Summary of Lakes and Reservoirs in the Flathead Lake Basin

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Public Review Draft

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Summary of Lakes and Reservoirs in the Flathead Lake Basin	1.0	September 28, 2011	

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ABBREVIATIONS AND ACRONMYNS

DEQ	Department of Environmental Quality (Montana)
DO	dissolved oxygen
EPA	U.S. Environmental Protection Agency
FWP	Department of Fish, Wildlife, and Parks (Montana)
FWS	U.S. Fish and Wildlife Service (U.S. Department of the Interior)
JPG	Joint Photographic Experts Group (a file format)
NHD	National Hydrography Dataset
NPS	U.S. National Park Service (U.S. Department of the Interior)
NRIS	Natural Resources Information System (Montana)
NWIS	National Water Information System
PDF	portable document format (a file format)
STORET	STOrage and RETrieval
TMDL	total maximum daily load
USGS	U.S. Geological Survey (U.S. Department of the Interior)
VMP	Volunteer Monitoring Program
WLI	Whitefish Lake Institute

FOREWORD

A series of brief technical reports have been prepared by the U.S. Environmental Protection Agency (EPA) in support of an effort by the Montana Department of Environmental Quality (DEQ) and EPA to establish Total Maximum Daily Loads (TMDLs) for nutrients and set up a water quality simulation model for the Flathead Basin. The series includes separate reports covering a broad range of topics including:

- Groundwater Quality and Hydrology
- Urban Stormwater Sources
- Point Source Discharges
- Agriculture/Irrigation
- Timber Harvest
- Forest Fires
- Roads
- Septic Systems
- Lakes and Reservoirs
- Existing and historic water quality in nutrient impaired waters

When combined, these technical reports are intended to define a preliminary conceptual understanding of the current water quality conditions relative to nutrients, sources of nutrients, and the ways in which water and nutrients are transported within the Basin. The information presented in this series of technical reports will be used to inform the modeling and TMDL processes. However, specific details on model setup are not discussed in the technical reports – that information will be included in the forthcoming Modeling Quality Assurance Project Plan (QAPP).

It should be noted that the data and information presented in these reports reflects what was available at the time that the reports were published. It is acknowledged that in some cases, not all data could be compiled by the publication date. Additional information will be incorporated into the modeling and TMDL processes as it becomes available.

Executive Summary

This document presents an inventory and analyses of available data for lakes and reservoirs in the Flathead Lake Basin. The specific objectives of the report are to answer the following questions:

- Given Montana's 2010 303(d) list and the necessity for future TMDL development in the Flathead Lake Basin, what lakes and reservoirs in the Basin are of concern for watershed-scale nutrient-loading?
- What data are available to characterize nutrients in each of these lakes and reservoirs?
- Is there sufficient information do determine if these lakes and reservoirs are sinks or sources of nutrients to downstream waterbodies?
- What are the most appropriate modeling approaches for the numerous lakes and reservoirs in the Flathead Lake Basin?

A methodology for identifying lakes of concern for the modeling effort was predetermined based on the scope of the nutrient modeling project. Lakes will be explicitly modeled if they are impaired for nutrients on Montana's 303(d) list or located immediately upstream or downstream of stream segments that are impaired for nutrients on Montana's 303(d) list. Additionally, lakes that are impacted by upstream anthropogenic activities, or impact natural stream flow through dam or reservoir regulation, will also be explicitly modeled. Finally, lakes with a surface area of 100 acres or greater will be explicitly modeled.

Fifty-one lakes meet these criteria, but the amount of data per lake varies considerably. For twenty-three lakes (e.g., Hidden Lake, Lake Monroe) only surface area and perimeter data are available. Bathymetry data are available for four lakes (Lake Mary Ronan, Lower Stillwater Lake, Swan Lake, and Whitefish Lake) and hydrology data, located downstream of the lake or at the lake outlet, are also available for four lakes (Ashley Lake, Hungry Horse Reservoir, Swan Lake, and Whitefish Lake). Trophic state and stratification data are available for sixteen and twenty lakes, respectively.

Recent available water quality data[1] are also limited. Samples were collected by governmental agencies at 16 lakes and immediately upstream or downstream of eight lakes. Volunteer Monitoring Program (VMP) data were collected at 43 lakes within the Basin, 16 of which meet the previously mentioned criteria to be modeled. In all, at least some water quality data were collected at 24 lakes. Additional in-stream data are available downstream of many of the lakes; however, such data are available at locations in which other sources discharge to the streams between the lakes and the sample stations. These intervening sources make it difficult to determine the impact of the lakes upon nutrient loading.

[1] For the purposes of this report, "recent" data are defined as data collected between January 1, 2000 and the present.

Lakes will be modeled via one of several different methodologies that depend upon the size, hydrography, and available data for the lake. The anticipated modeling approach is based on the following assumptions:

- Smaller lakes will have shorter mean residence times that result in less impact upon nutrient transport
- Lakes disconnected from the stream network will have more impact upon groundwater than surface water nutrient loads
- Lakes that are distant from Flathead Lake will have less impact upon nutrient loads to Flathead Lake than lakes that are close to Flathead Lake

1 Introduction

This is one of a series of brief technical reports prepared in support of an effort by the Montana Department of Environmental Quality (DEQ) and U.S. Environmental Protection Agency (EPA) to establish Total Maximum Daily Loads (TMDLs) for nutrients, sediment, and temperature and set up a water quality simulation model for the Flathead Basin. Lakes and reservoirs are prevalent throughout the Flathead Lake watershed, with over 700 waterbodies documented in the US Geological Survey's (USGS) medium-resolution National Hydrography Dataset (NHD); refer to Figure 1. Almost 5,300 lakes, ponds, and reservoirs are in the high-resolution NHD but almost 4,700 lakes are less than 10 acres. It is beyond the scope of this project to explicitly characterize and model every lake in the basin. However, it is important to have a thorough understanding of the cumulative impact of these lakes, ponds, and reservoirs because of their impact to water chemistry and hydrology. The purpose of this report is to determine which lakes and reservoirs are most important to the Flathead Basin modeling and TMDL processes, and to provide the necessary information to accurately characterize and model those waterbodies. The following sections describe the methodology for selecting the lakes and reservoirs, and provide a brief discussion of each waterbody to summarize the available data and information. The information provided for each waterbody is intended to ultimately answer the following questions:

- Given Montana's 303(d) list for 2010 and the necessity for future TMDL development in the Flathead Lake Basin, what lakes and reservoirs in the Basin are of concern for watershed-scale nutrient-loading?
- What data are available to characterize nutrients in each of these lakes and reservoirs?
- Is there sufficient information do determine if these lakes and reservoirs are sinks or sources of nutrients to downstream waterbodies?
- What are the most appropriate modeling approaches for the numerous lakes and reservoirs in the Flathead Lake Basin?

Finally, a preliminary modeling approach is described. The final modeling approach will be further documented in the Model Quality Assurance Project Plan (QAPP).

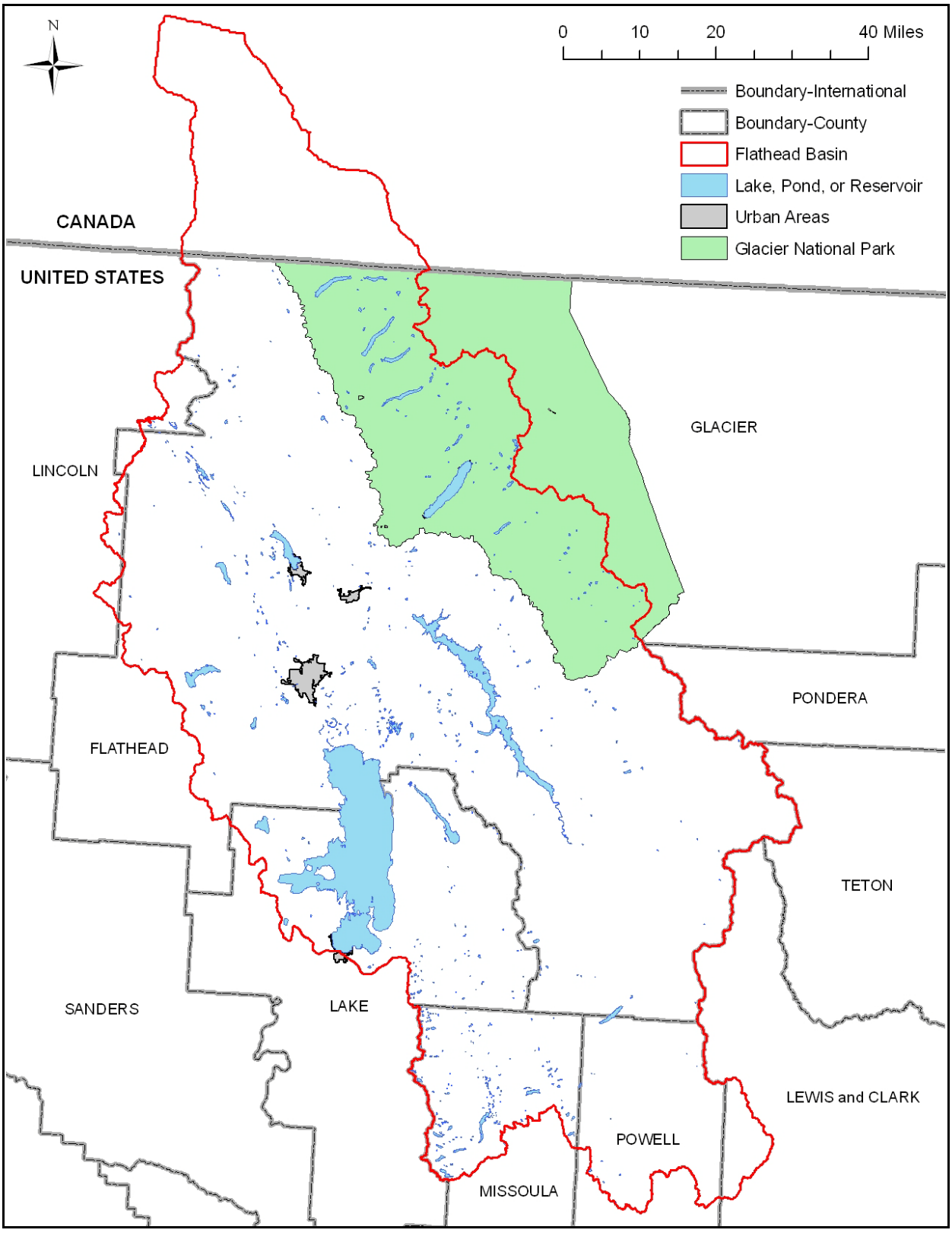

Figure 1. Lakes and reservoirs in the Flathead Basin (medium-resolution NHD).

2 Lake Selection Methodology and Results

A methodology has been developed to identify which lakes and reservoirs in the Flathead Basin are the most important from a TMDL and modeling perspective. For the purposes of this report, lakes and reservoirs are characterized in this report if they meet the following criteria:

- Impaired for nutrients on Montana's 303(d) list
- Located immediately upstream or downstream of stream segments that are impaired for nutrients on Montana's 303(d) list
- Impacted by upstream anthropogenic activities
- Impact natural streamflow through dam/reservoir regulation
- Surface area of 100 acres or greater

For modeling purposes, only lakes, ponds, and reservoirs that are directly connected to the perennial stream network will be explicitly modeled and are thus discussed in this memorandum. The following sections discuss the results of the lake selection process.

2.1 Lakes that are impaired for nutrients on Montana's 303(d) list

Three lakes in the Flathead Basin are impaired for various constituents on Montana's 303(d) list (refer to Appendix A for the 303(d) list):

- Flathead Lake (metals, nutrients, sediment, and toxic substances)
- Lake Mary Ronan (Chlorophyll-*a*)
- Whitefish Lake (metals, sediment, and toxic substances)

Flathead Lake will not be addressed in this report as it has been characterized in the Phase I TMDL and numerous other reports and will not be directly included in the watershed modeling effort.

2.2 Lakes that are immediately upstream or downstream of stream segments that are impaired for nutrients on Montana's 303(d) list

Within the Flathead Basin, eight streams and rivers are listed as impaired because of nutrients on Montana's 2010 303(d) list. Table 1 lists the lakes that are immediately upstream or downstream of one of these nutrient-impaired streams or rivers.

It should be noted that many streams in the Flathead Basin have old oxbow lakes and/or nearby disconnected lakes. These disconnected waterbodies are not considered in this analysis.

Table 1. Lakes immediately upstream or downstream of stream segments that are impaired for nutrients on Montana's 303(d) list

Lake to be modeled	Upstream listed waterbody	Downstream listed waterbody
Ashley Lake	Fish Creek	Ashley Creek
Lake Monroe	Ashley Creek	Ashley Creek
Lone Lake	Ashley Creek	Ashley Creek
Lower Stillwater Lake	Stillwater River	Stillwater River
Smith Lake	n/a	Ashley Creek
Tally Lake	Sheppard Creek	n/a
Upper Stillwater Lake	Stillwater River	Stillwater River
Upper Whitefish Lake	n/a	Swift Creek [a]
Whitefish Lake	n/a	Whitefish River

n/a = Not applicable (i.e., a listed waterbody is directly upstream or downstream of an identified lake)
[a] Upper Whitefish Lake is located on the East Fork of Swift Creek, just upstream of the listed segment on the mainstem of Swift Creek.

2.3 Lakes that are impacted by upstream anthropogenic activities

Lakes that are directly connected to upstream anthropogenic activities (via perennial streams) that affect water quality are characterized in this memorandum. Such activities can be broadly categorized as agriculture (e.g., animal feeding operations, livestock access, row crops), resources extraction (e.g., mines, roads, timber harvests), urban (e.g., industrial facilities, stormwater systems), and wastewater treatment (e.g., wastewater treatment plants, lagoons, septic systems). The lakes that will be modeled because of the affects of upstream anthropogenic activities are presented in Table 2.

Table 2. Lakes influenced by anthropogenic activities that affect water quality

Lake [a]	Planning area	Anthropogenic activity
Cyclone Lake	North Fork	Resources extraction
Ashley Lake	Flathead Lake	Resources extraction
Echo Lake		Agriculture
Hell Roaring Reservoir		Resources extraction
Lake Mary Ronan		Wastewater
Lake Monroe		Agriculture, Resources extraction
Lone Lake		Agriculture, Resources extraction
Lower Foy Lake		Agriculture, Resources extraction
*Middle Foy Lake		Agriculture, Resources extraction
Smith Lake [b]		Agriculture, Resources extraction
Hungry Horse Reservoir	South Fork	Resources extraction
Bull Lake	Stillwater River	Resources extraction
Dog Lake		Resources extraction
Duck Lake		Resources extraction
Fish Lake [c]		Resources extraction
Lower Stillwater Lake		Resources extraction
Skyles Lake		Agriculture
Spencer Lake		Agriculture
Tally Lake		Resources extraction
Upper Stillwater Lake		Resources extraction
Upper Whitefish Lake		Resources extraction
Whitefish Lake		Agriculture, Resources extraction, Urban
Mud Lake [d]	Swan River	Agriculture
Swan Lake		Resources extraction

[a] If a lake or pond appears in the NHD high but does not appear as a lake in the NRIS aerial imagery (e.g., it appears as developed land), then the waterbody is not included on this list.
[b] There are multiple Smith Lakes in the Flathead Basin; this Smith Lake is located on Ashley Creek southeast of Ashley Lake.
[c] There are multiple Fish Lakes in the Flathead Basin; this Fish Lake is located near Bull Lake and the Stillwater River.
[d] There are multiple Mud Lakes in the Flathead Basin; this Mud Lake is located near Echo Lake.

Not all lakes and ponds that may be affected by anthropogenic activities will be modeled. For example, numerous unnamed, small lakes and ponds are present in the agricultural areas of the Stillwater River valley. Additionally, numerous small lakes and ponds (both named and unnamed) are located near Echo Lake in areas that are forested but adjacent to agricultural lands. Such waterbodies may be affected by agricultural practices; however, these waterbodies are not directly connected to any major rivers or streams via any perennial surface waters. Hydrologically-isolated[2] waterbodies that do not appear to directly affect perennial flow or water quality are not discussed in this report.

2.4 Lakes that impact natural streamflow through dam/reservoir regulation

Table 3 presents the lakes and reservoirs in the Flathead Basin that are dammed. Kerr Dam, which is on the Flathead River downstream of Flathead Lake, is not discussed in this report.

Table 3. Lakes and reservoirs with dams

Lake to be modeled	Planning area	Type
Hungry Horse Reservoir	South Fork	Hydroelectric
Lion Lake		Earthen
Ashley Lake	Flathead Lake	Slip gate
Hell Roaring Reservoir		Earthen
Jessup Mill Pond		Earthen
Turtle Lake		Earthen
Skyles Lake	Stillwater River	Earthen

[2] Hydrologically-isolated refers to surface water hydrology. Such waterbodies may be connected to the principal stream network via groundwater.

2.5 Lakes with a surface area of 100 acres or more

Lakes that are directly connected to the natural, perennial stream network and have a surface are of at least 100 acres will be modeled.[3] Lakes of such size likely have sufficient water volumes and residence times to affect the hydrology of the natural, perennial stream network. Table 4 presents the lakes and reservoirs in the Flathead Basin that meet these criteria.

Table 4. Lakes and reservoirs with surface areas of at least 100 acres

Lake to be modeled	Planning area	Area (acres) [a]
Bowman Lake	North Fork	1,722
Cyclone Lake		140
Kintla Lake		1,713
Logging Lake		1,114
Lower Quartz Lake		166
Quartz Lake		872
Trout Lake		214
Upper Kintla Lake		464
Lake Ellen Wilson	Middle Fork	210
Harrison Lake		404
Hidden Lake		270
Lake McDonald		6,869
Ashley Lake	Flathead Lake	2,850
Echo Lake		716
Lake Blaine		382
Lake Mary Ronan		1,516
Lone Lake		133
Smith Lake		453
Big Salmon Lake	South Fork	972
George Lake		114
Hungry Horse Reservoir		23,577
Sunburst Lake		148
Bull Lake	Stillwater River	107
Lower Stillwater Lake		250
Tally Lake		1,211
Upper Stillwater Lake		592
Whitefish Lake		3,315
Crystal Lake	Swan River	187
Elk Lake		118
High Park Lake		220
Holland Lake		413
Glacier Lake		104
Gray Wolf Lake		339
Lindberg Lake		816
Lost Lake		110
Mud Lake		144
Swan Lake		3,271
Turquoise Lake		186

[a] Source: NHD.

[3] The following lakes have surface areas greater than 100 acres, but are not connected to the natural, perennial stream network: Blanchard Lake, Beaver Lake, Flotilla Lake, Foy Lake, Lake 5, and Loon Lake.

3 Characterization of Selected Lakes

A summary of the available data for each of the fifty-one lakes selected to be simulated as lake reaches is presented in this section. Section 3.1 summarizes the data sources, and Sections 3.2 through 3.7 provide summary information for the specific lakes of concern for the modeling effort.

3.1 Data Sources

This subsection provides background information and the source of data on the topics used to characterize each of the fifty-one lakes.

3.1.1 Bathymetry

Bathymetry data will be necessary for model development. Such data will be used to properly simulate lake hydrology. Bathymetry data are available for many of the lakes that will be explicitly modeled and also for lakes that will be indirectly simulated. Selected bathymetric maps for lakes discussed in this memorandum are presented in Appendix F. Additional maps are available but are not presented in this memorandum. The following is a summary of the currently available bathymetric data.

The U.S. Fish and Wildlife Service (FWS) provided photocopies of bathymetric maps of large lakes in Glacier National Park and in the Kalispell Valley. DEQ and Montana Fish, Wildlife, and Parks (FWP) provided PDF copies of bathymetric maps for lakes of varying size throughout the Basin. The National Park Service (NPS) provided georeferenced JPG copies of bathymetric maps of large lakes in Glacier National Park. The Whitefish Lake Institute (WLI) provided color posters of bathymetrical data for Whitefish Lake and Tally Lake that were created by Constellation Services. DEQ has contracted with Constellation Services to develop more bathymetrical maps that will be made available for the modeling effort as they are developed.

3.1.2 Hydrology

Historic and active continuous flow gages operated by USGS are present above and/or below a number of the lakes presented in this report. Additionally, hydrological data are available at some of the dams. Instantaneous discharge measurements have been made at lake outlets and the mouths of tributary streams on many of the lakes discussed in this memorandum; however, these data are not summarized here.

3.1.3 Dams

Eight dams are located in the Flathead River Basin (Figure 2). The following seven dams are briefly discussed in this document: Hungry Horse Dam, Bigfork Dam, Ashley Lake Dam, Lion Lake Dam, Jessup Mill Pond Dam, Hellroaring Dam, and Turtle Lake Dam.

Additional dams and other various impoundments are located throughout the Basin, but are beyond the scope of this document because they are not on the lakes and reservoirs of concern for modeling purposes.

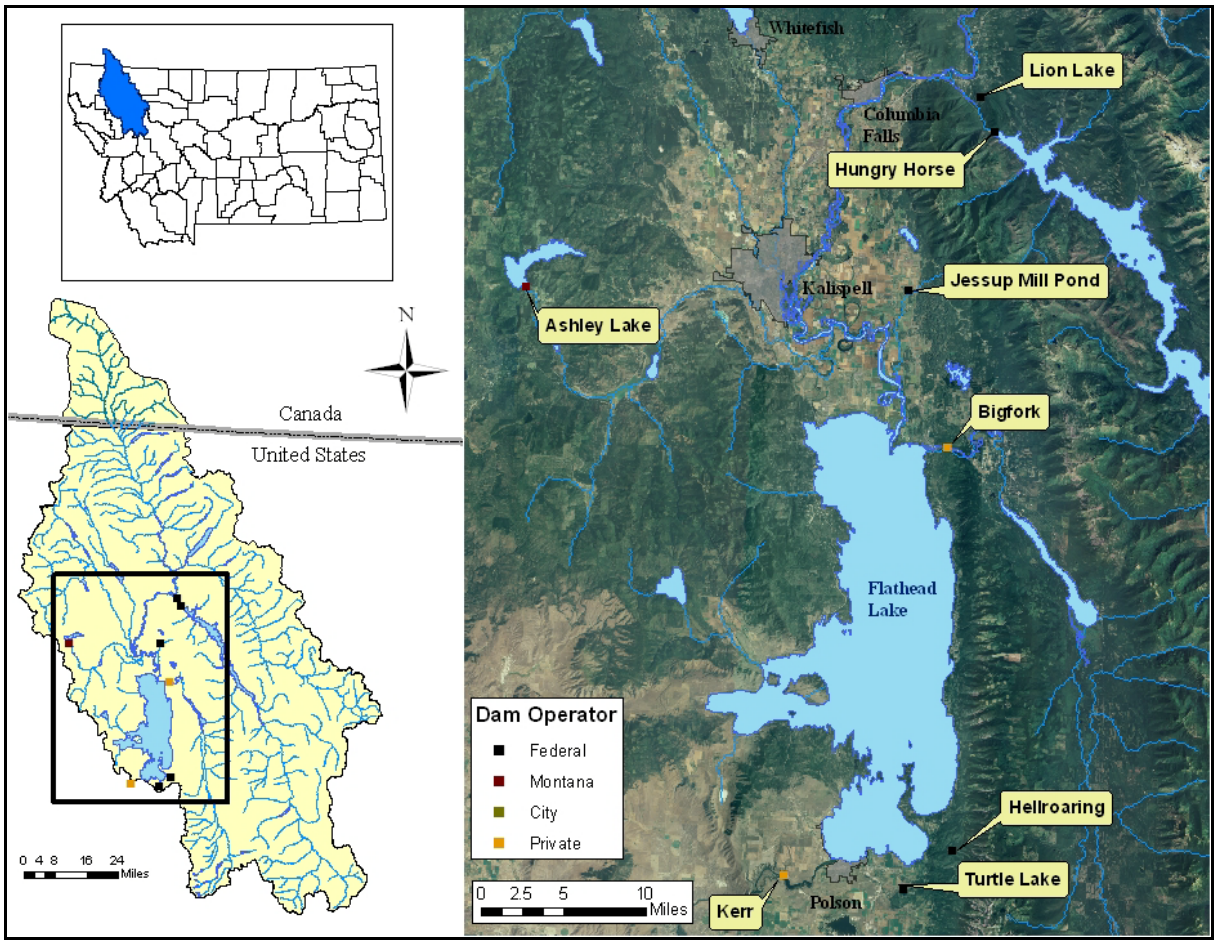

Figure 2. Dams in the Flathead Lake Basin.

3.1.4 Physical Parameters

Physical lake data include surface area and perimeter. Additionally, the land uses and land covers within a lake's subwatershed are important. Subwatershed land use and land cover, surface area, and perimeter data are available for all lakes.

3.1.5 Residence Time

Residence time, or retention time, of water in lakes is an important indicator that shows the rate that inflow water mixes with the lake water. For small lakes in the Flathead Lake Basin, residence time is assumed to be near or less than one day. For large- and medium-sized lakes, residence time is calculated for the lakes with available flow and volume data, although these data are not available for the majority of lakes located in the Flathead Lake Basin.

3.1.6 Trophic State

Lake trophic state is a simple index that is used to evaluate the overall nutrient and algae levels of a lake. The trophic state of the lakes in the Basin can be used to assess the degree to which they could be potentially affecting the downstream transport of nutrients. Trophic State Indices (TSI) are calculated using total phosphorus, chlorophyll-a, and Secchi depth (Carlson 1977).

Insufficient data are available for TSI's to be calculated at many of the lakes in the Basin. However, appropriate data were collected between 1993 and 2007 for some of the lakes through the Flathead Basin

Commission Lake Monitoring Program. In general, the trophic states of these lakes are mainly oligotrophic with some approaching mesotrophic levels.

3.1.7 Stratification

DEQ, the Volunteer Monitoring Program (Ellis and Craft 2008), and Whitefish Lake Institute (WLI) collected temperature and dissolved oxygen data for multiple depths on some lakes. Data are also available for some lakes for multiple sample events. Plotting the data in depth-profiles can show if a certain lakes stratify. These profiles are presented in Appendix C (Volunteer Study), Appendix E (DEQ), and Appendix F (WLI).

3.1.8 Water quality

Surface water quality samples have been collected both on the lakes, ponds, and reservoirs and streams and rivers since the 1970s. Although historic data can be useful for evaluating temporal trends in lake water quality, this report primarily includes data collected since 2000 as it will be more pertinent to the model calibration period (likely to be from 2000 to present).

Data were acquired from EPA's Legacy and Modern STOreage and RETrieval (STORET) databases, USGS's National Water Information System (NWIS), Flathead Lake BiologicalStation, numerous state agencies, and other local entities. Only nutrient data are summarized in this memorandum; however, additional water quality data are available.

Station locations and descriptions are presented in Appendix B. Historic data (i.e., collected prior to 2000) are available for some of the lakes but such data are not presented in this document.

3.1.9 Summary of data

Table 5 displays a summary of currently available data for each of the 51 lakes and reservoirs of interest.

Table 5. Summary of available data for selected lakes in the Flathead Lake Basin

Waterbody Name	Lake area [a]	Maximum depth [b]	Bathymetry [c]	Hydrology [d]	Trophic State [e]	Stratification [e]	Nutrient [f]	Dam / Reservoir [g]
HUC 17010206	***North Fork Planning Area***							
Bowman Lake	1,722	253	FWS	--	Oligotrophic	Yes	L	--
Cyclone Lake	140	--	--	--	--	No	L	--
Kintla Lake	1,713	390	FWS	--	Oligotrophic	Yes	--	--
Logging Lake	1,114	--	FWS	--	--	--	--	--
Lower Quartz Lake	166	--	FWS	--	--	Yes	L	--
Quartz Lake	872	--	FWS	--	--	--	--	--
Trout Lake	214	--	--	--	--	--	--	--
Upper Kintla Lake	464	--	FWP	--	--	--	--	--
HUC 17010207	***Middle Fork Planning Area***							
Lake Ellen Wilson	210	--	--	--	--	--	--	--
Harrison Lake	404	--	FWS	--		Yes	L	--
Hidden Lake	270	--	--	--	--	--	--	--
Lake McDonald	6,869	430	FWP, FWS	--		Yes	U D	--
HUC 17010208	***Flathead Lake Planning Area***							
Ashley Lake	2,850	255	FWP, FWS*	O	Oligomesotrophic	Yes	U L D	Dam
Echo Lake	716	66	FWP, FWS*	--	Oligomesotrophic	Yes	--	--
Hell Roaring Reservoir	5	--	--	--	--	--	--	Dam [h]
Jessup Mill Pond	22	--	--	--	--	--	--	Dam [h]
Lake Blaine	382	141	FWP, FWS*	--	Mesooligotrophic	--	--	--
Lake Mary Ronan	1,516	47	FWP, FWS*	--	Mesoeutrophic	Yes	L	--
Lake Monroe	48	--	--	--	--	--	--	--
Lone Lake	133	--	--	--	--	--	--	--
Lower Foy Lake	14	--	--	--	--	--	--	--
Middle Foy Lake	41	--	--	--	--	--	--	--
Turtle Lake	50	--	--	--	--	--	--	Dam [h]
Smith Lake	453	--	--	--	--	--	U D	--
HUC 17010209	***South Fork Planning Area***							
Big Salmon Lake	972	--	--	--	--	--	--	--
George Lake	114	--	FWP	--	--	--	--	--
Hungry Horse Reservoir	23,577	--	--	U D	--	Yes	U L D	Dam
Lion Lake	39	88	--	--	Oligotrophic	--	--	Dam [h]
Sunburst Lake	148	--	FWP	--	--	--	--	--
HUC 17010210	***Stillwater River Planning Area***							
Bull Lake	107	--	--	--	--	Yes	L	--
Dog Lake	102	--	--	--	--	--	--	--
Fish Lake	32	--	--	--	--	--	--	--
Duck Lake	60	--	--	--	--	No	L	--
Lower Stillwater Lake	250	53	DEQ, FWS*	--	Mesotrophic	Yes	L D	--
Skyles Lake	38	13	FWP	--	Oligomesotrophic	No	--	--

Waterbody Name	Lake area [a]	Maximum depth [b]	Bathymetry [c]	Hydrology [d]	Trophic State [e]	Stratification [e]	Nutrient [f]	Dam / Reservoir [g]
Spencer Lake	30	--	FWP	--	Mesooligotrophic	--	--	--
Tally Lake	1,211	495	FWP, FWS*	D	Oligotrophic	Yes	U L	--
Upper Stillwater Lake	592	75	FWS*	--	Oligotrophic	--	L	--
Upper Whitefish Lake	80	--	FWP	--	--	Yes	--	--
Whitefish Lake	3,315	223	DEQ, FWS*	--	Oligotrophic	Yes	U L D	--
HUC 17010211	***Swan River Planning Area***							
Crystal Lake	187	--	--	--	--	--	--	--
Elk Lake	118	--	--	--	--	--	--	--
High Park Lake	220	--	--	--	--	--	--	--
Holland Lake	413	156	FWP		Oligotrophic	Yes	L	--
Glacier Lake	104	--	--	--	--	--	--	--
Gray Wolf Lake	339	--	--	--	--	--	--	--
Lindberg Lake	816	121	FWP	--	Oligotrophic	Yes	L	--
Lost Lake	110	--	--	--	--	--	--	--
Mud Lake	144	--	--	--	--	--	--	--
Swan Lake	3,271	133	DEQ, FWS*	D	Oligotrophic	Yes	U L D	
Turquoise Lake	186	--	--	--	--	--	--	--

[a] Lake areas were extracted from the high resolution NHD and are reported in acres.
[b] Maximum depths are reported from Ellis and Craft (2008).
[c] Bathymetry data that were provided by various entities. An asterisk (*) refers to a map provided by FWS that was originally created by Montana Fish and Game.
[d] Data were downloaded from NWIS or provided by DNRC (Ashley Creek). Data are available at the lake/reservoir outlet (O) or on the major upstream (U) or downstream (D) stream reach.
[e] Trophic states are reported from Ellis and Craft (2008). Stratification data are from unpublished Volunteer Monitoring Program data or DEQ data.
[f] Nutrient data were obtained from multiple sources; only nutrient data collected since the year 2000 were evaluated. Sample stations are located on the lake (L), and on waterbodies immediately upstream (U) and downstream (D) of the lake.
[g] Dams and regulating reservoir data were obtained from multiple source; "Dam" denotes the presence of a dam on a waterbody.
[h] Data on these dams/reservoirs are limited and may include the following: construction date, construction material, length, height, volume, and year of construction.

3.2 HUC 17010206 – North Fork Planning Area

Eight lakes of interest are located in the North Fork Planning Area; seven of the lakes are displayed in Figure 3. Cyclone Lake is displayed in Figure 4.

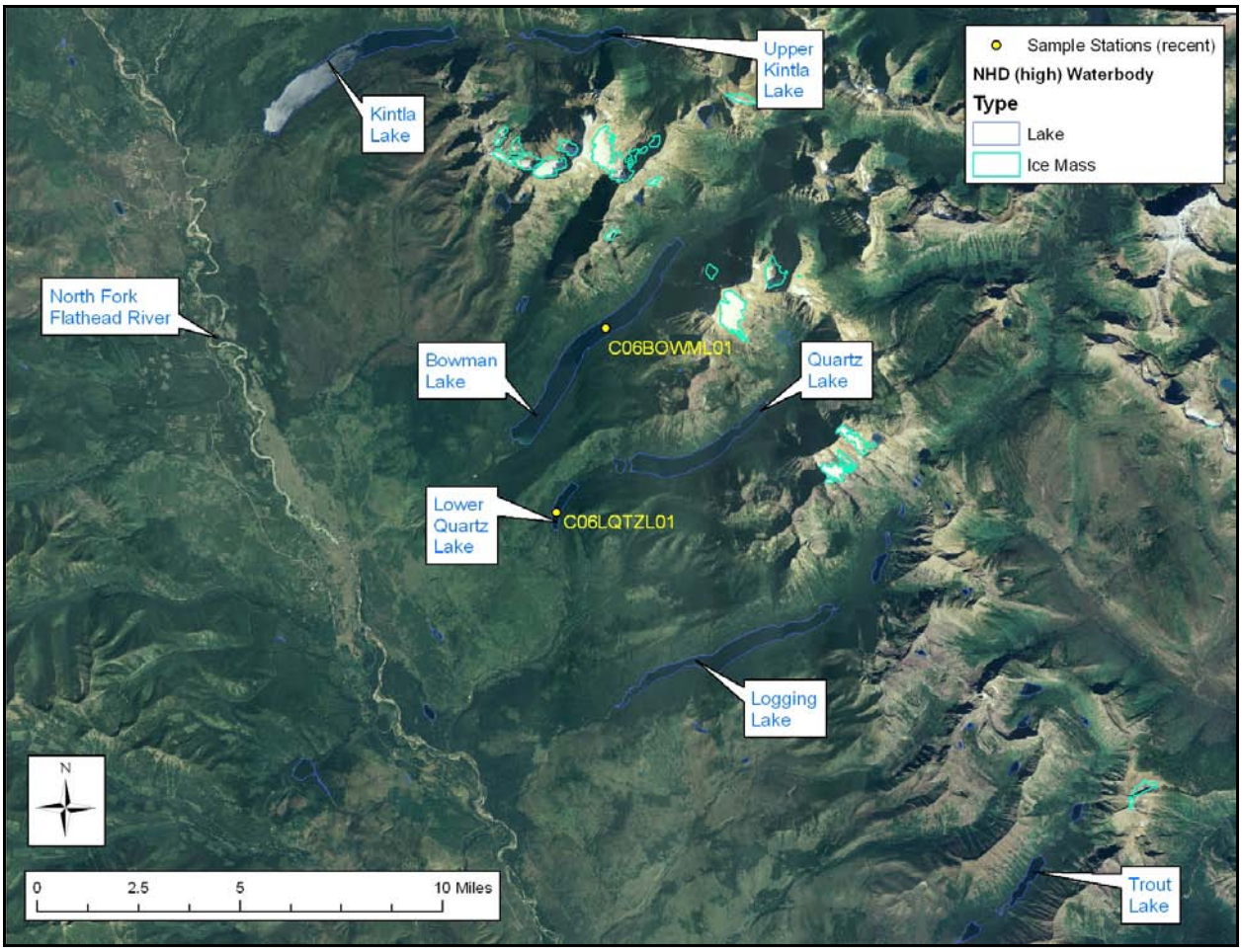

Figure 3. Bowman Lake, Kintla Lake, Logging Lake, Lower Quartz Lake, Quartz Lake, Trout Lake, and Upper Kintla Lake.[4]

3.2.1 Bowman Lake

Bowman Lake is located northeast of Flathead Lake in Glacier National Park (Figure 3). According to the National Hydrography Dataset (NHD), the surface area of Bowman Lake is 1,722 acres with a perimeter of 14.1 miles. Approximately 28,731 acres drain to Bowman Lake, its elevation is 3,999 feet, and its maximum depth is 253 feet (Ellis and Craft 2008). The U.S. Fish and Wildlife Service (FWS) provided an undated bathymetric map of Bowman Lake (Appendix F) and the National Park Service (NPS) provided a georeferenced JPG of the FWS map.

No water quality data from governmental agencies were located for the waterbodies immediately upstream or downstream of Bowman Lake. Only one sample station is located on Bowman Lake:

[4] Only stations that were sampled since 2000 and are located on a lake of interest or immediately upstream or downstream of a lake of interest are displayed.

C06BOWML01 (Bowman Lake at mid-lake). A summary of nutrient data collected at C06BOWMNL01 is presented in Table 6.

Table 6. Summary of nutrient data collected at station C06BOWML01

Parameter	Units	No. of Samples	Begin	End	Min	Max	Avg
Ammonia	mg/L as N	6	7/7/2008	9/1/2008	ND [a]	0.02	0.01
Chlorophyll-*a*	µg/L	8	7/7/2008	9/1/2008	0.6	1.6	1.0
Dissolved Oxygen [b]	mg/L	186	7/7/2008	9/1/2008	8.90	11.92	10.32
Dissolved Oxygen [b]	%	185	7/7/2008	9/1/2008	68.9	103.4	85.7
Nitrate + Nitrite	mg/L as N	6	7/7/2008	9/1/2008	0.059	0.081	0.067
Total Nitrogen	mg/L as N	6	7/7/2008	9/1/2008	0.08	0.13	0.10
Total Phosphorus	mg/L as P	6	7/7/2008	9/1/2008	ND [c]	0.006	0.003

[a] The detection limit is 0.01 mg/L; 0.005 mg/L was used for calculating statistics.
[b] Dissolved oxygen data were collected over multiple depths.
[c] The detection limit is 0.001 mg/L; 0.0005 mg/L was used for calculating statistics.

Volunteer Monitoring Program (VMP) data were collected from Bowman Lake six times from 1996 to 2005. Total phosphorus (mean: 5 µg/L), chlorophyll-*a* (mean: 0.6 µg/L), and Secchi depth (mean: 12.2 m) indicate that Bowman Lake is oligotrophic (Ellis and Craft 2008).

Bowman Lake stratified at 10 meters depth in August/September 1998, 2001, and 2005 (VMP, Appendix C) and at 5 to 15 meters depth in July through September 2008 (DEQ, Appendix E). VMP-collected DO concentrations remained above 6 mg/L up to the maximum observed sample depth of 33 meters (Appendix C). DEQ-collected DO concentrations remained above 8 mg/L up to the maximum observed sampling depth of 75 meters (Appendix E).

3.2.2 Cyclone Lake

Cyclone Lake is located north of Flathead Lake and east of the North Fork of the Flathead River (Figure 4). According to the NHD, the surface area of Cyclone Lake is 130 acres with a perimeter of 2.1 miles.

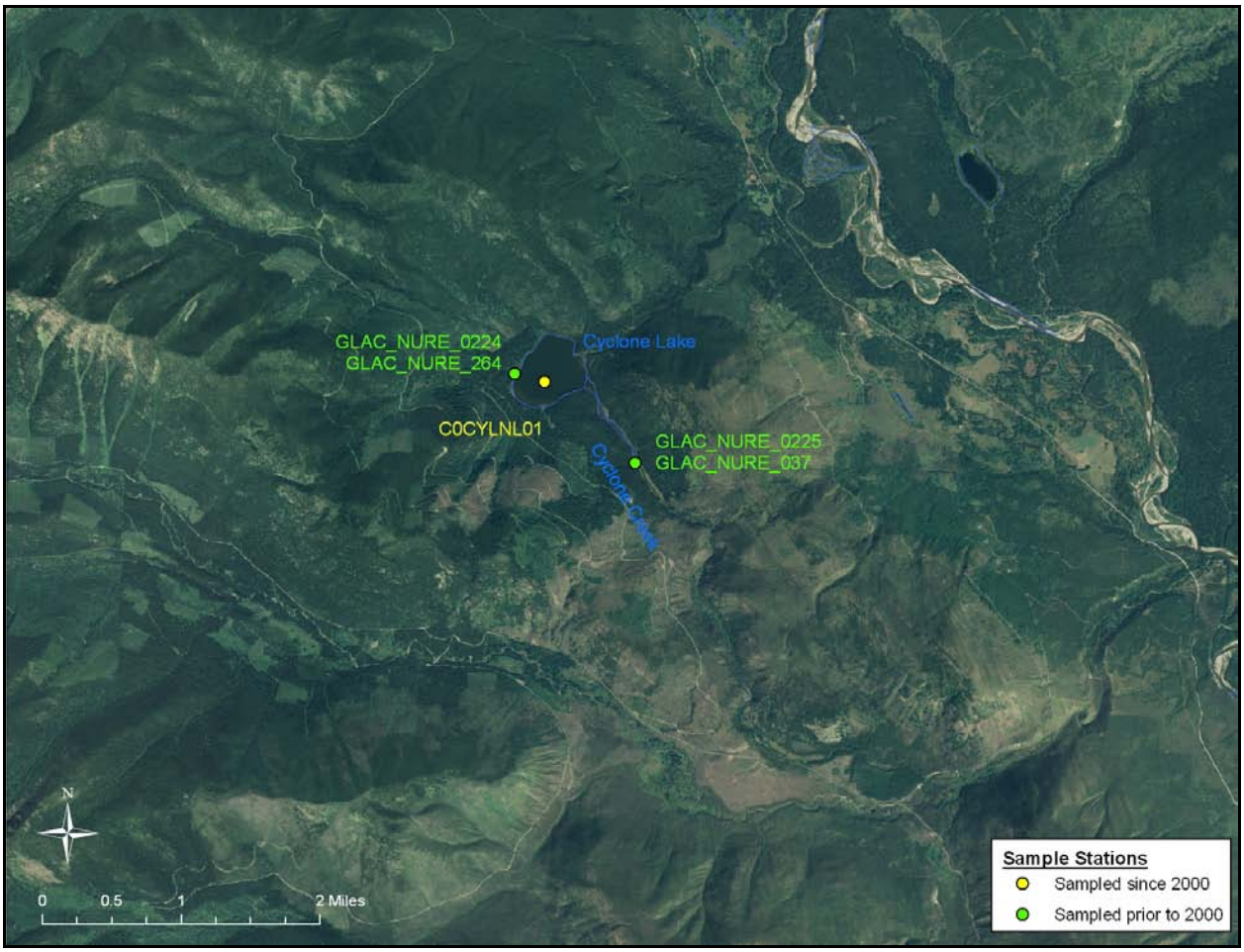

Figure 4. Cyclone Lake.

In June 1976, one sample each was collected from two nearby sample stations on an upstream, unnamed tributary to Cyclone Lake. Similarly, one sample each was collected from two nearby downstream sample stations on Cyclone Creek. The only recent sampling occurred on Cyclone Lake at station C06CYLNL01 (Cyclone Lake at mid-lake). A summary of the available nutrient data for this station is presented in Table 7.

Table 7. Summary of nutrient data collected at C06CYLNL01

Parameter	Units	No. of Samples	Begin	End	Min	Max	Avg
Ammonia	mg/L as N	3	7/9/2008	9/3/2008	ND [a]	0.02	0.01
Chlorophyll-*a*	µg/L	6	7/9/2008	9/3/2008	2.20	8.75	4.82
Dissolved oxygen [b]	mg/L	39	7/9/2008	9/3/2008	2.46	10.56	8.81
Nitrate + Nitrite	mg/L as N	3	7/9/2008	9/3/2008	ND [c]	0.011	0.006
Total Nitrogen	mg/L as N	3	7/9/2008	9/3/2008	0.17	0.28	0.21
Total Phosphorus	mg/L as P	3	7/9/2008	9/3/2008	0.002	0.024	0.012

[a] The detection limit is 0.01 mg/L; 0.005 mg/L was used for calculating statistics.
[b] Dissolved oxygen data were collected over multiple depths.
[c] The detection limit is 0.005 mg/L; 0.0025 mg/L was used for calculating statistics.

At station C06CYLNL01, DEQ temperature-depth data from 2008 do not show stratification. DO concentrations remain above 8 mg/L to a depth of 5.5 meters and drop below 4 mg/L at a depth of 6.0 meters.

3.2.3 Kintla Lake

Kintla Lake is located northeast of Flathead Lake in Glacier National Park (Figure 3). According to the NHD, the surface area of Kintla Lake is 1,713 acres with a perimeter of 12.0 miles. Approximately 34,665 acres drain to Kintla Lake, its elevation is 4,190 feet, and its maximum depth is 390 feet (Ellis and Craft 2008). The FWS provided an undated bathymetric map of Kintla Lake (Appendix F) and NPS provided a georeferenced JPG of the FWS map.

No water quality data from governmental agencies were located for Kintla Lake or for the waterbodies immediately upstream or downstream of the lake. VMP data were collected from Kintla Lake five times from 1996 to 2001. Total phosphorus (mean: 4 µg/L), chlorophyll-*a* (mean: 0.5 µg/L), and Secchi depth (mean: 13.2 m) indicate that Kintla Lake is oligotrophic (Ellis and Craft 2008).

VMP data show that Kintla Lake stratified at 13 meters depth in August 1998. DO concentrations remained above 8 mg/L up to the maximum observed sample depth of 33 meters (Appendix C).

3.2.4 Logging Lake, Quartz Lake, and Upper Kintla Lake

Logging Lake, Quartz Lake, and Upper Kintla Lake are located northeast of Flathead Lake in Glacier National Park (Figure 3). No water quality data were located for these lakes or on the waterbodies immediately upstream and downstream of the lakes. The FWS provided bathymetric maps for Logging Lake (1977), Lower Quartz Lake (1980), Middle Quartz Lake (1980), and Upper Kintla Lake (1980); see Appendix F. NPS provided georeferenced JPG's of the FWS maps.

3.2.5 Lower Quartz Lake

Lower Quartz Lake is located northeast of Flathead Lake in Glacier National Park (Figure 3). According to the NHD, the surface area of Lower Quartz Lake is 166 acres with a perimeter of 3.0 miles. The FWS provided a bathymetric map for Lower Quartz Lake from 1980 (Appendix F) and NPS provided a georeferenced JPG of the FWS map.

No water quality data were located for the waterbodies immediately upstream or downstream of Lower Quartz Lake. Only one sample station is located on Lower Quartz Lake: C10LQTZL01 (Lower Quartz Lake at mid-lake). A summary of nutrient data collected at C10LQTZL01 is presented in Table 8.

Table 8. Summary of nutrients data collected at station C10LQTZL01

Parameter	Units	No. of Samples	Begin	End	Min	Max	Avg
Ammonia	mg/L as N	3	7/8/2008	9/2/2008	ND [a]	ND [a]	ND [a]
Chlorophyll-a	µg/L	6	7/8/2008	9/2/2008	0.60	1.75	0.98
Dissolved Oxygen [b]	mg/L	52	7/8/2008	9/2/2008	1.42	12.10	9.15
Dissolved Oxygen [b]	mg/L	51	7/8/2008	9/2/2008	11.8	104.4	85.9
Nitrate + Nitrite	mg/L as N	3	7/8/2008	9/2/2008	ND [c]	0.025	0.012
Total Nitrogen	mg/L as N	3	7/8/2008	9/2/2008	0.04	0.08	0.06
Total Phosphorus	mg/L as P	3	7/8/2008	9/2/2008	ND [d]	0.006	0.004

[a] The detection limit is 0.01 mg/L; 0.005 mg/L was used for calculating statistics.
[b] Dissolved oxygen data were collected over multiple depths.
[c] The detection limit is 0.005 mg/L; 0.0025 mg/L was used for calculating statistics.
[d] The detection limit is 0.001 mg/L; 0.0005 was used for calculating statistics.

At station C10LQTZL01, Lower Quartz Lake stratified at depths of 7 to 9 meters in July through September 2008. DO concentrations remained above 8 mg/L up to depths of 13 meters and ranged from 2 to 7 mg/L at the maximum sample depth of 16 meters (Appendix E).

3.2.6 Trout Lake

Trout Lake is located northeast of Flathead Lake in Glacier National Park (Figure 3). According to the NHD, the surface area of Trout Lake is 213 acres with a perimeter of 4.4 miles. No water quality data were located for Trout Lake or on the waterbodies immediately upstream of the lake. No station downstream of Trout Lake was recently sampled. Two stations were sampled in August 1978: GLAC_NURE_0572 and GLAC_NURE_384 (Camas Creek).

3.3 HUC 17010207 – Middle Fork Planning Area

Four lakes and reservoirs of interest are in the Middle Fork Planning Area. Available data for these waterbodies are presented in the following subsections. The four lakes are displayed in Figure 5.

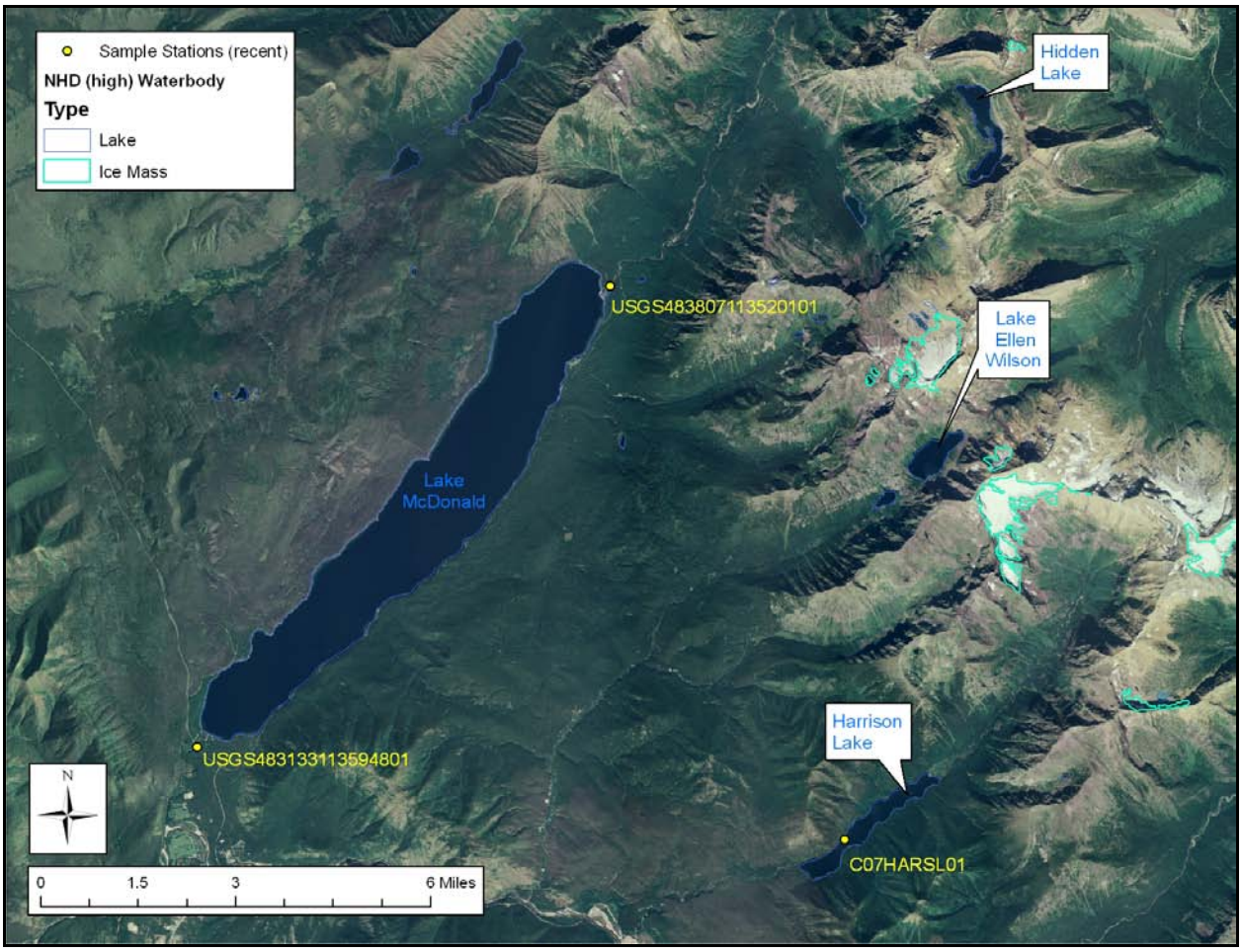

Figure 5. Harrison Lake, Hidden Lake, Lake Ellen Wilson, and Lake McDonald.[5]

[5] Only stations that were sampled since 2000 and are located on a lake of interest or immediately upstream or downstream of a lake of interest are displayed.

3.3.1 Harrison Lake

Harrison Lake is located northeast of Flathead Lake and east of Lake McDonald (Figure 5). It is fed by a number of small perennial and intermittent tributaries, including Harrison Creek, which is fed by glaciers. According to the NHD, the surface area of Harrison Lake is 404 acres with a perimeter of 6.1 miles. The FWS provided a bathymetric map for Harrison Lake from 1979 and FPS provided a georeferenced JPG of the FWS map.

Limited (one sampling event) recent data are available for stations located on waterbodies immediately upstream and downstream of Harrison Lake. Historic data from station 4C3-011 (Harrison Lake) are also available for one sample from 1985. DEQ recently sampled station C07HARSL01 (Harrison Lake at mide-Lake); a summary of data from C07HARSL01 is presented in Table 9.

Table 9. Summary of nutrient samples collected at C07HARSL01

Parameter	Units	No. of Samples	Begin	End	Min	Max	Avg
Ammonia	mg/L as N	3	7/5/2008	8/31/2008	ND [a]	ND [a]	ND [a]
Chlorophyll-*a*	µg/L	6	7/5/2008	8/31/2008	0.6	1.15	0.88
Dissolved Oxygen [b]	mg/L	97	7/5/2008	8/31/2008	6.18	10.85	9.31
Dissolved Oxygen [b]	%	96	7/5/2008	8/31/2008	48.4	99.7	81.9
Nitrate + Nitrite	mg/L as N	3	7/5/2008	8/31/2008	0.082	0.123	0.103
Total Nitrogen	mg/L as N	3	7/5/2008	8/31/2008	0.10	0.16	0.14
Total Phosphorus	mg/L as P	3	7/5/2008	8/31/2008	ND [c]	0.007	0.004

[a] The detection limit is 0.01 mg/L; 0.005 mg/L was used for calculating statistics.
[b] Dissolved oxygen data were collected at multiple depths.
[c] The detection limit is 0.001 mg/L; 0.0005 mg/L was used for calculating statistics.

At station C07HARSL01, Harrison Lake stratified at depths of 5 to 15 meters in July through September 2008. DO concentrations remained above 8 mg/L up to depths of 25 meters and remained above 6 mg/L up to the maximum observed sampling depth at 35 meters (Appendix E).

3.3.2 Hidden Lake and Lake Ellen Wilson

These lakes are located northeast of Flathead Lake and east of Lake McDonald (Figure 5). No water quality data were located for either lake or on the waterbodies immediately upstream and downstream of the lakes.

3.3.3 Lake McDonald

Lake McDonald is located northeast of Flathead Lake (Figure 5). It is fed by multiple tributaries. According to the NHD, the surface area of Lake McDonald is 6,869 acres with a perimeter of 21.6 miles. Approximately 112,840 acres drain to Lake McDonald, its elevation is 3,150 feet, and its maximum depth is 430 feet (Ellis and Craft 2008). The FWS provided a bathymetric map for Lake McDonald from 1979 and NPS provided a georeferenced JPG of the FWS map.

No recent water quality data from governmental agencies were located for Lake McDonald, but some data for tributaries to the lake are available. One station each located on waterbodies upstream and downstream of Lake McDonald were recently sampled: 483807113520101 (McDonald Creek ab McDonald Lake, Glacier NP) and 483133113594801 (McDonald Creek bl McDonald Lake, Glacier Nat'l Prk). Summaries of the nutrient data for these stations are presented in Table 10 and Table 11.

Table 10. Summary of nutrient samples collected at station 483807113520101

Parameter	Units	No. of samples	Begin	End	Min	Max	Avg
Nitrate	mg/L as N	41	3/10/2005	8/3/2007	0.1	0.6	0.3
Total Nitrogen	mg/L as N	41	3/10/2005	8/3/2007	0.07	0.63	0.30
Total Phosphorus	mg/L as P	41	3/10/2005	8/3/2007	0.003	0.015	0.006

Table 11.Summary of nutrient samples collected at station 483133113594801

Parameter	Units	No. of samples	Begin	End	Min	Max	Avg
Nitrate	mg/L as N	43	2/8/2005	8/3/2007	0.13	0.32	0.20
Total Nitrogen	mg/L as N	43	2/8/2005	8/3/2007	0.17	0.40	0.24
Total Phosphorus	mg/L as P	42	2/8/2005	8/3/2007	0.002	0.010	0.005

Volunteer data were collected from Lake McDonald ten times from 1996 to 2007. Total phosphorus (mean: 5 µg/L), total nitrogen (mean: 274 µg/L), chlorophyll-*a* (mean: 0.6 µg/L), and Secchi depth (mean: 12.9 m) indicate that Lake McDonald is oligotrophic (Ellis and Craft 2008).

Lake McDonald stratifies in late summer (Ellis and Craft 2008). VMP data shows that Lake McDonald stratifies at 10 meters in August (1998, 2001, 2002, and 2006). DO concentrations remained above 6 mg/L up to the maximum observed sampling depth of 33 meters (Appendix C).

3.4 HUC 17010208 – Flathead Lake Planning Area

Twelve lakes and reservoirs of interest are in the Flathead Lake Planning Area[6]. Available data for these waterbodies are presented in the following subsections.

3.4.1 Ashley Lake

Ashley Lake is located northwest of Flathead Lake (Figure 6). It is fed by a number of small tributaries, including Fish Creek, which is listed by DEQ as impaired for nutrients (Appendix A and Figure 6). According to the NHD, the surface area of Ashley Lake is 2,812 acres with a perimeter of 16.0 miles. Approximately 21,388 acres drain to Ashley Lake, its elevation is 3,999 feet, and its maximum depth is 225 feet (Ellis and Craft 2008).

[6] Timber harvests have occurred near Foy Lake and a small, unnamed lake southwest of Foy. Since these lakes are not connected to the stream network via perennial streams, they are not further addressed in this memorandum.

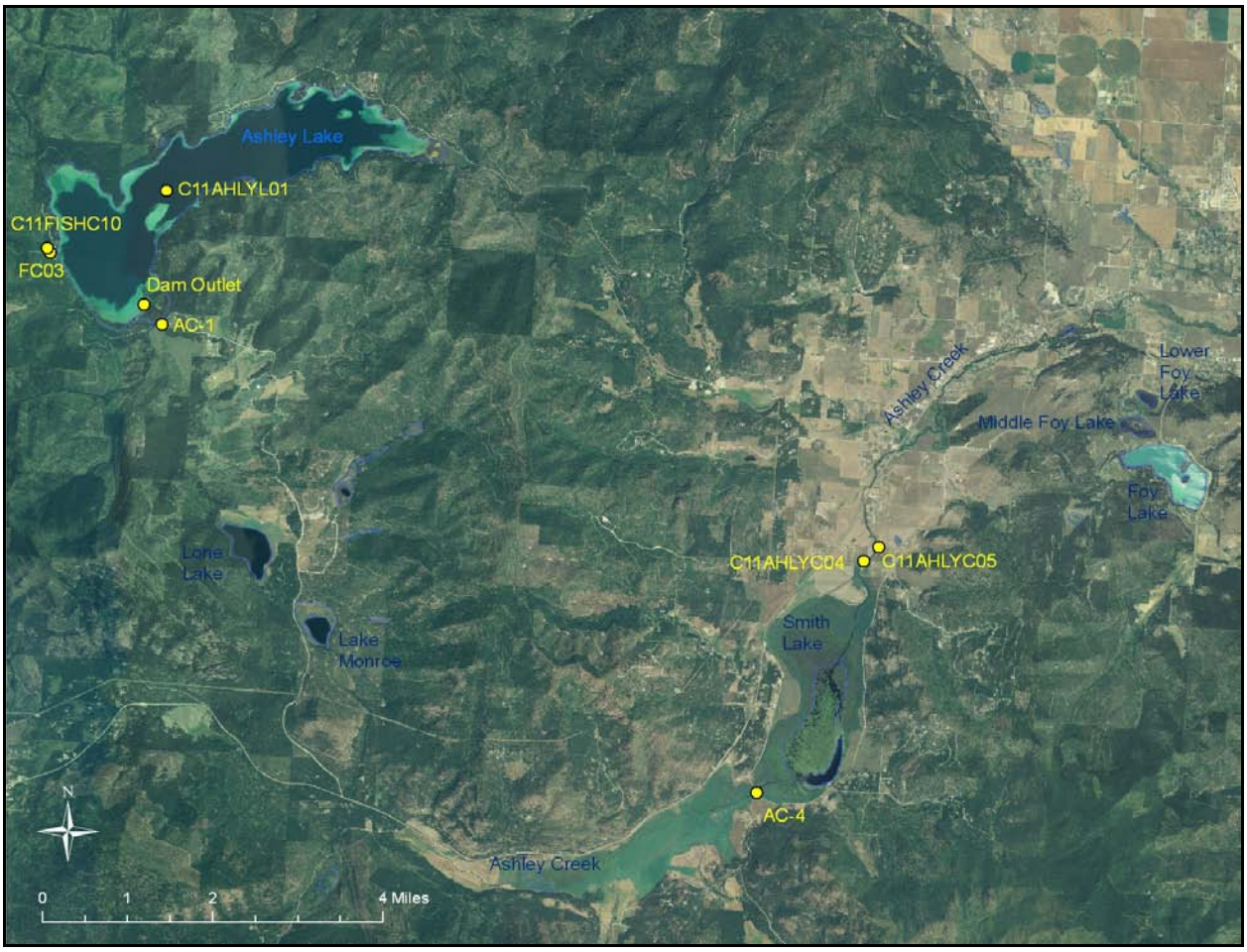

Figure 6. Ashley Lake, Lake Monroe, Lone Lake, Lower Foy Lake, Middle Foy Lake, and Smith Lake.[7]

3.4.1.1 Bathymetrical Data

The FWS provided a bathymetric map of Ashley Lake that was originally created in 1966 by Montana Fish & Game (Appendix F). FWP provided a PDF copy of this map.

3.4.1.2 Hydrological Data

Ashley Lake discharges to Ashley Creek at a slide gate dam. The Montana Department of Fish, Wildlife and Parks provided daily lake outflow data from 1/1/1995 through 12/31/2007.

3.4.1.3 Trophic State Data

Volunteer Monitoring Program data were collected on Ashley Lake. The Northeast Middle site was sampled nine times from 1993 to 2007 and the West End site was sampled seven times from 1995 to 2007. Total phosphorus, chlorophyll-*a*, and Secchi depth measures indicate that Ashley Lake is oligomesotrophic (Ellis and Craft 2008).

[7] Only stations that were sampled since 2000 and are located on a lake of interest or immediately upstream or downstream of a lake of interest are displayed.

3.4.1.4 Stratification Data

VMP data show that Ashley Lake stratifies at a depth of approximately 10 meters. The stratification occurred in July, August and September (1996-1998, 2001, 2002, and 2006). DEQ data show that Ashley Lake stratifies from 5 to 8 meters in 2006. With the exception of 1998, DO concentrations (at depth) tended to remain above 6 mg/L. In 2006, DO concentrations remained above 8 mg/L up to the maximum sampling depth of 29 meters. Depth profiles are presented in Appendices D and E.

3.4.1.5 Nutrient Data

A single sample was collected at the two stations upstream of Ashley Lake: C11FISHC10 (on 10/16/2003) and FC03 (9/13/2005); these samples are presented in Appendix C. Summaries of nutrient data for station AC-1 (downstream of Ashley Lake) and station C11AHLYL01 (on Ashley Lake) are presented in Table 12 and Table 13, respectively.

Table 12. Summary of nutrient samples collected at station AC-1

Parameter	Units	No. of samples	Begin	End	Min	Max	Avg
Ammonia	mg/L as N	1	9/21/2005		0.05		
Ammonia plus Organic Nitrogen	mg/L as N	19	10/16/2002	9/21/2005	0.05	1.50	0.34
Chlorophyll-*a*	mg/m^2	1	9/21/2005		43		
Dissolved Oxygen	mg/L	1	9/21/2005		4.5		
Nitrate plus Nitrite	mg/L as N	19	10/16/2002	9/21/2005	0.005	0.005	0.005
Total Nitrogen	mg/L as N	1	9/21/2005		1.5		
Total Phosphorus	mg/L as P	19	10/16/2002	9/21/2005	0.008	0.450	0.036
Soluble Reactive Phosphorus	mg/L as P	19	10/16/2002	9/21/2005	0.001	0.035	0.005

Table 13. Summary of nutrient samples collected at station C11AHLYL01

Parameter	Units	No. of samples	Begin	End	Min	Max	Avg
Ammonia plus Organic Nitrogen	mg/L as N	3	5/24/2006	8/3/2006	0.13	0.21	0.16
Chlorophyll-*a*	µg/L	6	5/24/2006	8/3/2006	0.2	1.1	0.5
Dissolved Oxygen [a]	mg/L	39	5/24/2006	8/3/2006	8.52	14.15	10.64
Nitrate plus Nitrite	mg/L as N	3	5/24/2006	8/3/2006	0.0025	0.0090	0.0058
Total Phosphorus	mg/L as P	3	5/24/2006	8/3/2006	0.002	0.010	0.005

[a] Dissolved oxygen data were collected at multiple depths.

3.4.1.6 Impoundment Data

Ashley Lake Dam (MT01163) was constructed in 1928 to provide irrigation storage for downstream users. The dam is constructed of earth fill and is 10 feet high, 20 feet wide, and the top of the gates is at an elevation of 3,955 feet MSL (DNRC 2007; refer to Figure 7). Normal pool storage is 17,522 acre feet at an elevation of 3,946 feet MSL. Maximum storage is 25,476 acre feet at an elevation of 3,955 feet MSL. The outlet works for the dam consists of three 4.5 foot wide slide gates in concrete bays.

Figure 7. Ashley Lake Dam.

The lake and dam are managed by MTFWP. The average stage of the lake is 5.14 feet, which translates into an average storage of approximately 14,300 acre-feet. The average outflow is 13.8 cfs. Figure 8 and Figure 9 present the daily average storage and daily gage height at Ashley Lake Dam.

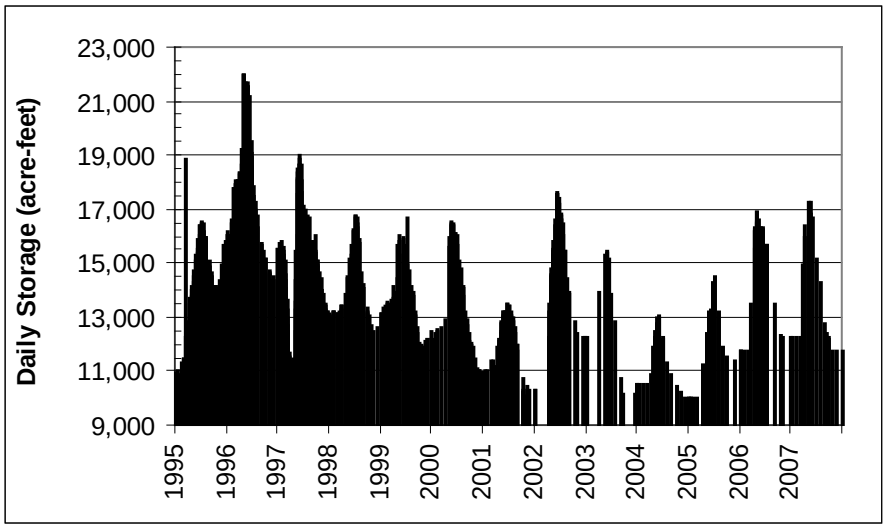

Figure 8. Daily lake storage at Ashley Lake Dam.

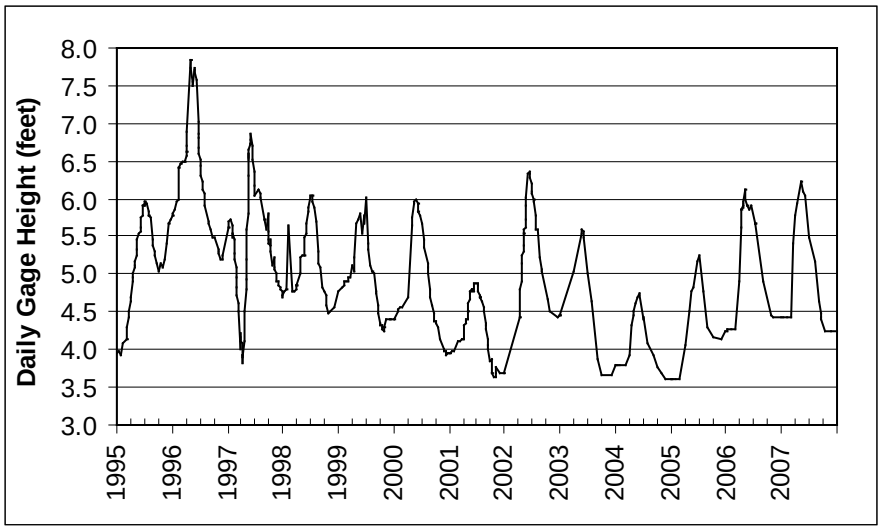

Figure 9. Daily gage height at Ashley Lake Dam.

3.4.2 Echo Lake[8]

Echo Lake is located northwest of Flathead Lake and west of Hungry Horse Reservoir. According to the NHD, the surface area of Echo Lake is 692 acres with a perimeter of 13.2 miles. Approximately 12,935 acres drain to Echo Lake, its elevation is 2,999 feet, and its maximum depth is 66 feet (Ellis and Craft 2008). The lake stratifies in late summer (Ellis and Craft 2008). The FWS provided a bathymetric map of Echo Lake that was originally created in 1967 by Montana Fish & Game (Appendix F). FWP provided a PDF copy of this map.

Temperature-depth profiles generated from the Volunteer Monitoring Program data show that Echo Lake stratified at a depth of approximately 6 meters in August 1998. Dissolved oxygen concentrations tended to remain above 5 mg/L at depths of up to 12 meters and dropped below 1 mg/L at depths greater than 14 meters. Depth profiles are presented in Appendix C.

Neither recent nor historic water quality data are available on the waterbodies immediately upstream and downstream of the lake; volunteer data were collected on eight occasions from 1993 to 2003. Recently-collected nutrients data are not available for Echo Lake. However, historic data collected by DEQ are available for five stations located on Echo Lake:

- 5516EC01 (1980-1981)
- 5516EC02 (1973-1974)
- 5516EC03 (1973-1974)
- 5516EC04 (1973-1974, 1995)
- 5516EC06 (1995)

Total phosphorus (mean: 15 µg/L), total nitrogen (133 µg/L), chlorophyll a (mean: 2.9 µg/L), and Secchi depth measures (mean: 5.9 m) indicate that Echo Lake is oligomesotrophic (Ellis and Craft 2008).

[8] Numerous lakes are located in the vicinity of Echo Lake, which is the valley west of the Flathead River and north of the Swan River. Most of the lakes are not named in the NHD and no water quality data are available for such lakes. The anthropogenic activities affecting Echo Lake may also affect the unnamed lakes. Since no information or water quality data are available for the unnamed lakes, they are not further addressed in this technical memorandum.

3.4.3 Hell Roaring Reservoir

Hell Roaring Reservoir is located east of Flathead Lake. According to the NHD, the surface area of Hell Roaring Reservoir is 5 acres with a perimeter of 0.4 mile. Neither recent nor historic water quality data are available for Hell Roaring Reservoir or on the waterbodies immediately upstream and downstream of the lake.

The dam (MT01463) on Hell Roaring Reservoir is 250 feet long. The dam was constructed in 1916 for drinking water, hydroelectric power, and irrigation and is managed by the U.S. Bureau of Indian Affairs.

3.4.4 Jessup Mill Pond

Jessup Mill Pond is located west of Flathead Lake. According to the NHD, the surface area of Jessup Mill Pond is 26 acres with a perimeter of 1.5 miles. Neither existing nor historic water quality data are available for the waterbodies immediately upstream and downstream of the lake. Recently-collected nutrients data are not available for Jessup Mill Pond. However, historic data collected by DEQ in 1975 are available for two stations located on Jessup Mill Pond: 5615NO01 and 5615SO01.

The Jessup Mill property was acquired by the National Park Service in 1939 to create the Creston National Fish Hatchery, which is now located just downstream of the dam. The dam (MT03425) and resulting pond supply water to the fish hatchery. The dam is constructed of earth fill and is 28 feet high and 290 feet wide. It has a storage capacity of 298 acre-feet.

3.4.5 Lake Blaine

Lake Blaine is located north of Flathead Lake. According to the NHD, the surface area of Lake Blaine is 382 acres with a perimeter of 4.5 miles. Approximately 18,963 acres drain to Lake Blaine, its elevation is 2,999 feet, and its mean and maximum depths are 51 and 141 feet, respectively (Ellis and Craft 2008). The FWS provided a bathymetric map of Lake Blaine that was originally created in 1961 by Montana Fish & Game (Appendix F). FWP provided a PDF copy of this map.

Neither recent nor historic water quality data are available for the waterbodies immediately upstream and downstream of the lake. Historic data collected by DEQ are available for three stations located on Lake Blaine:

- 5715LA01 (1973-1974)
- 5715LA02 (1973-1976)
- 5715LA03 (1981)

Volunteer data were collected on 4 occasions from 1993 to 1997. Total phosphorus (mean: 17 µg/L) and chlorophyll-*a* (mean: 6.5 µg/L) indicate that Lake Blaine is mesooligotrophic (Ellis and Craft 2008).

3.4.6 Lake Mary Ronan

Lake Mary Ronan is located west of Flathead Lake. It is fed by a number of small tributaries (Figure 10). According to the NHD, the surface area of Lake Mary Ronan is 1,491 acres with a perimeter of 7.1 miles. Approximately 18,977 acres drain to Lake Mary Ronan, its elevation is 3,711 feet, and its maximum depth is 47 feet (Ellis and Craft 2008).

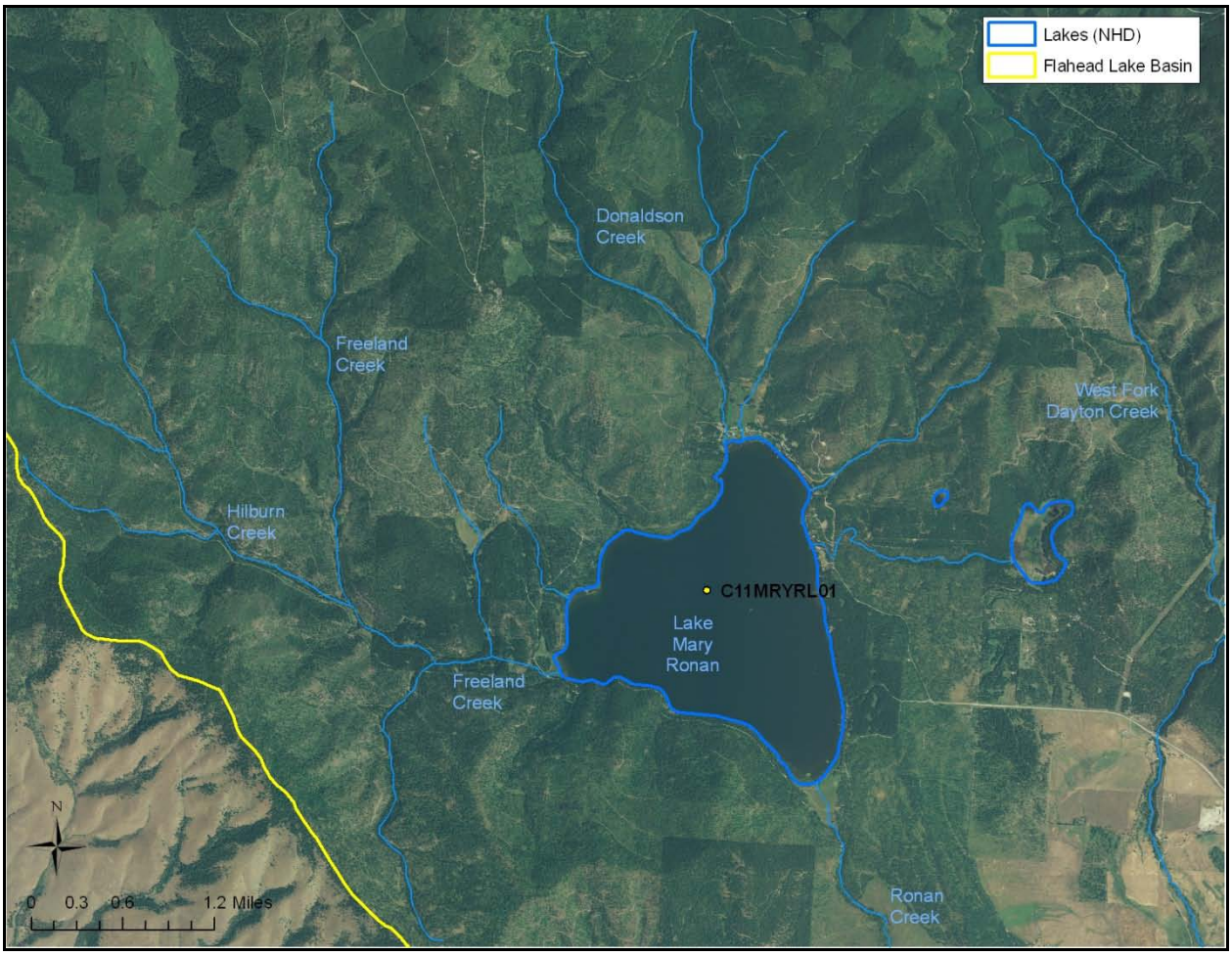

Figure 10. Lake Mary Ronan.[9]

3.4.6.1 Bathymetrical Data

The FWS provided a bathymetric map of Lake Mary Ronan that was originally created in 1966 by Montana Fish & Game (Appendix F). FWP provided a PDF copy of this map.

3.4.6.2 Stratification Data

VMP data show that Lake Mary Ronan stratified at a depth of approximately 8 meters in August and September 1998 to 2003, 2005, and 2006. DEQ data show that stratification occurred at 3 to 6 meters in May, July and August 2006. VMP's DO concentrations tended to remain above 5 mg/L up to depths of 6 to 9 meters and dropped below 1 mg/L at depths greater than 7 to 10 meters. DEQ's DO concentrations tended to remain above 8 mg/L up to depths of 8 meters and dropped to less than 1 mg/L by depths of 9 meters. Depth profiles are presented in Appendix C and D.

3.4.6.3 Nutrient Data

Based on the data available to EPA, sample stations located upstream (multiple tributaries) and downstream (Ronan Creek) of Lake Mary Ronan were not sampled within the past thirty years. A summary of nutrient data for station C11MRYRL01 (on Lake Mary Ronan) is presented in Table 14.

[9] Only stations that were sampled since 2000 are displayed.

Table 14. Summary of nutrient samples collected at station C11MRYRL01

Parameter	Units	No. of samples	Begin	End	Min	Max	Avg
Chlorophyll-*a*	µg/L	6	5/24/2006	8/2/2006	0.7	5.9	2.7
Dissolved Oxygen [a]	mg/L	32	5/24/2006	8/2/2006	0.22	13.54	8.31
Nitrate plus Nitrite	mg/L as N	3	5/24/2006	8/2/2006	0.008	0.031	0.016
Total Phosphorus	mg/L as P	3	5/24/2006	8/2/2006	ND [b]	0.017	0.010

[a] Dissolved oxygen data were collected over multiple depths.
[b] The detection limit is 0.01 mg/L; 0.005 mg/L was used for calculating statistics.

Volunteer data are available for Lake Mary Ronan. Site East Middle was sampled on eight occasions from 1995 to 2007 and site West Middle was sampled on six occasions from 1993 to 2005. Total phosphorus, chlorophyll-*a*, and Secchi depth measures indicate that Lake Mary Ronan is mesoeutrophic (Ellis and Craft 2008).

3.4.7 Lake Monroe and Lone Lake

These lakes are located west of Flathead Lake and south of Ashley Lake (refer to Figure 6 in Section 3.4.1). Ashley Creek flows through both Lakes. Neither recent nor historic water quality data are available for either lake or on the waterbodies immediately upstream and downstream of the lakes. Recent and historic data are available for stations along Ashley Creek; however, other lakes and tributaries discharge to Ashley Creek between each lake and these sample stations.

3.4.8 Lower Foy Lake and Middle Foy Lake

These lakes are located west of Flathead Lake and south and west of Ashley Creek (refer to Figure 6 in Section 3.4.1). Neither existing nor historic water quality data are available for either lake or on the waterbodies immediately upstream and downstream of the lakes.

3.4.9 Turtle Lake

Turtle Lake is located south of Flathead Lake and southeast of the city of Polson. According to the NHD, the surface area of Turtle Lake is 46 acres with a perimeter of 1.4 mile. Neither existing nor historic water quality data are available for Turtle Lake or on the waterbodies immediately upstream and downstream of the lake.

The dam (MT00597) on Turtle Lake (a.k.a. Twin Lake and Twin Lake Reservoir) is 2,340 feet long. The reservoir has a storage capacity of 937 acre-feet and is regularly maintained at 899 acre-feet. The dam was constructed in 1932 for irrigation and recreation and is managed by the U.S. Bureau of Indian Affairs.

3.4.10 Smith Lake

Smith Lake is located west of Flathead Lake and south of Ashley Lake (refer to Figure 6 in Section 3.4.1). Ashley Creek flows through Smith Lake. According to the NHD, the surface are of Smith Lake is 442 acres with a perimeter of 6.2 miles. Recently-collected nutrients data are not available for Smith Lake. However, historic data collected by DEQ in 1981 are available for one stations located on Smith Lake: 5513SM01.

Recent and historic data are available for stations along Ashley Creek downstream of Smith Lake; however, tributaries discharge to Ashley Creek between Smith Lake and these sample stations. Ashley Creek immediately upstream of Smith Lake was sampled by DEQ in 1976 through 1978 at station 5513AS01 and was recently sampled at station AC-4. A summary of nutrient data for station AC-4 is presented in Table 15.

Table 15. Summary of nutrient samples collected at station AC-4

Parameter	Units	No. of Samples	Begin	End	Min	Max	Avg
Ammonia	mg/L as N	1	9/21/2005		ND [a]		
Dissolved oxygen	mg/L	1	9/21/2005		4.6		
Nitrate + Nitrite	mg/L as N	19	10/16/2002	9/21/2005	ND [b]	ND [b]	ND [b]
Total Kjeldahl Nitrogen	mg/L as N	19	10/16/2002	9/21/2005	0.25	33.00	2.18
Total Nitrogen	mg/L as N	1	9/21/2005		1.3		
Total Phosphorus	mg/L as P	19	10/16/2002	9/21/2005	0.015	0.430	0.052
Orthophosphate	mg/L as P	19	10/16/2002	9/21/2005	0.004	0.017	0.011

[a] The detection limit is 0.1 mg/L; 0.05 mg/L was used for calculating statistics.
[b] The detection limit is 0.01 mg/L; 0.005 mg/L was used for calculating statistics.

Two stations downstream of Smith Lake were recently sampled: C11AHLYC04 (Ashley Creek near Smith Lake) and C11AHLYC05 (Ashley Creek near Smith Lake at bridge); it should be noted that small tributaries discharge to Ashley Creek between Smith Lake and these two stations. Summaries of nutrient data for station C11AHLYC04 and C11 AHLYC05 are presented in Table 16 and Table 17, respectively.

Table 16. Summary of nutrient samples collected at station C11AHLYC04

Parameter	Units	No. of Samples	Begin	End	Min	Max	Avg
Ammonia	mg/L as N	6	5/26/2007	9/19/2007	ND [a]	ND [a]	ND [a]
Chlorophyll-*a*	mg/m^3	4	5/26/2007	8/1/2007	2.3	14.0	8.4
Dissolved Oxygen	mg/L	6	5/26/2007	9/19/2007	5.24	12.55	7.85
Nitrate + Nitrite	mg/L as N	6	5/26/2007	9/19/2007	ND [b]	0.010	0.006
Total Nitrogen	mg/L as N	6	5/26/2007	9/19/2007	0.57	0.99	0.72
Total Phosphorus	mg/L as P	6	5/26/2007	9/19/2007	ND [c]	0.026	0.013
Orthophosphate	mg/L as P	6	5/26/2007	9/19/2007	ND [c]	0.003	0.001

[a] The detection limit is 0.05 mg/L; 0.025 mg/L was used for calculating statistics.
[b] The detection limit is 0.01 mg/L; 0.005 mg/L was used for calculating statistics.
[c] The detection limit is 0.001 mg/L; 0.0005 mg/L was used for calculating statistics.

Table 17. Summary of nutrient samples collected at station C11AHLYC05

Parameter	Units	No. of Samples	Begin	End	Min	Max	Avg
Ammonia	mg/L as N	10	5/7/2008	8/13/2008	ND [a]	ND [a]	ND [a]
Chlorophyll-*a*	mg/m^3	4	7/28/2008	10/1/2008	2.9	14.0	8.3
Dissolved Oxygen	mg/L	9	5/7/2008	10/1/2008	4.57	11.41	6.86
Nitrate + Nitrite	mg/L as N	12	5/7/2008	10/1/2008	ND [b]	ND [b]	ND [b]
Total Nitrogen	mg/L as N	12	5/7/2008	10/1/2008	0.6	0.83	0.72
Total Phosphorus	mg/L as P	12	5/7/2008	10/1/2008	0.015	0.026	0.019
Orthophosphate	mg/L as P	12	5/7/2008	10/1/2008	ND [c]	0.005	0.003

[a] The detection limit is 0.05 mg/L; 0.025 mg/L was used for calculating statistics.
[b] The detection limit is 0.01 mg/L; 0.005 mg/L was used for calculating statistics.
[c] The detection limit is 0.001 mg/L; 0.0005 mg/L was used for calculating statistics.

3.5 HUC 17010209 - South Fork Planning Area

Five lakes and reservoirs of interest are located in the South Fork Planning Area. Available data for these waterbodies are presented in the following subsections.

3.5.1 Big Salmon Lake, George Lake, and Sunburst Lake

These are located southeast of Flathead Lake and southeast of the Hungry Horse Reservoir. Neither existing nor historic water quality data are available for these lakes or on the waterbodies immediately upstream and downstream of the lakes. FWP provided an undated bathymetric map of Sunburst Lake (Appendix F) that included the maximum depth (220.5 ft), surface area (148.5 ac), and volume (12,687 ac-ft).

3.5.2 Hungry Horse Reservoir

Hungry Horse Reservoir is located east of Flathead Lake. The reservoir receives water from the South Fork of the Flathead River (Figure 11). According to the NHD, the surface area of Hungry Horse Reservoir is 23,799 acres with a perimeter of 151.5 miles. Ferreira (1992) indicates the reservoir strongly stratifies, with a full pool elevation of 1085.1 meters above sea level and an outlet elevation of 1011.6 meters. Marotz (1994) followed on this work by evaluating selective withdrawal scenarios for the operation of the reservoir. According to his study, the release temperature of Hungry Horse Reservoir is unnaturally cold year-round, approximately four degrees Celsius. Data from STORET shows similar thermal gradients in the epilimnion and hypolimnion.

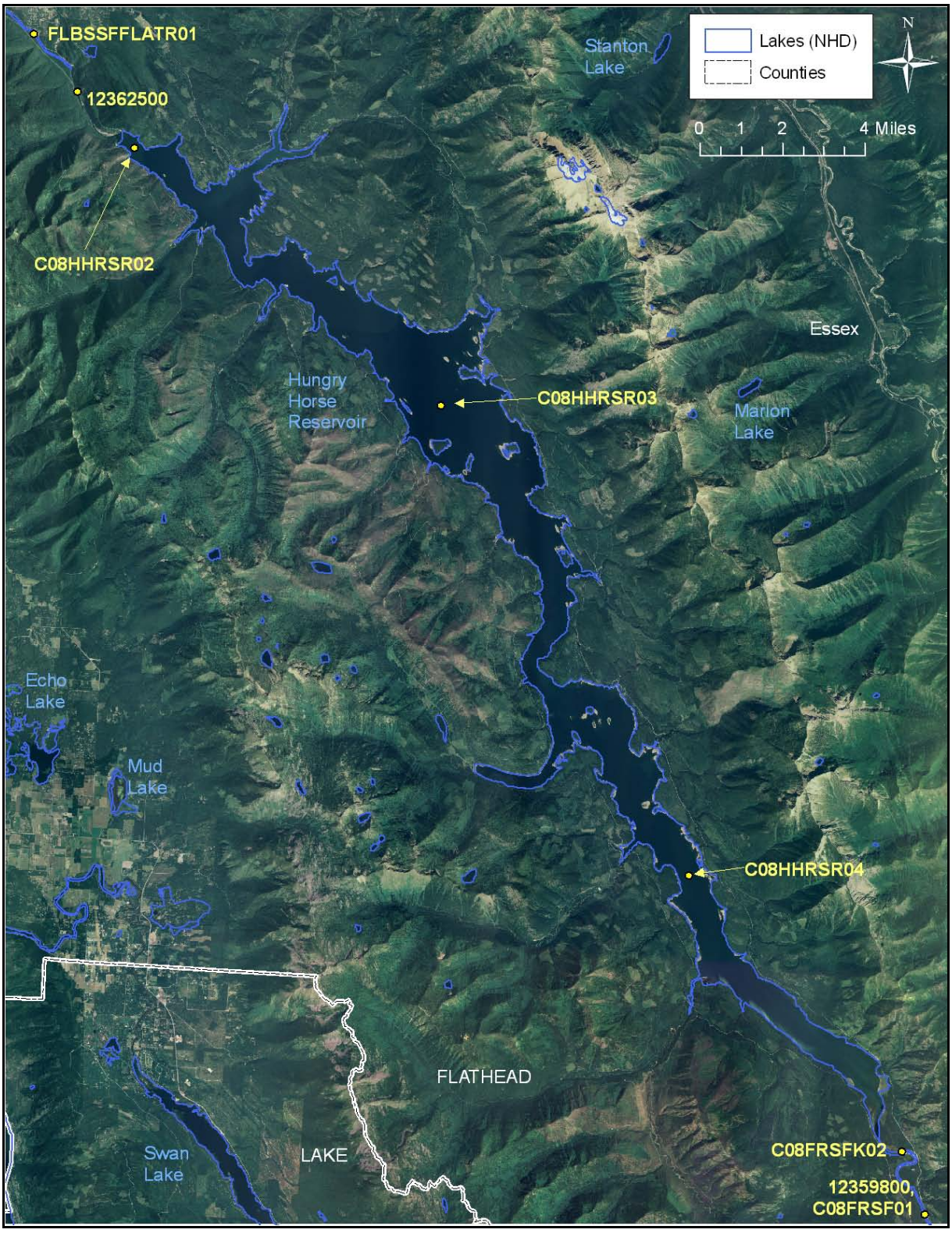

Figure 11. Hungry Horse Reservoir.[10]

[10] Only stations sampled since 2000 are displayed.

3.5.2.1 Hydrological Data

USGS Gage 12362500 (S F Flathead River nr Columbia Falls MT) is located downstream of the outlet of Hungry Horse Reservoir. Daily flow data are available from 10/1/2004 through 2/16/2010. USGS Gage 12359800 (S F Flathead River ab Twin C nr Hungry Horse MT) is located upstream of Hungry Horse Reservoir. Daily flow data are available from 10/1/1964 through 2/16/2010.

The average annual flow and peak flow at gage 12359800 were 87.9 and 331 m^3/s (respectively), for flow data collected since the year 2000. Given the volume of Hungry Horse Reservoir, the average and peak flow residence times were calculated to be 563 and 149 days, respectively.

3.5.2.2 Stratification Data

DEQ data show that stratification occurs at 5 to 10 meters (May to September 2007 and 2008). DO concentrations tended to remain above 8 mg/L up to maximum observed sampling depths (45 to 135 meters). Depth profiles are presented in Appendix E.

3.5.2.3 Nutrient Data

Summaries of nutrient data for two stations downstream of Hungry Horse Reservoir (12362500 and FLBSSFFLATR01) are presented in Table 18 and Table 19 (respectively).

Table 18. Summary of nutrient samples collected at gage 12362500

Parameter	Units	No. of samples	Begin	End	Min	Max	Avg
Ammonia	mg/L as N	10	3/26/2007	12/10/2007	0.012	0.020	0.0192
Chlorophyll-*a*	µg/L	2	5/14/2007	8/8/2007	0.2	1.3	0.8
Dissolved Oxygen	mg/L	10	3/26/2007	12/10/2007	9.20	12.40	10.74
Nitrate plus Nitrite	mg/L as N	10	3/26/2007	12/10/2007	0.019	0.091	0.064
Nitrite	mg/L as N	10	3/26/2007	12/10/2007	0.001	0.002	0.00190
Total Nitrogen	mg/L as N	10	3/26/2007	12/10/2007	0.07	0.16	0.12
Total Phosphorus	mg/L as P	10	3/26/2007	12/10/2007	0.005	0.008	0.008
Soluble Reactive Phosphorus	mg/L as P	10	3/26/2007	12/10/2007	0.003	0.006	0.005

Table 19. Summary of nutrient samples collected at station FLBSSFFLATR01

Parameter	Units	No. of samples	Begin	End	Min	Max	Avg
Ammonia	mg/L as N	144	1/21/1988	7/6/2006	0.002	0.013	0.004
Ammonia plus Organic Nitrogen	mg/L as N	40	12/20/1984	8/4/1987	0.03	0.15	0.06
Dissolved Oxygen	mg/L	2	10/10/2006	11/8/2006	9.93	11.40	10.67
Nitrate	mg/L as N	40	12/20/1984	3/8/1988	0.04	0.10	0.06
Nitrate plus Nitrite	mg/L as N	237	1/21/1988	7/6/2006	0.004	0.112	0.064
Total Nitrogen	mg/L as N	214	10/29/1987	7/6/2006	0.04	0.23	0.11
Total Phosphorus	mg/L as P	218	3/8/1988	7/6/2006	0.001	0.017	0.005
Organic Phosphorus	mg/L as P	225	10/29/1987	7/6/2006	0.0004	0.0178	0.0031
Soluble Reactive Phosphorus	mg/L as P	237	10/29/1987	7/6/2006	0.000	0.004	0.001

Summaries of nutrient data for two stations upstream of Hungry Horse Reservoir (C08FRSF01 and C08FRSF02) are presented in Table 20 and Table 21 (respectively).

Table 20. Summary of nutrients samples collected at station C08FRSF01

Parameter	Units	No. of samples	Begin	End	Min	Max	Avg
Ammonia plus Organic Nitrogen	mg/L as N	2	8/8/2004	8/8/2005	0.05	0.11	0.08
Chlorophyll-*a*	mg/m^2	4	8/11/2003	8/8/2005	6.4	7.8	7.3
Dissolved Oxygen	mg/L	3	8/11/2003	8/8/2005	9.58	10.93	10.23
Nitrate plus Nitrite	mg/L as N	2	8/8/2004	8/8/2005	0.005	0.010	0.008
Total Phosphorus	mg/L as P	2	8/8/2004	8/8/2005	5E-4	5E-4	5E-4

Table 21. Summary of nutrients samples collected at station C08FRSF02

Parameter name	Units	No. of samples	Begin	End	Min	Max	Avg
Ammonia	mg/L as N	7	5/24/2007	9/20/2007	0.025	0.025	0.025
Chlorophyll-*a*	µg/L	6	5/24/2007	9/20/2007	1.4	5.6	3.6
Dissolved Oxygen	mg/L	6	5/24/2007	9/20/2007	8.52	11.70	10.36
Nitrate plus Nitrite	mg/L as N	7	5/24/2007	9/20/2007	0.005	0.010	0.006
Total Nitrogen	mg/L as N	7	5/24/2007	9/20/2007	0.04	0.09	0.06
Total Phosphorus	mg/L as P	7	5/24/2007	9/20/2007	5E-4	0.008	0.005

Summaries of nutrient data for three stations located on Hungry Horse Reservoir (C08HHRSR02, C08HHRSR03, and C08HHRSR04) are presented in Table 22, Table 23, and Table 24 (respectively).

Table 22. Summary of nutrient samples collected at station C08HHRSR02

Parameter	Units	No. of samples	Begin	End	Min	Max	Avg
Ammonia	mg/L as N	30	5/25/2007	9/30/2008	0.023	0.025	0.025
Chlorophyll-*a*	µg/L	23	5/25/2007	9/30/2008	1.2	6.3	2.8
Dissolved Oxygen [a]	mg/L	144	5/25/2007	9/19/2007	7.12	12.09	10.41
Nitrate plus Nitrite	mg/L as N	32	5/25/2007	9/30/2008	0.005	0.100	0.037
Total Nitrogen	mg/L as N	32	5/25/2007	9/30/2008	0.04	0.21	0.09
Total Phosphorus	mg/L as P	32	5/25/2007	9/30/2008	5E-4	0.012	0.005
Soluble Reactive Phosphorus	mg/L as P	32	5/25/2007	9/30/2008	5E-4	0.002	7E-4

[a] Dissolved oxygen data were collected at multiple depths.

Table 23. Summary of nutrient samples collected at station C08HHRSR03

Parameter	Units	No. of samples	Begin	End	Min	Max	Avg
Ammonia	mg/L as N	29	5/25/2007	9/30/2008	0.025	0.025	0.025
Chlorophyll-*a*	µg/L	22	5/25/2007	9/30/2008	0.7	4.9	2.5
Dissolved Oxygen [a]	mg/L	147	5/25/2007	9/26/2007	8.91	11.35	10.20
Nitrate plus Nitrite	mg/L as N	31	5/25/2007	9/30/2008	0.005	0.070	0.034
Total Nitrogen	mg/L as N	31	5/25/2007	9/30/2008	0.05	0.17	0.10
Total Phosphorus	mg/L as P	31	5/25/2007	9/30/2008	5E-4	0.013	0.006
Soluble Reactive Phosphorus	mg/L as P	31	5/25/2007	9/30/2008	5E-4	0.002	7E-4

[a] Dissolved oxygen data were collected at multiple depths.

Table 24. Summary of nutrient samples collected at station C08HHRSR04

Parameter	Units	No. of samples	Begin	End	Min	Max	Avg
Ammonia	mg/L as N	25	5/24/2007	9/30/2008	0.025	0.025	0.025
Chlorophyll-*a*	µg/L	19	5/24/2007	9/30/2008	1.1	5.2	2.9
Dissolved Oxygen [a]	mg/L	113	5/24/2007	9/20/2007	6.65	11.38	9.85
Nitrate plus Nitrite	mg/L as N	27	5/24/2007	9/30/2008	0.005	0.080	0.028
Total Nitrogen	mg/L as N	27	5/24/2007	9/30/2008	0.05	0.18	0.09
Total Phosphorus	mg/L as P	27	5/24/2007	9/30/2008	5E-4	0.032	0.007
Soluble Reactive Phosphorus	mg/L as P	27	5/24/2007	9/30/2008	5E-4	0.006	0.0011

[a] Dissolved oxygen data were collected at multiple depths.

3.5.2.4 Impoundment Data

Hungry Horse Dam (MT00565) was built by the U.S. Bureau of Reclamation (USBR) in 1953 for power generation, flood control, and recreation purposes (USBR 2008a). Hungry Horse Dam is a concrete thick arch structure that is 564 feet high with a crest of 2,115 feet (USBR 2008b; refer to Figure 12). Water is routed through the dam via a series of pipes and spillways including (USBR 2008c):

- Four penstocks to the powerhouse with a maximum capacity of 13,000 cubic feet per second located at an elevation of 3,319 to 3,560 feet.
- Three outlet works conduit pipes with a maximum capacity of 14,000 cubic feet per second at an elevation of 3,565 feet.
- One morning glory spillway with a maximum capacity of 50,000 cubic feet per second at an elevation of 3565 feet.

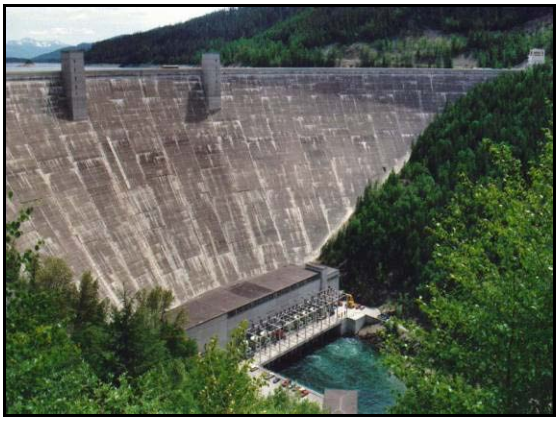

Figure 12. Hungry Horse Dam (USBR 2007)

During typical dam and reservoir operations, water is withdrawn through the penstocks to power the turbines and then discharged to the South Fork Flathead River below the dam. The penstocks and power turbines can be bypassed by routing water through the conduit pipes and/or morning glory spillway (Marotz et al. 1994). Traditionally, the penstocks withdrew water from deep in the reservoir at an elevation of 3,319 feet where water temperatures remain near 4 degrees Celsius year round (Marotz et al., 1994). In 1995, a selective withdrawal system was installed to the penstock system to allow for higher elevation, warmer water withdrawals. The selective withdrawal system consists of a series of gates than

can be raised and lowered along the penstock system to allow for selective withdrawals at a range of depths between 3,319 and 3,560 feet in elevation (i.e., the range of the penstock system). During normal summer operation, the selective withdrawal system is positioned between an elevation of 3,438.2 and 3,538.5 feet, depending on flow and water temperature needs (USBR 2008c). The selective withdrawal system is not used during the winter time period.

Hungry Horse Dam creates Hungry Horse Reservoir, which has a maximum volume of 3,468,000 acre-feet, and a full pool elevation of 3,560 ft. At the full pool elevation, the reservoir is 35 miles in length with an area of 23,800 acres (May et al. 1988). The mean depth of the reservoir is 146 feet (at full pool elevation). USBR measures stage at the dam (USGS gage 12362000 - Hungry Horse Reservoir near Hungry Horse MT). Figure 13 shows the reservoir stage over time from 1978 to 2008.

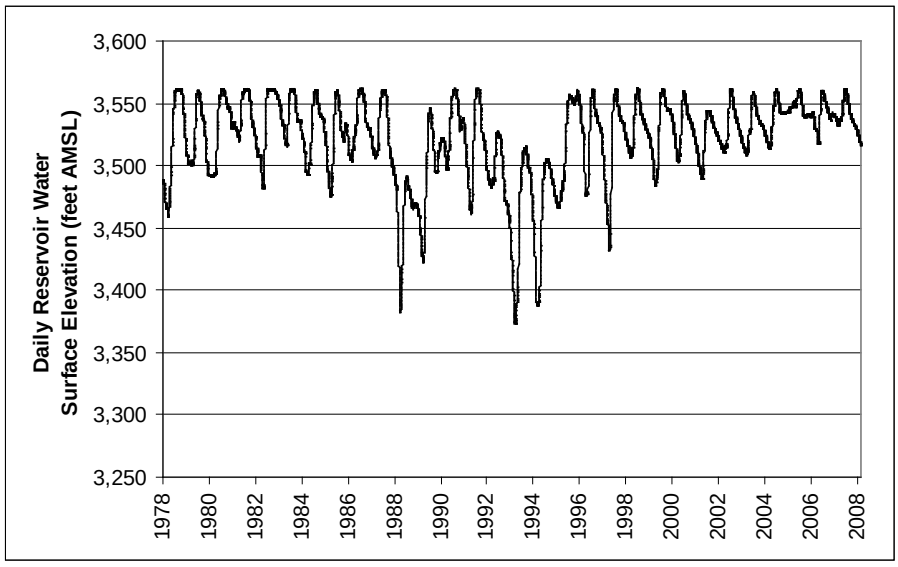

Figure 13. Daily reservoir water surface elevation at gage 12362000.

3.5.3 Lion Lake

Lion Lake is located northeast of Flathead Lake and northwest of Hungry Horse Reservoir. According to the NHD, the surface are of Lake Monroe is 36 acres with a perimeter of 1.0 miles. Approximately 818 acres drain to Lion Lake (Ellis and Craft 2008).

Volunteer monitoring data are available for Lion Lake from 1994-1996. No other data were available for the lake or downstream waterbodies. The National Park Service collected one sample each from three nearby stations located on Whelp Creek, upstream of Lion Lake. Total phosphorus (0.007 mg/L) and chlorophyll-*a* (mean: $9x10^{-4}$ mg/L) indicate that Lion Lake is oligotrophic (Ellis and Craft 2008).

Lion Lake dam (MT01571) was constructed in 1948 to provide for fish/wildlife and recreation. The dam is constructed of earth fill and is 23 feet high and 200 feet wide. The maximum capacity of the reservoir is 1,621 acre-feet, although normal storage is maintained at approximately 583 acre-feet. The dam is located in the Flathead National Forest and is operated by the U.S. Forest Service.

3.6 HUC 17010210 – Stillwater River Planning Area

Eleven lakes and reservoirs of interest are located in the Stillwater Planning Area[11]. Figure 14 and Figure 15 display most of the lakes in this planning area. Available data for these waterbodies are presented in the following subsections.

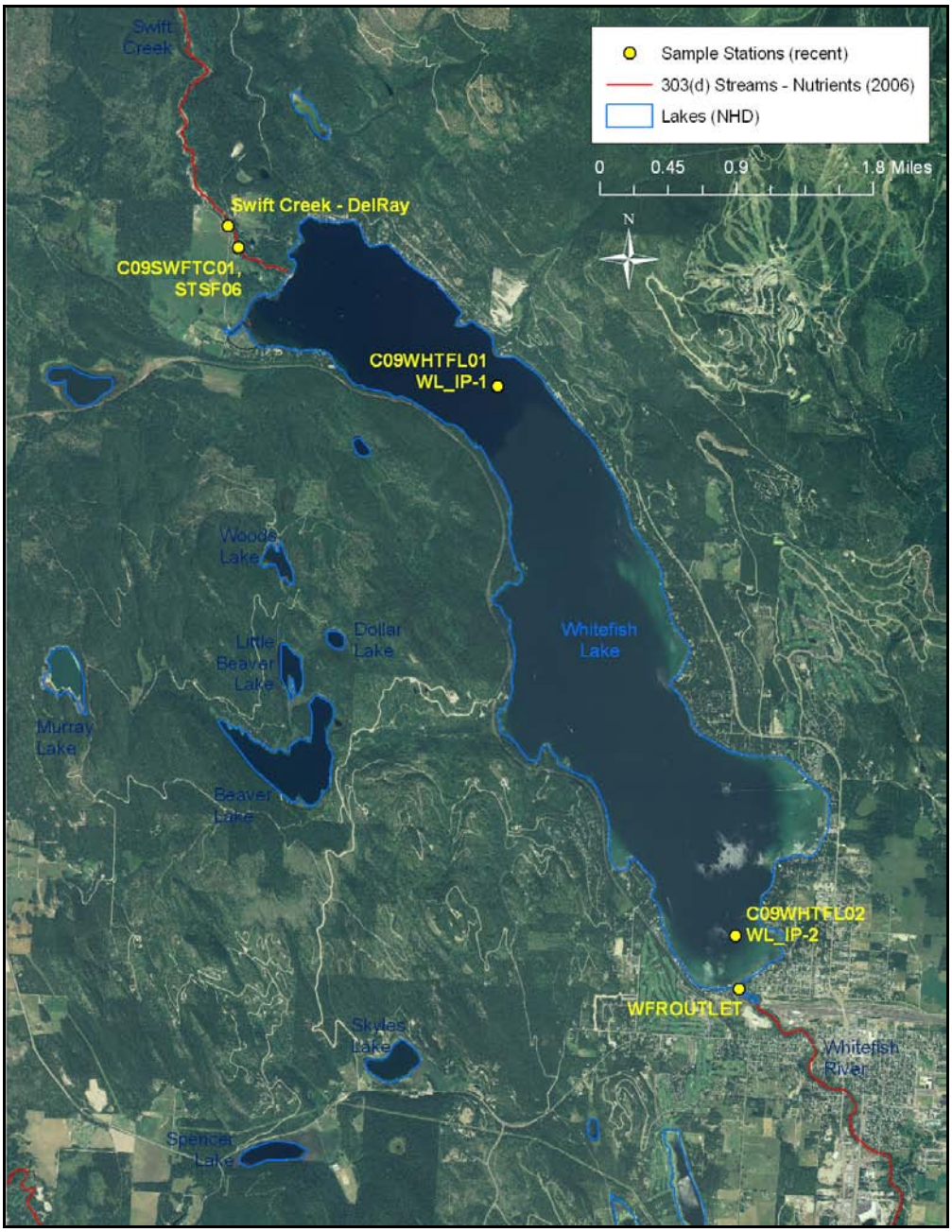

Figure 14. Skyles Lake, Spencer Lake, and Whitefish Lake.[12]

[11] Timber harvests have occurred near Beaver Lake, Dollar Lake, Little Beaver Lake, Murray Lake, and Woods Lakes (one located near Whitefish Lake, the other located near Duck Lake). However, none of these lakes is connected to the stream network via a perennial stream; therefore, these lakes are not further discussed in the memorandum.

[12] Only stations that were sampled since 2000 and are located on a lake of interest or immediately upstream or downstream of a lake of interest are displayed. WLI has collected data at ten bays in Whitefish Lake and four smaller tributaries (in addition to Swift Creek). Data collected at these stations are not evaluated in this memorandum; therefore, these stations are not displayed. WLI's Whitefish River station is not displayed.

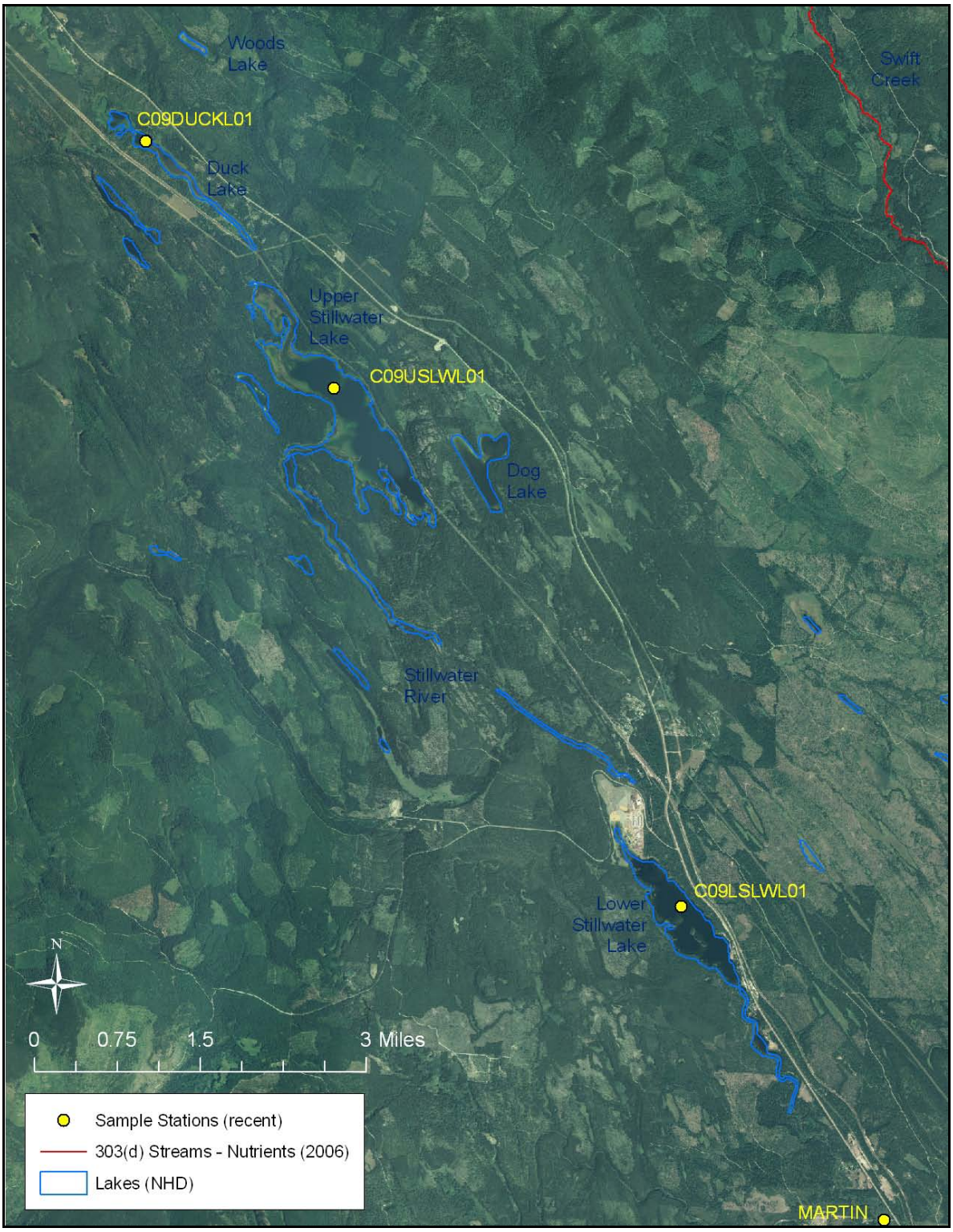

Figure 15. Dog Lake, Duck Lake, Lower Stillwater Lake, and Upper Stillwater Lake.[13]

[13] Only stations that were sampled since 2000 and are located on a lake of interest or immediately upstream or downstream of a lake of interest are displayed.

3.6.1 Bull Lake[14]

Bull Lake is located northwest of Flathead Lake and south of the Stillwater River. According to the NHD, the surface area of Bull Lake is 106 acres with a perimeter of 3.29 miles.

Only one water quality sample station is located on Bull Lake: C09BULLL01 (Bull Lake at mid-lake). A summary of the available nutrient data for this station is presented in Table 25.

Table 25. Summary of nutrients samples data collected at C09BULLL01

Parameter	Units	No. of Samples	Begin	End	Min	Max	Avg
Ammonia	mg/L as N	3	7/12/2008	9/14/2008	0.02	0.06	0.04
Chlorophyll-*a*	µg/L	6	7/12/2008	9/14/2008	0.9	2.7	1.6
Dissolved Oxygen [a]	mg/L	46	7/12/2008	9/14/2008	0.00	11.94	7.93
Nirate + Nitrite	mg/L as N	3	7/12/2008	9/14/2008	ND [b]	0.006	0.004
Total Nitrogen	mg/L as N	3	7/12/2008	9/14/2008	0.16	0.27	0.22
Total Phosphorus	mg/L as P	3	7/12/2008	9/14/2008	0.002	0.003	0.003

[a] Dissolved oxygen data were collected over multiple depths.
[b] The detection limit is 0.005 mg/L; 0.0025 mg/L was used for calculating statistics.

At station C09BULLL01, Bull Lake stratified at a depth of 4 to 8 meters in July through September 2008. DO concentrations remained above 8 mg/L at depths up to 11 meters and dropped to less than 1 mg/L at approximately 14 meters depth (Appendix E).

3.6.2 Dog Lake and Fish Lake

Dog Lake and Fish Lake are located northwest of Flathead Lake (refer to Figure 15 for Dog Lake). Neither current nor historic water quality data are available for either lake or on the waterbodies immediately upstream and downstream of the lakes.

3.6.3 Duck Lake

Duck Lake is located northwest of Flathead Lake and upstream of the Upper Stillwater River (r refer to Figure 15). According to the NHD, the surface area of Duck Lake is 74 acres with a perimeter of 4.3 miles.

Neither recent nor historic water quality data are available on the waterbodies immediately upstream and downstream of the lake. However, the Upper Stillwater Lake is less than 0.5 mile downstream from Duck Lake; data for the Upper Stillwater Lake are presented in Section 3.6.8.

The only recent sampling occurred on Duck Lake at station C09DUCKL01 (Duck Lake at mid-lake). A summary of the available nutrient data for this station is presented in Table 26.

[14] A small, unnamed lake is located northeast of Bull Lake. The anthropogenic activities affecting Bull Lake may also affect the unnamed lake. Since no information or water quality data are available for the unnamed lake, it is not further addressed in this technical memorandum.

Table 26. Summary of nutrients samples data collected at C09DUCKL01

Parameter	Units	No. of Samples	Begin	End	Min	Max	Avg
Ammonia	mg/L as N	3	7/10/2008	9/13/2008	ND [a]	0.06	0.025
Chlorophyll-a	µg/L	6	7/10/2008	9/13/2008	0.6	0.9	0.7
Dissolved oxygen [b]	mg/L	32	7/10/2008	9/13/2008	0.06	10.65	9.37
Nitrate + Nitrite	mg/L as N	3	7/10/2008	9/13/2008	ND [c]	0.013	0.009
Total Nitrogen	mg/L as N	3	7/10/2008	9/13/2008	0.02	0.03	0.03
Total Phosphorus	mg/L as P	3	7/10/2008	9/13/2008	ND [d]	0.004	0.003

[a] The detection limit is 0.01 mg/L; 0.005 mg/L was used for calculating statistics.
[b] Dissolved oxygen data were collected over multiple depths.
[c] The detection limit is 0.005 mg/L; 0.0025 mg/L was used for calculating statistics.
[d] The detection limit is 0.001 mg/L; 0.0005 was used for calculating statistics.

At station C09DUCKL01, stratification is not apparent from DEQ data collected in July through September 2008. DO concentrations remained above 8 mg/L up to the maximum sampling depth of 9 meters (Appendix E).

3.6.4 Lower Stillwater Lake

Lower Stillwater Lake is located northwest of Flathead Lake and south and west of Whitefish Lake (refer to Figure 15). According to the NHD, the surface area of Lower Stillwater Lake is 248 acres with a perimeter of 4.0 miles. Approximately 103,490 acres drain to Lower Stillwater Lake, its elevation is 3,199 feet, and its maximum depth is 53 feet (Ellis and Craft 2008). FWS provided a bathymetric map of the Lower Stillwater Lake that was originally created in 1965 by Montana Fish & Game (Appendix F). DEQ provided a PDF copy of this map.

VMP data show that the Lower Stillwater Lake stratified at a depth of 5 meters in August 2001. DEQ data show that the lake stratified at depths of 2 to 5 meters in July through September 2006. VMP DO concentrations tended to remain above 6mg/L up to a depth of 5 meters and dropped below 1 mg/L at depths greater than 6 meters. DEQ collected DO concentrations that remained above 8 mg/L up to depths of 6 meters, while DO dropped below 1 mg/L at depths of greater than 9 meters. Depth profiles are presented in Appendices D and E.

Volunteer data were collected on four occasions from 1993 to 2003. Total phosphorus (mean: 25 µg/L), chlorophyll a (mean: 5.3 µg/L), and Secchi depth measures (mean: 5.5 m) indicate that Lower Stillwater Lake is mesotrophic (Ellis and Craft 2008). No other data were available.

One station on the Stillwater River downstream of Lower Stillwater Lake was recently sampled: MARTIN (Martin Camp Road); a summary of nutrient for station MARTIN is presented in Table 27.

Table 27. Summary of nutrients samples collected at station MARTIN

Parameter	Units	No. of Samples	Begin	End	Min	Max	Avg
Nitrate + Nitrite	mg/L as N	8	4/7/2003	9/24/2003	0.01	0.05	0.018
Total Kjeldahl Nitrogen	mg/L as N	8	4/7/2003	9/24/2003	0.22	0.22	0.22
Total Phosphorus	mg/L as P	8	4/7/2003	9/24/2003	0.007	0.010	0.009
Orthophosphorous	mg/L as P	8	4/7/2003	9/24/2003	0.001	0.038	0.014

Historic data collected by DEQ are available for three stations located on Lower Stillwater Lake:

- 6012LO01 (1974-1981)
- 6012LO02 (1974)
- 6012LO03 (1974)

The only recent sampling occurred on Lower Stillwater Lake at station C09LSLWL01 (Lower Stillwater Lake at mid-lake). A summary of the available nutrient data for this station is presented in Table 28.

Table 28. Summary of nutrients samples collected at station C09LSWL01

Parameter	Units	No. of Samples	Begin	End	Min	Max	Avg
Chlorophyll-a	µg/L	6	7/10/2006	9/14/2006	0.5	1.4	0.9
Dissolved oxygen [a]	mg/L	36	7/10/2006	9/14/2006	0.14	14.33	6.65
Nitrate + Nitrite	mg/L as N	3	7/10/2006	9/14/2006	ND [b]	0.009	0.007
Total Kjeldahl Nitrogen	mg/L as N	3	7/10/2006	9/14/2006	ND [c]	0.18	0.12
Total Phosphorus	mg/L as P	3	7/10/2006	9/14/2006	0.002	0.005	0.003

[a] Dissolved oxygen data were collected over multiple depths.
[b] The detection limit is 0.005 mg/L; 0.0025 mg/L was used for calculating statistics.
[c] The detection limit is 0.01 mg/L; 0.005 mg/L was used for calculating statistics.

3.6.5 Skyles Lake[15]

Skyles Lake is located northwest of Flathead Lake and west of Whitefish Lake (refer to Figure 14). According to the NHD, the surface area of Skyles Lake is 37 acres with a perimeter of 1.0 mile. Approximately 1,260 acres drain to Skyles Lake and its maximum depth is 13 feet (Ellis and Craft 2008). FWP provided an undated bathymetric map of Skyles Lake (Appendix F).

VMP data show that the Skyles Lake did not stratify in August 1998, 2001, or 2002. DO concentrations remained above 6 mg/L throughout the depth of the lake. Depth profiles are presented in Appendix C.

Volunteer data were collected on 9 occasions from 1993 to 2002. Total phosphorus (mean: 15 µg/L), chlorophyll-*a* (mean: 2.3 µg/L), and Secchi depth (mean: 2.4 m) indicate that Skyles Lake is oligomesotrophic (Ellis and Craft 2008). No other data are available for Skyles Lake.

3.6.6 Spencer Lake

Spencer Lake is located northwest of Flathead Lake and west of Whitefish Lake (refer to Figure 14). According to the NHD, the surface area of Spencer Lake is 29 acres with a perimeter of 1.0 mile. Approximately 1,663 acres drain to Spencer Lake and its elevation is 3,199 feet (Ellis and Craft 2008). FWP provided an undated bathymetric map of Spencer Lake (Appendix F).

Neither recent nor historic water quality data are available for the waterbodies immediately upstream and downstream of the lake; volunteer data were collected from 1995 to 1995. Recently-collected nutrients data are not available for Spencer Lake. However, historic data collected by DEQ in 1994 are available for one stations located on Spencer Lake: 5813SP01. Total phosphorus (mean: 22 µg/L) and chlorophyll-*a* (mean: 3.6 µg/L) concentrations indicate that Spencer Lake is mesooligotrophic (Ellis and Craft 2008).

[15] Skyles Lake reportedly has a dam; however, no information regarding a dam is available.

3.6.7 Tally Lake

Tally Lake is located northwest of Flathead Lake (Figure 16). According to the NHD, the surface area of Tally Lake is 1,206 acres with a perimeter of 8.2 miles. Approximately 115,260 acres drain to Tally Lake and its elevation is 3,399 feet (Ellis and Craft 2008). Tally Lake has the distinction of being the deepest natural lake in Montana, with a depth of 495 feet (Ellis and Craft 2008).

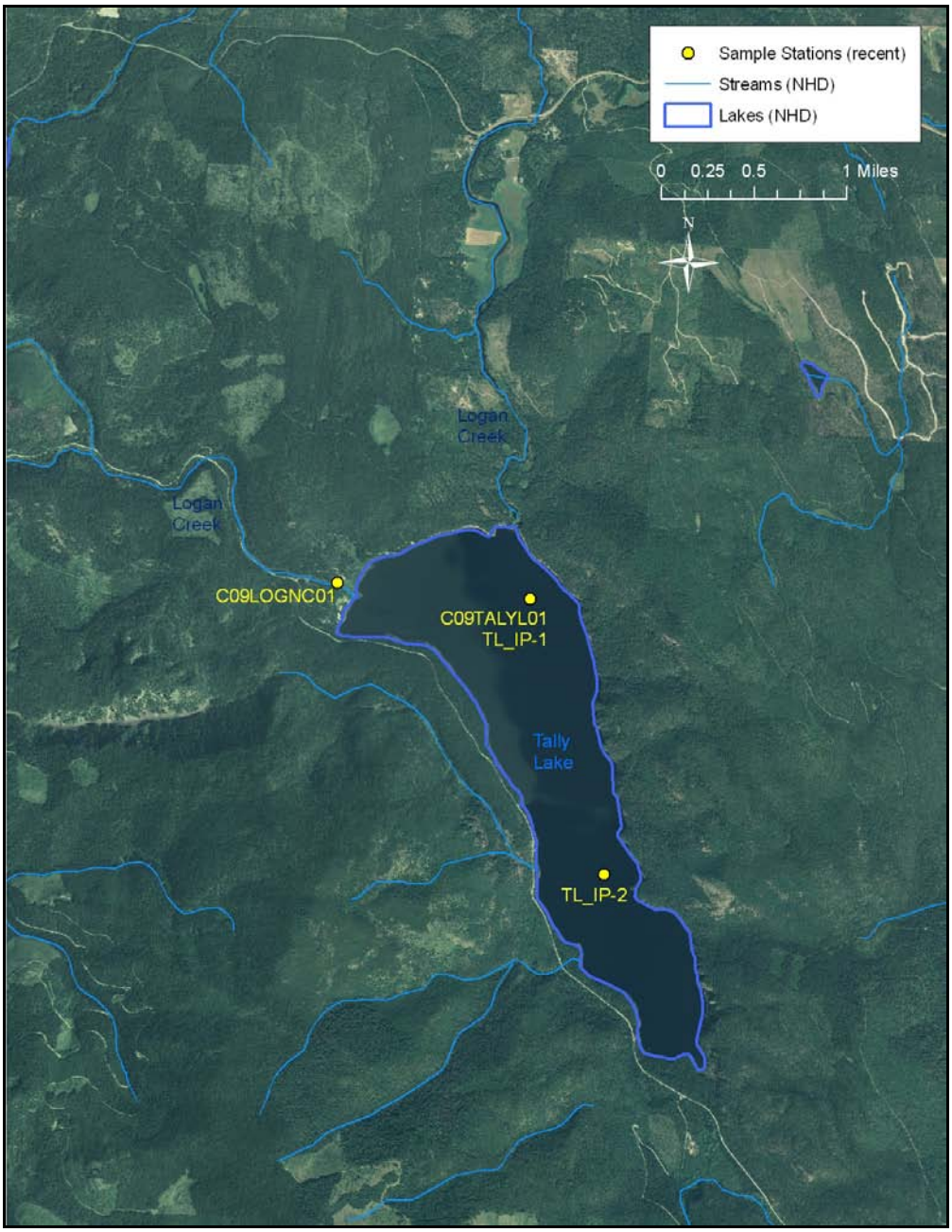

Figure 16. Tally Lake.[16]

[16] Only stations that were sampled since 2000 are displayed.

3.6.7.1 Bathymetrical Data

The FWS provided a bathymetric map of Tally Lake that was originally created in 1967 by Montana Fish & Game (Appendix F). FWP provided a PDF copy of this map. WLI hired Constellation Services to create a bathymetric map (a color poster copy was made available to EPA) and calculated the volume of Tally Lake to be 370,046,746.30 m^3 (approximately 300,002 ac-ft).

3.6.7.2 Hydrological Data

USGS Gage 12364000 (Logan Cr at Tally Lk nr Whitefish MT) was located downstream of the outlet of Tally Lake. Historic daily flow data are available from 8/1/1931 through 9/30/1947.

3.6.7.3 Trophic State Data

Volunteer data were collected on Tally Lake from 1993 to 1998. Total phosphorus (mean: µg/L), chlorophyll-*a* (mean: 0.9 µg/L), and Secchi depth measures (mean: 4.5 m) indicate that Tally Lake is oligotrophic (Ellis and Craft 2008).

3.6.7.4 Stratification Data

VMP data show that the Tally Lake stratified at a depth of approximately 6 meters in September 1998. DO concentrations remained above 6mg/L up to the maximum observed sampling depth of 33 meters and remained above 8 mg/L from 18 to 33 meters depth. Depth profiles are presented in Appendix C.

3.6.7.5 Nutrient Data

A single sample each was collected from one station upstream of Tally Lake: C09LOGNC01 (on 7/8/2003); these results are presented in Appendix C. A summary of nutrient data for stations located on Tally Lake are presented in Table 29, Table 30, and Table 31.

Table 29. Summary of nutrient samples collected at station C09TLYL01

Parameter	Units	No. of samples	Begin	End	Min	Max	Avg
Chlorophyll-*a*	mg/m^2	5	7/3/2008	10/12/2008	3.30	4.65	3.83
Nitrate + Nitrite	mg/L as N	5	7/3/2008	10/12/2008	0.019	0.030	0.025
Total Nitrogen	mg/L as N	5	7/3/2008	10/12/2008	0.07	0.24	0.14
Total Phosphorus	mg/L as P	5	7/3/2008	10/12/2008	0.008	0.021	0.014
Soluble Reactive Phosphorus	mg/L as P	5	7/3/2008	10/12/2008	0.003	0.007	0.005

Table 30. Summary of nutrient samples collected at station TL_IP-1

Parameter	Units	No. of samples	No. of detections	Begin	End	Min	Max	Avg
Dissolved Oxygen (laboratory)	mg/L	17	17	6/19/2009	11/7/2009	4.50	5.80	5.07
Total Organic Carbon	mg/L	20	20	5/31/2009	11/7/2009	4.3	5.6	4.9
TSS	mg/L	20	7	5/31/2009	11/7/2009	1.0	4.0	1.7
Total Nitrogen	mg/L as N	20	19	5/31/2009	11/7/2009	0.07	0.27	0.18
Total Phosphorus	mg/L as P	20	19	5/31/2009	11/7/2009	0.006	0.041	0.012
Dissolved Phosphorus	mg/L as P	20	17	5/31/2009	11/7/2009	0.001	0.032	0.008

Statistics exclude non-detects.

Table 31. Summary of nutrient samples collected at station TL_IP-2

Parameter	Units	No. of samples	No. of detections	Begin	End	Min	Max	Avg
Dissolved Oxygen (laboratory)	mg/L	16	15	6/19/2009	11/7/2009	4.70	5.90	5.27
Total Organic Carbon	mg/L	20	19	5/31/2009	11/7/2009	4.4	5.6	5.0
TSS	mg/L	20	9	5/31/2009	11/7/2009	1.0	2.0	1.2
Total Nitrogen	mg/L as N	20	20	5/31/2009	11/7/2009	0.06	0.28	0.18
Total Phosphorus	mg/L as P	20	19	5/31/2009	11/7/2009	0.007	0.020	0.011
Dissolved Phosphorus	mg/L as P	20	18	5/31/2009	11/7/2009	4 E-4	0.011	0.005

Statistics exclude non-detects.

3.6.8 Upper Stillwater Lake

Upper Stillwater Lake is located northwest of Flathead Lake and northwest of Whitefish Lake (refer to Figure 15). According to the NHD, the surface area of Upper Stillwater Lake is 694 acres with a perimeter of 15.0 mile. Approximately 79,986 acres drain to the Upper Stillwater Lake, its elevation is 3,199 feet, and its maximum depth is 75 feet (Ellis and Craft 2008). FWS provided a bathymetric map of the Upper Stillwater Lake that was originally created in 1967 by Montana Fish & Game (Appendix F).

Recent and historic data are available for stations along the Stillwater River; however, tributaries and other lakes discharge to the Stillwater River between Upper Stillwater Lake and these sample stations.

DEQ sampled station 6111UP01 (Stillwater Lakes) in November 1992 and sampled station 6112UP01 (Stillwater Lakes) in May 1981. The only recent sampling occurred on Upper Stillwater Lake at station C09USLWL01 (Upper Stillwater Lake at mid-lake). A summary of the available nutrient data for this station is presented in Table 32.

Table 32. Summary of nutrient samples collected at station C09USLWL01

Parameter	Units	No. of Samples	Begin	End	Min	Max	Avg
Chlorophyll-a	µg/L	6	7/11/2006	9/14/2006	0.5	0.9	0.6
Dissolved oxygen [a]	mg/L	30	7/11/2006	9/14/2006	0.19	10.90	7.77
Nitrate + Nitrite	mg/L as N	3	7/11/2006	9/14/2006	ND [b]	0.007	0.005
Total Kjeldahl Nitrogen	mg/L as N	3	7/11/2006	9/14/2006	ND [c]	0.17	0.09
Total Phosphorus	mg/L as P	3	7/11/2006	9/14/2006	ND [d]	0.003	0.002

[a] Dissolved oxygen data were collected over multiple depths.
[b] The detection limit is 0.005 mg/L; 0.0025 mg/L was used for calculating statistics.
[c] The detection limit is 0.01 mg/L; 0.005 mg/L was used for calculating statistics.
[d] The detection limit is 0.001 mg/L; 0.0005 mg/L was used for calculating statistics.

Volunteer data was also collected from the Upper Stillwater Lake on three occasions from 1993 to 1999. Total phosphorus (mean: 10 µg/L), chlorophyll-*a* (mean: 1.3 µg/L), and Secchi depth measures (mean: 7.0 m) indicate that Upper Stillwater Lake is oligotrophic (Ellis and Craft 2008).

At station C09USLW01, the Upper Stillwater Lake stratified at depths of 2 to 6 meters in July through September 2006 (Appendix E). DO concentrations remained above 8 mg/L up to a depth of 7 meters and dropped to below 1 mg/L at depths greater than 14 meters.

3.6.9 Upper Whitefish Lake

Upper Whitefish Lake is located north of Flathead Lake and north of Whitefish Lake. The East Fork of Swift Creek flows through Upper Whitefish Lake. According to the NHD, the surface are of Upper Whitefish Lake is 80 acres with a perimeter of 1.5 miles. Neither current nor historic water quality data are available for Upper Whitefish Lake or on the waterbodies immediately upstream and downstream of the lake. Recent and historic data are available for stations along East Fork Swift Creek; however, tributaries discharge to East Fork Swift Creek between Upper Whitefish Lake and these sample stations. FWP provided an undated bathymetric map of Upper Whitefish Lake (Appendix F).

3.6.10 Whitefish Lake

Whitefish Lake is located north of Flathead Lake. It is fed by numerous tributaries, one of which, Swift Creek, is listed as impaired for nutrients (refer to Figure 14). According to the NHD, the surface area of Whitefish Lake is 3,299 acres with a perimeter of 16.2 miles. Approximately 76,519 acres drain to Whitefish Lake, its elevation is 2,989 feet, and its maximum depth is 223 feet (Ellis and Craft 2008). Whitefish Lake stratifies in the late summer (Ellis and Craft 2008).

3.6.10.1 Bathymetric Data

The FWS provided a bathymetric map of Whitefish Lake that was originally created in 1964 by Montana Fish & Game (Appendix F). DEQ provided an electronic version of this map. WLI hired Constellation Services to create a bathymetric map in 2006 (a color poster copy was made available to EPA) and calculated the volume of Whitefish Lake to be 480,798,030.1 m^3 (approximately 389,789 ac-ft).

3.6.10.2 Hydrological Data

USGS Gage 12365800 (Swift Creek near Whitefish, MT) was located upstream Whitefish Lake. Historic daily flow data are available from 10/1/1972 through 10/2/1981.

3.6.10.3 Trophic State Data

Volunteer data were collected from three sites on Whitefish Lake from 1994 to 2007. Total phosphorus (mean: 6 pg L1), total nitrogen (mean: 83 µg/L), chlorophyll-*a* (mean: 0.8 µg/L), and Secchi depth measures (mean: 7.8 m) indicate that Whitefish Lake is oligotrophic (Ellis and Craft 2008).

3.6.10.4 Stratification Data

VMP data show that the Whitefish Lake stratified at a depth of 10 meters in August and September (1998, 2001, 2002, and 2006). DEQ data from C09WHTFL01 show that Whitefish Lake stratified at 10 meters in September 2007; however, the lake did not stratify at C09WHTFL02. Except for sampling at Monk's Bay in 2006, VMP-collected DO concentrations remained above 6mg/L up to the maximum observed sampling depth of 33 meters and remained above 7.5 mg/L from 12-33 meters depth. DEQ data collected from May to October 2007 and 2008 at C09WHTFL01 showed that DO concentrations remained above 8 mg/L up to depths of 45 meters and remained above 6 mg/L to maximum sampling depths (67 meters). At C09WHTFL02, DO concentrations remained above 8 mg/L to the maximum sampling depth of 17 meters. Depth profiles are presented in Appendices D and E.

3.6.10.5 Nutrient Data

Summaries of nutrient data for three stations located upstream of Whitefish Lake on Swift Creek are presented in Table 33, Table 34, and Table 35. A single chlorophyll-*a* sample was collected at station WWSSWFTC07 (22 µg/L on 10/21/2003). Upstream data collected by WLI from minor tributaries to Whitefish Lake (Hellroaring Creek, Lazy Creek, Smith Creek, and Viking Creek) and farther upstream on Swift Creek are also available but are not presented in this memorandum.

Table 33. Summary of nutrient samples collected at station C09SWFTC01

Parameter	Units	No. of samples	Begin	End	Min	Max	Avg
Ammonia	mg/L as N	7	5/23/2007	10/6/2007	ND [a]	ND [a]	ND [a]
Chlorophyll-*a*	µg/L	9	5/23/2007	10/6/2007	1.5	18.0	5.6
Dissolved Oxygen	mg/L	5	5/23/2007	10/6/2007	8.6	12.6	10.5
Nitrate + Nitrite	mg/L as N	7	5/23/2007	10/6/2007	ND [b]	0.020	0.009
Total Nitrogen	mg/L as N	7	5/23/2007	10/6/2007	0.05	0.13	0.06
Total Phosphorus	mg/L as P	7	5/23/2007	10/6/2007	ND [c]	0.0210	0.008
Soluble Reactive Phosphorus	mg/L as P	7	5/23/2007	10/6/2007	ND [c]	0.0030	0.001

[a] The detection limit is 0.05 mg/L; 0.025 mg/L was used for calculating statistics.
[b] The detection limit is 0.01 mg/L; 0.005 mg/L was used for calculating statistics.
[c] The detection limit is 0.001 mg/L; 0.0005 mg/L was used for calculating statistics.

Table 34. Summary of nutrient samples collected at station STSF06

Parameter	Units	No. of samples	Begin	End	Min	Max	Avg
Nitrate + Nitrite	mg/L as N	302	4/13/1982	6/21/2006	0.001	0.149	0.040
Total Phosphorus	mg/L as P	286	4/13/1982	6/21/2006	1.00 E-6	0.301	0.023
Total Phosphorus	mg/L as PO_4	210	4/17/1985	7/12/2001	1E-4	0.202	0.003

Table 35. Summary of nutrient samples collected at station Swift Creek – DelRay

Parameter	Units	No. of samples	No. of detections	Begin	End	Min	Max	Avg
Total Organic Carbon	mg/L	3	3	7/7/2009	10/9/2009	0.6	0.7	0.6
TSS	mg/L	3	2	7/7/2009	10/9/2009	1.0	2.0	1.5
Total Nitrogen	mg/L as N	3	0	7/7/2009	10/9/2009	ND		
Total Phosphorus	mg/L as P	3	3	7/7/2009	10/9/2009	0.005	0.008	0.007
Dissolved Phosphorus	mg/L as P	3	2	7/7/2009	10/9/2009	0.003	0.003	0.003

Statistics exclude non-detects.
ND = All samples were non-detects.

Summaries of nutrient data collected at two stations downstream of Whitefish Lake are presented in

Table 36Table 36 and Table 37.

Table 36. Summary of nutrient samples collected at station WFROUTLET

Parameter	Units	No. of samples	Begin	End	Min	Max	Avg
Dissolved Oxygen	mg/L	13	11/20/2003	10/11/2004	7.96	20.20	10.49
Nitrate + Nitrite	mg/L as N	14	11/20/2003	10/11/2004	3E-4	0.0054	8E-4
Total Nitrogen	mg/L as N	14	11/20/2003	10/11/2004	0.058	0.128	0.089
Total Phosphorus	mg/L as P	14	11/20/2003	10/11/2004	0.005	0.008	0.006
Soluble Reactive Phosphorus	mg/L as P	14	11/20/2003	10/11/2004	7E-4	0.0019	0.001

Table 37. Summary of nutrient samples collected at station Whitefish River

Parameter	Units	No. of samples	No. of detections	Begin	End	Min	Max	Avg
Total Organic Carbon	mg/L	6	6	5/3/2009	10/9/2009	1.4	1.6	1.5
TSS	mg/L	6	4	5/3/2009	10/9/2009	1.0	3.0	1.75
Total Nitrogen	mg/L as N	6	4	5/3/2009	10/9/2009	0.06	0.21	0.10
Total Phosphorus	mg/L as P	6	6	5/3/2009	10/9/2009	0.004	0.006	0.005
Dissolved Phosphorus	mg/L as P	6	5	5/3/2009	10/9/2009	0.002	0.005	0.003

Statistics exclude non-detects.

Summaries of nutrient data collected at four stations on Whitefish Lake (C09WHTFL01, C09WHTFL02, WF_IP-1, and WF_IP-2) are presented in Table 38,

Table 39, Table 40, and Table 41, respectively. WLI collected Hydrolab data at varying depth from ten bays in Whitefish Lake; these data are not presented in the memorandum.

Table 38. Summary of nutrient samples collected at station C09WHTFL01

Parameter	Units	No. of samples	Begin	End	Min	Max	Avg
Ammonia	mg/L as N	26	5/27/2007	7/21/2008	ND [b]	ND [b]	ND [b]
Chlorophyll-*a*	µg/L	22	5/27/2007	10/11/2008	2.0	9.8	4.4
Dissolved Oxygen [a]	mg/L	278	5/27/2007	10/7/2007	6.30	12.16	9.34
Nitrate + Nitrite	mg/L as N	28	5/27/2007	10/11/2008	ND [c]	0.010	0.005
Total Nitrogen	mg/L as N	28	5/27/2007	10/11/2008	0.04	0.18	0.072
Total Phosphorus	mg/L as P	28	5/27/2007	10/11/2008	0.002	0.010	0.006
Soluble Reactive Phosphorus	mg/L as P	28	5/27/2007	10/11/2008	ND [d]	0.0022	8E-4

[a] Dissolved oxygen data were collected over multiple depths.
[b] The detection limit is 0.05 mg/L; 0.025 mg/L was used for calculating statistics.
[c] The detection limit is 0.01 mg/L; 0.005 mg/L was used for calculating statistics.
[d] The detection limit is 0.001 mg/L; 0.0005 mg/L was used for calculating statistics.

Table 39. Summary of nutrient samples collected at station C09WHTFL02

Parameter	Units	No. of samples	Begin	End	Min	Max	Avg
Ammonia	mg/L as N	25	5/28/2007	10/12/2008	ND [b]	ND [b]	ND [b]
Chlorophyll-*a*	µg/L	22	5/28/2007	10/12/2008	1.0	8.7	3.6
Dissolved Oxygen [a]	mg/L	113	5/28/2007	10/7/2007	7.46	11.23	9.66
Nitrate + Nitrite	mg/L as N	26	5/28/2007	10/12/2008	ND [c]	0.010	0.005
Total Nitrogen	mg/L as N	26	5/28/2007	10/12/2008	0.045	0.170	0.071
Total Phosphorus	mg/L as P	26	5/28/2007	10/12/2008	0.001	0.011	0.006
Soluble Reactive Phosphorus	mg/L as P	26	5/28/2007	10/12/2008	ND [d]	0.0023	6E-4

[a] Dissolved oxygen data were collected over multiple depths.
[b] The detection limit is 0.05 mg/L; 0.025 mg/L was used for calculating statistics.
[c] The detection limit is 0.01 mg/L; 0.005 mg/L was used for calculating statistics.
[d] The detection limit is 0.001 mg/L; 0.0005 mg/L was used for calculating statistics.

Table 40. Summary of nutrient samples collected at station WL_IP-1

Parameter	Units	No. of samples	No. of detections	Begin	End	Min	Max	Avg
Total Organic Carbon	mg/L	11	11	5/2/2009	10/8/2009	1.4	1.5	1.5
TSS	mg/L	11	4	5/2/2009	10/8/2009	1.0	2.0	1.5
Total Nitrogen	mg/L as N	11	5	5/2/2009	10/8/2009	0.06	0.08	0.07
Dissolved Phosphorus	mg/L as P	11	7	5/2/2009	10/8/2009	0.001	0.005	0.003
Total Phosphorus	mg/L as P	11	11	5/2/2009	10/8/2009	0.005	0.020	0.008

Statistics exclude non-detects.

Table 41. Summary of nutrient samples collected at station WL_IP-2

Parameter	Units	No. of samples	No. of detections	Begin	End	Min	Max	Avg
Total Organic Carbon	mg/L	10	10	5/2/2009	10/8/2009	1.4	1.6	1.5
TSS	mg/L	10	5	5/2/2009	10/8/2009	1.0	4.0	1.6
Total Nitrogen	mg/L as N	10	5	5/2/2009	10/8/2009	0.04	0.10	0.07
Total Phosphorus	mg/L as P	10	10	5/2/2009	10/8/2009	0.001	0.012	0.006
Dissolved Phosphorus	mg/L as P	10	8	5/2/2009	10/8/2009	0.001	0.011	0.003

Statistics exclude non-detects.

3.7 HUC 17010211 - Swan River Planning Area

Eleven lakes of interest are located in the Swan River Planning Area. Available data for these waterbodies are presented in the following subsections. Nine of these lakes are displayed in Figure 17.

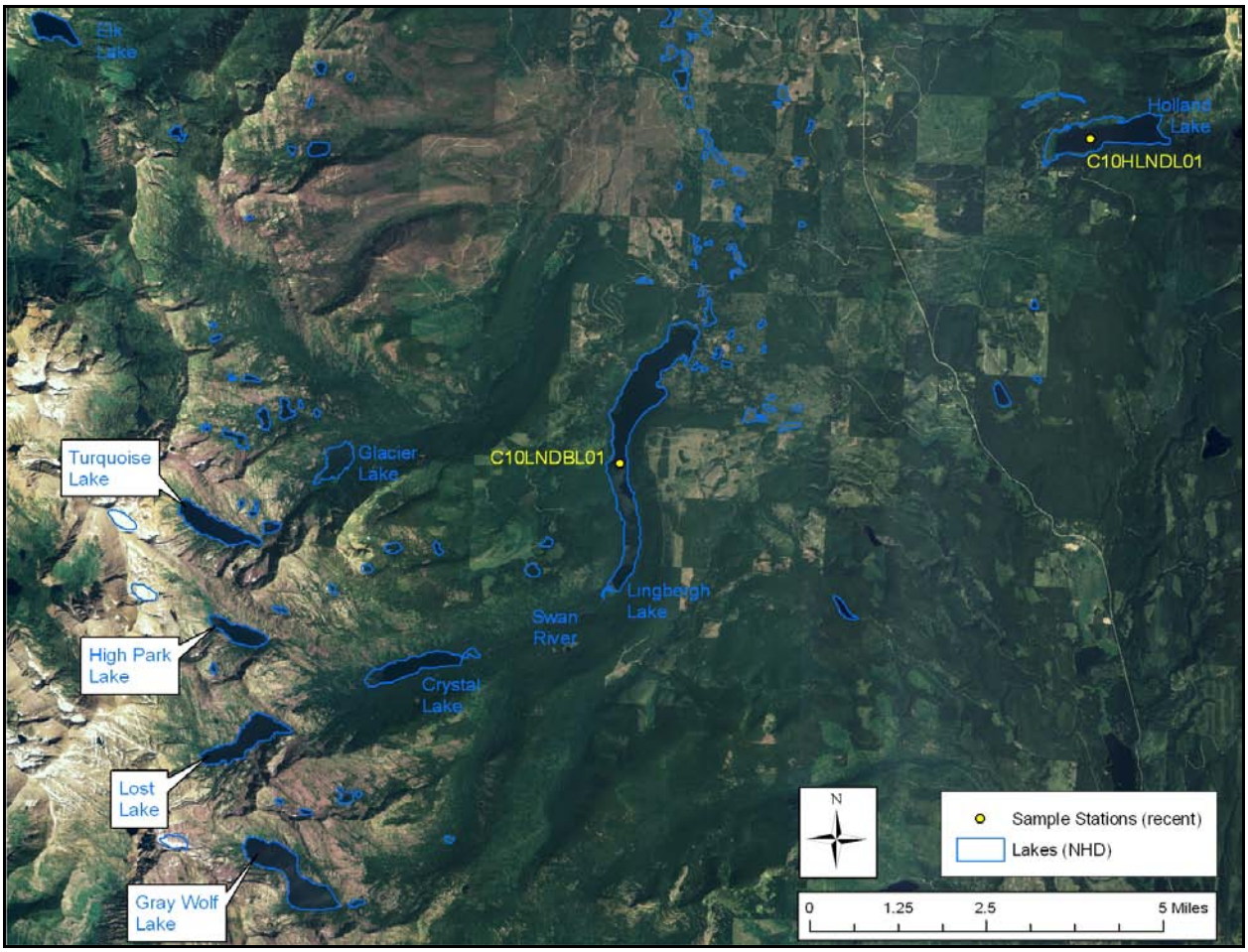

Figure 17. Crystal Lake, Elk Lake, Glacier Lake, Gray Wolf Lake, High Park Lake, Holland Lake, Lindbergh Lake, Lost Lake, and Turquoise Lake.[17]

3.7.1 Crystal Lake, Elk Lake, Glacier Lake, Gray Wolf Lake, High Park Lake, Lost Lake, and Turquoise Lake

These lakes are located southeast of Flathead Lake and in the headwaters of the Swan River Planning Area (Figure 17). Neither current nor historic water quality data are available for any of these lakes or on the waterbodies immediately upstream and downstream of the lakes.

3.7.2 Holland Lake

Holland Lake is located southeast of Flathead Lake (Figure 17). According to the NHD, the surface area of Holland Lake is 414 acres with a perimeter of 5.8 miles. Approximately 5,319 acres drain to Holland

[17] Only stations that were sampled since 2000 and are located on a lake of interest or immediately upstream or downstream of a lake of interest are displayed.

Lake, its elevation is 4,199 feet, and its maximum depth is 156 feet (Ellis and Craft 2008). FWP provided an undated bathymetric map of Holland Lake (Appendix F).

Neither recent nor historic water quality data are available for the waterbodies immediately and downstream of Holland Lake. The U.S. Forest Service collected data from 1976 to 1980 from station FL1017 (HOLLAND CR 13 MI NNW SEELY LAKE MT) and DEQ collected data at station 4819HO01 (Holland Creek) from 1976 to 1978; both stations are immediately upstream of Holland Lake.

Historic data collected on Holland Lake are not available. DEQ collected recent data at station C10HLNDL01 (Holland Lake). A summary of nutrient data for station C10HLNDL01 is presented in Table 44.

Table 42. Summary of nutrient samples collected at C10HLNDL01

Parameter	Units	No. of Samples	Begin	End	Min	Max	Avg
Chlorophyll-*a*	mg/m^3	9	7/20/2004	9/15/2004	0.281	0.667	0.394
Dissolved Oxygen [a]	mg/L	54	7/20/2004	9/15/2004	7.11	11.60	9.39
Nitrite	mg/L as N	3	7/20/2004	9/15/2004	ND	ND	ND
Total Kjeldahl Nitrogen	mg/L as N	3	7/20/2004	9/15/2004	ND	0.14	0.05
Total Phosphorus	mg/L as P	3	7/20/2004	9/15/2004	ND [b]	ND [b]	ND [b]

[a] Dissolved oxygen data were collected at multiple depths.
[b] The detection limit is 0.001 mg/L; 0.0005 mg/L was used for calculating statistics.

Volunteer data were collected from Holland Lake four times from 1997 to 2005. Total phosphorus (mean: 11 µg/L), total nitrogen (mean: 127 µg/L), and chlorophyll-*a* (mean: 1.3 µg/L) indicate that Holland Lake is oligotrophic (Ellis and Craft 2008).

Holland Lake stratifies in the summer (Ellis and Craft 2008). VMP-collected data show that Holland Lake stratified at a depth of 5 meters in August (1998 and 2005). DEQ-collected data shows that it stratified at depths of 4 to 11 meters from July through September 2004. VMP-collected DO concentrations remained above 5 mg/L to the maximum observed sampling depth of 29 meters (Appendix C); similarly DEQ-collected DO concentrations remained above 6 mg/L to the maximum observed sampling depth of 21 meters (Appendix E).

3.7.3 Lindbergh Lake

Lindbergh Lake is located southeast of Flathead Lake (Figure 17). According to the NHD, the surface area of Lindbergh Lake is 816 acres with a perimeter of 10.9 miles. Approximately 26,065 acres drain to Lindbergh Lake, its elevation is 4,400 feet, and its maximum depth is 121 feet (Ellis and Craft 2008). FWP provided an undated bathymetric map of Lindbergh Lake (Appendix F).

DEQ historically sampled station 4618SW01 (Swan River) from 1976 to 1995 and the U.S. Forest Service sampled station FL1016 (Swan River above Lindbergh Lake) from 1976 to 1980; both stations are immediately upstream of Lindbergh Lake. In 1985, DEQ collected one sample from Herrick Run, a tributary to Lindbergh Lake, from station 4718HE01 (Herrick Run). DEQ sampled station 4718SW01 (Swan River), which is downstream of Lindbergh Lake, from 1989 to 1995.

DEQ also sampled Lindbergh Lake; the historic sample stations are summarized in the list below:

- 4718LI01 (1989, 1991)
- 4718LI02 (1989-1995)

- 4718LI03 (1989-1995)
- 4718LI04 (1989-1992)
- 4718UN01 (1988)

DEQ collected recent data at station C10LNDBL01 (Lindberg Lake). A summary of nutrient data for station C10LNDBL01 is presented in Table 43.

Table 43. Summary of nutrient samples collected from station C10LNDBL01

Parameter	Units	No. of Samples	Begin	End	Min	Max	Avg
Chlorophyll-*a*	µg/L	9	7/20/2004	9/15/2004	0.238	0.972	0.595
Dissolved Oxygen [a]	mg/L	55	7/20/2004	9/15/2004	7.12	11.00	9.11
Nitrite	mg/L as N	3	7/20/2004	9/15/2004	ND	ND	ND
Total Kjeldahl Nitrogen	mg/L as N	3	7/20/2004	9/15/2004	ND	0.17	0.06
Total Phosphorus	mg/L as P	3	7/20/2004	9/15/2004	ND a	0.002	0.001

[a] Dissolved oxygen data were collected at multiple depths.
[b] The detection limit is 0.001 mg/L; 0.0005 mg/L was used for calculating statistics.

Volunteer data were collected from Lindbergh Lake five times from 1997 to 2005. Total phosphorus (mean: 9 µg/L), chlorophyll-*a* (mean: 1.4 µg/L), and Secchi depth (mean: 9.3 m) indicate that Holland Lake is oligotrophic (Ellis and Craft 2008).

Lindbergh Lake stratifies in late summer (Ellis and Craft 2008). VMP-collected data shows that Lindbergh Lake stratified at 5 meters depth in August (1998 and 2005). DEQ-collected data shows that it stratified at depths of 5 to 10 meters in July through September 2004. VMP-collected DO concentrations varied considerably between 1998 and 2005. In 1998, it ranged from 6 to 11 mg/L up to a depth of 32 meters; in 2001, it ranged from 4 to 6 mg/L up to a depth of 18 meters. DEQ-collected DO concentrations remained above 6 mg/L to the maximum observed sampling depth of 21 meters (Appendix E).

3.7.4 Mud Lake

Mud Lake is located northwest of Flathead Lake and west of Hungry Horse Reservoir. According to the NHD, the surface area of Mud Lake is 144 acres with a perimeter of 2.2 miles. Neither recent nor historic water quality data are available for Mud Lake or on the waterbodies immediately upstream and downstream of the lake.

3.7.5 Swan Lake

Swan Lake is located north of Flathead Lake. It is long, narrow, and oriented on a southeast-northwest axis (Figure 18). According to the NHD, the surface area of Swan Lake is 3,280 acres with a perimeter of 23.4 miles. Approximately 421,612 acres drain to Swan Lake, its elevation is 3,199 feet, and its maximum depth is 132 feet (Ellis and Craft 2008). The total volume is 193,000 acre-feet. There are two deepwater basins in the lake: South Basin and North Basin. The South Basin is located at the north of Swan River inlet. The North Basin is located at the northwest end of the lake. Dissolved oxygen depletion was observed in the two deep water basins during summer stratification (Spencer 1991; Chapra 1996).

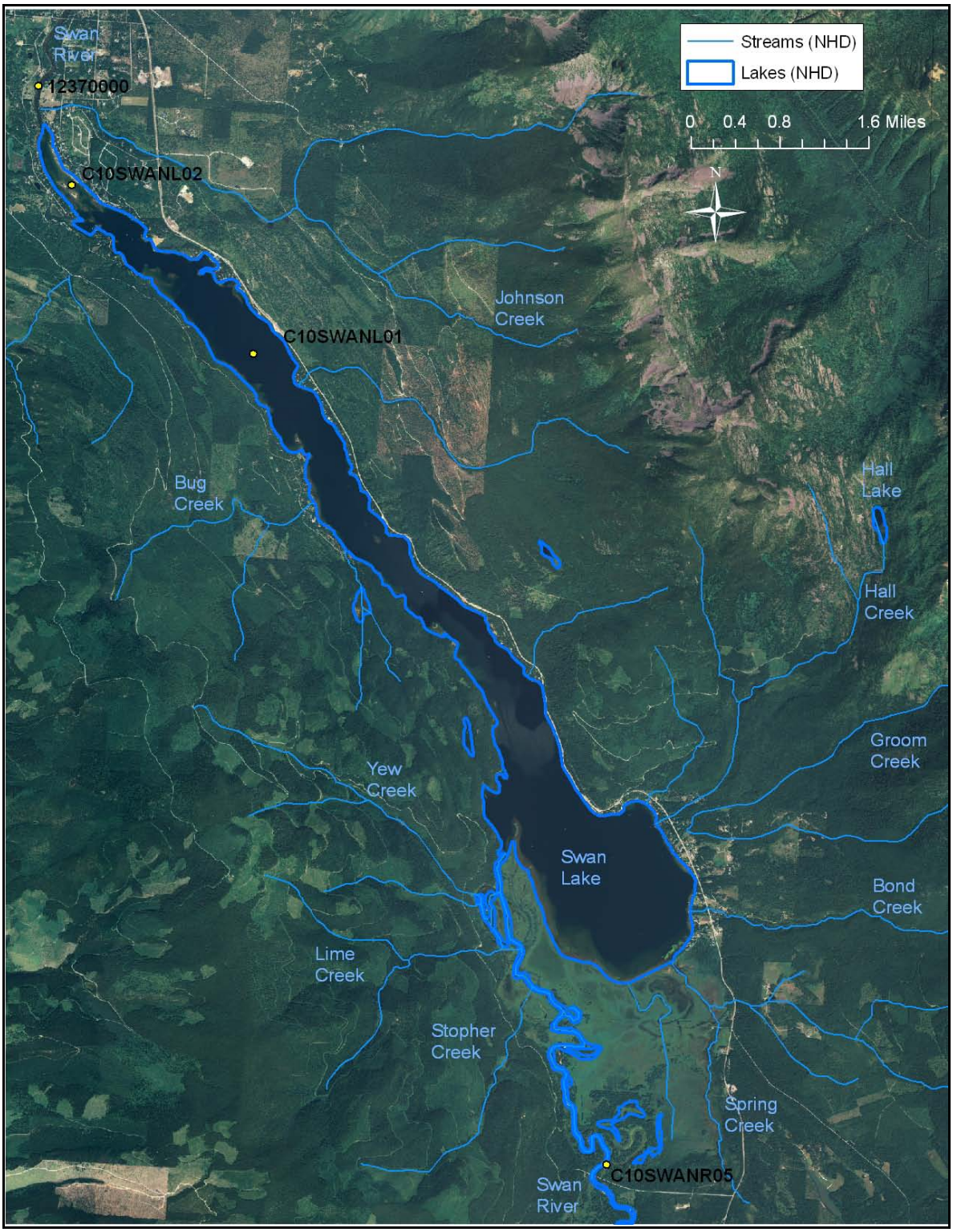

Figure 18. Swan Lake.[18]

[18] Only stations that were sampled since 2000 and are located on a lake of interest or immediately upstream or downstream of a lake of interest are displayed.

3.7.5.1 Bathymetrical Data

The FWS provided a bathymetric map of Swan Lake that was originally created in 1966 by Montana Fish & Game (Appendix F). DEQ provided a PDF copy of this map.

3.7.5.2 Hydrological Data

USGS Gage 12370000 (Swan River near Bigfork, MT) is located downstream of the outlet of Swan Lake. Daily flow data are available from 5/1/1922 through 2/16/2010.

The average annual flow and peak flow at gage 12370000 were 27.3 and 171 m^3/s (respectively), for flow data collected since the year 2000. Given the volume of Swan Lake, the average and peak flow residence times were calculated to be 101 and 16.1 days, respectively.

3.7.5.3 Trophic State Data

Volunteer data were collected on Swan Lake at four sites from 1993 to 2007. Total phosphorus, chlorophyll-*a*, and Secchi depth measures indicate that Swan Lake is oligotrophic.

3.7.5.4 Stratification Data

VMP data are inconclusive (Appendix C), but DEQ data show that Swan Lake stratifies at station C10SWANL01 from late May through September (Appendix E). VMP-collected DO concentrations remained above 5 mg/L up to the maximum observed sampling depth of 24 meters. DEQ-collected DO concentrations remained above 6 mg/L up to depths of 33 meters, but dropped below than 5 mg/L at depths greater than 35 meters in 2007 but not 2008.

Dissolved oxygen depletion was observed in the two deep water basins during summer stratification (Spencer 1991; Chapra 1996).

3.7.5.5 Nutrient Data

Summaries of nutrient data for station C10SWANR05 (upstream of Swan Lake), gage 12370000 (downstream of Swan Lake), station C10SWANL01 (on Swan Lake), and station C10SWANL02 (on Swan Lake) are presented in Table 44, Table 45, Table 46, and Table 47, respectively.

Table 44. Summary of nutrient samples collected at station C10SWANR05

Parameter	Units	No. of samples	Begin	End	Min	Max	Avg
Ammonia	mg/L as N	10	5/24/2007	9/27/2007	0.025	0.025	0.025
Chlorophyll-*a*	µg/L	10	5/24/2007	9/27/2007	1.2	13.0	5.2
Dissolved Oxygen	mg/L	7	5/24/2007	9/27/2007	9.01	11.21	9.86
Nitrate + Nitrite	mg/L as N	10	5/24/2007	9/27/2007	0.01	0.02	0.02
Total Nitrogen	mg/L as N	10	5/24/2007	9/27/2007	0.04	0.17	0.09
Total Phosphorus	mg/L as P	10	5/24/2007	9/27/2007	0.005	0.015	0.009
Orthophosphorus	mg/L as P	10	5/24/2007	9/27/2007	5E-4	5E-4	5E-4

Table 45. Summary of nutrient samples collected at gage 12370000

Parameter	Units	No. of samples	Begin	End	Min	Max	Avg
Ammonia plus Organic Nitrogen	mg/L as N	20	5/24/1999	8/20/2003	0.06	0.38	0.11
Dissolved Oxygen	mg/L	2	9/25/2001	6/13/2002	9.1	10.0	9.6
Nitrate	mg/L as N	2	7/12/2000	9/25/2001	0.01	0.01	0.01
Nitrate	mg/L as NO_3	2	7/12/2000	9/25/2001	0.027	0.058	0.043
Nitrate + Nitrite	mg/L as N	20	5/24/1999	8/20/2003	0.005	0.060	0.026
Nitrite	mg/L as N	20	5/24/1999	8/20/2003	0.001	0.010	0.003
Total Nitrogen	mg/L as N	2	6/11/2001	7/9/2001	0.09	0.13	0.11
Total Phosphorus	mg/L as P	20	5/24/1999	8/20/2003	0.002	0.010	0.005
Total Phosphorus	mg/L as PO_4	4	5/24/1999	7/12/2000	0.003	0.006	0.005
Orthophosphorus	mg/L as P	20	5/24/1999	8/20/2003	0.001	0.007	0.005

Table 46. Summary of nutrient samples collected at station C10SWANL01

Parameter	Units	No. of samples	Begin	End	Min	Max	Avg
Ammonia	mg/L as N	29	5/24/2007	8/1/2008	0.025	0.025	0.025
Chlorophyll-*a*	µg/L	24	5/24/2007	9/23/2008	2.3	11.0	5.2
Dissolved Oxygen [a]	mg/L	257	5/24/2007	9/27/2007	4.31	12.88	8.61
Nitrate + Nitrite	mg/L as N	31	5/24/2007	9/23/2008	0.005	0.080	0.024
Total Nitrogen	mg/L as N	31	5/24/2007	9/23/2008	5E-4	0.2000	0.0978
Total Phosphorus	mg/L as P	31	5/24/2007	9/23/2008	5E-4	0.0150	0.0054
Orthophosphorus	mg/L as P	31	5/24/2007	9/23/2008	5E-4	0.0050	0.0011

[a] Dissolved oxygen data were collected at multiple depths.

Table 47. Summary of nutrient samples collected at station C10SWANL02

Parameter	Units	No. of samples	Begin	End	Min	Max	Avg
Ammonia	mg/L as N	22	5/24/2007	8/1/2008	0.025	0.025	0.025
Chlorophyll-*a*	µg/L	16	5/24/2007	9/23/2008	2.5	12.0	5.3
Dissolved Oxygen	mg/L	47	5/24/2007	9/27/2007	6.88	10.39	8.70
Nitrate + Nitrite	mg/L as N	23	5/24/2007	9/23/2008	0.005	0.040	0.009
Total Nitrogen	mg/L as N	24	5/24/2007	9/23/2008	0.04	0.24	0.07
Total Phosphorus	mg/L as P	24	5/24/2007	9/23/2008	5E-4	0.0130	0.0062
Orthophosphorus	mg/L as P	24	5/24/2007	9/23/2008	5E-4	0.0020	0.0007

3.7.5.6 Impoundment Data

The Bigfork Dam (MT00220) was constructed in 1902. It is a concrete diversion dam that was constructed to raise the water surface of the Swan River such that water could be diverted to a hydroelectric power plant located approximately one mile downstream in the town of Bigfork, Montana. The diversion dam and power plant are currently owned and operated by PacifiCorp Energy. The dam has a height of 12 feet, a length of 300 feet, and a 235 foot spillway (PacifiCorp 2007; refer to Figure 19). The dam creates a 73 acre impoundment on the Swan River, and from this impoundment, PacifiCorp diverts an average of 494 cfs into a canal that leads to the hydroelectric plant. Water is then discharged back to the Swan River in the town of Bigfork. PacifiCorp has a water right to divert a maximum of 671.1 cfs from the Swan River. The Bigfork Dam is a 'run-of-the-river' facility; it cannot add or subtract to the

flow of the river, which means that water cannot be impounded to augment power production or for flood control (MB&G 2007b).

Figure 19. Bigfork Power House.

Flow data for the diversion canal were obtained from PacifiCorp; a summary of this data is presented in Figure 20. In 2003, Montana DEQ renewed PacifiCorp's Water Quality Certification for the Bigfork Dam. As part of the renewal, PacifiCorp is required to maintain a minimum flow of 70 cubic feet per second below the Bigfork Diversion Dam (DEQ 2003).

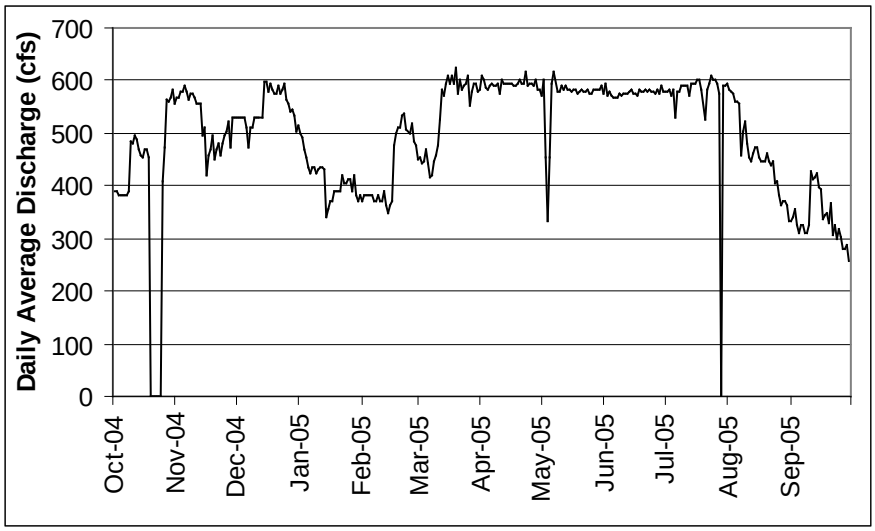

Figure 20. Average daily discharge in the power canal at Bigfork Dam.

4 Lake Modeling Methodology

Lakes will be modeled via one of several different methodologies that depend upon the size, hydrography, and available data for the lake. The anticipated modeling approach is based on the following assumptions:

- Smaller lakes will have shorter mean residence times that results in less impact upon nutrient transport
- Lakes disconnected from the stream network will have more impact upon groundwater than surface water nutrient loads
- Lakes that are distant from Flathead Lake will have less impact upon nutrient loads to Flathead Lake than lakes that are close to Flathead Lake

Summaries of the methodologies are presented in this section.

4.1 Lakes modeled as generic unit-volume lakes

Modeling the majority of lakes within the Basin as lake reaches is problematic because there are no available data on bathymetry, lake volume, or discharge rate. Additionally, many of the lakes can be characterized as follows:

- Lakes that are isolated and disconnected from the stream network
- Lakes that are connected to the stream network but are distant from the main reach within a subbasin
- Oxbow lakes, sloughs, and other small waterbodies along large rivers
- Waterbodies that do not appear on aerial imagery

One approach to addressing the data gaps may be to simulate all of these lakes as generic unit-volume lakes (one for each hydrometeorological area), assuming the watershed area to lake volume ratio and the land use mix for each lake in a generic set is fairly constant. The output of the unit-volume lake reaches would then be multiplied by the actual contributing area to add flow and nutrient loads to the watershed model.

4.2 Lakes modeled as lake reaches

The 32 lakes described in Section 3 will be modeled as lake reaches within their respective subbasins. In cases where multiple lakes exist in the modeling subbasin, the lakes will be aggregated together into a single modeling lake reach. Nitrogen- and phosphorus-loading will be simulated via first order decay rages (e.g., Vollenweider, Bachman). Decay rates are typically selected based upon residence times, which are not available for most of the lakes. Therefore, a generic set of assumptions that relate volume and consumptive use to lake surface area will be generated. For example, Figure 21 shows that the relationship between surface area and lake volume for 102 lakes in the Basin. With such a large population of lakes (i.e., more than 600), the errors should tend to average out if valid assumptions are generated. Another option would be to include residence time as a parameter to vary during calibration.

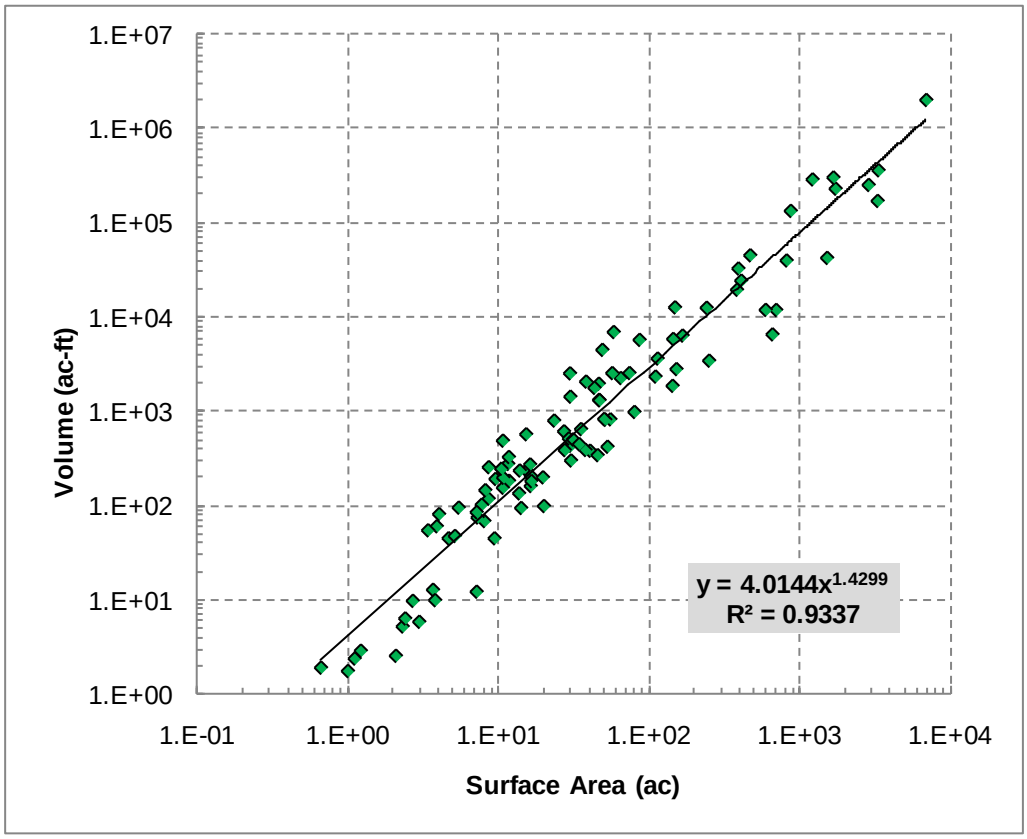

Figure 21. Relationship between surface area and volume for selected lakes within the Flathead Lake Basin.

4.3 Lakes modeled with lake models

Due to the limited amounts of data, it may be advisable to first model the very large lakes in the Basin (e.g., Hungry Horse Reservoir, Swan Lake, and Lower Stillwater) as lake reaches (as described in Section 4.2). A subsequent evaluation can then be used to determine if a true lake model (e.g., CE-QUAL-W2) would be worth the resources to attain the necessary level of detail.

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