thunderbird Watershed were assessed with emphasis on non-point sources, which was the focus of the TMDL and this compliance plan.

5.1 Point Sources

There are no NPDES wastewater dischargers in the Lake Thunderbird Watershed. There are 14 NPDES Multi-Sector General Permits (MSGP) for industrial storm water discharges in the watershed (Dynamic Solutions, 2013). However, only four of these are within the Norman MS4 boundary (Dynamic Solutions, 2013).

5.2 Non-point Sources

The portion of the Lake Thunderbird Watershed that is in the City of Norman MS4 boundary was evaluated. The critical Norman sub-watersheds where the most TSS and nutrients originate were assessed and discussed in Section 4.0. Figure 10 provides a map of the ranking of critical sub-watersheds, which will be the main focus of load reduction goals for the watershed. Based on the assessment findings (Sections 4.0) potential sources of pollution and their risk level in each of the sub-watersheds delineated and analyzed are presented below. Risk level was assigned based on matrix scoring (see Table 18 and Table 19), field observations and interpretation of GIS data.

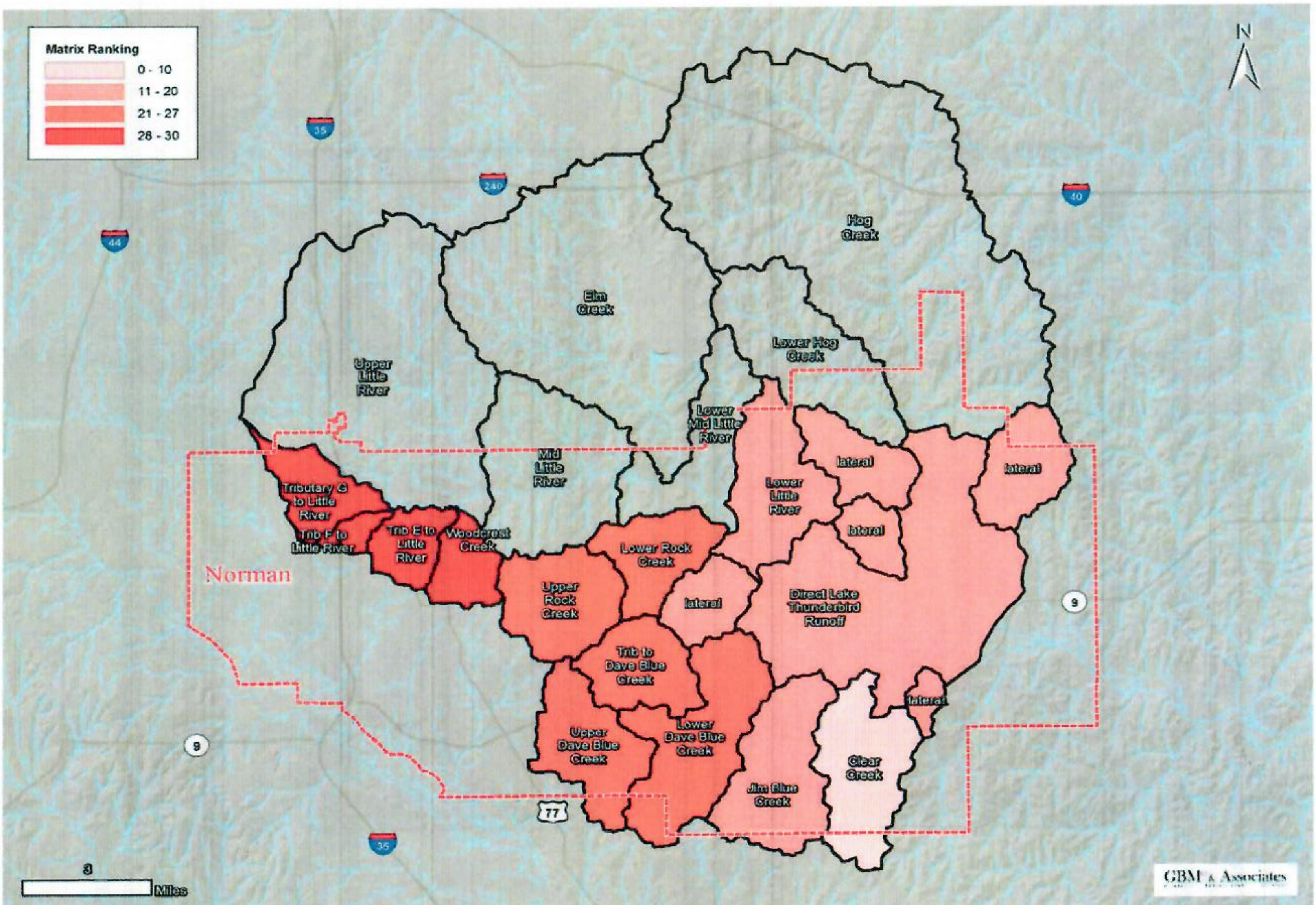


Figure 10. Ranking of Critical Sub-Watersheds According to the Priority Matrix.

Upper Rock Creek – This is in the headwaters portion of the Rock Creek sub-watershed and is mostly composed of developed (urban and suburban) and grassland (rangeland) land uses. Potential non-point sources identified in the Upper Rock Creek sub-watershed with estimated severity or relative risk for delivery of sediment and nutrients are listed in Table 20.

Table 20. Potential Non-Point Sources Identified in Upper Rock Creek.

Non-point source (Upper Rock Creek)	Severity/Risk
Commercial areas	Moderate - High
Residential areas	Moderate - High
New construction	High
Cattle	Low
Fertilized pastures and hay operations	Low
Rangeland/ Grasslands	Moderate
Stream bank erosion	High
Septic tanks	Low - Moderate
Un-paved roads	Moderate
Row Crops	Low

Lower Rock Creek – This sub-watershed is also in the middle portion of the overall lake watershed and is mostly composed of rangeland and pasture. Cattle pasture is more prominent in this sub-watershed than in other nearby sub-watersheds. Potential non-point sources identified in the Lower Rock Creek sub-watershed with estimated severity or relative risk for delivery of sediment and nutrients are listed in Table 21.

Table 21. Potential Non-Point Sources Identified in Lower Rock Creek.

Non-point source (Lower Rock Creek)	Severity/Risk
Commercial areas	Low
Residential areas	Low
New construction	Moderate
Cattle	Moderate
Fertilized pastures and hay operations	Moderate
Rangeland/ Grasslands	Moderate
Stream bank erosion	High
Septic tanks	Low - Moderate
Un-paved roads	Moderate
Row Crops	Low

Little River Tributaries (Tribs G, F, E and Woodcrest) – This is the northwest corner of Norman and is mostly composed of urban, suburban and commercial land uses. Potential non-point sources identified in the Little River Tributary (Tribs G, F, E and Woodcrest) sub-watersheds with estimated severity or relative risk for delivery of sediment and nutrients are listed in Table 22.

Table 22. Potential Non-Point Sources Identified in Little River Tributaries.

Non-point source (Little River Tribs)	Severity/Risk
Commercial / Industrial areas	Moderate - High
Residential areas	Moderate - High
New construction	High
Cattle	Low
Fertilized pastures and hay operations	Low
Rangeland/ Grasslands	Moderate
Stream bank erosion	High
Row Crops	Low - Moderate

Upper Dave Blue Creek - This sub-watershed drains the southern portion of Norman. The land-use is primarily grassland, developed (urban and suburban), and forest. Potential non-point sources identified in the Upper Dave Blue Creek sub-watershed with estimated severity or relative risk for delivery of sediment and nutrients are listed in Table 23.

Table 23. Potential Non-Point Sources Identified in Upper Dave Blue Creek.

Non-point source (Upper Dave Blue Creek)	Severity/Risk
Commercial areas	Low
Residential areas	Low – Moderate
New construction	Moderate
Cattle	Low
Fertilized pastures and hay operations	Low
Rangeland/ Grasslands	Moderate
Stream bank erosion	Moderate - High
Septic tanks	Low
Un-paved roads	Moderate
Row Crops	Low

Lower Dave Blue Creek and Tributary to Dave Blue - These sub-watersheds drain mostly rural areas southeast of Norman. The land-use is primarily grassland, forest and some pasture/hay. Potential non-point sources identified in the Upper Dave Blue Creek and Dave Blue Tributary sub-watersheds with estimated severity or relative risk for delivery of sediment and nutrients are listed in Table 24.

Table 24. Potential Non-Point Sources Identified in Lower Dave Blue Creek and Tributary.

Non-point source (Lower Dave Blue Creek)	Severity/Risk
Commercial areas	Low
Residential areas	Low
New construction	Low
Cattle	Low – Moderate
Fertilized pastures and hay operations	Low - Moderate
Rangeland/ Grasslands	Moderate
Stream bank erosion	Moderate
Septic tanks	Moderate
Un-paved roads	Moderate
Row Crops	Low

Jim Blue Creek - This sub-watershed drains mostly rural areas southeast of Norman. The land-use is primarily forest and grassland, with some pasture/hay. Potential non-point sources identified in the Jim Blue Creek sub-watershed with estimated severity or relative risk for delivery of sediment and nutrients are listed in Table 25.

Table 25. Potential Non-Point Sources Identified in Jim Blue Creek.

Non-point source (Jim Blue Creek)	Severity/Risk
Commercial areas	Low
Residential areas	Low
New construction	Low
Cattle	Low – Moderate
Fertilized pastures and hay operations	Low - Moderate
Rangeland/ Grasslands	Moderate
Stream bank erosion	Moderate
Septic tanks	Moderate
Un-paved roads	Moderate
Row Crops	Low

Clear Creek - This sub-watershed drains mostly rural areas south of Lake Thunderbird. The land-use is primarily forest and grassland. Potential non-point sources identified in the Clear Creek sub-watershed with estimated severity or relative risk for delivery of sediment and nutrients are listed in Table 26.

Table 26. Potential Non-Point Sources Identified in Clear Creek.

Non-point source (Clear Creek)	Severity/Risk
Commercial areas	Very Low
Residential areas	Very Low
New construction	Very Low
Cattle	Low
Fertilized pastures and hay operations	Low
Rangeland/ Grasslands	Moderate
Stream bank erosion	Moderate
Septic tanks	Moderate
Un-paved roads	Moderate
Row Crops	Very Low

Lake Thunderbird Direct and Laterals - This large sub-watershed is made up of all the smaller tributaries (laterals) and drainages that enter directly into Lake Thunderbird. The sub-watershed drains mostly rural areas near the lake. The land-use is primarily forest and grassland, with some pasture/hay. Potential non-point sources identified in the Thunderbird direct and lateral sub-watersheds with estimated severity or relative risk for delivery of sediment and nutrients are listed in Table 27.

Table 27. Potential Non-Point Sources Identified in Thunderbird Laterals.

Non-point source (Lake Thunderbird Laterals)	Severity/Risk
Commercial areas	Very Low
Residential areas	Very Low
New construction	Low
Cattle	Low – Moderate
Fertilized pastures and hay operations	Low - Moderate
Rangeland/ Grasslands	Moderate
Stream bank erosion	Moderate
Septic tanks	Moderate
Un-paved roads	Moderate
Row Crops	Low

6.0 Modeling Non-Point Source (NPS) Load Reduction Potential

Two water quality models were used to determine the potential of different management practices to reduce TSS and nutrients in the Norman portion of the Lake Thunderbird Watershed. The Watershed Treatment Model (WTM) developed by the Center for Watershed Protection was used to model non-structural BMPs. The EPA supported HSPF model (Bicknell, 2001), which contributed to the development of the TMDL, was used to model urban/suburban BMPs and rural BMPs. Each sub-watershed was modeled independently to arrive at a predicted load reduction potential with multiple management measures applied.

Both models (HSPF and WTM) are generally considered land-use based models that utilize annual rainfall, soil hydrologic groups and land-use categories to calculate primary pollutant loading in a watershed.

6.1 WTM Modeling for Non-Structural BMPs

The WTM model was used to assess potential load reductions from non-structural BMPs. A summary of the land use calculated for each sub-watershed of concern then entered into the WTM is provided in Table 28. The WTM is used in this plan exclusively as a tool to determine which non-structural BMPs most effectively reduce TSS and nutrients in each sub-watershed. BMPs evaluated with the WTM include:

- Residential Lawn Care Education
- Pet Waste Education Programs
- Street Sweeping
- Catch Basin Cleanouts
- Septic System Education Programs
- Sanitary Sewer Overflow Repair

Each non-structural BMP required additional land use data specific to each sub-watershed. The additional land use data included number of housing units, impervious surface area that drains to a storm drain, and miles of sanitary sewer lines which were calculated for each sub-watershed. Based upon the area of each sub-watershed, and the total number of housing units and area of Cleveland County; a proportion calculation was used to determine the number of housing units in each sub-watershed (Table 29). In the Storm Water Master Plan prepared by PBS & J, cumulative impervious surface area for each watershed was included. The impervious surface area in each sub-watershed was calculated using the total impervious surface area of the larger watershed from the Storm Water Master Plan and the area of each sub-watershed as a proportion (Table 29). Half of the total impervious surface area accounted for City roads; the area that remained was split into residential and parking lots for modeling purposes. City and residential roads were summed to determine the impervious surface draining to storm inlets (Table 29). The City of Norman provides an interactive GIS map with all sewer lines included. The map was integrated into GIS and force mains, gravity mains, and lateral sanitary sewage lines were summed for each sub-watershed in the City limits (Table 29). Impervious surface area, impervious surface area draining to storm inlets, and miles of sanitary sewer line were not calculated for rural watersheds as they are outside the City of Norman. Rural areas do not have their sewage piped to the City treatment facility, they do not receive street sweeping provided by the City, nor would the storm water runoff drain to a storm inlet. Therefore Jim Blue, Clear Creek, and Lake Thunderbird and laterals will not receive street sweeping, catch basin cleanout, or sanitary sewer overflow repairs as BMPs in the WTM.

Other data were required to evaluate certain BMPs. Much of this data is not directly available for the Norman area (such as fertilizer overuse rate by residents, pet waste management habits, etc.) so other reputable sources of data (Center for Watershed Protection is a primary source) were utilized and referenced in Section 8.1. Where no data was available conservative assumptions were made, particularly in the case of BMPs where public education and response is a component.

Table 28. Summary of WTM Inputs for Land Use in Each Sub-Watershed.

Land Use (acres)	Land Use in Sub-watersheds					
	Jim Blue	Clear Creek	Lake Thunderbird and Laterals	Little River	Rock Creek	Dave Blue
LDR[1]	46.5	49.8	216.0	1,184.2	509.4	411.6
MDR[1]	2.9	3.6	19.4	1,158.0	98.6	168.8
HDR[1]	0.0	1.1	9.0	295.6	9.0	27.3
Forest	2,833.1	2,589.9	17,515.7	471.5	1,912.2	4,462.8
Rural[2]	2,543.2	2,498.7	11,994.8	5,012.8	4,708.0	8,928.9
Water	11.1	2.4	1,570.3	122.4	141.1	151.3
Total area	5,436.8	5,145.5	31,325.5	8,944.5	7,478.2	14,150.6

[1] LDR stands for low density residential, MDR stands for medium density residential, and HDR stands for high density residential

[2] Rural land loading calculations are the default rates in the model, they include pollutants from grazed cattle, fertilizer used for hay and other common uses of rural land.

Table 2 . Summary of Inputs for Other Land Use Categories in each Sub-Watershed.

Source	Other Land Use Categories in Sub-watersheds					
	Jim Blue	Clear Creek	Lake Thunderbird and Laterals	Little River	Rock Creek	Dave Blue
Housing units	1,650	1,562	9,508	2,714	2,269	4,295
Impervious surface area (acres)[1]	--	--	--	609	1,056	626
Impervious surface draining to storm inlets (acres)[1]	--	--	--	457	792	470
Sanitary sewer lines (miles)[1]	--	--	--	84.4	38.5	14.0

[1]Areas outside of public services (storm, sewer, sanitary sewer, etc.) are omitted.

6.2 SPF Modeling for Urban/Suburban and Rural BMPs

HSPF is a widely used watershed model that can evaluate point source and non-point source loading of pollutants, transport, and their effect on water quality. It is one of the few models supported by both the USEPA and the USGS. The latest version of HSPF and the base model UCI file, which was used to develop the TMDL, were used in this report to evaluate BMP removal rates from various land uses in the Norman portion of the Lake Thunderbird Watershed. The HSPF model addresses load reductions from BMPs on a land use by land use basis. Each BMP is set-up in the model with BMP type, type of land use the BMP is effective for, and the percentage of that land use area (acres) that it is applied to. The model also allows the pollutant (sand, silt, clay, nitrate, phosphate, etc.) removal efficiency to be added to the BMP set-up. However, the HSPF model does not adjust the loading rate from a given land use based on removal efficiency. HSPF applies a BMP by simply adjusting the area of that land use that creates loading, (i.e. if a grazing BMP is applied to 25% of pasture then 25% less pasture produces pollutant loading in that model reach).

To simplify application of BMPs to the HSPF base model and allow removal efficiencies to play a direct role in the reductions, the model's land use loading output file was generated using HSPEXP+. The land use loading output file breaks out each land use area in acres, provides a loading rate (t/year, lb/year, etc.) for each pollutant for that land use type, and produces a total annual pollutant load by land use for that reach/sub-watershed. This modeling output data was then used to evaluate pollutant reductions for various BMPs on a land use basis by taking both the percent area on which BMPs were implemented and BMP reduction efficiency into account. For example, an urban BMP was applied to 25% of the Urban high density land-use (P:109URHD), achieving a 66% reduction of sediment (Table 30). This level of sediment reduction is calculated as (0.25 x 12acres) * (0.66 x 0.044 tons/acre/year) to arrive at 0.08712 tons reduced (Table 30). An example of how BMPs were implemented with the land use data is provided in Table 30.

Table 30. Example of SPF Land Use Sediment Loading Output and BMP Application.

Reach	Land-use	Area (ac)	Rate (tons/ac/year)	Total Load (tons/year)	Urban BMP (25% area/66% Reduction (tons)
RCHRES 65 - Rock Creek	P:101 WATR	186	0.018	3.38	n/a
RCHRES 65 - Rock Creek	P:102 BERM	477	0.298	141.91	n/a
RCHRES 65 - Rock Creek	P:103 FRSD	1742	0	0.003	n/a
RCHRES 65 - Rock Creek	P:104 RNGE	3880	0.073	285.05	n/a
RCHRES 65 - Rock Creek	P:105 URML	218	0.048	10.40	1.73
RCHRES 65 - Rock Creek	P:106 PAST	353	0.133	46.99	n/a
RCHRES 65 - Rock Creek	P:107 AGRL	166	0.088	14.61	n/a
RCHRES 65 - Rock Creek	WETN	0	NaN	0	n/a
RCHRES 65 - Rock Creek	P:109 URHD	12	0.044	0.53	0.087
RCHRES 65 - Rock Creek	FRSE	0	NaN	0	n/a
RCHRES 65 - Rock Creek	UCOM	0	NaN	0	n/a
RCHRES 65 - Rock Creek	P:112 URLD	1	0.045	0.045	0.0074
RCHRES 65 - Rock Creek	I:101 URML	218	0.304	66.20	10.93
RCHRES 65 - Rock Creek	I:102 URHD	46	0.723	33.25	5.49
RCHRES 65 - Rock Creek	I:103 UCOM	5	0.786	3.93	0.65

Land uses where BMPs were applied in the HSPF model include developed land (urban, suburban and commercial), open space turf grass areas, rangeland (also called grassland), pasture/hay land and row crops/cultivated fields. BMPs were applied in groupings to allow flexibility in BMP selection. BMPs in each grouping are provided in Table 31. Removal efficiencies for the BMPs listed in Table 31 were obtained from averaging removal efficiency from the literature (Appendix B).

Table 31. BMPs by Land Use and Group.

Land use	Group	BMP	Removal Efficiency (%)			Group Removal Efficiency (%)		
			N	P	Sed	N	P	Sed
Urban/Suburban, Commercial	Detention	Wetlands	25	49	69	25	40	66
		Wet ponds	29	59	72			
		Dry extended detention	10	19	65			
		Bioretention	35	32	60			
Urban/Suburban, Commercial, Open Space/Bermuda Grass	Bioswales	Bioswales	35	38	47	26	25	41
		Wet swales	29	24	32			
		Vegetated open channels	15	13	45			
Urban/Suburban (Commercial)	Rain gardens and barrels	Rain gardens	13	23	28	13	23	28
		Rooftop disconnection	13	23	28			
Rangeland	Cover crops[1]	Cover crops	33	22	15	33	22	15
Row Crops/Cultivated Fields	Cover crops	Cover crops	33	22	15	31	25	24
		Conservation Tillage	29	28	32			
Pasture/Hay	Grazing	Rotational grazing	10	24	30	21	12	15
		Alternative water sources	33	0	0			

[1]Cover crops on rangeland refers to minimizing bare soil through planting a perennial grass that will grow densely or by planting annual grasses (cover crops) to fill in gaps.

In order for the HSPF model to predict potential load reductions from each land use and each BMP applied, it was necessary for a reasonable portion of each land use to have a particular BMP applied to it. These land use applications are provided in Table 32. A goal to apply BMPs on approximately 25% of each respective land use was established. This goal is based on practicality and the reality that to achieve BMP implementation on more than 25% of an area is unreasonable and likely unattainable.

Table 32. Percent of each Land Use to which a Particular BMP was applied.

Land use[1]	BMP Group	% Land use Applied
Urban/Suburban (URLD, URML, URHD)	Detention	25
	Bioswale	25
Commercial (URCOM)	Detention	25
	Bioswale	25
	Rain garden/barrel	15
Rangeland (RNGE)	Cover Crops	25
Row Crops (AGRL)	Cover Crops	25
Pasture/Hay (PAST)	Grazing	25
Grass-open space (BERM)	Bioswale	25

[1]Each land use category includes the code used in HSPF for that land use.

7.0 Management Measures Already Implemented by Norman

The City of Norman has been implementing many good storm water management measures over the past few years. Several of these management measures have great potential to reduce pollutants in storm water. The City's Storm Water Master Plan (2009) outlines many of their efforts including improving drainage and creation of several ordinances to protect streams and Lake Thunderbird. These ordinances have been written and approved by the City Council and are described briefly below.

7.1 Water uality Protection one Ordinance

Water Quality Protection Zone (WQPZ) is provided in Section 19 of the Code of the City of Norman for streams in the Lake Thunderbird Watershed. This ordinance went into effect in June 2011. A WQPZ is a zone along a stream consisting of "...vegetated strip of land, preferably undisturbed and natural, extending along both sides of a stream and its adjacent wetlands, floodplains or slopes". A WQPZ is sometimes referred to as a riparian buffer zone or strip and is designed to protect stream banks from erosion and to filter pollutants entering the stream from storm water run-off. The width of the zone is required by the code to be the greater of:

a. 100 feet from the top of bank on either side; or
b. The width designated by a stream planning corridor (SPC) in the Storm Water Master Plan (2009); or
c. The FEMA floodplain; or
d. A reduced width based on use of engineered solutions such as implementation of a structural control to reduce nitrogen, phosphorus and sediment loading based on the accepted low impact development manual.

A low impact development (LID) manual was reviewed and adopted by the City for use in conjunction with this ordinance. The manual is based on the Wichita/Sedgwick County Storm Water Manual utilized by the City of Wichita, KS.

7.2 Storm Water Management Ordinance(s)

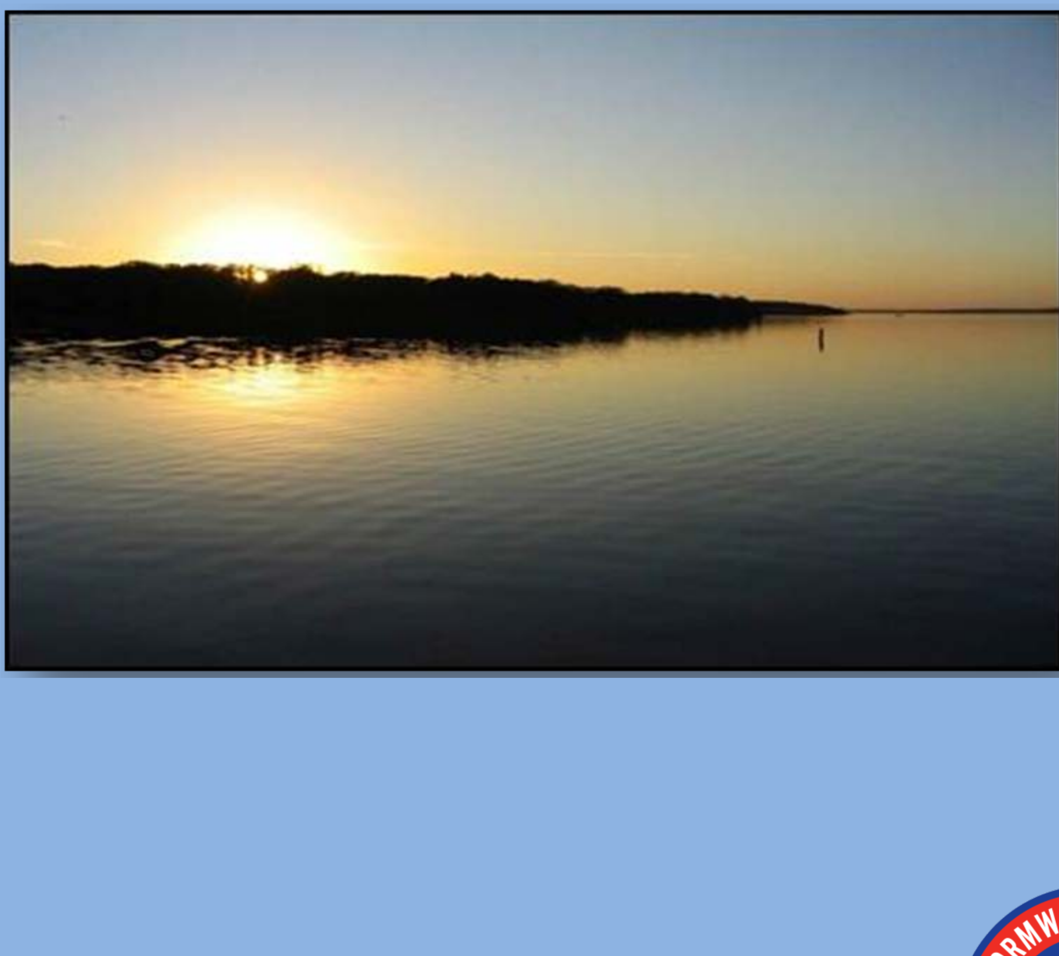
Detention/Retention

Storm water detention /retention basins are a valuable tool of controlling peak storm flows and reducing erosion. The 2009 Storm Water Master Plan for Norman states that there are 290 or more retention facilities, detention facilities, or other water bodies (ponds) present in the City of Norman MS4. The City of Norman Engineering Design Criteria specifies that development plans incorporate permanent storage for storm runoff, promote storm water infiltration, and reduce erosion and sediment transport. The limits of the City of Norman Water Quality Protection Zone (WQPZ) is shown in Figure 11.

Appendix A

CITY OF NORMAN
STORMWATER MANAGEMENT PROGRAM
FOR PHASE II MS4 COMPLIANCE
2016 TO 2020

Appendix F



NORMAN 2025 LAND USE AND TRANSPORTATION PLAN

CLARION

RESOLUTION

R-0405-39

A RESOLUTION OF THE COUNCIL OF THE CITY OF NORMAN, OKLAHOMA ADOPTING THE NORMAN 2025 LAND USE AND TRANSPORTATION PLAN.

1. WHEREAS, the Council of the City of Norman has relied upon a land use plan to guide development decisions throughout the City for decades; and

2. WHEREAS, the City Council has contracted with Clarion Associates to prepare a new land use and transportation plan for the City; and

3. WHEREAS, Clarion Associates, in cooperation with the Norman Future Committee, City Staff and the citizens of Norman, has prepared and recommended adoption of the NORMAN 2025 Land Use and Transportation Plan; and

4. WHEREAS, the City Council deems that the goals and policies stated in the NORMAN 2025 Land Use and Transportation Plan are in keeping with the best long term interests of both current and future citizens of Norman.

NOW, THEREFORE BE IT RESOLVED BY THE COUNCIL OF THE CITY OF NORMAN, OKLAHOMA:

5. That the NORMAN 2025 Land Use and Transportation Plan and modifications to the Adoption Draft Plan as outlined in Exhibit "A", attached hereto and made a part hereof, be adopted to direct future development and land use decisions within the City of Norman; and

6. That the City Staff be directed to develop programs and assist the City Council in establishing priorities which will serve to aid in the implementation of the NORMAN 2025 Plan; and

7. That an annual development report be prepared by City Staff for review by the Planning Commission relative to the NORMAN 2025 Land Use and Transportation Plan; and

8. That, approximately every five years, the City Council appoint a citizen committee to conduct a thorough review and update of the NORMAN 2025 Land Use and Transportation Plan; and

9. That the NORMAN 2025 Land Use and Transportation Plan shall become effective on December 16, 2004.

PASSED AND ADOPTED this 16th day of November, 2004.

____
(Mayor)

ATTEST:

____
(City Clerk)

Resolution No. R-0405-39
Page 2

EXHIBIT "A"

1. Add an additional policy to Goal 4, Economic Stability and Enhancement (Page 11): "Policy 11. Prepare and adopt design standards for commercial development in order to improve the appearance of the City's commercial corridors, help attract other high-quality development, and improve the city's economic foundation."

2. Delete conditions 3 and 4 in Special Planning Area 3 and replace them with a new condition 3 that states, "Convert the site from industrial to commercial use by either adaptive re-use of the existing old feed mill and accessory buildings or by demolition of the existing structures, so as to create a unified architectural appearance, especially on all building facades facing public streets."

3. As alternative wording for NORMAN 2025 Plan Amendment criteria, the third paragraph of Amendment Procedures on page 33 of the NORMAN 2025 Adoption Draft Plan would be deleted as written and replaced with the following: "Plan amendments may be submitted at any time. Staff will prepare a complete analysis of the impact of the proposed amendment and will identify all affected portions of the Plan. Staff will prepare a quarterly summary report to the City Council as a review of the last three-month and year to date impact of any and all Plan Amendments. Additionally, as a part of the required annual review, staff will prepare a Plan Amendment annual summary and analysis of all affects to the Plan."

4. It is proposed that this language would replace the present wording limiting Plan Amendments to only occur on a quarterly basis. If, at the time of the first annual review, the City Council felt that the first year of activity demonstrated a need to revisit the concept of limiting Plan Amendments to only every three months, that issue could be considered as an amendment to the procedures at that time.

5. Issue (7) addresses inconsistencies with transitions from urban to rural properties. Based upon existing zoning and development in the area, the areas north of Tecumseh Road and west of 12th Avenue NE are proposed to be amended on the Adoption Draft NORMAN 2025 Plan Map to reflect land uses consistent with that zoning, resulting of the replacement of the Country Residential Area with Suburban Residential.

ACKNOWLEDGEMENTS

Mayors

Harold Haralson
Ron Henderson – Past

City Council

Kevin Hopkins	Ward 1
Richard Stawicki	Ward 2
Jonathan Leavey	Ward 3*
Cindy Rosenthal	Ward 4
Rachel Butler	Ward 5
David Hopper	Ward 6
Doug Cubberley	Ward 7*
Mandy Haws	Ward 8*
David Ray	Ward 4 – Past Member

*NORMAN 2025 Council Steering Committee Members

Planning Commission

Michael J. LaBrie – Chair
Edward Adwon
Susan Ferguson
Al Griffin
Paul Minnis
David Nordyke
Duane Olinger
Fred Walden
Roy Walker

Harold Rogers – Past Member
James Howard – Past Member
Gary Bradley – Past Member

Norman Future Committee

The City would like to acknowledge the many citizens who took the time away from their busy lives to participate in this lengthy process. The NORMAN 2025 Land Use and Transportation Plan would not be possible without the dedication and vision of the Norman Future Committee members, and their interest in retaining the high quality of life enjoyed by the citizens of Norman.

NORMAN 2025 TEAM

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Christopher J. Duerksen
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Lesli K. Ellis, AICP

PRESLEY AND ASSOCIATES
Leo Presley

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Jimmy Berry, Director

Utilities Department
Mark Daniels, Utilities Engineer
Michelle Matthews, GIS Utilities Analyst

Information Systems
Jeff Champeau, PC Support Technician
Glenn Lauderdale, Internet Services Technician

TABLE OF CONTENTS

I. Plan Background

INTRODUCTION

The NORMAN 2025 Land Use and Transportation Plan is the long-range plan for the future physical development of the City. It represents a desired land use pattern in response to anticipated growth rates, public utility constraints, and environmental conditions. The Plan embodies a conscious decision by the City to anticipate and make choices about Norman's future. It provides a vision for the future and a foundation for managing the City's growth.

This Plan is the culmination of a process built on a dual foundation of strong citizen involvement and a solid understanding of the factual realities of growth trends, patterns, and constraints.

For a more detailed discussion of the technical elements of the NORMAN 2025 Land Use and Transportation Plan, the following technical reports are available:

- Development Capacity Technical Memorandum
- Land Demand Technical Memorandum
- Land Use Plan Implementation Techniques Technical Memorandum

COMMUNITY INVOLVEMENT

This Plan represents the values of the Norman citizenry. An intensive effort was made to involve citizens throughout the City in planning for Norman's future. The Norman Future Committee (NFC) was appointed by the City to act as an advisory group for citizens' views at key points throughout the planning process. The NFC met numerous times in settings that were open to the public. From October 2003 through October 2004 the NFC met a total of eight times. The citizen involvement process also included a citywide survey in which over 500 citizens participated. In addition, the local cable company broadcast most of the *NORMAN 2025 Land Use and Transportation Plan* meetings with citizens and elected officials.

PLANNING ISSUES

The community involvement component contributed greatly to gaining a balanced view of what is important to the citizens of the City. Clearly there is a strong appreciation for the quality of life enjoyed within Norman. Many believe it is important for the City to control the quality and location of growth, to discourage sprawl and ensure that adequate public facilities are available at the time of development. Particular emphasis was noted on the importance of design aspects of commercial and industrial development, which citizens would like to see occur in a more attractive manner.

Citizens remain supportive of restricting development in rural areas, and maintaining the 10-acre minimum lot size in the Country Residential area. Strong opposition to development in the flood plains, particularly within the Ten-Mile Flats flood plain and a desire for a significant Community Separator along much of the northern boundary of the city, developed in tandem with these discussions.

FOUNDATION OF EXISTING LAND USES

The City of Norman contains 121,134 acres of land (189.3 square miles). Of this land, almost 61,000 acres (slightly more than 50%) are developed or unavailable for development and are classified according to the following characteristics:

Developed land (including institutionally developed land)	31,344 acres	26%
Open space, lakes, and floodplains (including Lake Thunderbird)	17,823 acres	15%
Partially developed land (developed portion only)	4,320 acres	4%
Institutional land (vacant, but unavailable for private development)	1,070 acres	1%
Right of way	6,342 acres	5%

The developed land uses include residential and non-residential development. For purposes of this analysis, it is assumed that all land classified as open space, lakes, right- of-way, and institutional land is not developable. Approximately 50 percent of Norman's land area (60,237 acres) is vacant or only partially developed. Much of this undeveloped land (approximately 45,000 acres) is located in the western area (Ten-Mile Flats) and eastern area (from about 48th Avenue East to the City limits). These parts of the City lack readily available infrastructure such as water, sewer and an urban street network. This lack of infrastructure and remoteness make these areas extremely costly to develop, service, and maintain with urban systems. In addition, a significant portion of the vacant land is impacted by environmental or man-made constraints.

DEVELOPMENT CAPACITY

Development Capacity is an analysis of the undeveloped areas within the City, their suitability to be urbanized, and is designed to calculate the amount of different types of land uses that can be accommodated by the Land Use Plan. The analysis is made by preparing a summary of the proposed land uses within the City of Norman and, from that summary, by calculating the "capacity" of the vacant lands to accommodate future development. In preparing the future land use plan for the City, this analysis is needed to determine if the proposed Plan will allow the projected demands for land to be met. Multipliers derived from this analysis determine the degree of market flexibility provided for in the Land Use Plan.

The Development Capacity calculations are made through a process that first focuses on quantifying the amount of vacant, undeveloped land within the City by geographic location through an analysis of what lands are already developed. The second step further reduces the "quantity" of vacant, undeveloped lands through a qualitative process that involves determining the "suitability" of the land to support and sustain an urban environment. This step of the analysis was first used in development of NORMAN 2020 and is based to a large degree on work completed for the *Norman Greenway Study* undertaken through the College of

Architecture at the University of Oklahoma in 1994. This qualitative process utilizes primarily three groups of categories for analysis. Using geomorphology (bedrock geology and subsurface hydrology), physiography (flood plains and slopes) and soils (percolation rates, shrink/swell potential, fertility, erosion potential and depth to bedrock) the process identifies development constraints. This information was central to the identification of Growth Area boundaries and was integral to both the NORMAN 2020 Plan and this subsequent NORMAN 2025 Land Use and Transportation Plan. Based on a combination of existing zoning and proposed land uses, the development capacity of the vacant land is calculated. This analysis reveals that of Norman's approximately 60,237 acres of vacant land, only about 49,000 are unencumbered by development constraints. Of these 49,000 acres of vacant land, only about 8,000 acres are suitable for development at urban densities. Although preliminary numbers for capacity based upon NORMAN 2020 were prepared early in the planning process, only after preparation of a draft NORMAN 2025 Land Use and Transportation Plan could we prepare accurate calculations of development capacity. Those calculations reflect that the NORMAN 2025 Land Use and Transportation Plan will accommodate the following:

Land Use Type	Capacity
New Residential Units at urban densities	Over 22,000 units
New Office Construction	Almost 150 acres
New Commercial Construction	Over 600 acres
New Industrial Construction	Over 1,100 acres
Mixed-Use Development	Almost 800 acres
New Residential Units on Residential Estates	Over 3,000 units
New Residential Units on Large Lots	Over 5,000 units

Although not excessive, these numbers show that NORMAN 2025 provides adequate development capacity to accommodate the demand projected in the Development Demand Technical Memorandum.

FUTURE LAND DEMAND

An assessment of past, present and future population and employment growth is the foundation for projecting the amount of land needed over the next 20 years for new residential, commercial, industrial and institutional (recreational and educational) uses. These projections and land demand forecasts were prepared as part of the *NORMAN 2025 Land Demand Analysis,* a technical report prepared by the consulting team that assisted the City with preparation of this Plan. The methodology for this analysis follows a three-step process: 1) determine future employment in Norman (as a percent of Cleveland County projected employment) for private sector employment (retail commercial, offices, and industry) and estimate land requirements to accommodate the projected employment; 2) determine the number of future households and dwelling units in the City, by type (i.e., single family, multi-family, etc) and estimate land requirements to accommodate projected residential development; and 3) estimate land requirements for public sector uses, specifically schools and parks, based on projected population growth. The primary resource for the employment and population forecasts used in the *Land Demand Analysis* is data provided by Woods & Poole Economists, Inc., as excerpted from the *2003 Data Pamphlet: Cleveland County, Oklahoma*. The complete *NORMAN 2025 Land Demand Analysis* is available at the City of Norman website and from the City's Planning and Community Development Department.

Non-Residential Land Use Demand

The City's private sector employment is projected to rise from 45,438 in 2004, to 63,272 employees by 2025. There will also be continuing future emphasis on retail sales and services in the City. By 2025, it is estimated that almost 75% of all jobs in the private sector will be in the "retail trade" or "services" employment sectors. Based on the City's employment projections through 2025, a total of 1,041 acres will be needed to accommodate office, commercial and industrial growth demands over the 20-year planning period. Of these acres, 621 acres (60%) are projected to be consumed by retail uses, 198 acres (19%) by industrial/warehousing and 221 acres (21%) by office uses (Table 1).

Table 1
NONRESIDENTIAL LAND DEMAND BY LAND USE -- 2004-2025
CITY OF NORMAN

	2004 - 2010	2011 - 2015	2016 - 2020	2021 - 2025	TOTAL
OFFICE USES					
EMPLOYMENT INCREASE	1,761	1,598	1,718	1,842	6,919
FLOOR AREA GENERATED	528,300	479,400	515,400	552,600	2,075,700
NET ACRES CONSUMED	**56.3**	**51.0**	**54.9**	**58.8**	**221.0**
RETAIL USES					
EMPLOYMENT INCREASE	2,152	1,974	2,143	2,317	8,586
FLOOR AREA GENERATED	1,076,000	987,000	1,071,500	1,158,500	4,293,000
NET ACRES CONSUMED	**155.8**	**142.9**	**155.1**	**167.7**	**621.6**
INDUSTRIAL/WAREHOUSING USES					
EMPLOYMENT INCREASE	625	543	569	592	2,329
FLOOR AREA GENERATED	500,000	434,400	455,200	473,600	1,863,200
NET ACRES CONSUMED	**53.1**	**46.2**	**48.4**	**50.3**	**198.0**

SOURCE: NORMAN 2025 Land Demand Analysis

Residential Land Use Demand

Population and household projections show that Norman's population will increase by 34,046 people, rising from 103,101 in 2004 to 137,147 by 2025. The number of households in the City is projected to increase to 53,897 by 2025, an increase of 15,063 households (Table 2). Based on these population and household projections, it is estimated that Norman will have a demand for approximately 13,066 new housing units over the next 20 years. Of this number, it is estimated that 10,032 units (77%) will be single-family, 1,742 (13%) will be apartments and the remaining 1,291 (10%) will be a combination of duplexes, triplexes, quadriplexes and townhouses (Table 3).

Table 2
POPULATION FORECASTS -- 2000-2025
CITY OF NORMAN

	2000	2004	2010	2015	2020	2025
AVERAGE HOUSEHOLD SIZE IN CITY	2.31	2.29	2.29	2.31	2.34	2.39
NUMBER OF HOUSEHOLDS	38,834	42,199	45,964	48,946	51,586	53,897
POPULATION IN HOUSEHOLDS	89,623	96,747	105,404	112,949	120,779	129,074
POPULATION IN GROUP QUARTERS	6,071	6,354	6,804	7,203	7,625	8,073
TOTAL CITY POPULATION	**95,694**	**103,101**	**112,208**	**120,152**	**128,404**	**137,147**

Source: NORMAN 2025 Land Demand Analysis
* Group quarters include institutionalized persons and persons in dormitories and other nonhousehold living arrangements.

Table 3
HOUSING FORECAST -- 2025
CITY OF NORMAN

	2004			2025	
	Number	Percent	Increase %	Increase	Total
Single-Family Detached	27,270	61.25%	71.60%	9,356	36,625
Mobile Home	1,971	4.43%	5.18%	676	2,648
SUBTOTAL SINGLE-FAMILY	**29,241**	**65.67%**	**76.78%**	**10,032**	**39,273**
Two-Family (Duplex)	1,405	3.16%	2.13%	279	1,684
Triplex/Quadriplex	3,225	7.24%	4.90%	640	3,865
Townhouses	1,878	4.22%	2.85%	373	2,251
Multi-Unit (5+)	8,776	19.71%	13.33%	1,742	10,518
SUBTOTAL MULTI-FAMILY	**15,283**	**34.33%**	**23.22%**	**3,034**	**18,317**
TOTAL	**44,524**	**100.00%**	**100.00%**	**13,066**	**57,590**

Source: NORMAN 2025 Land Demand Analysis

Using information on dwelling units and average lot area per dwelling unit figures, projections for residential land acreage demand are estimated in Table 4. Of the 13,065 total new dwelling units projected through 2025, 84% are anticipated to be built in the urban area and 16% on larger lots in the rural areas. Of those to be built in the urban area, 7,952 are projected to be single-family and will require approximately 2,396 acres. An additional 293 acres are projected to be required for the over 3,000 anticipated multi-family units. Additionally, another 2,080 single-family units are projected for the rural areas. Of those, about 400 will be built on 2-acre residential estates with the remaining over 1600 units being built on mostly 10-acre parcels.

Table 4
RESIDENTIAL LAND DEMAND BY LAND USE -- 2004-2025
CITY OF NORMAN

	2004 - 2010	2011 - 2015	2016 - 2020	2021 - 2025	TOTAL
COUNTRY RESIDENTIAL					
NEW HOUSING UNITS	588	406	359	311	1,664
NET ACRES IN LOTS	5,880.0	4,060.0	3,590.0	3,110.0	16,640.0
NET ACRES CONSUMED	**6,174.0**	**4,263.0**	**3,769.5**	**3,265.5**	**17,472.0**
VERY LOW DENSITY RESIDENTIAL					
NEW HOUSING UNITS	147	101	90	78	416
NET ACRES IN LOTS	294.0	202.0	180.0	156.0	832.0
NET ACRES CONSUMED	**323.4**	**222.2**	**198.0**	**171.6**	**915.2**
LOW DENSITY RESIDENTIAL					
NEW HOUSING UNITS	2,810	1,941	1,718	1,483	7,952
NET ACRES IN LOTS	677.4	467.8	414.2	357.4	1,916.8
NET ACRES CONSUMED	**846.8**	**584.8**	**517.7**	**446.7**	**2,396.0**
MEDIUM DENSITY RESIDENTIAL					
NEW HOUSING UNITS	456	315	279	241	1,291
NET ACRES IN LOTS	55	38	34	29	156
NET ACRES CONSUMED	**65.8**	**45.5**	**40.3**	**34.8**	**186.3**
HIGH DENSITY RESIDENTIAL					
NEW HOUSING UNITS	615	426	376	325	1,742
NET ACRES IN LOTS	34.2	23.7	20.9	18.1	96.8
NET ACRES CONSUMED	**37.6**	**26.0**	**23.0**	**19.9**	**106.4**

SOURCE: Ross + Associates 2004

Summary of Land Demand Forecasts

Table 5 summarizes all of the land demand forecasts. During the 20-year planning period, over 22,600 acres of land (35.4 square miles) are forecasted to be consumed by the construction of residences and businesses, and through public acquisitions for parks and schools. These figures represent only the actual land projected to be occupied by new construction and development. Additional land also will be "consumed" by the development of subdivisions and other projects but will be vacant at any given point in time, awaiting building construction.

Table 5

SUMMARY--NET LAND DEMAND BY LAND USE -- 2004-2025

CITY OF NORMAN

	2004 - 2010	2011 - 2015	2016 - 2020	2021 - 2025	TOTAL
NONRESIDENTIAL PRIVATE SECTOR					
OFFICE USES	56.3	51.0	54.9	58.8	221.0
RETAIL USES	155.8	142.9	155.1	167.7	621.6
INDUSTRIAL/WAREHOUSING USES	53.1	46.2	48.4	50.3	198.0
SUBTOTAL--PRIVATE SECTOR	***265.2***	***240.1***	***258.4***	***276.9***	***1,040.6***
PUBLIC SECTOR					
PARKS	269.5	69.9	74.3	78.7	492.3
SCHOOLS*	-	-	20.0	20.0	40.0
SUBTOTAL--PUBLIC SECTOR	***269.5***	***69.9***	***94.3***	***98.7***	***532.3***
RESIDENTIAL					
COUNTRY RESIDENTIAL	6,174.0	4,263.0	3,769.5	3,265.5	17,472.0
VERY LOW DENSITY RESIDENTIAL	323.4	222.2	198.0	171.6	915.2
LOW DENSITY RESIDENTIAL	846.8	584.8	517.7	446.7	2,396.0
MEDIUM DENSITY RESIDENTIAL	65.8	45.5	40.3	34.8	186.3
HIGH DENSITY RESIDENTIAL	37.6	26.0	23.0	19.9	106.4
SUBTOTAL--RESIDENTIAL	***7,447.6***	***5,141.5***	***4,548.4***	***3,938.5***	***21,076.0***
TOTAL	**7,982.2**	**5,451.5**	**4,901.1**	**4,314.1**	**22,648.8**

* New schools only, not including expansion of existing schools or replacement of aging and obsolete schools.

II. Land Use & Transportation Plan

INTRODUCTION

The NORMAN 2025 *Land Use and Transportation Plan* represents a long-range 20-year vision for the physical development of the City. It is grounded in planning goals and policies that set the general direction of the Plan. These *Goals and Policies* articulate a basic desire by the City to manage the location of its growth in a fiscally and environmentally responsible manner, while encouraging healthy economic development. In order to accomplish these goals, the City is organized into geographic *Growth Areas*, based on factors related to infrastructure delivery and suitability for urban development. These growth areas, in turn, serve as a framework for the designation of a future *Land Use Plan*. This *Land Use Plan* recommends future land use categories for all property in the City. A *Transportation Plan* has been prepared which is consistent with the Growth Areas and supports the Land Use Plan.

The Plan sets the stage for the City to be proactive in the way it manages growth. Through the use of Growth Areas, the Plan establishes priority areas for urban development based on existing or proposed public facilities. The Plan depicts a healthy development balance between the eastern and western areas of the City, with significant areas identified for future urban densities. It identifies areas suitable for industrial development and sets the stage for providing that these areas be protected from conversion to other uses. It also establishes very low densities for areas that are environmentally sensitive such as the Garber-Wellington aquifer recharge area and the Ten-Mile Flats floodplain, so as to minimize the numbers of dwellings located in those areas. It further protects the City's environmentally sensitive areas by limiting development in the 100-year floodplain and requiring structures to be shifted to higher, non-flood plain parcels. Cluster developments are also encouraged to reduce environmental impacts and to help facilitate a greenway system throughout the City, primarily along the Little River and Canadian River and their tributaries.

GOALS AND POLICIES

The Goals and Policies are the key integrating force behind the *NORMAN 2025 Land Use and Transportation Plan*. They establish a general statement of intent for the future growth and development of the City and serve as the policy basis for the more specific growth area designations, land use recommendations, and streets and highway designations. They will be used as a guide for future land use and infrastructure decisions and for considering requests to amend the Plan.

The Goals and Policies encompass a progression of growth-related principles that articulate the most efficient and environmentally responsible way for Norman to handle growth through the year 2025. The City of Norman is best served by managing growth through influencing the location choices of future development. Infrastructure is recognized as being an effective tool to manage the location of growth. Urban-level growth is encouraged to locate where infrastructure is readily available and discouraged in the more rural and environmentally sensitive areas of the City. The long-term economic health of the City is also a major influencing factor for future growth, as are protection of the rural environment and the provision of a greenbelt system throughout the City. Each of these goals is stated below, followed by a series of policies related to the goal. These statements are the policy framework for the *NORMAN* 2025 *Land Use and Transportation Plan*.

Goal 1: Managed Growth

Affirmatively and responsibly manage the location of growth in Norman based on available public services and the environmental suitability of the land for development.

POLICIES:

1. Accommodate a projected year 2025 population of 137,000 people in a fiscally responsible and environmentally sensitive manner.
2. Promote a compact urban area by directing development into areas within or in proximity to the existing infrastructure-serviced areas.
3. Continue to support the revitalization and redevelopment of Norman's central business district.
4. Promote compatible mixed-use developments within existing urban areas.
5. Protect the water quality of Lake Thunderbird and the Garber-Wellington aquifer by restricting development in flood plains, aquifer recharge areas and areas of erosion-prone soils.
6. Guide development into locations where the land use is most cost-effectively served by urban level services (i.e., accessible to water, sewer, and the urban road network).
7. Balance development on the east and west sides of the urbanized area of Norman by continuing to encourage commercial and residential development on the urban east side.
8. Support infill development on properties that have been skipped over within the urban areas.
9. Discourage areas identified for urban densities from being prematurely developed at very low, non-urban densities by prohibiting the rezoning of areas located in the Current and Future Urban Service Areas for other than urban-level land uses (typically more than 3 dwelling units per acre).

Goal 2: Infrastructure-Supported Growth

Utilize the provision of infrastructure in supporting and influencing growth into areas most suitable for development.

POLICIES:

1. Support growth that minimizes operational costs by encouraging development in areas where adequate public water, sewer and roads are currently available or can inexpensively be extended.
2. Require urban development densities in areas where substantial investment in urban level infrastructure has been made, thereby encouraging greater utilization of the infrastructure investment.
3. Use infrastructure to influence growth toward areas suitable for development and away from areas of restricted or very low suitability.
4. Continue to prohibit development accessing unopened section line roads.
5. Maintain compact urban form by permitting new or expanded sewer lift services only in the Current Urban Service and Future Urban Service Areas and requiring appropriate fee surcharges for permanent maintenance of lift stations.
6. Maintain and improve infrastructure in the existing urban areas.
7. Monitor the impact of development on existing and future infrastructure capacities.

8. Extend major utility lines and facilities only into those areas identified for urban development.
9. Approve new development only when the facilities to serve it will be concurrently available
10. Advance fair and predictable standards for allocation of infrastructure costs between the development community and the City.
11. Address existing and future infrastructure right-of-way needs by acquiring land prior to development or as part of the development, to include adequate right-of-way for shared storm water and greenway systems.
12. Encourage regional and state highway planning for roadway improvements consistent with desired growth patterns and the Transportation Plan.
13. Encourage opportunities for multi-modal transportation, such as Park and Ride Facilities in both south and north Norman.
14. Explore and encourage opportunities for both on and off-street bicycle and pedestrian facilities for commuting to work, schools, shopping, between neighborhoods, and/or other destinations.
15. Discourage through traffic within existing neighborhoods or planned areas by routing it to the major street system.
16. Orient parks and recreational facilities to the needs of all Norman's citizens, including persons with disabilities, senior citizens, young children, and teenagers; and provide for a variety of interests and activities.

Goal 3: Housing and Neighborhoods

Encourage and support diversified housing types and densities in order to serve different income levels, family structures, and ownership.

Policies:

1. Proactively manage the preservation, revitalization and maintenance of existing urban neighborhoods.
2. Establish a neighborhood planning program for targeted portions of the City's core area, in order to address such issues as land use compatibility, parking, circulation, and neighborhood improvements.
3. Encourage opportunities for pedestrian and bicycle facilities in and between neighborhoods and other activity areas.
4. Foster and encourage construction of new residential units, and conversion of underutilized buildings into residential units, in downtown Norman.
5. Create an overlay Neighborhood Conservation District in order to more closely monitor and discourage illegal or inappropriate conversions of housing, as needed for neighborhood stabilization.
6. Adopt an implementation strategy regarding occupancy limits of a dwelling, such as requiring that occupancy be limited by adequate on-site parking, size and number of bedrooms, etc., to ensure that single-family units are used for their intended purpose instead of rooming/boarding houses.
7. Develop an incentive program that encourages development of affordable housing.
8. Support the provision of affordable housing through the periodic review of development regulations and administrative procedures to eliminate any unnecessary costs.
9. Encourage housing designed for university student occupancy in areas suitable for high intensity uses.
10. Equitably disperse publicly assisted housing throughout the City, utilizing sub-community planning districts as a geographic framework for distribution, in accordance with the allocation models and procedures contained within the Housing Master Plan, as amended.
11. Adopt an implementation strategy that seeks to ensure that the City's limited supply of land designated for medium and high-density residential is not converted to lower-density uses, in order to preserve the City's compact urban form.

Goal 4: Economic Stability and Enhancement

Enhance the quality of economic growth in the City by attracting high technology-related industries that have low environmental impacts.

POLICIES:

1. Diversify the economic base of the City to create a better balance of privately operated corporations with continued growth in the public sector employment base.
2. Direct environmentally responsible industrial growth onto land that is highly suited for industrial development.
3. Protect suitable industrial land from residential conversion or encroachment by:
   - Identifying and rezoning it to an industrial zoning classification;
   - Critically reviewing rezoning requests for conversion of industrial land to non-industrial uses; and
   - Assessing the impact of incompatible land uses adjacent to industrial lands.
4. Consider industrial uses that have minimal infrastructure demands and environmental impacts for suitable areas outside the urban service areas.
5. Solicit industrial prospects that do not overburden the City's existing or planned infrastructure such as water, sewer or roadways.
6. Initiate redevelopment and revitalization projects in the central business district that assist in enhancing the area as a viable economic entity in Norman.
7. Promote mixed-use developments that provide for a balance of housing, services, and employment in appropriate locations.
8. Support the extension of public utilities and business recruitment efforts for development of the University Research Park and South Campus.
9. Promote greater utilization of public transit services to support employment opportunities.
10. Secure payments-in-lieu of taxes related to development of for-profit ventures occurring within properties that are tax exempt.
11. Prepare and adopt design standards for commercial development in order to improve the appearance of the City's commercial corridors, help attract other high-quality development, and improve the city's economic foundation.

Goal 5: Rural Character and Development

Retain the distinct character of rural Norman and protect the environmentally sensitive Little River Drainage Basin.

POLICIES:

1. Preserve rural Norman's character and protect its environmentally sensitive nature.
2. Maintain development densities in rural Norman that generally do not exceed 1 unit per 10 acres.
3. Encourage cluster developments and preserve open space by providing bonus densities and by simplifying regulations.
4. Establish a level of public service delivery for rural Norman that is appropriate for the rural setting.
5. Protect water quality in Lake Thunderbird and the Garber-Wellington aquifer from point and non-point pollution related to development (impervious surface run-off, oil and gas drilling, disposal of toxic chemicals, etc.)

6. Minimize the amount of development that occurs in the 10-Mile Flats area, in order to preserve the area's character as well as protect residents from hazards associated with flooding.
7. Ensure that the costs for provision of services for development occurring in Norman's rural areas, such as roadways, police protection, emergency services, and solid waste disposal, are fully borne by rural area residents and are not subsidized by urban area residents.
8. Establish a community separator area between Norman and neighboring communities to the north.
9. Continue to accommodate limited commercial opportunities in rural east Norman through the use of Special Enterprise Areas (on 20-acre minimum lots), where service oriented tourism facilities relating to Lake Thunderbird as a destination can capitalize on the rural, pastoral qualities identified and sought to be maintained in the area.

Goal 6: Greenbelt Development

Develop and maintain a greenbelt system for Norman.

Policies:

1. Use greenbelts to protect environmentally sensitive lands that are generally the least suitable for development, especially flood prone areas.
2. Encourage the use of lot clustering in areas not served with sanitary sewers as a means to develop the greenbelt system.
3. Use the greenbelt system to link together existing recreation areas.
4. Create a multi-purpose greenbelt corridor that:
   - Creates a unique greenway character for Norman;
   - Protects the environmentally sensitive areas of the City and serves as a wildlife habitat;
   - Serves as a stormwater management resource for urban run-off and regional detention needs;
   - Provides recreation opportunities for bicycling, walking and jogging, as well as an alternative route to move through the City for commuting to work, schools, shopping, between neighborhoods, and/or other destinations by bicycling or walking;
   - Preserves agriculturally significant lands; and,
   - Provides suitable locations for sanitary sewer easements and facilities.
5. Use greenbelts to provide open space areas adjacent to highways and major streets for sound buffer zones and protection from incompatible land uses.
6. Continue to improve a natural landscape planting and maintenance program for City-owned properties and rights-of-way of major streets and highways.

Goal 7: Core Area Stability and Enhancement

Continue efforts to promote the enhancement and stability of the core area.

Policies:

1. Continue to promote public and private efforts to strengthen the Downtown area through implementation of the Downtown Norman Revitalization Plan.
2. Continue efforts to work with Norman Regional Hospital on issues related to land use, transportation, and expansion.
3. Continue efforts to work with the University of Oklahoma on issues related to facility location, design, and expansion, as well as student housing, parking, and public transit usage.

4. Establish a neighborhood planning program for targeted portions of the City's core area, in order to address such issues as land use compatibility, parking and circulation, bicycle and pedestrian facilities, public transit facilities and usage, and neighborhood improvements.
5. Adopt an implementation strategy to address the potential impacts of building conversions to parking in the core area.
6. Adopt an implementation strategy to address the potential impacts of parking in the core area, to ensure that new or expanded parking areas are properly designed and buffered to minimize impacts on other uses in the neighborhood.
7. Adopt an implementation strategy to strengthen controls on building demolitions and/or conversions in the core area.

GROWTH AREAS

An integral part of the NORMAN 2025 Land Use and Transportation Plan is the continued designation of various Growth Areas related to the character, density and level of appropriate public services. The Growth Areas are designated as part of the ongoing effort to accomplish the Goals and Policies related to managing the location of growth in relation to infrastructure and the suitability of land for development. The four Growth Areas are: Current Urban Service Area; Future Urban Service Area; Suburban Residential Area; and Country Residential Area. Each is described in the following text and depicted on Figure 1

Current Urban Service Area

The Current Urban Service Area consists of the urban area currently sewered or sewerable by gravity flow, as well as those areas served by existing lift stations or currently designed to be accommodated by them. It is a central policy of the Plan that the areas currently served by sanitary sewers have the highest priority for new growth and development.

To accomplish the policy priority of encouraging development in the existing sewer service area, it is necessary to reserve sewer capacity either as it exists now or as it is expanded through improvements. It is important that this area develop at urban densities (greater than 3.5 units per acre) appropriate for sewer expansion, and that costs of the required infrastructure expansion are shared by the development community.

The City will continue efforts to maintain the health and stability of this area in order to maintain the quality of life for residents and businesses, and to make the area attractive for new development. The City will continue to revitalize the central business district and the Campus Corner area through a variety of efforts as outlined in the *Downtown Norman Revitalization Plan* and as undertaken by the private sector in the Campus Corner Area. Continued efforts will be made to protect residential resources and strengthen existing neighborhoods through mechanisms such as the CDBG program.

Future Urban Service Area

The Future Urban Service Area is comprised of areas that are presently outside the existing water and/or sanitary sewer service areas, where urban land uses are recommended. The City recognizes that, due to infrastructure requirements, not all portions of the Future Urban Service Area will be able to develop at urban densities in the near future. This raises the concern about the need to prevent development at less than urban densities from occurring in those areas in the interim. In order to ensure that development at less than urban densities does not occur in these areas, City Council will continue the policy that does not allow for these areas to be rezoned to Residential Estate, and that they remain subject to the A-2 zoning regulations. It is recognized that existing A-2 zoned parcels would still be allowed to be built upon with individual water wells and sewage treatment. However, subdividing existing A-2 parcels into smaller than 40 acre tracts will be prohibited unless the development is done as a small cluster with provision for full urban services at a later date, whenever they become available. Approval of the cluster subdivision would require that appropriate agreements be recorded to preserve the remainder of the parcel for later development at higher densities. Subdivision design standards in this district could require, among other things, reservation of utility easements to accommodate future urban level development. Under such circumstances, the clustered lot sizes will range from ¾ acre to 2 acre depending upon specific site conditions, such as topography, soil conditions, etc.

In order for the designation of an area to change from Future Urban Service Area to Current Urban Service Area, the following criteria must be met:

- Adequate public facilities (water and sanitary sewer) are in place, or will be in place at the time that they develop.
- Development of these areas will not result in a utilization of the "Current Urban Service Area" sanitary sewer capacities within the outfall lines or at the treatment plant.

The Growth Area boundaries indicated on figure 1 are approximate, and may be modified slightly at the time of application for a designation change as a result of detailed engineering or topographic studies.

Suburban Residential Area

The Suburban Residential Area consists of areas suitable for development from an environmental standpoint, but not planned for sanitary sewer service. Therefore, the Plan recommends development at suburban densities of not more than one unit per two acres. Development will generally require individual water wells and sewage treatment systems; however, city water should be provided for any development in this area where high quality water cannot be assured. It is important for the City to maintain the rural nature of this area and to be explicit as to the limited infrastructure anticipated. Specifically, the City does not plan to extend sanitary sewer service to this area.

Much of the desired greenbelt is located in this area, so the use of lot clustering to preserve open space is appropriate in some circumstances. Through the Planned Unit Development process, a bonus will allow a gross density of one and one-half (1 ½) acres per dwelling unit (no bonus provided for those acres lying within the 100 year floodplain). The bonus requires that at least 35% of the total site be set aside as permanent open space. Conservation easements for privately owned lands are appropriate for such areas. The minimum lot size per dwelling unit will be 3/4 of an acre. To be granted this increased density, cluster developments will require installation of a community water system to current city standards, including the provision of fire protection.

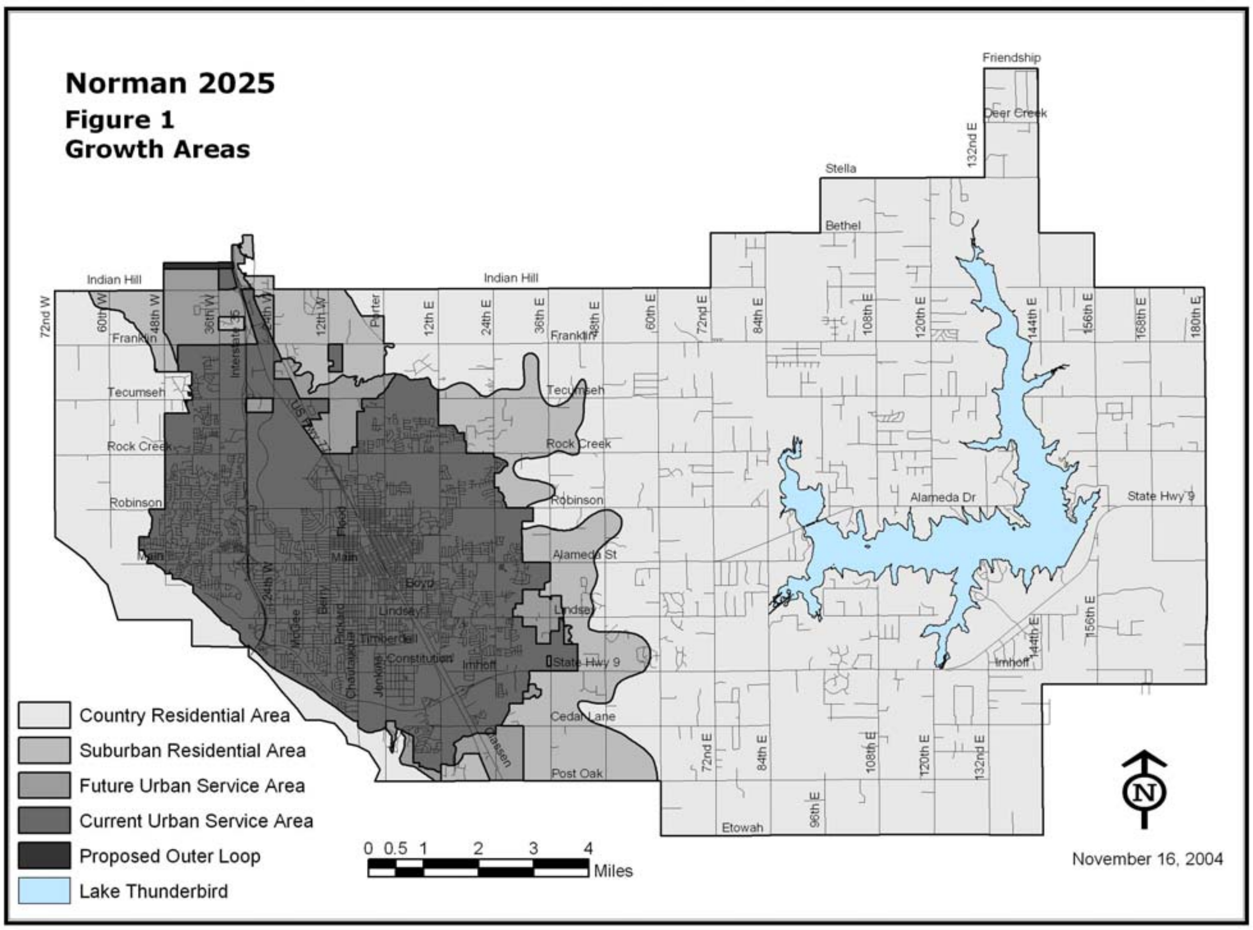
Country Residential Area

The Country Residential Area encompasses predominately those portions of Norman that are over the Garber-Wellington Aquifer primary recharge area and/or within the flood plains of the Little River and South Canadian River. These areas have low suitability for development at urban densities. This low suitability for development within the floodplains of the rivers is due to occasional flooding that will occur. The low suitability in the Garber-Wellington Aquifer primary recharge area is not only because of the threat of contamination to the ground water in the aquifer, but also because of the combination of generally erodible soils, steeper slopes, and the potential for contamination of this portion of the Lake Thunderbird watershed. Additionally, these areas provide significant benefits to the overall quality of life in Norman due to the large amounts of undeveloped open space and the presence of a substantial number of wildlife habitats.

Most of this area is planned for a maximum density of one dwelling unit per ten (10) acres (i.e. ten (10) acre minimum lot size.) A bonus is available for cluster developments, not including acres in the 100 year floodplain. For those areas subject to the ten (10) acre restriction, development may be done so that the home building sites are clustered on approximately two (2) acre lots. When this cluster development option is utilized (through the Planned Unit Development process), a bonus density of up to a total maximum number of dwelling units of one (1) unit per eight (8) acres gross density is available. The portion of the property on which a cluster development is based, but which is not used for the two (2) acre lots, must be set aside for permanent open space and should be at least 65% of the total acreage. (This open space can be held by a single owner or transferred to a mandatory Home Owners Association.)

For floodplain areas within the Little River/Lake Thunderbird tributaries, the City will require the shifting of density out of the 100-year floodplain onto areas of a site that are not in the floodplain, except in those instances where no such option exist on already created legal parcels. Floodplain areas within the Ten-Mile Flats area shall develop with at least twenty (20) acre lots.

Another issue that this Plan begins to address in the Country Residential Area is the cost differential between development in the urban area and the rural area. While service and maintenance costs are higher per capita in the rural areas for certain facilities and services (such as roads and solid waste disposal), the City does not currently have any mechanisms to address this cost differential. In reality, due to higher development costs in the urban area, the City's current low development standards and fees in the rural areas may artificially induce pressure for growth in these areas.



LAND USE PLAN

The *Norman 2025 Land Use and Transportation Plan* is grounded in the Goals and Policies that set the general direction of the Plan. In order to accomplish these goals, the City is organized into geographic Growth Areas, based on factors related to infrastructure delivery and suitability for urban development. These growth areas, in turn serve as a framework for the designation of a future *Land Use Plan*. This *Land Use Plan* recommends future land use categories for all property in the City.

The Plan is proactive in the way it manages growth. Through the use of Growth Areas, it establishes priority areas for urban development based on existing or proposed public facilities. It discourages sprawl and suggests minimum urban densities. The Plan depicts a development balance between the eastern and western areas of the City. It identifies areas suitable for industrial development and recommends that these areas be protected from conversion to other uses. It also establishes low densities for areas that are environmentally sensitive such as that portion of the Little River drainage basin overlaying the principal recharge areas of the Garber-Wellington aquifer and the Ten-Mile Flats flood plain. It further protects the City's environmentally sensitive areas by encouraging clustering of development to reduce environmental impacts and to complement a proposed greenway system throughout the City.

The Plan blends a healthy amount of residential and commercial growth with an aggressive amount of area recommended for industrial development. It also recognizes that commercial development in Norman may include commercial activities and services such as office uses; neighborhood and community shopping centers; the central business district; highway service areas; and regional shopping centers.

The NORMAN 2025 Plan will accommodate nearly 31,000 new dwelling units. Of these new units, an estimated capacity for over 15,000 new single-family structures accommodates almost twice the projected demand for 7,952 new single-family dwelling units by 2025. The capacity for slightly over 5,000 new dwelling units at medium and high density provides for about 165% of the projected demand for just over 3,000 new units by 2025. The NORMAN 2025 Plan also provides about 650 acres for new commercial land uses, about 150 acres for office land uses, almost 1,200 acres for future industrial land uses and almost 800 acres of land designated for mixed-use development (which will accommodate a mixture of residential, commercial, office and industrial land uses.) The projected demand through 2025 for each of the above uses is 221 acres of office, 622 acres of commercial, and 198 acres of industrial. The capacity provided will accommodate about 75% of the office demand, about 105 % of the commercial demand, and almost 1,000 more acres for industrial uses than the projected demand of slightly less than 200 acres. The almost 800 acres of mixed-use lands also provide for additional acres for commercial, office and industrial uses. The Plan also identifies three new community parks.

Mixed-Use Development

The Plan also introduces and incorporates the concept of *mixed-use development*, to provide for a more flexible approach to development in specific targeted areas. Mixed-use development is intended to create an environment for well-planned, mutually supportive uses containing a mixture of different densities and types of residential uses and supporting areas for office-based employment, retail activities and institutional uses, planned and designed according to a unified, cohesive master plan for a given area with high quality architectural design. Pedestrian-oriented, mixed-use neighborhoods that incorporate a variety of styles, residential types and densities and appropriate non-residential uses, include an interconnected street network, promote pedestrian travel and access, and foster neighborhood interaction, will be encouraged in appropriate locations throughout the City.

Uses for each mixed-use development will vary, but all should be designed as urban activity centers—community destinations for working, shopping, and/or entertainment. The planning of these areas should be pedestrian-oriented, and special improvements should be considered to make them rich, enjoyable public places. Mixed-use development can occur in two primary configurations – *Vertical Mixed-Use* or *Horizontal Mixed-Use*.

Vertical mixed-use refers to the integration of two or more land use types within a building, occurring on different floors. A typical example of a vertical mixed use building would incorporate active uses, such as stores and restaurants, at the street level and residential or office uses on the upper floors. *Horizontal mixed-use* refers to a pattern where several types of uses or buildings are included, as part of a cohesive development in proximity to each other – but each building would contain its own separate use. An example would be a development site that might include an area of multi-family housing, a professional office building, and a retail center. They would be designed as a set of coordinated uses, with common parking areas, good pedestrian connections, and perhaps similar design features, but would contain separate uses in each building.

Since mixed-use development provides for a flexible approach to development, it must be uniquely tailored to each site – there is no "one size fits all" approach. Thus, we are recommending a Special Planning Area designation (see below) for each of the areas designated on the NORMAN 2025 Land Use and Transportation Plan for *Mixed-Use* development, to ensure that an overall unified development plan is prepared for each site prior to development.

The design of mixed-use development should take into consideration the following characteristics:

Residential Density and Mix of Housing Types

Residential density should be sufficiently high in order to support a level of pedestrian activity, and should typically be not less than six (6) dwelling units per acre. A mix of two or more different housing types should be included, at varying densities. Residential dwellings located above first-floor retail, offices, and services are encouraged.

Non-Residential Uses

A mix of non-residential uses is encouraged, in order to incorporate opportunities for employment, shopping, and services. Non-residential uses should be designed so that they are integrated into the overall site plan and design, not as isolated areas from other uses in the development. Auto-oriented uses such as auto repair and service shops, large-format commercial "super-stores", and drive-through restaurants are generally discouraged in mixed-use development areas; however, the use of creative site layout and design techniques to develop pedestrian-supportive designs that would be appropriate within mixed-use areas may be considered. This would include an overall reduction in scale that accommodated reduced parking areas, building setbacks, and building footprints (for example, "super-stores" and other large commercial uses would typically be restricted to less than 40,000 square feet). In addition prototypes would seek to minimize conflicts between automobiles and pedestrians and provide detailed attention towards pedestrian orientation and accessibility.

Defined by Streets or Other Physical Features

Mixed-use developments should generally be bounded by physical or constructed features with some level of permanence, such as streets, greenways, or other open spaces.

Containing Public Plazas or Open Space Designed as a Focal Point

Mixed-use developments should include at least one predominant location for an outdoor open space or plaza, with amenities such as benches, monuments, kiosks, or public art, designed to serve as a central gathering place or community activity center. These areas should be designed to create comfortable outdoor spaces designed to attract and accommodate people, where higher pedestrian activity is likely to occur. Outdoor spaces should be linked to and made visible from streets and sidewalks.

Pedestrian-Oriented Site Design

Entrances and parking lots should be designed to be both functional and inviting with continuous landscaped walkways linking all land uses. Buildings should be oriented to sidewalks or other outdoor spaces for people, not set back behind parking lots or oriented only to parking lots. Buildings on isolated "pad sites" surrounded by parking lots and driveways should not be incorporated. Parking lots should not dominate the frontage of streets, interrupt pedestrian routes, or negatively affect surrounding land uses or neighborhoods. Access must serve the needs of the pedestrian as well as the motorist. Accordingly, the following design aspects must be considered: (1) pedestrian access to the site and buildings; (2) gathering areas for people; and (3) auto access and parking lots. Continuous internal pedestrian walkways should be provided to connect focal points of pedestrian activity such as transit stops, street crossings, building entry points, and parking areas.

Interconnected Network of Multi-Modal Streets

An interconnected hierarchy of streets should be established to clearly define primary pedestrian and vehicular travel routes between uses. Streets should be designed to accommodate all modes comfortably and should provide a separation between incompatible modes, such as bicycles and pedestrians where possible. Cul-de-sacs or other dead end streets are strongly discouraged in mixed-use developments.

SPECIAL PLANNING AREAS

Within the Land Use Plan Map, several areas are identified that exhibit characteristics requiring special consideration. It is anticipated that these areas would develop as recommended in the Land Use Plan only through the Planned Unit Development (PUD) process, except for the Northern Community Separator Overlay District (SPA 6). Each of these areas has unique features or circumstances that create the need for this process if the land use as reflected on the Plan is to become a reality. Some of the Special Planning Areas identified in NORMAN 2020 have been completed, and are no longer designated in this Plan. The following information presents the areas to be included in this PUD process, their current circumstances, the proposed land uses and conditions that need to be met in order for development/redevelopment to occur.

SPECIAL PLANNING AREAS 1 AND 2

Existing Conditions

Special Planning Areas 1 and 2 are situated on the west side of 24th Avenue SW, between Briggs Street and State Highway 9 and directly east of and adjacent to Interstate 35. Both of these areas are primarily residential in nature but have been surrounded over time by a varied assortment of commercial activities. Most of the remaining residential structures are of modest construction and date back several decades. Access to these areas is now limited to 24th Avenue SW.

Although the predominate zoning in both of these areas remains R-1 (single family residential), actual existing land uses include a mixture of commercial (including landscaping/nurseries, auto and small engine repair, retail and services.) While many of the homes are on small lots, there are a number of homes in both areas that are located on very large lots, many of which are well kept. Although some sanitary sewer is nearby, most of the residential properties are on individual septic tanks. The construction of Interstate 35 and the continuing intrusion of commercial uses into the area are creating a less than desirable residential environment. Additionally, some of the existing businesses and surrounding grounds are poorly maintained, have unscreened storage and inadequately paved parking and are generally of substandard quality and appearance. There are also a number of poorly maintained mobile homes and residential units in the area.

Proposed land uses

All of these areas are projected to become commercial. Provision for this use is recommended if certain conditions are met.

Required development conditions

1. Consolidation of properties into unified ownership for each area prior to its redevelopment.

2. Provision of a master redevelopment plan prior to any rezoning or platting.

3. Provision of all city services and infrastructure adequate to accommodate full build out.

SPECIAL PLANNING AREA 3

Existing Conditions

Special Planning Area 3 is located north of the residential properties along the north side of Acres Street between University Boulevard and the planned location of Front Street just north of Andrews Park. This largely undeveloped triangular site is within the Adams Neighborhood. The area is bounded by the Burlington Northern/ Santa Fe Railroad tracks to the east, single family residential properties to the north, light industrial /service operations to the west, and a mixture of single and multi-family residential development to the south.

The majority of the site is currently zoned I-1 light industrial and much of it is vacant. The site includes the Rhodes Feed and Seed operation. The dominant adjoining land uses are the service/warehousing operations located on the adjacent I-1 zoned properties.

Proposed Land Uses

The redevelopment opportunities for the former milling operation and the opportunities for the vacant portions of this tract will be greatly impacted by the roadway and landscaping improvements planned for Front Street. It is anticipated that these properties will be converted to commercial uses when Front Street is completed. Provision for this use is recommended if certain conditions are met.

Required Development Conditions

1. Front Street must be completed as planned and include the extension of Highland Parkway through this tract.

2. No ingress and egress will be granted directly onto Front Street.

3. Convert the site from industrial to commercial use by either adaptive re-use of the existing old feed mill and accessory buildings or by demolition of the existing structures, so as to create a unified architectural appearance, especially on all building facades facing public streets.

SPECIAL PLANNING AREA 4

Existing Conditions

Special Planning Area 4 is situated between 36th Avenue NW and I-35, from Indian Hill Road south ½ mile. The area is undeveloped, but has been under growing pressure to change, primarily due to continued growth and expansion in the northern area of the City and good access from the I-35/Indian Hill Road interchange.

Proposed Land Uses

This area is designated for Mixed-Use Development, if certain conditions are met. The primary emphasis of this mixed-use development area is to allow for a mix of employment uses (such as office or light industrial), with some supporting commercial and medium or high density residential housing, as part of an overall, unified planned development. It is envisioned that employment and commercial uses would be oriented towards Indian Hill Road and I-35 to the north and east, and residential uses would be oriented towards 36th Avenue NW to the west. The area along 36th Avenue NW could also accommodate vertically integrated mixed-use buildings, with appropriate design treatments and transitions to adjoining residential areas.

Required Development Conditions

1. A unified overall master development plan that includes well-planned, mutually supportive uses containing a mixture of different densities and types of residential uses and supporting areas for office-based employment, retail activities and institutional uses, planned and designed according to a unified, cohesive master plan for the area.

2. A unified overall master development plan that adequately addresses potential impacts on adjoining residential areas, (especially along the south boundary and along 36th Avenue NW). This should include landscape treatments and/or setbacks, solid masonry attractive walls, and design treatments and building height transitions of buildings.

3. A unified overall master development plan that assures appropriate ingress and egress so as to mitigate the potential traffic impacts on 36th Avenue NW and Indian Hill Road.

4. Design treatments for building architecture, site design, signage, and landscaping that reflect the importance of this site as a visual gateway into the community.

5. If the development planned for the site occurs in more than a single phase, each phase shall include a mix of at least two land uses, as specified in a phasing plan included as part of the overall development master plan.

SPECIAL PLANNING AREA 5

Existing Conditions

Special Planning Area 5 is situated between 36th Avenue NW and I-35, from Franklin Road north ¼ mile, directly north of the proposed community park site. The area is undeveloped, but has been under growing pressure to change, primarily due to continued growth and expansion in the northern area of the City and good access from the I-35/Indian Hill Road interchange.

Proposed Land Uses

This area is designated for Medium Density residential development due to its' proximity to the proposed community park site and if certain conditions are met.

Required Development Conditions

1. A unified overall master development plan that assures appropriate ingress and egress so as to mitigate the potential traffic impacts on 36th W and Franklin Road.

2. A unified overall master development plan that adequately addresses potential impacts on adjoining residential areas, (especially along the northern boundary). This may include landscape treatments and/or setbacks, solid masonry screening walls or fences, and design treatments and building height transitions of buildings.

3. Design treatments for building architecture, site design, signage, and landscaping that reflect the importance of this site relative to the planned Community Park.

4. Residential uses shall be a minimum of 6 to 8 dwelling units per net acre, with a mixture of housing types and densities encouraged.

SPECIAL PLANNING AREA 6 – Community Separator

EXISTING CONDITIONS

Special Planning Area 6 is situated between Broadway Avenue and 72nd Avenue NE, extending north of Franklin Road to Indian Hill Road. The area is generally undeveloped or in agricultural use. The land use designations for this area reflect two primary objectives: protect the Little River watershed and tributaries, and create a sense of visual, physical separation between Norman and Moore.

PROPOSED LAND USES

This area is designated for clustered rural residential development at a gross density of one dwelling unit per 10 acres with a minimum lot size of 2 acres, and open space, if certain conditions are met.

REQUIRED DEVELOPMENT CONDITIONS

1. Mandatory shifting of density out of the floodplain, in order to protect the integrity of the Little River watershed and its tributaries. In order to maintain the density allowed by the base zoning, the density that would be allocated to areas located in the floodplain would be shifted to areas on the property that are not located in the floodplain. Smaller lots would be allowed to the extent necessary to accommodate this shifting on the upland portions of the site, although the total permitted density should remain at no more than one (1) unit per ten (10) acres. In addition, clustered development on approximately two (2) acre lots would be allowed at an overall density of not more than one (1) unit per eight (8) acres, with the remainder of the property designated and preserved as common open space, or protected by a conservation easement.

2. In order to retain the visually open character of the area, all buildings will be required to be set back a minimum of four hundred (400) feet from the centerline of Indian Hill Road. This setback will be protected by requiring a recorded, no-build easement, in order to retain this visual quality over time.

3. To the maximum extent possible, access to development shall be obtained from north/south roads, and not directly from Indian Hill Road, in order to maintain the integrity of the view corridor along Indian Hill Road.

SPECIAL PLANNING AREA 7

EXISTING CONDITIONS

Special Planning Area 7 is situated in an area south of Cedar Lane and directly east of Highway 77/Classen, bisected by 24th Avenue SE. The area is generally undeveloped.

PROPOSED LAND USES

The area east of Highway 77/Classen, bisected by 24th Avenue SE, is designated for Mixed-Use Development. This is intended to accommodate a mixture of employment, commercial, and residential uses. The primary emphasis of this mixed-use development area is to accommodate employment uses (such as office or light industrial), with some supporting commercial and medium or high-density residential housing, as part of an overall planned development, if certain conditions are met.

REQUIRED DEVELOPMENT CONDITIONS

1. A unified overall master development plan for the entire area, to be approved by the city before development of the area could commence.

2. A unified overall master development plan that includes well-planned, mutually supportive uses containing a mixture of employment and commercial uses, as well as different densities and types of supporting residential uses. Residential uses shall comprise at least forty percent of the land area contained in the Special Planning Area.

3. A unified overall master development plan that adequately addresses specific design aspects unique to the area's location and surroundings, such as the design relationship and connections to the planned residential areas to the east, overall mix of uses, and design treatments of the site, landscaping, signage, and buildings.

4. A unified overall master development plan that assures appropriate ingress and egress so as to mitigate the potential traffic impacts on Highway 77.

SPECIAL PLANNING AREA 8

EXISTING CONDITIONS

Special Planning Area 8 is situated in an area south of Indian Hill Road, between the BNSF railroad and 24th Avenue NW.

PROPOSED LAND USES

The area is designated for industrial development.

Required Development Conditions

1. A unified overall master development plan for the entire area, to be approved by the city before development of the area could commence.

2. A development plan that adequately addresses potential impacts on adjoining residential areas, (especially along the east edge that abuts 24th Avenue NW). This will include landscape treatments for both the perimeter and in parking areas and will require building setbacks of at least 100 feet..

3. A unified development plan that assures appropriate ingress and egress so as to mitigate the potential traffic impacts on 24th Avenue NW.

4. No industrial development shall occur until sanitary sewer is available to serve the site.

III. Transportation Plan

One of the most critical elements of this Plan is the designation of a system of vehicular travel that supports the Land Use Plan. A Transportation Plan is needed to prescribe a system of safe, economical and efficient streets providing for a variety of functions. A comprehensive pedestrian and bikeway system should be pursued in conjunction with the other elements of the City's transportation system. The City's transportation system should also support enhanced opportunities for public transit service; both locally and regionally, in order to reduce dependency on private automobile travel, decrease congestion, and enhance air quality in the City.

HIGHWAYS

Highways include all roadways for which the primary responsibility for maintenance is other than the City. The function of these roadways is primarily to accommodate long trips between parts of Norman and to connect areas outside of Norman. Highways may also function as Urban Principal or Minor Arterials. The right-of-way requirements, number of lanes, and shoulder requirements will vary greatly within the highway system. The types of Highways include:

Freeway – a divided highway with full control of access.

Turnpike – a divided highway with full control of access, on which a "user fee" or toll is charged for each trip.

Expressway – a divided highway with partial control of access.

Gateway/Boulevard/Parkway Scenic Zones – any highway, generally divided, where special setbacks are imposed, signs are restricted, uniformity of street trees is required and extensive landscaping is encouraged, to enhance the park-like setting along the street.

Conventional – any non-divided road, maintained by the Oklahoma Department of Transportation.

URBAN STREETS

Urban Streets include all roadways within urbanized Norman; this includes that portion of Norman falling within the Current and Future Urban Service Areas. The Urban Streets include:

Urban Principal Arterials – distributes traffic throughout the City and link major community-wide traffic generators.

Includes all "Highways" within or passing through urbanized Norman.

Requires a minimum of four travel lanes with curb and gutter and a minimum of 100 feet of right-of-way. Additional lanes, turn lanes, medians and rights-of-way may be required based upon traffic generation or unique conditions.

Urban Minor Arterials – are intended to distribute traffic throughout the City and link major community-wide traffic generators, but because of limited right-of-way or adjacent land development cannot or need not be constructed to the Principal Arterial standard. A Minor Arterial will typically consist of two travel lanes, with turn lanes required at intersections with all other arterials, and sometimes with collectors. In some instances, a third lane will be required.

Urban Collectors – allow traffic to move from the local street system to the arterial system. Collectors typically have two travel lanes, with turn lanes required at some intersections, including all arterials.

Urban Locals – provide access to property abutting public rights-of-way and a means to travel to the higher classified street system. Local streets have two travel lanes.

RURAL ROADS

Rural Roads include all roadways outside of urbanized Norman in the Suburban and Country Residential areas. The right-of-way requirements, width of lanes, width and types of shoulders, and requirements for turn lanes vary widely. Rural roads include:

Rural Principal Arterials – distribute traffic throughout areas which have low land development capacities and lower traffic demand than the Urban Arterial System. Rural Principal Arterials represent an integrated rural network linking large traffic generators and providing intra-county service. They also represent the most heavily traveled roads in the Rural System and will sometimes serve as a connection to an Urban Arterial. Rural Principal Arterials should be designed to provide for relatively high overall travel speeds, with minimum interference to through movement. Roads in this classification require a minimum of 100 feet of right-of-way, two paved lanes of 12 feet each, a 10 foot paved shoulder adjoining each lane, and in some instances, acceleration/deceleration/turn lanes at intersections with other arterial and collectors. No curb and gutter is required, however, a 4 to 1 side slope, or flatter, is required for all bar ditches.

Rural Minor Arterials – represent the second tier of roads in the Rural System. Rural Minor Arterials are also intended to distribute traffic throughout areas that have low land development capacities and lower traffic demand than the Urban Arterial System. Rural Minor Arterials form part of an integrated rural network linking large traffic generators and providing intra-county service. They should be designed to provide for moderate overall travel speeds, with minimum interference to through movement. Roads in this classification require a minimum of 100 feet of right-of-way, two paved lanes of 12 feet each, a 6 foot paved shoulder adjoining each lane, and in most instances, acceleration/deceleration/turn lanes at intersections with other arterials and collectors. No curb and gutter is required, however, a 4 to 1 side slope, or flatter, is required for all bar ditches.

Rural Collectors – represents a roadway system designed to serve travel on which predominate travel distances are shorter or slower than on arterial roads. Rural Collectors should be consistent with population density, to collect traffic from local roads and connect all developed areas within a reasonable distance to an arterial. Roads in this classification require a minimum of 100 feet of right-of-way, two paved lanes of 12 feet each, a 6-foot earthen shoulder adjoining each lane, and acceleration/deceleration/turn lanes at intersections with arterials. No curb and gutter is required, however, a 4 to 1 side slope, or flatter, is required for all bar ditches.

Rural Locals – represent a road system designed primarily to provide access to adjacent land and provide service to travel over relatively short distances as compared to collectors or other higher systems. These roads require a minimum of 80 feet of right-of-way, two paved lanes of 11 feet each with a 4-foot earthen shoulder adjoining each lane. No curb and gutter is required, however, a 4 to 1 side slope, or flatter, is required for all bar ditches.

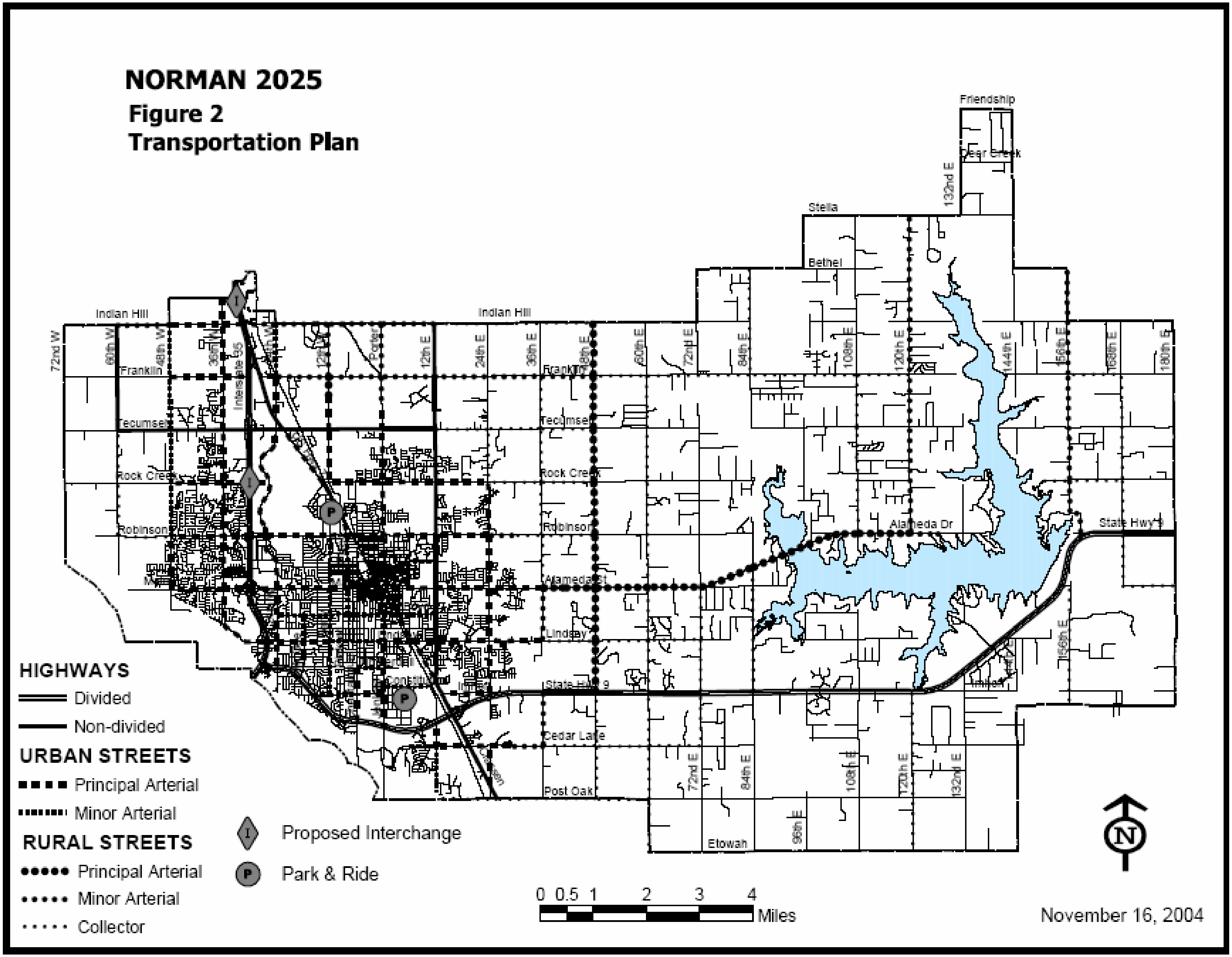
PUBLIC TRANSIT

Bus transit service is currently provided in Norman by Cleveland Area Rapid Transit (CART), which provides fixed route service to the urban core as well as curb-to-curb paratransit service. The CART system is part of a regional transit system that provides public transportation for the entire central Oklahoma region under the auspices of METRO Transit. Through the over 25-year development of this system, service to the City of Norman and the University of Oklahoma, the CART system has grown in the number of services offered and the area served.

Currently, CART operates six fixed routes within the City of Norman and provides commuter service from Norman to the METRO Transit system in Oklahoma City via downtown Oklahoma City, the OU Health Sciences Center, and the State Capitol. The fixed route services include both University-oriented shuttle services as well as community routes. The University's south oval is the transfer point between all fixed routes.

System ridership has increased significantly in recent years. During the current 2003/2004 fiscal year, total system ridership was more than 1 million passengers, which represents an increase of more than 32% from the prior year's total of 758,000 passengers.

NORMAN 2025
Figure 2
Transportation Plan



IV. Plan Implementation

The long-term success of the NORMAN 2025 Land Use and Transportation Plan rests largely on the ability of the City of Norman to pursue the implementation of the Plan.

To ensure the plan is implemented, various land use implementation techniques or programs are needed. These techniques fall into three major categories: Regulatory Techniques, Public Facilities Financing Techniques, and Miscellaneous Implementation Techniques. Each of these techniques or programs should be considered by the City of Norman as possible approaches for implementing the Land Use Plan. The specific techniques or programs are:

REGULATORY TECHNIQUES

Urban Development and Protection

- Core area protection regulations
- Mixed-use development

Rural Protection

- Country Residential Preservation Standards
- Floodplain protection zoning
- Cluster development standards
- Northern separator area overlay zoning

Quality Development Standards

Multifamily and commercial design standards
Natural resource protection standards

PUBLIC FACILITIES FINANCING TECHNIQUES

- Wastewater Plant Investment Fees/Excise Tax
- Water and Sewer Utility Payback Fees
- Arterial Road Improvement Recoupment Program
- Improvement Districts
- Rural Cost of Growth Analysis

MISCELLANEOUS IMPLEMENTATION TECHNIQUES

- Neighborhood Planning Program
- CBD Enhancement Programs
- Greenbelt/Greenway Programs

A full discussion of these techniques or programs is found in the *NORMAN 2025 Implementation Techniques Technical Memorandum*. This memorandum provides a discussion of the geographical applicability of each implementation technique, the Plan policies implemented, a description of each of the techniques or programs listed above, its purpose, an implementation strategy, adoption procedures, administrative requirements, and the advantages and disadvantages to be considered with each.

It should be noted that no one single program or technique will implement the Plan; nor will all programs be feasible at the time of initial adoption of the Plan. It is the combined effect of the various methods that must work together over time to achieve the desired results. Each should be evaluated within the overall implementation framework.

V. Plan Administration & Amendment

The NORMAN 2025 Land Use and Transportation Plan will be utilized in several different ways, as discussed below. Its role in the City's ongoing and diverse planning activities means that it must be a flexible document that is updated and amended periodically.

FUNCTIONS OF THE PLAN

The Plan serves several functions for the City of Norman. First, it serves as a guide for public investment by articulating policies and strategies that suggest both general and specific capital projects. The various policies and specific recommendations must ultimately be tied to capital improvement programs that define, budget, coordinate and schedule specific projects. The Plan should be used as a policy basis for the expenditure of capital funds.

Second, the Plan serves as a policy basis for the development of various regulatory techniques. In order for the recommendations of the Plan to be carried out, various zoning and subdivision regulation amendments may be necessary, and other mechanisms must be developed. This plan serves as the policy base for those changes.

Third, this Plan defines the desired land use pattern for use and development of all private sector properties. As such, this Plan will serve as a policy guide for zoning and planning requests as they are presented to the Planning Commission and City Council.

CONSISTENCY WITH THE PLAN

As a long-range policy guide it is important that decisions made about the expenditure of capital funds, amendments to the City's land use regulations, and decisions about zoning and planning requests be consistent with the Plan. As such decisions are contemplated, explicit consideration should be given to whether the decisions are, or are not, consistent with the Plan. When requests are consistent with the Plan, they should be approved under normal circumstances. When requests are not consistent with the Plan, they should not be approved.

ADMINISTRATIVE PROCEDURES

In order to encourage open space preservation through cluster development design, simultaneous rezoning and platting proposals may be processed for the single fee associated with the corresponding traditional zoning or platting for such cluster developments. Public access to open space is encouraged.

In order to promote better design, parcels lying within more than a single Growth Area may have the total maximum density distributed throughout the development based upon the average density for the entire parcel.

AMENDMENT PROCEDURES

At a minimum the Plan should be reviewed annually by the Planning Commission and every five years by a special task force appointed by the City Council to make recommendations concerning policy changes.

Requests for amendments to the Plan may be considered by the City Council after a recommendation by the Planning Commission. Amendment requests may be initiated by any citizen of Norman, by the Planning Commission, or by City Council. Major amendments may require greater than thirty days review time by staff prior to being considered by the Planning Commission.

Plan amendments may be submitted at any time. Staff will prepare a complete analysis of the impact of the proposed amendment and will identify all affected portions of the Plan. Staff will prepare a quarterly summary report to the City Council as a review of the last three-month and year to date impact of any and all Plan Amendments. Additionally, as a part of the required annual review, staff will prepare a Plan Amendment annual summary and analysis of all affects to the Plan.

AMENDMENT GUIDELINES

In reviewing proposed amendments to the Plan, it is recognized that different types of amendments will require different consideration. Specifically, there are three types of potential changes which might be contemplated. The three types are as follows:

- Land Use Designation Changes;
- Changes to Functional Classification of Roadways; and
- Growth Area Boundary Changes.

Land Use Designation Changes

The following criteria must be met in order to approve requested land use designation changes from the adopted NORMAN 2025 Plan:

1. There has been a change in circumstances resulting from development of properties in the general vicinity which suggest that the proposed change will not be contrary to the public interest; and

2. There is a determination that the proposed change would not result in adverse land use or adverse traffic impacts to surrounding properties or the vicinity.

Changes to Functional Classification of Roadways

The following criteria should be examined in reviewing proposed amendments to the Transportation Plan:

1. The appropriateness of a proposed functional classification change in the Transportation Plan should be determined by analyzing:

    a. The location and type of land use served,
    b. The potential travel distances,
    c. The speed and volume of traffic to be accommodated,
    d. The primary type of vehicles to be carried, and
    e. The degree of interference with through movement created by abutting uses and intersections;

2. Regional and system wide transportation impacts must be assessed for each proposed change; and

3. The potential need for Transportation Plan changes should be evaluated with every Land Use or Growth Area Amendment request.

Growth Area Boundary Changes

The Growth Area boundaries are approximate, and may be modified slightly as a result of detailed engineering or topographic studies at the time of application for a designation change. Such minor adjustments are not considered to be formal Plan amendments. The following criteria shall apply and set requirements for changes in Growth Area Boundaries:

Change from Future Urban Service Area to Current Urban Service Area

1. The area proposed for change is contiguous to the Current Urban Service Area and constitutes a logical and cohesive service area expansion; and

2. The request for amendment demonstrates that the subject area has been provided, or will be at the time of development, with complete infrastructure systems. At a minimum, these systems will consist of:

    a) Additional sanitary sewer collection and treatment capacity needed to serve the expanded area,

    b) Water service with adequate pressure for fire-fighting,

    c) Adequate storm drainage to insure that the proposed development will not create downstream drainage problems, and

    d) Access to at least one arterial street connecting the subject area to the Current Urban Service Area.

CHANGE FROM SUBURBAN RESIDENTIAL AREA TO CURRENT OR FUTURE URBAN SERVICE AREA

1. The land must be contiguous to existing Current or Future Urban Service Area land;

2. There must be an indication that the existing Urban Service Areas may not be adequate to accommodate the full range of urban land demands based upon land use type and the area of the community;

3. Justification for expansion of the Urban Service Areas should accompany the request; and

4. Concurrent application for Planned Unit Development zoning must accompany the request in order to insure compliance with development criteria for the Current or Future Urban Service Areas.

Country Residential Area

Based upon the significance of this area to the NORMAN 2025 Plan in assisting in orderly development and managed growth and providing adequate safeguards for the sensitive environmental issues and protection of the water resources of the city, conversion to another area is neither desirable nor in the public interest. Any such conversion from Country Residential would be based upon meeting both of the following conditions:

1. The area must be contiguous to an Urban Service Area; and
2. Extension of full urban services to the area will be required.

CITY OF NORMAN
STORMWATER MANAGEMENT PROGRAM
FOR PHASE II MS4 COMPLIANCE
2016 TO 2020

Appendix G

February 1, 2016

Enforcement Procedure Guidance Policy

City of Norman Public Works, Engineering Division

Purpose: This document is a tool to assist staff in enforcement of The City of Norman Code of Ordinances regarding erosion control and discharges to the City storm sewer system. It establishes steps to notify responsible parties of violations and enforcement actions to bring the site into compliance. The document provides guidance to be used in most enforcement actions; however, deviations from the guidelines are permissible if, in the opinion of the inspector or Engineering Staff, they are warranted.

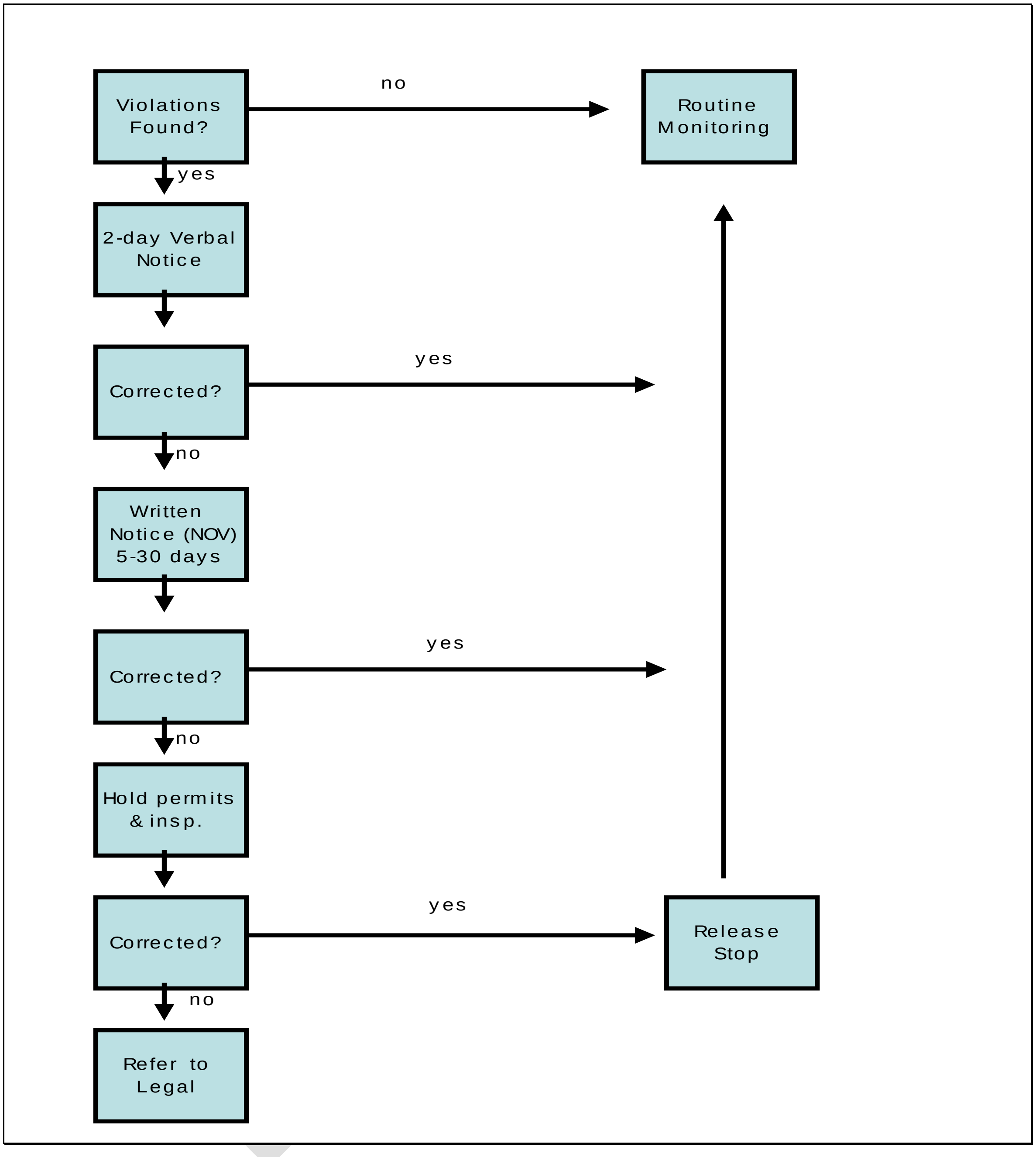
Enforcement Procedure: Upon observation of a violation, the inspector will verbally notify the responsible party (RP) as soon as possible. The RP will be given two to five working days after notification to correct the problem. If the violation is not corrected after the allowed time, but substantial progress has been made, additional time may be granted to the RP to complete work. . If the violation constitutes an immediate threat to human health or the environment the RP may be required to correct the violation immediately.

If the violation is not corrected after the allowed time has passed and substantial progress has not be made, a written Notice of Violation (NOV) will be issued to the RP by certified mail, detailing the violation(s), corrective actions to be taken, and potential penalties for noncompliance. The RP will be given at least five working days and no more than thirty working days from receipt of the letter to achieve compliance. The RP may submit a written request for additional time to achieve compliance, which may be granted if substantial progress toward compliance has been made. Generally, completion of at least fifty percent of required tasks may be considered substantial progress.

If the violation is not corrected by the due date listed in the written notice the provisions of The City of Norman Code of Ordinances, including the Engineering Design Criteria and any other applicable ordinances will be enforced. Enforcement actions taken may include stopping work at the site, suspending inspections and permits and issuing fines. When the site is deemed by staff to have achieved compliance, any suspensions may be revoked and the site returned to normal monitoring.

If, at any site a violation re-occurs, or a new violation is found within sixty days after achieving compliance from the original violation, the inspector may immediately take enforcement action, including referring the case to the City of Norman Legal Department.

Enforcement Procedure Flow Chart



Shawn O'Leary, Director of Public Works   Date

CITY OF NORMAN
STORMWATER MANAGEMENT PROGRAM
FOR PHASE II MS4 COMPLIANCE
2016 TO 2020

Appendix H

Ordinance Exerpts

Sec. 16-101. - Engineering Design Criteria and Standard Specifications and Construction Drawings for Streets, Storm Drainage, Water Lines, and Sanitary Sewers: Adoption.

(a) The City of Norman Engineering Design Criteria and Standard Specifications and Construction Drawings for Streets, Storm Drainage, Water Lines, and Sanitary Sewers dated September 24, 1996, and amended April 28, 1998; March 28, 2000; May 8, 2001; July 24, 2001, February 26, 2002, September 9, 2003; January 11, 2005; and June 13, 2006, shall be further amended to read as attached hereto and incorporated herein by reference.

(b) The City of Norman Engineering Design Criteria and Standard Specifications and Construction Drawings for Streets, Storm Drainage, Water Lines, and Sanitary Sewers as referred to above shall not become effective until at least three (3) copies of each have been filed in the Office of the City Clerk for examination by the public.

(Ord. No. 0-9697-13; Ord. No. 0-9798-43; Ord. No. 0-9900-32; Ord. No. 0-0001-53; Ord. No. 0-0102-36; Ord. No. 0-0304-19; Ord. No. 0-0405-33, § 1; Ord. No. 0-0506-67; Ord. No. 0506-76)

Editor's note— Section 1 of Ord. No. 0-9697-13, adopted Sept. 24, 1996, amended § 16-101 to read as herein set out. Prior to such amendment, § 16-101 pertained to penalties for violation of this chapter and derived from Ord. No. 0-7374-82; Ord. No. 0-8283-05; and Ord. No. 0-9596-45. Further, Ord. No. 0-9900-32, § 1, adopted Mar. 28, 2000, amended the title of § 10-101 to read as herein set out.

Sec. 16-102. - Standard Specifications and Construction Drawings and Engineering Design Criteria: Penalties for violation.

(a) Any person convicted of violating the provisions of the City's Standard Specifications and Construction Drawings and/or Engineering Design Criteria or material referenced therein, or of failing to act or comply with the provisions thereof, shall be punished by a fine of not less than fifty dollars ($50.00) nor more than seven hundred fifty dollars ($750.00) for each violation or failure to comply.

(b) Each day that a violation or failure to comply exists shall constitute a separate and distinct offense, and any one (1) or more of such offenses may be set out in any citation or complaint or information filed.

(Ord. No. 0-9697-13; Ord. No. 0-9900-11; Ord. No. 0-0405-26; Ord. No. 0-0506-10)

Manufactured Fertilizer Ordinance

Sec. 10-801. - Purpose.

City Council finds that certain compounds containing phosphorus, which are contained in manufactured fertilizer, enter into the City's and neighboring communities' water sources resulting in excessive and accelerated growth of algae and aquatic plants which is detrimental to these water resources. It is the purpose and intent of this section to regulate the application of manufactured fertilizers containing phosphorus within the City of Norman.

(Ord. No. 0-1213-34, § 1)

Sec. 10-802. - Definitions.

For the purposes of this chapter, the following words and phrases shall have the meanings described in this section:

Applicator: Any person who applies manufactured fertilizer in the City, including, but not limited to, homeowners, occupants of rental property, and property managers.

Buffer: The land area, twenty-five (25) feet in width, adjacent to any waterbody.

Commercial applicator means any corporation, partnership, or business that is engaged in the business of applying fertilizer for hire and is required to register under this chapter of the City of Norman Code.

Commercial seller: Any person who sells or displays for sale any manufactured fertilizer in the City.

General turf: Nonagricultural land managed using turf grasses including but not limited to home lawns, vegetable and flower gardens, golf courses, cemeteries, park areas as well as commercial, school, university and government grounds.

Impervious cover: Roads, parking areas, buildings, pools, patios, sheds, driveways, private sidewalks, and other impermeable construction covering the natural land surface. This shall include, but not be limited to, all streets and pavement within a subdivision. Vegetated water quality basins, vegetated swales, other vegetated conveyances for overland drainage, areas with gravel placed over pervious surfaces that are used only for landscaping or by pedestrians, and public sidewalks shall not be calculated as impervious cover.

Manufactured fertilizer: A commercially manufactured substance containing one (1) or more recognized plant nutrients, which is used for its plant nutrient content and which is designed for use, or claimed to have value, in promoting plant growth. Fertilizer does not include unadulterated animal and vegetable manures, marl, lime, limestone, and wood ashes.

Phosphate: A form of phosphorus used to measure the phosphorus content of fertilizers. It is expressed as the chemical formula P_2O_5. The phosphorus (P) content of a fertilizer is forty-three (43) percent of its phosphate (P_2O_5) content.

Phosphorus fertilizer: Any fertilizer that contains phosphorus, expressed as P_2O_5, with a guaranteed analysis of greater than zero.

Soil test: A set of scientific measurements that determine the basic texture of soil, the pH level of soil, and the various nutrient levels of phosphorus, potassium, calcium and magnesium in soil, for the purpose of providing a fertilizer recommendation regarding the amount of nutrients and rate of application of nutrients for general turf growth.

Waterbody: A surface water feature such as a lake, river, stream, creek, pond, lagoon, bay, or estuary.

(Ord. No. 0-1213-34, § 2)

Sec. 10-803. - Phosphorus fertilizer application.

(a) Manufactured fertilizer that contains any amount of phosphorus or a compound containing phosphorus, such as phosphate, shall not be applied to general turf within the City, except under one (1) of the following exceptions:

(1) Application of manufactured fertilizer to an area during the first six (6) months of turf establishment from seed or sod;

(2) The naturally occurring phosphate in unadulterated natural or organic fertilizing products;

(3) The general turf and lawn area has been soil tested, with results from a certified laboratory, which confirms that the phosphate levels are less than or equal to ten (10) parts per million. In such cases, lawn fertilizer application shall not exceed the laboratory recommended application rate for phosphorous;

(b) Manufactured fertilizer containing phosphorous applied pursuant to the above listed exceptions shall be watered into the soil within fourteen (14) hours so that the phosphorous can be immobilized and generally protected from loss by runoff.

(Ord. No. 0-1213-34, § 3)

Sec. 10-804. - Prohibited conduct.

No person may do any of the following:

(a) Apply manufactured fertilizer when a runoff producing rainfall is occurring or predicted and/or when soils are saturated and a potential for fertilizer movement off-site exists.

(b) Apply manufactured fertilizer to impervious cover. Fertilizer applied to impervious cover, is to be removed by sweeping or blowing back into the target surface, returned to an appropriate container for reuse, or collected and disposed of properly. Excess fertilizer may not be disposed of by placing it in any area likely to lead into a storm drain.

(c) Store manufactured fertilizer uncontained on driveways or other areas of impervious cover.

(d) Apply manufactured fertilizer within 25 feet of any wetland, watercourse, or storm water retention or detention basin.

(e) Blow, sweep, dump, direct, or place leaves, grass clippings, or any yard debris into any street, storm drain, ditch, creek, pond, or waterway.

(Ord. No. 0-1213-34, § 4)

Sec. 10-805. - Soil testing.

(a) Soil testing is required before an applicator or commercial applicator may apply phosphorus containing manufactured fertilizer. A soil sample or samples shall be taken from the general turf area on which an applicator or commercial applicator is proposing to apply manufactured fertilizer containing phosphorus or a compound containing phosphorus, following the procedure requirement by the soil testing service.

(b) The applicator or commercial applicator shall submit a soil sample to the soil testing service following the procedure required by the soil testing service.

(c) The soil testing service shall determine the rate and application of manufactured fertilizer containing phosphorus based on the results of the soil test and the requirements of this chapter.

(d) The results of the soil test shall be maintained for a period of three (3) years following receipt of the test by the applicator or commercial applicator.

(e) The applicator or commercial applicator shall provide a copy of the soil test results to Director of Public Works or his/her designee within forty-eight (48) hours of a written request for the test results.

(Ord. No. 0-1213-34, § 5)

Sec. 10-806. - Information regarding manufactured fertilizer.

(a) The Director of Public Works or his/her designee shall prepare an informational pamphlet that includes, at minimum, the following:

(1) A summary, or complete text, of this chapter;

(2) Facts regarding the environmental benefit of phosphorus reduction;

(3) A description of penalties for violation of this chapter; and

(4) A City phone number and website address where additional information will be available.

(b) A copy of the informational pamphlet shall be made available to commercial applicators at the time of registration each year. Commercial applicators may make reasonable facsimiles or copies of the informational pamphlet for distribution.

(c) A copy of the informational pamphlet shall be made available to commercial sellers no later than March 1 of each year. Commercial sellers may make reasonable facsimiles or copies of the informational pamphlet for distribution.

(Ord. No. 0-1213-34, § 6)

Sec. 10-807. - Sale of fertilizer containing phosphorus.

(a) Any corporation, partnership or business establishment selling or displaying lawn fertilizer, liquid or granular, within the City of Norman that is labeled to contain more than zero (0) percent phosphate (P_2O_5) shall be required to clearly identify those fertilizers by displaying a sign indicating the phosphate levels and advising the use of such fertilizer is regulated within the City of Norman in accordance with this chapter.

(b) Commercial sellers shall have copies of the informational pamphlets on display, and have copies of the informational pamphlet available to customers, adjacent to the display of any manufactured fertilizer containing phosphorus for sale.

(Ord. No. 0-1213-34, § 7)

Sec. 10-808. - Storage of fertilizer.

All manufactured fertilizer must be stored in a covered area from which rainwater runoff does not run directly into a storm sewer. Any spillage must be swept up and disposed of properly.

(Ord. No. 0-1213-34, § 8)

Sec. 10-809. - Registration.

(a) Commercial applicators shall register annually.

(b) No commercial applicator shall engage in the business of lawn fertilizer application in the City of Norman without first having registered as provided in this chapter; however, any owner occupant of a single-family dwelling may spread fertilizer on the lawn of the dwelling occupied by that owner occupant or owner occupant's immediate family.

(c) All City programs for fertilizer use shall be reviewed and approved by the Storm Water Engineer prior to any application upon City property.

(d) All commercial applicators shall receive a copy of Article VIII of Chapter 10 of the Code of the City of Norman and an informational pamphlet, which shall be provided to all employees who may be applying manufactured fertilizer containing phosphorus.

(Ord. No. 0-1213-34, § 9)

Sec. 10-810. - Registration application.

(a) The following information shall be included in a complete application for registration:

(1) The legal name of the commercial applicator, any other names used, the address, telephone number, and contact person for the registrant;

(2) The product name, type of use, and percentage weight and ration of elemental phosphorus for every manufactured fertilizer to be used on general turf; and

(3) A notarized, sworn statement signed by an owner or duly authorized representative of a commercial applicator indicating that the applicator will provide appropriate training to its employees to ensure compliance with the requirements of Article VIII of Chapter 10 of the Code of the City of Norman throughout the registration period, including, but not limited to, completing soil test prior to applying manufactured fertilizer containing phosphorus and applying manufactured fertilizer at rates required by soil tests.

(b) The completed registration form shall be returned to the Storm Water Engineer or his/her designee along with:

(1) Annual registration fee pursuant to Section 13-108 of this Code; or

(2) If the commercial applicator certifies, on the registration form, that the commercial applicator will not use any manufactured fertilizer containing phosphorus, the annual registration fee shall be waived.

(Ord. No. 0-1213-34, § 10)

Sec. 10-811. - Inspections and log book.

(a) The Director of Public Works or his/her designee shall have the right to inspect property on which manufactured fertilizer has been applied by a registered applicator.

(b) The commercial applicator shall provide a five-ounce sample of any manufactured fertilizer used by the commercial applicator in the City of Norman upon request by Director of Public Works or his/her designee to enforce this chapter.

(c) The commercial applicator shall keep a log book of each place where manufactured fertilizer containing phosphorus has been applied and shall make the log book available for inspection to the City of Norman upon request. The log book shall contain:

(1) Address of site of application;

(2) Amount of manufactured fertilizer containing phosphorus applied; and

(3) Results of the soil test conducted prior to application of manufactured fertilizer containing phosphorus.

(d) The commercial applicator shall keep a log of all employees who have received training on Article VIII of Chapter 10 of the Code of the City of Norman and informational pamphlets for distribution.

(Ord. No. 0-1213-34, § 11)

Sec. 10-812. - Required distribution of information regarding manufactured fertilizer.

(a) Commercial applicators will be provided a copy of an informational pamphlet at the time of registration each year. Commercial applicators may make facsimiles or copies of the informational pamphlet for distribution.

(b) A commercial applicator shall provide at least one (1) copy of the informational pamphlet to the owner or occupant of each address at the time of first application of manufactured fertilizer each year.

(Ord. No. 0-1213-34, § 12)

Sec. 10-813. - Violations and penalties.

Any applicator, commercial applicator or commercial seller found to be in violation of the provisions of this chapter shall be subject to a fine in the amount of not less than fifty dollars ($50.00) nor more than seven hundred fifty dollars ($750.00).

(Ord. No. 0-1213-34, § 13)

O-1011-52

AN ORDINANCE OF THE COUNCIL OF THE CITY OF NORMAN, OKLAHOMA AMENDING CHAPTER 19 OF THE CODE OF THE CITY OF NORMAN TO PROVIDE FOR STANDARDS AND REQUIREMENTS FOR A DESIGNATED WATER QUALITY PROTECTION ZONE INCLUSIVE OF THE LAKE THUNDERBIRD WATERSHED; AND PROVIDING FOR THE SEVERABILITY THEREOF.

NOW, THEREFORE, BE IT ORDAINED BY THE COUNCIL OF THE CITY OF NORMAN, OKLAHOMA:

§ 1. That Section 19-210 of Chapter 19 of the Code of the City of Norman shall be amended to read as follows:

Sec. 19-210. Definitions.

The following words and phrases when used in this chapter, shall for the purposes of this chapter, have the meanings respectively ascribed to them in this article, except where the context otherwise requires:

A. *Alley:* A minor right-of-way dedicated to public use, which gives a secondary means of vehicular access to the back or side of properties otherwise abutting a street, and which may be used for public utility purposes.

B. *Best Management Practices (BMP):* An effective integration of storm water management systems, with appropriate combinations of non-structural controls and structural controls which provide an optimum way to convey, store and release runoff, so as to reduce peak discharge, reduce pollutants, enhance water quality, assist in stream and/or stream bank stabilization, prevent property damage due to flooding, and assist in sediment reduction. BMP's include, but are not limited to, the following:

1. Structural controls such as:
    a. Sediment forebay;
    b. Grassed swale;
    c. Enhanced bio-swale;
    d. Voluntary urban nutrient management;
    e. Statutory urban nutrient management;
    f. Wetlands;
    g. Extended detention-enhanced;
    h. Retention basins;

i. Bioretention, surface sand, organic, and similar filters;
j. Soaking trench;
k. Infiltration trench;
l. Storm water pond;
m. Dry extended detention pond; and
n. In-channel detention.

2. Non-structural controls such as:
   a. Landscape conservation;
   b. Reduction in impervious cover;
   c. Schedule of maintenance activities;
   d. Prohibition of practices;
   e. Maintenance procedures.
   f. Street sweeping;
   g. Fertilizer restrictions.

C. *Bicycle lane:* That portion of a roadway set aside and appropriately designated for the use of bicycles.

D. *Bicycle path:* A paved facility physically separating the bicycle from motor vehicle traffic.

E. *Block:* A parcel of land, intended to be used for urban purposes, which is entirely surrounded by public streets, highways, railroad rights-of-way, public walks, parks or greenstrips, rural land or drainage channels or a combination thereof.

F. *Buffer:* A vegetated area, including trees, shrubs, and herbaceous vegetation that exists or is established to protect a stream system, lake or reservoir, reduce pollutants, enhance water quality, assist in stream and/or stream bank stabilization, and assist in sediment reduction.

G. *Building line:* A line parallel to the lot or property line beyond which a structure or building cannot extend, except as specifically provided under the zoning ordinance. It is equivalent to the setback or yard line.

H. *Cluster development:* cluster development is a method of subdividing land which allows the maximum density available within the zoning district while allowing smaller lots than those specified, provided that the land saved is reserved for permanent agricultural use or open space, ideally in common ownership for community use.

I. *Combustible structure:* That which is built or constructed, an edifice or building of any kind, or any piece of work artificially built up or composed of parts joined together in some definite manner and consisting of any material that, in the form in which it is used and under the conditions anticipated, will ignite and burn or will add appreciable heat to an ambient fire.

J. *Degradation:* any condition caused by the activities of humans which result in the prolonged impairment of any constituent of the aquatic environment.

K. *Development:* The erection, construction, or change of use of buildings; or the erection or construction of any additions to existing buildings where outer walls are added or altered as to location, but not including alterations or remodeling of buildings where said outer walls are not added or altered as to location. As it relates to water quality protection, any man-made change to improved or unimproved real estate, including, but not limited to, buildings or other structures, mining, dredging, filling, grading, paving, excavation, drilling, or storage of equipment or materials.

L. *Development committee:* The City of Norman Development Committee shall be comprised of the following staff members: The Director of Public Works (who shall be the chairman), the Director of Planning and Community Development, the Director of Utilities, the City Engineer, the Development Coordinator, and the Manager of Current Planning, or their designees.

M. *Director of Public Works:* The Director of Public Works of the City of Norman, including his or her designee.

N. *Easement:* A grant by the property owner to the public, a corporation, or persons, of the use of an area of land for specific purposes.

O. *Impervious Cover:* Roads, parking areas, buildings, pools, patios, sheds, driveways, private sidewalks, and other impermeable construction covering the natural land surface. This shall include, but not be limited to, all streets and pavement within a subdivision. Vegetated water quality basins, vegetated swales, other vegetated conveyances for overland drainage, areas with gravel placed over pervious surfaces that are used only for landscaping or by pedestrians, and public sidewalks shall not be calculated as impervious cover.

P. *Lot:* A subdivision of a block or other parcel intended as a unit for the transfer of ownership or for development.

Q. *Lot, corner:* A lot which abuts two (2) intersecting streets. The front of a lot is defined by the filed plat of the subdivision, and is addressed accordingly. Although the front door of the house should face the front yard, a house may be oriented towards the side street if the plat was designed to provide two (2) front and rear yards or if there is sufficient room to provide both a new front and rear setback.

R. *Lot, depth:* The average distance from the front property line of the lot adjacent to the street to its rear property line, measured in the general direction of side lines of the lot.

S. *Lot, double frontage:* A lot which runs through a block from street to street and which has frontage on two (2) or more streets, but not including a corner lot.

T. *Lot, reverse frontage:* A corner lot of such size and shape that a building erected on it might logically be designed to face on either adjoining street, thus causing the building to rear on the side line of any abutting lot.

U. *Lot, townhouse:* A lot shown on a townhouse plat and intended as the site of a single attached dwelling unit.

V. *Lot line adjustment:* A relocation of the lot lines of two (2) or more lots included in a plat which is filed of record, for the purpose of making necessary adjustments to building sites.

W. *Low Impact Development (LID):* a comprehensive land planning and engineering design approach to development that can be used to replicate or restore natural watershed functions and/or address targeted watershed goals and objectives.

X. *Non-degradation*: The proper use of BMP's and pollution prevention criteria in activity so as to prevent property damage due to flooding and degradation as defined herein.

Y. *Non-structural controls*: Pollution prevention measures that focus on the management of pollutants by practices and procedures which minimize exposure to runoff, as well as preserve open space and natural systems. Non-structural controls may include riparian buffers, modified development practices, and regulations on pesticide, herbicide, and fertilizer use.

Z. *Norman 2025 Plan:* The comprehensive development plan for the City of Norman which has been officially adopted to provide long-range development policies for the City in the foreseeable future and which includes, among other things, the plan for land use, land subdivision, traffic circulation and community facilities, utilities, and drainage facilities.

AA. *Person:* Any natural person, corporation, partnership, joint venture, association (including homeowners or neighborhood associations), trust, or any other entity recognized by law.

BB. *Planning Commission:* The City Planning Commission of the City of Norman.

CC. *Plat, final:* A map of a land subdivision giving, in form suitable for filing in the office of the County Clerk, necessary affidavits, dedications, and acceptances, and delineating the layout of such subdivision as required herein.

DD. *Plat, preliminary:* A map of a proposed subdivision showing the character and proposed layout of the tract in sufficient detail to indicate the relationship of the proposed development to topography, existing streets, drainage facilities and utilities, existing easements of record, the Norman 2025 Plan, existing urban development and zoning, and to indicate the nature of the land planning design.

EE. *Pollution:* the contamination or other alteration of the physical, chemical or biological properties of any stream or other water source, or such discharge of any liquid, gaseous or solid substance into any stream or other water source as will or is likely to create a nuisance or render such waters harmful or detrimental or injurious to public health, safety or welfare, or to domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or to livestock, wild animals, birds, fish or other aquatic life.

FF. *Public improvements:* Any utility, structure, or modification of topography which is, or will be, located within, under, or over a right-of-way or easement of record and which is, or will be, owned and/or maintained by other than the individual owner(s) of developed real estate.

GG. *Raised mound septic system:* a soil absorption system that is elevated above the natural soil surface in a suitable fill material. It is a variation of the raised bed utilizing sandy fill material but not requiring a stabilization period prior to the construction of the absorption area.

HH. *Raised septic system:* a wastewater absorption trench system which has been constructed in soil fill material which has been placed on top of the natural soil on a building lot.

II. *Reserve strip:* A strip of land located adjacent to a public easement or right-of-way which has the effect of denying access to adjacent property owners to said public easement or right-of-way.

JJ. *Right-of-way:* Any street, avenue, parkway, highway, boulevard, road, alley, bicycle path or pedestrian walkway reserved and/or dedicated for public or private use chiefly by vehicular or pedestrian traffic. Its width shall be established as the shortest horizontal distance measured between lines delineating the right-of-way.

KK. *Rural and suburban area:* All that part of the incorporated area of the City of Norman which is not classified on the Norman 2025 Plan for urbanization.

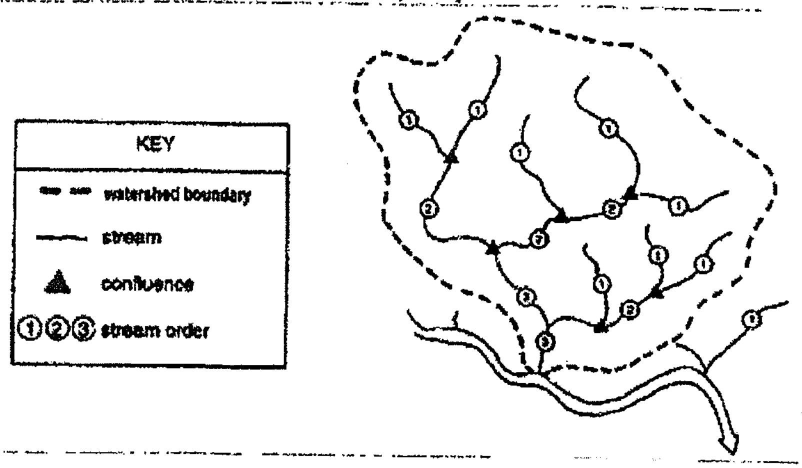
LL. *Setback line:* See building line or yard line.

MM. *Site development plan:* A plan drawn at a scale of not less than fifty (50) feet equal one (1) inch which shows the topographic characteristics of the site not more than a one (1) foot contour interval in the urban areas and not more than two (2) feet contour intervals in the rural areas; the location and dimensions of buildings, yards, courts, landscape, pedestrian and vehicular circulation and parking, fences and screening; service areas and service courts, and other features; the use of each building and area; the height of buildings; adjacent street, alleys, utility, drainage and other easements; and the relationship of the development to adjacent areas which it may affect.

NN. *Streams:* Watercourses that are either identified through site inspection and/or notification by the United States Army Corp of Engineers or by the United States Geological Survey (USGS) 7.5 minute series (topographic) maps drawn at a scale of 1:24,000 or 1 inch = 2000 feet. Perennial streams are those which are depicted on a USGS map with a solid blue line. Intermittent streams are those which are depicted on a USGS map with a dotted blue line.

OO. *Stream Order:* A method of numbering streams as part of a drainage basin network. Tributaries which have no branches are designated as of the first order, streams which receive two first-order tributaries are of the second order, larger branches which receive two second-order tributaries are designated third order, and so on, the main stream being always of the highest order. Designation of stream order shall be determined utilizing a USGS 7.5 minute series (topographic) map drawn at a scale of 1:24,000 or 1 inch = 2000 feet. See Figure 1 below.

Figure 1: Stream Order (Source: Schueler, 1995)



PP. *Stream Planning Corridor (SPC):* the areas of land designated as an SPC in Exhibit 4-4 to the PBS&J Storm Water Master Plan dated October 2009 along both sides of a stream or natural drainage corridor that encompasses the area projected to be inundated by the one-percent (1%) chance flood event (i.e. the 100-year floodplain) in any given year assuming full build-out watershed conditions (based upon the Norman 2025 Plan and subsequent updates) in those areas with 40 or more acres of drainage area in the Lake Thunderbird watershed.

QQ. *Street:* Any public or private right-of-way which affords the primary means of access to abutting property.

RR. *Street, collector.* A minor street collecting traffic from other minor streets and serving as the most direct route to a major street or community facility.

SS. *Street, cul-de-sac:* A local street having one (1) closed end terminated by a turn-around.

TT. *Street, estate type:* A local street in a Residential Estate (R-E) or Agricultural (A-1, A-2) zone or district.

UU. *Street, frontage or service:* A minor street located adjacent and parallel to a major street for land service to abutting properties and access to adjacent areas and for allowing control of access to the major street.

VV. *Street, local:* A minor street which collects and distributes traffic between parcels of land and collector or arterial streets, with the principal purpose to provide access to abutting property.

WW. *Street, major:* A freeway, principal arterial, or minor arterial designated on the adopted Transportation Plan of the City of Norman.

XX. *Street, minor:* Any street other than one (1) designated as a freeway, principal arterial, or minor arterial on the adopted Transportation Plan of the City of Norman, but not including alleys.

YY. *Street, public:* Any pre-existing county road heretofore annexed by the City of Norman and which forms a part of said City by reason of such annexation, or any street or road granted or dedicated to and accepted by the City of Norman.

ZZ. *Structural controls:* engineered solutions designed to reduce pollution in surface water runoff primarily through five basic mechanisms: infiltration, amelioration, treatment, filtration and detention. In effect, these systems attempt to counteract the opposite tendencies of decreased infiltration, filtration and detention which urbanization imposes upon the land.

AAA. *Subdivider (developer):* Any person, firm, partnership, corporation, or other entity acting as a unit, subdividing or proposing to subdivide or develop land as herein defined.

BBB. *Subdivision:* The division, re-division, or delineation of land by lots, tracts, sites or parcels for the purpose of transfer of ownership, or for urban development, or for the dedication or vacation of a public or private right-of-way or easement.

CCC. *Swale:* A natural depression or wide shallow ditch used to temporarily store, route, or filter runoff and encourage infiltration.

DDD. *Top of bank:* The point along a stream bank where abrupt change in slope is evident, and where the stream is generally able to overflow the banks and enter the adjacent floodplain. The top of bank may be identified from topography maps but must be verified through field inspection. Where no top of bank is discernable by the City Storm Water Engineer or his designee, measurements should be taken from the center line of the stream.

EEE. *Transportation Plan:* The arrangement, character, extent, and width of major streets within the City of Norman as designated on the most currently adopted Land Use and Transportation Plan document.

FFF. *Townhouse:* One (1) of a series of two (2) or more attached dwelling units, separated from one (1) another by continuous, vertical party walls without openings from basement floor to the roof deck and tight against same or through the roof and which are intended to have ownership transferred in conjunction with a platted lot.

GGG. *Urban area:* All that part of the incorporated area of the City of Norman which is designated on the Norman 2025 Plan for urbanization.

HHH. *Water Quality Protection Zone (WQPZ):* A vegetated strip of land that lies along a Stream or Lake Thunderbird and its adjacent wetlands, floodplains or slopes that is comprised of the stream bed and areas adjacent to the stream bed and the distance of which is determined by Section 19-411(B), (C) and (D) herein.

III. *Way:* Any street, avenue, parkway, highway, boulevard, road, alley, bicycle path or pedestrian walkway reserved and/or dedicated for public or private use chiefly be vehicular or pedestrian traffic. Its width shall be established as the shortest horizontal distance measured between lines delineating the right-of-way.

JJJ. *Wetland:* the term, as used herein, shall have the same meaning as set forth in 40 C.F.R. §230.3.

KKK. *Yard line:* An open space at grade between a building and the adjoining lot lines, unoccupied and unobstructed by any portion of a structure from the ground upward except as specifically provided in Chapters 18 or 22. In measuring a yard for the purpose of determining the width of the side yard, the depth of a front yard, or the depth of a rear yard, the least horizontal distance between the lot line and the main building shall be used.

LLL. *Yard line, front.* A yard extending the full width of a lot between the side property lines and being the minimum horizontal distance between the street side property line and the main building or any projection thereof.

MMM. *Yard line, rear:* A yard extending across the rear of a lot measured between side yard lines and being the minimum horizontal distance between the rear lot line and the rear of the main building or any projections other than steps, unenclosed balconies or unenclosed porches. On corner lots the rear yard shall be considered as parallel to the street upon which the lot has its least dimension. On both corner lots and interior lots the rear yard shall in all cases be at the opposite end of the lot from the front yard.

NNN. *Yard line, side:* A yard between the building and the side line of the lot and extending from the front yard line to the rear lot line and being the minimum horizontal distance between a side lot line and the side of the main building or any projections other than steps.

§ 2. That Section 19-303 of Chapter 19 of the Code of the City of Norman shall be amended to read as follows:

Sec. 19-303. Preliminary Plat: Contents.

The preliminary plat shall be drawn at a scale of not more than one hundred (100) feet to the inch, except where impractical and shall show:

A. The scale, north arrow, date and legend;

B. The proposed name of the subdivision;

C. The name and address of the owner of record, the subdivider, the owner's engineer, and the registered land surveyor preparing the plat;

D. Legal description of the proposed subdivision, including the acreage and the number of lots proposed in the subdivision, by type;

E. A key map showing the location of the proposed subdivision referenced to existing or proposed arterial streets or highways and to government section lines, and including the boundaries and number of acres of the drainage area of which the proposed subdivision is a part;

F. The names, with locations of intersecting boundary lines, of adjoining subdivisions, and the location of the Norman City limits if falling within or immediately adjoining the tract;

G. The land contours with vertical intervals of one foot in the urban areas and two (2) feet in the rural areas referenced to a United States Geological Survey datum (1988) or Coast and Geodetic Survey bench mark or monument;

H. The location of dedicated streets at the point where they adjoin and/or are immediately adjacent; but actual measured distances shall not be required;

I. Important features such as existing permanent buildings; large trees (a minimum eight (8) inch caliber); streams; railway lines; oil and gas line or wells as shown on the records of the Oklahoma Corporation Commission (including abandoned gas or oil wells and dry holes which remain unplugged);

J. The location of all existing easements of record, sanitary and storm sewers, water mains, streets, culverts, power lines, and other surface or subsurface structures within the tract or immediately adjacent thereto, and the proposed location, layout, type, and size of the following structures and utilities:

1. Water mains;

2. Sanitary sewer mains, sub-mains and laterals;

3. Storm sewers; and,

4. Street improvements.

K. The location of all drainage channels and subsurface drainage structures, and the proposed method of disposing of all run-off from the proposed subdivision, and the location and size of all drainage easements relating thereto, whether they be located within or outside of the proposed plat;

L. The length of the boundaries of the tract, measured to the nearest foot, and the proposed location and width of streets, alleys, easements, and setback lines, and the approximate lot dimensions;

M. The existing zoning and proposed changes of zoning in the tract and of the property immediately adjacent thereto;

N. One hundred (100) year flood boundaries;

O. Water Quality Protection Zone boundaries;

P. Preliminary drawings showing compliance with the applicable requirements of this Chapter for structural controls on development;

Q. A topographic map, drawn to a scale of one hundred (100) feet to one inch, or in an appropriate scale. The map should display, according the best information available, topographic information and features (including, but not limited to, faults and fractures along waterways, wetlands, and sinkholes), and the WQPZ. Current limits of the FEMA floodplain and the SPC shall be displayed;

R. Location of all temporary and permanent runoff detention basins, constructed and altered waterways and other physical facilities to be installed to comply with the terms of this ordinance;

S. Location of all existing monitoring stations, sample points or other significant devices used in measuring or assuring water quality;

T. Any technical surveys or studies necessary to support a request for modification of WQPZ boundaries affecting the subject parcel;

U. In the instance where there is one (1) or more active oil and/or gas well(s), lease road(s), tank batteries, flow lines, gas sales lines, dead man anchors or any other related equipment, located within a proposed preliminary plat, any and all such items shall be shown on the submitted preliminary plat. Both existing conditions and any proposed changes to the existing conditions must be indicated on the preliminary plat. The information shall include, but not be limited to well access, size of the well location, including appurtenant equipment, any change in lay out or operations of the well site such as relocation of the lease road or moving of the tank batteries and flow lines, fencing, easements for flow lines, gas sales line, communication cables, and electric power lines. The information must also stipulate the parties responsible for constructing any lease road and approach and fencing. Easements necessary to provide for flow lines, gas sales lines, power supply lines and communication cables must be designated in writing. All information required must be shown on a site plan that has been reviewed and approved for compliance with oil and gas ordinances. A copy of the site plan shall be provided to the oil and gas inspector to become part of the well records until such time of the plugging and restoration of well location(s) has been completed. Oil well operators shall be notified by the oil and gas inspector of any predevelopment informational meeting(s) as an interested part where a preliminary plat contains a well(s), lease road, tank battery, flow line, gas sales line, dead man anchors, or any other related equipment that they operate. Notice shall be given in the same format as property owners within the required notice area.

§ 3. That Section 19-308(E) of Chapter 19 of the Code of the City of Norman shall be amended to read as follows:

E. In the case of a plat proposing the reserving or dedicating of land or amenities to be used in common by owners of lots in a single-family residential subdivision, or in the case of a plat or Norman Rural Certificate of Survey that contains any portion of the WQPZ, the applicant shall submit evidence acceptable to the City Attorney that all necessary steps have been taken for:

1. The establishment of a mandatory Property Owner's Association ("POA") or establishment of another acceptable arrangement for adequate maintenance of the common elements and any designated non-structural controls for storm water management. All mandatory POAs shall submit a Declaration of Covenants, Conditions and Restrictions (the "Declaration") which establishes a minimum framework that provides for the fair and effective administration of the POA and thereby assures the greater likelihood that the interests of the City and its citizens are secure and which include the following provisions:
    a. A list of all common property in the plat, by legal description. A specific description of all of the common elements within the subdivision including any abutting arterial roadways, the uses allowed for each common element and a description of the person responsible for initially constructing or installing each common element and the responsibility for maintaining the common element after initial installation;
    b. In those plats containing any portion of the WQPZ, a list of any non-structural controls located on the property.

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§ 4. That Section 19-411 of Chapter 19 of the Code of the City of Norman shall be added to read as follows:

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 WQPZ's shall be equal to:

   1. The greater of the following:

      a. 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 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 75% and a reduction in phosphorus of at least 58% 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 1% chance flood event in an given year assuming full build-out watershed conditions in those areas with 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 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.

Table of Design Pollutant Removal Efficiencies for Storm Water Controls (%)				
Structural Control	Total Suspended Solids	Total Phosphorus	Total Nitrogen	Metals
Storm Water 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

C. For each portion of any 25 foot segment of the buffer, as set forth in Section 19-411(B), that has a slope over 20%, 25 feet shall be added to the width of the WQPZ. To determine the extent of steep slopes, a cross section of the topography every 100 feet shall be prepared and utilized by the Applicant.

D. In second-order streams with continuous water or in higher order streams, 25 feet shall be added to the base width outlined in Section 19-411 (B) above.

E. Drainage easements, of sufficient size to carry the runoff of a 1% chance flood event from all drainage areas on the Plat greater than forty (40) acres within the WQPZ must be shown on dotted lines on the Preliminary and Final Plats, along with a written legal description of any such easement, all certified by a licensed Professional Engineer. Such easement shall be granted to the City of Norman for the purpose of access for inspecting, repairing, and maintaining drainage channels.

F. For all developments, particularly those containing some portion of the WQPZ, utilization of low impact development strategies are encouraged. For plats or Norman Rural Certificates of Survey that include portions of the WQPZ, the current Engineering Design Criteria may be modified when Low Impact Development strategies are utilized in accordance with City of Wichita/Sedgwick County Stormwater Manual.

G. Water Pollution Hazards. The following land uses and/or activities are designated as potential water pollution hazards and must be set back from the top of the bank of any stream or waterbody by the distance indicated below:

1. Storage of hazardous substances—(300 feet)

2. Aboveground or underground petroleum storage facilities—(300 feet)

3. Drainfields from onsite sewage disposal and treatment systems (i.e., septic systems)—(200 feet)

4. Raised septic systems and raised mound septic systems—(500 feet)

5. Solid waste landfills or junkyards—(600 feet)

6. Subsurface discharges from a wastewater treatment plant—(200 feet)

7. Land application of biosolids—(200 feet)

H. WQPZ Design Restrictions. Except as required for initial construction, there shall be no clearing, grading, construction that disturbs vegetation on any portion of the WQPZ, the width of which is determined by Section 19-411(B), (C) and (D) herein. Any development containing a WQPZ shall not be designed to contain within that zone any permanent structures or portions of septic systems, except for structural controls or other enhancing design features that will further the objectives of this ordinance.

I. All applications for preliminary plats and Norman Rural Certificates of Survey that contain any portion of property within the WQPZ shall also submit a report outlining the Best Management Practices to be employed.

§ 5. That Section 19-514 of Chapter 19 of the Code of the City of Norman shall be added to read as follows:

Sec. 19-514. Water Quality Protection Zone Management and Maintenance.

A. All preliminary plats, final plats, and Norman Rural Certificates of Survey shall clearly:

1. Show the extent of any WQPZ on the subject property.

2. Label the WQPZ.

3. Provide a note to reference any WQPZ stating: "There shall be no clearing, grading, construction or disturbance of vegetation

except as permitted by the Director of Public Works unless such disturbance is done in accordance with 19-514(E) of the Norman City Code.

4. Provide a note to reference any protective covenants governing all WQPZ areas stating: "Any WQPZ shown hereon is subject to protective covenants that may be found in the land records and that restrict disturbance and use of these areas."

5. All subdivisions containing a WQPZ area shall ensure maintenance of the non-structural controls/aspects in the WQPZ area by its Property Owners' Association through the filing of a protective covenant, which is required to be submitted to the City Attorney's office for approval. The covenant shall be recorded in the land records and shall run with the land and continue in perpetuity. Any changes to the covenants and restrictions shall be consistent with the provisions herein.

B. An offer of dedication of a WQPZ to the City of Norman does not convey to the general public the right of access to this area unless such a right is explicitly set forth in said dedication. Further, an offer of dedication of a WQPZ is not a mandate for a public trail system or any portion thereof.

C. The Public Works Department shall inspect the buffer annually and following severe storms for evidence of sediment deposition, erosion, or concentrated flow channels and corrective actions taken to ensure the integrity and functions of the WQPZ.

D. Any portion of the WQPZ that is within thirty (30) feet of a combustible structure shall be maintained (regardless of the underlying zoning designation) as provided in Section 10-209.

E. Portions of the WQPZ that are not within thirty (30) feet of a combustible structure may be left undisturbed and natural, and in no event, shall grassy vegetation in this area be mowed or otherwise cut down to less than six (6) inches tall.

§ 6. That Section 19-601 of Chapter 19 of the Code of the City of Norman shall be amended to read as follows:

Sec. 19-601. Variations.

A. Occasionally the tract to be subdivided is of such unusual size or shape or is surrounded by such development or unusual conditions that the strict application of the requirements contained in this chapter would result in substantial hardship or inequity. The City Council may vary or modify, except as otherwise indicated, such requirements of design, but not of procedure or public improvements, so that the subdivider may develop the subject property in a reasonable manner. At the same time, the public welfare and interests of the City must be protected and the general intent and spirit of this chapter are preserved by granting such variance. Such modification may be granted upon written request of the subdivider or the subdivider's engineer, stating the reason for each modification, and may be approved by vote of the regular membership of the City Council, with the recommendation of the Planning Commission, subject to the acceptance of the plat and the dedications thereon by the City Council; provided, however, that a variation based on unique condition(s) shall not be granted when the unique condition(s) was created or contributed to by the subdivider.

B. WQPZ Averaging. The width of the WQPZ may be reduced in some circumstances to accommodate unusual or historical development patterns, shallow lots, stream crossings, or storm water ponds. Any averaging of the WQPZ must be done in accordance with the following:

1. An overall average WQPZ width of at least the base width as determined in 19-411(B) must be achieved within the boundaries of the property to be developed. The WQPZ on adjoining properties cannot be included with buffer averaging on a separate property, even if owned by the same property owner.

2. The average width must be calculated based upon the entire length of stream bank that is located within the boundaries of the property to be developed. When calculating the WQPZ length, the natural stream channel should be followed.

3. WQPZ averaging shall be applied to each side of a stream independently. If the property being developed encompasses both sides of a stream, WQPZ averaging can be applied to both sides of the stream, but must be applied to both sides of the stream independently, unless the natural topography of the stream makes one side of the stream not conducive to the establishment of a WQPZ and in that event, averaging using both sides may be utilized.

4. WQPZ averaging is prohibited in developments that have, or will have after development areas that have slopes greater than 15% that are located within fifty feet of the stream to be buffered.

5. Appeal from Decision of Public Works Director. If the applicant desires to appeal from the decision of the Public Works Director or his or her designee made in accordance with this subsection, the applicant may file such request, and any documentation supporting said appeal, with the City Clerk. The City Clerk will place the appeal on the agenda of the next available regular City Council meeting. The decision of the Public Works Director, or his or her designee, may be upheld or overturned by vote of the regular membership of the City Council.

C. Whenever infrastructure has been installed that will benefit the full build-out of a Preliminary Plat which was approved within five (5) years prior to the effective date of this ordinance, the Preliminary Plat shall not be deemed expired, for purposes only of the application of this ordinance, even after the passage of three (3) years from the date of approval of the Preliminary Plat, or five (5) years from the date of approval of the Preliminary Plat if a Final Plat has been filed on part of the land embraced in the Preliminary Plat.

§ 7. That Section 19-606 of Chapter 19 of the Code of the City of Norman shall be amended to read as follows:

Sec. 19-606 Exception to allow Norman Rural Certificates of Survey as plats in A-1 and A-2 Zoning Districts.

A. It is the purpose of this exception to allow lots of ten (10) acres or more to be developed and sold adjacent to public or private roadways in the A-1 and A-2 Agricultural Districts; however, private roadways should be constructed and maintained in such a manner that said roadways may be traversed and used by police, fire and other official vehicles of all municipal, county, state and federal agencies. Lots created under this process shall be designated as "Norman Rural Certificate of Survey Subdivisions" and may be permitted under the following procedures (Ord. No. O-0203-34):

* * * * *

2. An accurate survey of the lot, prepared by a land surveyor registered in the State of Oklahoma, and the proposed subdivision thereof shall be submitted to the Public Works Department and shall show the same information required for a preliminary plat as referenced in Section 19-303 of this Code, except the ground

contours may be drawn at five-foot intervals in such cases where the average ground slope is three (3) percent or greater.

*   *   *   *   *

§ 8. If the provisions of any existing section of Chapter 19 conflicts with any section of this Water Quality Protection Zone ordinance, then the provisions of this ordinance O-1011-52 will control and prevail.

§ 9. Severability. If any section, subsection, sentence, clause, phrase, or portion of this ordinance is, for any reason, held invalid or unconstitutional by any court of competent jurisdiction, such portion shall be deemed a separate, distinct, and independent provision, and such holding shall not affect the validity of the remaining portions of this ordinance, except that the effective date provision shall not be severable from the operative provisions of the ordinance.

ADOPTED this 28th day	NOT ADOPTED this ______ day
of June, 2011.	of ________________, 2011.
Cindy Rosenthal	
Cindy Rosenthal, Mayor	Cindy Rosenthal, Mayor

ATTEST:

Brenda Hall

Brenda Hall, City Clerk

CITY OF NORMAN CORPORATE SEAL OKLAHOMA

CITY OF NORMAN
STORMWATER MANAGEMENT PROGRAM
FOR PHASE II MS4 COMPLIANCE
2016 TO 2020

Appendix I

Allowable Non-Stormwater Discharges

Part I.B.2, Authorized Non-Stormwater Discharges, of the General Permit for Stormwater Discharges Associated with Municipal Separate Storm Sewer Systems in Small Cities, Urbanized Area, and Other County Areas in the State of Oklahoma, OKR04, states that the following are allowable non-stormwater discharges:

1. Water line flushing;
2. Landscape irrigation;
3. Diverted stream flows;
4. Rising ground waters;
5. Residential building wash water without detergents;
6. Uncontaminated pumped ground water;
7. Uncontaminated ground water infiltration;
8. Discharges from potable water sources;
9. Foundation drains;
10. Air conditioning condensate;
11. Irrigation water;
12. Springs;
13. Water from crawl space pumps;
14. Footing drains;
15. Lawn watering;
16. Individual residential car washing;
17. De-chlorinated swimming pool discharges;
18. Street wash water;
19. Fire hydrant flushing;
20. Discharges from riparian areas and wetlands;
21. Discharges in compliance with a separate Oklahoma Pollutant Discharge Elimination System or National Pollutant Discharge Elimination System permit;
22. Discharges of gray water from municipal splash pads, unless otherwise permitted or regulated by DEQ, provided discharges comply with all applicable municipal and county ordinances and discharges from recirculating systems are de-chlorinated prior to discharge; and
23. Discharges or flows from emergency firefighting activities provided procedures are in place for the Incident Commander, Fire Chief, or other on-scene firefighting official in charge to make an evaluation regarding potential releases of pollutants from the scene. Measures must be taken to reduce any such pollutant releases to the maximum extent practicable subject to all appropriate actions necessary to ensure public health and safety. These procedures must be documented in your SWMP. Discharges or flows from firefighting training activities are not authorized by this Permit.

Section 6003.1, Allowable Discharges, of the City of Norman Engineering Design Criteria, which was adopted by the Norman City Council through Ordinance No. O-0506-76, also includes a list of allowable non-stormwater discharges that have been determined to not be substantial contributors of pollutants to the MS4:

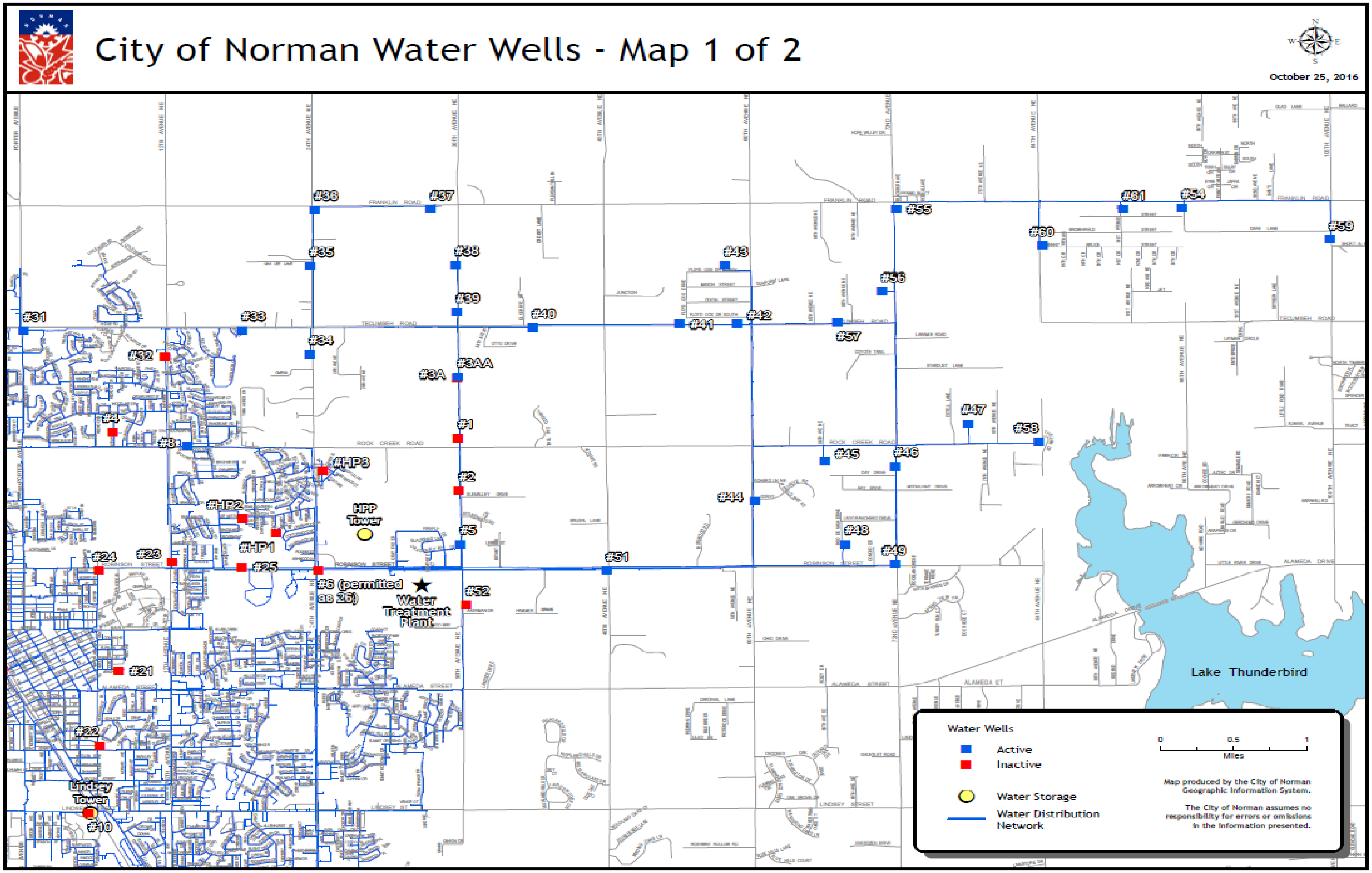
1. Potable water discharges, including potable water line flushing;
2. Uncontaminated groundwater;
3. Uncontaminated water from crawl space and footing drains;
4. Flows from riparian habitats, wetlands, springs, or streams;
5. Irrigation water;
6. Residential car washing (including charity car washes);
7. Air conditioner condensate;
8. Discharges resulting from City operations, including street washing, firefighting, maintenance and repair work;
9. Any discharge covered by a current OPDES/NPDES permit so long as the discharge is not in violation of the permit or Section 6003.1 of this ordinance;
10. Discharges containing chemicals applied according to manufacturer instructions for legitimate residential or commercial use, including legal pesticides, herbicides and fertilizers;
11. Runoff from agricultural activities, including residential gardening and landscaping;
12. Any other type of discharge determined allowable by the Director; and
13. De-chlorinated swimming pool discharges.

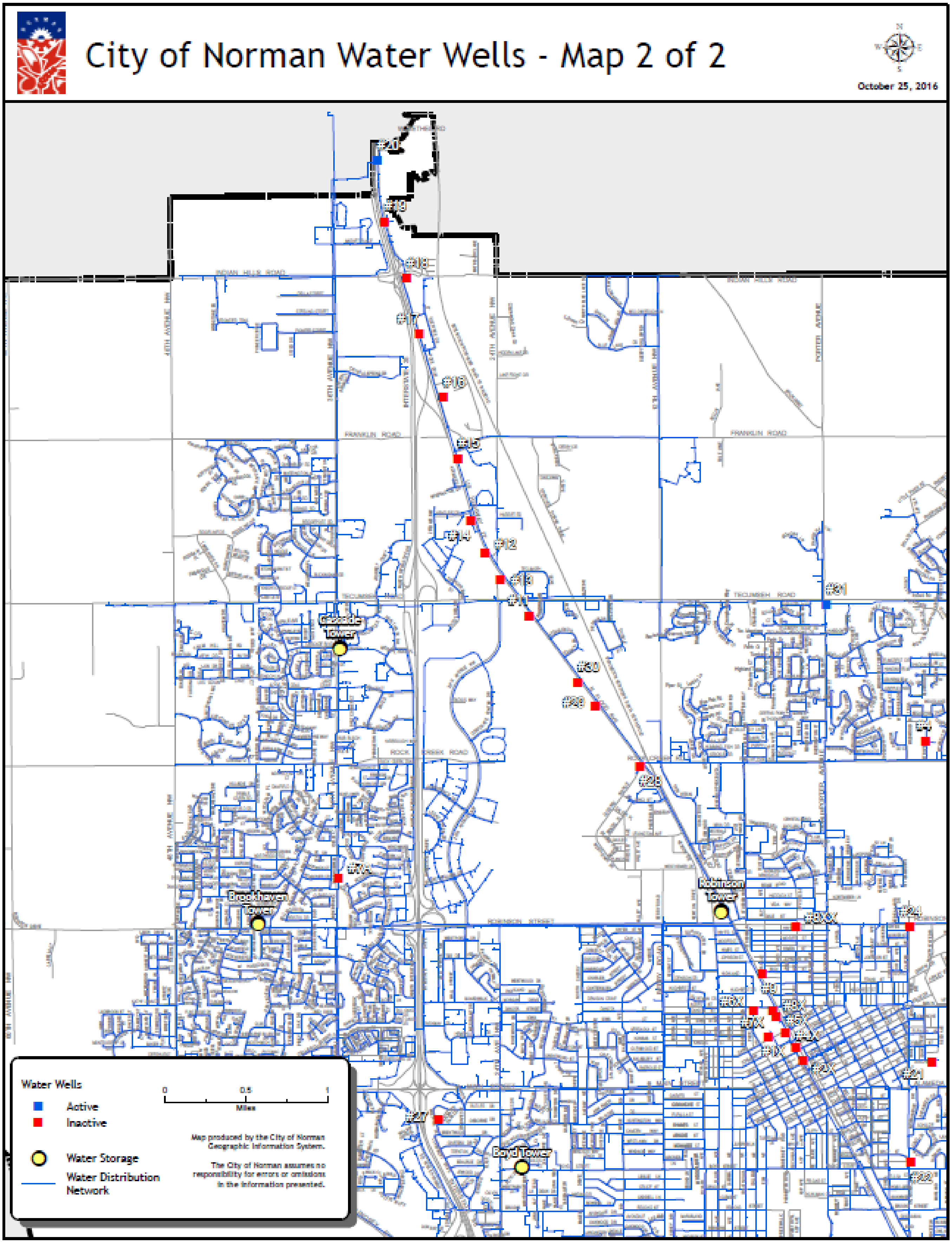
Any of the above allowable discharges may be present throughout the City of Norman on any given day. Specific allowable discharges will be included in the table below upon notification and occurrence, and any additional information will be kept with the SWMP:

Discharge Type	Location	Start Date	Duration	End Date
WTP Pilot Project	City Water Wells	October 13, 2016	~9 months	

WTP Pilot Project:

The Utilities Department, Water Treatment Plant, is conducting a pilot project to test treatment technologies for the removal of naturally-occurring Hexavalent Chromium from groundwater wells used for public water supply purposes. Discharge to the MS4 will consist of treated groundwater and well purge water, which are allowable non-stormwater discharges as uncontaminated groundwater. Locations of City of Norman Water Wells No. 44 and 48 can be seen in the maps below. Additional project details can be found by contacting Chris Mattingly, Capital Projects Engineer, Utilities Department, (405) 366-5443, chris.mattingly@normanok.gov.


City of Norman Water Wells - Map 1 of 2
October 25, 2016
#36
#37
#35
#38
#39
#40
#31
#33
#34
#32
#3A
#3AA
#4
#1
#8
#HP3
#2
#HP2
HPP Tower
#5
#HP1
#24
#23
#25
#6 (permitted as 26)
Water Treatment Plant
#52
#51
#21
#22
Lindsey Tower
#10
#43
#41
#42
#44
#55
#56
#57
#45
#46
#48
#49
#47
#58
#61
#54
#60
#59
Lake Thunderbird
Water Wells
Active
Inactive
Water Storage
Water Distribution Network
Miles
Map produced by the City of Norman Geographic Information System.
The City of Norman assumes no responsibility for errors or omissions in the information presented.


City of Norman Water Wells - Map 2 of 2
October 25, 2016
INDIAN HILLS ROAD
FRANKLIN ROAD
TECUMSEH ROAD
ROCK CREEK ROAD
ROBINSON STREET
#21
#19
#18
#17
#16
#15
#14
#12
#13
#11
#30
#29
#28
#31
#7A
#27
#8XX
#24
#9
#6X
#7X
#4X
#3
#21
#22
Cascade Tower
Brookhaven Tower
Robinson Tower
Boyd Tower
Water Wells
Active
Inactive
Water Storage
Water Distribution Network
0
0.5
1
Miles
Map produced by the City of Norman Geographic Information System.
The City of Norman assumes no responsibility for errors or omissions in the information presented.