APPENDIX F TO SULLIVAN CREEK SETTLEMENT AGREEMENT

COLD WATER RELASE FACILITY PLAN

SULLIVAN CREEK PROJECT
FERC NO. 2225

Cold Water Release Facility Plan

Prepared for
PUD No. 1 of Pend Oreille County
Newport, WA

Prepared By

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February 2010

SULLIVAN CREEK PROJECT
Cold Water Release Facility Plan

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1.0 Introduction

Public Utility District No.1 of Pend Oreille County (PUD) has operated the non-generating Sullivan Creek Project under FERC license No.2225 since 1958, for the benefit of downstream generation projects. The project does not include facilities for the generation of power and has never generated power during the 50-year term of its license. Prior to the expiration of the original license in September 2008, PUD notified FERC of its intent not to relicense the project. PUD continues to operate the project as before, under an annual license, while plans are made for the disposition of project facilities. The Project includes two dams, and other facilities; some occupy PUD-owned lands and some are on lands administered by the Colville National Forest.

Sullivan Dam raised the level of the pre-existing, natural Sullivan Lake, creating a lake of approximately 1260 acres at full pond elevation of 2588.66 ft MSL. Sullivan Dam controls the Lake level and the amount of water discharged into Outlet Creek. Outlet Creek is a small creek extending one half mile downstream from Sullivan Dam, to a confluence with Sullivan Creek. Outlet Creek has a USGS flow gauging station about 0.4 miles downstream of Sullivan Dam. The drainage area upstream of the gauge is about 50 sq. mi.

Upper Sullivan Creek is an unregulated creek with a drainage area of about 70 sq. mi. at its confluence with Outlet Creek. After its confluence with Outlet Creek, Sullivan Creek nearly doubles in size, and flows about one mile to Mill Pond. Mill Pond Dam impounds Sullivan Creek to create a lake of approximately 80 acres. Sullivan Creek flows over the uncontrolled spillway of Mill Pond Dam and continues about four miles to its confluence with the Pend Oreille River.

PUD and several other Parties[1], have negotiated requirements for decommissioning the Mill Pond Dam, and a new operating plan for Sullivan Dam, which will remain in place, and will be subject to a special use authorization for continued occupation of USFS lands. The Parties were interested in the water temperatures in Sullivan Lake, Sullivan Creek and Outlet Creek during the year, and in the effect on downstream water temperatures of draining Sullivan Lake, which occurs annually in the fall. To assist in analyzing these effects, WDFW deployed a series of temperature recorders throughout the system from July 1, 2009 through November 15, 2009. This data provided simultaneous temperature readings from a variety of locations in the creek and lake system.

PUD retained EES Consulting, Inc. (EESC) to analyze the temperature data and to create a computer model that could predict mixed water temperatures downstream of the confluence of Outlet and Sullivan Creeks, for a variety of discharge rates at the dam. After this model was constructed and reviewed, the Parties suggested that a concept be developed for release of colder water from deeper in the lake than currently is possible at the low level dam outlets. It was

[1] USDA Forest Service (USFS, the US Fish and Wildlife Service (USFWS) the Washington Department of Fish and Wildlife (WDFW), the Washington Department of Ecology (Ecology), Seattle City Light (SCL), American Whitewater, the US Department of Interior/BIA, the Kalispel Tribe and members of the public.

suggested that such a facility could consist of a pipe system extending deep into the lake. The Parties assumed that releasing colder water in this way would have beneficial effects on water temperatures in Outlet and Sullivan Creeks, and possibly as far downstream as the Pend Oreille River. PUD was asked to model the effects of such a facility, and once the temperature effects of the release of cold water were reviewed by the Parties and understood, PUD was asked to develop a design concept for a facility.

This plan describes the steps summarized above that were taken to develop the concept for a cold water release facility. They included: analyzing the WDFW water temperature data and modeling the effects of discharge flows on downstream temperatures, both with and without release of cold water; gathering information on fish entrainment at the dam, gathering preliminary lake productivity data, and developing a preliminary design for a cold water release pipe facility that would meet discharge requirements and agency biological criteria.

2.0 Modeling Effects of Discharge Flows on Downstream Temperatures

Water temperature data was obtained from the USGS and WDFW for the period July 1 through November 15, 2009. WDFW installed 12 water temperature recording devices in several locations in Outlet Creek, Sullivan Creek above the confluence with Outlet Creek, Sullivan Creek below Outlet, Mill Pond, and downstream of Mill Pond; and collected simultaneous water temperature data in Sullivan lake. The station in Sullivan Lake had sensors deployed at various depths, from 20 m deep to the surface, in 2 m increments. The data consisted of 24 daily readings, taken once per hour, for the period the recorders were deployed. EESC converted the data to daily average readings for the period of record.

PUD retained EES Consulting to analyze the data and to develop a computer model to predict mixed water temperatures in Sullivan Creek downstream of its confluence with Outlet Creek. See a detailed explanation in the report of Sullivan Creek Mixed Water Temperature Modeling in Attachment 1 to this plan. The results of the modeling indicated that using cold water releases from approximately 20 m of depth would improve the downstream temperature regime measurably, cooling the summer and fall water temperatures in Outlet and Sullivan Creeks such that it would be possible to meet and even exceed state water quality standards for temperature. Temperatures of water being released at Sullivan Dam into Outlet Creek were found to be similar to those at approximately 5 m to 6 m of depth in the lake.

An engineering concept was then developed for a 48-inch-diameter pipe that would be fitted with fish exclusion screens at the intake end, and then lowered to the lake bottom. The pipe would be routed down the lake outlet channel to Sullivan dam and then through one of the three existing low-level outlet gates at Sullivan Dam. The detailed preliminary design report is included in Attachment 2. This cold water release facility would allow discharge flows to be managed to meet water temperature standards and other water temperature management goals as described in detail in Attachment 1. This work confirmed with some certainty that measurable improvements could be made to the downstream temperature regime with the proposed cold water release facility. To evaluate some of the biological effects of this cold water facility, studies were done in Sullivan Lake as described below.

3.0 Biological Effects of Cold Water Releases

To gather biological information on the effects of potential changes in the operation of Sullivan Dam, PUD commissioned two studies:

1. To obtain preliminary data on productivity in the lake. (Study Report in Attachment 3)
2. To determine whether and to what extent fish were being entrained at the dam. (Study Report in Attachment 4)

The objective of the productivity study was to do a preliminary assessment of primary and secondary productivity as a function of time of the year and depth in the lake. Primary productivity is the production of organic compounds from atmospheric or aquatic carbon dioxide through the process of photosynthesis. Secondary productivity is the biomass formation or energy fixation by heterotrophic organisms, such as grazers and decomposers, deriving their energy from photosynthetic plants or other autotrophs.

The detailed productivity study results can be reviewed in Attachment 3. In summary, the study found:

- The lake has sufficient oxygen content throughout the water column.
- DO in Outlet Creek was considerably lower.
- The pH of Sullivan Lake was within the recommended range.
- Turbidity in both Sullivan Lake and Outlet Creek was well below the level at which impacts are typically seen.
- Conductivity is low in the lake, somewhat higher in Outlet Creek but still at the low end of the range for streams supporting good fisheries.
- The lake had very low primary productivity and Outlet Creek was even lower.
- Secondary productivity in the lake was concentrated during the day-light hours in the upper part of the hypolimnion or lower part of the metalimnion, and by dusk moved up into the metalimnion and epilimnion, which is typical diurnal vertical migration behavior.

These results supported the conclusion that withdrawing water from a depth of 20 m or deeper during the months when the lake is stratified by temperature, July – November, will have very little effect on lake productivity, which is concentrated in the upper layers of the water column.

The entrainment study's objective was to document species and numbers of fish being removed from Sullivan Lake through the outlet gates at the dam into Outlet Creek. The report did not cover the entire summer and fall seasons, but gathered data in October and November when the lake level was being lowered for the winter and discharge flows at the dam are high. The report is included in Attachment 4.
According to the entrainment study results, a cold water pipe at 20 m or deeper depth with fish screens should be effective in preventing entrainment of fish, most of which were found between 10-40 m depth.

The temperature model demonstrated the amounts of water at any particular time that would be passing Sullivan Dam either by seepage of groundwater, release through the low level gates, or release from the cold water pipe. It was found, for example, that in an average water year, the preferred operation of the cold water pipe (described in Attachment 2) would result in 93.8% of all waters released from July through December being either groundwater seepage or screened via the cold water release pipe. The calculation follows.

Calculate the Percent of Released Water that comes from Cold Pipe, and is thus screened- Average Year						
	from model cfs total flow	Thru gate	Seepage	Thru cold water pipe	total spill cubic feet in week	total gate cubic feet in week
July Week 1	40	0	15	25	24,192,000	0
July Week 2	35	0	15	20	21,168,000	0
July Week 3	30	0	15	15	18,144,000	0
July Week 4	30	0	15	15	25,920,000	0
Aug Week 1	30	0	15	15	18,144,000	0
Aug Week 2	30	0	15	15	18,144,000	0
Aug Week 3	30	0	15	15	18,144,000	0
Aug Week 4	30	0	15	15	25,920,000	0
Sep Week 1	30	0	15	15	18,144,000	0
Sep Week 2	180	7	15	158	108,864,000	4,233,600
Sep Week 3	200	32	15	153	120,960,000	19,353,600
Sep Week 4	200	42	15	143	155,520,000	25,401,600
Oct Week 1	157	6	15	136	94,953,600	3,628,800
Oct Week 2	140	0	15	125	84,672,000	0
Oct Week 3	130	0	15	115	78,624,000	0
Oct Week 4	130	3	15	112	112,320,000	1,814,400
Nov Week 1	125	6	15	104	75,600,000	3,628,800
Nov Week 2	122	11	15	96	73,785,600	6,652,800
Nov Week 3	120	17	15	88	72,576,000	10,281,600
Nov Week 4	115	23	15	77	89,424,000	13,910,400
Dec Week 1	72	0	15	57	43,545,600	0
Dec Week 2	68	0	15	53	41,126,400	0
Dec Week 3	64	0	15	49	38,707,200	0
Dec Week 4	58	0	15	43	50,112,000	0
				Totals	1,428,710,400	88,905,600
calculation by J. Snyder					% screened	93.8%
25-Jan-10						

This shows that by installing and screening the cold water release pipe, nearly all of the water released from the project would be groundwater or would be screened to prevent fish entrainment. When releases are required from the two low-level gates at the dam, they would only need to be opened a few inches at limited times during the fall drawdown. WDFW indicated this arrangement would meet the requirement for fish screening to prevent entrainment at Sullivan Dam and that no further screening would be required at the dam on the low-level outlets.

4.0 Conclusions

Results of the temperature modeling, productivity studies and entrainment studies and preliminary design studies indicated that a cold water release pipe consisting of a 48-inch-diameter pipe with fish screening at the pipe intake, would be effective in lowering temperatures in Outlet and Sullivan Creeks during the summer and fall, with no unacceptable impacts to productivity or fish populations in Sullivan Lake or Outlet Creek.

Attachment 1

Sullivan Creek Mixed Water Temperature Modeling report

Sullivan Creek Mixed Water Temperature Modeling

(Including Cold Water Release Pipe Modeling)

Based on

2009 Washington Department of Fish and Wildlife Water Temperature Measurements in Sullivan Creek and Lake

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Based on 2009 Washington Department of Fish and Wildlife Water Temperature Measurements in Sullivan Creek and Lake

1.0 Introduction

The Sullivan Creek Project consists of the following features:

- Sullivan Lake - approximately 1260 acres at elevation 2588.66
- Sullivan Dam - controls Lake level and discharges into Outlet Creek
- Outlet Creek - small creek extending ½ mile downstream from Sullivan Dam, to its confluence with Sullivan Creek. Outlet Creek has a USGS flow gauging station installed about 0.4 miles downstream of Sullivan Dam. Outlet Creek drainage area upstream of the gauge is about 50 sq mi.
- Upper Sullivan Creek - an unregulated creek with a drainage area of about 70 sq mi at its confluence with Outlet Creek
- Lower Sullivan Creek - After its confluence with Outlet Creek, Sullivan Creek nearly doubles in size, and flows about 1 mile into Mill Pond. At the outlet of Mill Pond, it flows over the uncontrolled spillway of Mill Pond Dam and continues about 4 miles to its confluence with the Pend Oreille River

As part of the Sullivan Creek Project FERC License (#2225) Surrender Process, all Parties indicated interest in the water temperatures in Sullivan Lake, Sullivan Creek and Outlet Creek during various parts of the year. Also of interest was the effect on downstream water temperatures of draining Sullivan Lake in the Fall. Washington Department of Fish and Wildlife (WDFW) installed temperature recording devices in several locations, as described below, and collected simultaneous water temperature data in the lake (at various levels), in Outlet Creek, Sullivan Creek above the confluence with Outlet Creek, Sullivan Creek below Outlet, Mill Pond, and downstream of Mill Pond.

After this simultaneous data was collected, the Public Utility District No. 1 of Pend Oreille County (PUD) retained EES Consulting to analyze the data and to prepare a computer model to be used to predict mixed water temperatures in Sullivan Creek downstream of its confluence with Outlet Creek. This report summarizes the data and the modeling efforts.

2.0 WDFW Water Temperature Data Collection

WDFW installed 12 water temperature recording instruments in various locations. The station in Sullivan Lake had sensors deployed at various depths, from 20 m deep to the surface, in 2 m increments. Several other stations (but not all) had duplicate instruments at the same site to insure accurate and complete records would be recorded. The recording instruments were located as follows:

Table 1 WDFW Water Temperature Monitoring Stations			
Recorder #	**Location**	**Date Installed**	**Date Removed**
1	Sullivan Lake- with sensors at depths from 20m to the surface in 2m increments	5/8/09	11/16/09
2	Sullivan Creek- 50m Upstream of Confluence with Outlet Creek- Unit 1	7/1/09	11/16/09
3	Sullivan Creek- 50m Upstream of Confluence with Outlet Creek- Unit 2	7/1/09	11/16/09
4	Sullivan Creek- 75m downstream of confluence with Outlet Creek- Unit 4	7/1/09	11/16/09
5	Sullivan Creek- 1.5 km downstream of Mill Pond Dam- Unit 5	7/1/09	11/16/09
6	Sullivan Creek- 1.5 km downstream of Mill Pond Dam- Unit 6	7/1/09	11/16/09
7	Outlet Creek- 75m downstream of Dam outlet- Unit 1	7/1/09	11/16/09
8	Outlet Creek- 75m downstream of Dam outlet- Unit 2	7/1/09	11/16/09
9	Mill Pond 15m upstream of Mill Pond Dam- Unit 1	7/1/09	11/16/09
10	Mill Pond 15m upstream of Mill Pond Dam- Unit 1	7/1/09	11/16/09
11	Harvey Creek- Unit 1	7/1/09	11/16/09
12	Harvey Creek Unit 2	7/1/09	11/16/09

The data was collected and provided to EES Consulting in raw form on November 17, 2009. The data consisted of 24 daily readings, taken once per hour, for the period the recorders were deployed. EESC converted the data to daily average readings for the period of record. This re-formatted data is shown in Appendix A.

Once formatted, the data was graphed in various ways in order to visually evaluate what the data indicated. Note that lake temperature data was available from May 8, but all other temperature data began with temperatures first measured on July 1, 2009.

The lake water temperatures versus depth were graphed as appeared as shown in Figure 1 below.

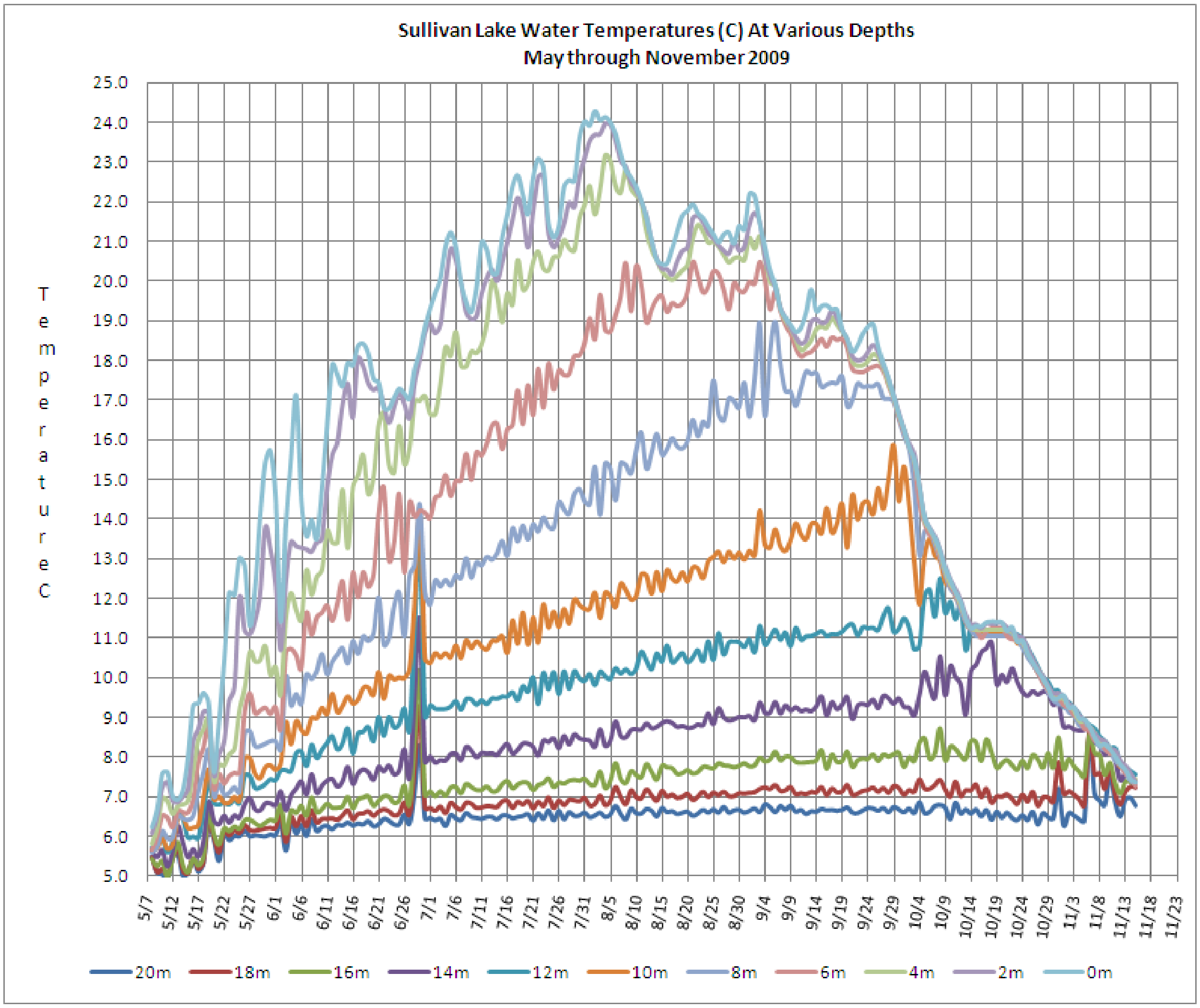


Figure 1
Sullivan Lake Water Temperatures (C) at Various Depths May through November 2009

The data show that the maximum lake surface water temperature in 2009 occurred around August 2, and reached about 24.3 C. Strong stratification of water temperatures with depth became evident beginning in the latter half of May and was fully developed by June 15. About October 1, surface water temperatures began to drop very quickly and the stratification began to "turn over" about October 1. By November 1, almost no difference in temperature remained between the surface water and water at depth.

The other data streams from Harvey, Sullivan and Outlet Creeks were also graphed. The results are shown in Figure 2, below.

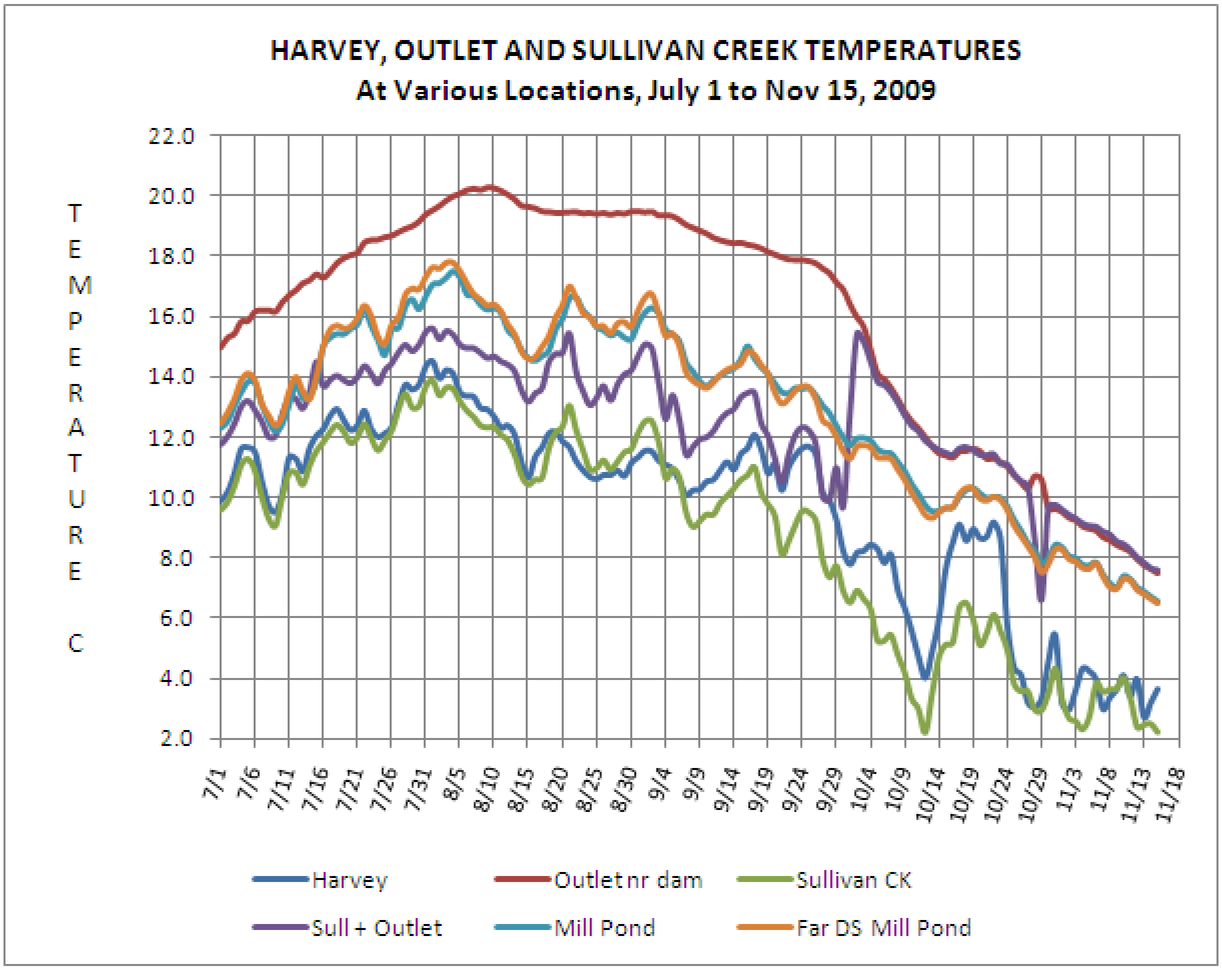


Figure 2
Harvey, Outlet and Sullivan Creek Temperatures at Various Locations, July 1 to November 15, 2009

Of interest to note in this data are the following points:

1. Harvey Creek and Sullivan Creek (upstream of confluence) temperatures (green and dark blue lines) are the coolest of all creek waters and are very similar.

2. Outlet Creek water temperatures are the warmest of the creeks, mainly due to releasing of the water warmed in Sullivan Lake.

3. Mill Pond near its outlet has considerably warmer water than Sullivan Creek upstream of the confluence with Outlet Creek. But when Sullivan lake begins to drain in the fall, the mixed temperature of Outlet + Sullivan jumps rapidly (purple line). The combined Sullivan and Outlet waters are warmed up quickly by the warm Sullivan Lake water. This is shown in more detail below. In 2009, Sullivan Creek flows were about 70% of the long term average for the Fall, and these low flows were rapidly warmed by the Sullivan lake releases. But, this warm water was moderated by Mill Pond, as Mill Pond temperature did not show any jump when Sullivan Lake began to drain.

4. Water temperature in Sullivan Creek 1.5 km downstream of Mill Pond dam appears to be almost the same as the temperature in Mill Pond. Data taken in 1996 as part of the PUD License Amendment process at that time showed that 1 to 2 degrees C of change was typical between Mill Pond and the confluence of Sullivan Creek with the Pend Oreille River (about 4 miles or 6.5 km downstream). In future temperature studies, a data recorder located at the mouth of Sullivan Creek at the Pend Oreille River would provide further useful information.

As described in item 3 above, when draining of Sullivan Lake began around October 1, warm water from Sullivan Lake mixed with cool water in Sullivan Creek, and the mixed water temperature rose very quickly to almost match the Outlet Creek temperature. From spot flow readings taken by the Kalispel Tribe in Sullivan Creek, 2009 Sullivan Creek flows were quite low, about 70% of average for October, and in the range of 25 to 28 cfs during October. When close to 200 cfs of warm water was added from Sullivan Lake, the mixed temperature jumped. This is shown clearly in Figure 3.

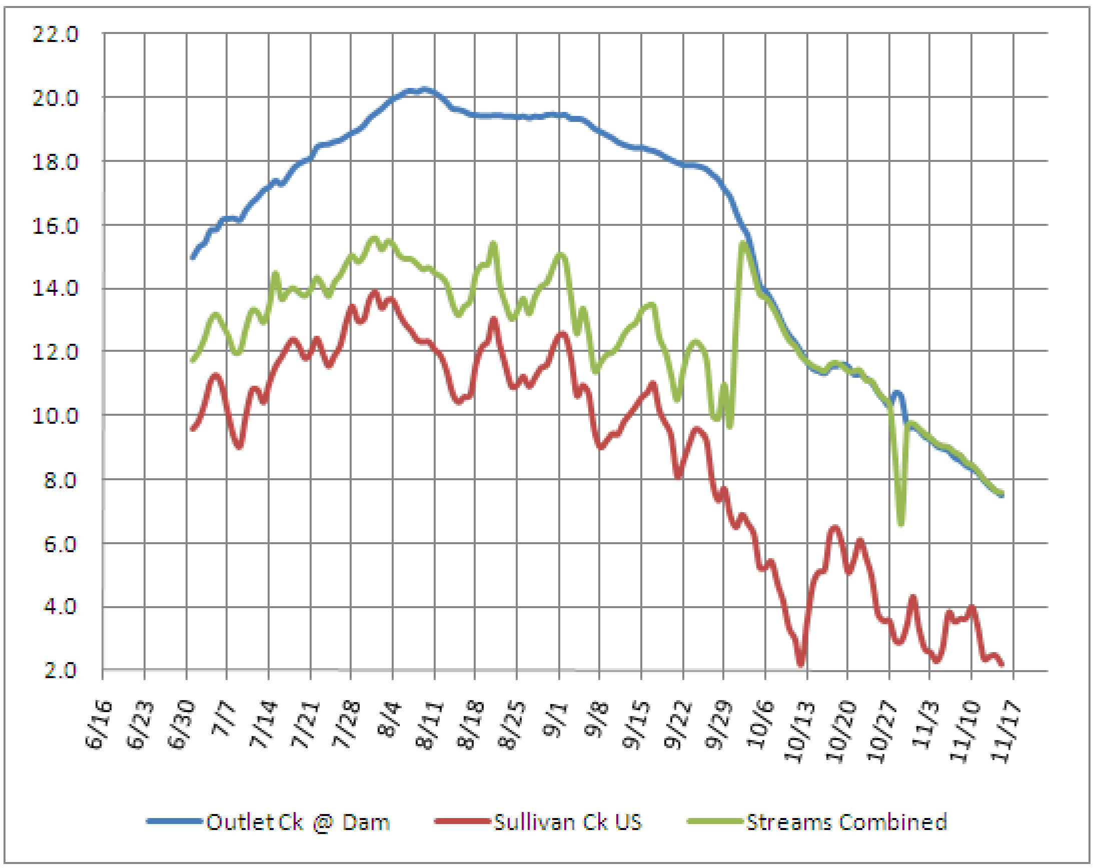


Figure 3
Temperatures in Outlet and Sullivan Creeks and Mixed Temperatures
June 16 through November 17, 2009

Until all this simultaneous data was gathered by WDFW, it was unclear how the Outlet Creek temperature related to the actual measured Sullivan Lake temperature. To examine that, we plotted Outlet Creek temperature against lake water temperatures at various depths. This is shown in Figure 4, below.

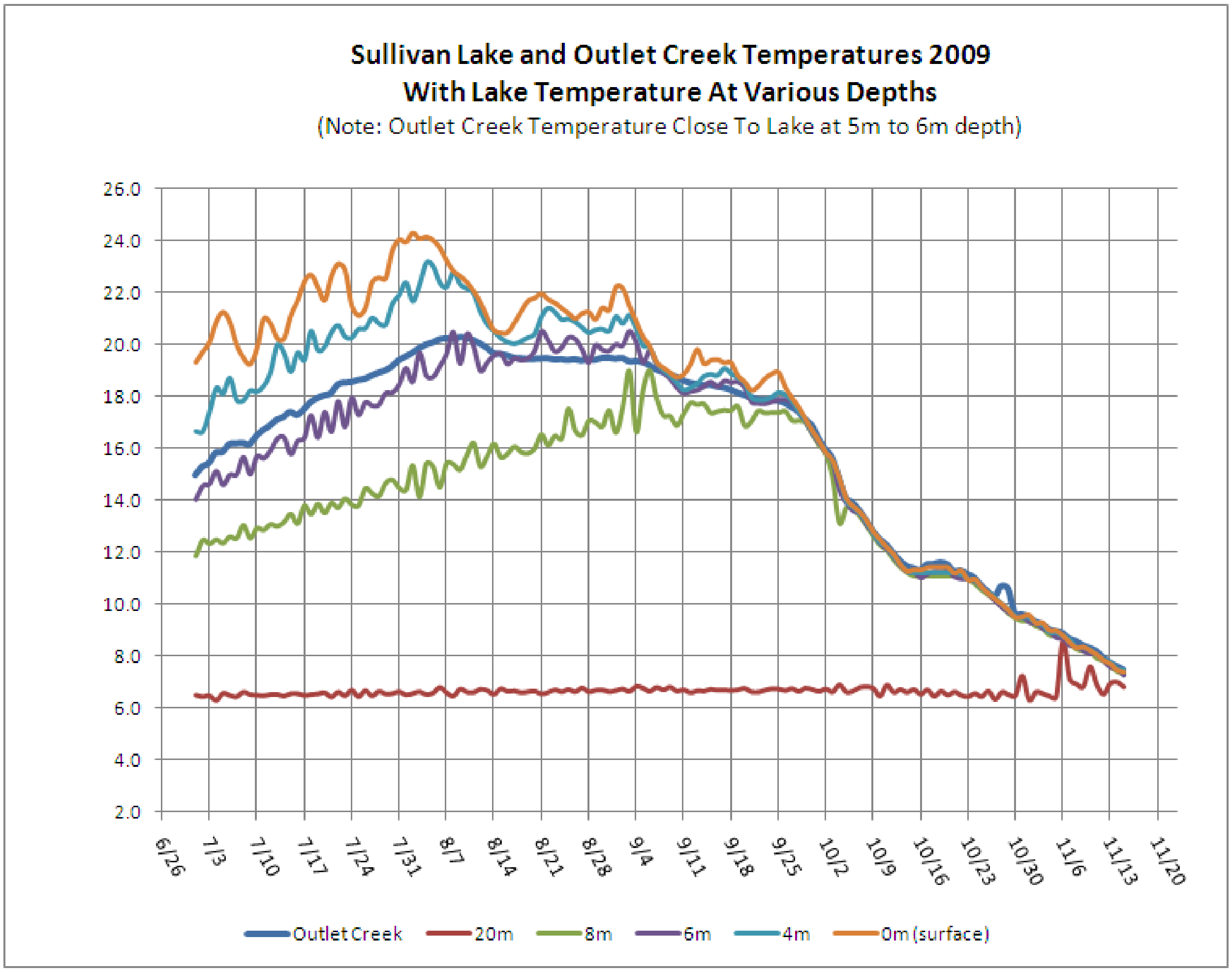


Figure 4
Sullivan Lake and Outlet Creek Temperatures 2009 with Lake Temperature at Various Depths

The graph shows that the Outlet Creek temperature (dark blue smooth line) does not correspond to the Sullivan Lake surface temperature (orange). Instead, Outlet Creek temperature most closely tracks the lake temperatures recorded around 6 m below the lake surface (purple line). This makes sense because the Sullivan Dam outlet gates are at the base of the dam at an invert elevation of 2563.6 MSL. This is 25 feet (7.6 m) below the surface of the full pool on October 1, so it should be expected that water released at this time would be cooler as it was coming from deeper within the lake. The data confirm this.

Finally, we compared Sullivan Creek and Harvey Creek natural temperatures with the lake temperatures. This data is shown in Figure 5, below.

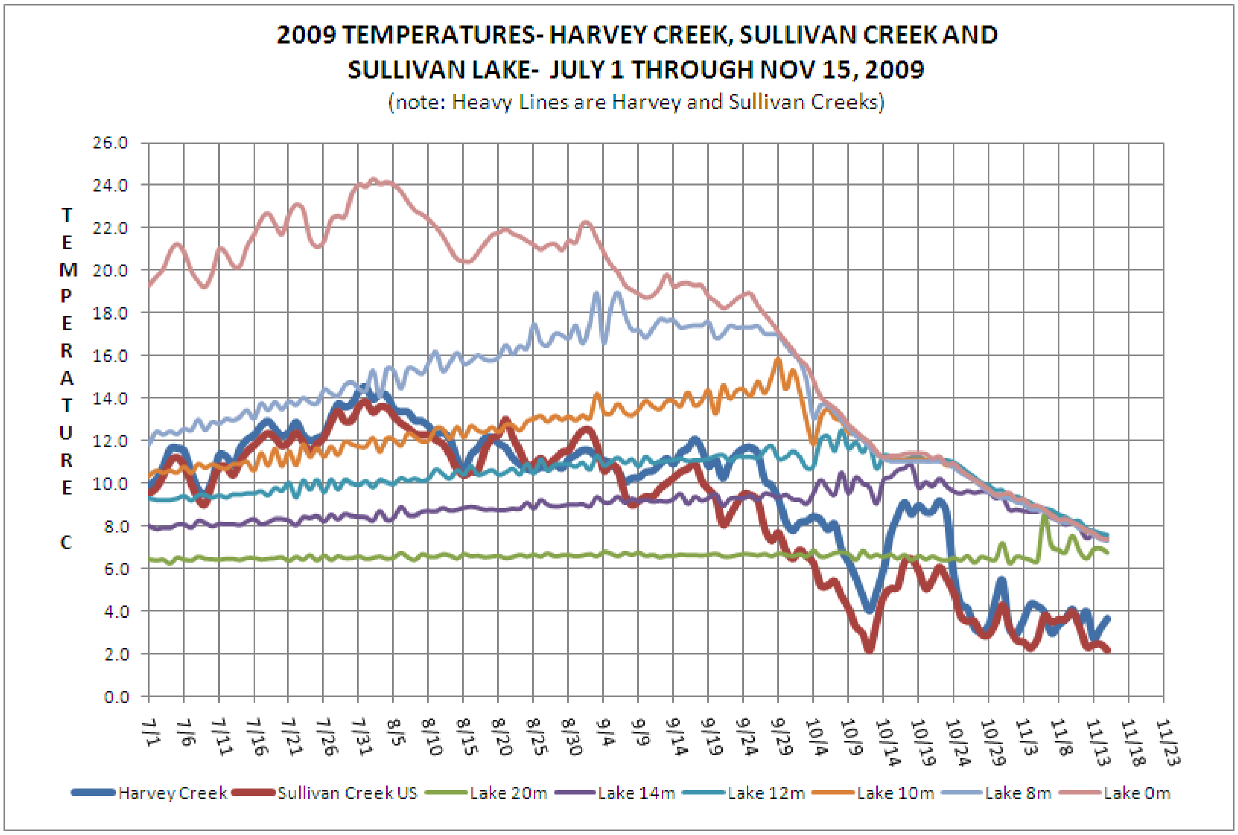


Figure 5
2009 Temperatures-Harvey Creek, Sullivan Creek and Sullivan Lake
July1 through November 15, 2009

Sullivan and Harvey Creeks (bold red and dark blue lines in Fig. 5 above) had temperatures that corresponded to lake temperatures down at around the 8 m to 10 m depth level through August 10. After August 10, the creeks began to cool slowly due presumably to cooler nights that began to occur, but the lake stayed warm. By September 15, the creek temperatures were most similar to lake temperatures at depths between 12 m and 14 m.

3.0 Basic Model Development

With simultaneous water temperature data available, there was a unique opportunity to construct a water temperature prediction model, and use the simultaneous data to calibrate the model. The goal of the model was to be able to select any outlet flow from Sullivan Lake, and model with precision the combined water temperature downstream of the confluence of Outlet and Sullivan Creeks.

EES Consulting was retained to build the model. The model was developed using the EXCEL spreadsheet software. The basic idea of the model was to input any desired flow regime for releases from Sullivan Dam into Outlet Creek, and then to calculate what the mixed temperature would be downstream of Sullivan Creek's confluence with Outlet Creek. The basic math of the mixing of warm and cool water is straightforward. It is a simple energy balance of flow #1 at temperature A, plus flow #2 at temperature B, combining into flow #3 (sum of #1 and #2) with temperature C equal to the weighted average of the temperatures of #1 and #2. The model was constructed to model only from July 1 through November 15, to correspond to the date range of the actual data gathered.

Modeling mixed temperature requires the temperature of each water stream (WDFW data) and the flow rate in each stream. At PUD's request, the USGS downloaded the Outlet Creek USGS gauge station, and provided the daily average flow data for July 1 through November 15, 2009. Sullivan Creek actual measured flow data was not available. To establish the flows in Sullivan Creek, we first obtained the existing 20 years of USGS gauge data on Sullivan Creek (gauge removed in 1996). By averaging this data, we obtained daily average flows for July 1 through Nov 15. However, to refine these flows further, we compared these average daily flows to about 6 spot flow readings taken by the Kalispel Tribe in Sullivan Creek during this period. The actual flow data indicated that flows in Sullivan at this time were around 70% of the long term average flows. During the fall of 2009, there was an extended period of hot, dry weather that would seem to support the conclusion that flows were below average in the July through November period.

The model was constructed using Sullivan Creek daily flows of 70% of the long term average. We input the actual measured flows released from Sullivan Dam as measured in Outlet Creek, and the actual temperatures measured by WDFW in Outlet Creek, as well as measured temperatures from Sullivan Creek. The resulting predicted mixed temperatures were graphed and compared to the actual measured mixed temperatures, shown below in Figure 6.

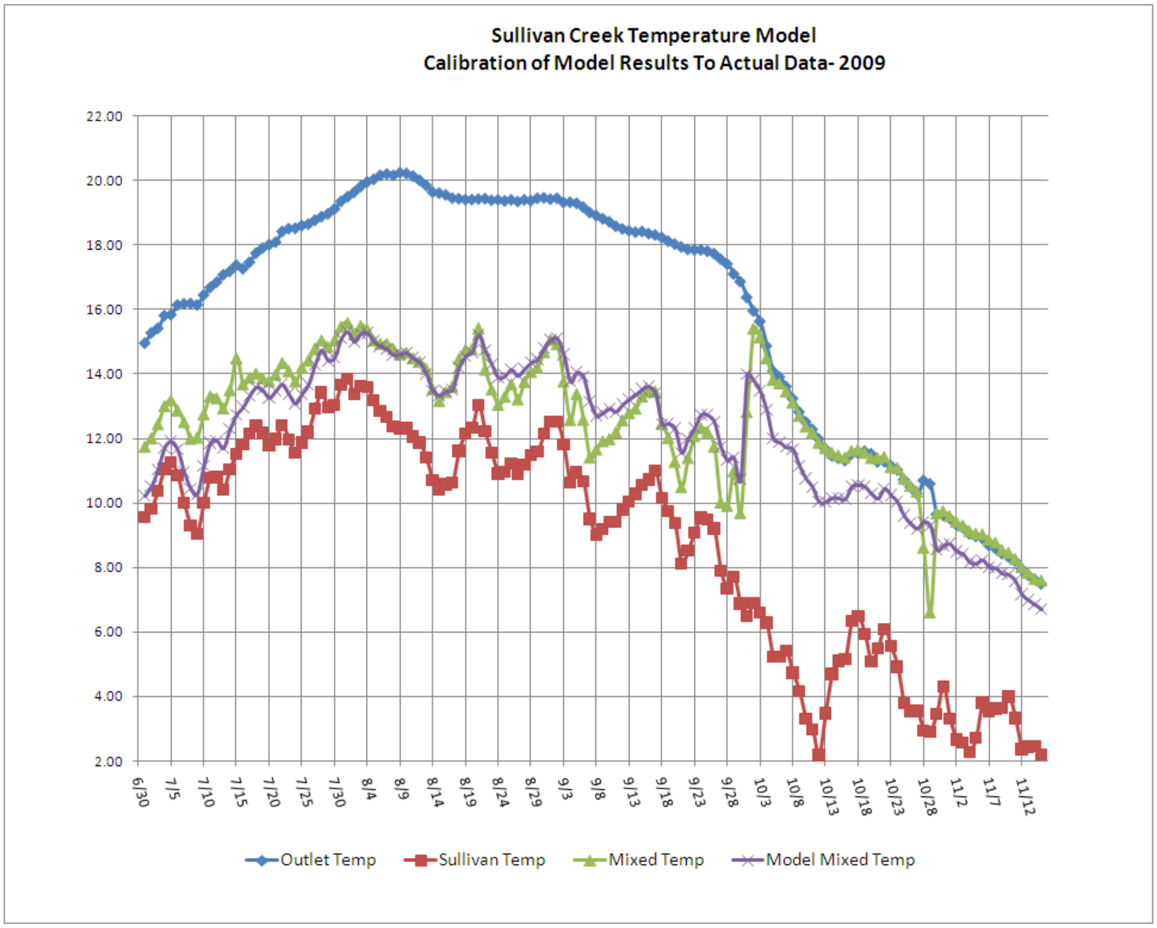


Figure 6
Sullivan Creek Temperature Model Calibration of Model Results to Actual Data-2009

The model results are shown by the purple line and the actual measured results for mixed temperature are represented by the green line. The model does a good job of predicting mixed water temperature. The differences between predicted and actual measured temperatures are due to actual stream flows being slightly different than the average flows used here. Without actual concurrent and simultaneous stream flow measurements in Sullivan Creek, this is the best calibration possible. The model works very well between July 1 and October 1, but under-predicts mixed temperature by ½ to 1 degree C during Sullivan Lake draining. We attempted to use other flow corrections for Sullivan Creek flows (instead of 70%) but 70% produced the closest correlation to measured temperatures. We decided to set up the model to allow the user to vary the "percent of long-term average flow" in Sullivan Creek to test percentages other than 70% if so desired, and this feature was added to the model. With completion of the calibration process described above, the model was considered functional.

4.0 Other Model Features

Other features and user inputs were added to the model to allow examination of a variety of scenarios. Features that were added included:

1) Flows to be released at Sullivan Dam were set up in an input table that allows a different flow to be used every week, from July 1 through November 15.

2) Five different scenarios for releases were set up in a second input table. The user can switch between these scenarios by simple input of the desired scenario number in the input table. The five scenarios were; 1-Wet Year; 2- Average Year; 3- Dry Year; 4-Actual 2009 year; and 5-Pre-project conditions with no dam. Use of scenario 5 allows examination of “without dam” conditions.

3) The impact of a potential cold water release pipe was added to the model. The user can select the fixed percentage of the release flow to come from the cold water pipe, and the depth from which the cold water would be withdrawn. By selecting different depths for the source of cold water, and different percentages of the total being released, the user can examine effectiveness of the cold water pipe. Setting the cold water percentage as zero reflects current conditions (no cold water pipe).

4) A table was set up to display the average number of degree-days that the mixed water was warmer than the Sullivan Creek upstream cool water. This allows the user to quickly see the impact of various flow scenario changes in a numerical format.

5) Results were also set up to be displayed graphically, so any changes made by the user could instantly be seen in the graph.

6) The final feature of the model is the ability to examine any scenario for flow releases, not just one of the 5 pre-established scenarios. To examine a scenario, the user can select any of the pre-set scenarios, such as scenario 2 (average year). Then, in the scenario table, the release flow can be changed to any desired value, and the values will be automatically updated in the input table and displayed on the graph.

The scenario input table in the model with the five Outlet Flow Scenarios is shown in Figure 7, below.

Dam Outlet Flow Scenarios- (pick the one you want to test and put number 1,2,3,4, or 5 in cell D10 abo

	1- Wet Year	2- Average Year	3- Dry Year	4- Actual 2009	5- Pre-Project-No Dam	
July Week 1	40	40	40	18.2	102.8	
July Week 2	35	35	35	18.9	76.9	
July Week 3	30	30	30	18.7	58.7	
July Week 4	30	30	30	15.03	45.9	
Aug Week 1	30	30	30	15.0	37.8	
Aug Week 2	30	30	30	15.2	32.6	
Aug Week 3	30	30	30	15.7	29.4	
Aug Week 4	30	30	30	16.00	26.1	
Sep Week 1	30	30	30	15.9	24.0	
Sep Week 2	60	60	60	15.0	22.7	
Sep Week 3	90	90	90	15.0	27.0	
Sep Week 4	120	120	120	15.84	23.1	
Oct Week 1	225	200	200	80.58	22.8	
Oct Week 2	225	200	200	108.4	23.8	
Oct Week 3	225	200	200	103.0	22.7	
Oct Week 4	225	200	200	126.52	22.9	
Nov Week 1	225	200	150	177.95	23.9	
Nov Week 2	225	180	100	189.5	27.2	
Nov Week 3	170	90	80	230	28.7	= estimated
Nov Week 4	119	70	60	150	27.6	
				(Uses Outlet Synthesized Ave Flows)		
Target Drain Ac-Ft	27,280	23,360	21,100	(and assumes water comes from 2m depth)		
Drain Ac-Ft here	27,873	23,365	21,104			
CRI Ac-Ft June- Aug 3rd wk	3,031	3,031	3,031			
(CRI Totals only correct for scenarios 1,2 or3)						

Figure 7
Temperature Model Dam Outlet Flow Scenario Table (Example)

In the example shown above, flows include potential CRI flow releases that might be made for sale to downstream users, in addition to minimum instream flow releases, in Scenarios 1, 2, and 3. These scenarios are simply examples. The user may change any flow in this table to observe the impact on mixed temperatures. Changes to any flow will automatically change the total run-off acre-feet shown at the bottom, and therefore the total seasonal run-off in any scenario should be adjusted to match the target run-off, to keep the scenario realistic. If, for example, a flow in August is increased, a flow at a later date should be reduced to keep the total drainage for the season unchanged. Scenarios 4 and 5 are for specific circumstances and should not be changed by the user.

The User input table appears as shown below.

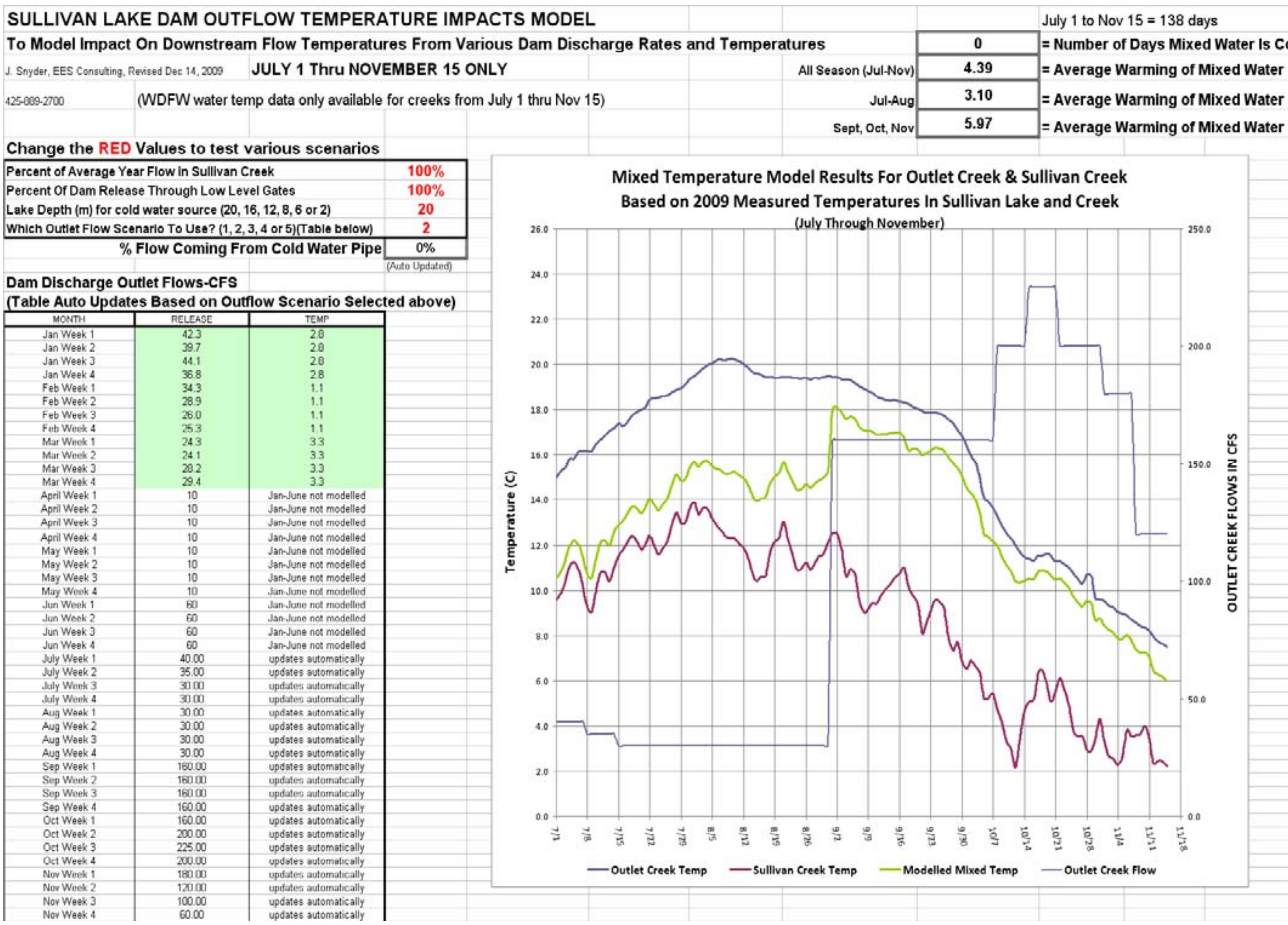
Change the RED Values to test various scenarios	
Percent of Average Year Flow in Sullivan Creek	70%
Percent Of Dam Release Through Low Level Gates	100%
Lake Depth (m) for cold water source (20, 16, 12, 8, 6 or 2)	20
Which Outlet Flow Scenario To Use? (1, 2, 3, 4 or 5)(Table below)	3
% Flow Coming From Cold Water Pipe	0%
	(Auto Updated)

Figure 8
Sullivan Temperature Model User Input Table (Example)

In this table, the user can select which of the above scenarios to model by simply selecting the scenario number, ("#3" in this example). Cold water releases can also be modeled by selecting the depth for the source of the cold water (20 m in this example), and the percentage of the total release coming through the existing gate (100% here). The remainder will automatically be assumed to be coming from the cold water pipe.

5.0 Modeling Results

Following are some examples of model output for various scenarios. In Figure 9, Scenario 2, Average Year hydrology, is modeled, with no cold water pipe (100% through the low level gates).



MONTH	RELEASE	TEMP
Jan Week 1	42.3	2.8
Jan Week 2	39.7	2.8
Jan Week 3	44.1	2.8
Jan Week 4	36.8	2.8
Feb Week 1	34.3	1.1
Feb Week 2	28.9	1.1
Feb Week 3	26.0	1.1
Feb Week 4	25.3	1.1
Mar Week 1	24.3	3.3
Mar Week 2	24.1	3.3
Mar Week 3	28.2	3.3
Mar Week 4	29.4	3.3
April Week 1	10	Jan-June not modelled
April Week 2	10	Jan-June not modelled
April Week 3	10	Jan-June not modelled
April Week 4	10	Jan-June not modelled
May Week 1	10	Jan-June not modelled
May Week 2	10	Jan-June not modelled
May Week 3	10	Jan-June not modelled
May Week 4	10	Jan-June not modelled
Jun Week 1	60	Jan-June not modelled
Jun Week 2	60	Jan-June not modelled
Jun Week 3	60	Jan-June not modelled
Jun Week 4	60	Jan-June not modelled
July Week 1	40.00	updates automatically
July Week 2	35.00	updates automatically
July Week 3	30.00	updates automatically
July Week 4	30.00	updates automatically
Aug Week 1	30.00	updates automatically
Aug Week 2	30.00	updates automatically
Aug Week 3	30.00	updates automatically
Aug Week 4	30.00	updates automatically
Sep Week 1	160.00	updates automatically
Sep Week 2	160.00	updates automatically
Sep Week 3	160.00	updates automatically
Sep Week 4	160.00	updates automatically
Oct Week 1	160.00	updates automatically
Oct Week 2	200.00	updates automatically
Oct Week 3	225.00	updates automatically
Oct Week 4	200.00	updates automatically
Nov Week 1	180.00	updates automatically
Nov Week 2	120.00	updates automatically
Nov Week 3	100.00	updates automatically
Nov Week 4	60.00	updates automatically

Figure 9
Sullivan Dam Outflow Temperature Model Output for Scenario 2, Average Year Hydrology

Outlet Creek flow is graphed as a purple line, using the scale on the right side of the graph. The increase in flow as the lake is drained can be clearly seen. In this example, ramping up lake drainage flows very slowly, starting Sept. 15, allows mixed water temperature to be held at no more than 16 degrees C, while flows are steadily ramped up as Sullivan Lake cools. After about October 3, the lake has cooled to below 16 C, and lake drainage rates can be increased further without concern for exceeding the 16 C mixed temperature limit (WAC 173-201A-200). Note that in this example, the all-season average warming of the downstream mixed temperature is 4.39 degrees C (from table at top). When changes in scenario flows are made, this number is recalculated so the user can see quickly whether the flows being tested improve or degrade downstream temperatures.

For comparison purposes, the model allows the user to run the pre-project or “without dam” scenario (Scenario 5). In this scenario, it is assumed that the lake outflow is equal to inflow for the entire modeling period (July 1 through November 15). Outlet Creek flows are obtained for this scenario from the unregulated Outlet Creek flows developed as part of the Lake Level Modeling efforts completed earlier this year. In this scenario, the model assumes that water leaving Sullivan Lake would be surface water or water from very near the surface. We used water temperature data taken by WDFW from the 2 m depth, but this may be slightly conservative (actual water may be warmer). The results are shown in Figure 10, below.

SULLIVAN LAKE DAM OUTFLOW TEMPERATURE IMPACTS MODEL

July 1 to Nov 15 = 138 days

To Model Impact On Downstream Flow Temperatures From Various Dam Discharge Rates and Temperatures

J. Snyder, EES Consulting, Revised Nov 19, 2009 — JULY 1 Thru NOVEMBER 15 ONLY

425-889-2700 — (WDFW water temp data only available for creeks from July 1 thru Nov 15)

	0	= Number of Days Mixed Water Is Co
All Season (Jul-Nov)	4.07	= Average Warming of Mixed Water c
Jul-Aug	4.54	= Average Warming of Mixed Water c
Sept, Oct, Nov	3.51	= Average Warming of Mixed Water c

Change the RED Values to test various scenarios

Percent of Average Year Flow in Sullivan Creek	70%
Percent Of Dam Release Through Low Level Gates	100%
Lake Depth (m) for cold water source (20, 16, 12, 8, 6 or 2)	20
Which Outlet Flow Scenario To Use? (1, 2, 3, 4 or 5)(Table below)	5
% Flow Coming From Cold Water Pipe	0% (Auto Updated)

Dam Discharge Outlet Flows-CFS
(Table Auto Updates Based on Outflow Scenario Selected above)

MONTH	RELEASE	TEMP
Jan Week 1	42.3	2.8
Jan Week 2	39.7	2.8
Jan Week 3	44.1	2.8
Jan Week 4	36.8	2.8
Feb Week 1	34.3	1.1
Feb Week 2	28.9	1.1
Feb Week 3	26.0	1.1
Feb Week 4	25.3	1.1
Mar Week 1	24.3	3.3
Mar Week 2	24.1	3.3
Mar Week 3	28.2	3.3
Mar Week 4	29.4	3.3
April Week 1	10	Jan-June not modelled
April Week 2	10	Jan-June not modelled
April Week 3	10	Jan-June not modelled
April Week 4	10	Jan-June not modelled
May Week 1	10	Jan-June not modelled
May Week 2	10	Jan-June not modelled
May Week 3	10	Jan-June not modelled
May Week 4	10	Jan-June not modelled
Jun Week 1	60	Jan-June not modelled
Jun Week 2	60	Jan-June not modelled
Jun Week 3	60	Jan-June not modelled
Jun Week 4	60	Jan-June not modelled
July Week 1	102.79	updates automatically
July Week 2	76.89	updates automatically
July Week 3	58.70	updates automatically
July Week 4	45.87	updates automatically
Aug Week 1	37.85	updates automatically
Aug Week 2	32.64	updates automatically
Aug Week 3	29.41	updates automatically
Aug Week 4	26.11	updates automatically
Sep Week 1	24.03	updates automatically
Sep Week 2	22.74	updates automatically
Sep Week 3	26.98	updates automatically
Sep Week 4	23.06	updates automatically
Oct Week 1	22.82	updates automatically
Oct Week 2	23.80	updates automatically
Oct Week 3	22.71	updates automatically
Oct Week 4	22.90	updates automatically
Nov Week 1	23.86	updates automatically
Nov Week 2	27.24	updates automatically
Nov Week 3	0.00	updates automatically
Nov Week 4	27.62	updates automatically

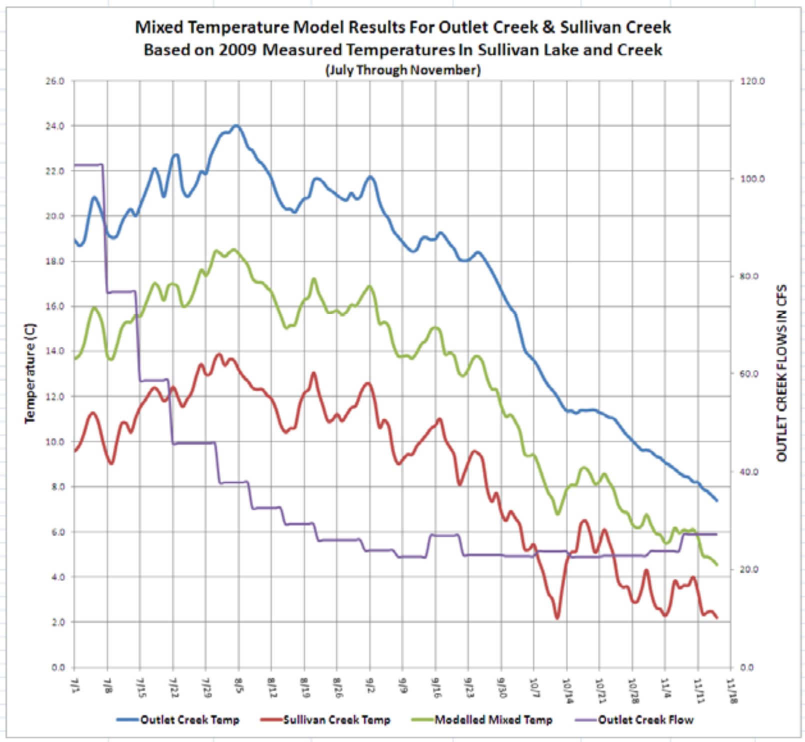


Figure 10
Sullivan Dam Outflow Temperature Model Output for “Without Dam” Scenario

As can be seen, under this scenario, the all-season, average temperature increase downstream is 4.07 C, which is slightly lower than the Scenario 2 example shown above. This is because flow releases in the fall are much less under natural conditions compared to flows required to drain the Lake after it has been held full in the summer months. As expected, mixed temperature is just about midway between Lake temperature and Sullivan Creek upstream temperature, since the flows are similar from these two sources. However, Outlet Creek temperatures are much higher under the “no dam” scenario, because the water leaving the lake is all surface (warmest) waters.

As discussed above, the impact of a cold water release pipe can also be modeled. In the example below, using average-year flows (Scenario 2), a cold water pipe is modeled, coming from the 20 m depth in Sullivan Lake; 30% of water released comes from the cold water pipe and 70% leaves through the existing low level gates. The results can be seen both graphically and numerically in Figure 11, below:

SULLIVAN LAKE DAM OUTFLOW TEMPERATURE IMPACTS MODEL

To Model Impact On Downstream Flow Temperatures From Various Dam Discharge Rates and Temperatures

J. Snyder, EES Consulting, Revised Dec 14, 2009 — **JULY 1 Thru NOVEMBER 15 ONLY**

425-889-2700 — (WDFW water temp data only available for creeks from July 1 thru Nov 15)

		July 1 to Nov 15 = 138 days
	0	= Number of Days Mixed Water Is Co
All Season (Jul-Nov)	2.89	= Average Warming of Mixed Water c
Jul-Aug	1.60	= Average Warming of Mixed Water c
Sept, Oct, Nov	4.48	= Average Warming of Mixed Water c

Change the RED Values to test various scenarios

Percent of Average Year Flow in Sullivan Creek	100%
Percent Of Dam Release Through Low Level Gates	70%
Lake Depth (m) for cold water source (20, 16, 12, 8, 6 or 2)	20
Which Outlet Flow Scenario To Use? (1, 2, 3, 4 or 5)(Table below)	2
% Flow Coming From Cold Water Pipe	30% (Auto Updated)

Dam Discharge Outlet Flows-CFS
(Table Auto Updates Based on Outflow Scenario Selected above)

MONTH	RELEASE	TEMP
Jan Week 1	42.3	2.8
Jan Week 2	39.7	2.8
Jan Week 3	44.1	2.8
Jan Week 4	36.8	2.8
Feb Week 1	34.3	1.1
Feb Week 2	28.9	1.1
Feb Week 3	26.0	1.1
Feb Week 4	25.3	1.1
Mar Week 1	24.3	3.3
Mar Week 2	24.1	3.3
Mar Week 3	28.2	3.3
Mar Week 4	29.4	3.3
April Week 1	10	Jan-June not modelled
April Week 2	10	Jan-June not modelled
April Week 3	10	Jan-June not modelled
April Week 4	10	Jan-June not modelled
May Week 1	10	Jan-June not modelled
May Week 2	10	Jan-June not modelled
May Week 3	10	Jan-June not modelled
May Week 4	10	Jan-June not modelled
Jun Week 1	60	Jan-June not modelled
Jun Week 2	60	Jan-June not modelled
Jun Week 3	60	Jan-June not modelled
Jun Week 4	60	Jan-June not modelled
July Week 1	40.00	updates automatically
July Week 2	35.00	updates automatically
July Week 3	30.00	updates automatically
July Week 4	30.00	updates automatically
Aug Week 1	30.00	updates automatically
Aug Week 2	30.00	updates automatically
Aug Week 3	30.00	updates automatically
Aug Week 4	30.00	updates automatically
Sep Week 1	160.00	updates automatically
Sep Week 2	160.00	updates automatically
Sep Week 3	160.00	updates automatically
Sep Week 4	160.00	updates automatically
Oct Week 1	160.00	updates automatically
Oct Week 2	200.00	updates automatically
Oct Week 3	225.00	updates automatically
Oct Week 4	200.00	updates automatically
Nov Week 1	180.00	updates automatically
Nov Week 2	120.00	updates automatically
Nov Week 3	100.00	updates automatically
Nov Week 4	60.00	updates automatically

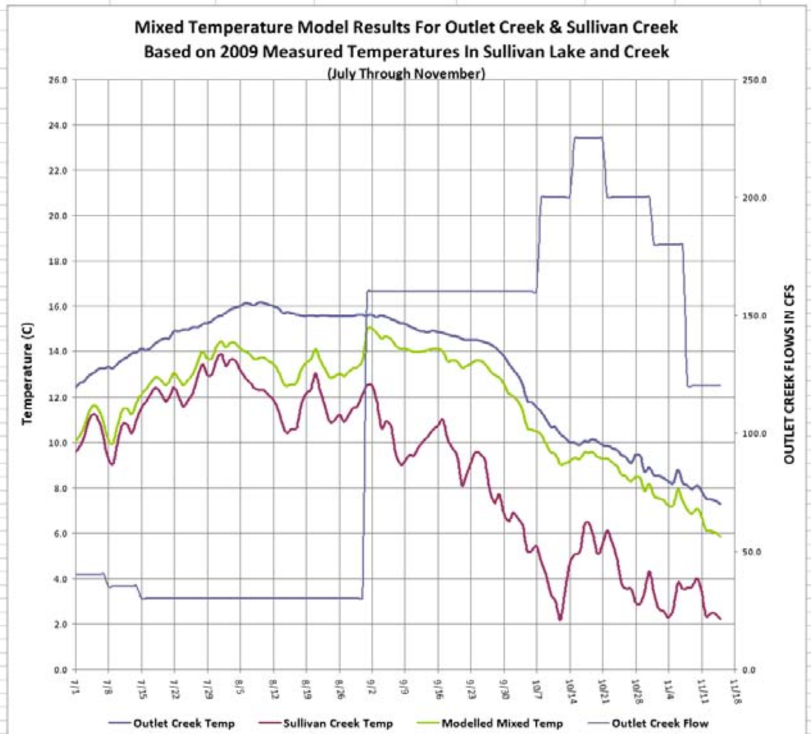


Figure 11
Sullivan Temperature Model Results-Scenario 2 with Cold Water Release

The predicted all-season mixed water temperature increase is 2.89 C in this example. Mixed water temperatures only briefly go above 14 C, about a 2C improvement from current operations. The user can adjust the gate opening percentage and source depth for the cool water to examine the impact on mixed temperatures by adjusting these parameters.

6.0 Cold Water Release Pipe Detailed Modeling

After review of the modeling results by the District and various agencies in the Sullivan Settlement discussions, interest in cold water release pipe options required some additional features be added to the model. Using the model described above, the following features were added:

1. The ability was added to permit the % of flow coming from Sullivan Lake to be split between the low level outlet and the cold water pipe with different flows *each week*, from 7/1 to 11/15.

2. The model now also calculates the Sullivan Lake level at the end of every week, so it can be sure any scenarios we look at have the lake down to elevation 2577.0 by November 15, the target elevation indicated by WDFW.

3. The Fall drawdown in all cases now starts the 8th of September in the model.

4. The Fall drawdown period does not necessarily reach 2570.0 by November 30, but it definitely gets there by December 31. All Parties agreed this was acceptable. This extra time to drawdown makes the peak flows during lake draining quite a bit lower than in previous model runs, and helps make it possible to control temperature better.

5. The cold water pipe design is based upon a 48" pipe with inlet fish screens, placed at a depth of 20m or more. As lake levels drop during draining, there is less driving pressure head on the cold water release pipe and its flow capacity begins to fall as lake levels fall. A check was added in the model to be sure that any flow the user asks for from the cold water pipe is actually possible based on the 48" design now being considered, since the cold pipe capacity drops as the lake level drops. If the user asks for too much flow, the model will indicate a problem and the user will have to increase flow through the low level gates until the problem clears.

6. For wet and dry years, the model uses 1999 and 1970 lake inflow data from Outlet Creek Unregulated Flows data file. These years were 141.2% and 66.6% of average, respectively. For "Average" runs, the average of 19 years of data was used.

7. The agencies were interested to know how much the low level outlet gates would actually be open (in inches) to release any particular flow. It is believed that smaller gate openings would likely result in less fish entrainment during releases. We have added a table right in the model that gives the capacity of the low level gates at full pond depending on opening. That data is as follows:

One Gate Opening (inches)	Calculated Discharge (cfs)
4	36
8	71
12	107
16	144
20	182
24	223
28	267
31	313
35	363
39	417

Figure 12
Flow vs. Gate Opening

8. Recreational boaters and kayakers noted that release flows from Sullivan Lake during draining in the range of 200 cfs were preferred for best boating conditions. In the lake draining scenarios used, a few weeks were included at close to or at 200 cfs to provide these recreational optimum flows.

9. It was noted that during summer and fall, some water from Sullivan Lake seeps underground and enters Outlet Creek just downstream of the dam. Because of this seepage, not 100% of water releases at the dam would come from the gates or the cold water pipe, and the seepage needs to be accounted for in the model. Checks of USGS gauge data show that in the summer season in 2009, seepage flows were between 10 and 15 cfs. Temperature data confirmed this seepage water was about the same temperature as water released from the low level gates (roughly equivalent to lake temperatures at a depth of 6m). The modeled flow releases were adjusted to simulate at least 15 cfs at all times from the low level gates (which would be equivalent to 15 cfs of seepage).

Included in the following pages are some example model runs of the revised model, examining in detail the capability of the proposed cold water release pipe.

In the first examples, using Scenario 3 (dry flow year) two output runs are shown below. One run shows the absolute maximum amount of water cooling that would be possible from the cold water pipe, and then a second run was made adjusting the amount released from the low level gate in order to achieve a mixed water temperature that was both a) within 1 degree C of the upstream Sullivan Creek water temperature; and b) never above 14 C. As can be seen in Figure 13, the cold water pipe has plenty of capacity to cool down the Sullivan dam discharge, and achieve the goals, in almost all situations. During September, for example, the cooled waters actually cool Sullivan Creek well below its temperature upstream of the confluence. In practice, this would not be done. Figure 14 below shows a more optimized operation. You can see that the combined waters match the Sullivan Creek upstream temperatures very closely. This demonstrates the flexibility of the proposed cold water release pipe design. It should be noted, however, that after about November 1 each year, Sullivan Lake has turned over and all of its waters are around 6C, and when Sullivan Creek subsequently drops below 6C, it is no longer possible to cool it down, and in fact, the dam releases warm it up slightly from around 4C up to near 6C. This is unavoidable and the cold water pipe cannot assist in this situation.

SULLIVAN LAKE DAM OUTFLOW TEMPERATURE IMPACTS MODEL

To Model Impact On Downstream Flow Temperatures From Various Dam Discharge Rates and Temperatures

J. Snyder, EES Consulting, Revised Jan 25, 2010 — **JULY 1 Thru NOVEMBER 15 ONLY**

425-889-2700 — (WDFW water temp data only available for creeks from July 1 thru Nov 15)

July 1 to Nov 15 = 138 days

	37	= Number of Days Mixed Water Is Cooler than Sullivan Creek Natural Temperature
All Season (Jul-Nov)	1.04	= Average Warming of Mixed Water compared to Sullivan Creek Natural Temps (July 1 to
Jul-Aug	0.18	= Average Warming of Mixed Water compared to Sullivan Creek Natural Temps (July 1 to
Sept, Oct, Nov	2.10	= Average Warming of Mixed Water compared to Sullivan Creek Natural Temps (Sept 15 t

Percent of Average Year Flow in Sullivan Creek	74%
Change the RED Values to test various scenarios	
Percent Of Dam Release Through Low Level Gates	per below
Lake Depth (m) for cold water source (20, 16, 12, 8, 6 or 2)	20
Which Outlet Flow Scenario To Use? (1, 2, or 3)(Table below)	3
% Flow Coming From Cold Water Pipe	Calc below (Auto Updated)

1=Wet (1999), 2=Average, 3=Dry(1970)

Dam Discharge Outlet Flows-CFS
(Table Auto Updates Based on Outflow Scenario Selected above)

MONTH	RELEASE	TEMP	USER INPUT Seepage or Out of Gate	(CALCULATED) Out of Cold Water Pipe	Check- Is Cold Pipe Flow OK?	Lake Level at End of Week
Jan Week 1	42.3	2.8				
Jan Week 2	39.7	2.8				
Jan Week 3	44.1	2.8				
Jan Week 4	36.8	2.8				
Feb Week 1	34.3	1.1				
Feb Week 2	28.9	1.1				
Feb Week 3	26.0	1.1				
Feb Week 4	25.3	1.1				
Mar Week 1	24.3	3.3				
Mar Week 2	24.1	3.3				
Mar Week 3	28.2	3.3				
Mar Week 4	29.4	3.3				
April Week 1	10	Jan-June not modelled				
April Week 2	10	Jan-June not modelled				
April Week 3	10	Jan-June not modelled				
April Week 4	10	Jan-June not modelled				
May Week 1	10	Jan-June not modelled				
May Week 2	10	Jan-June not modelled				
May Week 3	10	Jan-June not modelled				
May Week 4	10	Jan-June not modelled				
Jun Week 1	60	Jan-June not modelled				
Jun Week 2	60	Jan-June not modelled				
Jun Week 3	60	Jan-June not modelled				
Jun Week 4	60	Jan-June not modelled				
July Week 1	40.00	updates automatically	15.0	25.0	YES	2588.66
July Week 2	35.00	updates automatically	15.0	20.0	YES	2588.66
July Week 3	30.00	updates automatically	15.0	15.0	YES	2588.66
July Week 4	30.00	updates automatically	15.0	15.0	YES	2588.66
Aug Week 1	30.00	updates automatically	15.0	15.0	YES	2588.60
Aug Week 2	30.00	updates automatically	15.0	15.0	YES	2588.53
Aug Week 3	30.00	updates automatically	15.0	15.0	YES	2588.43
Aug Week 4	30.00	updates automatically	15.0	15.0	YES	2588.24
Sep Week 1	30.00	updates automatically	15.0	15.0	YES	2588.16
Sep Week 2	160.00	updates automatically	15.0	145.0	YES	2586.59
Sep Week 3	160.00	updates automatically	15.0	145.0	YES	2585.01
Sep Week 4	160.00	updates automatically	15.0	145.0	YES	2583.00
Oct Week 1	160.00	updates automatically	21.0	139.0	YES	2581.38
Oct Week 2	160.00	updates automatically	29.0	131.0	YES	2579.78
Oct Week 3	200.00	updates automatically	81.0	119.0	YES	2577.71
Oct Week 4	200.00	updates automatically	101.0	99.0	YES	2574.77
Nov Week 1	150.00	updates automatically	63.0	87.0	YES	2573.25
Nov Week 2	130.00	updates automatically	54.0	76.0	YES	2571.96
Nov Week 3	100.00	updates automatically	32.0	68.0	YES	2571.01
Nov Week 4	70.00	updates automatically	15.0	55.0	YES	2570.19
Dec Week 1	50.00	3.3	15.0	35.0	YES	2569.83
Dec Week 2	40.00	3,3	15.0	25.0	YES	2569.58
Dec Week 3	30.00	3.3	15.0	15.0	YES	2569.43
Dec Week 4	14.00	3.3	15.0	-1.0	YES	2569.41

One Gate Opening (inches)	Calculated Discharge (cfs)
4	36
8	71
12	107
16	144
20	182
24	223
28	267
31	313
35	363
39	417

LAKE ELEVATION On Nov. 15th	Assumes Lake Level July 1 (Full)
2571.96	2588.6

Target 2577.0 or less

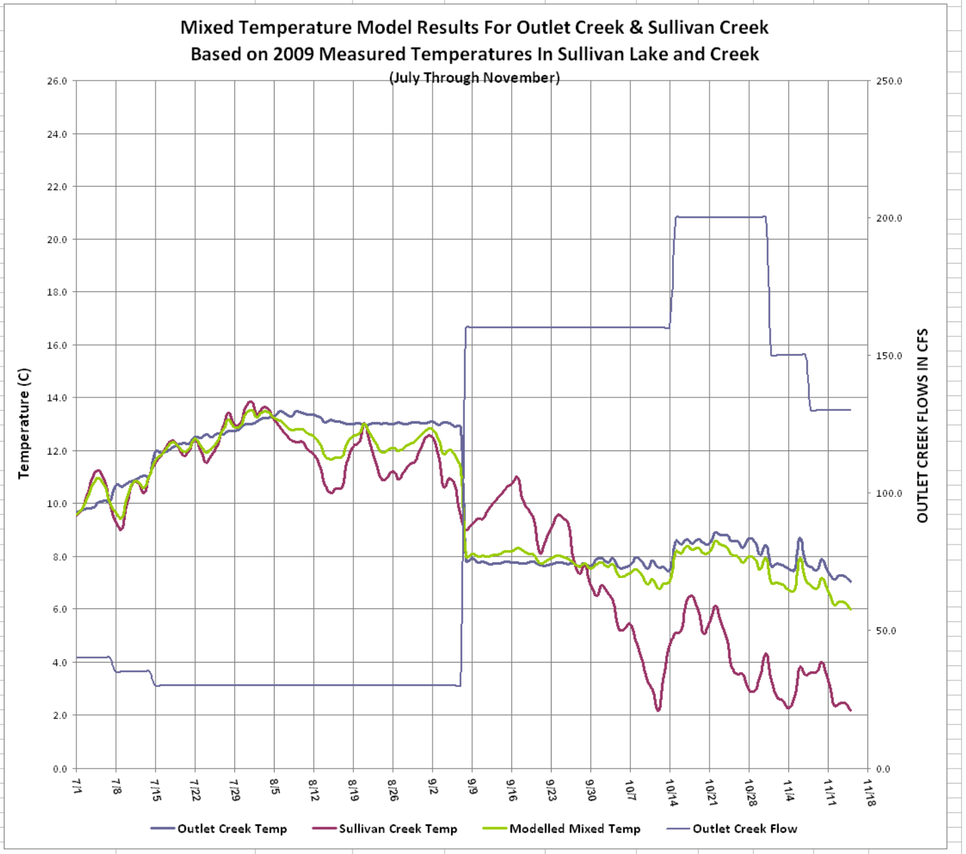


Figure 13
Sullivan Temperature Model Results-Scenario 3 (Dry Year) with Cold Water Release and Maximum Possible Cooling

SULLIVAN LAKE DAM OUTFLOW TEMPERATURE IMPACTS MODEL

July 1 to Nov 15 = 138 days

To Model Impact On Downstream Flow Temperatures From Various Dam Discharge Rates and Temperatures

J. Snyder, EES Consulting, Revised Jan 25, 2010

425-889-2700

JULY 1 Thru NOVEMBER 15 ONLY

(WDFW water temp data only available for creeks from July 1 thru Nov 15)

	27	**= Number of Days Mixed Water Is Cooler than Sullivan Creek Natural Temperature**
All Season (Jul-Nov)	**1.29**	**= Average Warming of Mixed Water compared to Sullivan Creek Natural Temps (July 1 to**
Jul-Aug	**0.33**	**= Average Warming of Mixed Water compared to Sullivan Creek Natural Temps (July 1 to**
Sept, Oct, Nov	**2.48**	**= Average Warming of Mixed Water compared to Sullivan Creek Natural Temps (Sept 15 t**

Percent of Average Year Flow in Sullivan Creek	**74%**
Change the RED Values to test various scenarios	
Percent Of Dam Release Through Low Level Gates	**per below**
Lake Depth (m) for cold water source (20, 16, 12, 8, 6 or 2)	**20**
Which Outlet Flow Scenario To Use? (1, 2, or 3)(Table below)	**3**
% Flow Coming From Cold Water Pipe	Calc below (Auto Updated)

1=Wet (1999), 2=Average, 3=Dry(1970)

Dam Discharge Outlet Flows-CFS
(Table Auto Updates Based on Outflow Scenario Selected above)

MONTH	RELEASE	TEMP	USER INPUT Seepage or Out of Gate	(CALCULATED) Out of Cold Water Pipe	Check- Is Cold Pipe Flow OK?	Lake Level at End of Week
Jan Week 1	42.3	2.8				
Jan Week 2	39.7	2.8				
Jan Week 3	44.1	2.8				
Jan Week 4	36.8	2.8				
Feb Week 1	34.3	1.1				
Feb Week 2	28.9	1.1				
Feb Week 3	26.0	1.1				
Feb Week 4	25.3	1.1				
Mar Week 1	24.3	3.3				
Mar Week 2	24.1	3.3				
Mar Week 3	28.2	3.3				
Mar Week 4	29.4	3.3				
April Week 1	10	Jan-June not modelled				
April Week 2	10	Jan-June not modelled				
April Week 3	10	Jan-June not modelled				
April Week 4	10	Jan-June not modelled				
May Week 1	10	Jan-June not modelled				
May Week 2	10	Jan-June not modelled				
May Week 3	10	Jan-June not modelled				
May Week 4	10	Jan-June not modelled				
Jun Week 1	60	Jan-June not modelled				
Jun Week 2	60	Jan-June not modelled				
Jun Week 3	60	Jan-June not modelled				
Jun Week 4	60	Jan-June not modelled				
July Week 1	40.00	updates automatically	15.0	25.0	YES	2588.66
July Week 2	35.00	updates automatically	15.0	20.0	YES	2588.66
July Week 3	30.00	updates automatically	15.0	15.0	YES	2588.66
July Week 4	30.00	updates automatically	15.0	15.0	YES	2588.66
Aug Week 1	30.00	updates automatically	15.0	15.0	YES	2588.60
Aug Week 2	30.00	updates automatically	15.0	15.0	YES	2588.53
Aug Week 3	30.00	updates automatically	15.0	15.0	YES	2588.43
Aug Week 4	30.00	updates automatically	15.0	15.0	YES	2588.24
Sep Week 1	30.00	updates automatically	15.0	15.0	YES	2588.16
Sep Week 2	160.00	updates automatically	40.0	120.0	YES	2586.59
Sep Week 3	160.00	updates automatically	52.0	108.0	YES	2585.01
Sep Week 4	160.00	updates automatically	30.0	130.0	YES	2583.00
Oct Week 1	160.00	updates automatically	21.0	139.0	YES	2581.38
Oct Week 2	160.00	updates automatically	29.0	131.0	YES	2579.78
Oct Week 3	200.00	updates automatically	81.0	119.0	YES	2577.71
Oct Week 4	200.00	updates automatically	101.0	99.0	YES	2574.77
Nov Week 1	150.00	updates automatically	63.0	87.0	YES	2573.25
Nov Week 2	130.00	updates automatically	54.0	76.0	YES	2571.96
Nov Week 3	100.00	updates automatically	32.0	68.0	YES	2571.01
Nov Week 4	70.00	updates automatically	15.0	55.0	YES	2570.19
Dec Week 1	50.00	3.3	15.0	35.0	YES	2569.83
Dec Week 2	40.00	3,3	15.0	25.0	YES	2569.58
Dec Week 3	30.00	3.3	15.0	15.0	YES	2569.43
Dec Week 4	14.00	3.3	15.0	-1.0	YES	2569.41

One Gate Opening (inches)	Calculated Discharge (cfs)
4	36
8	71
12	107
16	144
20	182
24	223
28	267
31	313
35	363
39	417

LAKE ELEVATION On Nov. 15th	Assumes Lake Level July 1 (Full)
2571.96	**2588.6**

Target 2577.0 or less

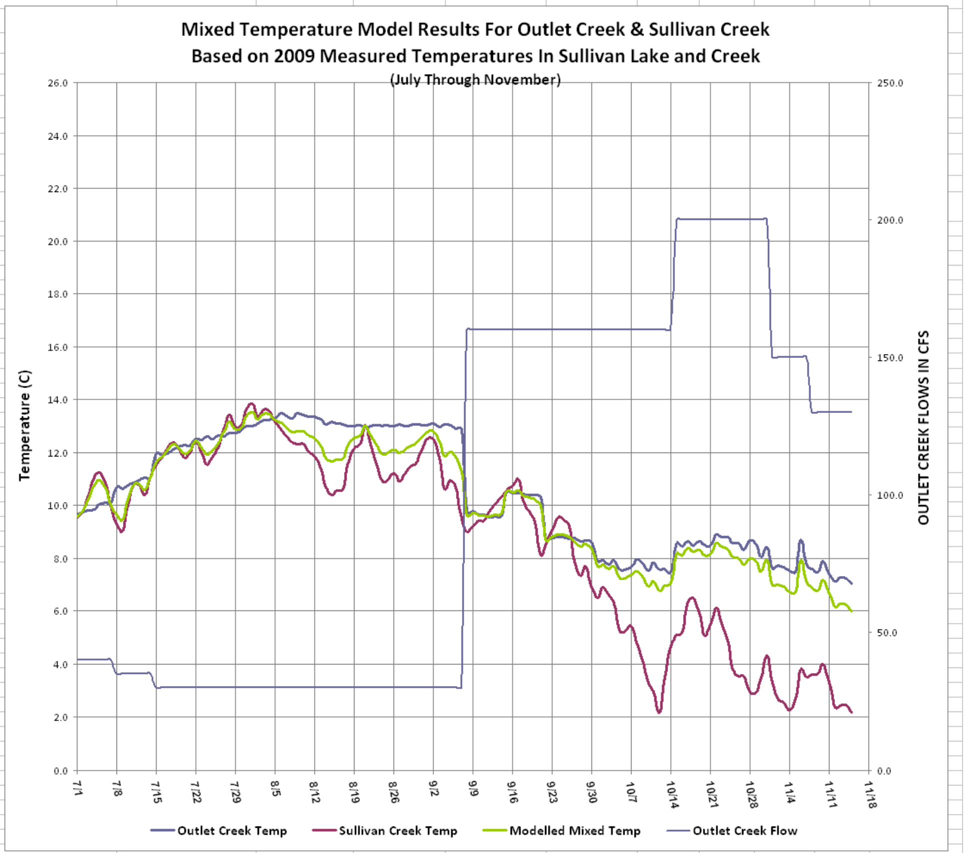


Figure 14
Sullivan Temperature Model Results-Scenario 3 (Dry Year) with Cold Water Release and Optimized Cooling

Two additional model runs are displayed as Figures 15 and 16 below, showing optimized cooling in average flow years and wet flow years. These runs demonstrate that the cold water pipe is very effective over a range of hydrologic conditions.

SULLIVAN LAKE DAM OUTFLOW TEMPERATURE IMPACTS MODEL

To Model Impact On Downstream Flow Temperatures From Various Dam Discharge Rates and Temperatures

J. Snyder, EES Consulting, Revised Jan 25, 2010 — **JULY 1 Thru NOVEMBER 15 ONLY**

425-889-2700 — (WDFW water temp data only available for creeks from July 1 thru Nov 15)

July 1 to Nov 15 = 138 days

	29	= Number of Days Mixed Water Is Cooler than Sullivan Creek Natural Temperature
All Season (Jul-Nov)	0.93	= Average Warming of Mixed Water compared to Sullivan Creek Natural Temps (July 1 to
Jul-Aug	0.16	= Average Warming of Mixed Water compared to Sullivan Creek Natural Temps (July 1 to
Sept, Oct, Nov	1.88	= Average Warming of Mixed Water compared to Sullivan Creek Natural Temps (Sept 15 t

Percent of Average Year Flow in Sullivan Creek — **100%**

Change the RED Values to test various scenarios	
Percent Of Dam Release Through Low Level Gates	per below
Lake Depth (m) for cold water source (20, 16, 12, 8, 6 or 2)	20
Which Outlet Flow Scenario To Use? (1, 2, or 3)(Table below)	2
% Flow Coming From Cold Water Pipe	Calc below (Auto Updated)

1=Wet (1999), 2=Average, 3=Dry(1970)

Dam Discharge Outlet Flows-CFS

(Table Auto Updates Based on Outflow Scenario Selected above)

MONTH	RELEASE	TEMP	USER INPUT Seepage or Out of Gate	(CALCULATED) Out of Cold Water Pipe	Check- Is Cold Pipe Flow OK?	Lake Level at End of Week
Jan Week 1	42.3	2.8				
Jan Week 2	39.7	2.8				
Jan Week 3	44.1	2.8				
Jan Week 4	36.8	2.8				
Feb Week 1	34.3	1.1				
Feb Week 2	28.9	1.1				
Feb Week 3	26.0	1.1				
Feb Week 4	25.3	1.1				
Mar Week 1	24.3	3.3				
Mar Week 2	24.1	3.3				
Mar Week 3	28.2	3.3				
Mar Week 4	29.4	3.3				
April Week 1	10	Jan-June not modelled				
April Week 2	10	Jan-June not modelled				
April Week 3	10	Jan-June not modelled				
April Week 4	10	Jan-June not modelled				
May Week 1	10	Jan-June not modelled				
May Week 2	10	Jan-June not modelled				
May Week 3	10	Jan-June not modelled				
May Week 4	10	Jan-June not modelled				
Jun Week 1	60	Jan-June not modelled				
Jun Week 2	60	Jan-June not modelled				
Jun Week 3	60	Jan-June not modelled				
Jun Week 4	60	Jan-June not modelled				
July Week 1	40.00	updates automatically	15.0	25.0	YES	2588.66
July Week 2	35.00	updates automatically	15.0	20.0	YES	2588.66
July Week 3	30.00	updates automatically	15.0	15.0	YES	2588.66
July Week 4	30.00	updates automatically	15.0	15.0	YES	2588.66
Aug Week 1	30.00	updates automatically	15.0	15.0	YES	2588.66
Aug Week 2	30.00	updates automatically	15.0	15.0	YES	2588.66
Aug Week 3	30.00	updates automatically	15.0	15.0	YES	2588.61
Aug Week 4	30.00	updates automatically	15.0	15.0	YES	2588.55
Sep Week 1	30.00	updates automatically	15.0	15.0	YES	2588.48
Sep Week 2	180.00	updates automatically	22.0	158.0	YES	2586.72
Sep Week 3	200.00	updates automatically	47.0	153.0	YES	2584.78
Sep Week 4	200.00	updates automatically	57.0	143.0	YES	2582.23
Oct Week 1	157.00	updates automatically	21.0	136.0	YES	2580.73
Oct Week 2	140.00	updates automatically	15.0	125.0	YES	2579.43
Oct Week 3	130.00	updates automatically	15.0	115.0	YES	2578.23
Oct Week 4	130.00	updates automatically	18.0	112.0	YES	2576.52
Nov Week 1	125.00	updates automatically	21.0	104.0	YES	2575.38
Nov Week 2	122.00	updates automatically	26.0	96.0	YES	2574.32
Nov Week 3	120.00	updates automatically	32.0	88.0	YES	2573.30
Nov Week 4	115.00	updates automatically	38.0	77.0	YES	2572.04
Dec Week 1	72.00	3.3	15.0	57.0	YES	2571.54
Dec Week 2	68.00	3.3	15.0	53.0	YES	2571.04
Dec Week 3	64.00	3.3	15.0	49.0	YES	2570.61
Dec Week 4	58.00	3.3	15.0	43.0	YES	2570.02

One Gate Opening (inches)	Calculated Discharge (cfs)
4	36
8	71
12	107
16	144
20	182
24	223
28	267
31	313
35	363
39	417

LAKE ELEVATION On Nov. 15th	Assumes Lake Level July 1 (Full)
2574.32	2588.6

Target 2577.0 or less

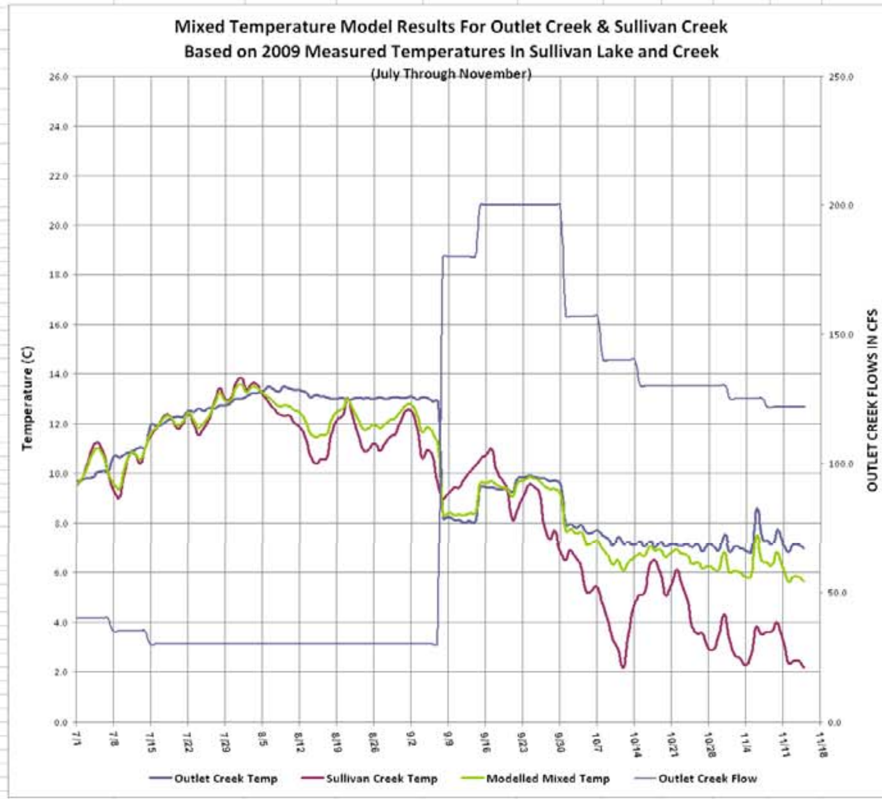


Figure 15

Sullivan Temperature Model Results-Scenario 2 (Average Year) with Cold Water Release and Optimized Cooling

SULLIVAN LAKE DAM OUTFLOW TEMPERATURE IMPACTS MODEL

To Model Impact On Downstream Flow Temperatures From Various Dam Discharge Rates and Temperatures

J. Snyder, EES Consulting, Revised Jan 25, 2010 **JULY 1 Thru NOVEMBER 15 ONLY**

425-889-2700 (WDFW water temp data only available for creeks from July 1 thru Nov 15)

July 1 to Nov 15 = 138 days

	30	**= Number of Days Mixed Water Is Cooler than Sullivan Creek Natural Temperature**
All Season (Jul-Nov)	**1.26**	**= Average Warming of Mixed Water compared to Sullivan Creek Natural Temps (July 1 to Nov 30)**
Jul-Aug	**0.21**	**= Average Warming of Mixed Water compared to Sullivan Creek Natural Temps (July 1 to Sept 14)**
Sept, Oct, Nov	**2.55**	**= Average Warming of Mixed Water compared to Sullivan Creek Natural Temps (Sept 15 to Nov 3(**

Percent of Average Year Flow in Sullivan Creek **134%**

Change the RED Values to test various scenarios

Percent Of Dam Release Through Low Level Gates	**per below**	
Lake Depth (m) for cold water source (20, 16, 12, 8, 6 or 2)	**20**	
Which Outlet Flow Scenario To Use? (1, 2, or 3)(Table below)	**1**	**1=Wet (1999), 2=Average, 3=Dry(1970)**
% Flow Coming From Cold Water Pipe	**Calc below** (Auto Updated)	

Dam Discharge Outlet Flows-CFS
(Table Auto Updates Based on Outflow Scenario Selected above)

One Gate Opening (inches)	Calculated Discharge (cfs)
4	36
8	71
12	107
16	144
20	182
24	223
28	267
31	313
35	363
39	417

LAKE ELEVATION
On Nov. 15th
2571.83
Target 2577.0 or less

Assumes Lake Level July 1 (Full)
2588.6

MONTH	RELEASE	TEMP	USER INPUT Seepage or Out of Gate	(CALCULATED) Out of Cold Water Pipe	Check- Is Cold Pipe Flow OK?	Lake Level at End of Week
Jan Week 1	42.3	2.8				
Jan Week 2	39.7	2.8				
Jan Week 3	44.1	2.8				
Jan Week 4	36.8	2.8				
Feb Week 1	34.3	1.1				
Feb Week 2	28.9	1.1				
Feb Week 3	26.0	1.1				
Feb Week 4	25.3	1.1				
Mar Week 1	24.3	3.3				
Mar Week 2	24.1	3.3				
Mar Week 3	28.2	3.3				
Mar Week 4	29.4	3.3				
April Week 1	10	Jan-June not modelled				
April Week 2	10	Jan-June not modelled				
April Week 3	10	Jan-June not modelled				
April Week 4	10	Jan-June not modelled				
May Week 1	10	Jan-June not modelled				
May Week 2	10	Jan-June not modelled				
May Week 3	10	Jan-June not modelled				
May Week 4	10	Jan-June not modelled				
Jun Week 1	60	Jan-June not modelled				
Jun Week 2	60	Jan-June not modelled				
Jun Week 3	60	Jan-June not modelled				
Jun Week 4	60	Jan-June not modelled				
July Week 1	40.00	updates automatically	15.0	25.0	YES	2588.66
July Week 2	35.00	updates automatically	15.0	20.0	YES	2588.66
July Week 3	30.00	updates automatically	15.0	15.0	YES	2588.66
July Week 4	30.00	updates automatically	15.0	15.0	YES	2588.66
Aug Week 1	30.00	updates automatically	15.0	15.0	YES	2588.66
Aug Week 2	30.00	updates automatically	15.0	15.0	YES	2588.66
Aug Week 3	30.00	updates automatically	15.0	15.0	YES	2588.66
Aug Week 4	30.00	updates automatically	15.0	15.0	YES	2588.66
Sep Week 1	30.00	updates automatically	15.0	15.0	YES	2588.66
Sep Week 2	160.00	updates automatically	35.0	125.0	YES	2587.17
Sep Week 3	160.00	updates automatically	45.0	115.0	YES	2585.70
Sep Week 4	180.00	updates automatically	32.0	148.0	YES	2583.49
Oct Week 1	200.00	updates automatically	60.0	140.0	YES	2581.53
Oct Week 2	225.00	updates automatically	96.0	129.0	YES	2579.34
Oct Week 3	225.00	updates automatically	110.0	115.0	YES	2577.10
Oct Week 4	200.00	updates automatically	104.0	96.0	YES	2574.32
Nov Week 1	180.00	updates automatically	98.0	82.0	YES	2572.59
Nov Week 2	130.00	updates automatically	55.0	75.0	YES	2571.83
Nov Week 3	100.00	updates automatically	28.0	72.0	YES	2571.46
Nov Week 4	100.00	updates automatically	35.0	65.0	YES	2570.67
Dec Week 1	70.00	3.3	15.0	55.0	YES	2570.35
Dec Week 2	60.00	3,3	15.0	45.0	YES	2570.09
Dec Week 3	50.00	3.3	15.0	35.0	YES	2569.92
Dec Week 4	31.00	3.3	15.0	16.0	YES	2569.92

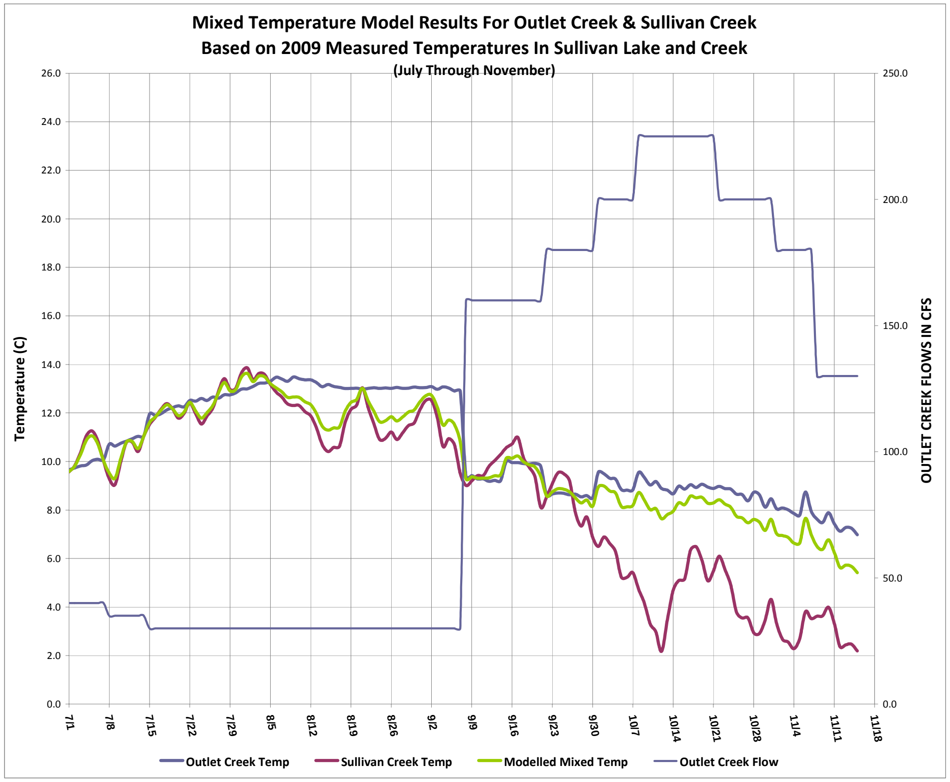


Figure 16
Sullivan Temperature Model Results-Scenario 1 (Wet Year) with Cold Water Release and Optimized Cooling

7.0 Results and Recommendations

This Sullivan Lake outflow temperature model can be used to examine rates of lake draining in the fall and impacts on downstream mixed water temperature. This model can also be used to examine the use of a cold water discharge pipe, and to see how successful this cold water pipe can be in lowering downstream temperatures, based on how deep in Sullivan Lake cold water is drawn from, and how much cold water flow is added. The model also can be used to examine pre-project or "without dam" conditions, to compare current operations with natural flow conditions.

The cold water release pipe was examined. It was found that using 2009 stream flow and temperature data, that the cold water release pipe could achieve a mixed water temperature (downstream of the confluence of Sullivan and Outlet Creeks) that was both a) within 1 degree C of the upstream Sullivan Creek water temperature; and b) never above 14 C. This includes accounting for groundwater seepage into Outlet Creek. The system actually demonstrated some excess capability that indicates additional cooling may be possible if needed under other hydrologic conditions. This capability is shown by the model to be adequate in dry, wet and average flow years.

To be able to monitor the system if a cold water pipe is installed, temperature recorders should be installed in Sullivan Creek both upstream and downstream of the confluence with Outlet Creek.

We recommend that in any future studies, when temperature data is gathered, simultaneous water flow measurements be taken in both Outlet Creek and Sullivan Creek. This will allow closer model calibration. In addition, we recommend that a simultaneous temperature measurement be made at the mouth of Sullivan Creek where it enters the Pend Oreille River, and also in the Pend Oreille River upstream and downstream of the Sullivan Creek confluence, so that a complete record of all temperature-related parameters for this system can be obtained simultaneously.

A copy of the EXCEL temperature model has been provided to all the agencies and the Tribe during Sullivan Dam talks. A copy is available to any interested Party.

8.0 Model Limitations

In using this model, several model limitations should be kept in mind:

1) This model is based on data gathered in one year, 2009. Therefore, the dates for some parameters, such as the date that the lake hits maximum temperature, the temperatures in Sullivan Creek, the maximum lake temperature, can be expected to be somewhat different in different years.

2) This model only works from July 1 through November 15, the time period of the available data upon which it was constructed. It could be easily modified to model longer periods if more data becomes available.

3) The calculations of mixed water temperature results are accurate, but the calibration results in this model are based on "inferred" flows in Sullivan Creek, based on some spot flow measurements and not a continuous flow record. In any future modeling, flow recorders should be installed on Sullivan Creek during the data gathering to improve accuracy of results.

Appendix A

WDFW Water Temperature Data
Collected between May 8 and November 16, 2009

SULLIVAN LAKE AND CREEK TEMPERATURE DATA

Collected by WDFW 2009

Converted to daily data by EESC Nov 17 2009

															75m DS	DS Mill Pond				In Lake			
													50m US Confluence		Confluence	1.5 km		75m DS of Dam		Just US of Dam 15m			
	Lake	Lake	Lake	Lake	Lake	Lake	Lake	Lake	Lake	Lake	Lake		Sullivan	Sullivan	Sullivan	Sullivan	Sullivan	Outlet	Outlet	Mill Pond	Mill Pond	Harvey	Harvey
	20m	18m	16m	14m	12m	10m	8m	6m	4m	2m	0m		Creek 1	Creek 2	Creek 4	Creek 5	Creek 6	Creek 1	Creek 2	1	2	1	2
5/8/2009	5.5	5.5	5.4	5.6	5.7	5.7	5.6	5.7	5.8	6.1	6.2		-	-	-	-	-	-	-	-	-	-	-
5/9/2009	5.1	5.1	5.3	5.5	5.8	5.7	5.7	6.0	6.2	6.5	6.7		-	-	-	-	-	-	-	-	-	-	-
5/10/2009	5.0	5.2	5.4	5.7	6.0	6.0	6.1	6.5	6.9	7.2	7.6		-	-	-	-	-	-	-	-	-	-	-
5/11/2009	4.9	5.1	5.0	5.3	5.6	5.7	6.0	6.5	6.9	7.4	7.6		-	-	-	-	-	-	-	-	-	-	-
5/12/2009	5.4	5.4	5.4	5.6	5.9	5.8	6.0	6.2	6.6	6.9	7.0		-	-	-	-	-	-	-	-	-	-	-
5/13/2009	5.6	5.7	5.9	6.3	6.6	6.5	6.5	6.7	6.8	6.9	6.9		-	-	-	-	-	-	-	-	-	-	-
5/14/2009	5.0	5.1	5.3	5.9	6.4	6.5	6.5	6.6	6.8	7.0	7.2		-	-	-	-	-	-	-	-	-	-	-
5/15/2009	5.1	5.1	5.1	5.5	6.0	6.2	6.4	6.6	6.9	7.2	8.0		-	-	-	-	-	-	-	-	-	-	-
5/16/2009	5.4	5.5	5.5	5.7	6.0	6.2	6.5	7.0	7.6	8.4	9.3		-	-	-	-	-	-	-	-	-	-	-
5/17/2009	5.1	5.2	5.3	5.5	6.0	6.3	7.2	7.9	8.4	8.7	9.4		-	-	-	-	-	-	-	-	-	-	-
5/18/2009	5.3	5.4	5.5	5.9	6.6	7.0	7.6	8.3	8.7	9.2	9.6		-	-	-	-	-	-	-	-	-	-	-
5/19/2009	6.3	6.4	6.6	6.9	7.4	7.7	8.2	8.8	9.0	9.1	9.4		-	-	-	-	-	-	-	-	-	-	-
5/20/2009	5.9	6.0	6.1	6.4	6.9	6.9	7.0	7.2	7.4	7.6	7.6		-	-	-	-	-	-	-	-	-	-	-
5/21/2009	5.4	5.6	5.8	6.3	6.8	7.0	7.3	7.6	7.8	8.1	8.9		-	-	-	-	-	-	-	-	-	-	-
5/22/2009	6.1	6.1	6.2	6.5	6.9	6.9	7.1	7.4	7.8	8.4	10.4		-	-	-	-	-	-	-	-	-	-	-
5/23/2009	5.9	6.0	6.1	6.4	6.8	6.9	7.1	7.5	8.1	9.4	12.1		-	-	-	-	-	-	-	-	-	-	-
5/24/2009	6.0	6.2	6.3	6.5	6.9	7.0	7.2	7.6	8.2	9.8	12.1		-	-	-	-	-	-	-	-	-	-	-
5/25/2009	6.0	6.1	6.2	6.5	6.8	6.9	7.1	7.6	9.2	12.0	13.0		-	-	-	-	-	-	-	-	-	-	-
5/26/2009	6.2	6.3	6.4	6.8	7.5	8.0	8.6	9.2	9.7	11.2	12.8		-	-	-	-	-	-	-	-	-	-	-
5/27/2009	6.0	6.2	6.4	7.0	7.5	8.0	8.7	9.6	10.6	11.1	11.3		-	-	-	-	-	-	-	-	-	-	-
5/28/2009	6.0	6.2	6.3	6.7	7.2	7.6	8.3	9.1	10.4	11.5	12.2		-	-	-	-	-	-	-	-	-	-	-
5/29/2009	6.0	6.2	6.3	6.7	7.2	7.5	8.3	9.2	10.4	12.1	14.1		-	-	-	-	-	-	-	-	-	-	-
5/30/2009	6.0	6.2	6.4	6.8	7.3	7.8	8.3	9.3	10.8	13.8	15.4		-	-	-	-	-	-	-	-	-	-	-
5/31/2009	6.1	6.2	6.4	6.8	7.4	7.8	8.4	9.1	10.1	13.3	15.7		-	-	-	-	-	-	-	-	-	-	-
6/1/2009	6.0	6.2	6.4	6.8	7.4	7.7	8.4	9.3	10.3	12.4	14.6		-	-	-	-	-	-	-	-	-	-	-
6/2/2009	6.4	6.6	6.8	7.1	7.7	7.8	8.2	8.7	9.6	10.7	11.4		-	-	-	-	-	-	-	-	-	-	-
6/3/2009	5.6	5.9	6.1	6.7	7.7	8.9	10.0	10.7	11.5	12.5	13.9		-	-	-	-	-	-	-	-	-	-	-
6/4/2009	6.4	6.5	6.7	7.0	7.7	8.3	9.3	10.7	12.1	13.4	15.5		-	-	-	-	-	-	-	-	-	-	-
6/5/2009	6.1	6.3	6.6	7.2	8.1	8.9	9.6	10.6	11.7	13.3	17.1		-	-	-	-	-	-	-	-	-	-	-
6/6/2009	6.3	6.5	6.8	7.4	8.1	8.7	9.3	10.2	11.5	13.3	14.5		-	-	-	-	-	-	-	-	-	-	-
6/7/2009	6.0	6.3	6.5	7.1	7.8	8.6	10.1	11.6	12.7	13.3	13.6		-	-	-	-	-	-	-	-	-	-	-
6/8/2009	6.4	6.7	7.0	7.6	8.3	9.0	10.0	11.1	12.1	13.2	14.0		-	-	-	-	-	-	-	-	-	-	-
6/9/2009	6.1	6.4	6.6	7.1	8.0	9.0	10.2	11.5	12.5	13.4	13.5		-	-	-	-	-	-	-	-	-	-	-
6/10/2009	6.2	6.5	6.7	7.3	8.2	9.2	10.6	11.6	12.7	13.5	14.8		-	-	-	-	-	-	-	-	-	-	-
6/11/2009	6.3	6.5	6.8	7.4	8.4	9.1	10.1	11.8	13.7	14.8	16.4		-	-	-	-	-	-	-	-	-	-	-
6/12/2009	6.2	6.5	6.7	7.5	8.5	9.6	10.4	11.4	13.4	15.6	17.9		-	-	-	-	-	-	-	-	-	-	-
6/13/2009	6.3	6.4	6.7	7.3	8.2	9.1	10.6	11.9	13.4	16.0	17.6		-	-	-	-	-	-	-	-	-	-	-
6/14/2009	6.3	6.5	6.8	7.4	8.3	9.3	10.8	12.4	14.7	16.9	17.4		-	-	-	-	-	-	-	-	-	-	-
6/15/2009	6.4	6.7	7.0	7.8	8.7	9.5	10.4	11.5	13.3	17.4	17.9		-	-	-	-	-	-	-	-	-	-	-
6/16/2009	6.3	6.4	6.7	7.3	8.1	9.4	10.9	12.7	14.8	16.6	17.9		-	-	-	-	-	-	-	-	-	-	-
6/17/2009	6.3	6.6	6.9	7.6	8.6	9.4	10.6	12.0	15.1	18.1	18.4		-	-	-	-	-	-	-	-	-	-	-
6/18/2009	6.3	6.6	7.0	7.7	8.6	9.7	11.0	12.7	15.6	17.9	18.4		-	-	-	-	-	-	-	-	-	-	-
6/19/2009	6.4	6.6	7.0	7.6	8.8	9.8	10.9	12.3	14.6	17.4	18.2		-	-	-	-	-	-	-	-	-	-	-
6/20/2009	6.3	6.5	6.8	7.4	8.4	9.6	11.1	12.6	15.1	17.3	17.5		-	-	-	-	-	-	-	-	-	-	-
6/21/2009	6.3	6.6	6.9	7.8	9.0	10.1	12.0	14.1	16.3	17.3	17.5		-	-	-	-	-	-	-	-	-	-	-
6/22/2009	6.5	6.7	7.0	7.7	8.5	9.5	10.8	14.8	16.7	16.9	16.8		-	-	-	-	-	-	-	-	-	-	-
6/23/2009	6.4	6.6	7.0	7.8	9.0	10.0	11.0	13.0	15.4	16.4	16.8		-	-	-	-	-	-	-	-	-	-	-
6/24/2009	6.3	6.5	6.9	7.6	8.7	10.0	11.8	13.4	15.2	16.8	17.1		-	-	-	-	-	-	-	-	-	-	-
6/25/2009	6.3	6.6	6.9	7.7	8.8	10.0	12.2	14.6	16.3	17.2	17.3		-	-	-	-	-	-	-	-	-	-	-
6/26/2009	6.6	6.9	7.3	8.2	9.2	10.0	11.1	12.7	15.4	16.9	17.2		-	-	-	-	-	-	-	-	-	-	-
6/27/2009	6.3	6.6	6.8	7.5	8.7	10.2	12.6	14.4	15.8	16.6	17.1		-	-	-	-	-	-	-	-	-	-	-
6/28/2009	7.2	7.8	8.4	9.6	11.2	11.9	12.9	14.1	17.0	17.4	17.8		-	-	-	-	-	-	-	-	-	-	-
6/29/2009	8.3	9.3	10.2	11.5	13.4	14.3	14.4	14.2	17.0	18.0	18.2		-	-	-	-	-	-	-	-	-	-	-
6/30/2009	6.5	6.7	7.1	7.9	9.0	10.5	12.2	14.2	17.1	18.7	18.8		-	-	-	-	-	-	-	-	-	-	-
7/1/2009	6.5	6.7	7.1	8.0	9.3	10.4	11.8	14.0	16.7	18.9	19.3	7/1/2009	9.6	9.6	11.7	12.4	12.4	15.0	14.8	12.3	12.3	9.9	9.9
7/2/2009	6.4	6.7	7.0	7.9	9.2	10.6	12.5	14.5	16.6	18.7	19.7	7/2/2009	9.8	9.8	12.0	12.8	12.8	15.3	15.1	12.5	12.5	10.2	10.2
7/3/2009	6.5	6.8	7.1	7.9	9.2	10.5	12.3	14.6	17.4	18.9	20.1	7/3/2009	10.4	10.4	12.4	13.3	13.2	15.4	15.2	13.1	13.0	10.8	10.8
7/4/2009	6.3	6.6	7.0	7.9	9.2	10.6	12.5	15.1	18.3	19.9	20.9	7/4/2009	11.1	11.1	13.0	13.9	13.8	15.8	15.6	13.5	13.5	11.6	11.6
7/5/2009	6.5	6.9	7.2	8.1	9.3	10.5	12.3	14.6	18.1	20.8	21.2	7/5/2009	11.3	11.2	13.2	14.1	14.1	15.8	15.6	13.9	13.9	11.7	11.7
7/6/2009	6.5	6.8	7.3	8.1	9.4	10.8	12.6	15.0	18.7	20.5	20.9	7/6/2009	10.9	10.9	12.9	13.9	13.8	16.1	15.9	13.8	13.8	11.5	11.5
7/7/2009	6.4	6.7	7.1	7.9	9.2	10.5	12.5	15.0	17.9	20.0	20.0	7/7/2009	10.0	10.0	12.5	13.1	13.0	16.2	16.0	13.1	13.1	10.5	10.6
7/8/2009	6.6	6.9	7.3	8.3	9.5	10.9	13.0	15.6	17.8	19.2	19.5	7/8/2009	9.3	9.3	12.0	12.7	12.7	16.2	16.0	12.5	12.6	9.7	9.8
7/9/2009	6.5	6.8	7.3	8.2	9.5	10.8	12.5	15.0	18.2	19.0	19.2	7/9/2009	9.0	9.0	12.0	12.3	12.3	16.1	15.9	12.2	12.3	9.5	9.5
7/10/2009	6.5	6.7	7.2	8.0	9.3	10.9	12.9	15.7	18.2	19.1	19.8	7/10/2009	10.0	10.0	12.8	12.7	12.6	16.5	16.2	12.4	12.5	10.1	10.2
7/11/2009	6.5	6.7	7.2	8.1	9.4	10.8	12.8	15.6	18.4	19.7	21.0	7/11/2009	10.8	10.8	13.3	13.5	13.5	16.7	16.5	13.1	13.1	11.3	11.4

SULLIVAN LAKE AND CREEK TEMPERATURE DATA

Collected by WDFW 2009

Converted to daily data by EESC Nov 17 2009

	Lake 20m	Lake 18m	Lake 16m	Lake 14m	Lake 12m	Lake 10m	Lake 8m	Lake 6m	Lake 4m	Lake 2m	Lake 0m		50m US Confluence Sullivan Creek 1	Sullivan Creek 2	75m DS Confluence Sullivan Creek 4	DS Mill Pond 1.5 km Sullivan Creek 5	Sullivan Creek 6	75m DS of Dam Outlet Creek 1	Outlet Creek 2	In Lake Just US of Dam 15m Mill Pond 1	Mill Pond 2	Harvey 1	Harvey 2
7/12/2009	6.5	6.8	7.3	8.1	9.3	10.7	13.1	15.9	18.9	20.1	20.8	7/12/2009	10.8	10.8	13.3	14.0	13.9	16.9	16.7	13.8	13.8	11.3	11.3
7/13/2009	6.5	6.8	7.1	8.1	9.5	10.9	13.0	16.4	20.0	20.3	20.2	7/13/2009	10.4	10.4	12.9	13.5	13.5	17.1	16.9	13.3	13.3	10.9	10.9
7/14/2009	6.4	6.8	7.2	8.1	9.5	10.9	13.1	16.4	19.7	20.0	20.2	7/14/2009	11.0	11.1	13.5	13.2	13.2	17.2	17.0	13.4	13.4	11.6	11.7
7/15/2009	6.5	6.9	7.3	8.2	9.5	11.1	13.5	15.8	19.0	20.5	21.1	7/15/2009	11.5	11.6	14.5	14.0	14.0	17.4	17.2	13.9	13.9	12.0	12.1
7/16/2009	6.5	6.9	7.4	8.3	9.5	10.6	13.1	16.3	19.7	21.0	21.7	7/16/2009	11.8	11.9	13.7	15.0	15.0	17.3	17.2	15.0	15.1	12.3	12.3
7/17/2009	6.5	6.7	7.2	8.1	9.6	11.4	13.8	16.4	19.4	21.6	22.4	7/17/2009	12.2	12.2	13.9	15.5	15.5	17.5	17.3	15.3	15.3	12.7	12.7
7/18/2009	6.5	6.9	7.3	8.2	9.4	10.9	13.4	17.2	20.5	22.1	22.7	7/18/2009	12.4	12.4	14.0	15.7	15.6	17.8	17.6	15.4	15.4	12.9	12.9
7/19/2009	6.5	6.8	7.4	8.4	9.8	11.6	13.8	16.4	19.8	21.7	22.2	7/19/2009	12.2	12.1	13.9	15.6	15.6	17.9	17.7	15.4	15.4	12.6	12.6
7/20/2009	6.6	6.9	7.3	8.4	9.6	10.8	13.5	17.4	19.9	20.9	21.7	7/20/2009	11.8	11.8	13.8	15.6	15.6	18.0	17.8	15.6	15.6	12.2	12.3
7/21/2009	6.4	6.7	7.2	8.3	10.0	11.5	13.9	16.6	20.5	21.8	22.6	7/21/2009	12.0	12.0	14.0	15.9	15.9	18.1	17.9	15.8	15.7	12.4	12.4
7/22/2009	6.6	6.9	7.3	8.1	9.3	10.9	13.7	17.8	20.7	22.6	23.1	7/22/2009	12.4	12.5	14.4	16.3	16.3	18.4	18.2	16.3	16.3	12.9	12.9
7/23/2009	6.5	6.8	7.3	8.4	10.1	11.8	14.1	16.8	20.3	22.7	22.9	7/23/2009	12.0	12.0	14.1	16.0	16.0	18.5	18.3	15.7	15.8	12.3	12.3
7/24/2009	6.7	7.0	7.5	8.4	9.7	11.3	13.8	17.9	20.3	21.2	21.5	7/24/2009	11.5	11.6	13.8	15.3	15.3	18.5	18.4	15.2	15.2	12.0	12.0
7/25/2009	6.4	6.7	7.3	8.5	10.1	11.7	13.8	17.3	20.6	20.9	21.1	7/25/2009	11.9	11.9	14.2	15.1	15.0	18.6	18.4	14.7	14.8	12.1	12.1
7/26/2009	6.7	6.9	7.4	8.2	9.6	11.3	14.4	17.8	20.6	21.1	21.4	7/26/2009	12.2	12.2	14.4	15.7	15.7	18.7	18.4	15.6	15.6	12.3	12.4
7/27/2009	6.4	6.8	7.3	8.5	10.2	11.7	14.3	17.6	21.0	21.5	22.4	7/27/2009	12.9	12.9	14.8	16.0	15.9	18.8	18.5	15.6	15.7	13.1	13.1
7/28/2009	6.6	6.9	7.4	8.3	9.7	11.4	14.1	17.7	20.8	22.0	22.6	7/28/2009	13.4	13.4	15.1	16.7	16.7	18.9	18.7	16.3	16.4	13.7	13.8
7/29/2009	6.5	6.9	7.4	8.6	10.2	12.0	14.6	18.1	20.8	21.9	22.5	7/29/2009	13.0	13.0	14.8	16.9	16.9	19.0	18.8	16.6	16.6	13.6	13.6
7/30/2009	6.5	6.9	7.4	8.5	10.0	11.8	14.8	18.1	21.6	22.6	23.6	7/30/2009	13.0	13.0	15.1	16.9	16.8	19.1	18.9	16.3	16.3	13.7	13.7
7/31/2009	6.6	7.0	7.5	8.4	9.9	11.7	14.5	18.4	21.9	23.1	24.0	7/31/2009	13.7	13.7	15.5	17.3	17.3	19.4	19.1	16.7	16.7	14.3	14.4
8/1/2009	6.5	6.8	7.3	8.4	10.1	11.7	14.4	19.1	22.4	23.5	23.9	8/1/2009	13.9	13.9	15.6	17.6	17.6	19.5	19.3	17.1	17.1	14.5	14.5
8/2/2009	6.5	6.8	7.3	8.3	9.8	12.1	15.3	18.5	21.7	23.7	24.3	8/2/2009	13.4	13.4	15.2	17.6	17.5	19.6	19.4	17.1	17.1	13.9	13.9
8/3/2009	6.6	7.0	7.6	8.7	10.1	11.5	14.1	19.7	22.3	23.7	24.1	8/3/2009	13.6	13.7	15.5	17.8	17.7	19.8	19.7	17.3	17.3	14.2	14.3
8/4/2009	6.5	6.8	7.2	8.3	10.0	12.1	15.4	18.8	23.2	24.0	24.1	8/4/2009	13.6	13.6	15.4	17.8	17.7	20.0	19.8	17.5	17.5	14.1	14.1
8/5/2009	6.6	6.9	7.4	8.4	10.0	12.1	15.3	18.7	23.0	23.9	24.0	8/5/2009	13.2	13.2	15.1	17.5	17.4	20.0	19.9	17.3	17.3	13.5	13.5
8/6/2009	6.8	7.3	7.8	8.9	10.2	11.8	14.5	19.1	22.4	23.6	23.7	8/6/2009	12.9	12.9	14.9	17.1	17.0	20.2	20.0	16.7	16.8	13.4	13.4
8/7/2009	6.6	7.0	7.5	8.5	10.1	12.4	15.4	19.6	22.2	23.0	23.2	8/7/2009	12.7	12.7	14.9	16.7	16.7	20.2	20.1	16.7	16.7	13.3	13.4
8/8/2009	6.4	6.8	7.3	8.5	10.2	12.2	15.4	20.5	22.8	22.9	22.8	8/8/2009	12.4	12.4	14.8	16.5	16.5	20.2	20.0	16.4	16.4	13.0	13.0
8/9/2009	6.7	7.2	7.7	8.7	10.1	12.0	15.2	19.2	22.3	22.5	22.6	8/9/2009	12.3	12.4	14.6	16.3	16.3	20.3	20.1	16.2	16.2	12.9	13.0
8/10/2009	6.6	7.0	7.6	8.7	10.2	12.1	15.7	20.4	22.2	22.3	22.4	8/10/2009	12.3	12.3	14.7	16.4	16.3	20.2	20.1	16.3	16.3	12.7	12.7
8/11/2009	6.6	7.0	7.5	8.7	10.7	12.6	16.2	19.9	22.0	22.0	22.1	8/11/2009	12.1	12.1	14.5	16.2	16.1	20.1	20.0	16.1	16.2	12.3	12.3
8/12/2009	6.7	7.2	7.8	8.9	10.4	12.6	15.3	19.0	21.3	21.6	21.6	8/12/2009	11.9	11.9	14.4	15.7	15.7	20.0	19.8	15.6	15.6	12.4	12.4
8/13/2009	6.7	7.0	7.6	8.7	10.2	12.1	15.7	19.3	20.8	21.0	21.0	8/13/2009	11.4	11.4	14.2	15.4	15.4	19.9	19.7	15.3	15.3	12.1	12.1
8/14/2009	6.5	6.9	7.4	8.8	10.6	12.7	16.2	19.5	20.5	20.6	20.5	8/14/2009	10.7	10.7	13.5	14.8	14.8	19.7	19.4	14.9	14.9	11.2	11.2
8/15/2009	6.7	7.2	7.8	8.9	10.4	12.2	15.6	19.6	20.2	20.3	20.4	8/15/2009	10.4	10.4	13.2	14.6	14.5	19.6	19.5	14.6	14.6	10.6	10.7
8/16/2009	6.6	7.0	7.7	8.9	10.8	12.7	15.8	19.2	20.1	20.3	20.5	8/16/2009	10.6	10.6	13.4	14.6	14.6	19.6	19.4	14.5	14.6	11.3	11.3
8/17/2009	6.6	7.1	7.7	8.9	10.4	12.5	16.1	19.4	20.0	20.2	20.8	8/17/2009	10.6	10.7	13.6	15.0	14.9	19.5	19.3	14.7	14.7	11.7	11.7
8/18/2009	6.6	7.0	7.6	8.8	10.5	12.4	15.8	19.4	20.1	20.5	21.3	8/18/2009	11.6	11.7	14.5	15.3	15.3	19.4	19.2	14.9	14.9	12.1	12.2
8/19/2009	6.6	7.0	7.6	8.8	10.6	12.7	15.8	19.4	20.3	20.8	21.7	8/19/2009	12.1	12.2	14.8	15.9	15.9	19.4	19.2	15.6	15.6	12.2	12.2
8/20/2009	6.6	7.1	7.7	8.7	10.4	12.4	16.0	19.7	20.4	20.9	21.8	8/20/2009	12.3	12.4	14.8	16.4	16.3	19.4	19.2	15.9	16.0	11.9	11.9
8/21/2009	6.5	6.9	7.6	8.8	10.5	12.8	16.5	20.5	21.1	21.6	21.9	8/21/2009	13.0	13.1	15.4	17.0	16.9	19.4	19.2	16.6	16.6	11.7	11.7
8/22/2009	6.6	7.0	7.6	8.8	10.7	12.7	16.1	20.1	21.4	21.6	21.7	8/22/2009	12.2	12.2	14.1	16.6	16.6	19.4	19.2	16.6	16.7	11.2	11.2
8/23/2009	6.7	7.1	7.8	8.8	10.4	12.5	16.5	19.7	21.2	21.5	21.6	8/23/2009	11.5	11.5	13.5	16.1	16.1	19.4	19.2	16.2	16.3	10.9	10.9
8/24/2009	6.6	7.0	7.7	9.1	10.9	12.9	16.4	19.9	21.0	21.2	21.4	8/24/2009	10.9	10.9	13.0	15.9	15.9	19.4	19.2	16.0	16.0	10.7	10.7
8/25/2009	6.7	7.1	7.7	8.8	10.4	13.0	17.5	20.2	21.0	21.1	21.2	8/25/2009	11.0	11.0	13.3	15.7	15.6	19.4	19.2	15.7	15.7	10.6	10.6
8/26/2009	6.6	7.1	7.8	9.2	11.1	13.2	16.7	20.2	20.9	20.9	21.0	8/26/2009	11.2	11.3	13.7	15.7	15.6	19.4	19.2	15.6	15.6	10.7	10.7
8/27/2009	6.8	7.1	7.8	9.0	10.6	12.9	16.5	19.8	20.7	20.8	21.2	8/27/2009	10.9	10.9	13.2	15.4	15.4	19.4	19.2	15.4	15.4	10.7	10.7
8/28/2009	6.6	7.0	7.8	8.9	10.9	13.2	17.1	19.3	20.5	20.7	21.2	8/28/2009	11.2	11.2	13.8	15.8	15.7	19.4	19.3	15.5	15.5	10.9	10.9
8/29/2009	6.7	7.0	7.7	9.0	10.9	13.0	17.0	19.9	20.6	21.0	21.0	8/29/2009	11.5	11.5	14.1	15.8	15.7	19.4	19.2	15.3	15.3	10.7	10.7
8/30/2009	6.7	7.1	7.8	9.0	10.9	13.1	16.8	19.8	20.6	20.8	21.4	8/30/2009	11.6	11.6	14.2	15.6	15.6	19.5	19.3	15.3	15.3	11.1	11.2
8/31/2009	6.6	7.1	7.8	9.0	10.8	13.0	17.4	19.7	20.5	20.9	21.3	8/31/2009	12.1	12.1	14.7	16.2	16.2	19.5	19.3	15.8	15.8	11.3	11.4
9/1/2009	6.7	7.1	7.8	9.0	11.0	13.2	16.6	20.0	21.1	21.4	22.2	9/1/2009	12.5	12.5	15.1	16.6	16.6	19.4	19.3	16.1	16.2	11.5	11.6
9/2/2009	6.7	7.1	7.8	8.9	10.6	13.1	17.5	19.9	20.8	21.7	22.2	9/2/2009	12.5	12.6	14.9	16.7	16.7	19.5	19.3	16.3	16.3	11.5	11.5
9/3/2009	6.6	7.2	8.0	9.4	11.3	14.2	19.0	20.5	21.1	21.5	21.5	9/3/2009	11.8	11.8	13.8	16.1	16.0	19.3	19.2	16.1	16.2	11.2	11.3
9/4/2009	6.8	7.2	7.9	9.1	10.8	13.4	16.6	20.0	20.6	20.6	20.9	9/4/2009	10.6	10.6	12.6	15.3	15.3	19.3	19.2	15.6	15.6	11.1	11.1
9/5/2009	6.7	7.2	7.9	9.1	11.0	13.3	18.2	19.3	20.0	20.1	20.3	9/5/2009	10.9	11.0	13.4	15.4	15.4	19.3	19.2	15.4	15.5	10.9	11.0
9/6/2009	6.6	7.3	8.1	9.4	11.2	13.7	19.0	19.7	19.9	19.9	19.9	9/6/2009	10.7	10.7	12.6	15.0	15.0	19.2	19.0	15.2	15.2	10.6	10.6
9/7/2009	6.8	7.2	7.9	9.1	11.0	13.3	17.9	19.2	19.3	19.3	19.3	9/7/2009	9.5	9.5	11.4	14.1	14.1	19.0	18.8	14.5	14.5	10.1	10.1
9/8/2009	6.7	7.2	8.0	9.3	11.1	13.2	17.2	18.9	19.0	19.1	19.1	9/8/2009	9.0	9.0	11.7	13.8	13.8	18.9	18.8	14.2	14.2	10.2	10.3
9/9/2009	6.8	7.3	8.0	9.2	10.8	13.5	17.2	18.7	18.8	18.8	18.9	9/9/2009	9.2	9.3	11.9	13.7	13.7	18.8	18.6	13.9	13.9	10.3	10.3
9/10/2009	6.6	7.1	7.9	9.3	11.3	13.9	16.9	18.3	18.5	18.6	18.7	9/10/2009	9.4	9.5	12.0	13.6	13.6	18.7	18.6	13.7	13.7	10.5	10.5
9/11/2009	6.7	7.1	7.9	9.2	11.0	13.6	17.3	18.1	18.3	18.4	18.8	9/11/2009	9.4	9.4	12.2	13.8	13.8	18.6	18.4	13.9	13.9	10.6	10.6
9/12/2009	6.6	7.1	7.9	9.2	11.0	13.5	17.7	18.2	18.3	18.5	19.2	9/12/2009	9.8	9.8	12.6	14.1	14.0	18.5	18.3	14.1	14.1	10.9	10.9

SULLIVAN LAKE AND CREEK TEMPERATURE DATA

Collected by WDFW 2009

Converted to daily data by EESC Nov 17 2009

	Lake 20m	Lake 18m	Lake 16m	Lake 14m	Lake 12m	Lake 10m	Lake 8m	Lake 6m	Lake 4m	Lake 2m	Lake 0m		50m US Confluence Sullivan Creek 1	Sullivan Creek 2	75m DS Confluence Sullivan Creek 4	DS Mill Pond 1.5 km Sullivan Creek 5	Sullivan Creek 6	75m DS of Dam Outlet Creek 1	Outlet Creek 2	In Lake Just US of Dam 15m Mill Pond 1	Mill Pond 2	Harvey 1	Harvey 2
9/13/2009	6.6	7.1	7.9	9.2	11.0	13.9	17.7	18.2	18.5	19.0	19.8	9/13/2009	10.0	10.1	12.8	14.2	14.2	18.4	18.3	14.2	14.2	11.2	11.2
9/14/2009	6.6	7.1	7.9	9.3	11.1	13.9	17.7	18.4	18.8	19.0	19.3	9/14/2009	10.3	10.3	12.9	14.3	14.3	18.4	18.2	14.3	14.3	10.9	10.9
9/15/2009	6.7	7.3	8.2	9.5	11.2	13.6	17.3	18.5	18.9	18.9	19.4	9/15/2009	10.6	10.6	13.3	14.4	14.4	18.4	18.3	14.6	14.6	11.4	11.4
9/16/2009	6.7	7.1	7.7	9.1	11.0	14.3	17.4	18.3	18.8	19.0	19.4	9/16/2009	10.7	10.7	13.5	14.8	14.8	18.4	18.2	15.0	15.1	11.6	11.6
9/17/2009	6.7	7.2	8.1	9.4	11.1	13.7	17.5	18.6	19.1	19.3	19.3	9/17/2009	11.0	11.0	13.5	14.7	14.7	18.3	18.2	14.6	14.7	12.1	12.1
9/18/2009	6.7	7.1	7.9	9.2	11.1	13.9	17.4	18.5	18.9	19.1	19.3	9/18/2009	10.1	10.2	12.5	14.4	14.3	18.2	18.0	14.3	14.4	11.6	11.6
9/19/2009	6.7	7.1	7.9	9.3	11.2	14.4	17.6	18.5	18.7	18.8	18.8	9/19/2009	9.8	9.8	12.0	14.1	14.1	18.1	18.0	14.1	14.1	10.8	10.8
9/20/2009	6.7	7.3	8.1	9.5	11.3	13.3	16.9	18.3	18.5	18.5	18.6	9/20/2009	9.4	9.4	11.3	13.4	13.4	18.0	17.9	13.8	13.8	11.1	11.1
9/21/2009	6.6	7.1	7.8	9.0	11.3	14.6	17.0	17.8	18.0	18.1	18.2	9/21/2009	8.1	8.1	10.5	13.1	13.0	17.9	17.7	13.5	13.5	10.2	10.2
9/22/2009	6.6	7.1	7.9	9.3	11.1	14.0	17.4	17.7	17.9	18.0	18.4	9/22/2009	8.5	8.5	11.4	13.2	13.2	17.9	17.7	13.5	13.5	11.0	10.9
9/23/2009	6.7	7.2	8.0	9.3	11.3	14.4	17.3	17.7	17.9	18.0	18.7	9/23/2009	9.1	9.1	12.1	13.5	13.5	17.9	17.7	13.6	13.6	11.4	11.4
9/24/2009	6.7	7.2	8.0	9.3	11.2	14.4	17.4	17.8	18.0	18.2	18.9	9/24/2009	9.5	9.6	12.3	13.7	13.6	17.9	17.6	13.6	13.6	11.6	11.6
9/25/2009	6.7	7.2	8.1	9.5	11.3	14.1	17.4	17.8	18.2	18.4	18.9	9/25/2009	9.5	9.5	12.2	13.6	13.6	17.8	17.6	13.6	13.7	11.7	11.6
9/26/2009	6.7	7.1	7.9	9.2	11.2	14.8	17.4	17.9	18.1	18.2	18.4	9/26/2009	9.2	9.2	11.7	13.2	13.2	17.7	17.6	13.4	13.4	11.4	11.3
9/27/2009	6.7	7.2	8.1	9.6	11.5	14.3	17.1	17.7	17.8	17.9	17.9	9/27/2009	7.9	7.9	10.0	12.5	12.5	17.6	17.4	13.0	13.1	10.1	10.0
9/28/2009	6.6	7.1	8.0	9.5	11.7	15.0	17.0	17.4	17.4	17.5	17.6	9/28/2009	7.3	7.4	9.9	12.4	12.3	17.4	17.3	12.8	12.8	9.9	9.7
9/29/2009	6.8	7.3	8.1	9.4	11.2	15.9	17.0	17.0	17.1	17.1	17.1	9/29/2009	7.7	7.7	11.0	12.0	12.0	17.1	17.0	12.4	12.4	9.3	9.2
9/30/2009	6.7	7.2	8.1	9.5	11.2	14.4	16.5	16.6	16.6	16.7	16.7	9/30/2009	6.9	6.9	9.7	11.5	11.5	16.9	16.7	12.0	12.0	8.2	8.2
10/1/2009	6.6	7.1	7.8	9.3	11.5	15.3	16.1	16.2	16.3	16.3	16.3	10/1/2009	6.5	6.5	12.8	11.3	11.2	16.4	16.2	11.7	11.7	7.8	7.7
10/2/2009	6.7	7.2	8.0	9.3	11.3	14.3	15.8	15.8	15.8	15.9	15.8	10/2/2009	6.9	6.9	15.4	11.7	11.6	16.0	15.8	12.0	12.0	8.2	8.1
10/3/2009	6.6	7.1	7.9	9.1	10.7	12.9	14.8	15.5	15.5	15.6	15.5	10/3/2009	6.6	6.6	15.1	11.7	11.7	15.6	15.4	12.0	12.0	8.2	8.2
10/4/2009	6.9	7.5	8.4	9.6	10.8	11.8	13.1	14.4	14.8	14.9	14.8	10/4/2009	6.3	6.3	14.5	11.6	11.6	14.9	14.7	11.9	11.9	8.4	8.2
10/5/2009	6.6	7.2	8.5	10.2	12.0	13.1	13.7	13.9	14.0	14.1	14.1	10/5/2009	5.2	5.2	13.8	11.3	11.3	14.1	13.9	11.6	11.6	8.3	8.1
10/6/2009	6.6	7.2	8.0	9.8	12.2	13.5	13.7	13.6	13.7	13.8	13.8	10/6/2009	5.2	5.2	13.7	11.3	11.2	13.9	13.7	11.5	11.5	7.8	7.6
10/7/2009	6.8	7.3	8.1	9.5	11.5	13.1	13.4	13.5	13.5	13.6	13.5	10/7/2009	5.4	5.4	13.5	11.3	11.2	13.6	13.4	11.5	11.5	8.1	8.0
10/8/2009	6.8	7.4	8.7	10.5	12.5	12.9	13.0	13.1	13.1	13.2	13.2	10/8/2009	4.7	4.8	13.1	10.9	10.8	13.2	13.0	11.2	11.2	6.9	7.0
10/9/2009	6.7	7.2	7.9	9.6	11.6	12.4	12.6	12.7	12.7	12.8	12.8	10/9/2009	4.2	4.2	12.7	10.6	10.5	12.8	12.6	10.9	10.9	6.3	6.5
10/10/2009	6.4	7.0	8.3	10.3	11.9	12.3	12.3	12.3	12.4	12.5	12.5	10/10/2009	3.3	3.3	12.4	10.1	10.1	12.5	12.3	10.4	10.5	5.6	5.7
10/11/2009	6.9	7.4	8.2	10.0	11.5	12.0	12.1	12.1	12.2	12.3	12.2	10/11/2009	3.0	3.0	12.2	9.8	9.8	12.3	12.1	10.1	10.2	4.7	5.1
10/12/2009	6.6	7.0	8.0	9.8	11.8	11.8	11.7	11.8	11.8	12.0	11.9	10/12/2009	2.2	2.2	11.9	9.4	9.4	12.0	11.8	9.7	9.8	4.0	4.5
10/13/2009	6.7	7.2	8.0	9.1	10.7	11.4	11.4	11.5	11.5	11.6	11.5	10/13/2009	3.5	3.5	11.7	9.3	9.3	11.7	11.4	9.5	9.5	4.9	5.0
10/14/2009	6.6	7.2	8.4	10.2	11.3	11.2	11.2	11.3	11.2	11.4	11.3	10/14/2009	4.7	4.7	11.6	9.5	9.4	11.5	11.2	9.6	9.6	6.0	6.0
10/15/2009	6.7	7.3	8.4	10.3	11.3	11.2	11.1	11.2	11.2	11.4	11.3	10/15/2009	5.1	5.1	11.5	9.6	9.6	11.4	11.1	9.6	9.7	7.6	7.6
10/16/2009	6.5	7.0	7.9	10.7	11.1	11.2	11.1	11.0	11.2	11.3	11.3	10/16/2009	5.2	5.2	11.4	9.6	9.6	11.3	11.2	9.7	9.7	8.5	8.4
10/17/2009	6.7	7.2	8.4	10.7	11.1	11.2	11.1	11.2	11.2	11.4	11.4	10/17/2009	6.3	6.3	11.6	10.1	10.1	11.5	11.3	10.0	10.0	9.1	9.1
10/18/2009	6.4	6.9	8.1	10.9	11.2	11.2	11.1	11.3	11.2	11.4	11.4	10/18/2009	6.5	6.5	11.7	10.3	10.3	11.5	11.3	10.3	10.3	8.6	8.6
10/19/2009	6.6	7.0	7.7	9.8	11.3	11.2	11.1	11.3	11.2	11.4	11.4	10/19/2009	5.9	6.0	11.6	10.3	10.2	11.6	11.4	10.3	10.4	9.0	9.0
10/20/2009	6.5	7.0	7.8	10.1	11.1	11.2	11.1	11.3	11.2	11.4	11.4	10/20/2009	5.1	5.1	11.4	9.9	9.9	11.5	11.3	10.1	10.2	8.6	8.6
10/21/2009	6.6	7.1	7.9	9.9	11.1	11.1	11.1	11.1	11.2	11.3	11.2	10/21/2009	5.5	5.5	11.4	9.9	9.9	11.3	11.1	10.0	10.0	8.7	8.7
10/22/2009	6.5	7.0	7.8	10.2	11.1	11.1	11.1	11.0	11.1	11.2	11.3	10/22/2009	6.1	6.1	11.4	10.0	10.0	11.3	11.1	10.0	10.1	9.2	9.2
10/23/2009	6.4	6.8	7.7	9.9	11.1	10.9	11.0	11.0	10.9	11.1	10.9	10/23/2009	5.6	5.6	11.1	9.9	9.9	11.2	10.8	10.0	10.0	8.6	8.6
10/24/2009	6.5	7.1	7.9	9.7	11.0	10.9	10.8	10.9	10.9	11.0	11.0	10/24/2009	4.9	4.9	11.1	9.5	9.5	11.0	10.8	9.7	9.8	5.8	5.8
10/25/2009	6.4	6.9	7.7	9.6	10.8	10.6	10.5	10.7	10.6	10.8	10.6	10/25/2009	3.8	3.8	10.8	9.0	9.0	10.7	10.5	9.3	9.3	4.4	4.4
10/26/2009	6.6	7.1	8.1	9.7	10.5	10.4	10.4	10.4	10.4	10.5	10.4	10/26/2009	3.6	3.5	10.5	8.7	8.7	10.5	10.3	8.9	8.9	4.1	4.2
10/27/2009	6.3	6.8	7.9	9.6	10.3	10.1	10.1	10.1	10.2	10.2	10.2	10/27/2009	3.6	3.6	10.3	8.4	8.3	10.3	10.1	8.5	8.5	3.2	3.3
10/28/2009	6.6	7.0	7.7	9.7	10.0	10.0	9.9	9.9	10.0	10.1	10.0	10/28/2009	2.9	2.9	8.6	8.0	8.0	10.7	10.5	8.2	8.3	3.0	3.1
10/29/2009	6.5	7.0	8.1	9.6	9.9	9.7	9.6	9.7	9.8	9.8	9.7	10/29/2009	2.9	2.9	6.6	7.5	7.4	10.6	10.4	7.8	7.9	3.3	3.3
10/30/2009	6.5	6.9	7.7	9.3	9.7	9.5	9.4	9.5	9.5	9.6	9.5	10/30/2009	3.5	3.5	9.7	7.8	7.8	9.6	9.4	8.0	8.0	4.5	4.6
10/31/2009	7.2	7.9	8.5	9.4	9.7	9.4	9.3	9.5	9.5	9.6	9.5	10/31/2009	4.3	4.4	9.7	8.2	8.2	9.6	9.4	8.4	8.4	5.4	5.4
11/1/2009	6.3	7.1	7.7	8.8	9.3	9.4	9.3	9.3	9.5	9.6	9.6	11/1/2009	3.3	3.3	9.6	8.2	8.2	9.5	9.4	8.3	8.4	3.2	3.2
11/2/2009	6.6	7.2	8.0	8.8	9.4	9.2	9.1	9.3	9.3	9.4	9.3	11/2/2009	2.7	2.7	9.4	7.9	7.9	9.3	9.1	8.1	8.1	3.0	3.0
11/3/2009	6.5	7.1	7.8	8.7	9.2	9.1	9.1	9.1	9.2	9.3	9.3	11/3/2009	2.6	2.5	9.3	7.8	7.8	9.2	9.0	8.0	8.0	3.6	3.6
11/4/2009	6.4	6.9	7.6	8.7	9.1	8.9	8.8	9.0	8.9	9.1	9.0	11/4/2009	2.3	2.3	9.1	7.6	7.6	9.0	8.8	7.8	7.8	4.3	4.3
11/5/2009	6.4	6.8	7.5	8.7	8.9	8.9	8.8	8.7	8.9	9.0	9.0	11/5/2009	2.7	2.7	9.0	7.6	7.6	9.0	8.7	7.7	7.7	4.2	4.3
11/6/2009	8.6	8.7	8.6	8.8	8.8	8.8	8.7	8.7	8.8	8.8	8.8	11/6/2009	3.8	3.8	9.0	7.8	7.8	8.9	8.7	7.8	7.8	4.0	4.0
11/7/2009	7.1	7.6	8.1	8.4	8.7	8.6	8.5	8.4	8.6	8.6	8.5	11/7/2009	3.5	3.5	8.9	7.3	7.3	8.7	8.5	7.4	7.5	3.0	3.0
11/8/2009	6.9	7.6	8.1	8.3	8.5	8.3	8.3	8.4	8.3	8.5	8.3	11/8/2009	3.6	3.6	8.8	7.0	7.0	8.6	8.4	7.1	7.2	3.4	3.4
11/9/2009	6.8	7.2	7.6	8.1	8.4	8.3	8.2	8.2	8.3	8.4	8.3	11/9/2009	3.6	3.7	8.5	6.9	6.9	8.4	8.2	7.0	7.0	3.6	3.7
11/10/2009	7.6	7.8	7.9	8.2	8.2	8.2	8.2	8.1	8.2	8.2	8.2	11/10/2009	4.0	4.0	8.4	7.3	7.3	8.3	8.1	7.4	7.4	4.1	4.1
11/11/2009	6.9	7.1	7.3	7.9	8.2	8.0	7.9	8.1	8.0	8.2	8.0	11/11/2009	3.3	3.3	8.3	7.2	7.2	8.2	7.9	7.3	7.3	3.4	3.5
11/12/2009	6.5	6.8	7.1	7.4	7.9	7.8	7.8	7.8	7.8	7.9	7.8	11/12/2009	2.4	2.4	8.0	6.9	6.9	8.0	7.7	7.0	7.0	4.0	4.0
11/13/2009	6.9	7.1	7.4	7.6	7.8	7.7	7.6	7.6	7.7	7.8	7.7	11/13/2009	2.4	2.4	7.8	6.8	6.7	7.8	7.5	6.9	6.9	2.7	2.8
11/14/2009	7.0	7.3	7.4	7.5	7.7	7.4	7.4	7.5	7.5	7.6	7.5	11/14/2009	2.5	2.5	7.6	6.6	6.6	7.6	7.4	6.7	6.7	3.2	3.2
11/15/2009	6.8	7.2	7.3	7.4	7.6	7.4	7.3	7.3	7.4	7.4	7.4	11/15/2009	2.2	2.2	7.6	6.5	6.4	7.5	7.3	6.5	6.6	3.7	3.7

Attachment 2

Sullivan Lake Dam Cold Water Gravity Intake Conceptual Design

TECHNICAL MEMORANDUM 003

MCMILLEN, LLC

To:	Peter Barton	Project:	Sullivan Lake Dam Cold Water Gravity Intake Conceptual Design
From:	Mort McMillen	Cc:	File
Date:	January 5, 2010	Job No:	
Subject:	F&A PME Measure No. XX: Sullivan Lake Dam Cold Water Gravity Intake – Advanced Gravity Water Supply		

Confidential Document Prepared for Purposes of Settlement Negotiations

1.0 PURPOSE

The purpose of this memorandum is to outline the conceptual design approach, operating parameters, and cost associated with developing a cold water gravity intake at the existing Sullivan Lake Dam.

2.0 BACKGROUND

The resource agencies have indicated that cold water may be desirable downstream of Sullivan Lake Dam to lower downstream creek temperatures, improving habitat conditions for resident fish species. To deliver cold water from the existing Sullivan Lake reservoir, a cold water intake will be required to withdraw water from depth at Sullivan Lake and deliver the cold water to the project tailrace. The resource agencies have indicated that the cold water intake could require a flow capacity ranging from 40 to 200 cubic feet per second (cfs). In order to ensure water temperatures are approximately 5 °C (41 °F) or below, the intake structure for the pipeline will be at a depth of approximately 120 feet (ft) in the reservoir.

3.0 DESIGN APPROACH

McMillen, LLC (McMillen) has been involved in developing cold water intake systems for hatcheries located in Southeast Alaska. These intake systems have similar physical and reservoir operation conditions to those found at Sullivan Lake Dam where the reservoir level fluctuates with the season and a cold water gravity intake is desired to provide cold water for a downstream use. The operating intake systems located in Southeast Alaska consist of a high-density polyethylene (HDPE) pipe installed along the reservoir floor to a point in the lake where sufficient depth is available to meet the temperature criteria. The HDPE pipe was sized to minimize headloss through the pipe system allowing the pipeline to operate as a "siphon" during low reservoir periods. An intake trashrack was installed on the pipeline to remove debris, though these deep intakes tend to see very little debris. The pipeline normally extends through the dam with the hydraulic control valve located at a lower elevation downstream from the dam crest.

The operating cold water intakes in Alaska were constructed at a relatively low cost compared to conventional intake and pipeline projects.

For the Sullivan Lake Project, a similar approach would be used. A HDPE pipeline will extend out into the reservoir approximately 800 to 1000 ft following the lake profile to reach the 120 ft minimum depth requirement. The pipeline would then be routed through the dam into the project tailrace. Two options are available for routing the pipeline through the dam:

(1) Option 1. Route through the left abutment (looking downstream) to a discharge valve house located downstream from the dam on the left bank. This option would require extensive work to penetrate the dam and extend the pipe through the non-overflow dam abutment. The main advantage to this option is that the downstream end of the pipe could be constructed at a lower elevation allowing the lake to be drafted through a siphon operation.

(2) Option 2. Route the pipe through one of the existing low level outlets. These outlets are four ft square and fitted with an upstream sluice gate to control the flow released from the reservoir. A total of three existing conduits are currently in operation. With this option, the pipe would be extended through the existing conduit with a downstream control gate mounted to the pipe. The pipe would discharge onto the existing concrete apron. The main advantage to this option is that the existing outlet conduit could be used minimizing the impact to the existing dam structure. The main disadvantage is that the pipeline would not be operational at lower reservoir elevations since the downstream pipe elevation would be set by the existing concrete conduit outlet.

Working with the PUD, Option 2 was the preferred approach, so the conceptual design presented within this memorandum is based on Option 2. A brief description of the primary intake components is presented in the following paragraphs and illustrated in Drawings 1 through 4.

Hydraulic Analysis. McMillen completed a hydraulic analysis considering various pipeline sizes and the downstream pipeline outlet elevation to determine the potential hydraulic capacity of the cold water intake. As outlined in the previous paragraph, two options were considered for routing the water supply pipeline through the dam: (1) Option 1 through the left abutment to a downstream outlet structure, and (2) Option 2 through the dam utilizing an existing outlet conduit. The analysis was completed assuming a reservoir operating range of 2588.0 ft to 2563.0 ft. The lower reservoir operating levels are only achievable if the pipeline outlet structure is moved downstream to a point where the pipeline invert elevation of 2555.0 ft could be provided (Option 1). The analysis was completed assuming both a trashrack box (Figure 1 and Table 1) installed on the intake pipe as well as full criteria fish screens (Figure 2 and Table 2). These figures assume the outlet structure is located downstream from the dam.

In preparing this memorandum, it was assumed that the outlet structure would be located immediately downstream from the existing outlet conduit (Option 2). Using the existing outlet conduits restricts the minimum reservoir operating level to approximately 2565.0 ft since the existing conduit elevation is 2563.0 ft. Assuming a full criteria fish screen is provided, the maximum flow rate which could be expected from a 48 inch pipeline is approximately 160 cfs which occurs at a reservoir operating level of 2588.0 ft. Figure 3 and Table 3 presents the rating curve assuming a 48 inch pipeline fitted with an intake screen and the outlet structure at the dam.

Figure 1. Rating Curve with Trashrack operating as Siphon

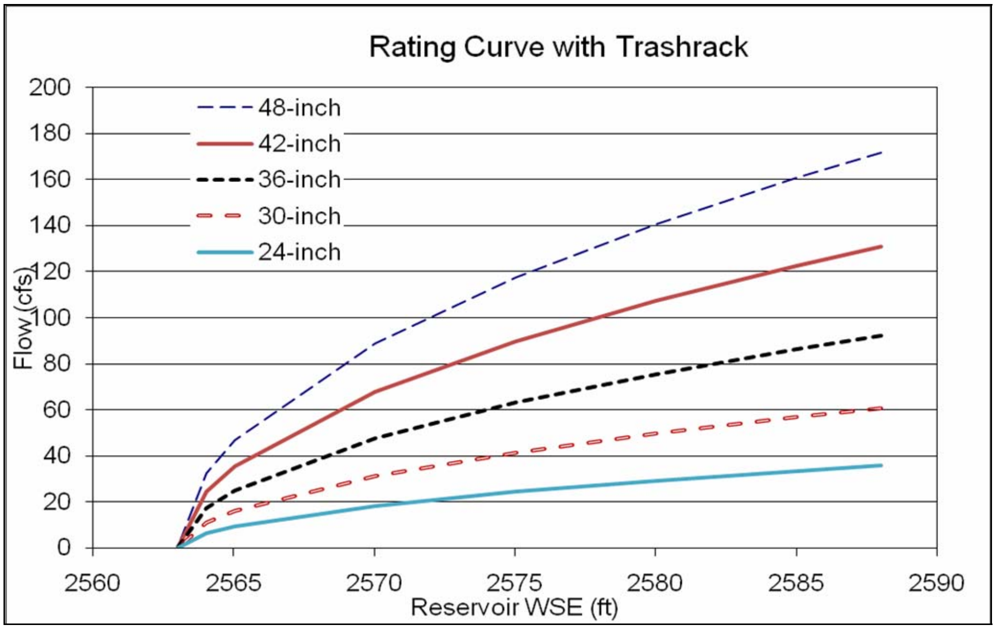


Figure 2. Rating Curve with Fish Screen operating as Siphon

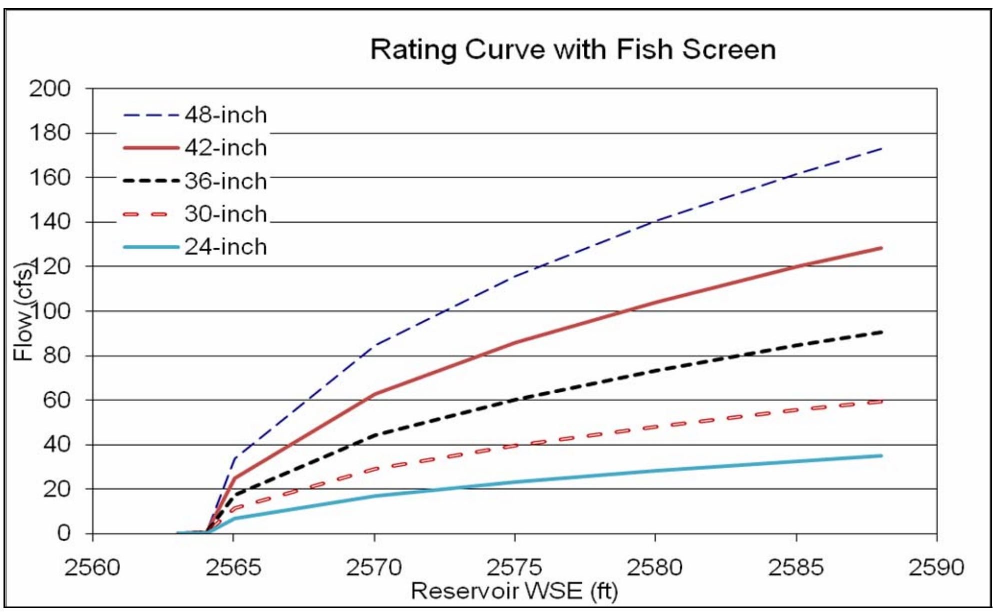


Table 1. Siphon Conditions with Trashrack at Intake

Res. Head (ft)	Flow (cfs)	Pipe Velocity (fps)	Velocity Head (ft)	K	Minor Losses (ft)	Unit Friction Loss (ft/100ft)	Sum HL at Dam (ft)	Sum HL at Outlet (ft)	Head at Dam Crest (ft)	Head at Outlet (ft)
48-inch Pipe with Trashrack										
2588	172	14	2.90	5	14.5	0.95	24.0	25.0	0.3	5.0
2585	161	13	2.55	5	12.7	0.84	21.2	22.0	0.1	5.0
2580	141	11	1.95	5	9.8	0.66	16.3	17.0	0.0	5.0
2575	118	9	1.36	5	6.8	0.47	11.5	12.0	-0.2	5.0
2570	89	7	0.78	5	3.9	0.28	6.7	7.0	-0.4	5.0
2565	47	4	0.21	5	1.1	0.08	1.9	2.0	-0.6	5.0
2564	33	3	0.10	5	0.5	0.04	1.0	1.0	-0.7	5.0
2563	1	0	0.00	5	0.0	0.00	0.0	0.0	-0.7	5.0
42-inch Pipe with Trashrack										
2588	131	14	2.88	5	14.4	0.96	24.0	25.0	0.3	5.0
2585	123	13	2.53	5	12.6	0.85	21.1	22.0	0.2	5.0
2580	107	11	1.94	5	9.7	0.67	16.3	17.0	0.0	5.0
2575	90	9	1.35	5	6.8	0.48	11.5	12.0	-0.2	5.0
2570	68	7	0.77	5	3.9	0.28	6.7	7.0	-0.4	5.0
2565	36	4	0.21	5	1.1	0.09	1.9	2.0	-0.6	5.0
2564	25	3	0.10	5	0.5	0.04	1.0	1.0	-0.7	5.0
2563	1	0	0.00	5	0.0	0.00	0.0	0.0	-0.7	5.0
36-inch Pipe with Trashrack										
2588	92	13	2.65	5	13.3	1.07	23.9	25.0	0.4	5.0
2585	86	12	2.32	5	11.6	0.94	21.1	22.0	0.2	5.0
2580	76	11	1.78	5	8.9	0.74	16.3	17.0	0.0	5.0
2575	63	9	1.24	5	6.2	0.53	11.5	12.0	-0.2	5.0
2570	48	7	0.71	5	3.5	0.31	6.7	7.0	-0.4	5.0
2565	25	4	0.19	5	1.0	0.09	1.9	2.0	-0.6	5.0
2564	17	2	0.09	5	0.5	0.05	1.0	1.0	-0.7	5.0
2563	0	0	0.00	5	0.0	0.00	0.0	0.0	-0.7	5.0
30- inch Pipe with Trashrack										
2588	61	12	2.38	5	11.9	1.19	23.8	25.0	0.5	5.0
2585	57	12	2.08	5	10.4	1.05	20.9	22.0	0.4	5.0
2580	50	10	1.59	5	8.0	0.82	16.2	17.0	0.1	5.0
2575	41	8	1.11	5	5.5	0.59	11.4	12.0	-0.1	5.0
2570	31	6	0.63	5	3.2	0.35	6.7	7.0	-0.4	5.0
2565	16	3	0.17	5	0.9	0.10	1.9	2.0	-0.6	5.0
2564	11	2	0.08	5	0.4	0.05	0.9	1.0	-0.6	5.0
2563	0	0	0.00	5	0.0	0.00	0.0	0.0	-0.7	5.0
24- inch Pipe with Trash Rack										
2588	36	11	2.05	5	10.2	1.34	23.7	25.0	0.6	5.0
2585	34	11	1.79	5	9.0	1.19	20.8	22.0	0.5	5.0
2580	29	9	1.37	5	6.8	0.92	16.1	17.0	0.2	5.0
2575	25	8	0.95	5	4.7	0.66	11.3	12.0	0.0	5.0
2570	19	6	0.54	5	2.7	0.39	6.6	7.0	-0.3	5.0
2565	10	3	0.15	5	0.7	0.12	1.9	2.0	-0.6	5.0
2564	7	2	0.07	5	0.4	0.06	0.9	1.0	-0.6	5.0
2563	0	0	0.00	5	0.0	0.00	0.0	0.0	-0.7	5.0

Table 2. Siphon Conditions with Fish Screens at Intake

Res. Head (ft)	Flow (cfs)	Pipe Velocity (fps)	Velocity Head (ft)	K	Minor Losses (ft)	Unit Friction Loss (ft/100ft)	Sum HL at Dam (ft)	Sum HL at Outlet (ft)	Head at Dam Crest (ft)	Head at Outlet (ft)
48-inch Pipe with Fish Screen										
2588	170	14	2.95	5	15.7	0.84	24.2	25.0	0.1	5.0
2585	159	13	2.57	5	13.8	0.74	21.3	22.0	0.0	5.0
2580	139	11	1.94	5	10.7	0.57	16.4	17.0	-0.1	5.0
2575	116	9	1.32	5	7.6	0.40	11.6	12.0	-0.3	5.0
2570	85	7	0.71	5	4.5	0.22	6.8	7.0	-0.5	5.0
2565	34	3	0.11	5	1.6	0.04	2.0	2.0	-0.7	5.0
2564	1	0	0.00	5	1.0	0.00	1.0	1.0	-0.7	5.0
2563	0	0	0.00	5	1.0	0.00	1.0	1.0	-1.7	4.0
42-inch Pipe with Fish Screen										
2588	128	13	2.76	5	14.8	0.93	24.1	25.0	0.2	5.0
2585	120	12	2.41	5	13.0	0.81	21.2	22.0	0.1	5.0
2580	104	11	1.82	5	10.1	0.63	16.4	17.0	-0.1	5.0
2575	86	9	1.23	5	7.2	0.44	11.6	12.0	-0.3	5.0
2570	63	7	0.66	5	4.3	0.25	6.8	7.0	-0.5	5.0
2565	25	3	0.10	5	1.5	0.04	2.0	2.0	-0.7	5.0
2564	0	0	0.00	5	1.0	0.00	1.0	1.0	-0.7	5.0
2563	0	0	0.00	5	1.0	0.00	1.0	1.0	-1.7	4.0
36-inch Pipe with Fish Screen										
2588	90	13	2.54	5	13.7	1.03	24.0	25.0	0.3	5.0
2585	84	12	2.22	5	12.1	0.90	21.1	22.0	0.2	5.0
2580	73	10	1.67	5	9.4	0.69	16.3	17.0	0.0	5.0
2575	60	9	1.13	5	6.7	0.48	11.5	12.0	-0.2	5.0
2570	44	6	0.60	5	4.0	0.27	6.7	7.0	-0.4	5.0
2565	17	2	0.09	5	1.5	0.05	2.0	2.0	-0.7	5.0
2564	0	0	0.00	5	1.0	0.00	1.0	1.0	-0.7	5.0
2563	0	0	0.00	5	1.0	0.00	1.0	1.0	-1.7	4.0
30-inch Pipe with Fish Screen										
2588	59	12	2.28	5	12.4	1.15	23.9	25.0	0.4	5.0
2585	55	11	1.98	5	10.9	1.01	21.0	22.0	0.3	5.0
2580	48	10	1.50	5	8.5	0.77	16.2	17.0	0.1	5.0
2575	40	8	1.01	5	6.1	0.54	11.5	12.0	-0.2	5.0
2570	29	6	0.54	5	3.7	0.30	6.7	7.0	-0.4	5.0
2565	11	2	0.08	5	1.4	0.05	1.9	2.0	-0.6	5.0
2564	0	0	0.00	5	1.0	0.00	1.0	1.0	-0.7	5.0
2563	0	0	0.00	5	1.0	0.00	1.0	1.0	-1.7	4.0
24-inch Pipe with Fish Screen										
2588	35	11	1.96	5	10.8	1.29	23.7	25.0	0.6	5.0
2585	33	10	1.71	5	9.5	1.13	20.9	22.0	0.4	5.0
2580	29	9	1.28	5	7.4	0.87	16.1	17.0	0.2	5.0
2575	23	7	0.87	5	5.3	0.61	11.4	12.0	-0.1	5.0
2570	17	5	0.46	5	3.3	0.34	6.7	7.0	-0.4	5.0
2565	7	2	0.07	5	1.4	0.06	1.9	2.0	-0.6	5.0
2564	0	0	0.00	5	1.0	0.00	1.0	1.0	-0.7	5.0
2563	0	0	0.00	5	1.0	0.00	1.0	1.0	-1.7	4.0

Figure 3. 48-inch Pipeline with Fish Screen and Outlet Structure at Dam

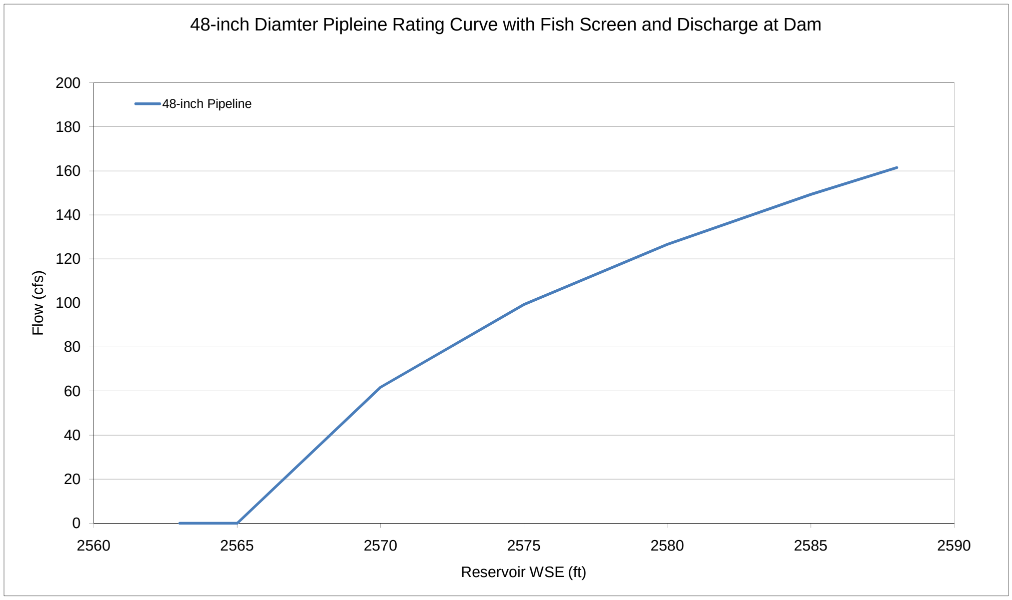


Table 3. 48-inch Pipeline with Fish Screen and Outlet Structure at Dam

48-inch Pipeline with Fish Screen and Discharge at Dam										
Res. Head (ft)	**Flow (cfs)**	**Pipeline Velocity (fps)**	**Velocity Head (ft)**	**K**	**Minor Losses (ft)**	**Unit Friction Loss (ft/100ft)**	**Sum HL at Dam (ft)**	**Sum HL at Outlet (ft)**	**Head at Dam Crest (ft)**	**Head at Outlet (ft)**
2588	161	13	2.56	5	13.8	0.85	22.3	22.3	2.0	2.0
2585	149	12	2.19	5	12.0	0.73	19.3	19.3	2.0	2.0
2580	127	10	1.58	5	8.9	0.54	14.3	14.3	2.0	2.0
2575	99	8	0.97	5	5.9	0.34	9.3	9.3	2.0	2.0
2570	62	5	0.37	5	2.9	0.14	4.3	4.3	2.0	2.0
2565	0	0	0.00	5	1.0	0.00	1.0	1.0	0.3	0.3
2564	0	0	0.00	5	1.0	0.00	1.0	1.0	-0.7	-0.7
2563	0	0	0.00	5	1.0	0.00	1.0	1.0	-1.7	-1.7

Pipeline Intake. The pipeline intake will be fitted with two Tee style fish screens designed to meet NOAA Fisheries screening criteria. For this application, the screen would be designed to meet a maximum approach velocity of 0.2 fps which is required by NOAA Fisheries for intake structures which do not have a positive bypass system. The minimum effective screen area required assuming a maximum design flow of 160 cfs would then be 800 square feet (sf). An air burst cleaning system would be provided. The air compressor, storage tank, piping, valves, and associated equipment would be located on the left abutment in a metal building. An air line will be ran from a new system control house near the dam, along the top of the pipeline to the intake. A support structure for the intake will be installed on the reservoir bottom. The structure will elevate the intake off of the reservoir bottom enough to ensure unimpeded flows entering the pipeline. An air bust system will be required in order to clean the intake screens.

Reservoir Pipeline. The HDPE pipeline will installed on the reservoir floor for majority of the pipeline length. From the intake structure to just upstream from the existing vehicle bridge, the pipeline will be installed from a barge by floating the pipeline into position, then sinking the pipeline to the floor with concrete collar anchors and releasing the air buoyancy. Divers will be required to clear the pipeline alignment of any debris and large rocks as well as ensure the pipeline is properly installed. The air line feeding the air burst system will be routed adjacent to the main water supply pipeline. From the upstream side of the bridge to the dam, the pipeline will be buried in the channel floor to maintain the hydraulic capacity of the approach channel as well as protect the pipeline from damage during large spill events. As the pipeline approaches the dam, the pipe will extend up onto the existing concrete apron upstream from the dam and connect via a bolted flange to a steel pipe section which extends through the dam.

Pipeline Dam Pentration. A steel pipe section will be used to extend through dam. The pipe section will consist of a 4 ft round to steel transition, then a 4 ft square steel insert which will be installed inside the existing concrete conduit. The steel pipeline section will bolt to the new HDPE pipeline on the upstream end. A flanged connection will be provided at the downstream end to allow installation of a control gate. The steel transition section will be encased in concrete to provide thrust restraint for the steel pipeline section. Epoxy or expansion anchors will be installed through the liner into the existing concrete conduits as required to provide additional shear resistance. The steel pipe section will be provided with an epoxy coating on the inside of the pipe.

Pipeline Outlet Structure. A fabricated steel control gate will be installed on the downstream end of the pipeline. The gate will be used to control the flow released from the dam during the cold water release periods. The gate will be fitted with a pneumatic operator with the air provided from a small air compressor located in the mechanical equipment enclosure.

Mechanical Equipment Building. A pre-fabricated metal building will be provided to house the air burst equipment and pneumatic operator air compressor. A standby generator will be required to provide power to the mechanical equipment.

4.0 COST ESTIMATE ASSUMPTIONS

A cost estimate was prepared for the cold water intake assuming a 48 inch water supply pipeline routed through the existing low level intake gate and release conduit. The outlet structure was assumed to be located on the downstream face of the existing concrete low level outlet structure. Drawings 1 through 4 illustrate the conceptual design details upon which the construction cost estimate was developed. The assumptions used in developing the cost estimate were as follows:

(1) Staging and lay down area is available adjacent to the dam.
(2) Reservoir level will be drawn down to low level gates to complete work at dam face.
(3) A pre-fabricated steel bulkhead/cofferdam system will be installed at the dam face to allow work on the steel pipe sleeve and transitions from steel pipe to HDPE
(4) Steel bulkhead/cofferdam system will divert water to the remaining two low level gates for stream bypass.
(5) Air burst equipment will be housed in an onsite conditioned metal building

(6) Intake screen piping manifold will be epoxy coated.
(7) 48 inch diameter HDPE pipe will be welded on shore with a blind flange adaptor and cap on intake end.
(8) Concrete ballast weights will be installed on HDPE pipeline as it is extended into the reservoir.
(9) Upon completion of HDPE welding the pipeline will be aligned in position and be sunk in a controlled manner.
(10) Time line for sinking the line is based off of a similar project completed off the Washington coast by Northwest Underwater Construction
(11) Sinking of HDPE line will be completed by a controlled fill of the pipeline with a crane attached to the upstream end to control alignment of pipeline
(12) Crane and long reach excavator will work from a six unit – 10 ft x 5 ft x40 ft modular floating barge.
(13) Intake screen and piping manifold will be lowered into position with a barge mounted crane.
(14) Intake screens were assumed to be Hendricks or approved equal designed to provide 80 cfs at an approach velocity of 0.2 fps. The screens will be mounted on a pre-cast concrete pads, two per screen lowered to the reservoir floor.
(15) Divers will be required for the entire pipeline and intake installation.
(16) The new downstream control gate will be installed on the end of the new 48 inch square conduit insert and provided with a pneumatic gate operator.

5.0 COST ESTIMATE

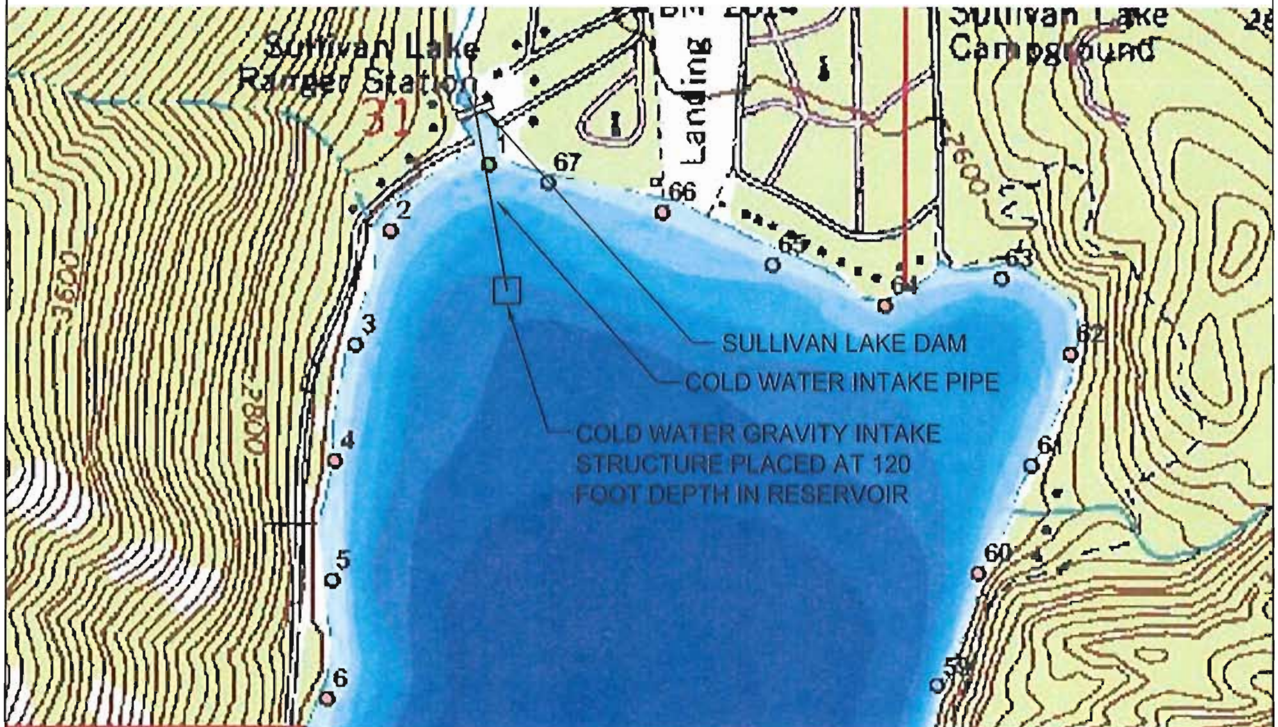
Table 4 presents the estimated cost for PME XX including construction, planning, engineering, permitting and contingency. Detailed backup for the construction cost is attached to the memorandum. An estimate of the annual operation and maintenance cost is also presented in Table 2 with a detailed breakdown enclosed with the construction cost tables.

Table 4. PME XX Sullivan Lake Dam Advanced Cold Water Intake with Fish Screen

	Construction	**Planning (10%) ($)**	**Engineering (10%) ($)**	**Permitting (5%) ($)**	**Contingency (30%) ($)**	**Total Project Cost ($)**
Base Cost	$1,670,700	165,000	165,000	80,000	624,220	2,704,900
Replacement Period	30 Years					
Replacement Cost at 100 %	at Present Value					
O&M	$51,000					

CONFIDENTIAL DOCUMENT PREPARED FOR PURPOSES OF SETTLEMENT NEGOTIATIONS

N



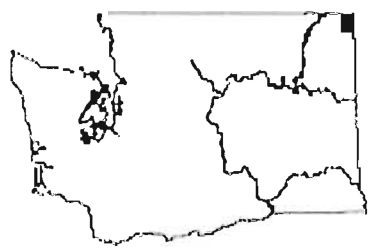
Legend

Lake Depth in Feet

- 0 - 40
- 41 - 80
- 81 - 120
- 121 - 160
- 161 - 200
- 201 - 240
- 241 - 320

Transect Breaks (200 meter interval)

- 1 (Transect Start)
- 2
- 3
- 4
- 5



SULLIVAN DAM - PLAN

SCALE: 1"=1000'

0" 1000' 2000'

Seattle City Light

MCMILLEN, LLC
THE SONNA BUILDING
910 MAIN ST. SUITE 258
BOISE, ID 83702
OFFICE: 208.342.4214
FAX: 208.342.4216

TITLE: Cold Water Gravity Intake Concept For Sullivan Lake Dam

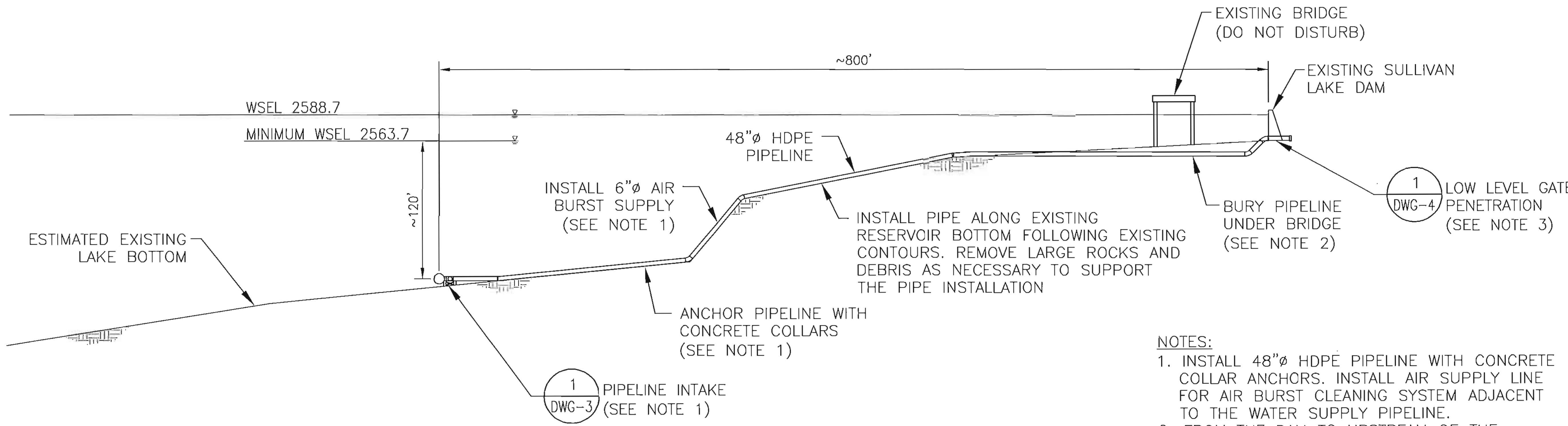
Cold Water Gravity Intake Site Plan

DRAWING 1

Scale: 1"=1000'

12/31/09

CONFIDENTIAL DOCUMENT PREPARED FOR PURPOSES OF SETTLEMENT NEGOTIATIONS



NOTES:

1. INSTALL 48"ø HDPE PIPELINE WITH CONCRETE COLLAR ANCHORS. INSTALL AIR SUPPLY LINE FOR AIR BURST CLEANING SYSTEM ADJACENT TO THE WATER SUPPLY PIPELINE.
2. FROM THE DAM TO UPSTREAM OF THE EXISTING VEHICLE BRIDGE, BURY THE PIPE IN THE CHANNEL FLOOR PROVIDING A MINIMUM OF 1.5 FEET OF COVER.
3. ROUTE NEW 48"ø PIPELINE THROUGH THE EXISTING 48" LOW LEVEL OUTLET AT SULLIVAN LAKE DAM. PROVIDE A NEW SLUICE CONTROL GATE ON THE DOWNSTREAM END OF THE NEW PIPELINE.

COLD WATER INTAKE PROFILE

SCALE: 1"= 100'

Seattle City Light

REV	DATE	BY	DESCRIPTION

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

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BOISE, ID 83702
OFFICE: 208.342.4214
FAX: 208.342.4216

SEATTLE CITY LIGHT

Sullivan Lake Dam

Cold Water Gravity Intake Profile

DESIGNED W. Zimmerman

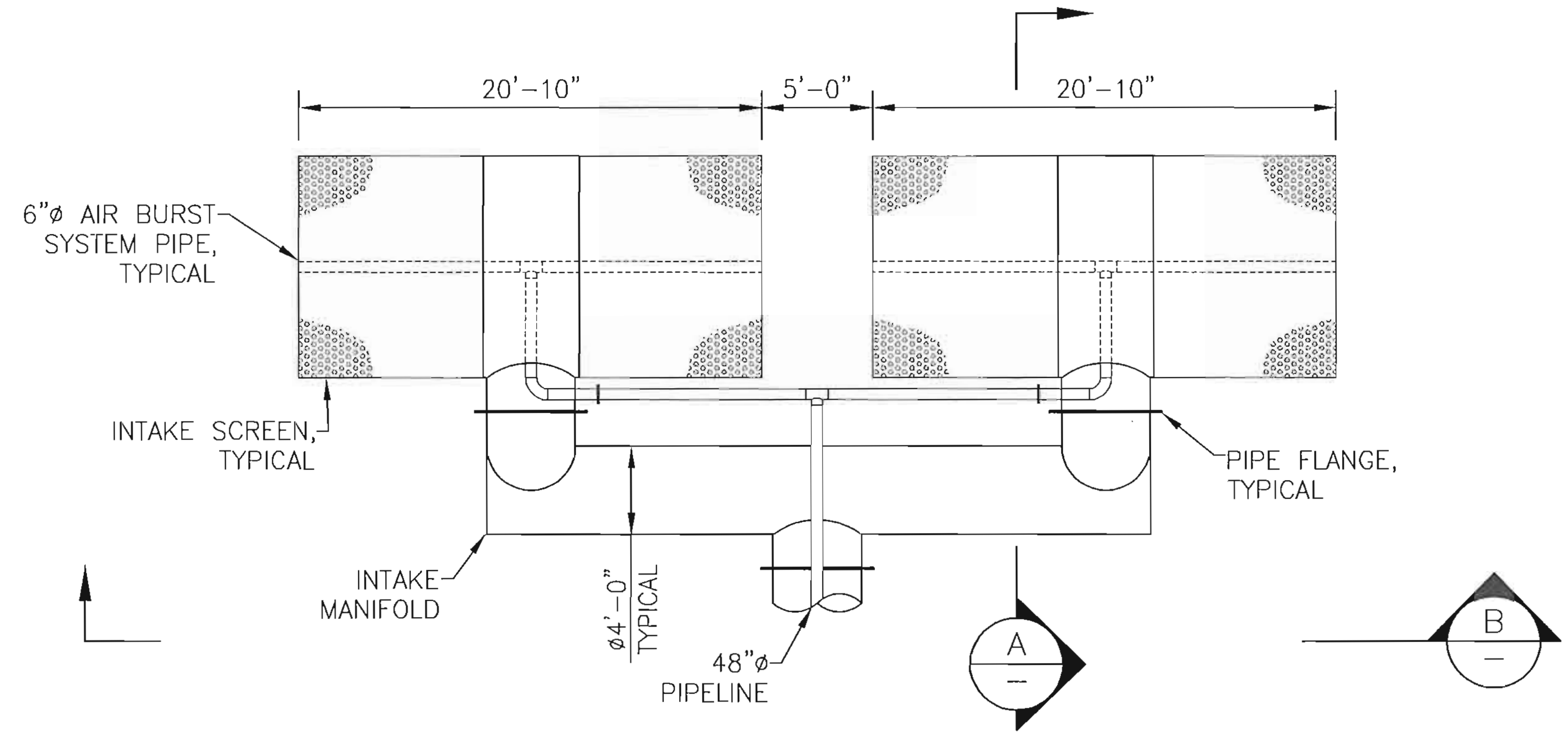
DRAWN W. Zimmerman

CHECKED M. McMillen

ISSUED DATE 12/31/09

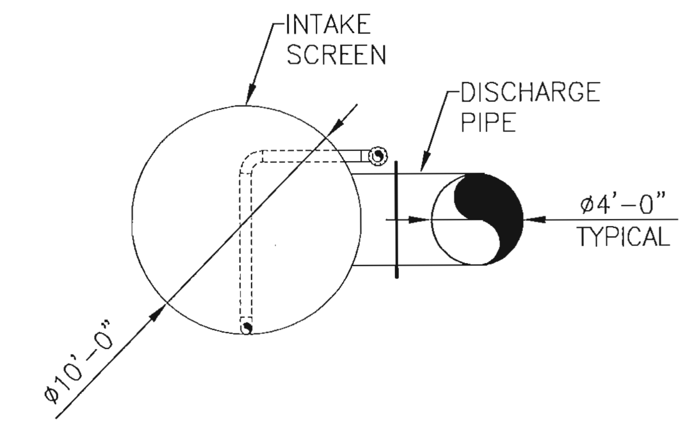
DRAWING 2

SCALE: AS NOTED



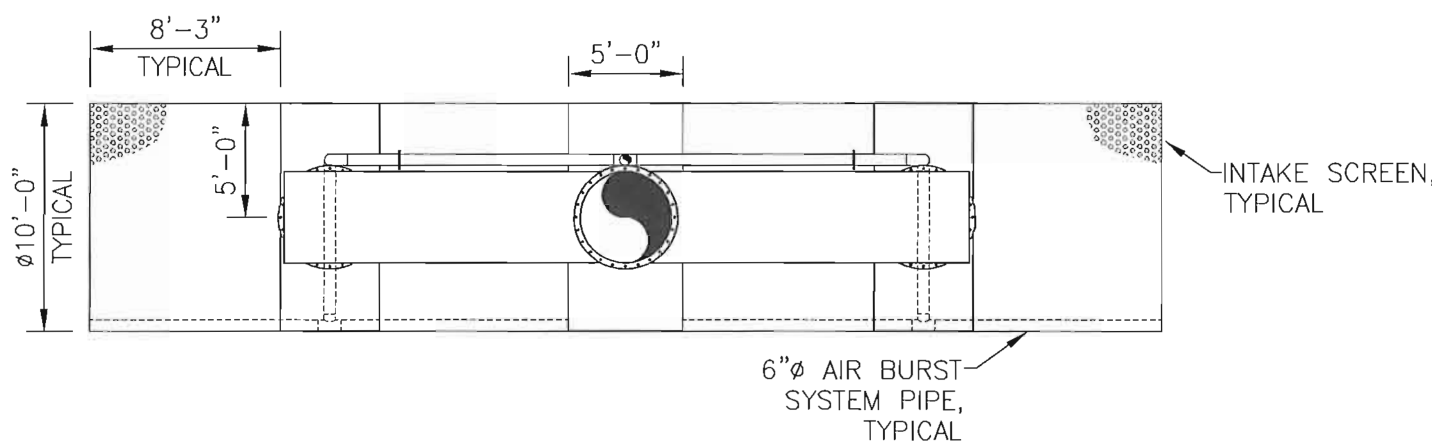
PIPELINE INTAKE PLAN (1 / FIG-2)

SCALE: 1/8"= 1'-0"



SECTION VIEW (A / –)

SCALE: 1/8"= 1'-0"



SECTION VIEW (B / –)

SCALE: 1/8"= 1'-0"

Seattle City Light

REV	DATE	BY	DESCRIPTION

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

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OFFICE: 208.342.4214
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SEATTLE CITY LIGHT

Sullivan Lake Dam

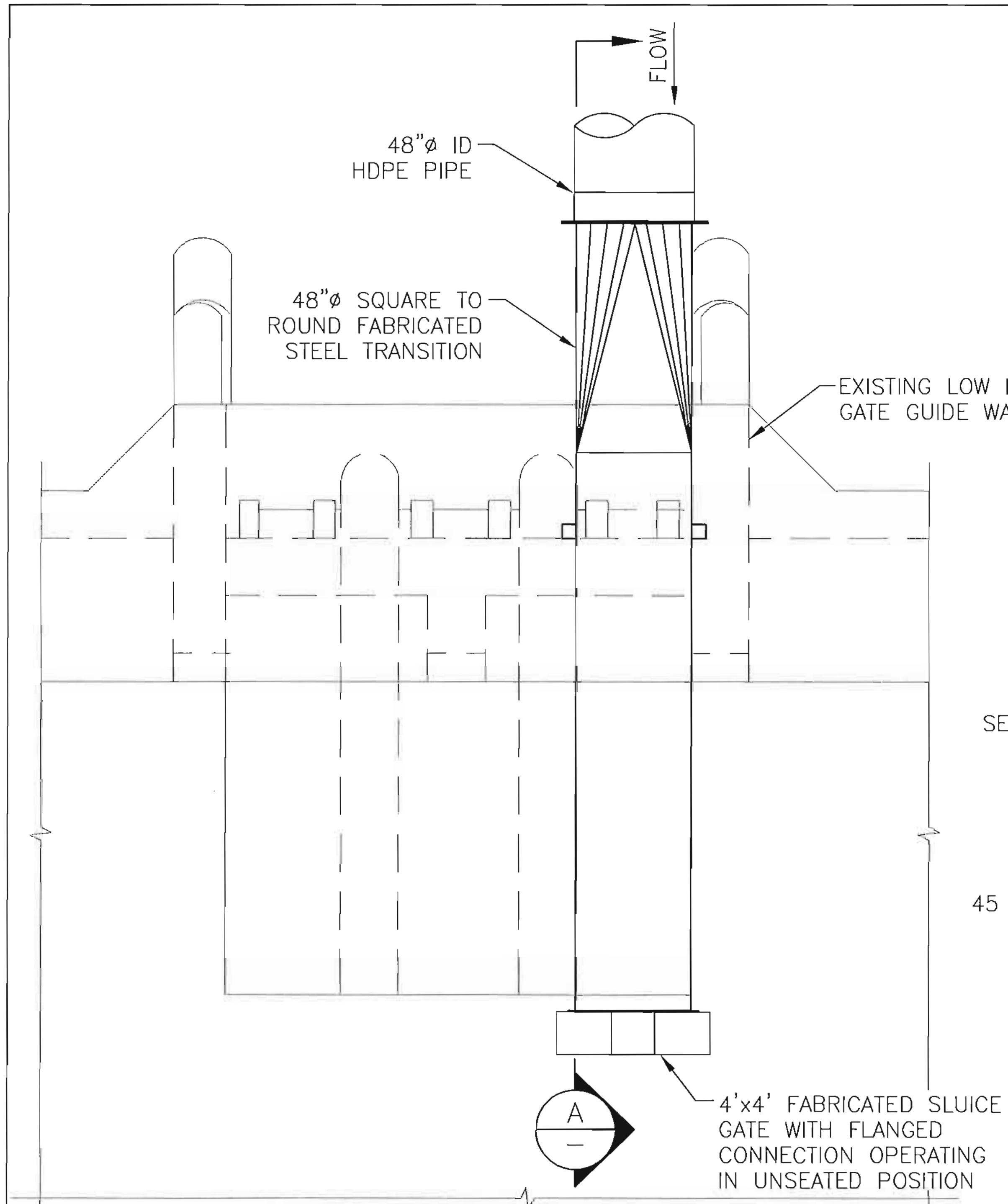
Cold Water Gravity Intake
Pipeline Intake

DESIGNED W. Zimmerman
DRAWN W. Zimmerman
CHECKED M. McMillen
ISSUED DATE 12/31/09

DRAWING 3

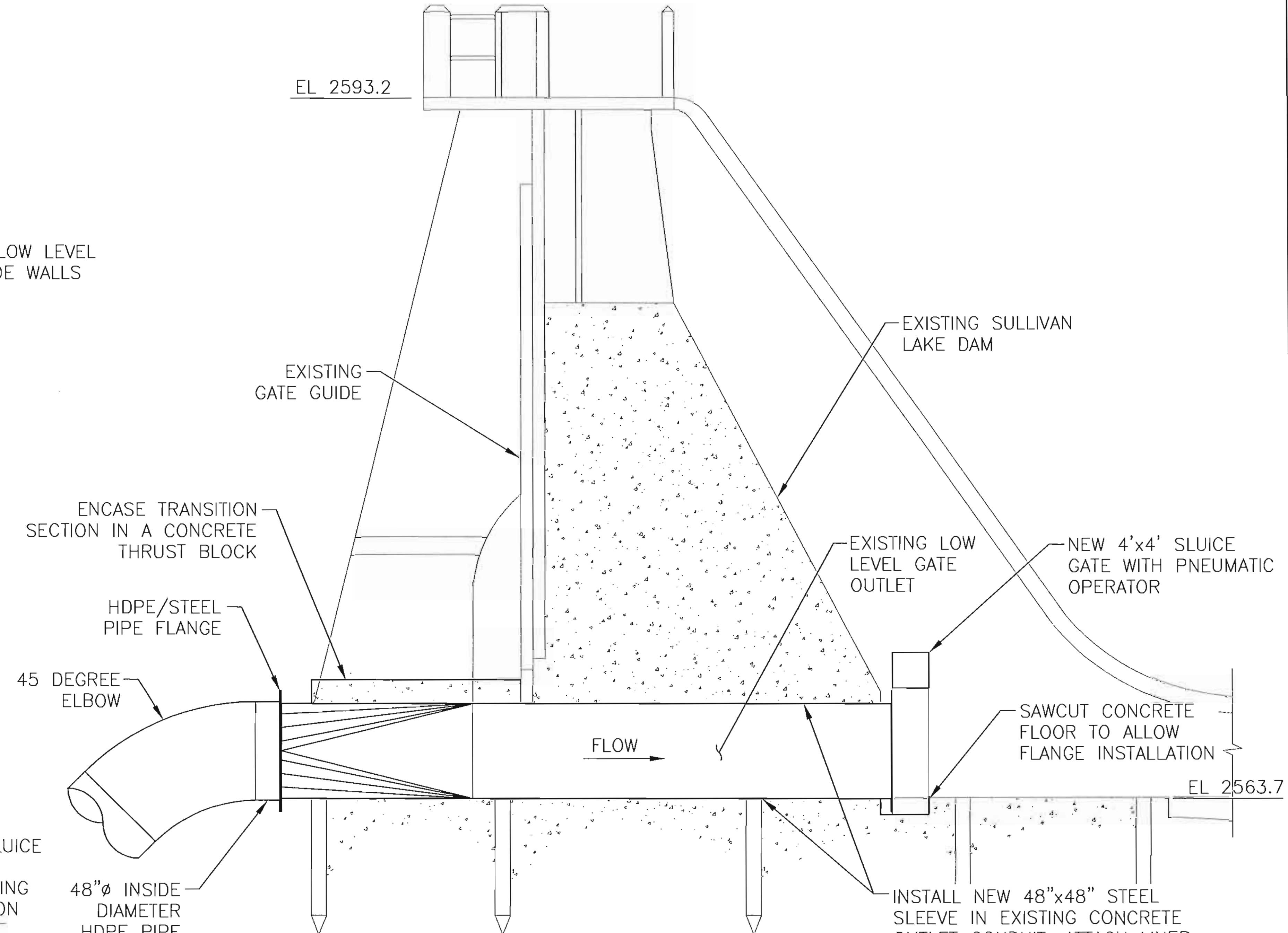
SCALE: AS NOTED

CONFIDENTIAL DOCUMENT PREPARED FOR PURPOSES OF SETTLEMENT NEGOTIATIONS



LOW LEVEL GATE PENETRATION PLAN

SCALE: 3/16" = 1'–0"



SECTION VIEW

SCALE: 3/16"= 1'–0"

A
—

Seattle City Light

REV	DATE	BY	DESCRIPTION

WARNING

0 1/2 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE.

McMILLEN, LLC
THE SONNA BUILDING
910 MAIN ST. SUITE 258
BOISE, ID 83702
OFFICE: 208.342.4214
FAX: 208.342.4216

SEATTLE CITY LIGHT

Sullivan Lake Dam

Cold Water Gravity Intake
Low Level Gate Penetration

DESIGNED W. Zimmerman
DRAWN W. Zimmerman
CHECKED M. McMillen
ISSUED DATE 12/31/09

DRAWING 4

SCALE: AS NOTED

Attachment 3

Report on Productivity Sampling in Sullivan Lake and Outlet Creek

DRAFT

SULLIVAN CREEK HYDROELECTRIC PROJECT
FERC No. 2225

Report on Productivity Sampling in Sullivan Lake and Outlet Creek

Prepared for the Public Utility District No.1 of Pend Oreille County
Newport, Washington

Prepared by
EES Consulting, Inc.

December 28, 2009

TABLE OF CONTENTS

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LIST OF TABLES

REPORT ON PRODUCTIVITY SAMPLING IN SULLIVAN LAKE AND OUTLET CREEK

1.0 INTRODUCTION AND BACKGROUND

This study was conducted by EES Consulting (EESC) for the Pend Oreille Public Utility District (District) in connection with decommissioning the Sullivan Creek Hydroelectric Project (FERC No. 2225).

Sullivan Lake is located approximately seven miles east of Metaline Falls, WA. Sullivan Lake is of glacial origin, with a surface area of roughly 1,300 acres, at a surface elevation of approximately 2,580 ft above mean sea level (AMSL). The lake is fed by three tributaries - Harvey, Noisy, and Hall creeks, with Harvey Creek being the only perennial tributary. The lake drains into Outlet Creek, which then merges with Sullivan Creek, eventually draining into the Pend Oreille River near Metaline Falls.

Sullivan Lake supports a population of kokanee (*Oncorhynchus nerka*), which originally stemmed from several different stocking efforts, but now reproduces naturally. The Washington Department of Ecology (WDOE 1997) classified Sullivan Lake as oligotrophic due to low concentrations of total phosphorus and chlorophyll *a*, and high Secchi disk depth values. Oligotrophic lakes generally have low production of algae and zooplankton and high water clarity (Horne and Goldman 1994). Aquatic macrophyte densities are low in Sullivan Lake (WDOE 1997).

The dam at the outlet of Sullivan Lake is owned and operated by the District under FERC license for the benefit of downstream power producers. Under current operations, Sullivan Lake is drawn down approximately 20 ft each fall from its full pool elevation of 2588 ft AMSL, beginning October 1. During settlement negotiation meetings regarding operations of Sullivan Lake dam, there was concern expressed that this drawdown might further deplete nutrients and/or productivity in Sullivan Lake.

Preliminary investigations suggest that productivity in oligotrophic lakes increases in spring, starting in April or May, and that productivity drops off considerably by early October (EESC 2009). These investigations also suggest that productivity is concentrated in the upper layers of such lakes.

2.0 OBJECTIVE

The objective of this study was to assess primary and secondary productivity as a function of time of the year and depth in the lake. Primary productivity is the production of organic compounds from atmospheric or aquatic carbon dioxide through the process of photosynthesis. Secondary productivity is the biomass formation or energy fixation by heterotrophic organisms, such as grazers and decomposers, deriving their energy from photosynthetic plants or other autotrophs.

3.0 METHODS

The methods employed in this study closely follow those used by Nine and Scholz (2005) in their limnological studies of Sullivan Lake, with the intent of allowing comparison between data gathered in this study with that obtained by Nine and Scholz from 2003.

Field measurements included monthly samples of:

- Water column profiles for temperature, dissolved oxygen (DO), conductivity, and pH at 5m intervals at the deepest point in the lake.
- Secchi disk transparency at the deepest point in the lake.
- Water samples taken at 5m intervals at the deepest points in the northern, middle, and southern portions of the lake for water quality and productivity analyses.
- Primary production assessed by measuring chlorophyll *a*, with water samples collected at the deepest points in the northern, middle, and southern portions of the lake.
- Secondary production assessed by monitoring zooplankton, with zooplankton samples collected at the deepest points in the northern, middle, and southern portions of the lake.
- Temperature, DO, conductivity, and pH in Outlet Creek below the dam.
- Water samples collected from Outlet Creek below the dam.
- Primary and secondary productivity assessed in Outlet Creek.

3.1 Water Quality

Water quality assessments followed the guidelines recommended by the American Public Health Administration (APHA 1985). One water quality station was established at the deepest point (northern end) in Sullivan Lake (Figure 1). Water quality data were collected once per month from July through November. A Hydrolab Sonde® was used to measure profiles of temperature, dissolved oxygen, conductivity, and pH. Profiles were measured from the surface to 50m at 5m intervals. A 20cm limnological Secchi disk was used to measure water transparency. The Secchi disk was slowly lowered in the water column until it was no longer visible to the biologist.

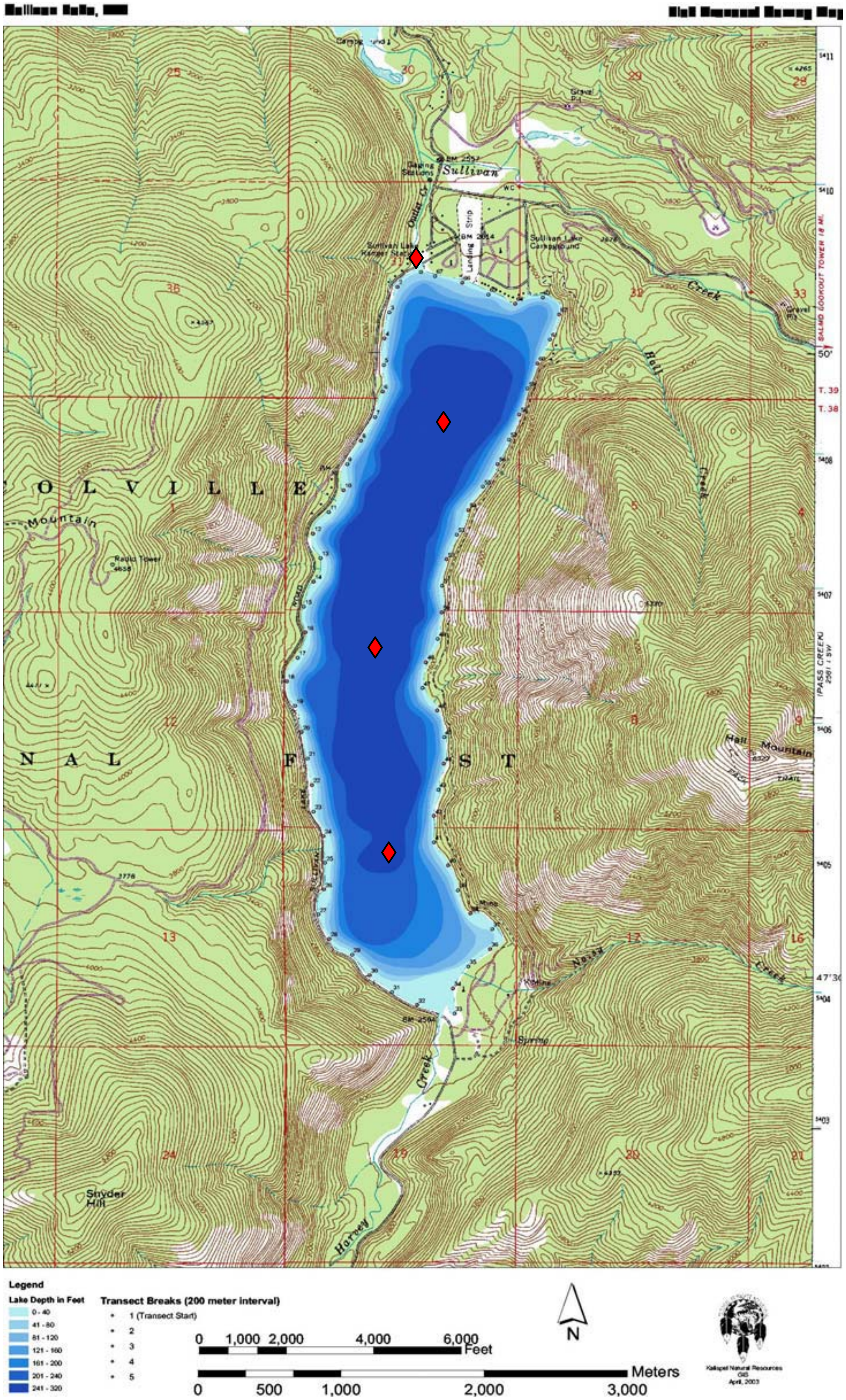

Figure 1. Approximate locations of limnological sampling sites in Sullivan Lake and Outlet Creek.

3.2 Nutrients

Water samples were taken from the surface to the bottom at 5m intervals in the epilimnion and metalimnion and 10m intervals in the hypolimnion using a Van Dorn sampling bottle.[1] Composite samples were made for each stratum by taking an equal amount of water from each depth sampled in the stratum. Water samples were stored on ice until analyzed. Each composite sample was analyzed for:

- Ammonia nitrogen (EPA 350.1)
- Nitrate nitrogen (EPA 300.0)
- Total nitrogen (EPA 351.2)
- Orthophosphate (EPA 365.1)
- Total phosphorus (EPA 365.4)
- Sulfate (EPA 300.0)
- Total dissolved solids (TDS) (SM2540C)
- Turbidity (portable turbidimeter used on site)

All water quality tests (except turbidity) were performed by the Spokane Tribal Laboratory, which is accredited by The Washington Department of Ecology.

A water quality sampling station was established in Outlet Creek immediately downstream of the dam. Water quality data were collected once per month from July through November, on the same date that data were collected in the lake. A Hydrolab Sonde® was used to measure temperature, dissolved oxygen, conductivity, and pH.

3.3 Primary Productivity

Phytoplankton production was assessed by measuring chlorophyll *a*. Chlorophyll *a* composite samples were taken from the epilimnion, metalimnion, and hypolimnion at three established water quality sites. One site was the water quality sampling location established at the deepest point (northern end) in the lake. Two additional sites were established at the deepest points in the middle and southern parts of the lake.

For the middle and southern chlorophyll sampling sites, the Hydrolab was used to measure water temperatures every 5m of depth to establish the epilimnion, metalimnion, and hypolimnion. Water samples were again taken from the surface to the bottom at 5m intervals in the epilimnion and metalimnion and 10m intervals in the hypolimnion using a Van Dorn sampling bottle. Composite samples were made for each stratum by taking an equal amount of water from each depth sampled in the stratum. Water samples were stored on ice until analyzed.

[1] Epilimnion, metalimnion, and hypolimnion refer to the layers of a thermally stratified lake. The epilimnion is the uppermost layer, which is well mixed by winds and currents. The hypolimnion is the deepest and coldest layer. The metalimnion is the transition zone between the two.

A chlorophyll sample was also taken in Outlet Creek from the same location as the water quality sample.

3.4 Secondary Productivity

Zooplankton samples were collected each month from July through November, taken from the northern, middle, and southern portions of the lake. A vertical tow plankton net with 80µ mesh and a silk bucket was used to collect zooplankton. Vertical tows were made from the bottom to the surface and from 5m to the surface to allow density comparisons between the entire water column and the epilimnion.

A zooplankton sample was also taken in Outlet Creek from the same location as the water quality and chlorophyll samples.

4.0 RESULTS

4.1 Water Quality

Sullivan Lake water temperature, DO, pH, conductivity, and turbidity are illustrated in Figures 2-7. For comparison purposes, the same parameters for Outlet Creek are shown in Table 1. Over the summer and fall, temperatures in the lake ranged from 3.3-21.5°C over all depths (Figure 2). The five-month lake average was 14.8°C in the epilimnion, 7.3°C in the metalimnion and 3.7°C in the hypolimnion. Outlet Creek temperature averaged 15.7°C.

The five-month lake average for dissolved oxygen was 9.0 mg/l in the epilimnion, 10.5 mg/l in the metalimnion, and 9.6 mg/l in the hypolimnion (Figure 3). Dissolved oxygen remained close to saturation levels through the epilimnion and metalimnion for the duration of the study period, but dropped to near 70% at 50m depth (Figure 4). It is unclear why DO appears to have increased during the September sampling period; it is possible this is due to an equipment malfunction, although the instrument was calibrated prior to each sampling date. Outlet Creek DO averaged 5.2 mg/l and 55% saturation.

Sullivan Lake remained alkaline throughout the five-month study period (Figure 5). The five-month lake average pH was 8.3 in the epilimnion, 8.0 in the metalimnion, and 7.7 in the hypolimnion. The pH showed a consistent increasing trend through the summer and into fall. Outlet Creek pH averaged 7.9.

The five-month lake average conductivity was 0.092 mS/cm in the epilimnion, 0.093 mS/cm in the metalimnion, and 0.097 mS/cm in the hypolimnion (Figure 6). The lowest conductivity value was 0.086 mS/cm in the metalimnion in July; the highest was 0.098 mS/cm in the hypolimnion in November. Outlet Creek conductivity averaged 0.114 mS/cm.

The five-month lake average turbidity was 0.79 NTU in the epilimnion, 0.91 NTU in the metalimnion, and 0.81 in the hypolimnion (Figure 7). Lake turbidity remained below 1.0 NTU, except in November; it is uncertain whether turbidity actually rose in November, or if this is due to the fact that the November sampling employed a different sampling team with a different turbidimeter, which was necessitated due to scheduling conflicts. Outlet Creek turbidity averaged 0.77 NTU.

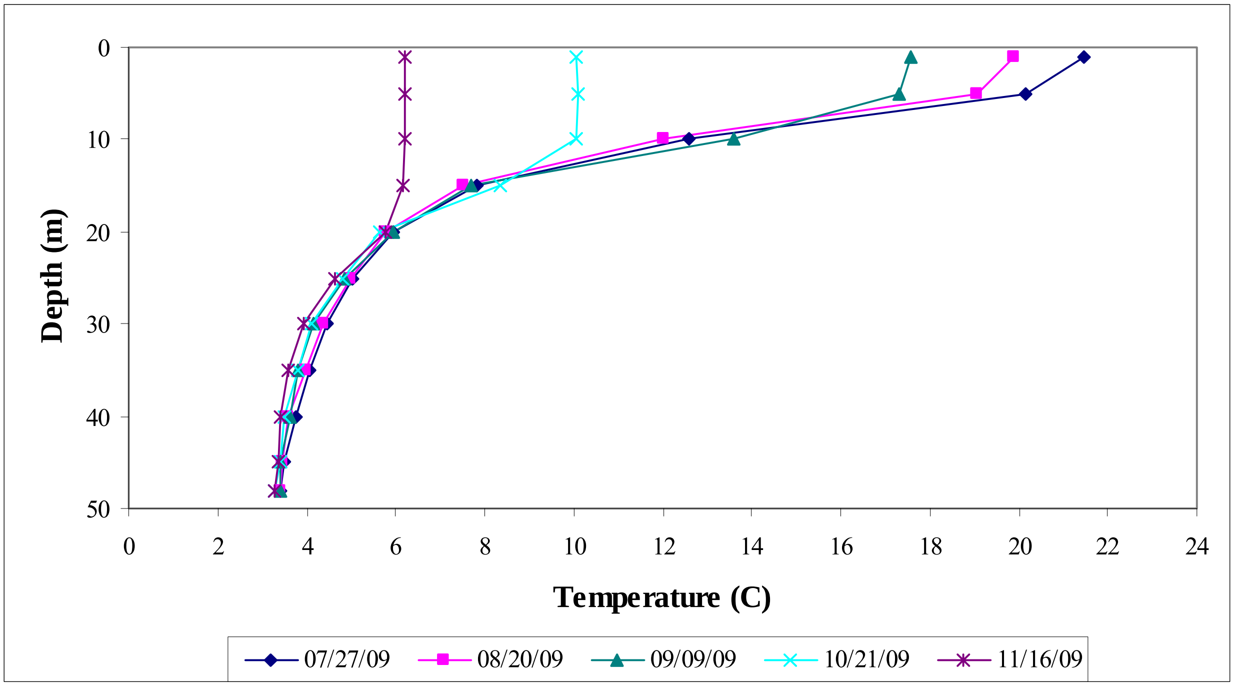

Figure 2. Sullivan Lake temperature profiles.
Averages between northern, middle, and southern lake locations.

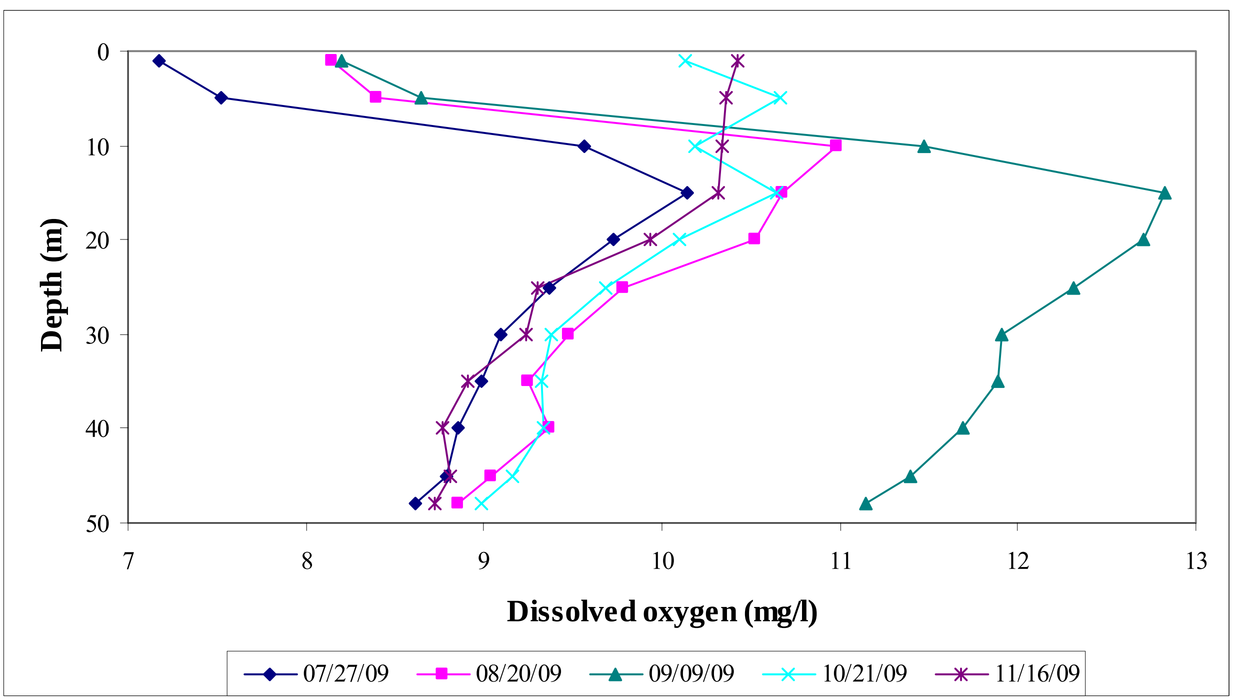

Figure 3. North Sullivan Lake dissolved oxygen profiles.

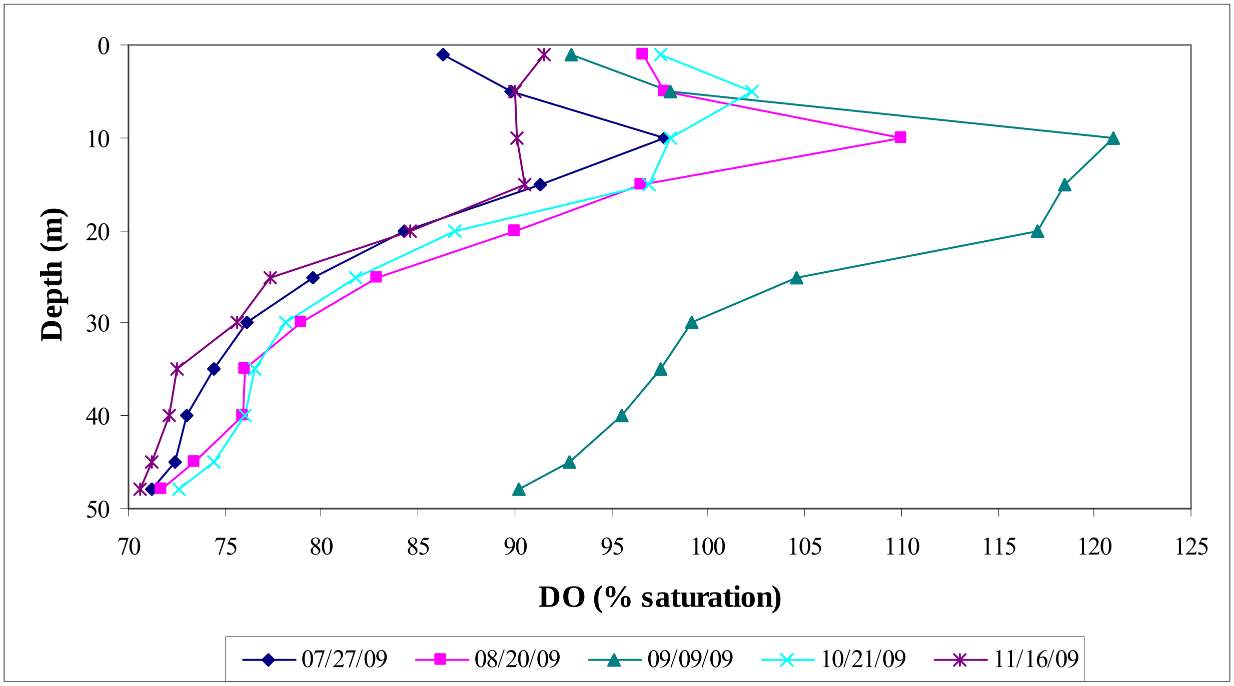

Figure 4. North Sullivan Lake DO saturation profiles.

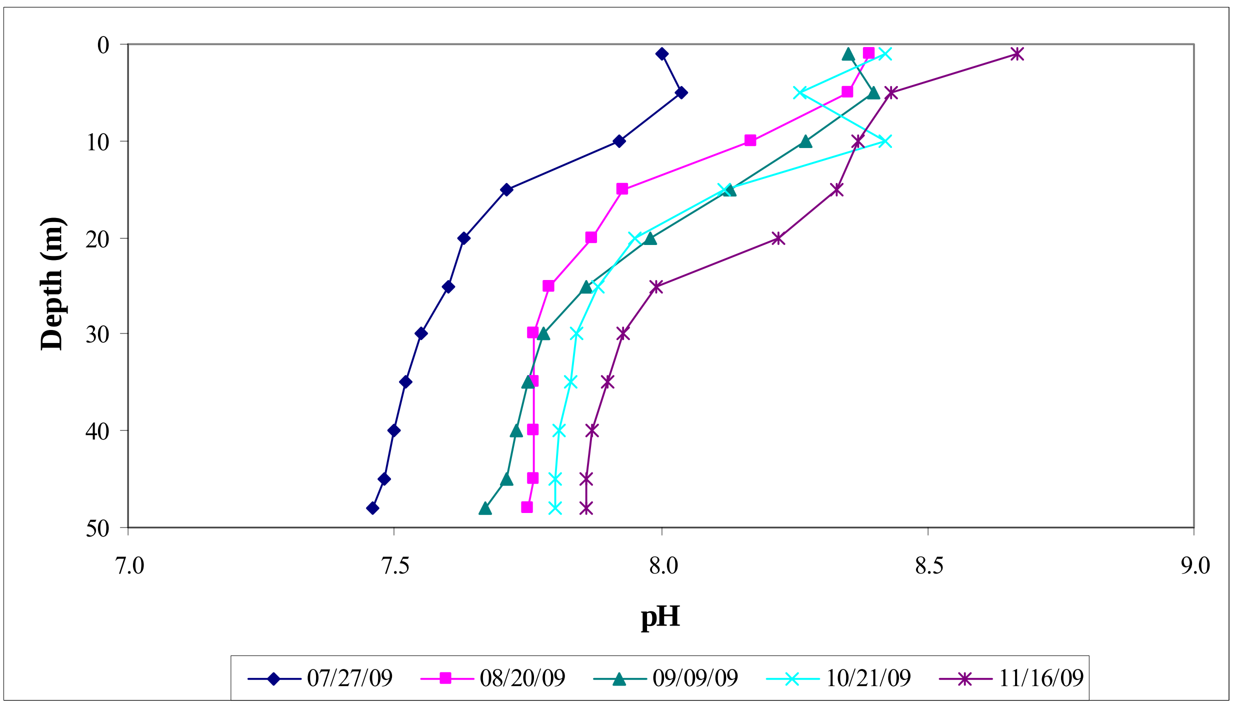

Figure 5. North Sullivan Lake pH profiles.

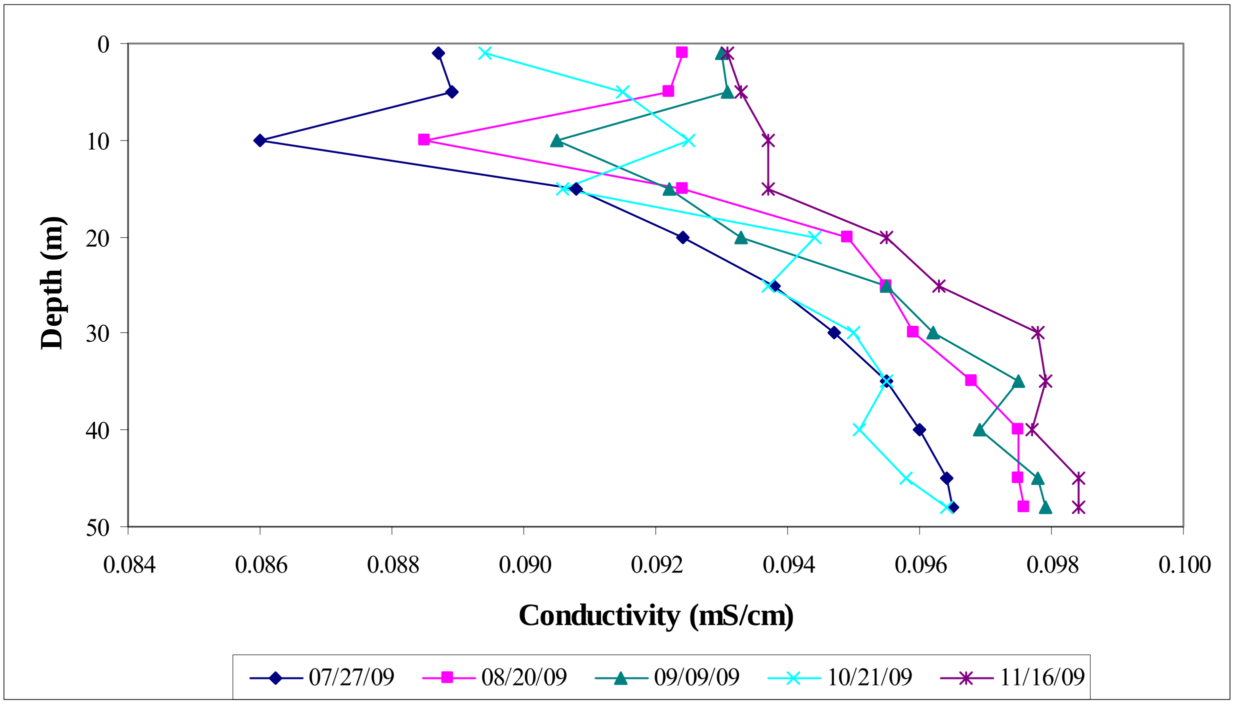

Figure 6. North Sullivan Lake conductivity profiles.

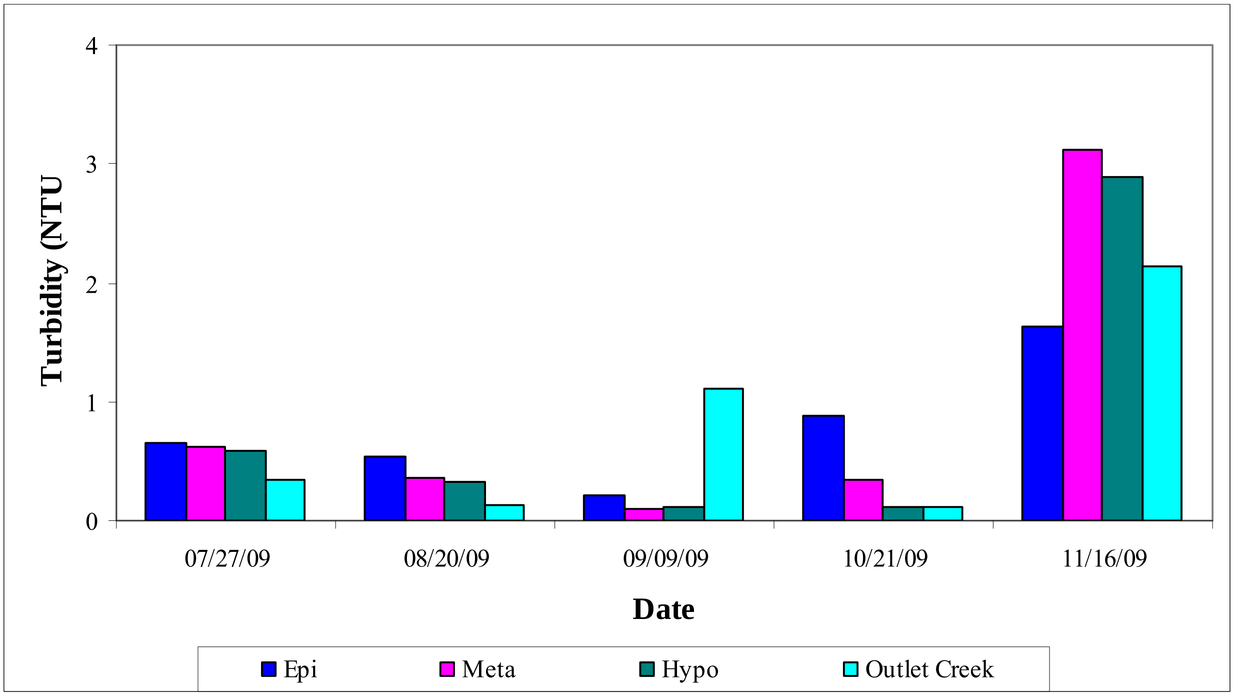

Figure 7. Turbidity in Sullivan Lake and Outlet Creek.
Lake values represent averages between northern, middle, and southern lake locations.

Table 1. Water Quality Parameters for Outlet Creek.

	07/27/09	08/20/09	09/09/09	10/21/09 *	11/16/09	Average
Temperature (°C)	17.7	18.9	17.9		8.1	15.7
DO (mg/l)	4.44	3.97	3.97		8.28	5.17
DO saturation	50.2%	46.3%	45.6%		79.2%	55.3%
pH	7.73	7.78	7.83		8.35	7.92
Conductivity (mS/cm)	0.113	0.116	0.119		0.107	.114
Turbidity (NTU)	0.35	0.13	1.11	0.12	2.14	0.77
* Outlet Creek water quality parameters could not be sampled in October due to a bad battery in the Hydrolab display unit.						

4.2 Nutrients

Nutrients (nitrogen and phosphorus) were low in Sullivan Lake. Monthly values of nitrites, nitrates, ammonia, and Total Kjeldahl Nitrogen (TKN) are summarized in Table 2. All values of nitrite nitrogen in all strata of the water column were at or below the detection limits (≤ 0.01 mg/l). The five-month average values for the epilimnion, metalimnion, hypolimnion, and Outlet Creek are shown at the bottom of the table.

Monthly values of total phosphorus, ortho-phosphate, sulfate, and total dissolved solids (TDS) are summarized in Table 3. The five-month average values for the epilimnion, metalimnion, hypolimnion, and Outlet Creek are shown at the bottom of the table.

Table 2. Nitrogen Concentrations in Sullivan Lake and Outlet Creek.
All concentrations are in mg/l.

Date	Stratum	Nitrite (NO_2^-)	Nitrate (NO_3^-)	Ammonia (NH_4^+)	TKN
7/27/09	Epilimnion	<0.01	0.03	0.018	0.19
	Metalimnion	<0.01	<0.01	0.016	0.16
	Hypolimnion	<0.01	0.02	0.022	0.17
	Outlet Cr.	<0.01	0.06	0.010	0.15
8/20/09	Epilimnion	<0.01	0.03	0.017	0.12
	Metalimnion	<0.01	<0.01	0.019	0.14
	Hypolimnion	<0.01	0.02	0.018	0.26
	Outlet Cr.	<0.01	0.06	0.017	0.18
9/9/09	Epilimnion	<0.01	<0.01	0.013	0.16
	Metalimnion	<0.01	<0.01	<0.010	0.14
	Hypolimnion	<0.01	0.02	0.012	0.13
	Outlet Cr.	<0.01	0.05	<0.010	0.08
10/21/09	Epilimnion	<0.01	<0.01	<0.010	0.14
	Metalimnion	<0.01	0.01	<0.010	0.12
	Hypolimnion	<0.01	0.02	<0.010	0.11
	Outlet Cr.	<0.01	<0.01	<0.010	0.12
11/16/09	Epilimnion	<0.01	<0.01	<0.010	0.16
	Metalimnion	<0.01	<0.01	<0.010	0.17
	Hypolimnion	<0.01	0.02	<0.010	0.12
	Outlet Cr.	<0.01	0.02	<0.010	0.11
Average	Epilimnion	<0.01	<0.01	<0.010	0.16
	Metalimnion	<0.01	<0.01	<0.010	0.15
	Hypolimnion	<0.01	0.02	<0.010	0.16
	Outlet Cr.	<0.01	0.04	<0.010	0.13

Table 3. Phosphorus, Sulfate, and TDS Concentrations in Sullivan Lake and Outlet Creek.
All concentrations are in mg/l.

Date	**Stratum**	**Total Phosphorus**	**Ortho-phosphate (PO_4^-)**	**Sulfate (SO_4^-)**	**TDS**
7/27/09	Epilimnion	0.008	0.004	3.20	73
	Metalimnion	0.018	0.011	3.67	67
	Hypolimnion	0.011	0.008	3.92	70
	Outlet Cr.	0.015	0.008	3.54	60
8/20/09	Epilimnion	0.009	0.007	3.49	82
	Metalimnion	0.009	0.008	3.74	95
	Hypolimnion	0.008	0.007	4.05	98
	Outlet Cr.	0.012	0.013	3.61	90
9/9/09	Epilimnion	0.012	0.009	3.36	42
	Metalimnion	0.010	0.009	3.59	68
	Hypolimnion	0.010	0.009	3.90	63
	Outlet Cr.	0.014	0.012	3.38	90
10/21/09	Epilimnion	0.007	0.003	4.08	53
	Metalimnion	0.006	0.003	4.29	53
	Hypolimnion	<0.005	0.004	4.58	57
	Outlet Cr.	<0.005	<0.002	4.05	50
11/16/09	Epilimnion	<0.005	0.003	3.63	83
	Metalimnion	<0.005	0.004	3.71	87
	Hypolimnion	<0.005	0.003	3.88	88
	Outlet Cr.	0.005	0.005	3.66	80
Average	Epilimnion	0.006	0.005	3.55	67
	Metalimnion	0.009	0.007	3.80	74
	Hypolimnion	0.006	0.006	4.07	75
	Outlet Cr.	0.009	0.008	3.65	74

4.3 Primary Productivity

Monthly values for chlorophyll *a* are summarized in Table 4. Average values by strata and by date are also shown in the table. The average water column chlorophyll *a* concentration in the lake throughout the study period was 0.60 µg/l. The five-month average chlorophyll *a* concentration in Outlet Creek was 0.35 µg/l. Data from Table 4 are also plotted in Figure 8.

Secchi disk depths measured in Sullivan Lake are shown in Table 5. The five-month average Secchi disk depth in the lake was 12.9m.

Table 4. Chlorophyll *a* Concentrations in Sullivan Lake and Outlet Creek.
All concentrations are in µg/l.

	07/27/09	**08/20/09**	**09/09/09**	**10/21/09**	**11/16/09**	**Average**
Epilimnion	0.40	0.63	0.48	0.73	0.97	0.64
Metalimnion	0.49	1.09	0.50	0.75	1.26	0.82
Hypolimnion	0.36	0.25	0.11	0.35	0.70	0.35
Lake average	0.42	0.66	0.36	0.61	0.98	0.60
Outlet Cr.	<0.01	<0.01	<0.01	1.41	0.35	0.35

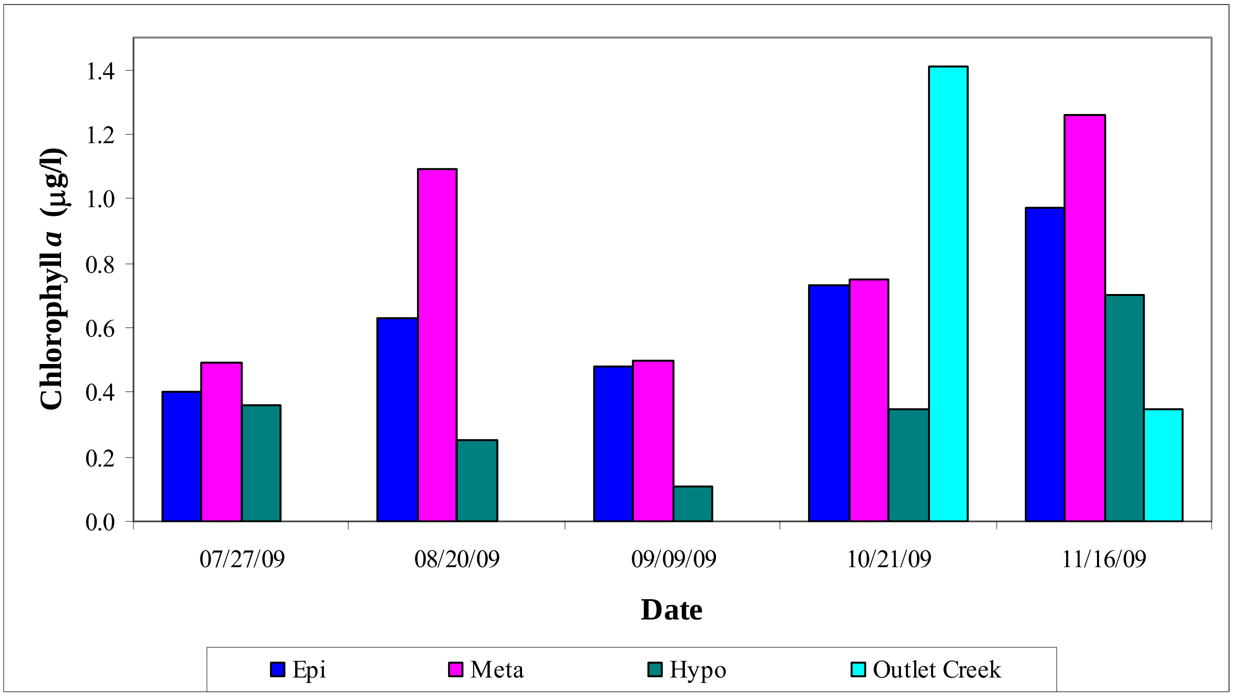

Figure 8. Chlorophyll *a* in Sullivan Lake and Outlet Creek.
Lake values represent averages between northern, middle, and southern lake locations.

Table 5. Sullivan Lake Secchi disk depths.

	07/27/09	**08/20/09**	**09/09/09**	**10/21/09**	**11/16/09**	**Average**
Depth (m)	11.7	12.5	10.5	13.0	17.0	12.9

4.4 Secondary Productivity

For the most part, zooplankton from Sullivan Lake and Outlet Creek were identified by species, with the exception of cyclopoids and calanoids (both subclass Copepoda, order Eucopepoda). For the purposes of reporting here, results were tallied by four categories into totals for *Daphnia spp.*, *Bosmina spp.* (both subclass Branchiopoda, order Cladocera), copepods, and rotifers (class Monogononta, order Ploima). The majority of zooplankton identified were either *Daphnia spp.*

or cyclopoids (28% *Daphnia spp.*, 2% *Bosmina spp.*, 44% cyclopoid, 10% calanoid, 16% rotifer). Tables 6-10 summarize the zooplankton results (Table 10 is the sum of Tables 6-9).

Table 6. *Daphnia spp.* Concentrations in Sullivan Lake and Outlet Creek.
All concentrations in #/l.

Location	Tow depth (m)	07/27/09	08/20/09	09/09/09	10/21/09	11/16/09	Average
North	5	26.63	0.99	0.66	1.92	1.97	6.43
	90	4.05	1.28	0.88	0.89	0.38	1.50
Middle	5	9.53	1.32	3.95	3.95	1.81	4.11
	90	4.05	1.25	0.60	0.41	0.35	1.33
South	5	3.95	0.66	3.95	5.92	0.49	2.99
	60	3.56	0.49	0.63	0.78	0.38	1.17
Average	5	13.37	0.99	2.85	3.93	1.42	4.51
	90	3.89	1.01	0.70	0.69	0.37	1.33
Outlet Cr.		3.29	0.55	0.00	1.64	0.55	1.21

Table 7. *Bosmina spp.* Concentrations in Sullivan Lake and Outlet Creek.
All concentrations in #/l.

Location	Tow depth (m)	07/27/09	08/20/09	09/09/09	10/21/09	11/16/09	Average
North	5	0.99	0.00	0.00	1.92	0.11	0.60
	90	0.09	0.00	0.00	0.34	0.24	0.13
Middle	5	0.33	0.00	0.66	0.16	0.16	0.26
	90	0.03	0.00	0.05	0.10	0.02	0.04
South	5	0.00	0.66	0.00	0.33	0.25	0.25
	60	0.05	0.08	0.11	0.05	0.11	0.08
Average	5	0.44	0.22	0.22	0.80	0.17	0.37
	90	0.06	0.03	0.05	0.16	0.12	0.08
Outlet Cr.		0.00	0.00	0.00	0.55	1.64	0.44

Table 8. Copepod Concentrations in Sullivan Lake and Outlet Creek.
All concentrations in #/l.

Location	Tow depth (m)	07/27/09	08/20/09	09/09/09	10/21/09	11/16/09	Average
North	5	16.77	3.62	13.15	19.45	9.53	12.50
	90	2.40	2.01	1.31	3.87	2.57	2.43
Middle	5	10.19	2.30	9.86	12.00	9.70	8.81
	90	2.50	1.22	0.89	2.26	1.42	1.66
South	5	6.25	3.29	18.41	12.49	4.27	8.94
	60	2.33	1.01	1.95	3.24	1.95	2.10
Average	5	11.07	3.07	13.81	14.65	7.83	10.09
	90	2.41	1.41	1.38	3.12	1.98	2.06
Outlet Cr.		7.67	1.10	0.00	10.96	14.25	6.80

Table 9. Rotifer Concentrations in Sullivan Lake and Outlet Creek.
All concentrations in #/l.

Location	**Tow depth (m)**	**07/27/09**	**08/20/09**	**09/09/09**	**10/21/09**	**11/16/09**	**Average**
North	5	1.97	0.66	0.00	2.47	1.42	1.30
	90	1.58	0.67	1.13	0.79	0.27	0.89
Middle	5	1.64	0.00	4.27	1.32	1.97	1.84
	90	1.00	1.25	0.68	0.55	0.27	0.75
South	5	0.66	0.00	3.62	0.00	0.74	1.00
	60	1.96	0.60	0.85	0.82	0.19	0.88
Average	5	1.42	0.22	2.63	1.26	1.38	1.38
	90	1.51	0.84	0.89	0.72	0.24	0.84
Outlet Cr.		2.19	0.55	0.00	2.19	0.55	1.10

Table 10. Total Zooplankton Concentrations in Sullivan Lake and Outlet Creek.
All concentrations in #/l.

Location	**Tow depth (m)**	**07/27/09**	**08/20/09**	**09/09/09**	**10/21/09**	**11/16/09**	**Average**
North	5	46.36	5.27	13.81	25.76	13.03	20.85
	90	8.12	3.96	3.32	5.89	3.46	4.95
Middle	5	21.69	3.62	18.74	17.43	13.64	15.02
	90	7.58	3.72	2.22	3.32	2.06	3.78
South	5	10.86	4.61	25.98	18.74	5.75	13.19
	60	7.90	2.18	3.54	4.89	2.63	4.23
Average	5	26.30	4.50	19.51	20.64	10.81	16.35
	90	7.87	3.29	3.03	4.70	2.72	4.32
Outlet Cr.		13.15	2.20	0.00	15.34	16.99	9.54

Selected results tabulated in Tables 6-9 are illustrated in Figures 9-13. Figure 9 shows densities by zooplankton category for the entire water column (vertical tows of 60-90m depending on location) averaged across all three sites (northern, middle, and southern). Figure 10 shows the corresponding data for Outlet Creek (3m horizontal tow). Figure 11 shows a comparison between the two most prevalent zooplankton categories for vertical tows of 5m and 90m at the North Sullivan Lake location. Figures 12 and 13 show the corresponding comparisons for the Middle and South Sullivan Lake locations, respectively.

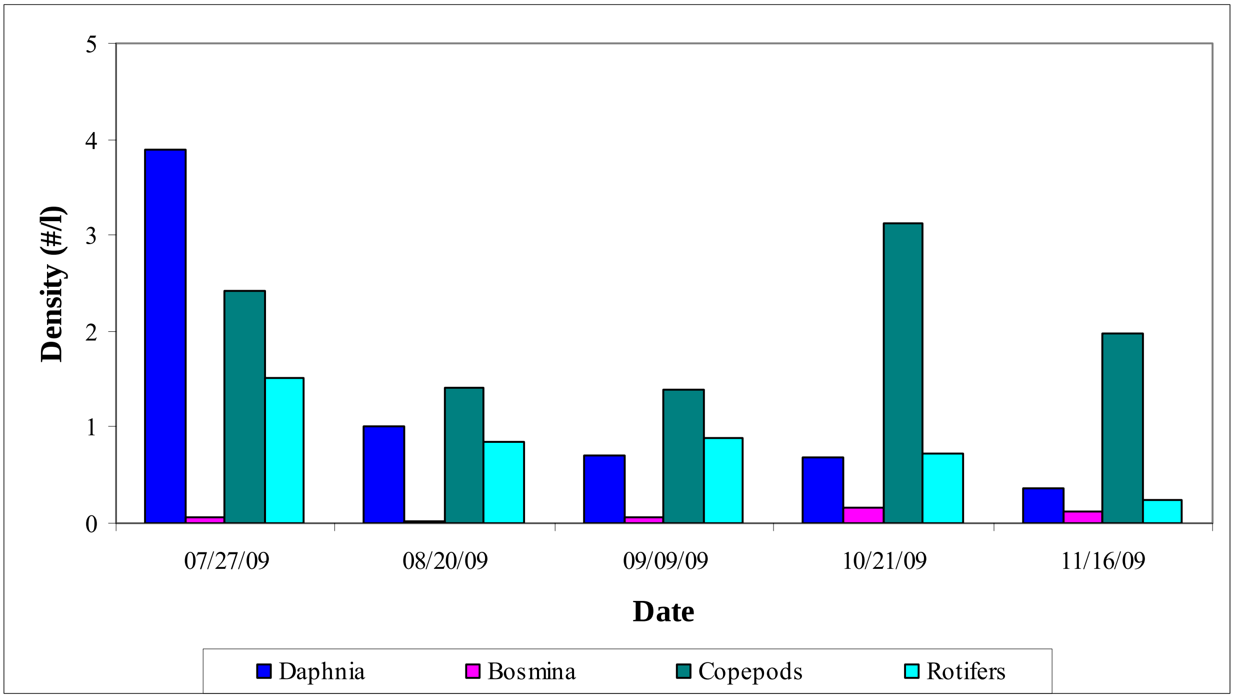

Figure 9. Zooplankton density in Sullivan Lake in total water column.
Averages between northern, middle, and southern lake locations.

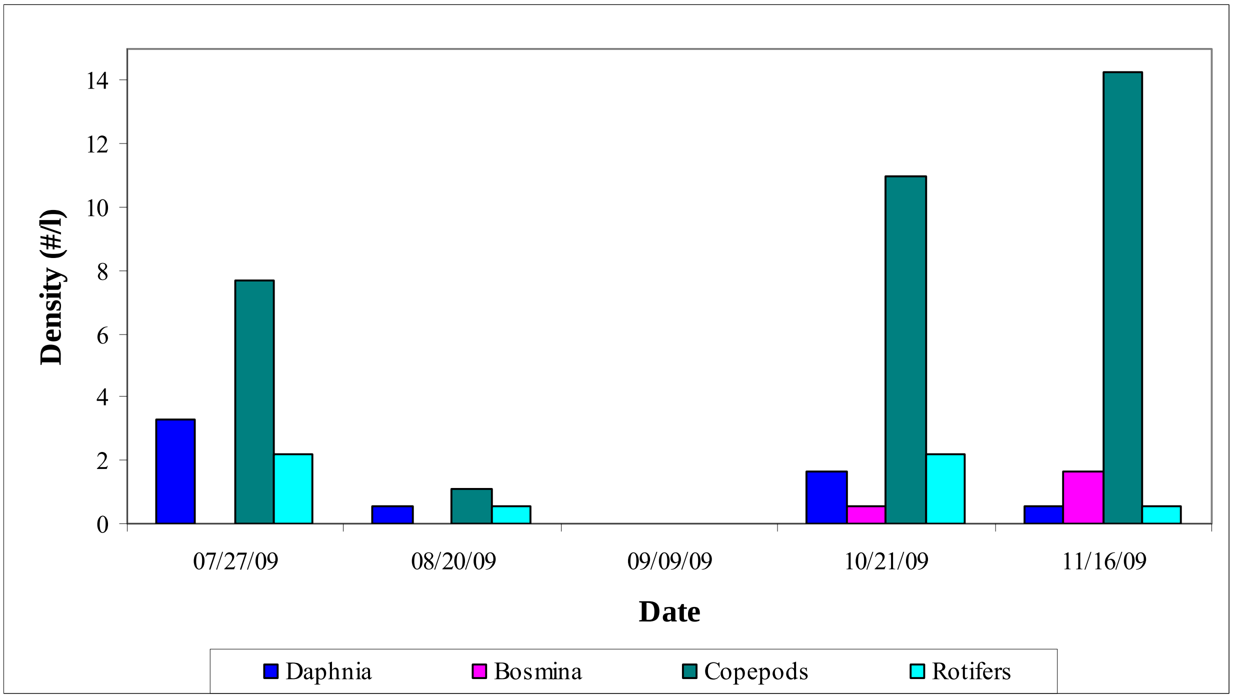

Figure 10. Zooplankton density in Outlet Creek.
No zooplankton was found in the September samples.

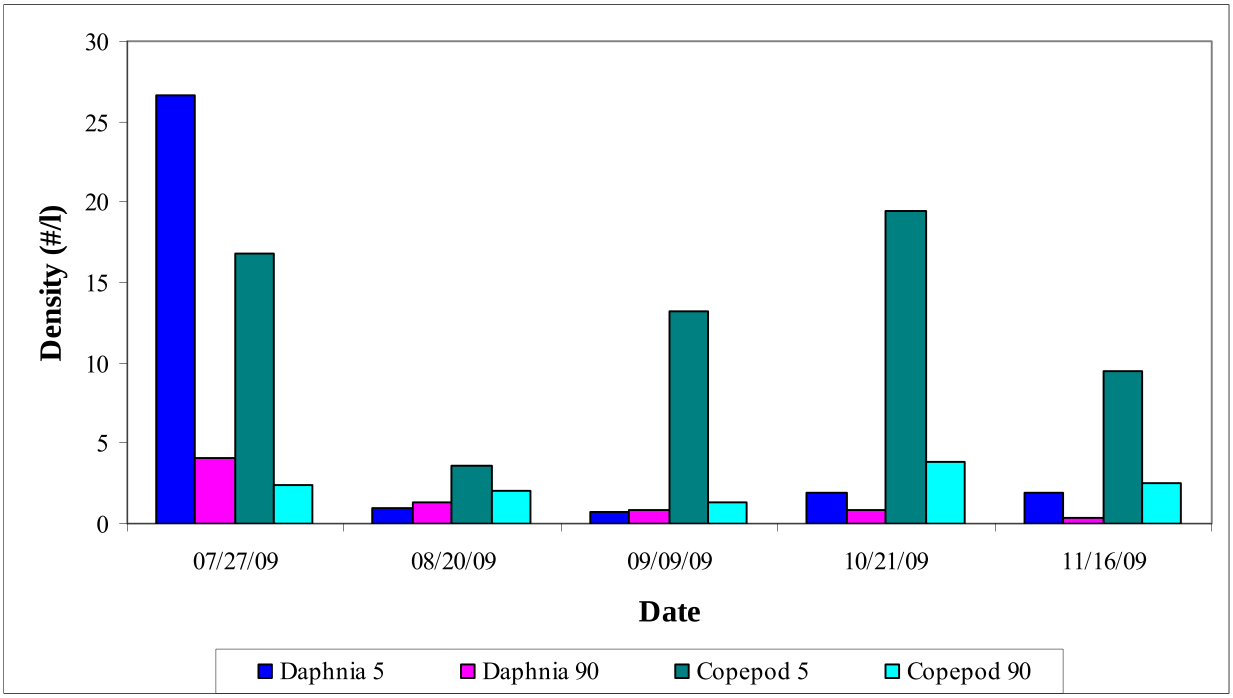

Figure 11. Zooplankton density comparison at North Sullivan Lake location for vertical tows of 5m and 90m.

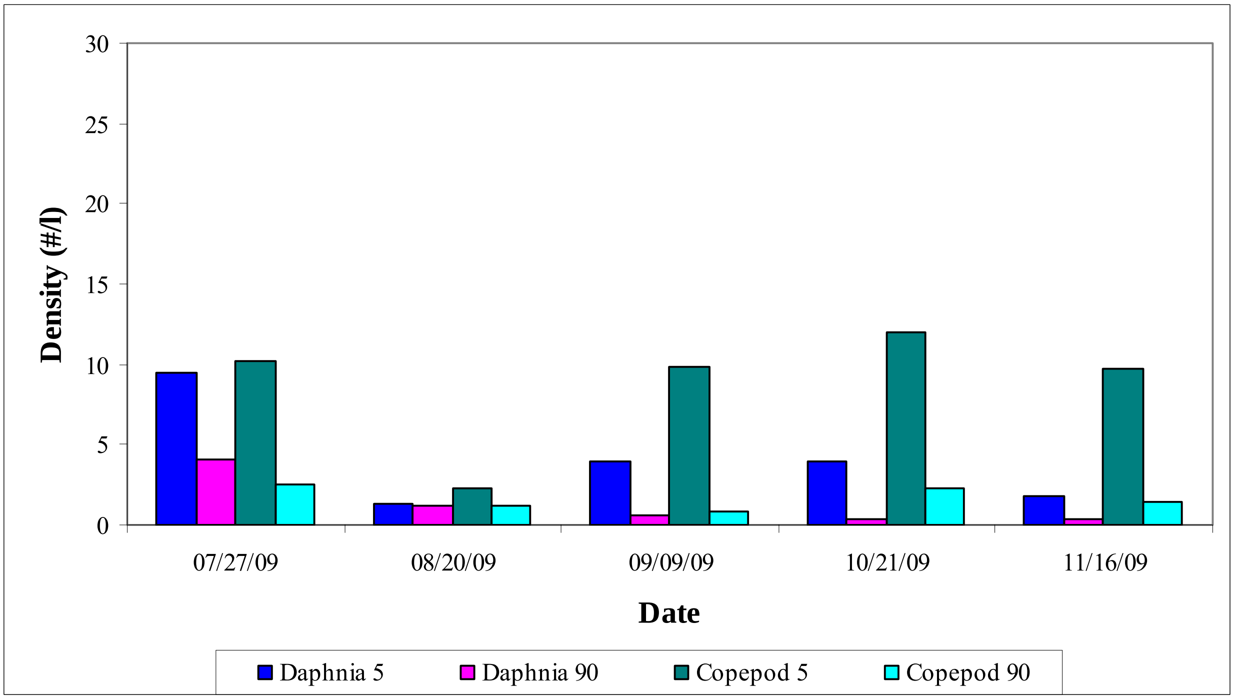

Figure 12. Zooplankton density comparison at Middle Sullivan Lake location for vertical tows of 5m and 90m.

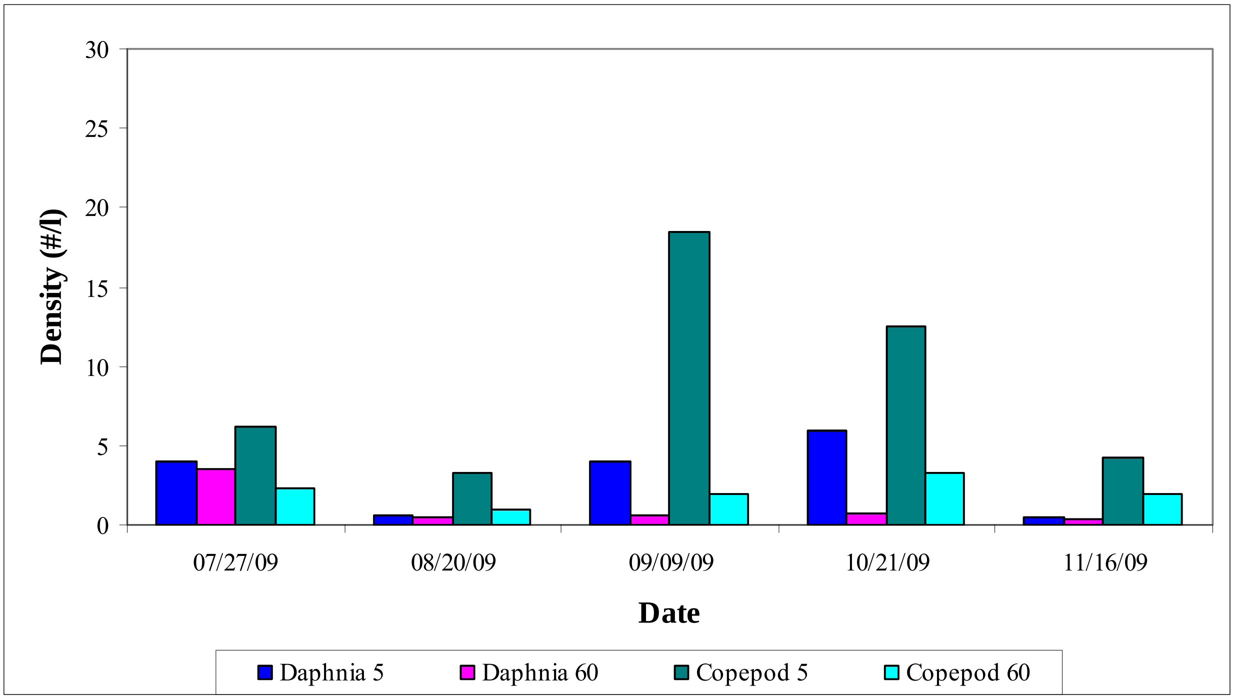

Figure 13. Zooplankton density comparison at South Sullivan Lake location for vertical tows of 5m and 60m.

5.0 DISCUSSION AND CONCLUSIONS[2]

5.1 Water Quality

Sullivan Lake was stratified for the entire study period, but was approaching isothermal conditions by the last sampling period in mid-November (Figure 2). This is consistent with continuous monitoring data collected independently by the District in 2009 (Figure 14). The spatial and temporal patterns of temperature distribution in the lake found in this study were consistent with that found by Nine and Scholz (2005). The highest water temperature recorded in this study was 21.5°C in the epilimnion in July. Water quality standards for surface waters of Washington State suggest an upper limit of 17.5°C for rearing and migration of salmonids (WAC 1999). Temperature does not appear to limit fish production in Sullivan Lake, because average temperatures fall between the preferred temperatures for salmonids (10°C to 20°C). In some cases, water temperatures at the surface may exceed optimum temperatures for salmonids, but temperatures in the metalimnion and hypolimnion provide refuge from higher temperatures at the surface, since there is abundant oxygen in all strata. Water temperatures in Outlet Creek were similar to those at approximately 5m depth in the lake.

[2] Much of the background information in this discussion is drawn from Nine and Scholz (2005).

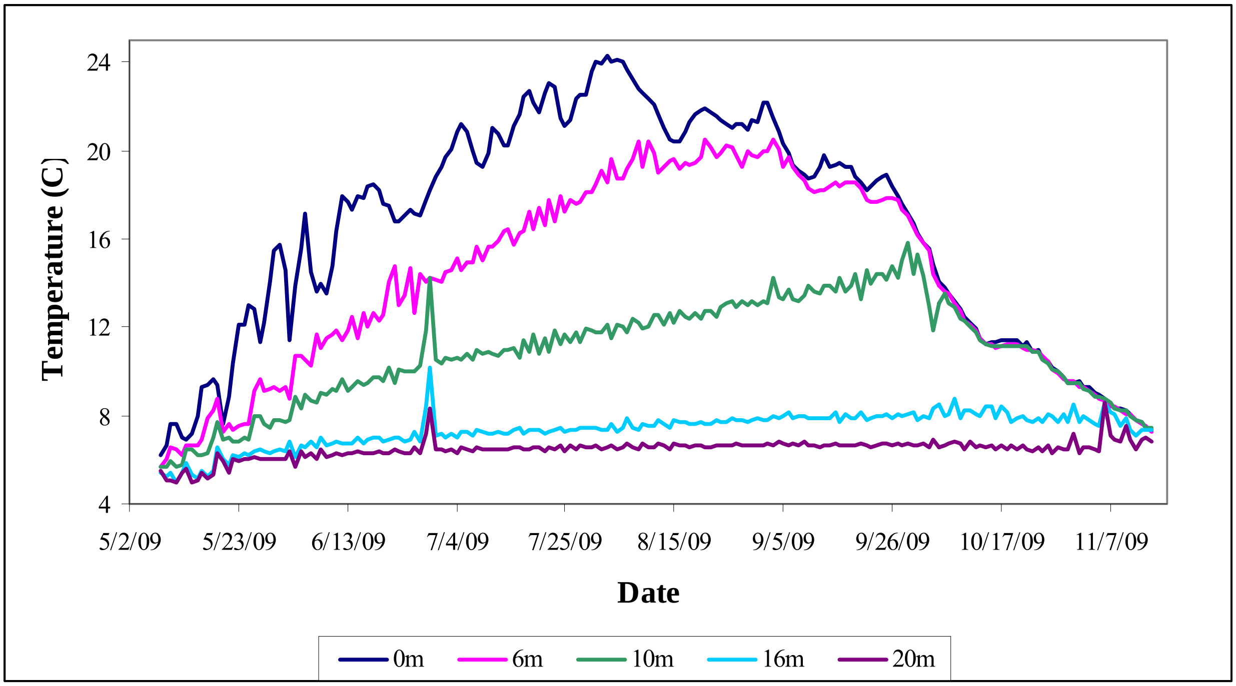

Figure 14. Continuous temperature monitoring data in Sullivan Lake at selected depths.

Dissolved oxygen concentrations averaged 9.0 mg/l in the epilimnion, which is within the optimum range for normal physiological functions in salmonids (Bjorn and Reiser 1991). Concentrations never declined below 7.2 mg/l anywhere in the lake, which is more than the 6.5 mg/l DO concentration required by salmonids (WAC 1999). The spatial and temporal patterns of DO distribution in the lake were consistent with that found by Nine and Scholz (2005). DO does not appear to limit fish production in Sullivan Lake. The lake also has sufficient oxygen content throughout the water column. DO in Outlet Creek was considerably lower, averaging 5.2 mg/l.

The optimum pH for fish is between 5 and 10, with the upper and lower ends of the range having negative impacts on fish (Bennett 1971). Washington State criteria recommend a range between 6.5 and 8.5 for salmonids (WAC 1999). The pH of Sullivan Lake averaged 8.3 in the epilimnion, 8.0 in the metalimnion and 7.7 in the hypolimnion. The pH measured in this study was in the same range as that found by Nine and Scholz (2005). However, there did appear to be an increasing trend in pH through the summer and into the fall, which was not apparent in observations made by Nine and Scholz (2005). Sullivan Lake falls within the recommended range, and therefore pH does not appear to limit fish distribution. Outlet Creek pH was in the same range as the lake.

Turbidity is a measure of the amount of suspended particulate in the water. The greater the amount of total suspended particulate in the water, the murkier it appears, and the higher the measured turbidity. For disturbance-related effects on turbidity, the recommended standard is 5 NTU over background when the background is less than 50 NTU (WAC 1999). The maximum turbidity recorded was 1.6 NTU in the epilimnion, 3.1 NTU in the metalimnion, and 2.9 NTU in the hypolimnion. Turbidities measured in this study were in the same range as those found by

Nine and Scholz (2005). The increased turbidity during the November sampling period may be due to a different sampling crew and equipment, or may be due to increased precipitation in the fall. Turbidity does not appear to be a limiting factor in Sullivan Lake. Turbidity in Outlet Creek was similar to that in the lake.

Conductivity is a measure of total dissolved ions in the water, such as ionized nutrients (NH_4^+, NO_2^-, NO_3^-, PO_4^-). Conductivity is therefore a useful indicator of a lake's productivity. The typical range of conductivity values for surface waters is 0.030-0.400 mS/cm (EPA 2001). Studies of inland fresh waters indicate that streams supporting good fisheries have a range between 0.15 and 0.50 mS/cm (EPA 2001). Conductivity in Sullivan Lake averaged 0.092 mS/cm in the epilimnion, 0.093 mS/cm in the metalimnion, and 0.097 in the hypolimnion. Conductivity measured in this study was similar to that found by Nine and Scholz (2005). This suggests that limited amounts of ionized nutrients may limit production in the lake. Conductivity in Outlet Creek was somewhat higher than in the lake, averaging 0.114 mS/cm.

5.2 Nutrients

Nitrogen and phosphorus are nutrients required to form proteins and other necessary biological compounds. Nitrogen availability in lakes is usually greater than phosphorus, with normal ratios in the range of 7:1 to 10:1. Higher ratios indicate a deficiency in phosphorus (Horne and Goldman 1994), and lakes with these higher ratios tend to be phosphorus limited. Phosphorus limitation is typically associated with oligotrophy (Horne and Goldman 1994). Lakes with lower ratios of nitrogen to phosphorus tend to be nitrogen limited. Nitrogen limitation is typically associated with eutrophy (Horne and Goldman 1994).

Phosphorus is a common growth limiting nutrient for phytoplankton in freshwater lakes, because it is present in very low concentrations (Horne and Goldman 1994). Oligotrophic lakes average less than 0.01 mg/l, compared to mesotrophic and eutrophic lakes that average 0.01-0.25 mg/l and >0.25 mg/l, respectively (EPA 1986). Sullivan Lake falls within the federal criteria for classification as oligotrophic, averaging 0.007 mg/l. Total phosphorus limits phytoplankton production in Sullivan Lake. Total phosphorus levels in Outlet Creek were similar to those in the lake. However, total phosphorus did appear to trend downward in the fall in both the lake and Outlet Creek (Figure 15), which is consistent with results found by Nine and Scholz (2005).

Total reactive phosphorus (ortho-phosphate) is a measure of the inorganic oxidized form of soluble phosphorus. It is a better measure of phosphorus in less productive lakes, because it determines what is biologically available to phytoplankton for photosynthesis (Horne and Goldman 1994). Sullivan Lake averaged 0.006 mg/l ortho-phosphate. Ortho-phosphate levels in Outlet Creek were similar to those in the lake. Ortho-phosphate levels also appear to have trended down in the fall (Figure 16), which is also consistent with results found by Nine and Scholz (2005).

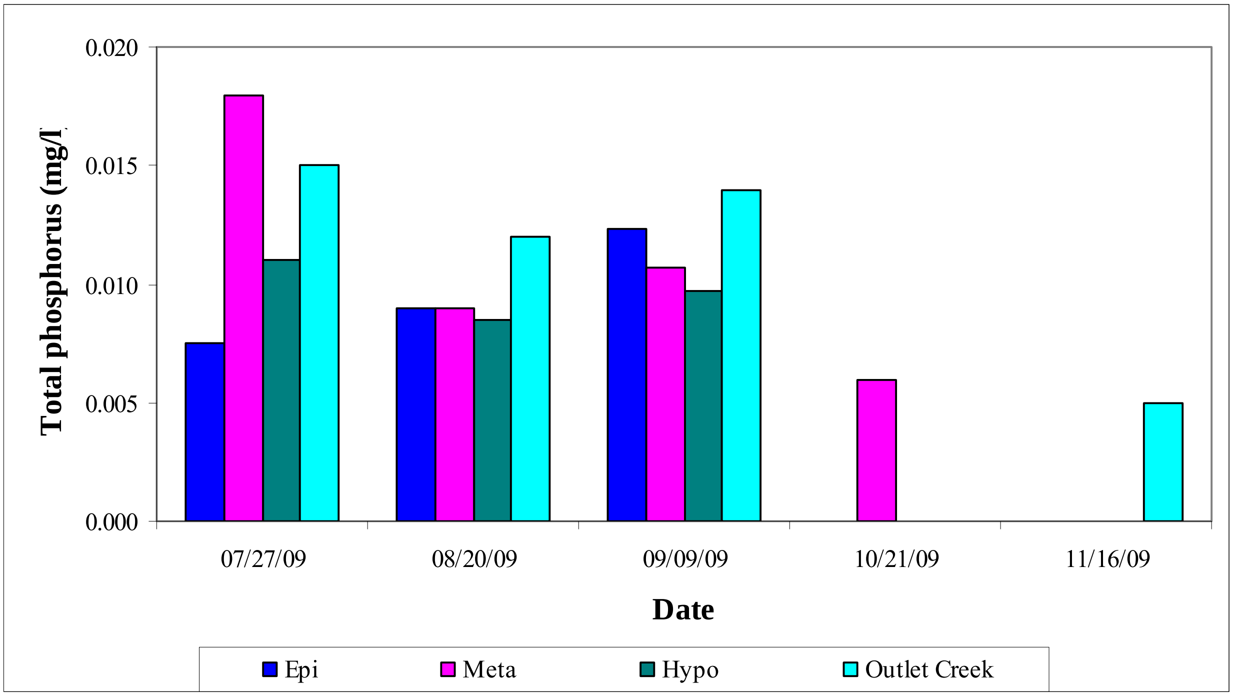

Figure 15. Total phosphorus in Sullivan Lake and Outlet Creek.

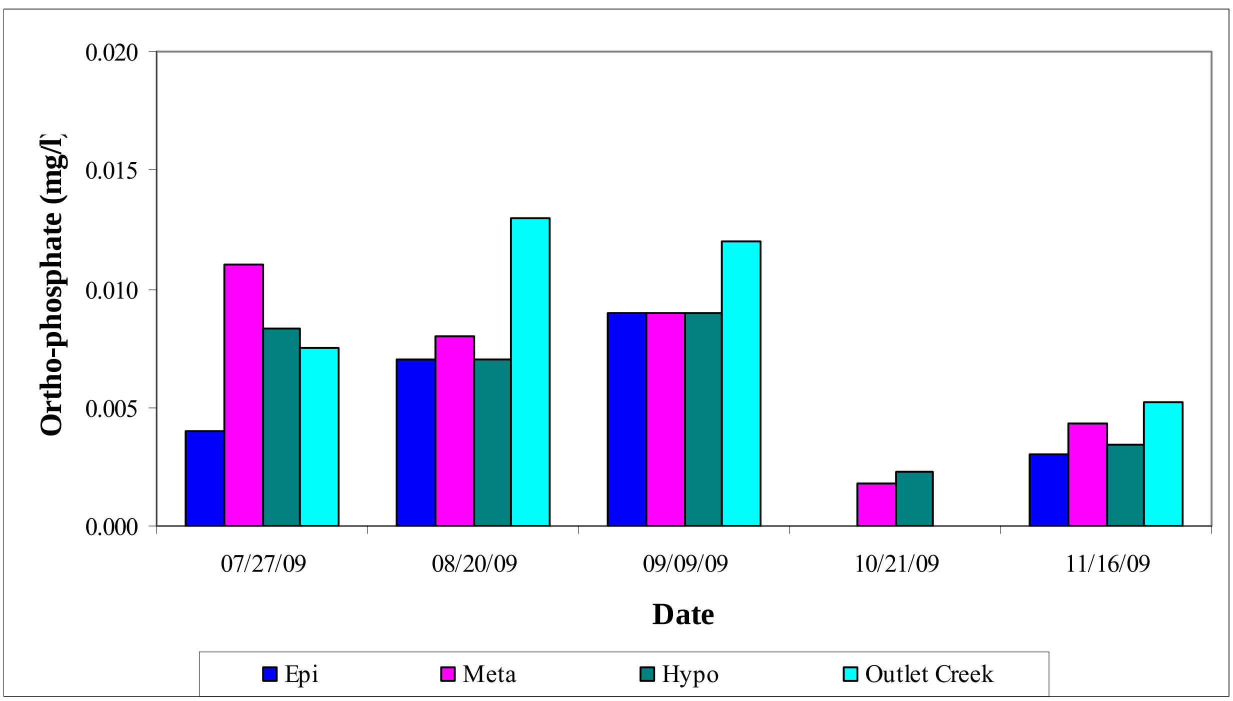

Figure 16. Ortho-phosphate in Sullivan Lake and Outlet Creek.

Published data on average total nitrogen and total phosphorus in the epilimnion have shown that nitrogen:phosphorus ratios are very high in oligotrophic lakes, because the majority of nitrogen and phosphorus come from undisturbed watersheds, which export much less phosphorus than nitrogen (Downing and McCauley 1992). Lakes that receive the majority of their runoff from forests should have higher ratios compared to those that receive primarily groundwater or river water inputs (Downing and McCauley 1992). Sullivan Lake had a high ratio of 27:1 in the epilimnion (average of 0.16 mg/l of TKN and 0.006 mg/l of total phosphorus), indicating a system limited by phosphorus. This is higher than the ratio of 13:1 found by Nine and Scholz (2005). Nitrogen does not currently limit fish production, because the lake is phosphorus limited. However, if phosphorus levels increased, the lake would rapidly become nitrogen limited, because nitrogen levels are low. Total nitrogen and total phosphorus levels in Outlet Creek were generally in the same range as in the lake, but with a ratio of nitrogen:phosphorus of 14:1.

Nitrite is an unstable form of nitrogen that is rapidly oxidized to nitrate or reduced to nitrogen gas, and is usually found in small amounts, such as those found in Sullivan Lake (<0.01mg/l). Although a certain amount of nitrogen in this form is necessary to sustain life, nitrites can be toxic to aquatic life at relatively low concentrations. The nitrite nitrogen level in Sullivan Lake never increased above detection limits (0.01 mg/l). This is consistent with results found by Nine and Scholz (2005). Therefore, nitrite toxicity does not present a problem for fish in Sullivan Lake. Extremely low levels of nitrite may contribute to limiting phytoplankton production in Sullivan Lake, although the lake is currently limited by phosphorus, as described above. Nitrite nitrogen in Outlet Creek was also consistently below the detection limits of 0.01 mg/l.

Nitrate nitrogen in the lake was often less than 0.01 mg/l, but at times rose as high as 0.03 mg/l. Nitrate nitrogen is not toxic to fish until it increases above 10 mg/l (Horne and Goldman 1994). Piper et al. (1982) suggest nitrate nitrogen levels ranging from 0.0-0.3 mg/l for rearing trout. Nitrate levels in Sullivan Lake were within the recommended range, and therefore do not present a nitrate toxicity problem to fish. Nitrate levels measured in this study were in the same range as those found by Nine and Scholz (2005). Low levels of nitrate may contribute to limiting phytoplankton production in Sullivan Lake, although the lake is currently limited by phosphorus, as described above. Nitrate nitrogen in Outlet Creek was somewhat higher than in the lake, averaging 0.04 mg/l. Nitrate nitrogen levels were relatively consistent over the study period in both the lake and Outlet Creek.

Ammonia levels in most lakes are below 0.1 mg/l (Horne and Goldman 1994). Ammonia is a nutrient utilized by phytoplankton in combination with carbon. It is toxic to aquatic animals at concentrations between 10 and 30 mg/l and aquatic plant life at concentrations above 500 mg/l (Horne and Goldman 1994). Sullivan Lake had low levels of ammonia, often below detection limits of 0.01 mg/l, and always less than 0.1 mg/l. Ammonia levels measured in this study were in the same range as those found by Nine and Scholz (2005). Ammonia levels in Outlet Creek were similar to those in the lake. Ammonia levels in both the lake and Outlet Creek had diminished to below detectable limits by September and remained there into the fall (Table 2).

Hydrogen sulfide (H_2S) released at the mud-water interface oxidizes and forms sulfate (Horne and Goldman 1994). Sulfate in Sullivan Lake increased from an average of 3.55 mg/l in the epilimnion to 4.07 mg/l in the hypolimnion. This indicates an oxygenated micro-zone at the bottom of the lake, which is characteristic of oligotrophic lakes. Eutrophic lakes typically are unable to oxidize H_2S into sulfate, because oxygen content is too low in the deepest waters. These results are consistent with those found by Nine and Scholz (2005). Sulfate levels in Outlet Creek were in the same range as those in the lake. Sulfate levels were relatively steady over the study period in both the lake and Outlet Creek.

Total dissolved solids (TDS) include inorganic salts and organic matter dissolved in the water. TDS concentration varies with different mineral solubilities. TDS is typically 30 mg/l-65 mg/l in water in contact with igneous and metamorphic rock, siliceous sand, well-leached soil, or other relatively insoluble material (Rainwater 1960; Garrison Investigative Board 1977). In areas where carbonates, chlorides, calcium, magnesium, and/or sulfates are present, TDS levels range between 195 mg/l-1100 mg/l (Garrison Investigative Board 1977). In a survey of the Great Lakes, TDS levels ranged from 61 mg/l-227 mg/l (Upper Lakes Reference Group 1977). In Sullivan Lake, TDS concentrations averaged 67 mg/l in the epilimnion, 74 mg/l in the metalimnion, and 75 mg/l in the hypolimnion. Since these concentrations are less than 195 mg/l, this indicates a system that is relatively clear of inorganic salts. TDS levels measured in this study were in the same range as those found by Nine and Scholz (2005). TDS levels in Outlet Creek were similar to those in the lake, averaging 74 mg/l. TDS levels were relatively consistent over the study period in both the lake and Outlet Creek.

5.3 Primary Productivity

Chlorophyll *a* is often used as a trophic state indicator for primary production (Carlson 1977). Chlorophyll *a* in Sullivan Lake was low, averaging 0.60 µg/l, compared to 1.5 µg/l - 20 µg/l in more productive lakes. In addition, Secchi disk transparency was deep (average 13m), allowing for a large euphotic zone, indicating a system with dispersed phytoplankton production throughout the large euphotic zone. It also indicates a lake with very low primary productivity. Chlorophyll *a* was relatively steady in the lake over the study period, which is consistent with results found by Nine and Scholz (2005). Chlorophyll *a* in Outlet Creek was even lower than in the lake, averaging 0.35 µg/l. However, chlorophyll *a* in Outlet Creek was undetectable in the summer, increased dramatically in October, then declined somewhat in November (Figure 8). This increase in chlorophyll *a* in Outlet Creek appears to have coincided with the drawdown of Sullivan Lake, which began approximately October 1.

5.4 Secondary Productivity

Zooplankton were limited with respect to both density and species diversity. Only two species of cladocerans were found, including one species each of *Daphnia spp.* and *Bosmina spp.* Zooplankton in Sullivan Lake are likely limited by low phytoplankton production. They may also be limited due to an abundant kokanee population, which crops off the larger sized zooplankton.

The collection of zooplankton samples from the epilimnion and from the bottom to the surface indicated that zooplankton are utilizing areas below the epilimnion, although they tend to be more concentrated nearer the surface. Zooplankton likely spend the day-light hours in the upper part of the hypolimnion or lower part of the metalimnion, and by dusk move up into the metalimnion and epilimnion. This is a typical diurnal vertical migration behavior displayed by many zooplankton, especially larger-sized cladocerans, to avoid size-selective predation by visual predators (Zaret and Suffern 1976). Samples for this study were collected near the middle of the day, generally between 10:00 a.m. and 3:00 p.m., and may therefore reflect zooplankton migration toward the hypolimnion. The spatial pattern of zooplankton densities in this study is consistent with that found by Nine and Scholz (2005).

Species population data are inherently highly variable, which is also true in this instance, as illustrated by the data displayed in Figures 11-13. Therefore, trends in zooplankton density with time or location are difficult to discern. Nonetheless, *Daphnia spp.* appear to have declined in the lake over the study period, while copepods remained relatively steady or slightly increased (Figure 9). The temporal pattern of zooplankton densities is consistent with that found by Nine and Scholz (2005): *Daphnia spp.* peaked in July, copepods peaked in October, and *Bosmina spp.* remained relatively low but increased slightly in the fall. Zooplankton densities in Outlet Creek were similar to average densities found in the lake through the entire water column (compare Figures 9 and 10). However, copepods increased substantially in Outlet Creek in the fall (after initiation of lake drawdown in October) (Figure 10).

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Attachment 4

Draft Report Entrainment Investigation and Study of Fish Presence in the Vicinity of Sullivan Lake Dam

Revised DRAFT REPORT

ENTRAINMENT INVESTIGATIONS
AND
STUDY OF FISH PRESENCE IN THE VICINITY OF SULLIVAN LAKE DAM

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~~December 4, 2009~~
Revised February 2010

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1.0 INTRODUCTION

The Public Utility District No. 1 of Pend Oreille County (POPUD), currently the federal Licensee of the non-generating Sullivan Lake Project (FERC No. 2225), has proposed to surrender the FERC license and continue to operate the Project under a Special Use Authorization to be issued by the USDA Forest Service. In the course of settlement discussions for these processes, the POPUD, resource agencies and other stakeholders are examining possible future operating scenarios for the Project that would differ somewhat from the way it has been operated under the FERC license. Currently, Sullivan Lake is annually drawn down approximately 20 feet each fall from its full pool elevation of 2,588.66 ft MSL, beginning October 1.

The settlement Team (Team) is examining an operating regime that would draw the lake down during the summer period, with the fall drawdown commencing either in September or October. In the process of developing this scenario for the management of Sullivan Lake, several questions were identified regarding the potential impacts of the changes. These included, but were not limited to:

- Productivity in Sullivan Lake and Outlet Creek, and potential changes in productivity due to lake operations
- Distribution of fish in the vicinity of Sullivan Lake Dam that could potentially be entrained
- Fish entrainment below the Sullivan Lake Dam during periods of spill

POPUD initiated studies to address these questions, and this report summarizes results of the study for fish entrainment; a separate report provides information on the productivity investigations. The District also conducted a hydroacoustic analysis along with a series of netting surveys in Sullivan Lake to document fish presence. Given recent agreements reached related to the license surrender, however, these results were deemed unnecessary and thus, are not included in this report.

Sullivan Lake supports a naturally reproducing population of kokanee (*Oncorhynchus nerka*), originally stemming from several different stocking efforts. The Washington Department of Ecology (WDOE 1997) classified Sullivan Lake as oligotrophic due to low concentrations of total phosphorus and chlorophyll *a* and high Secchi disk depth values. Oligotrophic lakes generally have low production of algae and zooplankton, and high water clarity (Horne and Goldman 1994). Aquatic macrophyte densities were low in Sullivan Lake (WDOE 1997).

2.0 METHODS

This section describes methods used to determine the level of fish entrainment immediately below the Sullivan Lake Dam in Outlet Creek. The entrainment study documented species and numbers of fish being removed from Sullivan Lake through the outlet gates at the dam into Outlet Creek.

Traps were used below the Sullivan Lake Dam concrete apron in Outlet Creek between October 1 and November 30, 2009 to determine the abundance and species composition of fish being removed from Sullivan Lake during spill.

On October 1, an Oneida trap with a 1.22 m^2 opening was installed approximately 65 m below the concrete dam apron (Figure 2-1). The mesh size in the net and trap was 6.4 mm. This site was selected due to extreme turbulence a previously selected site below the apron near the alarm. Due to the change in channel geometry at this alternate location, the trap could not be fished at 200 cfs as proposed, so approximately 130 cfs was released to maintain the integrity of the trap. The trap design was modified on October 29 with steel-reinforced rotating panels, with 6.4 mm mesh replacing the net. In addition, two traps were set at the downstream end: a 1.22m X 1.22m frame and a 0.91m X 0.91m frame with individual traps set up for each. Figure 2-1 shows the location of the traps.

Prior to operation of the trap, the Outlet Creek stream channel downstream of the concrete apron and upstream of the trap was electrofished by two crews to remove fish that resided in this section of Outlet Creek and to prevent double counting. Four times during the sampling period, this section of Outlet Creek was also electrofished to enumerate those fish that had not travelled downstream and been captured in the trap.

Initially, the trap was checked Monday through Friday; after the redesign of the trap, the net was checked at least once per day. Often, however, stream conditions (e.g., wind, leaf deposit, etc.) warranted the net begin checked several times per day to prevent clogging.

Data collected included:

- Species
- Length
- Condition/Health
- Comments related to any apparent injury
- Evidence of predation

Figure 2-1. Approximate Oneida Trap Location on Outlet Creek.

3.0 RESULTS

Oneida traps were used to capture fish in Outlet Creek below the concrete apron of Sullivan Dam between October 1, 2009 and November 30, 2009. A total of 1,291 fish were captured in the Outlet Creek during the netting period. This number represents a combination of fish captured in the net and via monthly electrofishing efforts. Table 3-1 displays capture information by species on a weekly basis. Forty-two percent of the total fish captured were captured during the first week of sampling (Oct. 1 - Oct. 7). The highest number of kokanee (45.7% of species total) was captured during the week of Oct. 22 – Oct. 28. It is important to note that during this week, an electrofishing survey was conducted. The number of kokanee captured during this week represents the combined total between electrofishing and netting. Red sided shiner numbers diminished significantly after the first week when 76% of the shiners were captured. The size distribution of the fish captured varied widely depending on the specific species. Figure 3-1 displays catch-per-week data for the Outlet Creek netting; Table 3-2 summarizes the size distribution of fish captured in Outlet Creek by species.

The initial net was put in place on September 29, 2009 and was fished continuously until October 29, with the exception of October 19 and 20, when the net was pushed over by an abundance of leaves and other natural debris. As previously discussed, the net configuration was modified on October 29 to facilitate higher flows down Outlet Creek. The new net fished continuously until November 30 except for November 18 and 19 when a large amount of windfall clogged the nets and required cleaning. The average flow down Outlet Creek while the

Table 3-1. Summary of Fish Captured in Outlet Creek (Netting and Electrofishing)

Species	Time Period									Total
	Oct 1 – 7	Oct 8 - 14	Oct 15 - 21	Oct 22 - 28	Oct 29 – Nov 4	Nov 5 - 11	Nov 12 - 18	Nov 19 – 25	Nov 26 – 30	
Cut-bow		2								2
German Brown Trout	27	23	27	22	5	5	4	10		122
Kokanee	1	10	12	136	25	36	46	15	20	297
Burbot	8	14	36	39	21	10	6	4	10	148
Long-Nose Sucker	5	2	3		2	1	1	1	1	16
Pygmy Whitefish		1	2	4	1		2	3	1	14
Mountain Whitefish			1	2						3
Rainbow Trout				1						1
Red Sided Shiner	496	80	32	10	9	15		6	2	649
Unknown Salmonid			1							1
Sculpin	2	1	1	11	2			1		18
Tiger Trout		1		1	1					3
Westslope Cutthroat Trout	3		5	6	1	1				16
Total	**542**	**134**	**120**	**233**	**67**	**68**	**59**	**40**	**34**	**1291**

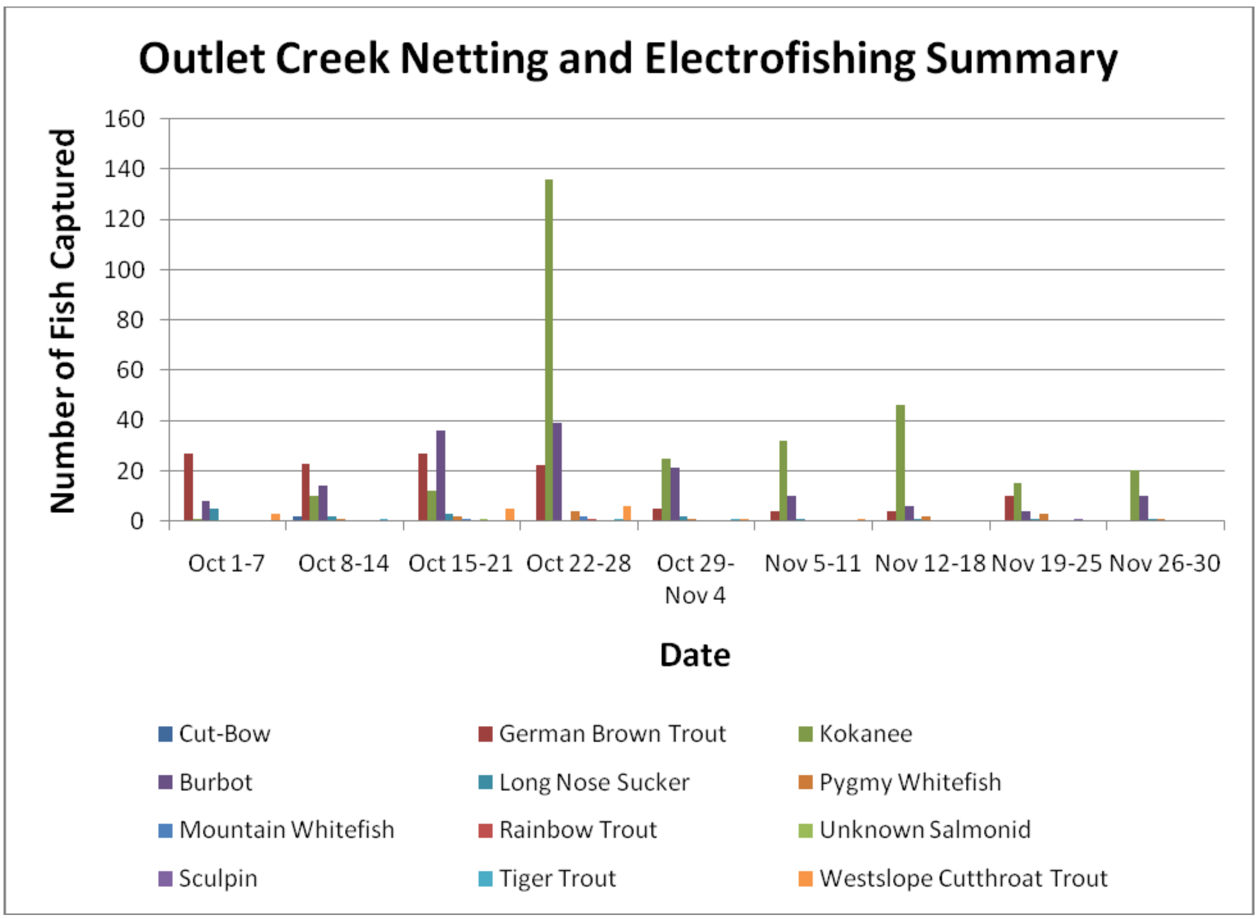

Figure 3-1. Outlet Creek netting summary

[Note: Due to large sample size, Red Sided Shiners were excluded from this graph.]

Table 3-2. Size Distribution of Fish Captured During Netting and Electrofishing in Outlet Creek						
Species	**Fork Length Range (mm)**					**Total**
	11-30	**31-60**	**61-120**	**121-250**	**251-500**	
Cut-bow				1	1	2
German Brown Trout		3	75	40	3	122
Kokanee		1		164	101	297
Burbot		2	69	45	27	148
Long-Nose Sucker		1	9	3	3	16
Pygmy Whitefish		1	7	6		14
Mountain Whitefish				2	1	3
Rainbow Trout				1		1
Red Sided Shiner	8	351	287	2	1	649
Unknown Salmonid				1		1
Sculpin		9	9			18
Tiger Trout				3		3
Westslope Cutthroat Trout			4	9	3	16
Total	**8**	**368**	**460**	**276**	**140**	**1291**

first net was in place was approximately 117 cfs. Flow after the nets were installed on October 29 ranged from over 180 cfs – 200 cfs (down periods for maintenance excluded).. The District electrofished 4 times during the netting period:

- October 2nd
- October 5th
- October 28th
- November 30th

On electrofishing days, the District did not differentiate between fish captured via electrofishing and those captured in the net. The District biologist conducting the work stated that the numbers of fish in the net on the days of shocking were similar to the day before and the day after (pers. comm.., Scott Jungblom). Figure 3-1 depicts numbers of fish netted on days of shocking that are the average of the day before and the day after shocking occurred.

Since capture methodology was not differentiated during District sampling, EESC estimated the numbers of fish that were in the area between the dam and the traps. These estimates were:

- October 2: 200
- October 5: 93
- October 28: 150
- November 30. No estimates of the number of fish that were electrofished between the dam and the net were provided when the study terminated on November 30.

WDFW, however, noted more than 100 kokanee between the dam and the traps on November 16; EESC staff noted between 100 and 150 kokanee on November 20.

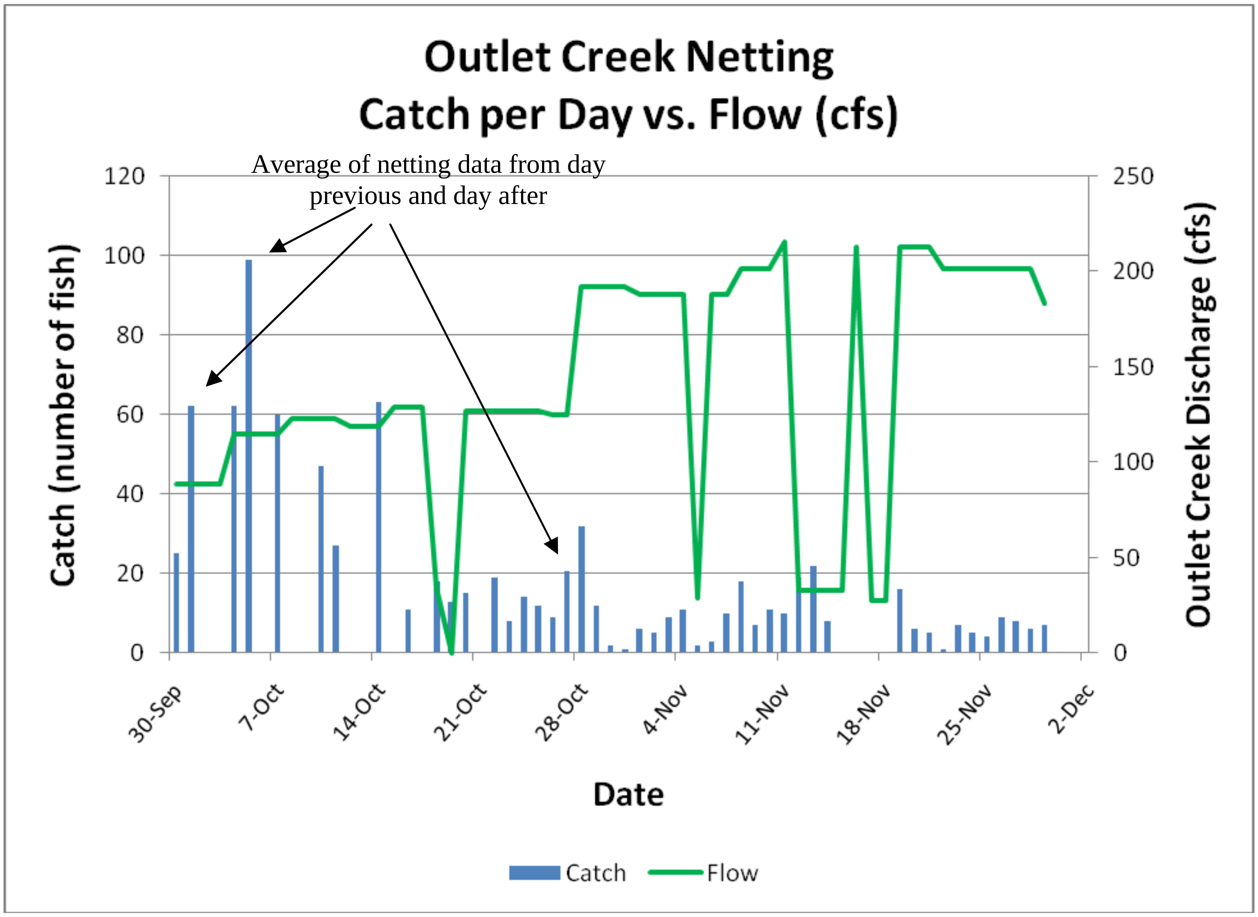

Figure 3-1. Outlet Creek Catch Data vs. Flow.
[Note: net and electroshocking catch were combined in catch records; electroshocking numbers were estimated and removed from the total numbers on the days when electroshocking occurred. Approximately 100 – 150 kokanee observed between November 16 -20 and are not represented in the graph].

4.0 DISCUSSION

A majority (76%) of the red-sided shiners captured during the nine-week netting period in Outlet Creek were captured during the first week of the survey. It is likely that many of the shiners captured were present in Outlet Creek above the net prior to its deployment. During the Outlet Creek Instream Flow Study conducted by WDFW, WDOE and the District in July, flows of up to 250 cfs or more were released from the lake, likely entraining many of these fish prior to the study beginning. Limited electrofishing in the area upstream of the net took place prior to net deployment and a large number of red-sided shiners were captured and moved downstream. Significantly more were identified and not moved simply due to the large numbers of the species, specifically near the concrete apron of the dam in groups of large boulders.

Prior to the net being removed on November 30, this District electrofished above the net to document any fish that were entrained but not captured in the net. Observations by WDFW personnel on November 16 and EESC personnel on November 18 described 100 plus kokanee present between the dam apron and the net in Outlet Creek. Personal communication with the the District biologist confirmed that an electrofishing survey took place on November 30, prior to the net being removed and that approximately 100 kokanee were captured. Approximately another 40 were not collected and likely moved downstream after the net was removed (pers. comm., Scott Jungblom). Since the net had collapsed during the study, the origin of those fish milling between the dam and traps is unknown; fish could have been swept through the gates and entrained below the dam, or could have migrated upstream from below the traps when the traps were inoperable and not able to return downstream.

As a result the total numbers of fish captured during the netting survey in Outlet Creek is an underestimate of the total number of fish entrained. The flow that was to be provided per the study plan had to be modified due to the limitations of the initially installed nets.