US Army Corps of Engineers®
Portland District

BUREAU OF RECLAMATION

WATER QUALITY REPORT

HUNGRY HORSE RESERVOIR
COLUMBIA RIVER BASIN
SOUTH FORK FLATHEAD RIVER, MONTANA

Hungry Horse Reservoir

Water Quality Report
May 2020

EXECUTIVE SUMMARY

Hungry Horse Dam lies along the South Fork Flathead River in relatively pristine mountains near Columbia Falls, Montana, and has a total storage of approximately 3.1 Maf of water at full pool. Tributaries of Hungry Horse Reservoir originate in mountainous terrain from alpine lakes and springs that exhibit few anthropogenic effects on water quality. The water is released from the dam into the South Fork Flathead River, which flows for about 8 miles before joining the mainstem of the Flathead River near Columbia Falls, Montana. Partially as a result of little anthropogenic activity in the basin upstream of the reservoir, few studies have been conducted which focus on the waters in the reservoir or its influent. Because few and sporadic water samples have been collected, many of the water quality parameters collected in this report are presented as averages, maximums, and minimums over multiple years.

Although operations at Hungry Horse have changed over the previous two decades to lessen its downstream effects (Montana Fish, Wildlife & Parks [MFWP], Northwest Power and Conservation Council [NPCC], and Confederated Salish and Kootenai Tribes of the Flathead Reservation [CSKT] 2017), the area below the dam and upstream of the mainstem of the Flathead River remains an environmental concern. This section of the South Fork Flathead River is impaired in terms of high total dissolved gas (TDG), low sediment load, and often low temperature in the fall. Though dam flows are managed to reduce TDG passed downstream, releases as low as 3,000 cfs can push the TDG above 110 percent, and given this, the standard of 110 percent is frequently exceeded. Temperature downstream of the dam can be too cold in the fall due, in part, to the stratification that takes place within the reservoir. The selective withdrawal system used since 1995 has helped mitigate this issue to some extent (Heller et al. 2016). Stream temperature data was not collected at the Hydromet station in the South Fork Flathead River until 1998.

In addition to TDG and temperature impairments downstream of the dam, the South Fork Flathead River has suffered due to sediment alterations related to the regulation of flows. Before Hungry Horse Dam began regulating flows within the South Fork Flathead River, downstream beds and banks were flushed of fine sediments during periods of high springtime runoff in late May or early June. In addition to the dam restricting high flows to push fine sediments downstream, coarse sediments which assist in spawning and provided security cover for young fish and invertebrates are held behind the dam. Historically the high flows carrying sediment needed to flush fine sediments downstream have rarely occurred, and coarse sediments cannot pass through the dam; resulting in degraded fish and invertebrate habitat downstream within the South Fork of the Flathead River less beneficial (MFWP 2011).

Hungry Horse Reservoir is drawn down in late winter to create space in the reservoir to capture the spring snowmelt for flood mitigation. The drawdown operation also allows for minimum river flows between 3,200 and 3,500 cfs at Columbia Falls in the mainstem Flathead River to improve habitat conditions for fish. In 2001, flood risk management operations changed from using standard to variable flow flood risk management rule curves. The updated operational curves allow for less winter flood risk management

draft in average and wet water years, which results in higher springtime flows in the river, thus more closely mimicking natural conditions, and somewhat alleviating the fine sediment issues noted above (MFWP, NPCC, and CSKT 2017).

Because the waters flowing into the reservoir have little opportunity for contamination, the waters in the reservoir have only been sporadically sampled for chemical analysis, and the sediments have never been extensively sampled. This has produced minimal data which is available through Hydromet and STORET (U.S. Bureau of Reclamation 2017, 2018) and is displayed in the figures and tables throughout Chapter 2 of this appendix. While the sediments have not been analyzed in depth, sediment deposition has been observed at the upper end of the reservoir and has formed a delta where the South Fork Flathead River slows into slack water as it enters the reservoir.

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ACRONYMS

Acronym	Description
#/100 mL	Number per 100 Milliliters
µg/L	Micrograms per Liter
µS/cm	Microsiemens per Centimeter
CSKT	Confederated Salish and Kootenai Tribes of the Flathead Reservation
MFWP	Montana Fish, Wildlife & Parks
mg/L	Milligrams per Liter
mg/m^3	Milligrams per Cubic Meter
NPCC	Northwest Power and Conservation Council
NTU	Nephelometric Turbidity Unit
ORP	Oxidation Reduction Potential
Reclamation	U.S. Bureau of Reclamation
SC	Specific Conductivity
TDG	Total Dissolved Gas
TOC	Total Organic Carbon
TSS	Total Suspended Solids
USGS	U.S. Geological Survey
VarQ	Variable Flow

SECTION 1 - INTRODUCTION

1.1 STUDY AREA

The Hungry Horse Reservoir is located 15 miles south of the western Glacier National Park Entrance, and 20 miles northeast of Kalispell, Montana (Figure 1-1). Congress authorized Hungry Horse Dam on June 5, 1944 (Public Law 78-329) for irrigation and reclamation of arid lands, controlling floods, improving navigation, regulating the flow of the South Fork of the Flathead River, generation of electric energy, and for other beneficial uses such as fish and wildlife and recreation in the State of Montana and downstream areas. Hungry Horse Dam houses four turbines with nameplate capacity of 107 megawatts each and a maximum hydraulic capacity of 11,200 cfs for power generation, but transmission capacity limits use to three units and 9,000 cfs. The dam generates, on average, a little under one billion kilowatt-hours per year (Stene 1995).

Hungry Horse Dam stands 564 feet high. At full pool, the reservoir is slightly less than 30 miles in length, approximately 23,800 acres in area, and has a storage capacity of about 3.1 Maf. Very little water is drawn out of the reservoir for irrigation purposes; therefore, nearly all the water that flows into the reservoir continues past the dam (Stene 1995).

The scope of this evaluation includes the waters that drain into the reservoir, and the 5.1 miles of the South Fork Flathead River which lie below the dam. Water concerns below the confluence of the South Fork Flathead River and the Flathead River, where the South Fork contributes less than 10 percent of total river flows are not discussed in this report. Figure 1-2 and Figure 1-3 depict streamflows in the South Fork Flathead River and Flathead River, respectively. The drainage area of the reservoir is approximately 1,660 square miles (Figure 1-4); mean annual precipitation within the basin is approximately 49 inches; and the basin terrain is steep, with almost 35 percent of its area having slopes greater than 50 percent (U.S. Geological Survey [USGS] 2018a).

Figure 1-1. Location of Hungry Horse Reservoir in Northwestern Montana and Its Relation to Nearby Towns and Waterbodies

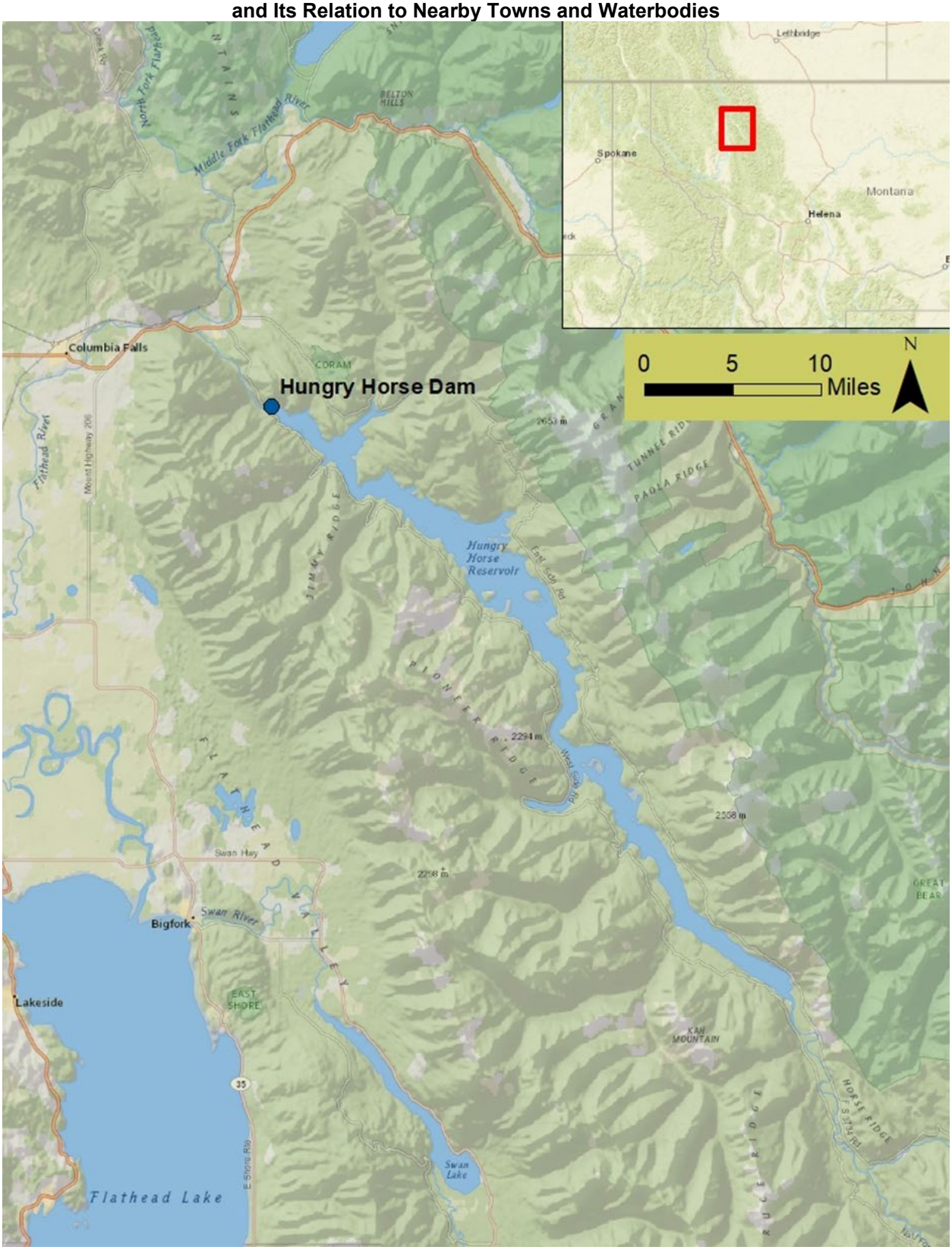
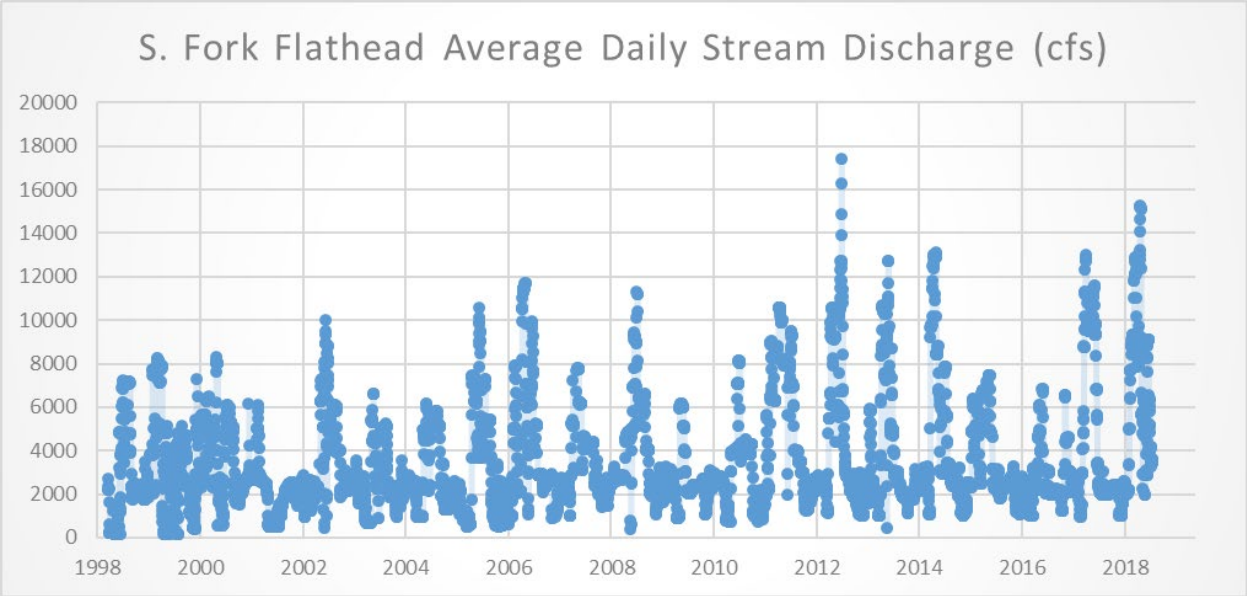
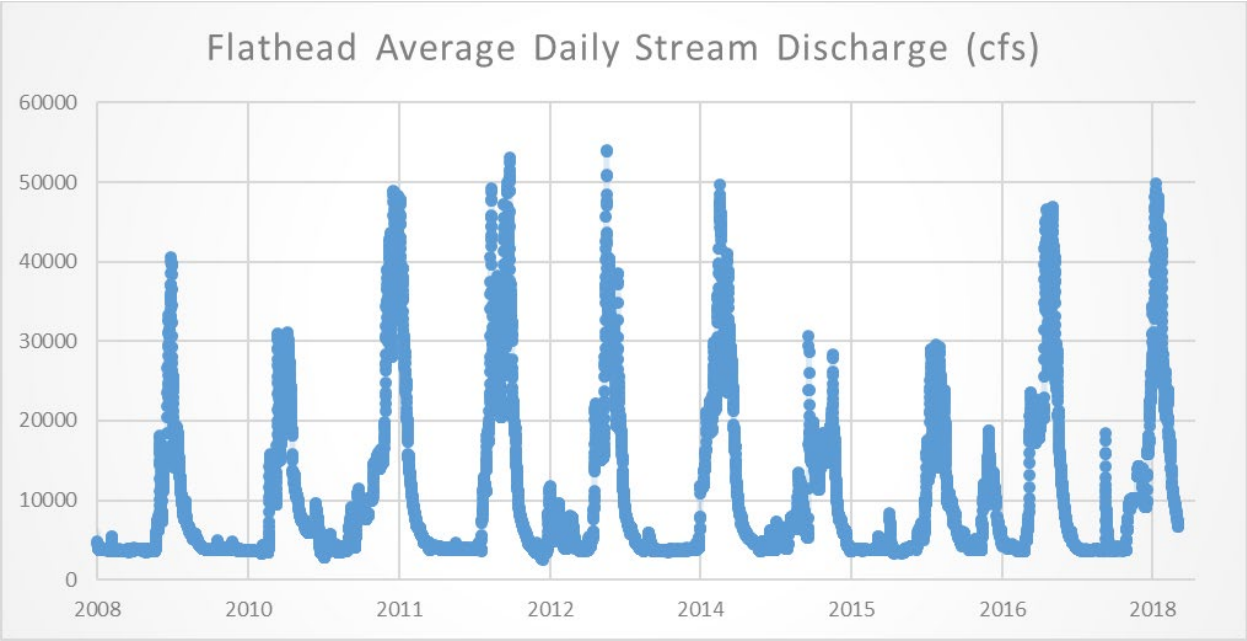


Figure 1-2. Average Daily Stream Discharge Within the South Fork Flathead River Downstream of Hungry Horse Dam



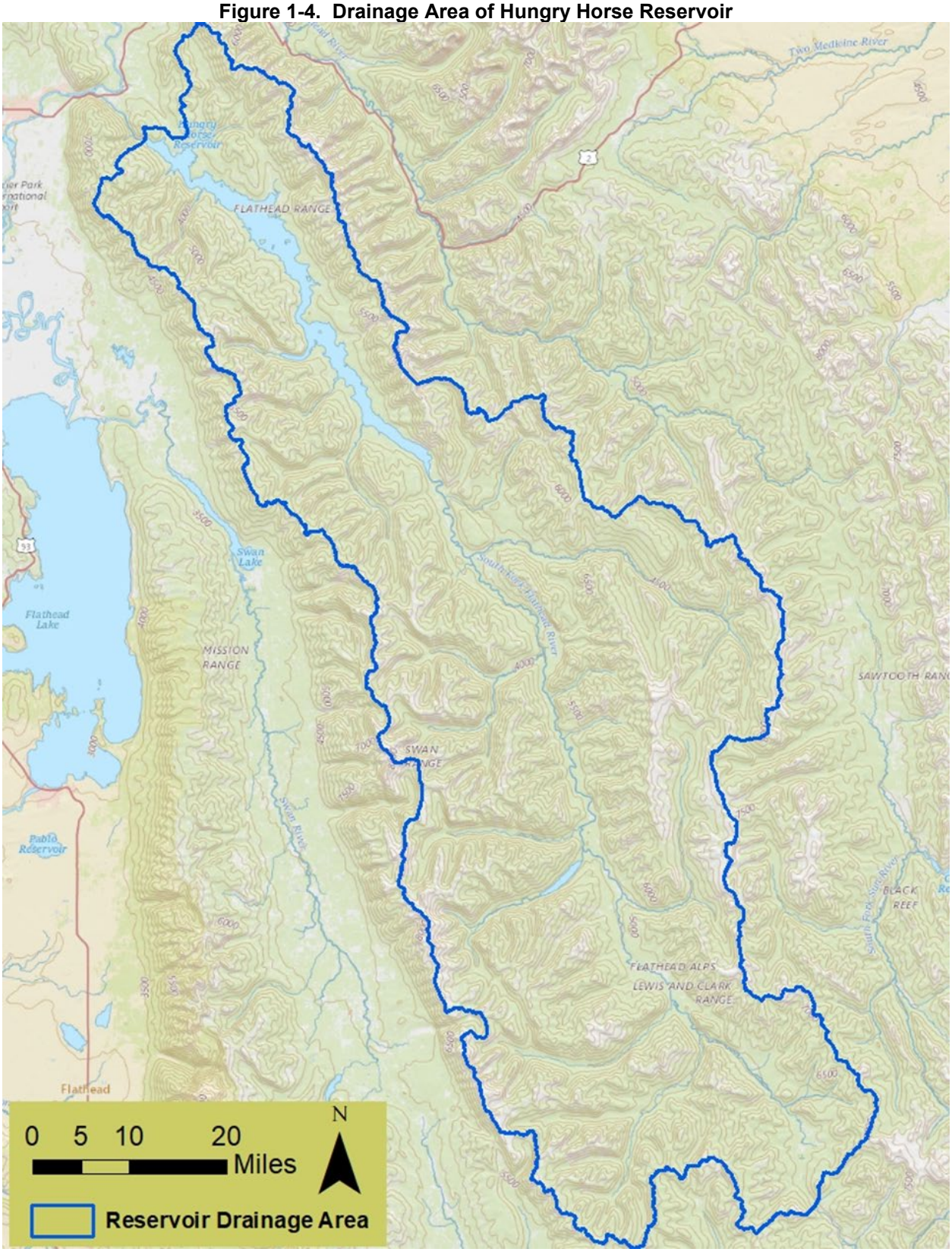
Source: U.S. Bureau of Reclamation (Reclamation, 2017)

Figure 1-3. Average Daily Stream Discharge Within the Flathead River near Columbia Falls, Montana



Source: USGS (2018b)

Figure 1-4. Drainage Area of Hungry Horse Reservoir



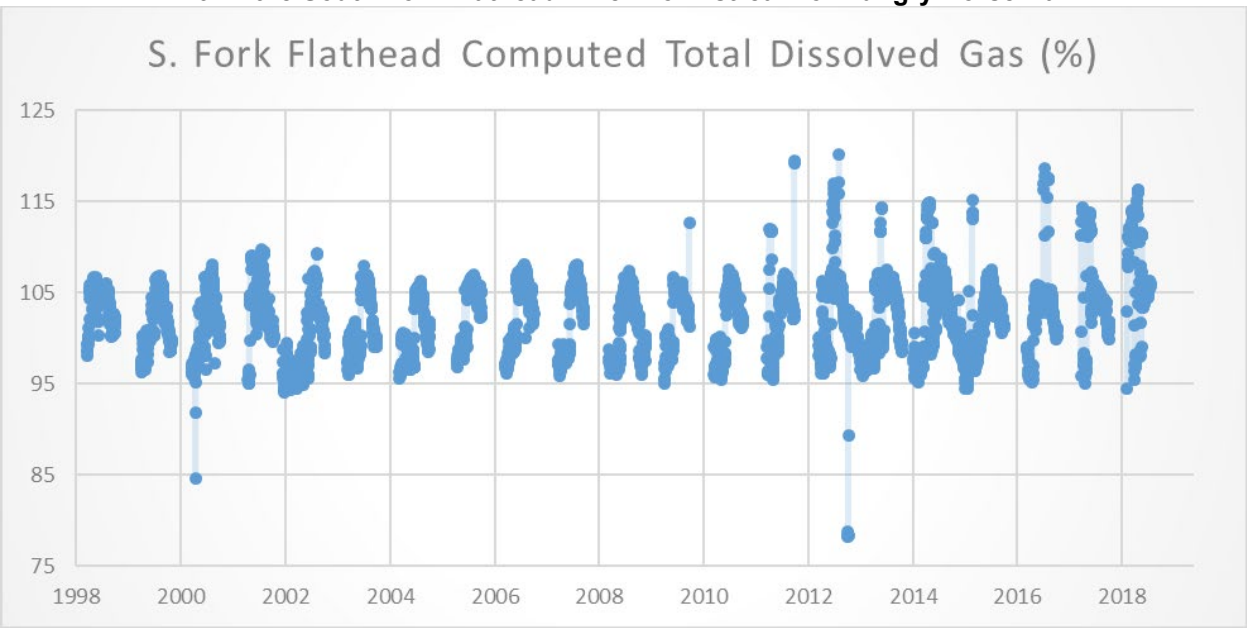
Source: USGS (2018a)

SECTION 2 - WATER QUALITY

2.1 GENERAL DESCRIPTION

Due to its remote and sparsely populated location, water quality in Hungry Horse Reservoir is relatively pristine. Because of this and the biological community that these waters support, Montana Department of Environmental Quality (DEQ) has designated Hungry Horse Reservoir and the South Fork Flathead River below it as Water Quality Class B-1 Waters. The primary environmental concern related to Hungry Horse Reservoir is the portion of the South Fork Flathead River below the dam which has historically been impacted by the timing of water release from the dam resulting in summer water temperatures that are often colder than ideal, higher than ideal total dissolved gas (TDG) concentrations, and lack of sediment transport. While the Variable Flow (VarQ) dynamic flood regulation strategy has been successful in returning this section of the river to semi-normal historical flow patterns, and selective water withdrawal control structures have helped return the river thermograph in the mainstream Flathead to a more typical pattern, environmental concerns still exist (Heller et al. 2016). Significantly reduced sediment load downstream of the dam has caused the substrate in this section of the South Fork Flathead River to be severely armored (Heller et al. 2016), TDG levels above 110 percent at some point in the summer is not uncommon (Figure 2-1), and a sudden drop in water temperature that is often reported in the fall can harm aquatic populations (Heller et al. 2016). Hungry Horse Dam management attempts to reduce TDG and elevate water temperature to improve downstream ecosystem health as much as possible.

Figure 2-1. Average Daily Computed Total Dissolved Gas Within the South Fork Flathead River Downstream of Hungry Horse Dam



Source: Reclamation (2017)

2.2 PHYSICAL CHARACTERISTICS

2.2.1 Hydrologic

One of the primary purposes for Hungry Horse Dam is flood protection. The dam provides flood protection for communities immediately downstream to cities as far away as Portland, Oregon, and has altered the natural hydrology of the river below the dam. Flood operations techniques have varied since the dam's construction; however, the techniques can be broken into two primary periods: pre-VarQ and post-VarQ.

VarQ operations guide the evacuation of space for flood risk management, this operation began in 2002. The required space within the reservoir is a function of the May to September runoff forecast. Refill is guided by VarQ rules as well as anticipated runoff in the lower Columbia River. In addition to VarQ operation guidelines, further guidelines direct instream flow requirements (Table 2-1), and ramping rates (Table 2-2) at Hungry Horse (Montana Fish, Wildlife & Parks [MFWP], Northwest Power and Conservation Council [NPCC], and Confederated Salish and Kootenai Tribes of the Flathead Reservation [CSKT] 2017).

VarQ operations have the effect of reducing wintertime drawdown of Hungry Horse Reservoir in average years for more storage of anticipated flood waters relative to pre-VarQ operations. It provides a better assurance of reservoir refill in average years and increases the likelihood that multiple water use objectives can be met, including maintaining stream ecosystem quality in fish spawning areas below the dam while maintaining flood protection and meeting energy goals. In practice, the new operation often results in increased flows in May and June, and reduced flows in April (Reclamation 2002). The VARQ operating strategy improves flow conditions for the conservation of listed fish species (2002).

Table 2-1. Instream Flows Requirements Released at Hungry Horse Dam and 10 miles Downstream at Columbia Falls Given an Anticipated Inflow into the Reservoir

Hungry Horse Apr–Aug inflow forecast (KAF)	Hungry Horse min flow (CFS)	Columbia Falls min flow (CFS)
< 1190	400	3200
1190 - 1790	Interpolate between 400-900	Interpolate between 3200-3500
> 1790	900	3500

Note: KAF = thousand acre-feet. The flows are based on water availability and attempts to balance the needs of the reservoir fishery with flow requirements.
Source: MFWP, NPCC, and CSKT (2017).

Table 2-2. The Ramping Rates for Increasing and Decreasing Outflows from the Dam

Flow Range (measured at Columbia Falls)	Unit Limit (daily max)	Unit Limit (hourly max)
Ramp Up Rates		
3200 - 6000 cfs	1800 cfs/day	1000 cfs/hour
>6000 - 8000 cfs	1800 cfs/day	1000 cfs/hour
>8000 - 10000 cfs	3600 cfs/day	1800 cfs/hour
>10000 cfs	No limit	1800 cfs/hour
Ramp Down Rates		
3200 - 6000 cfs	600 cfs/day	600 cfs/hour
>6000 - 8000 cfs	1000 cfs/day	600 cfs/hour
>8000 - 12000 cfs	2000 cfs/day	1000 cfs/hour
>12000 cfs	5000 cfs/day	1800 cfs/hour

Note: The daily and hourly maximum ramping rates are adjusted based on flows at Columbia Falls and attempts to prevent fish stranding.
Source: MFWP, NPCC, and CSKT (2017)

Dam releases from Hungry Horse are recorded in the South Fork Flathead River just downstream of the dam, and are displayed in Figure 2-2, and the corresponding water surface elevations within the reservoir are displayed in Figure 2-3 (Reclamation 2017).

Figure 2-2. Average Daily Stream Discharge Within the South Fork Flathead River Downstream of Hungry Horse Dam

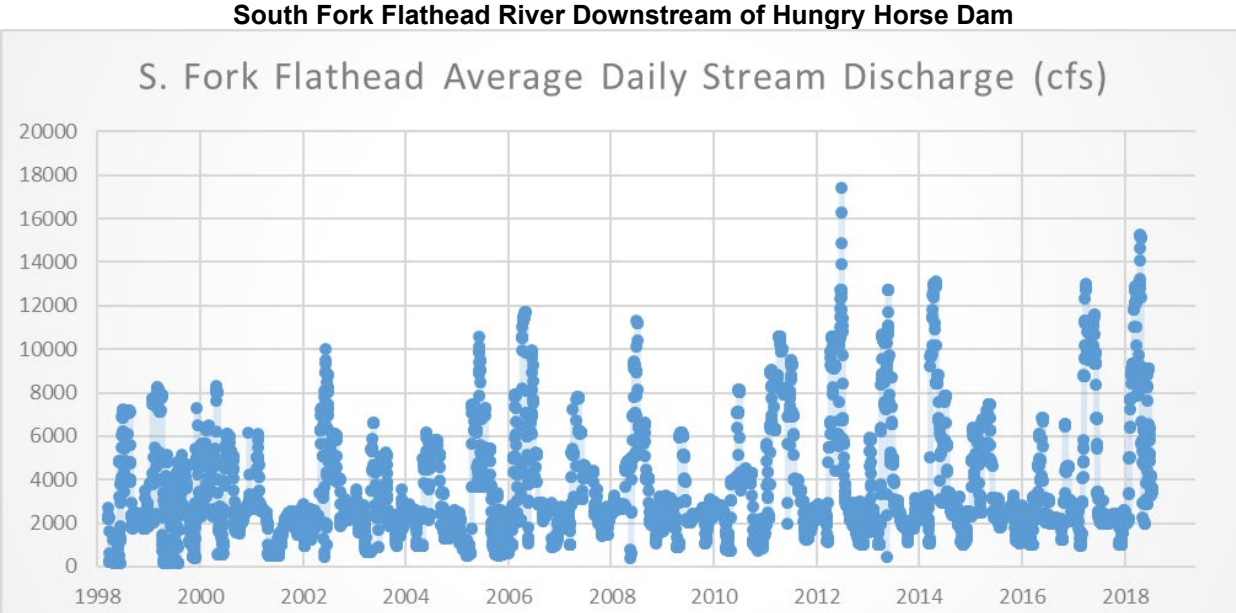
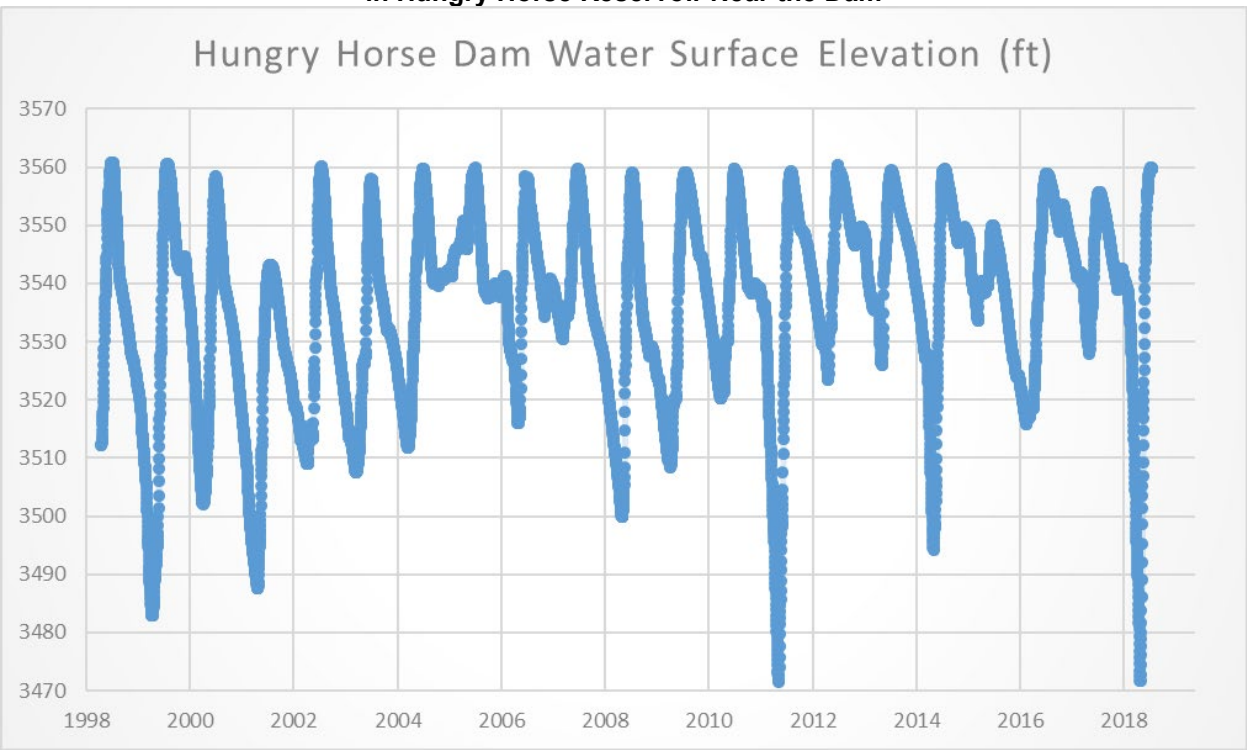


Figure 2-3. Water Surface Elevation (feet above mean sea level NAVD88) in Hungry Horse Reservoir Near the Dam

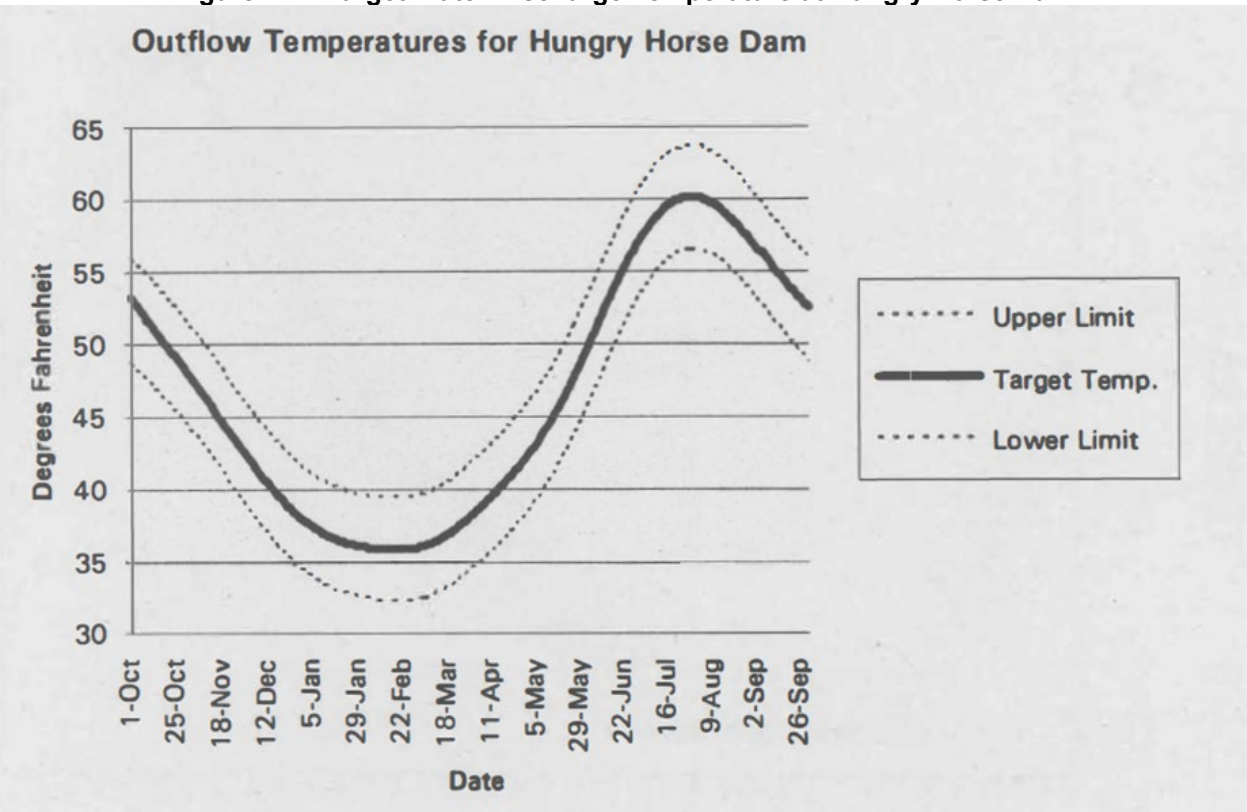


Source: Reclamation (2017)

2.2.2 Temperature

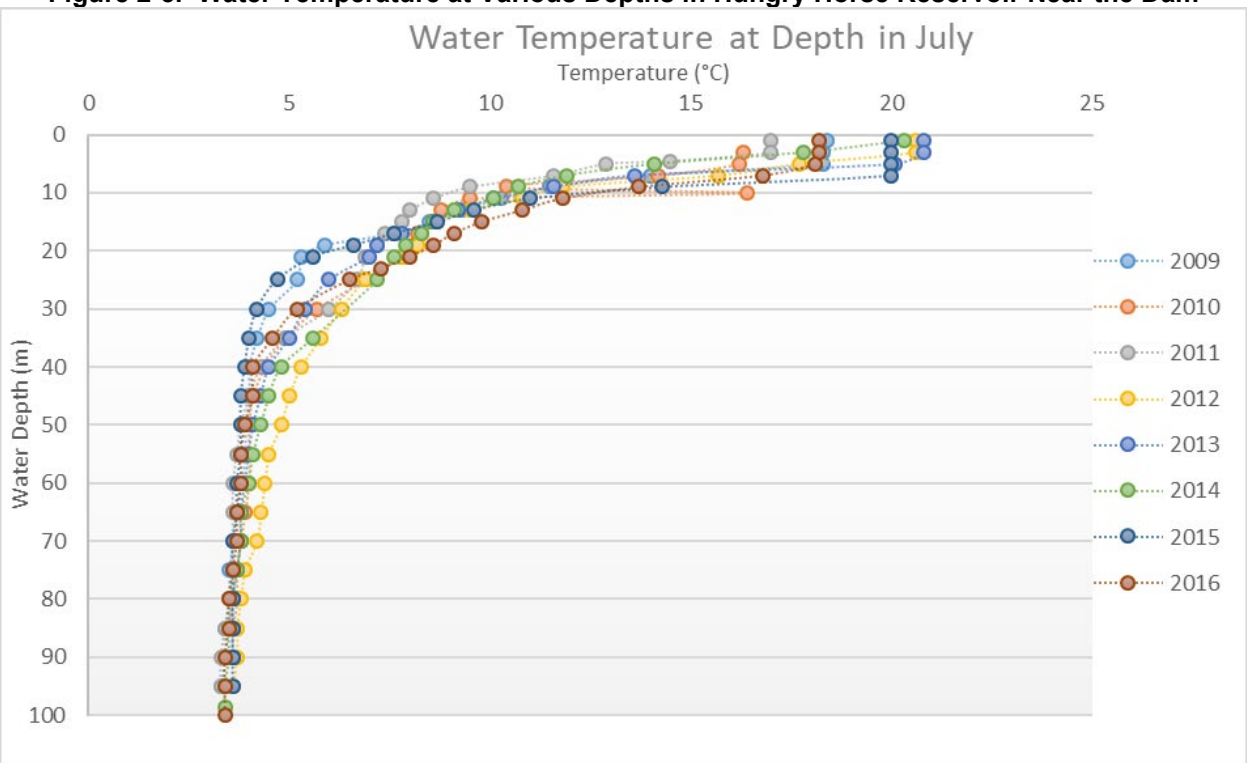
In 1995, a selective withdrawal structure was placed in Hungry Horse Dam to improve temperatures in the South Fork below the dam (Reclamation 2006). Prior to installation, water was released from deep in the reservoir and water temperatures in the river below the dam were colder than ideal (Vermeyen 2006). The selective withdrawal device has since allowed dam operators to better approximate the natural temperature regime in the river below the dam (Reclamation 2006; MFWP 2011). Target water discharge temperatures at the outlet are displayed in Figure 2-4 (Marotz et al. 1996). Water temperatures recorded at various depths in Hungry Horse Reservoir in July near the outlet are displayed in Figure 2-5, and water temperatures downstream of the dam are displayed in Figure 2-6 (Reclamation 2017). Studies indicate an increase in overall water temperatures in the river below the dam, but a sudden drop that often occurs in the fall has the potential to damage aquatic communities (Heller et al. 2016). This increase in water temperature has increased habitat quality for threatened bull trout (*Salvelinus confluentus*) and west-slope cutthroat trout (*Oncorhynchus clarki lewisi*) populations in the river below the dam (Vermeyen 2006). However, data on the effects on fish communities has not been sufficiently documented to quantify the beneficial impact from the selective withdrawal system.

Figure 2-4. Target Water Discharge Temperature at Hungry Horse Dam



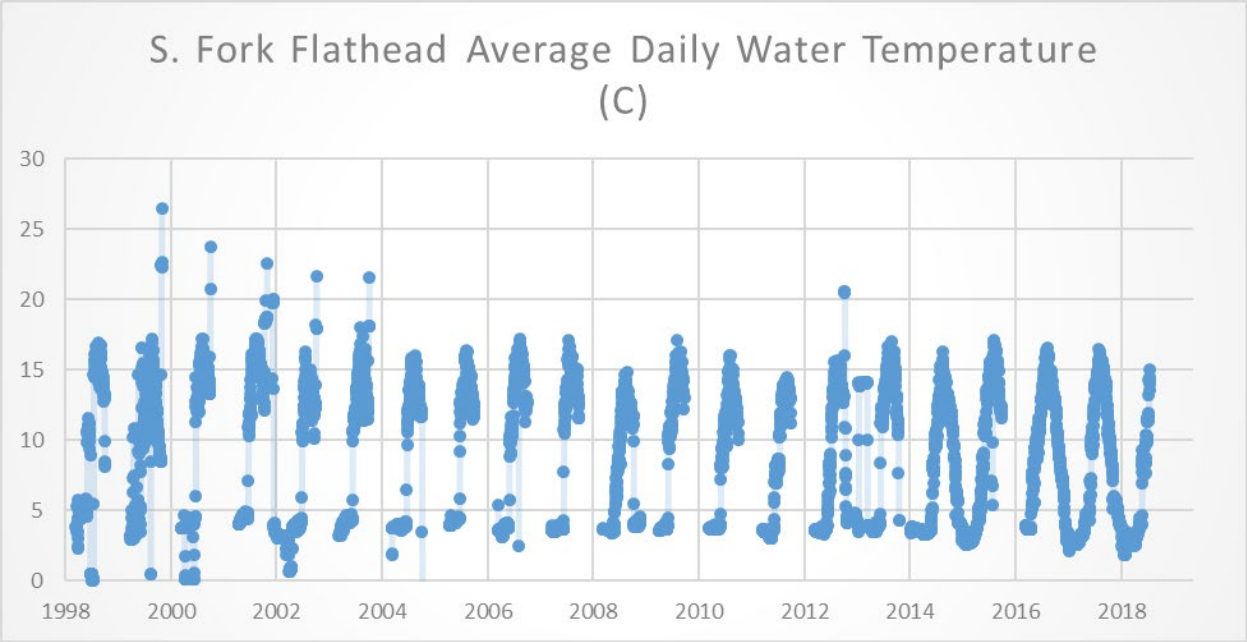
Source: Marotz et al. (1996)

Figure 2-5. Water Temperature at Various Depths in Hungry Horse Reservoir Near the Dam



Note: All readings for each year were collected on a single day in early July.

Figure 2-6. Average Daily Temperature Within the South Fork Flathead River Downstream of Hungry Horse Dam



Source: Reclamation (2017)

Initially, it was hypothesized that selective withdrawal of reservoir water at different elevations would destabilize the temperature stratification near the dam forebay; however, research conducted from 2000 to 2003 revealed that the epilimnion (the upper layer of a stratified lake) thickened near the dam and overall stratification was not affected (Vermeyen 2006). Temperature profiles in Hungry Horse Reservoir in July from 2009 to 2016 are displayed in Figure 2-5. This figure illustrates the strong stratification that occurs within the reservoir, with water towards the surface (less than 30 meters deep) exhibiting warmer temperatures and the deeper parts of the reservoir (greater than 30 meters deep) exhibiting fairly constant cold water temperatures around 4 to 5 degrees Celsius.

2.2.3 Oxidation Reduction Potential

Oxidation reduction potential (ORP) indicates the influence of a fluid on changing the electro-potential state of metal ions or their associated compounds. ORP is important because the reduction and oxidation conditions present in the reservoir can mobilize compounds, such as metals, which would otherwise remain immobile. However, it is unknown what compounds are associated with the sediments at the bottom of the reservoir, or if any are present at all. ORP readings collected at Hungry Horse Reservoir forebay from 2009 to 2016 are displayed in Table 2-3 (Reclamation 2017). In general, the reducing conditions are not significant and would not be anticipated to mobilize any contaminants which may be present.

Table 2-3. Compilation of all Surface Water (upper 6.5 feet) Oxidation Reduction Potential Readings at Hungry Horse Reservoir from 2009 to 2016

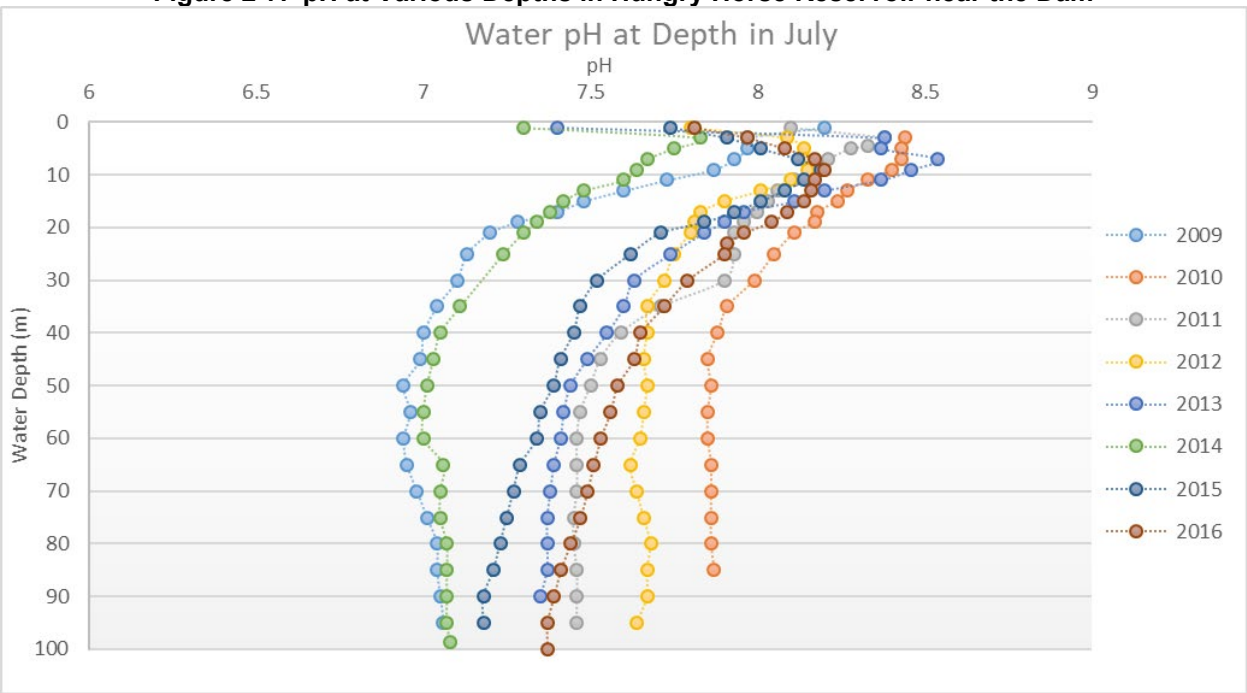
Analyte	Average	Maximum	Minimum	First Sample	Last Sample
ORP (mV)	210.48	294	51	6/22/2009	8/3/2016

Source: Reclamation (2018)

2.2.4 pH

Data collected in the Hungry Horse Reservoir forebay from 2004 to 2016 indicate that pH values show the water to be circumneutral to slightly alkaline (Figure 2-6). Surface water pH was found to be slightly more alkaline than that of the lower water column (Reclamation 2017). The ranges found in Hungry Horse Reservoir (pH 6.9 to 8.57) are within standards which are anticipated to be naturally present within the waterbody. This range of pH is similar (but a little lower) to the natural pH range found in the North Fork of the Flathead River near Columbia Falls which, in one study, was found to have a range of pH 7.9 to 8.57 in 2007 to 2008 (Mills et al. 2011). This agrees well with the data from STORET displayed in Figure 2-7. The Montana DEQ Class-1B designation requires that “induced variation of pH within the range of 6.5 to 8.5 must be less than 0.5 pH unit. Natural pH outside this range must be maintained without change. Natural pH above 7.0 must be maintained above 7.0”.

Figure 2-7. pH at Various Depths in Hungry Horse Reservoir near the Dam



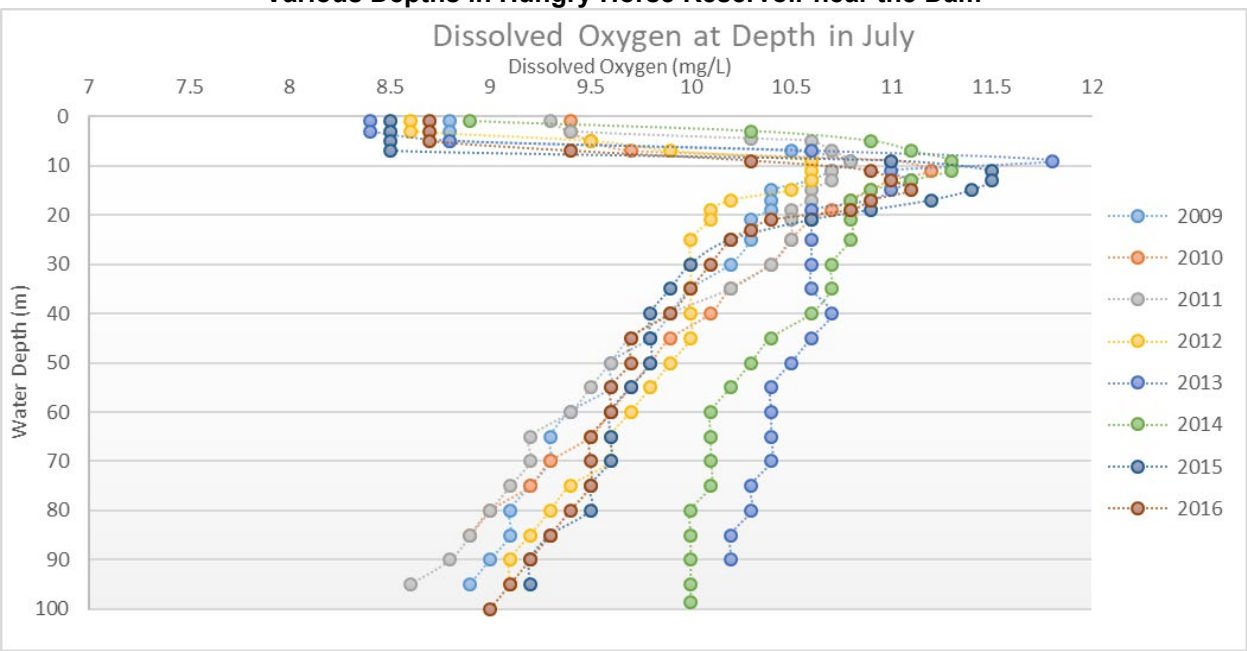
Note: All readings for each year were collected on a single day in early July.
Source: Reclamation (2018)

2.2.5 Dissolved Gas

Dissolved oxygen in the reservoir is generally not an issue but can be a concern if it drops too low. In general, when dissolved oxygen levels drop below 5 milligrams per

liter (mg/L) aquatic life can be stressed and can kill large fish if it remains below 1 mg/L for a few hours. While Figure 2-8 shows that dissolved oxygen concentrations are low, they do not reach dangerous levels even at the reservoir bed during July. That said, dissolved oxygen concentrations in August and September (when dissolved oxygen levels tend to be lower in many waterbodies in the Columbia River Basin) has not been measured and is unknown.

Figure 2-8. Dissolved Oxygen Measurements at Various Depths in Hungry Horse Reservoir near the Dam



Note: All readings for each year were collected on a single day in early July.
Source: Reclamation (2018)

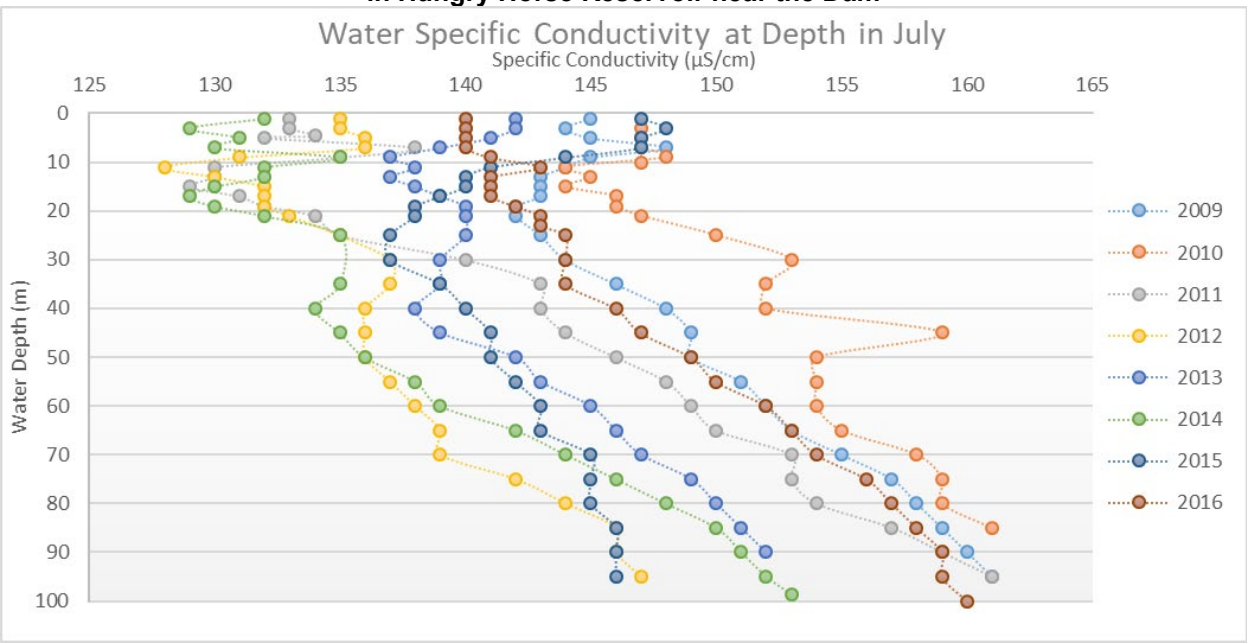
Total dissolved gas (TDG) concerns have developed downstream of the dam in the 5.1-mile portion of the South Fork Flathead River before it joins the Flathead River. TDG below the dam has also been identified as a water quality concern (Vermeyen 2006) due to the water routed through the dam which follows one (or a combination) of three paths: (1) turbines inside the dam to generate electricity, (2) outlet works (hollow-jet valves), or (3) the glory hole emergency spillway (operations limited to the top twelve feet of the normal operating range). Discharge from the hollow-jet valves is of particular concern. Water passes through these valves at high pressure and velocity causing air (primarily oxygen and nitrogen) to saturate the water at levels higher than generally seen in unregulated river systems. This results in supersaturated gases in the water that can have deleterious effects on fish, causing a disease known as bubble trauma disease. Based on the level of saturation and the length of exposure, this disease can be acute or chronic and may result in mortality of fish in the system (Monk, Absolon, and Dawley 1997). In the summer TDG often exceeds the state standard of 110 percent below the dam (see Figure 2-1). However, management of Hungry Horse Dam attempts to adjust releases to lower TDG when the standard is exceeded.

2.2.6 Specific Conductivity

Specific conductivity (SC) is a measure of a water's ability to pass electrical flow and is a physical characteristic that is non-specific to any contaminant; it is primarily used to indicate a change over time. Change in SC may indicate the introduction of a wide range of pollutants into a waterbody.

Typically, a fresh waterbody would be expected to have a range between 100 to 500 microsiemens per centimeter (µS/cm) (McKee and Wolf 1963). Hungry Horse Reservoir typically falls within this range. In 1987, a study of Hungry Horse Reservoir found the SC of the reservoir ranged from 110 to 160 µS/cm (May et al. 1988). Comparing the 1987 study to the most recent data suggests that little change in the overall character of soluble minerals has occurred over the past three decades. SC data collected at the surface of Hungry Horse Reservoir forebay is displayed in Figure 2-9 (Reclamation 2017). Vertical water column SC data collected at Hungry Horse Reservoir near the dam is displayed in Figure 2-9 and agrees with the previous studies of SC referenced above (Reclamation 2017).

Figure 2-9. Water Specific Conductivity at Various Depths in Hungry Horse Reservoir near the Dam



Note: All readings for each year were collected on a single day in early July.
Source: Reclamation (2018)

2.3 CHEMICAL CHARACTERISTICS

2.3.1 Major Ions, Alkalinity, and Hardness

Chemical constituents in the reservoir are found at a relatively low concentrations compared to those further down in the Columbia River watershed (Reclamation 2017). The water hardness in the reservoir is generally classified as soft to moderately hard, particularly when bicarbonate, pH, and temperature are used to determine hardness.

Alkalinity, metal ion concentrations, and water hardness (i.e., bicarbonate) collected from the surface of Hungry Horse Reservoir forebay are displayed in Table 2-4 (Reclamation 2017). Overall, there is no indication of elevated metal concentrations within the waters of the reservoir as there no known sources of contamination in Hungry Horse Reservoir except for atmospheric deposition.

Table 2-4. Compilation of Surface Water (upper 6.5 feet) Ion Concentration Readings at Hungry Horse Reservoir from 2004 to 2016

Analyte	Average	Maximum	Minimum	First Sample	Last Sample
Alkalinity, total (mg/L)	69.53	76.3	52	9/2/2004	8/3/2016
Bicarbonate (mg/L)	84.73	93	63	9/2/2004	8/3/2016
Calcium (mg/L)	18.47	21.2	10	9/2/2004	8/3/2016
Chloride (mg/L)	0.56	0.9	0.4	9/2/2004	8/3/2016
Iron (µg/L)	20.23	30	10	9/2/2004	8/3/2016
Lead (µg/L)	4.40	6.49	2.85	6/7/2016	8/3/2016
Magnesium (mg/L)	5.33	8	4.7	9/2/2004	8/3/2016
Manganese (ug/L)	14.00	14	14	7/18/2013	7/19/2013
Potassium (mg/L)	0.30	0.30	0.30	7/16/2009	8/3/2016
Silica (mg/L)	3.64	4.20	3.20	7/16/2009	8/3/2016
Sodium (mg/L)	0.61	1.00	0.50	9/2/2004	8/3/2016
Sulfate (mg/L)	2.63	10	1.40	9/2/2004	8/3/2016
Zinc (µg/L)	12.15	12.15	12.15	7/18/2013	7/18/2013

Note: µg/L = micrograms per liter.
Source: Reclamation (2018)

2.3.2 Turbidity

Turbidity is a measurement of water transparency. Water transparency is affected by both organic and inorganic particles suspended in the water column and is measured in studies used here in Nephelometric Turbidity Units (NTUs). As previously mentioned, Montana DEQ has designated Hungry Horse Reservoir and the South Fork Flathead below the dam as B-1 Waters. This designation requires that turbidity not exceed background levels by more than 5 NTUs. Data collected from 2009 to 2011 in the reservoir forebay indicates that the maximum value was 2.85 NTUs as shown in Table 2-5 (Reclamation 2017). Assuming a background value of 0, turbidity in the reservoir falls within the acceptable state standard.

Table 2-5. Compilation of all Surface Water (upper 6.5 feet) Turbidity Readings at Hungry Horse Reservoir from 2009 to 2011

Analyte	Average	Maximum	Minimum	First Sample	Last Sample
Turbidity (NTU)	1.54	2.85	0.83	6/22/2009	7/21/2011

Source: Reclamation (2018)

2.3.3 Total Suspended Solids

Total suspended solids (TSS) is a measurement of the dry weight of particles in a water sample. It is used to determine the silt, plankton, wastes, and any other matter suspended in the water. Elevated TSS levels may increase turbidity, thus reducing water clarity and limiting light penetration. This condition may lead to adverse effects on primary productivity within a large waterbody. The low turbidity rates typically found in the reservoir, as previously stated, indicate that little suspended solids are found within the water column. Samples collected in the reservoir forebay from 2007 to 2016 (presented below in Table 2-6) show low TSS in the reservoir (Reclamation 2017).

Table 2-6. Compilation of all Surface Water (upper 6.5 feet) Total Suspended Solid Readings at Hungry Horse Reservoir from 2007 to 2016

Analyte	Average	Maximum	Minimum	First Sample	Last Sample
Total Suspended Solids (mg/L)	4.4	39	1	5/24/2007	6/7/2016

Source: Reclamation (2018)

2.3.4 Nitrogen and Phosphorous

Nitrogen and phosphate are found at low levels in the reservoir but are generally high enough for aquatic life. This observation, coupled with the low primary productivity and high-water clarity, results in a trophic classification of oligotrophic. This classification is common for many mountain lakes in the region.

The primary forms of inorganic nitrogen in the waters of Hungry Horse Reservoir are nitrite and nitrate. Kjeldahl nitrogen, also referred to as organic nitrogen or nutrient nitrogen, is a measure of the bioavailable nitrogen in a system which may be used in primary productivity. The primary source of nitrogen is from suspended organic material that accompanies tributary flows into the waterbody. Data collected from 2004 to 2016, shown in Table 2-7, displays nitrogen and phosphorous concentrations in the reservoir (Reclamation 2017). Sources of inorganic nitrogen above the reservoir may include forest fires, rainwater, and mining activities that use blasting powder.

Table 2-7. Compilation of all Surface Water (upper 6.5 feet) Nitrogen and Orthophosphate Readings at Hungry Horse Reservoir from 2004 to 2016

Analyte	Average	Maximum	Minimum	First Sample	Last Sample
Inorganic Nitrogen (mg/L)	0.03	0.06	0.01	9/2/2004	8/3/2016
Kjeldahl Nitrogen (mg/L)	0.16	1	0.04	9/2/2004	8/3/2016
Orthophosphate (mg/L)	0.002	0.004	0.001	5/24/2007	6/23/2009

Source: Reclamation (2018)

Like nitrogen, phosphorous is an essential, and often limiting, nutrient for life. Orthophosphate (also referred to as simply phosphate, soluble reactive phosphorus, or reactive phosphorous) is the bioavailable form of phosphorus. Elevated concentrations of phosphorous and nitrogen, in the proper ratios, can result in large algal blooms in reservoirs. As the algae begins to die and decompose, the decomposition process strips oxygen from the water column causing stress and potentially mortality to fish and other

species. Nitrogen to phosphorous ratios can also be an indicator of phytoplankton growth.

Organic nitrogen, inorganic nitrogen, and orthophosphate (dissolved phosphorous) concentrations collected at the reservoir forebay are displayed in Table 2-7 (Reclamation 2017).

2.3.5 Organic Carbon

High total organic carbon (TOC) content can be an indicator of excessive growth of microorganisms primarily through the decomposition of dead organic matter. However, soils and peat can leach organic carbon into water as well. The decomposition from microbial growth or plant matter, as previously stated, may contribute to the depletion of oxygen and the potential for aquatic impairment. Like other nutrients found in Hungry Horse Reservoir, the concentration of organic carbon found in the waterbody is relatively low. Table 2-8 presents a summary of measured summarizes TOC concentration in the reservoir forebay.

Table 2-8. Compilation of all Surface Water (upper 6.5 feet) Organic Carbon Measurements at Hungry Horse Reservoir from 2007 to 2016

Analyte	Average	Maximum	Minimum	First Sample	Last Sample
Organic Carbon (mg/L)	1.67	2.8	0.9	5/24/2007	8/3/2016

Source: Reclamation (2018)

2.3.6 Pesticides

As there is no agricultural activity occurring in the watershed above Hungry Horse Reservoir, no pesticide studies exist in available literature.

2.4 BIOLOGICAL CHARACTERISTICS

In general, biological activity in Hungry Horse Reservoir is low, but is adequate to maintain fish. As a result of the low nutrient input and the resulting low primary productivity in the waterbody, the euphotic zone tends to be deeper than other comparable lakes in the area, such as Lake Koocanusa (May et al. 1988).

2.4.1 Chlorophyll a

Chlorophyll a is a molecule used in oxygenic photosynthesis in eukaryotes, cyanobacteria, and prochlorophytes. Because it is a measure of algal growth, it is one method to determine primary productivity in a waterbody. As nutrients in the reservoir are low, but sustainable for life, the low concentration of chlorophyll a found in the surface water is anticipated. Chlorophyll a measurements recorded in the surface waters at Hungry Horse Reservoir are displayed in Table 2-9 as a compilation of all values recorded from 2004 to 2009 in the upper 6.5 feet of the reservoir (Reclamation 2017).

Table 2-9. Compilation of all Surface Water (upper 6.5 feet) Chlorophyll a Measurements at Hungry Horse Reservoir from 2004 to 2009

Analyte	Average	Maximum	Minimum	First Sample	Last Sample
Chlorophyll a (mg/m^3)	3.04	15.9	1.1	9/2/2004	7/16/2009

Note: mg/m^3 = milligrams per cubic meter.
Source: Reclamation (2018)

2.4.2 Coliforms

Partially due to the lack of upstream activity at this reservoir, fecal coliforms are low. Fecal coliform measurements recorded in the surface waters at Hungry Horse Reservoir are displayed in Table 2-10 as a compilation of all values recorded from 2009 to 2016 in the upper 6.5 feet of the reservoir (Reclamation 2017).

Table 2-10. Compilation of all Surface Water (upper 6.5 feet) Fecal Coliform Measurements at Hungry Horse Reservoir from 2009 to 2016

Analyte	Average	Maximum	Minimum	First Sample	Last Sample
Fecal Coliform (#/100 mL)	2	2.8	1.4	7/16/2009	8/3/2016

Note: #/100 mL = number per 100 milliliters.
Source: Reclamation (2018)

SECTION 3 - REFERENCES

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