Ketchikan Creek Watershed Water Temperature Study for the Ketchikan Lakes Hydroelectric Project

FERC Project No. 420-000-Alaska
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1.0 Introduction

The purpose of this report is to provide the methods and results of the Ketchikan Creek Watershed Water Temperature Study for the Ketchikan Lakes Hydroelectric Project. This study is mandated by Article 404 of the project license issued by the Federal Energy Regulatory Commission (FERC).

1.1 Project Background

The City of Ketchikan, Alaska, acting through Ketchikan Public Utilities (KPU) holds a FERC license to operate and maintain the Ketchikan Lakes Hydroelectric Project (FERC 2000) for the purpose of providing power to the residents of Ketchikan. The hydroelectric project consists of a 4,200-kilowatt facility located within the Ketchikan Creek watershed, which includes Ketchikan Lakes, Ketchikan Creek, and Granite Basin (**Figure 1**). The entire hydroelectric project is within the boundaries of the Ketchikan Gateway Borough, on lands owned by the City of Ketchikan, State of Alaska, Bureau of Land Management, and the U.S. Forest Service. For a complete description of all components of the Ketchikan Lakes Hydroelectric Project, refer to the *Final Environmental Assessment for Hydropower License*, issued by the FERC and the USFS on May 17, 2000.

1.2 Temperature Study Area

The study focuses on the areas of the Ketchikan Creek watershed impacted by the hydroelectric project: Ketchikan Lakes and Granite Basin, down gradient to Ketchikan Creek below the tailrace at the Fair Street Bridge (**Figure 1**).

1.3 Temperature Study Goals and Objectives

The stated purpose of the FERC license Article 404 was to "…*conduct a water temperature study to identify the effect of project operations and facilities on water temperatures in Ketchikan Creek downstream of the project tailrace*." The specific objectives of the water temperature study are described below.

Objective # 1 – Determine if the Ketchikan Lakes Watershed's water temperatures are too warm and thus negatively affect either: (1) the receiving stream fishery below the powerhouse tailrace; or (2) the Deer Mountain Tribal Hatchery, which receives a portion of tailrace water.

Objective # 2 –Use the data collected from the study to identify effects of the project on water temperature and determine whether operational changes could reduce water temperatures during critical periods for sensitive fishery life stages.

This water temperature study was required by the resource agencies and FERC because of concern that the project may be increasing the water temperature and thereby adversely affecting the Hatchery or fish habitat in Ketchikan Creek downstream of the tailrace. There are no pre-project (1907) data of any kind, so all involved agreed that it would be impossible to conclusively assess conditions existing prior to creation of the Fawn Lake forebay, connection (using explosives) of Upper and Lower Ketchikan Lakes and construction of dams on Ketchikan Lakes that increased storage capacity.

Because potential benefits and costs of operational or structural improvements designed to reduce any water-warming effects could not be known until after the water temperature study was completed, the resource agencies agreed not to require KPU to make expensive project-related improvements. Therefore, FERC determined that the intent of this study would be to provide information about the effects of the project on water temperatures and to identify what, if any, zero or low-cost operational changes could be made to reduce water temperatures during critical periods for sensitive fishery life stages.

The ADF&G has cited 16 °C as the temperature at which Chinook salmon incubation can be affected if it is held constant (Alderdice and Velsen 1978). The same 16°C temperature was used in this study as the threshold to evaluate whether negative effects may be occurring. Furthermore, the Alaska Department of Environmental Conservation's 18 AAC 70 water quality standards show that their recommended temperature standards for aquaculture may not exceed 20°C at any time. They also recommend that the following maximum temperatures may not be exceeded, where applicable: Migration routes 15 °C; Rearing areas 15 °C; Spawning areas 13°C; Egg & fry incubation 13 °C (ADEC 2003). These temperature standards were also used to assess temperature conditions in the system.

The study focused on the season with a potential for these high temperatures to occur: the summer months of June, July, August, and September. This period can be considered the "worst case scenario", as no other months are likely to be of any concern regarding temperature.

During consultation, the following potential causes of warming (hypotheses to test) were identified by the agencies:

1) "Friction from the tunnel walls and from the turbines may increase water temperatures while in transit from Fawn Lake to the tailrace."
2) "Fawn Lake increases the surface area and exposure time to solar radiation."
3) "Damming the outlet of Ketchikan Lakes increased the lake surface area exposed to solar radiation."
4) "The water conveyance system from Ketchikan Lakes to Fawn Lake includes an 1,800-foot-long above ground pipeline that may contribute to higher water temperatures on sunny days."
5) "The project tunnels and pipelines shield the water from the sun, decrease the travel time and may, also, cool the water under some flow atmospheric conditions."
6) "Because the Granite Basin diversion has no storage, the project is operated to make maximum use of the Granite Basin flows, which are cooler than Ketchikan Lakes: under some conditions, this probably results in a higher proportion of the flow below the project coming from Granite Basin."

1.4 Important Deviation from Objectives

The origination of the temperature concern was an apparent misinterpretation of the needs of the Deer Mountain Tribal Hatchery, expressed in an interview between Hatchery personnel and ADF&G personnel. It was thought that the hatchery staff was struggling with high water temperatures in KPU's tailrace and that "the hatchery staff has learned to work around the high temperatures by using refrigeration techniques" (Denton 1996). However, the hatchery manager stated that the temperature of the ambient (receiving) water is not too high. The reason they are refrigerating/ cooling the water is to suppress development for management convenience. They chill king salmon so they can hold back development until March, and they chill the coho salmon to hold them back until the tanks are available. This typically has nothing to do with the health of the salmon. Furthermore, he stated that they chill the water down to 2.5°C, so they would need to use refrigeration no matter what water temperature was provided to the hatchery (Jerry Guthrie 2003). This temperature would be impossible for KPU to provide to the hatchery even if the intake was located in the very cold deepest portions of Ketchikan Lakes (in several hundred feet of water), which was documented during this study to average about 4.4°C.

However, the temperature issue evolved over the course of the permitting process to include possible operational temperature affects to the receiving stream and not just to the hatchery, so that is the focus of this study. The study results are summarized in the following sections.

2.0 Methods

2.1 Data Collection (Deployment and Retrieval) Methods

Nineteen temperature loggers were deployed between June 6-8, 2002 in Ketchikan Lake, Granite Basin, Fawn Lake, Scout Creek, and Ketchikan Creek (**Figure 1**). The loggers were programmed to measure water temperatures hourly through September, 2002.

HOBO® Water Temp Pro loggers developed by the Onset Computer Corporation were used for this study. The loggers have a measurement range of 0 °C to 50°C (32°F to 122°F) in water, a resolution of 0.02°C at 25°C and an accuracy of +/-0.2°C at 25°C. Complete specifications for the Water Temp Pro loggers are provided in **Appendix B**.

OtterTail staff calibrated and assembled the temperature loggers during the first week of June 2002. Prior to deployment, the loggers were placed in a bucket of water for two 24-hour periods to collect data at 1-hour intervals at the same ambient temperature. Through this exercise it was determined that there was no significant individual variability among recorders; therefore, no correction factor was needed for the data analysis. When deployed below stream confluences, all temperature loggers were placed far enough downstream to verify measuring fully mixed conditions.

The temperature logger identification numbers and deployment locations are listed in **Table 2-1,** starting with the point farthest downstream.

Table 2-1
Stream Temperature Monitoring Locations Within the Ketchikan Creek Watershed

Logger	Waterbody	Location
T1	Ketchikan Creek	Below powerhouse tailrace in Ketchikan Creek (T2+T3 flows)
T2	KPU powerhouse	In powerhouse tailrace
T3	Ketchikan Creek	Above powerhouse tailrace in Ketchikan Creek (bypassed reach)
T4	Ketchikan Creek	Below Scout Creek confluence
T5	Ketchikan Creek	Above Scout Creek confluence
T6	Scout Creek	At mouth (confluence with Ketchikan Creek)
T7	Ketchikan Creek	Below Granite Creek confluence
T8	Ketchikan Creek	Above Granite Creek confluence
T9	Granite Creek	Granite Creek at diversion- logger was stolen
T10	Granite Creek	Granite Creek Diversion
T11	Fawn Lake	Inflow from Granite Creek diversion
T12	Fawn Lake	Outflow to powerhouse
T13	Fawn Lake	Inflow from Ketchikan Lakes
T14a	Ketchikan Lake	Near surface above West intake
T14b	Ketchikan Lake	Near lake bottom at West intake entrance
T15a	Ketchikan Lake	Near surface above East Intake
T15b	Ketchikan Lake	Near lake bottom at East intake entrance
T16	Ketchikan Lake	Near surface midway between shore and max lake depth (326 ft)
T17	Ketchikan Lake	Near lake bottom (197 ft) at T16 location

All temperature loggers were retrieved October 1, 2002, with the exception of T9 on Granite Creek that was stolen during the sampling period (the anchor was present, but the recorder had been removed). Data were collected with the HOBO® Water Pro loggers for approximately 130 days at 1-hour intervals, 24 hours a day. The loggers operated under “stealth mode” without the flashing light to limit any manipulation, vandalism or theft. The loggers were retrieved from each site and the data were subsequently downloaded using the HOBO® data logger-specific software BoxCar® Pro 4.

To obtain accurate weather information in the project area relative to the stream temperature loggers, two weather stations were deployed in the Ketchikan Creek watershed; one at Ketchikan Lake and one just upstream from the tailrace above Ketchikan Creek on the penstocks (**Figure 1**). The HOBO® Weather Stations were assembled and outfitted with a rain gauge, a solar radiation shield with a temperature and relative humidity sensor, and a solar radiation sensor. The weather stations were launched the first week of June 2002 and located at the lake level gage platform at Ketchikan Lake (W1) and just upstream from the tailrace above Ketchikan Creek on the penstocks (W2).

Historical climate data has been collected at the nearest point in the project area at the Ketchikan International Airport (KIA) located at 55.36°N 131.71°W at about 75 feet above mean sea level. Data have been collected from 1949 to present and includes 24-hour precipitation, 24-hour snowfall, snow depth at observation, 24-hour maximum temperature and 24-hour minimum temperature. These data were obtained to determine if the on site weather stations were comparable to this long-term data set, thereby allowing the long-term data to represent weather at the Ketchikan Lakes Watershed.

Precipitation was recorded to allow real-time correlation between rainfall and water temperature. Solar radiation or light intensity was measured to be able to correlate solar radiation to water temperature (e.g., determination of how much a sunny day versus a cloudy day influences the temperature dynamics of the system). Ambient air temperature was collected for similar correlations to those above.

2.2 Data Analysis Methods

Data collected from the temperature loggers were compiled and summarized using the BoxCar® Pro 4 readout function and MS Excel. Hourly, daily, weekly and monthly temperature data were assessed for the study area. To obtain an overview of the system, figures were developed that illustrate the average mean, maximum and minimum monthly temperatures measured from June through September in the Ketchikan Creek watershed. Figures presenting hourly temperature data per station were also developed.

The HOBO® Weather Stations W1 and W2 were located at the sites identified on **Figure 1** and had a sampling interval set at every three minutes with a one-hour logging interval.

3.0 Results

Results of the hourly water temperature data are provided in the following sections. Because of the differences in lake dynamics compared to the stream stations, the Ketchikan Lake stations are discussed separately from the stream stations.

3.1 Weather Station Results

The weather stations were deployed down at the lower elevations near the tailrace (W2) and at an upper elevation area on the Ketchikan Lakes dam (W1). Although there is a considerable elevation difference between weather stations, the data suggests that these two stations showed no significant differences during the study period. Furthermore, the KIA weather data were evaluated with these site specific stations and appeared to accurately represent the study area, thereby allowing use of historical climatological data to represent the Ketchikan Lakes Watershed and compare the study year to the period of record..

The total monthly precipitation for all three weather stations is shown in **Appendix A-5** and the average daily precipitation for the study period is shown in **Appendix A-6**. Based on the data collected at weather stations W1 and W2 and at KIA, the sample period was wetter than average and August had almost double the amount of precipitation compared to the historical period of record.

W1 was selected as the station to use in this study's data analysis because it is located approximately in the center of the watershed and; therefore, was thought to best capture the weather patterns of the system.

It was hypothesized that any potential critical summer time temperature spikes were related to extended periods with no rain and full sunshine. Therefore, correlations were conducted on water temperature vs. precipitation, water temperature vs. solar radiation, and water temperature vs. air temperature. No correlations were found with any of these statistics; however, one obvious--though nonstatistical--observation was found; rainfall appeared to be the most important factor controlling stream temperatures (**Figures 12 - 30**). As can be easily seen in **Figure 12**, almost every significant rain event resulted in a substantial decrease in water temperatures. Solar radiation and air temperature did not show this obvious trend at all. So, while there is no doubt that sunshine and higher air temperatures influence the water temperatures, they do not appear to be as substantial of an influence as rainfall.

3.2 Stream Water Temperature Results

The 2002 data suggests that there is not a major temperature concern to the fishery, as none of the average temperatures in the stream stations reached the 16 °C chinook threshold, nor did it ever reach the 20 °C not-to-exceed maximum state water quality standard (**Figure 3**). The temperatures do frequently exceed the ADEC's 13°C standard for spawning areas and egg & fry incubation and occasionally the 15 °C standard for migration routes and rearing areas. However, these data suggest that there is almost no doubt that the natural/pre-project temperatures within Ketchikan Creek were above these standards and that they are not realistic for this system. For example, the Ketchikan Lake station T15a likely represents temperatures that are very close to what would have occurred naturally in the outlet stream of the lake. This is because the lake is natural and has only had its storage capacity increased slightly. T15a exceeds the 13°C over half of the study period and over a month straight during the peak of the summer (**Figure 26**).

Using the 16°C chinook threshold, the waters in Ketchikan Creek below the tailrace (T1) only reached 16°C a few times in August, and even then it was only in short duration ((**Figure 4** and **Figure 12**). This is due to the temperature buffering affect of Granite Basin Creek as discussed below. As would be expected, the lowest average minimum monthly temperatures occurred in the month of June due primarily to residual snowmelt. The majority of average maximum monthly temperatures occurred during August.

3.2.1 Scout Creek Station

The temperature monitoring station at the mouth of Scout Creek (T6) represents a perennial creek that has not been affected by the project operation and, therefore, has natural flows and temperatures. Scout Creek typically contributes approximately half of the flows to the above-tailrace station, according to one flow measurement, several qualitative field observations, and even the temperature data itself. To get a mean temperature of 11.09°C at the Ketchikan Creek station above Scout Creek (T5), and 10.55°C immediately downstream of Scout Creek (T4); the Scout Creek (T6) mean water temperature of 10.0°C result could only be obtained with a volume of approximately half of the T5 volume (Figure 3). In other words, 1.09 divided by 2 is 0.55, and adding 10.0 to 0.55 provide a value very close to the T6 value (identical to the hundredths).

It is important to note that it should not be considered a true "control" nor should it represent historic conditions of the Ketchikan Creek Mainstem because the mainstem would have historically been influenced by the warm waters of Ketchikan Lakes prior to diversion and snowmelt at higher elevations. In other words, while the natural Scout Creek flows (T6) reduce the water temp of the residual bypass flows in Ketchikan Creek (T5) due to it being approximately 50 % of the flows, this creeks contribution would be much less significant if the natural flows were in this reach of Ketchikan Creek. Natural Scout (T6) is not as cold as natural Granite (T10) probably due to less snowmelt within its lower elevational watershed. What station T6 does indicate is that Scout Creek currently reduces the water temperature in the mainstem.

3.2.2 Granite Creek Stations

Granite Creek diversion water temperature station (T10) represents natural temperature conditions as it is located above any project operations. Additionally, Granite Basin is diverted, but not dammed. Its water flows directly into Fawn Lake with no regulation ability (i.e., it's operated as run of the river). Therefore, the project does not alter the temperature of this portion of the watershed.

Because the Granite Basin diversion has no storage, the project is operated to make maximum use of the Granite Basin water, which is cooler than Ketchikan Lakes. Under some conditions, this probably results in a higher proportion of the flow below the project coming from Granite Basin. Although not quantified for this study, it appears that this difference would be negligible to the system during the summer critical periods.

Station T10 is by far the coldest of all the stream stations (8.54°C mean) as was expected because a large component of its flow comes from snowmelt. Granite Creek contributes a significant amount of flow to the Ketchikan Creek system.

The water temperatures of Granite Basin diversion (T10) and Granite Basin inlet to Fawn Lake (T11) had almost identical data sets. This documents that there are no temperature changes occurring between these two stations.

3.2.3 Ketchikan Creek Stations

The station on Ketchikan Creek below its confluence with Granite Creek (T7) is representative of the water temperatures in the segment of bypassed reach that captures both the Granite diversion leakage and the Ketchikan Lakes dam seepage. The temperature at this site is reflective of its location, where the warmer water of the Ketchikan Lake seepage (T8), mixes with much colder Granite diversion leakage (T10).

Temperatures were found to be colder at the above-tailrace station (T3) compared to the below – tailrace station (T1). This is likely because: (1) the 1.34 miles of bypassed river reach is comprised of high canyon walls and good tree canopy, providing shade; and (2) The T3 water is now typically comprised of only river water, compared to pre-1907, when the warmer waters of Ketchikan Lakes was a large percentage of the flow. The now river-only waters come primarily from Scout Creek and Granite Basin during the critical non-rain periods. Scout Creek is an unaffected perennial creek that has naturally cool water temperatures compared to the tailrace water (T2), which is now dominated by Ketchikan Lakes water.

The average monthly water temperatures below the tailrace (T1) and in the tailrace (T2) are virtually identical. This is to be expected as the cooler water above the tailrace (T3) is typically a minor contributor to the flows during the summer months. Flows are minor because this station is within the reach where all the flows are bypassed except for leakage from the dam, leakage from Granite Basin diversion, perennial Scout Creek, and runoff from the watershed during precipitation events (See **Figure 1**). The only exception to the minor summer contribution of the bypass reach would be when a significant (in both duration and intensity) rainstorm occurs.

3.2.4 Fawn Lake/Tunnel and Penstock Conveyance Stations

The study suggests that the project does not increase water temperatures through solar warming within Fawn Lake. Ketchikan Lakes inflow (T13) and Granite Basin diversion inflow (T11) both empty into Fawn Lake to mix and exit via the tunnel to the powerhouse (T12). This appears to not increase temperatures as shown in **Figure 3**. Furthermore, because Fawn Lake has a 40 acre-foot total volume (27 usable acre-foot volume) and a use of between approximately 47 and 280 cfs, the residence time in Fawn Lake is approximately 2 to 4 hours. This short residence time would not likely allow enough solar warming to increase the water temperature any measurable amount. Therefore, the agencies' suggestion to cover Fawn Lake or to deepen or expand Fawn Lake would not be of any value.

The study also documents that the project does not influence temperature between Fawn Lake and the tailrace, where the average monthly temperatures at both the Fawn Lake outlet (T12) and within the tailrace (T2) were virtually identical for each of the 4 months of the study. The regressions were 0.999 for the min, max, and mean for the study period. This result does not support agency concerns that friction on the walls of the tunnel may increase water temperature, or that the turbine blades may generate enough heat to increase temperatures.

The agencies expressed concern that the above-ground penstocks between Ketchikan Lakes and Fawn Lake might be increasing water temperatures due to solar warming. The study data suggest that this is not occurring as temperatures measured at the Ketchikan Lake intake (T14b) were actually slightly warmer than those measured at the inflow into Fawn Lake (T13).

3.3 Ketchikan Lakes Water Temperature Results

The Ketchikan Lakes (Upper and Lower) are natural lakes connected by an excavated channel. The current dam across the south end of Lower Ketchikan Lake was constructed in 1957 to raise the lake level and increase storage for hydroelectric generation and municipal water supply. Water is conveyed from two intakes at Ketchikan Lakes (T14b and T15b) through penstocks and a tunnel to Fawn Lake. Because the two lakes are essentially at the same elevation, the outflow rate from Ketchikan Lakes depends on KPU's ability to maintain a small head differential between the lakes, the magnitude of which varies on the level of Ketchikan Lakes, inflows from Granite Basin and outflows to the powerhouse.

Ketchikan Lakes clearly is the source of the warmest water in the system due to its relatively long retention time in the lake. The two warmest stations, T14b and T16, had mean study-long values of 12.9°C and 13.5°C. This demonstrates that the 13°C ADEC standard is exceeded very often. However, the highest maximum hourly temperature was only 18.2°C, recorded on August 4, 2002, at station T14b. This is still below ADEC's not-to-exceed 20°C standard.

The data indicates that water temperatures in Ketchikan Lakes are most likely not a concern. Although the lake is the source of the warmest water in the system, the Granite and Scout watersheds reduce/buffer water temperatures in Ketchikan Creek during the warmest periods of the year - both in the bypass reach and tailrace waters (**Figures 3 and 4**).

Four temperature loggers (T14a, T14b, T15a and T15b) were placed near the dam at the intake; two near the surface and two on the bottom at the intake entrances. The loggers measured very similar temperatures over the sampling period (**Figures 6 and 7**). As expected, the west intake is slightly colder because it is slightly deeper; however, the difference is too small to consider operational changes.

It is important to note that the surface temperatures (T14a & T14b) are consistently warmer than their corresponding intake temperatures (T14b & T15b). It can be assumed that the surface temperature is the temperature at which water would historically/naturally have been discharged from the lake into Ketchikan Creek. The intake temperature is the temperature at which water is now discharged from the lake (project temperature). Therefore, the pre-project temperatures were quite possibly higher than those occurring now. Because the temperature of the other major source of water in the system (Granite Basin) is not being changed by the project as it is run-of-the-river, it is very possible that the project is lowering water temperatures in the anadromous portions of the system (T1).

As was expected, the Ketchikan Lakes deep-water station (T17, at 197 feet) recorded the lowest temperature measured during all four months with a mean seasonal temperature of 4.4°C. This temperature fluctuated little during the 4 month season, and the mean, minimum, and maximums were virtually unchanged (within 0.5 degree) (**Figure 6 and 7**). These data clearly show what was expected: that moving the intake deeper into the Lake would indeed cool the water substantially. However, extension of the intake would be very costly and the data collected in this study does not indicate that such a measure is needed.

The maximum surface temperature recorded at the lake's center station (T16) is less than those recorded at the surface sites near the intakes (T14a & T15a). This is most likely due to wave action at the center vs. sheltered surface conditions at the intake location.

3.4 Evaluation of Hatchery Temperature Records to Represent Average Tailrace Temperatures

One key objective of the study was to determine if the existing long-term hatchery temperature records could be used to approximate temperatures in the tailrace receiving stream. If this were possible, it would enable determination of long-term temperature trends and a corresponding assessment of any possible long-term effects to the fishery.

Hatchery temperature data has been collected from 1970 to the present. A required flow of 4.7 cfs is conveyed from the powerhouse tailrace to the hatchery. Tailrace water was sampled with an hourly data logger during this study and is labeled T2. Therefore, T2 and the hatchery inflows are the same waters and accordingly, will be the same water temperature.

One of the key questions that needed to be answered by this study was: Can the *once-daily* hatchery temperature records be used to represent the *average* tailrace/receiving stream temperatures to determine long-term temperature trends and possible effects to the fishery?

In order to answer this question fully, it is important to know that the hatchery's receiving water, which comes from the tailrace just before entering Ketchikan Creek, can essentially be considered to be representative of the entire flow for Ketchikan Creek during the highest temperature periods. This is because any potential critical temperature spikes would occur during extended periods with no rainfall and full sunshine when very little flow is coming from T3 (the bypassed reach of Ketchikan Creek upstream of the tailrace). Therefore, T1 (Ketchikan Creek below the tailrace) is essentially the same temperature as T2 (the tailrace).

The hatchery uses a 1:00 pm once-daily sampling to approximate the average daily temperature of its receiving water, which is the tailrace (T2). Comparison of 2002 hatchery data with the detailed hourly data logger data shows that the hatchery data closely approximates both the daily means and monthly means collected by the logger (**Figure 8**). The mean difference in daily temperature was 0.21 °C and the only 3 days with a large difference were June 24-26. The monthly averages were similar, with a regression of 0.84 (0.90 if the three outlier days are removed).

The minimum, mean, and maximum temperatures shown in **Figure 9** further illustrate the correlation; the mean is by far the most similar to the hatchery temperatures.

Because of this good correlation, the historical hatchery data (1970 to 2002) was used to represent daily average tailrace water temperatures over that 32-year time period (**Figure 10**). Accordingly, the evaluation of potential affects to critical life stages of the fishery is expanded to the hatchery's period of record. As described earlier, for the purposes of this study, 16 °C is used as the threshold value for potential negative effects to the Chinook salmon. As shown in **Figure 10**, the monthly average temperatures did not reach 16 °C in the 8 years previous to 2002, and reached the threshold only three times since 1970. The more stringent aquaculture standards of the ADEC of 13°C are exceeded quite frequently.

Only monthly averages are available from hatchery records between 1970 and 1993. However, daily averages were kept from 1993 to 2002, allowing and analysis of daily maximum averages for this smaller period of record (**Figure 11**). Because these are daily maximums, these can be considered "worst case" conditions, as the 16 °C threshold needs to be held constant (e.g., 8 hours or more) in order to have the potential to negatively affect fish. Over this period of record, the 16 °C maximums were reached in 4 of the 8 years, or 50% of the summers. ADEC's aquaculture standard of 13°C are exceeded quite frequently.

4.0 Recommendations

Although the Ketchikan Creek Watershed is a complex system, and it is not possible to ascertain conclusively whether the project increases or decreases the water temperature, the overall indication is that the current temperature regime does not negatively affect the Ketchikan Creek Watershed. Therefore, we do not recommend any action to modify project facilities or operations.

Even if the project had been found to increase temperatures in the system, the only viable option of those explored in this report would be moving the intake farther and deeper into Ketchikan Lake. This action would no doubt cool the temperature of the tailrace water. However, such a modification would be costly, may not provide any real benefit to the fishery or hatchery, and would not meet the FERC directive of only considering “low or zero cost operational changes”. All other options considered would have little, if any, positive affect to the system.

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Figures

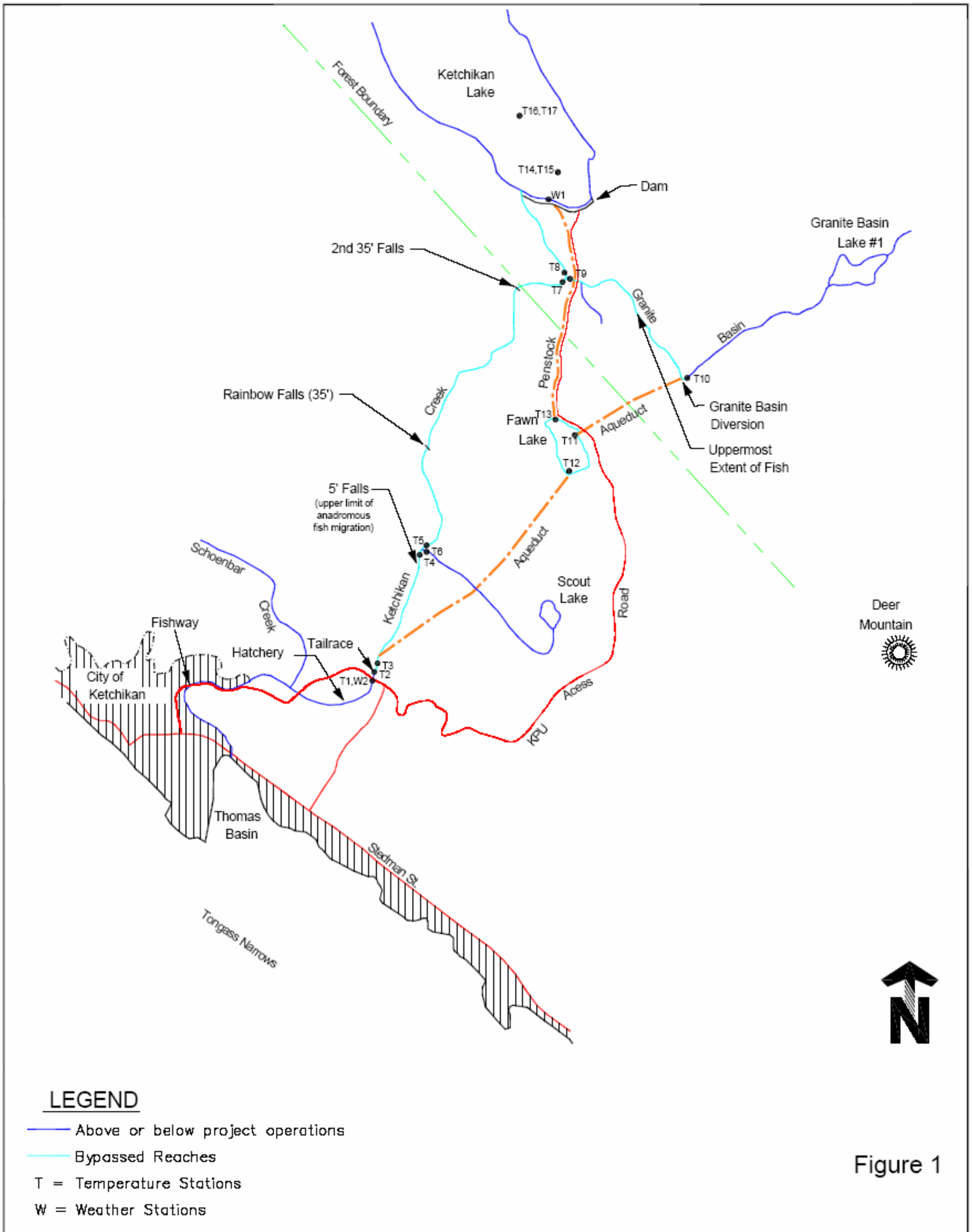


Figure 1

Stream Temperature Monitoring Sites

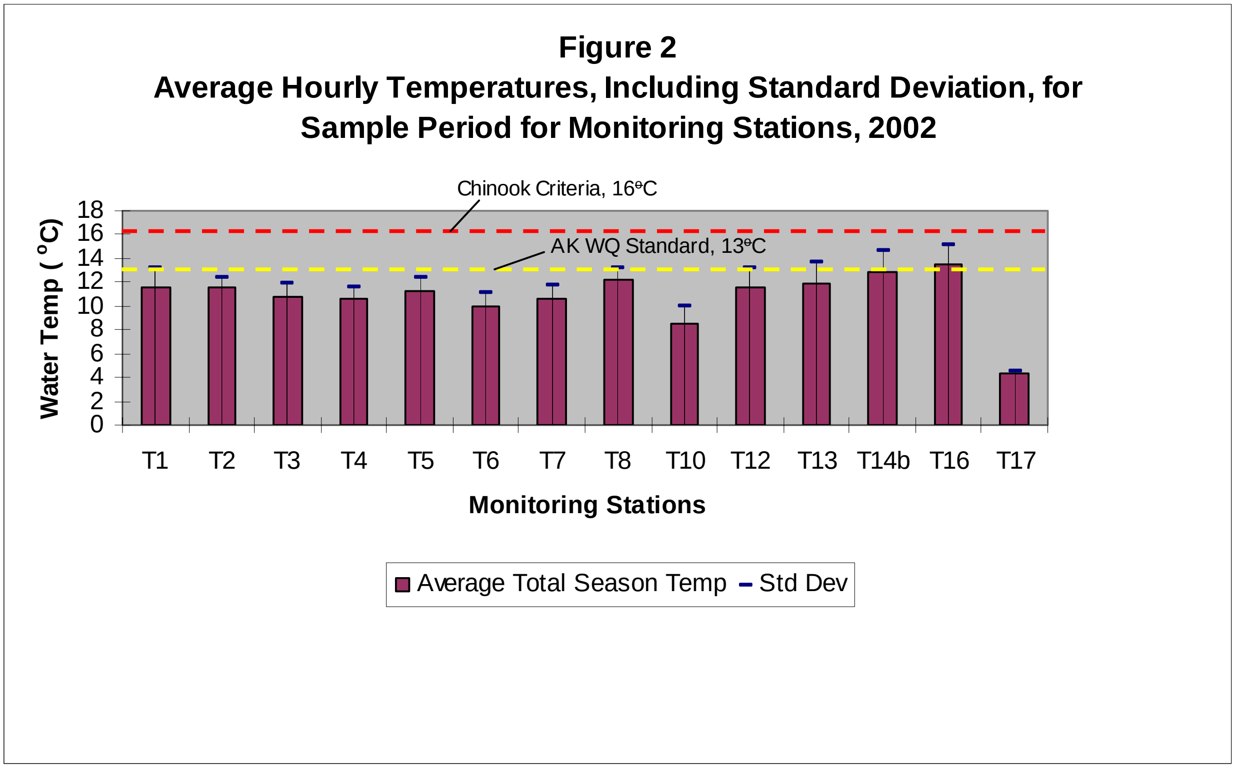


Figure 2
Average Hourly Temperatures, Including Standard Deviation, for Sample Period for Monitoring Stations, 2002
Chinook Criteria, 16ºC
AK WQ Standard, 13ºC
Water Temp (°C)
18
16
14
12
10
8
6
4
2
0
T1
T2
T3
T4
T5
T6
T7
T8
T10
T12
T13
T14b
T16
T17
Monitoring Stations
Average Total Season Temp
Std Dev

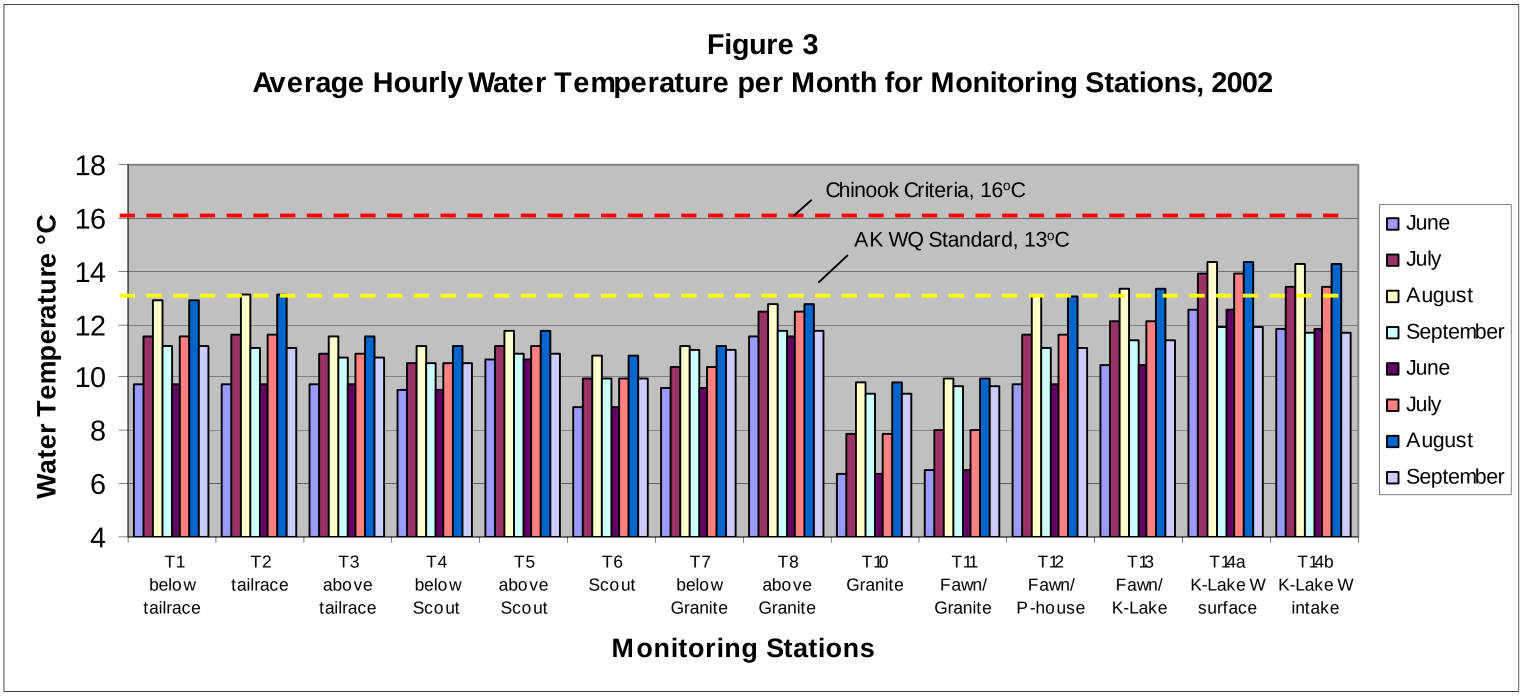


Figure 3
Average Hourly Water Temperature per Month for Monitoring Stations, 2002
Chinook Criteria, 16ºC
AK WQ Standard, 13ºC
Water Temperature °C
18
16
14
12
10
8
6
4
T1 below tailrace
T2 tailrace
T3 above tailrace
T4 below Scout
T5 above Scout
T6 Scout
T7 below Granite
T8 above Granite
T10 Granite
T11 Fawn/ Granite
T12 Fawn/ P-house
T13 Fawn/ K-Lake
T14a K-Lake W surface
T14b K-Lake W intake
Monitoring Stations
June
July
August
September
June
July
August
September

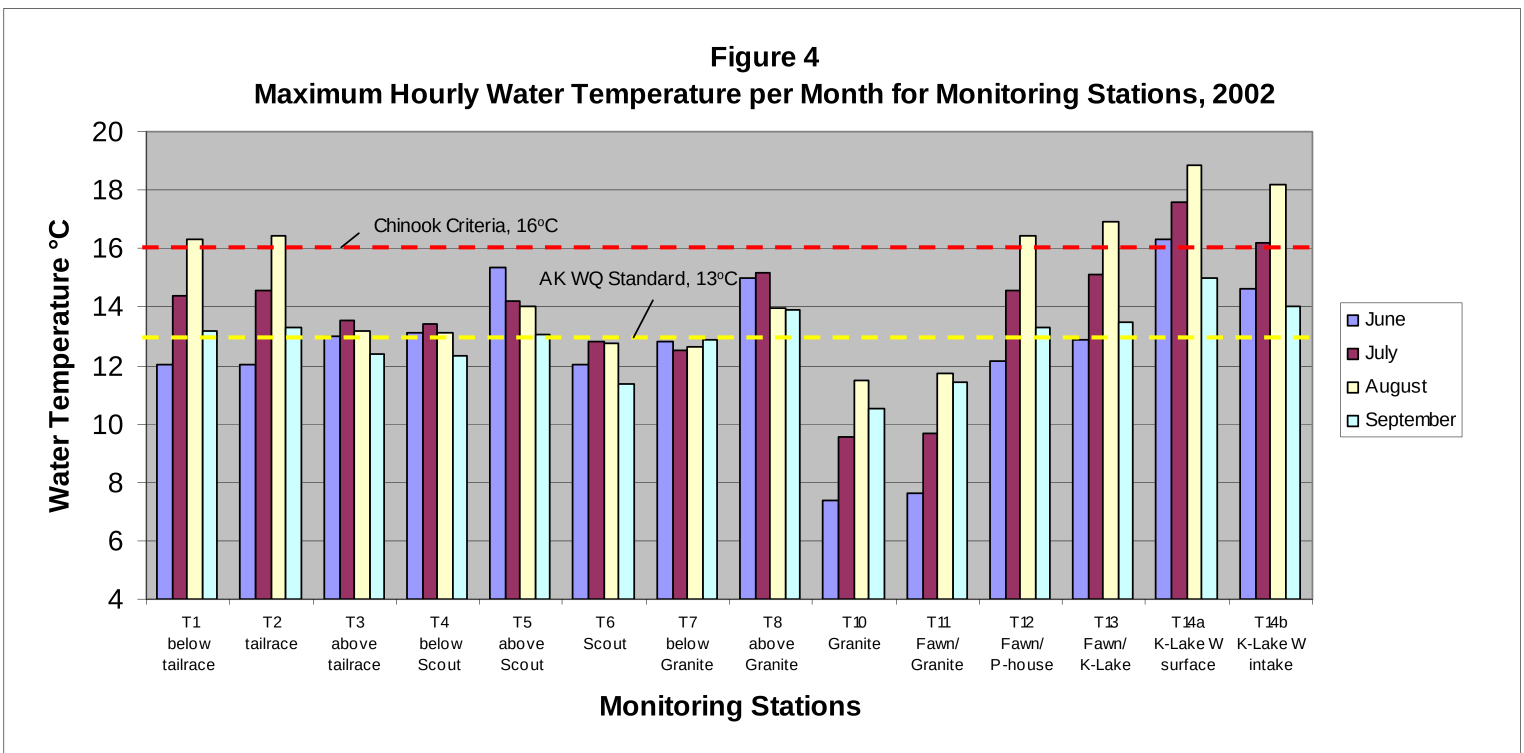


Figure 4
Maximum Hourly Water Temperature per Month for Monitoring Stations, 2002
Chinook Criteria, 16ºC
AK WQ Standard, 13ºC
Water Temperature °C
20
18
16
14
12
10
8
6
4
T1 below tailrace
T2 tailrace
T3 above tailrace
T4 below Scout
T5 above Scout
T6 Scout
T7 below Granite
T8 above Granite
T10 Granite
T11 Fawn/ Granite
T12 Fawn/ P-house
T13 Fawn/ K-Lake
T14a K-Lake W surface
T14b K-Lake W intake
Monitoring Stations
June
July
August
September

Figure 5
Distribution of Maximum Daily Water Temperature Values for the Monitoring Stations, 2002

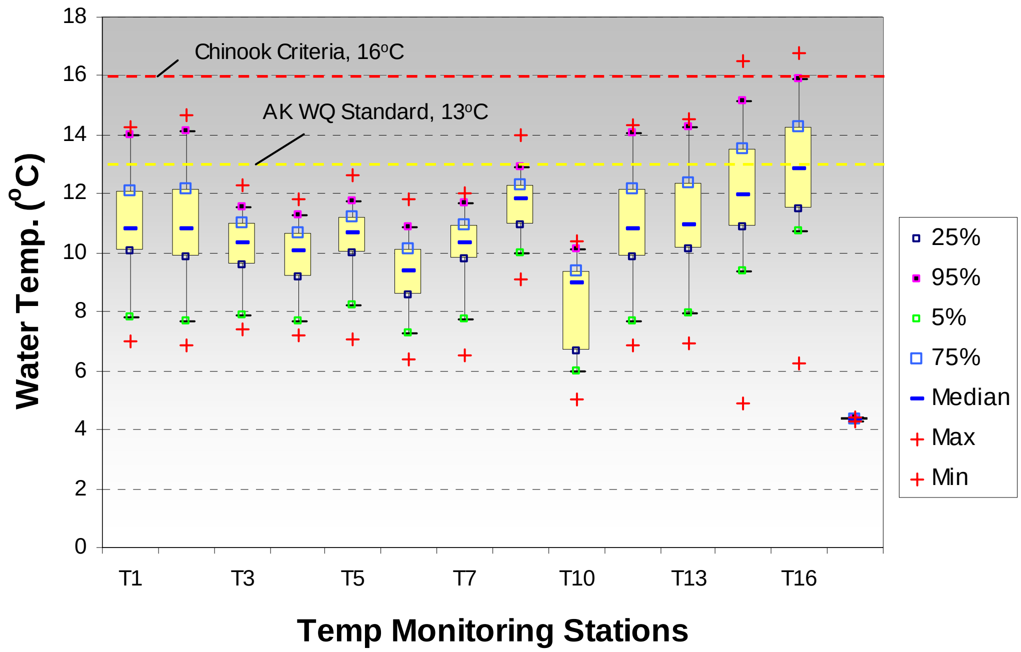


Figure 6
Average Hourly Temperature per Month of the Ketchikan Lake Stations, 2002

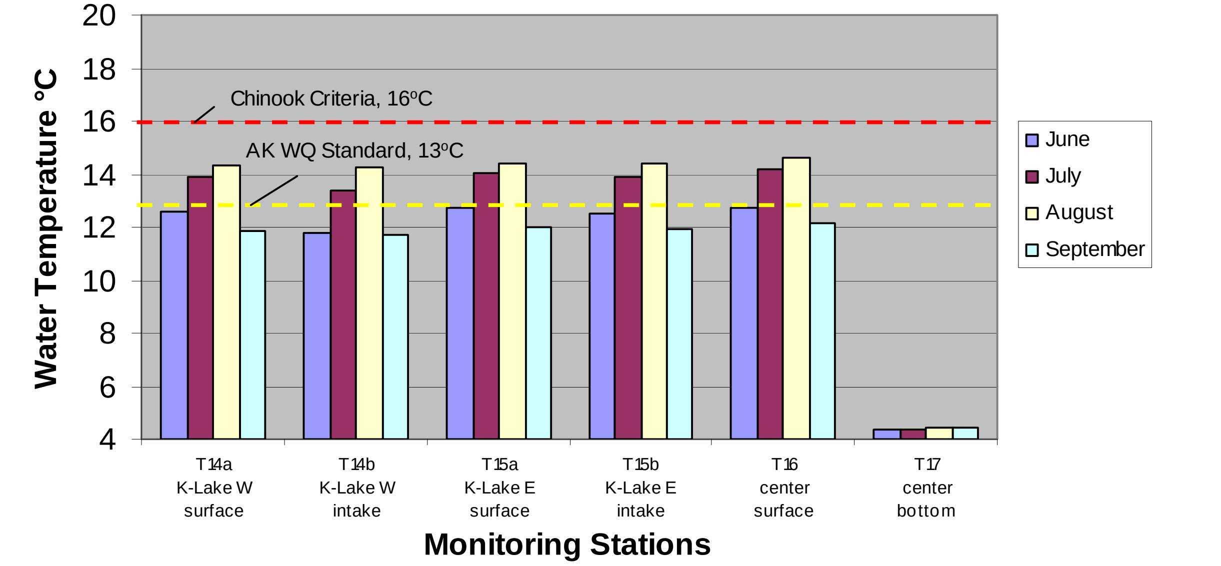
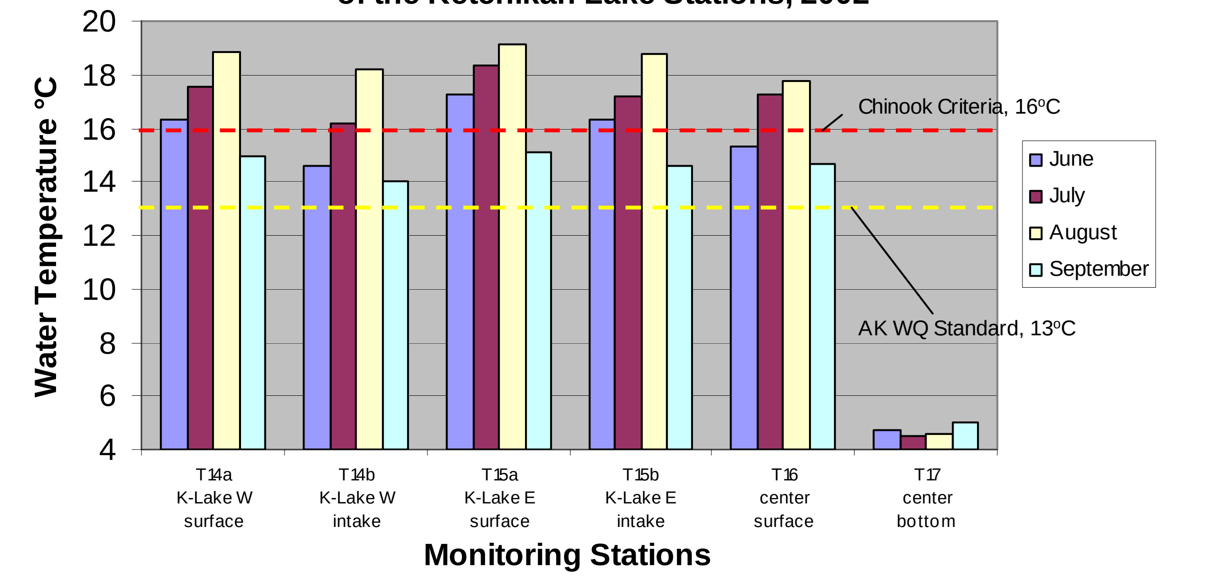


Figure 7
Maximum Hourly Temperature per Month of the Ketchikan Lake Stations, 2002



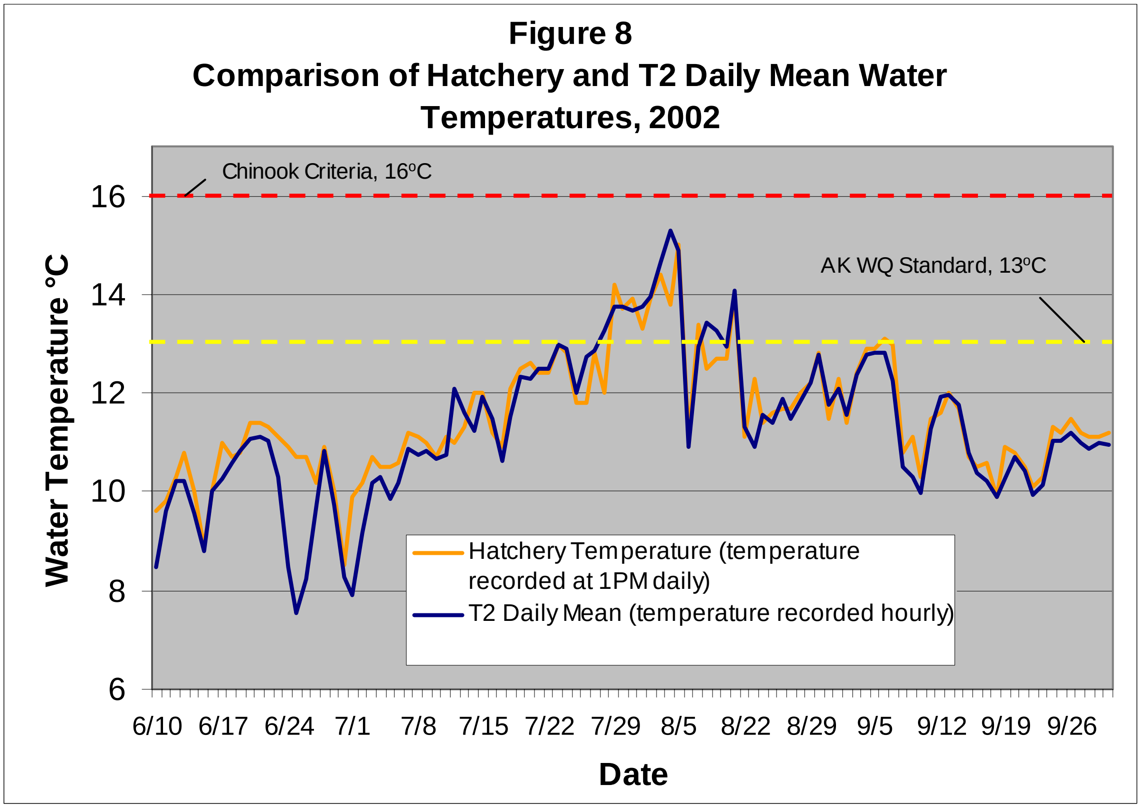


Figure 8
Comparison of Hatchery and T2 Daily Mean Water Temperatures, 2002
Chinook Criteria, 16ºC
AK WQ Standard, 13ºC
Water Temperature °C
16
14
12
10
8
6
Hatchery Temperature (temperature recorded at 1PM daily)
T2 Daily Mean (temperature recorded hourly)
6/10
6/17
6/24
7/1
7/8
7/15
7/22
7/29
8/5
8/22
8/29
9/5
9/12
9/19
9/26
Date

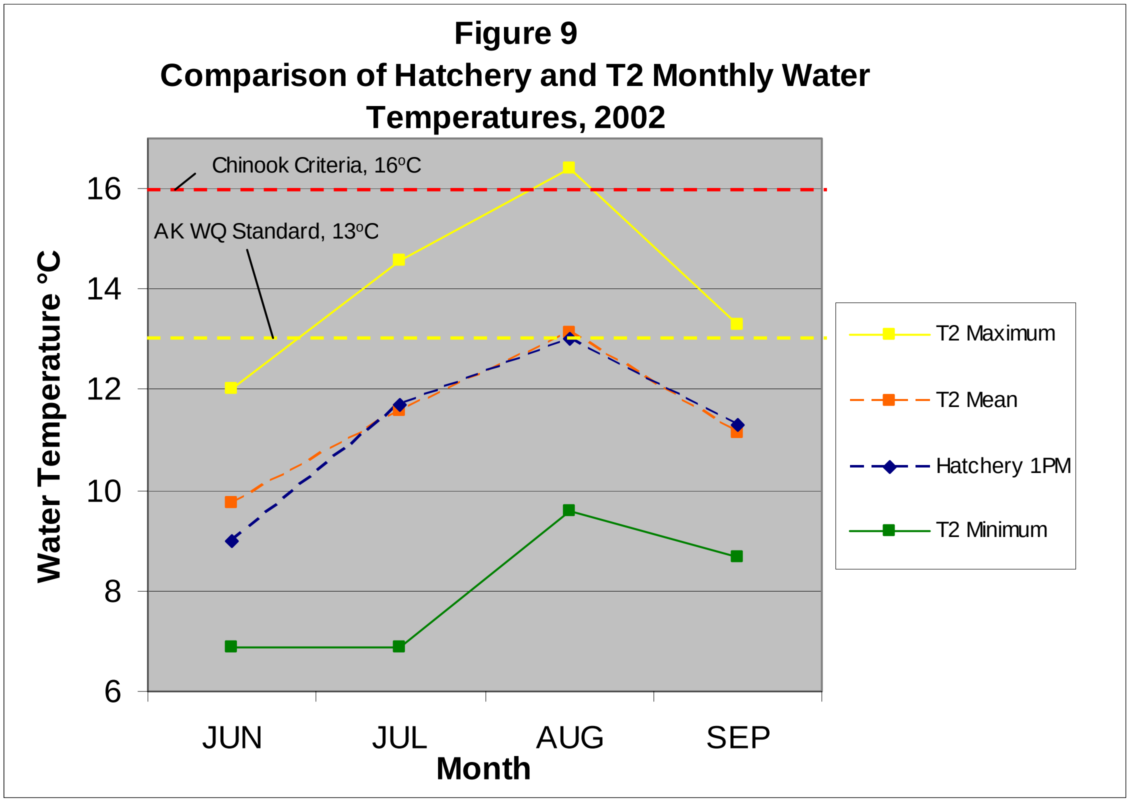
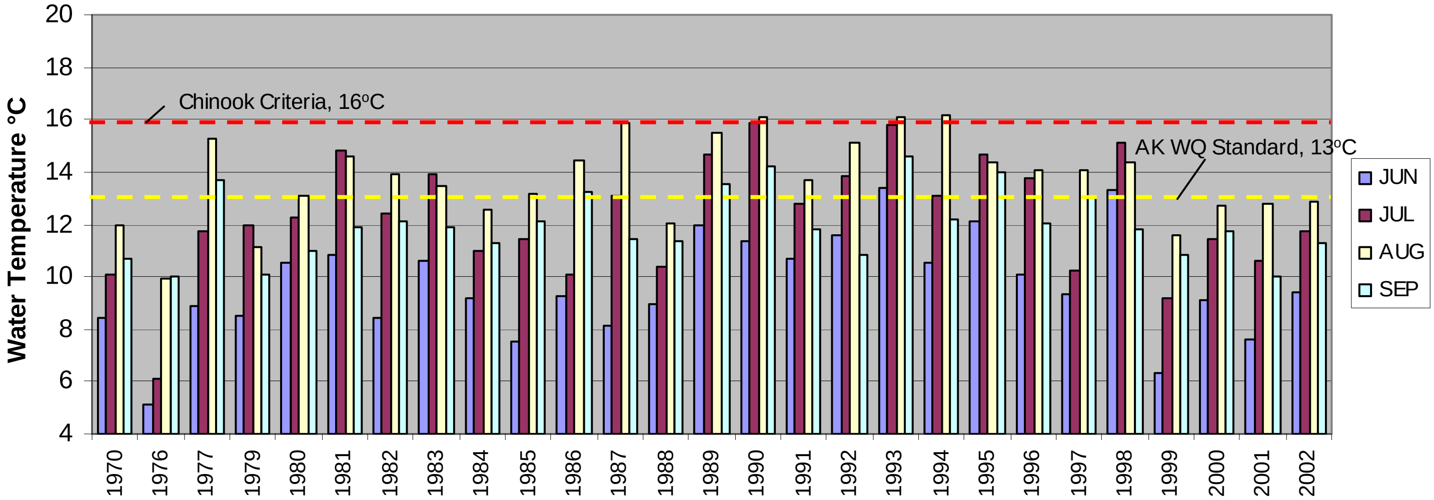


Figure 9
Comparison of Hatchery and T2 Monthly Water Temperatures, 2002
Chinook Criteria, 16ºC
AK WQ Standard, 13ºC
Water Temperature °C
16
14
12
10
8
6
JUN
JUL
AUG
SEP
Month
T2 Maximum
T2 Mean
Hatchery 1PM
T2 Minimum

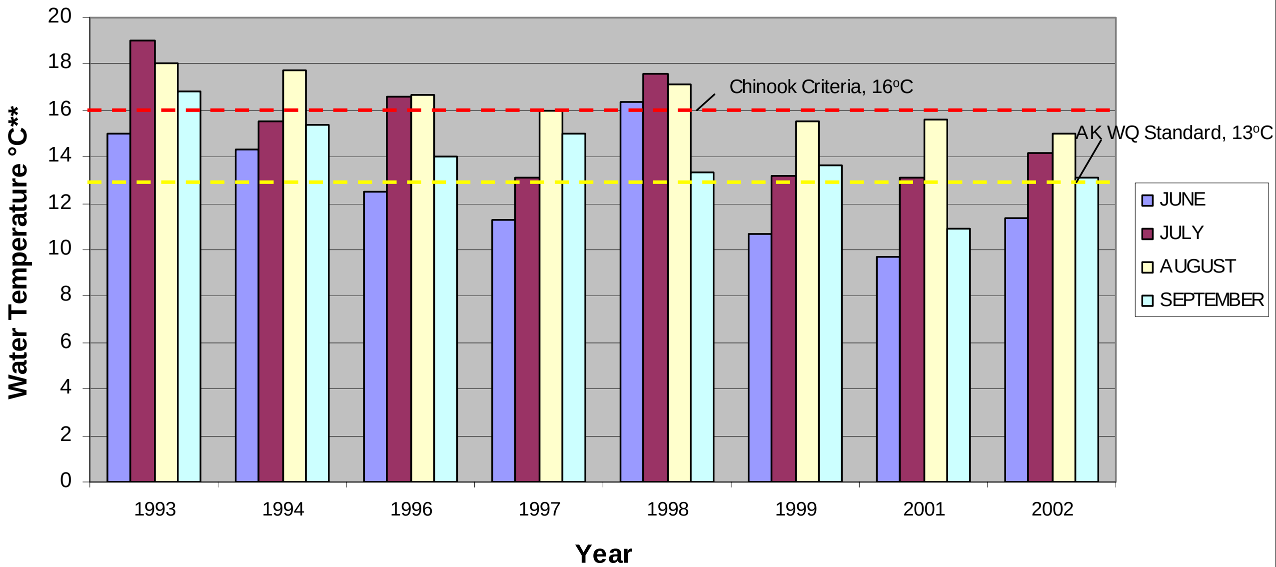
Figure 10
Average Daily Water Temperature per Month of Deer Mountain Fish Hatchery Receiving Water (1970-2002)



(Source: Deer Mountain Hatchery 2002)

Notes: Study results suggest these hatchery temperature records adequately represent mean temperatures for Ketchikan Creek below the tailrace (the area of

Figure 11
Maximum Daily Water Temperature per Month of Deer Mountain Hatchery Receiving Water, 1993-2002*



Notes: * no data were provided for 1995 or 2000,
** Temperature was recorded at 1300 each day with the intent of representing the average daily temperature

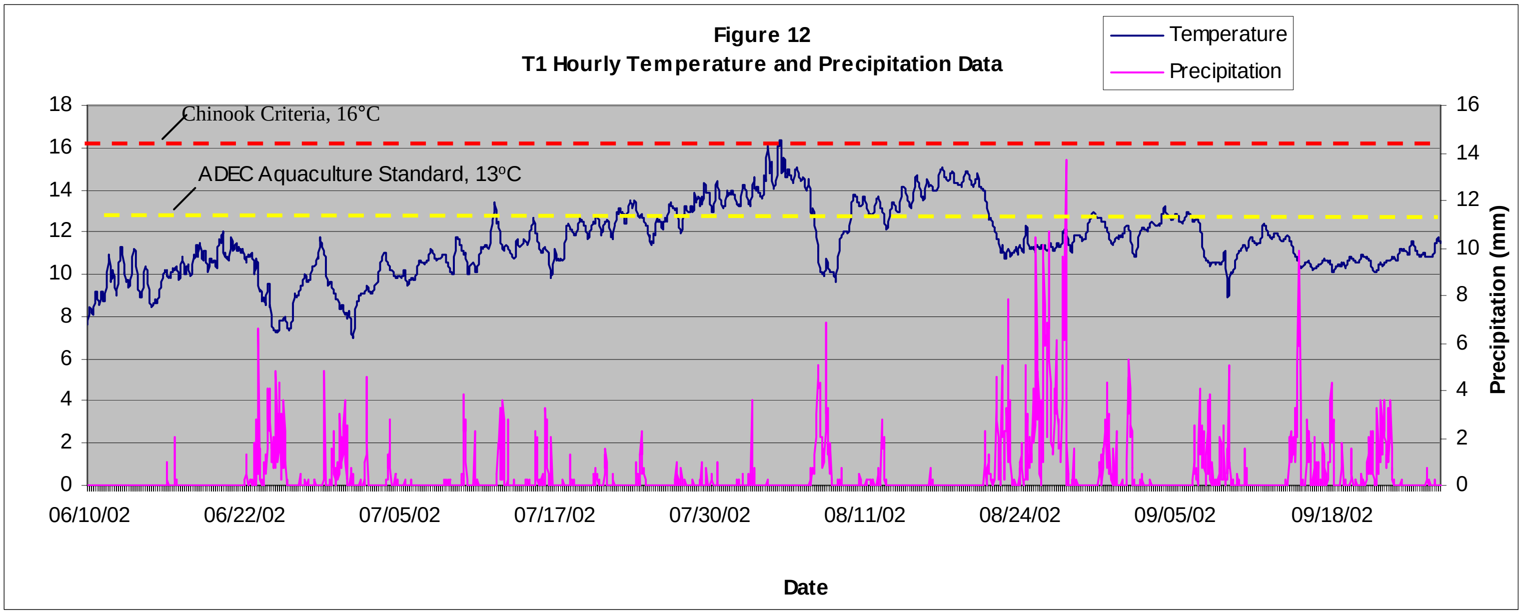


Figure 12
T1 Hourly Temperature and Precipitation Data
Temperature
Precipitation
Chinook Criteria, 16°C
ADEC Aquaculture Standard, 13°C
18
16
14
12
10
8
6
4
2
0
Precipitation (mm)
06/10/02
06/22/02
07/05/02
07/17/02
07/30/02
08/11/02
08/24/02
09/05/02
09/18/02
Date

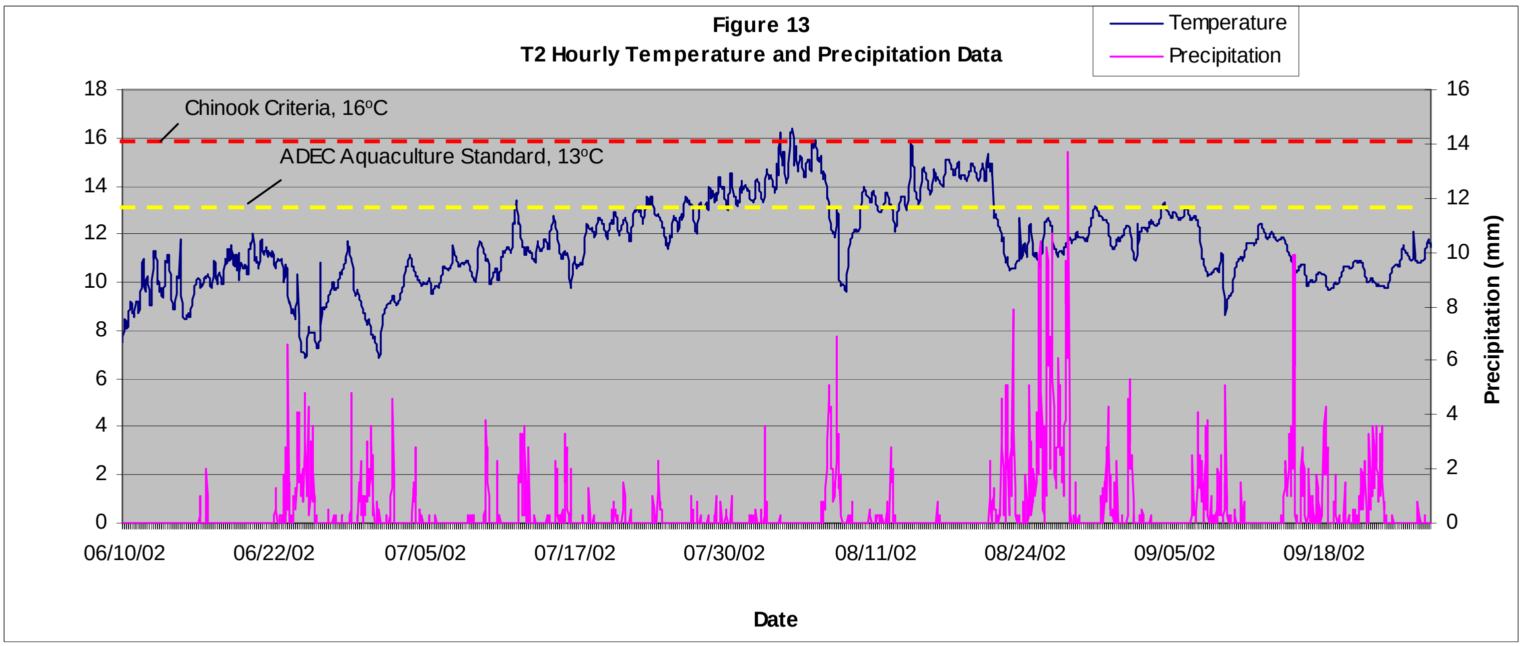


Figure 13
T2 Hourly Temperature and Precipitation Data
Temperature
Precipitation
Chinook Criteria, 16°C
ADEC Aquaculture Standard, 13°C
18
16
14
12
10
8
6
4
2
0
Precipitation (mm)
06/10/02
06/22/02
07/05/02
07/17/02
07/30/02
08/11/02
08/24/02
09/05/02
09/18/02
Date

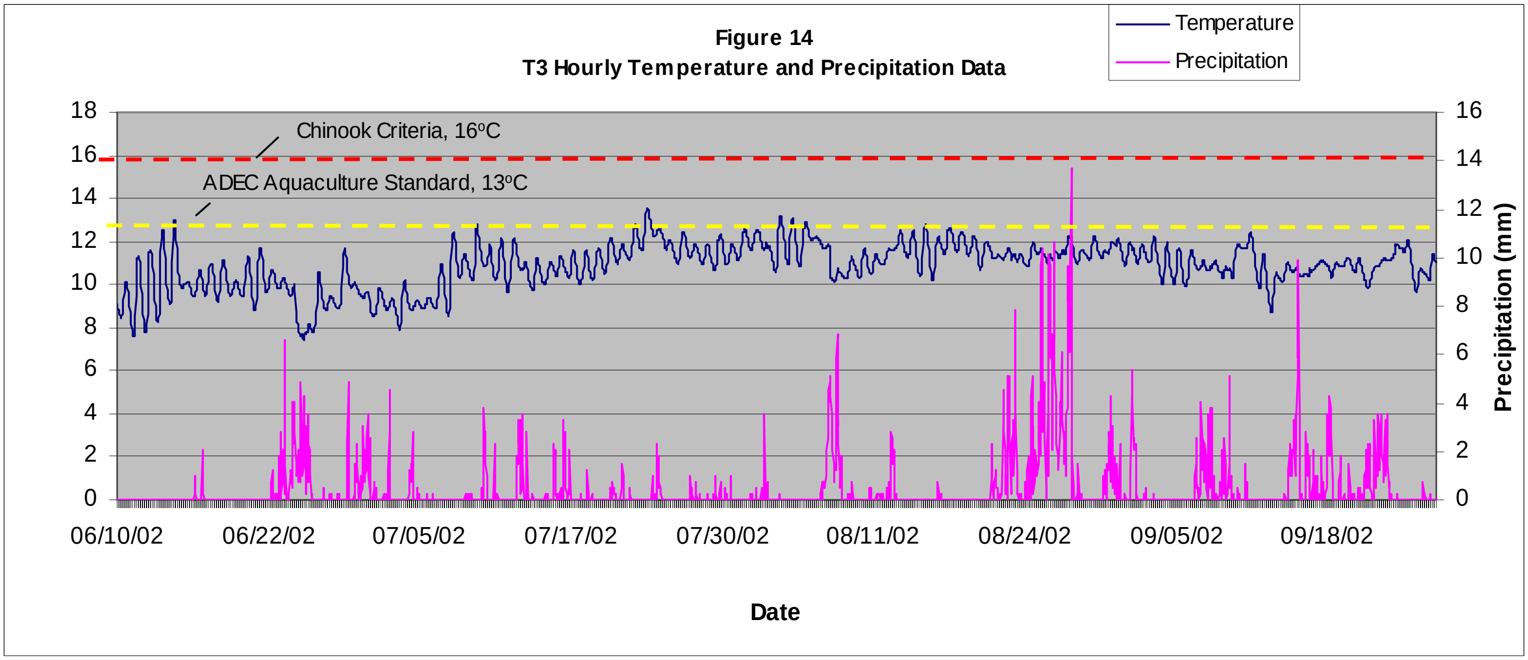


Figure 14
T3 Hourly Temperature and Precipitation Data
Temperature
Precipitation
Chinook Criteria, 16ºC
ADEC Aquaculture Standard, 13ºC
18
16
14
12
10
8
6
4
2
0
16
14
12
10
8
6
4
2
0
Precipitation (mm)
06/10/02
06/22/02
07/05/02
07/17/02
07/30/02
08/11/02
08/24/02
09/05/02
09/18/02
Date

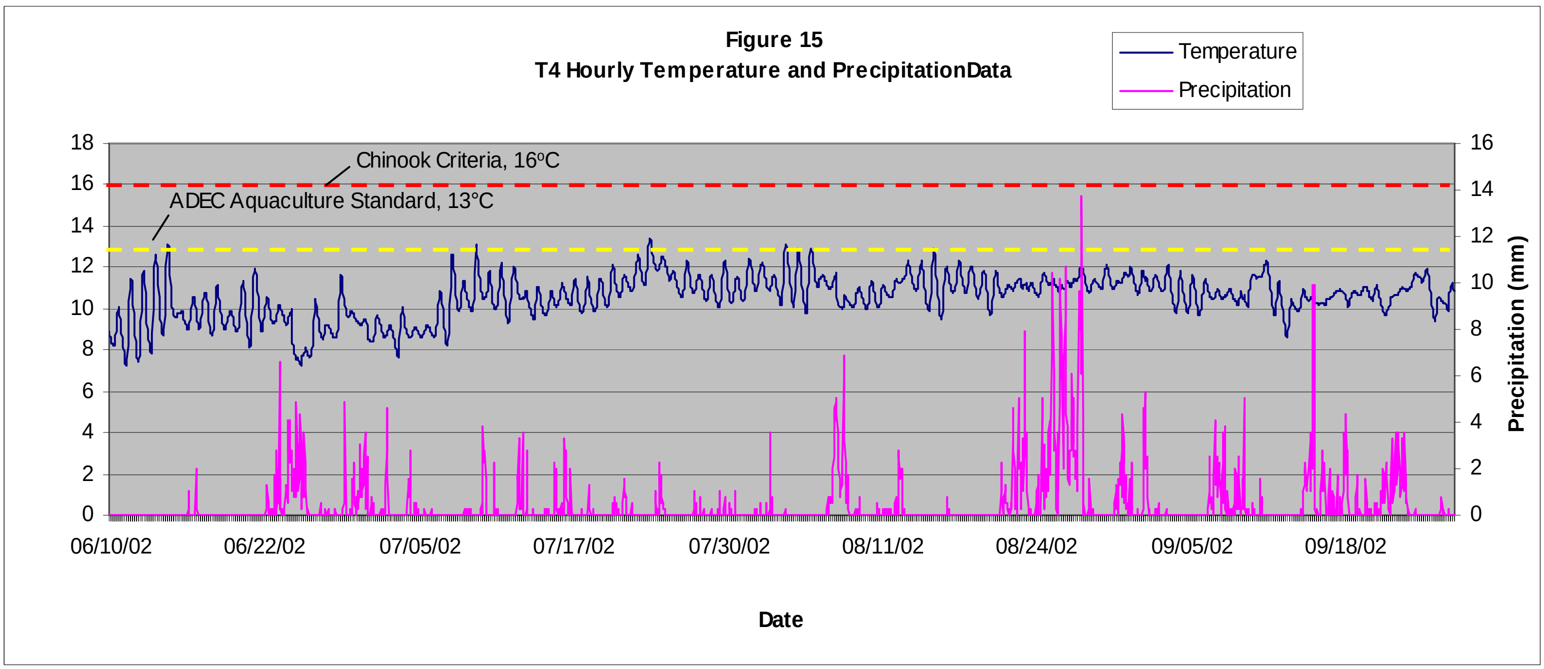


Figure 15
T4 Hourly Temperature and PrecipitationData
Temperature
Precipitation
Chinook Criteria, 16ºC
ADEC Aquaculture Standard, 13°C
18
16
14
12
10
8
6
4
2
0
16
14
12
10
8
6
4
2
0
Precipitation (mm)
06/10/02
06/22/02
07/05/02
07/17/02
07/30/02
08/11/02
08/24/02
09/05/02
09/18/02
Date

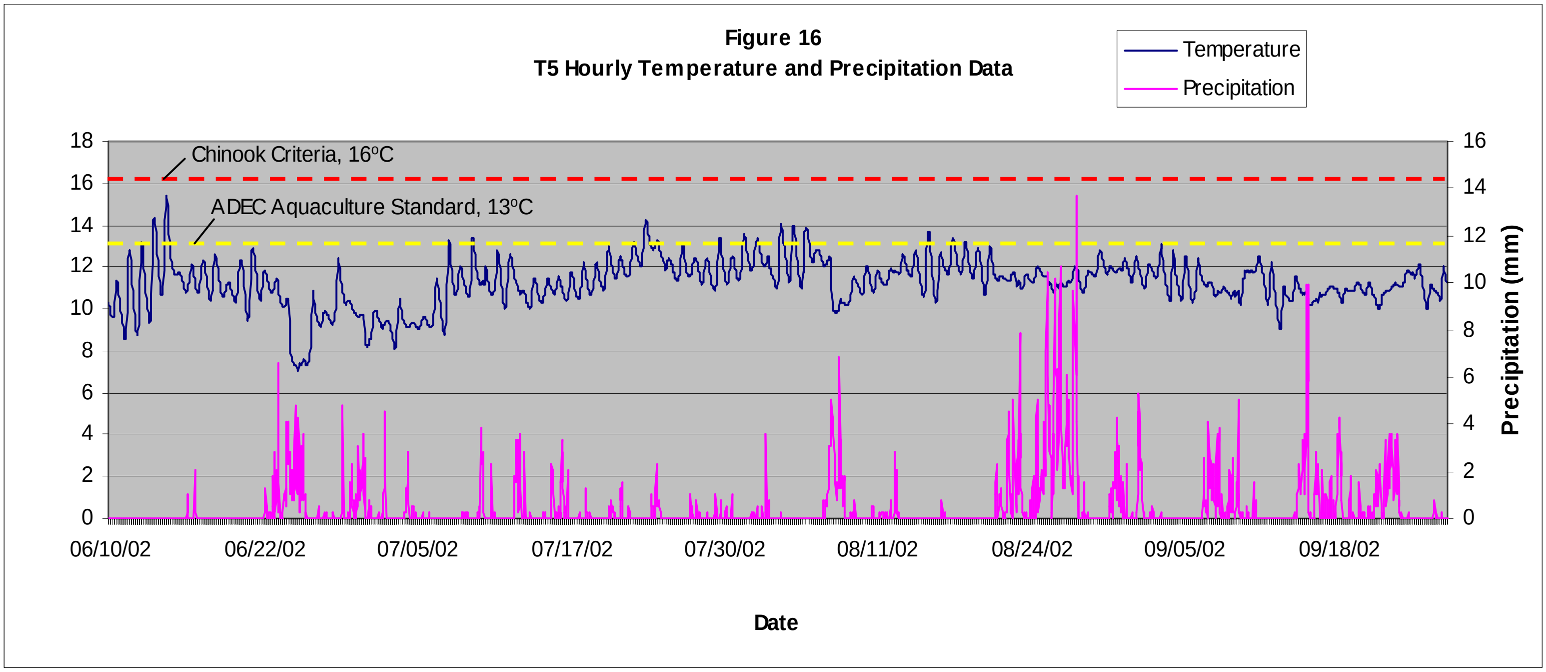


Figure 16
T5 Hourly Temperature and Precipitation Data
Temperature
Precipitation
Chinook Criteria, 16°C
ADEC Aquaculture Standard, 13°C
18
16
14
12
10
8
6
4
2
0
16
14
12
10
8
6
4
2
0
Precipitation (mm)
06/10/02
06/22/02
07/05/02
07/17/02
07/30/02
08/11/02
08/24/02
09/05/02
09/18/02
Date

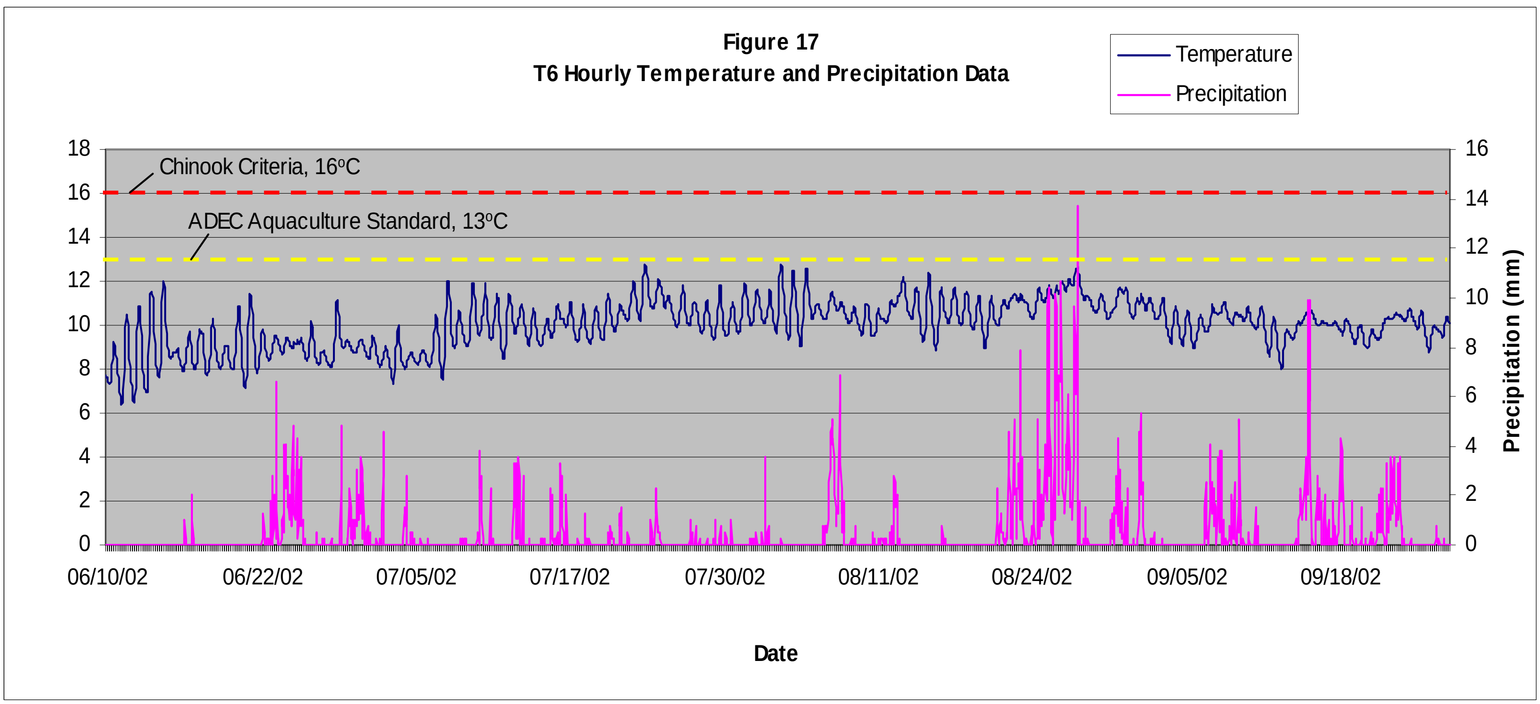


Figure 17
T6 Hourly Temperature and Precipitation Data
Temperature
Precipitation
Chinook Criteria, 16°C
ADEC Aquaculture Standard, 13°C
18
16
14
12
10
8
6
4
2
0
16
14
12
10
8
6
4
2
0
Precipitation (mm)
06/10/02
06/22/02
07/05/02
07/17/02
07/30/02
08/11/02
08/24/02
09/05/02
09/18/02
Date

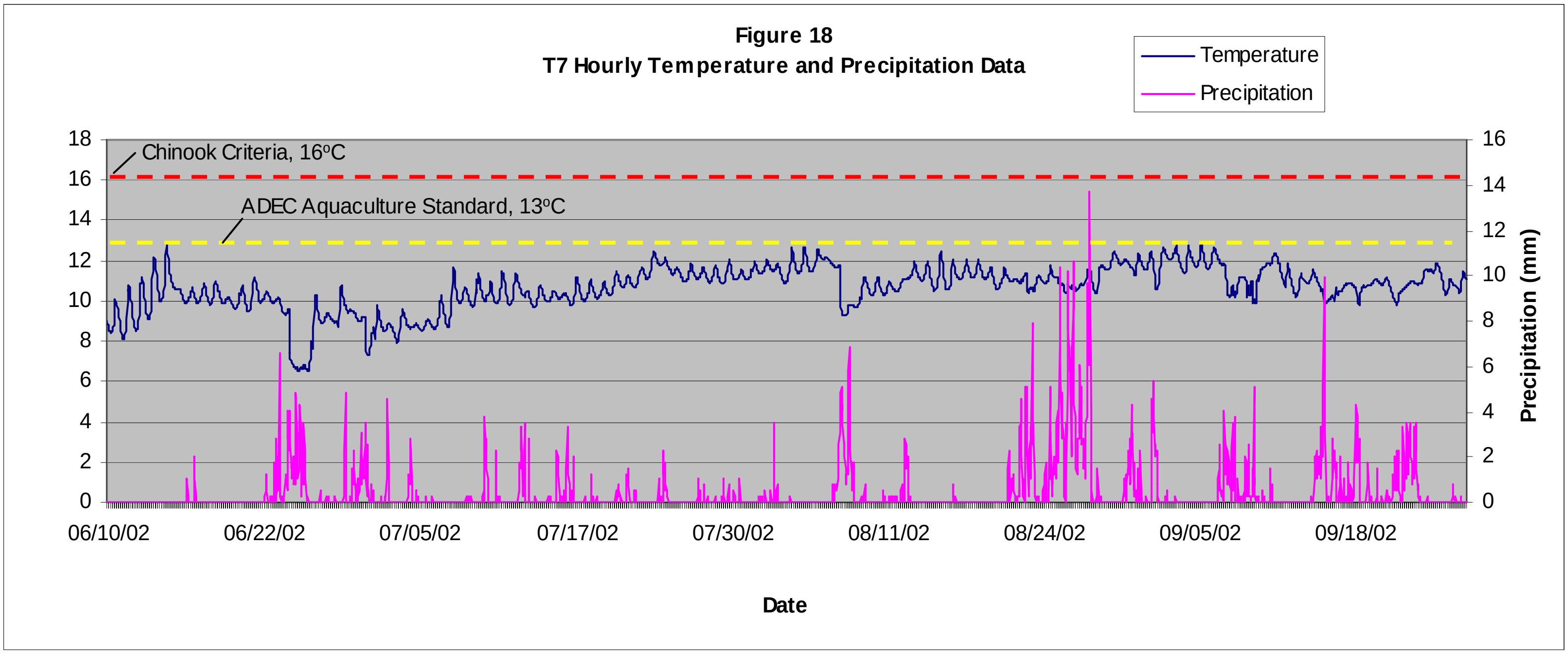


Figure 18
T7 Hourly Temperature and Precipitation Data
Temperature
Precipitation
Chinook Criteria, 16°C
ADEC Aquaculture Standard, 13°C
18
16
14
12
10
8
6
4
2
0
16
14
12
10
8
6
4
2
0
Precipitation (mm)
06/10/02
06/22/02
07/05/02
07/17/02
07/30/02
08/11/02
08/24/02
09/05/02
09/18/02
Date

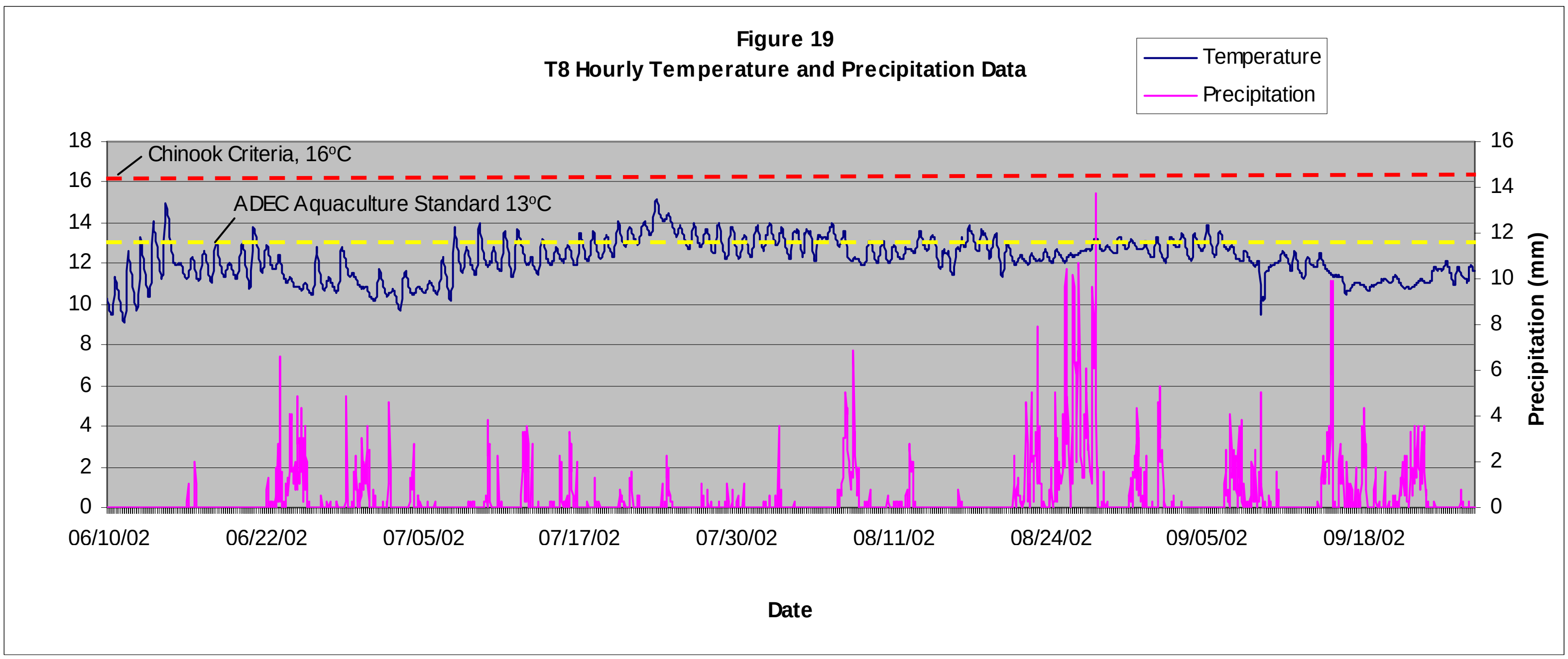


Figure 19
T8 Hourly Temperature and Precipitation Data
Temperature
Precipitation
Chinook Criteria, 16°C
ADEC Aquaculture Standard 13°C
18
16
14
12
10
8
6
4
2
0
16
14
12
10
8
6
4
2
0
Precipitation (mm)
06/10/02
06/22/02
07/05/02
07/17/02
07/30/02
08/11/02
08/24/02
09/05/02
09/18/02
Date

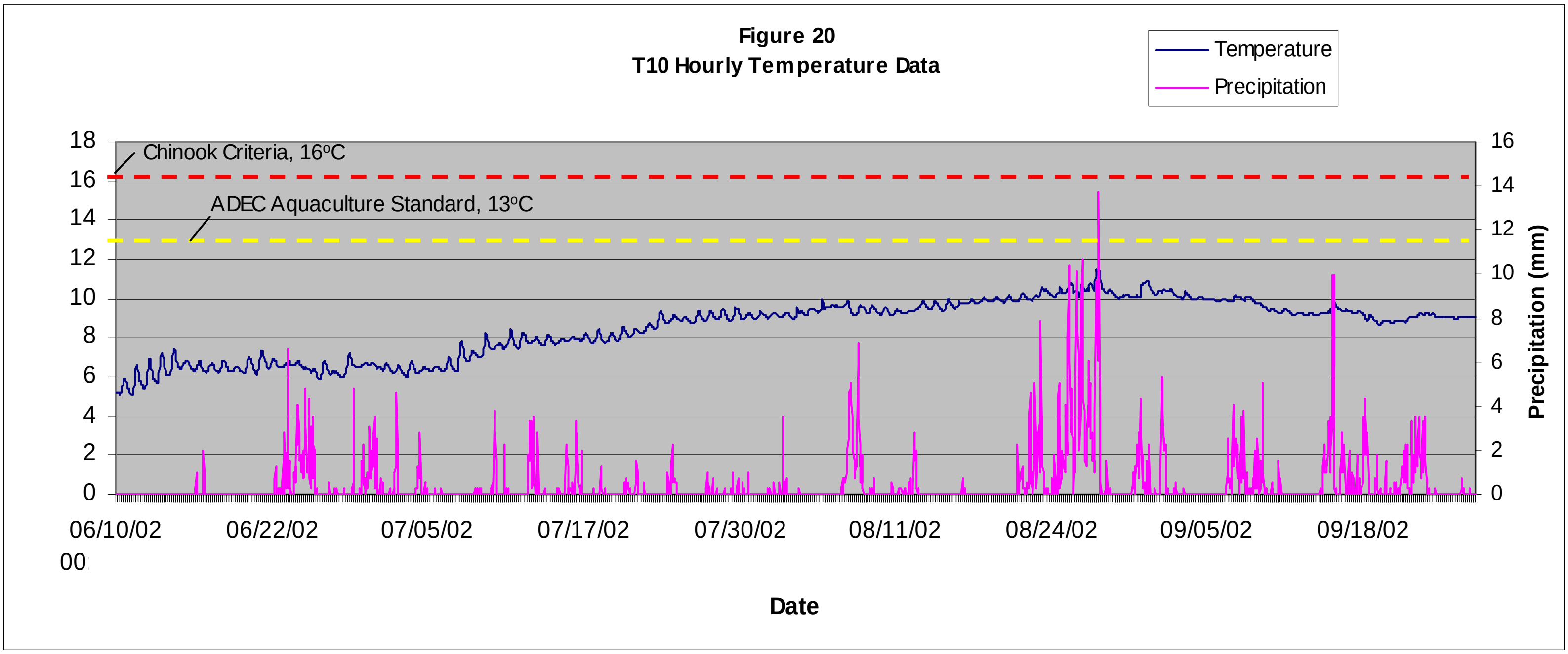


Figure 20
T10 Hourly Temperature Data
Temperature
Precipitation
Chinook Criteria, 16ºC
ADEC Aquaculture Standard, 13ºC
18
16
14
12
10
8
6
4
2
0
Precipitation (mm)
06/10/02 00
06/22/02
07/05/02
07/17/02
07/30/02
08/11/02
08/24/02
09/05/02
09/18/02
Date

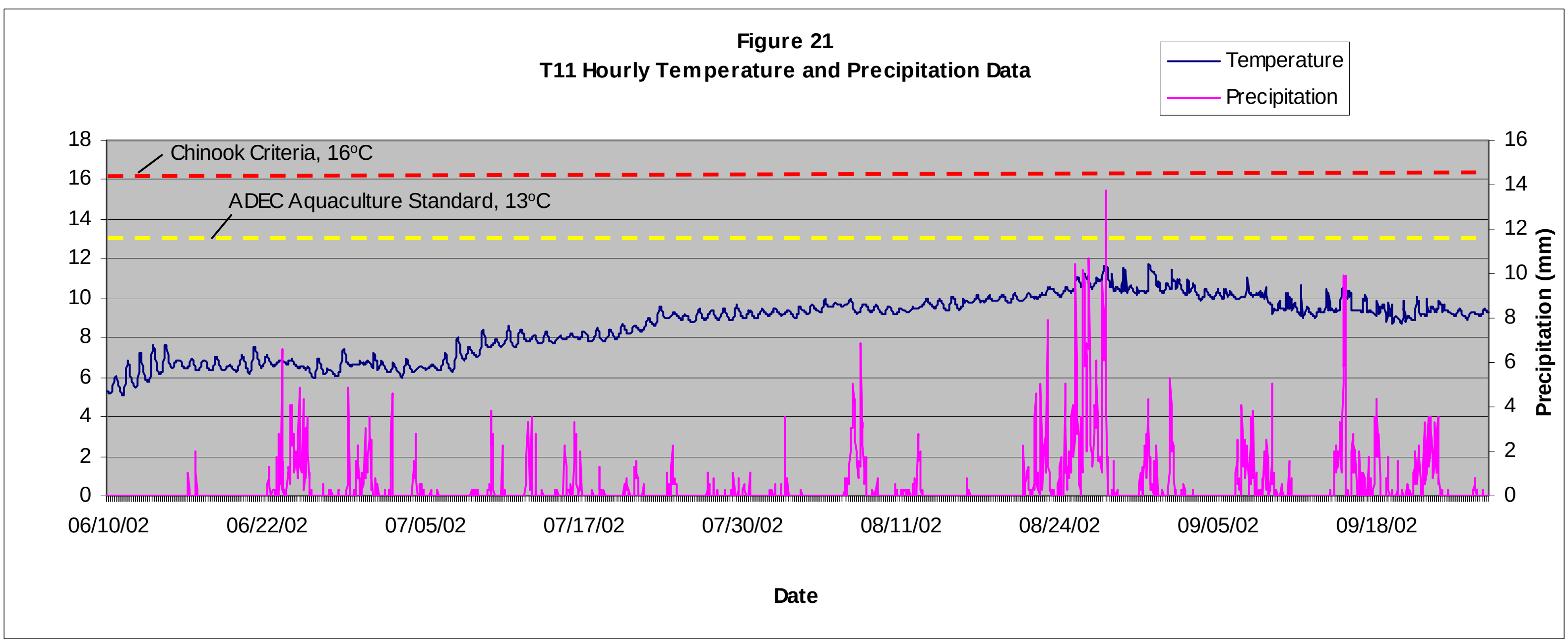


Figure 21
T11 Hourly Temperature and Precipitation Data
Temperature
Precipitation
Chinook Criteria, 16ºC
ADEC Aquaculture Standard, 13ºC
18
16
14
12
10
8
6
4
2
0
Precipitation (mm)
06/10/02
06/22/02
07/05/02
07/17/02
07/30/02
08/11/02
08/24/02
09/05/02
09/18/02
Date

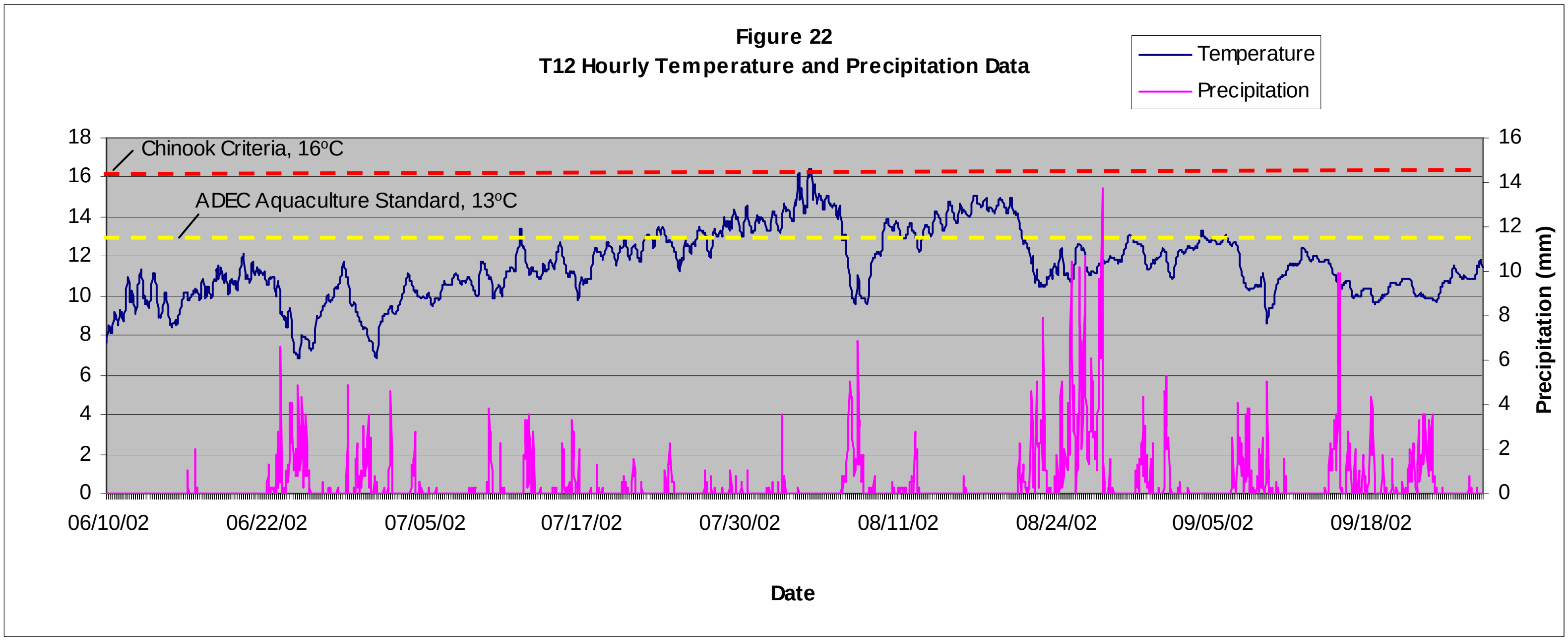


Figure 22
T12 Hourly Temperature and Precipitation Data
Temperature
Precipitation
Chinook Criteria, 16ºC
ADEC Aquaculture Standard, 13ºC
18
16
14
12
10
8
6
4
2
0
16
14
12
10
8
6
4
2
0
Precipitation (mm)
06/10/02
06/22/02
07/05/02
07/17/02
07/30/02
08/11/02
08/24/02
09/05/02
09/18/02
Date

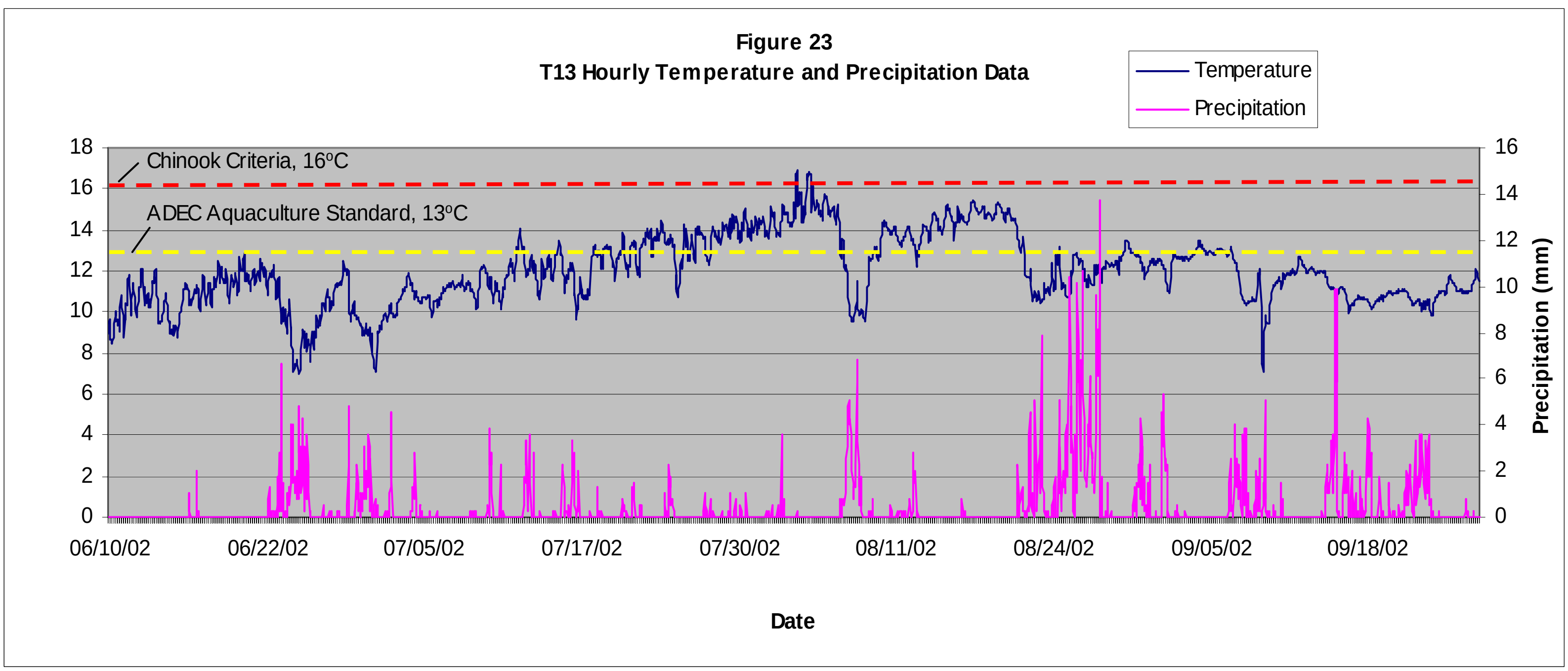


Figure 23
T13 Hourly Temperature and Precipitation Data
Temperature
Precipitation
Chinook Criteria, 16ºC
ADEC Aquaculture Standard, 13ºC
18
16
14
12
10
8
6
4
2
0
16
14
12
10
8
6
4
2
0
Precipitation (mm)
06/10/02
06/22/02
07/05/02
07/17/02
07/30/02
08/11/02
08/24/02
09/05/02
09/18/02
Date

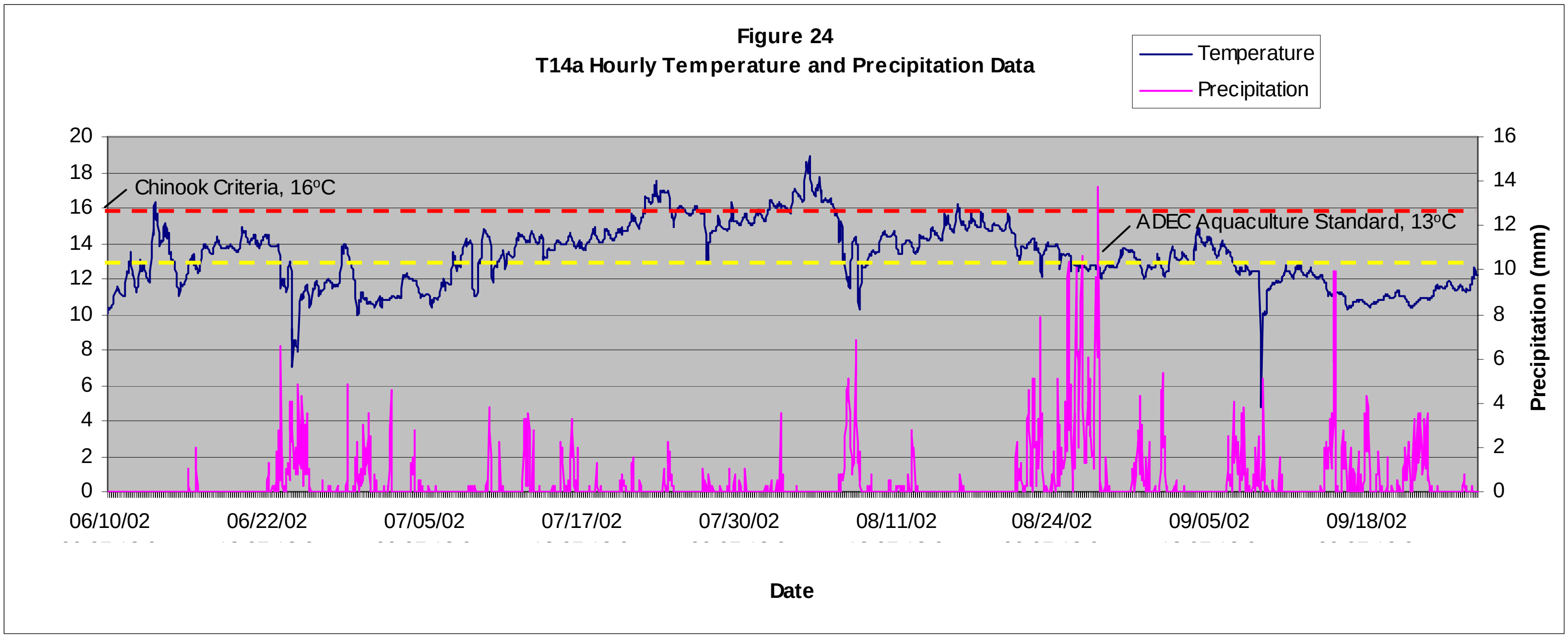


Figure 24
T14a Hourly Temperature and Precipitation Data
Temperature
Precipitation
Chinook Criteria, 16°C
ADEC Aquaculture Standard, 13°C
20
18
16
14
12
10
8
6
4
2
0
06/10/02
06/22/02
07/05/02
07/17/02
07/30/02
08/11/02
08/24/02
09/05/02
09/18/02
Date
Precipitation (mm)

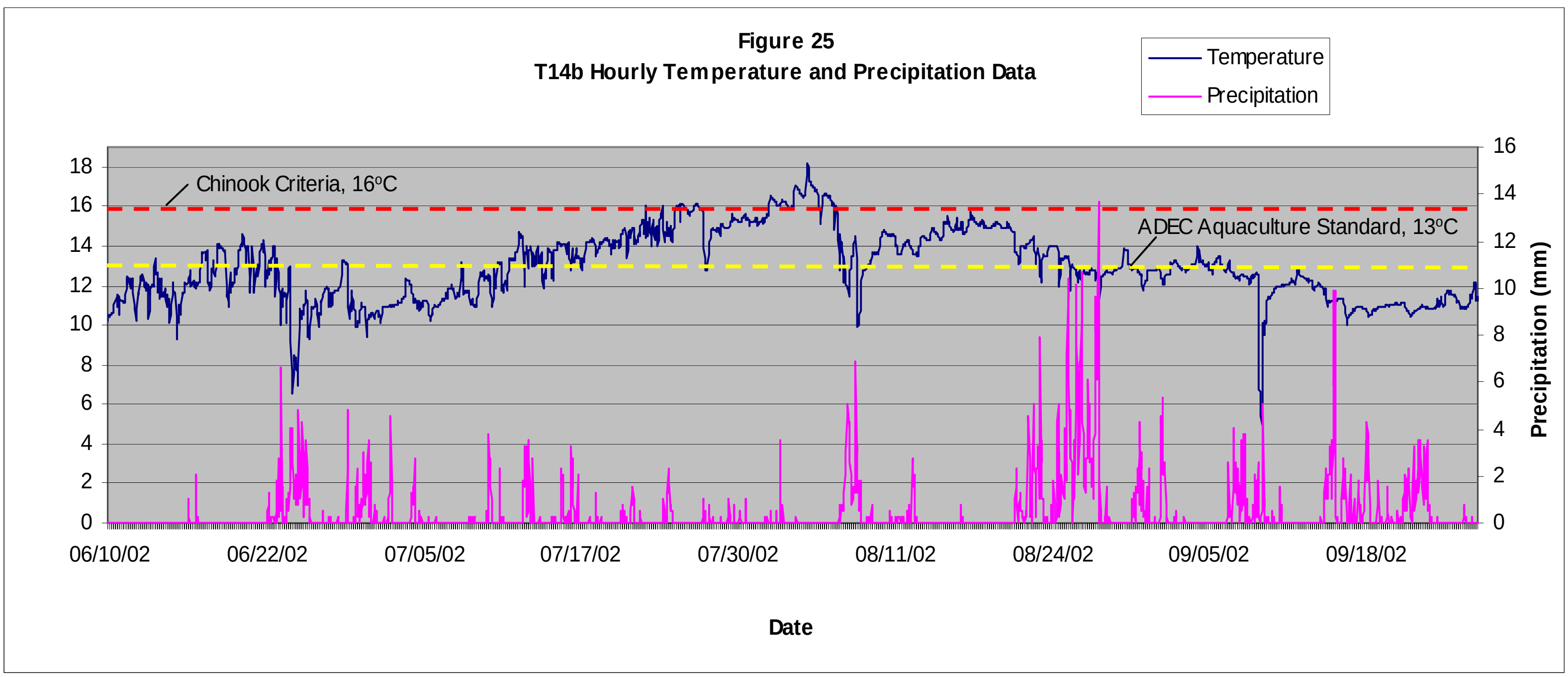


Figure 25
T14b Hourly Temperature and Precipitation Data
Temperature
Precipitation
Chinook Criteria, 16°C
ADEC Aquaculture Standard, 13°C
18
16
14
12
10
8
6
4
2
0
06/10/02
06/22/02
07/05/02
07/17/02
07/30/02
08/11/02
08/24/02
09/05/02
09/18/02
Date
Precipitation (mm)

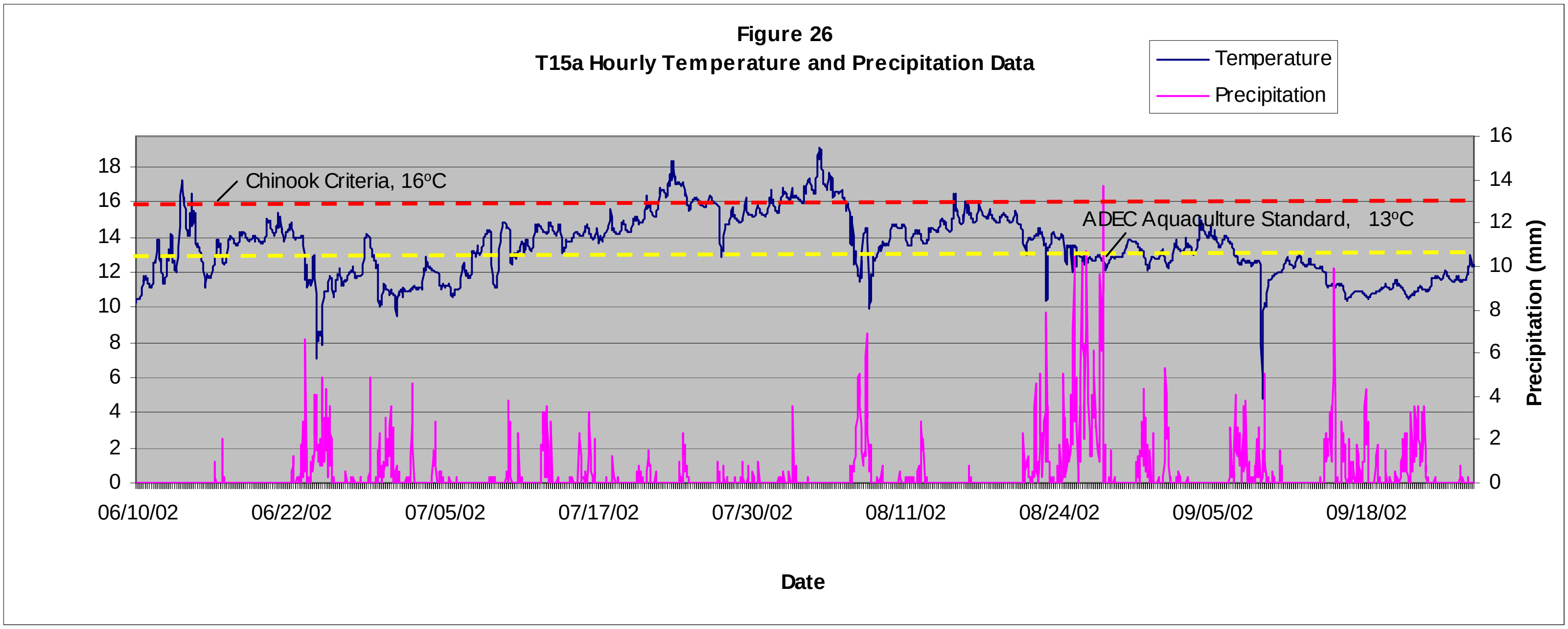


Figure 26
T15a Hourly Temperature and Precipitation Data
Temperature
Precipitation
Chinook Criteria, 16ºC
ADEC Aquaculture Standard, 13ºC
18
16
14
12
10
8
6
4
2
0
16
14
12
10
8
6
4
2
0
Precipitation (mm)
06/10/02
06/22/02
07/05/02
07/17/02
07/30/02
08/11/02
08/24/02
09/05/02
09/18/02
Date

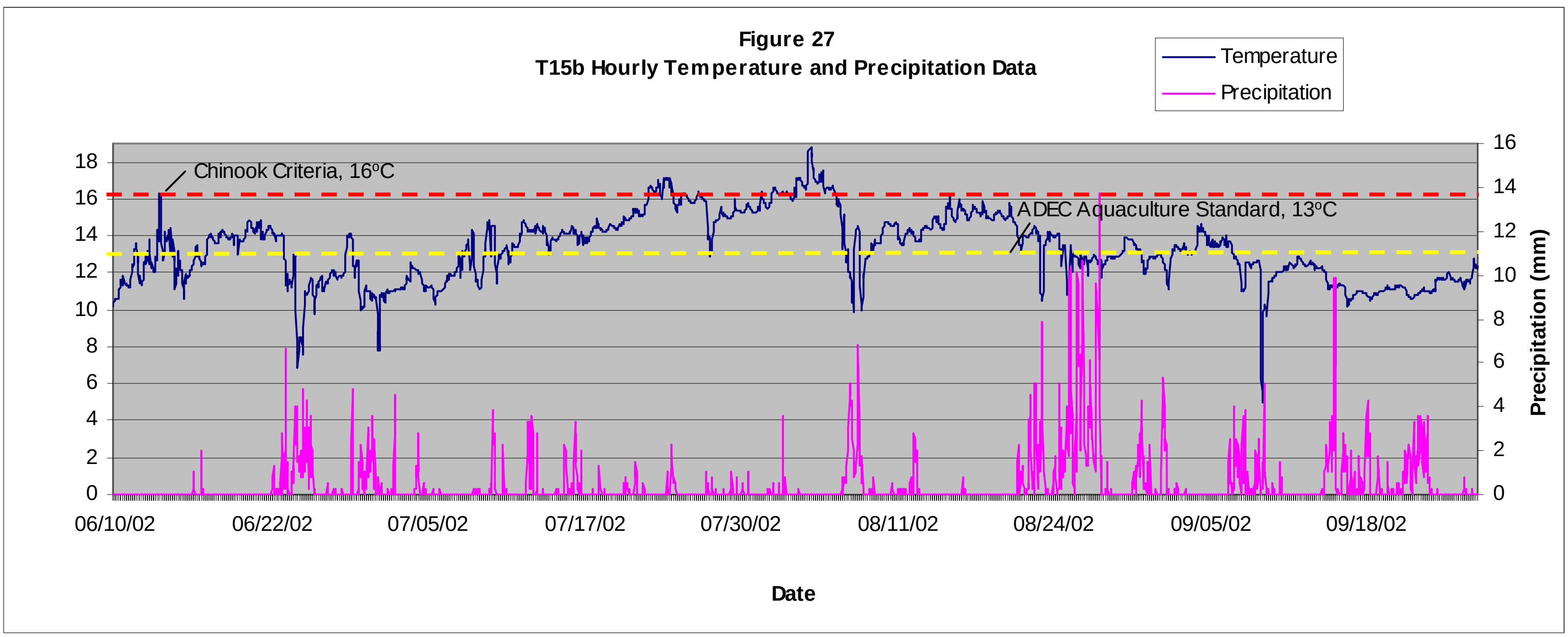


Figure 27
T15b Hourly Temperature and Precipitation Data
Temperature
Precipitation
Chinook Criteria, 16ºC
ADEC Aquaculture Standard, 13ºC
18
16
14
12
10
8
6
4
2
0
16
14
12
10
8
6
4
2
0
Precipitation (mm)
06/10/02
06/22/02
07/05/02
07/17/02
07/30/02
08/11/02
08/24/02
09/05/02
09/18/02
Date

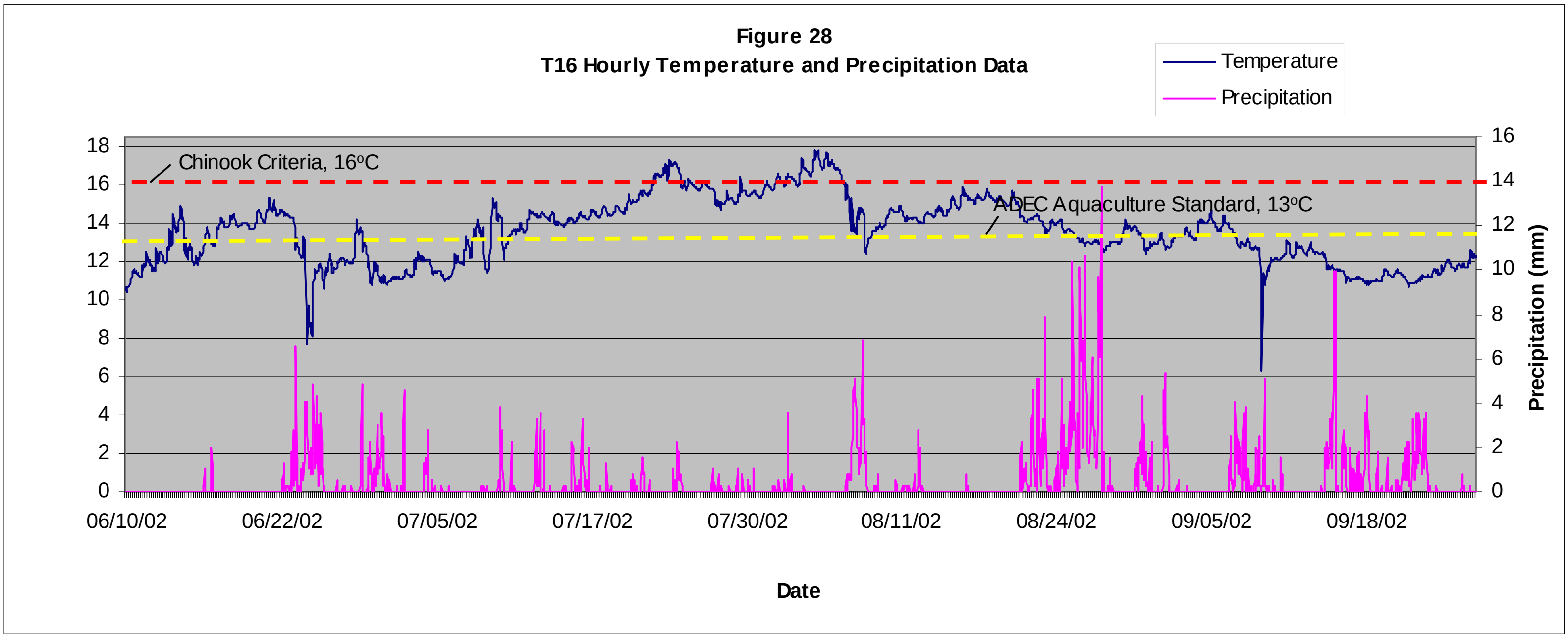


Figure 28
T16 Hourly Temperature and Precipitation Data
Temperature
Precipitation
Chinook Criteria, 16ºC
ADEC Aquaculture Standard, 13ºC
18
16
14
12
10
8
6
4
2
0
16
14
12
10
8
6
4
2
0
Precipitation (mm)
06/10/02
06/22/02
07/05/02
07/17/02
07/30/02
08/11/02
08/24/02
09/05/02
09/18/02
Date

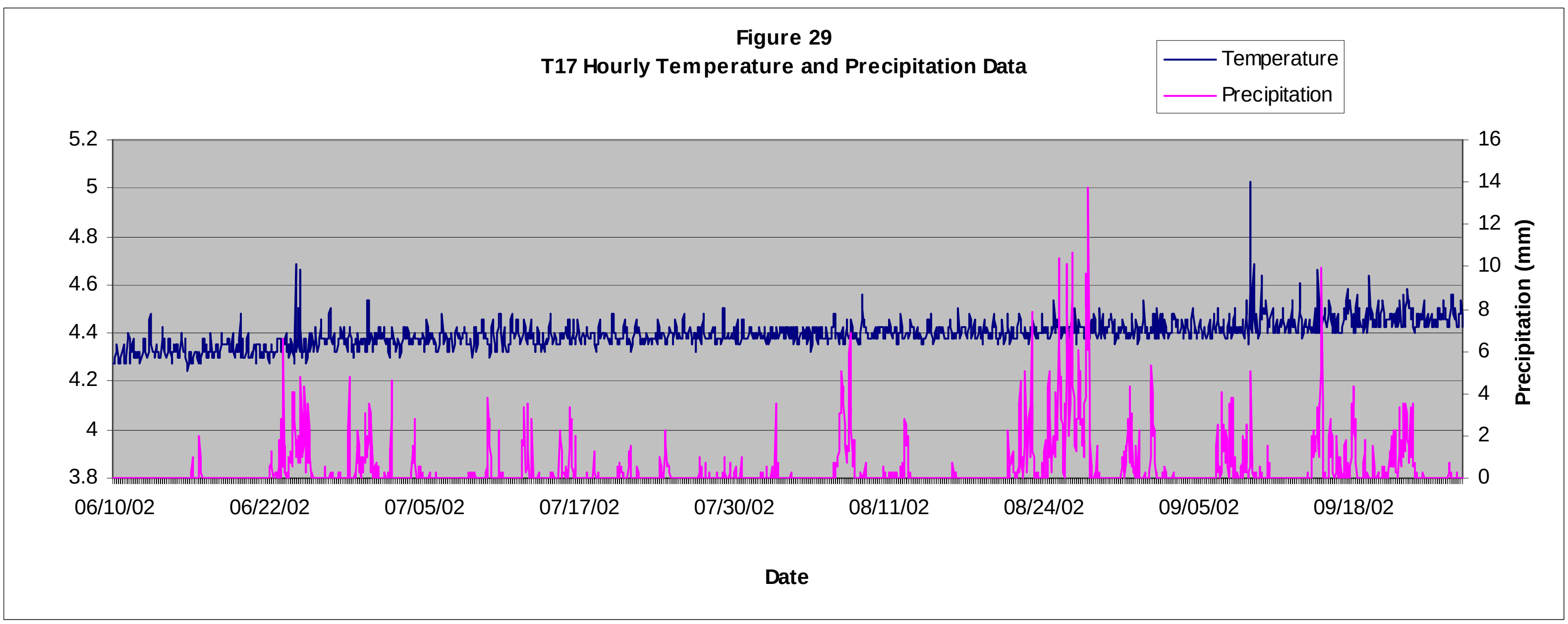
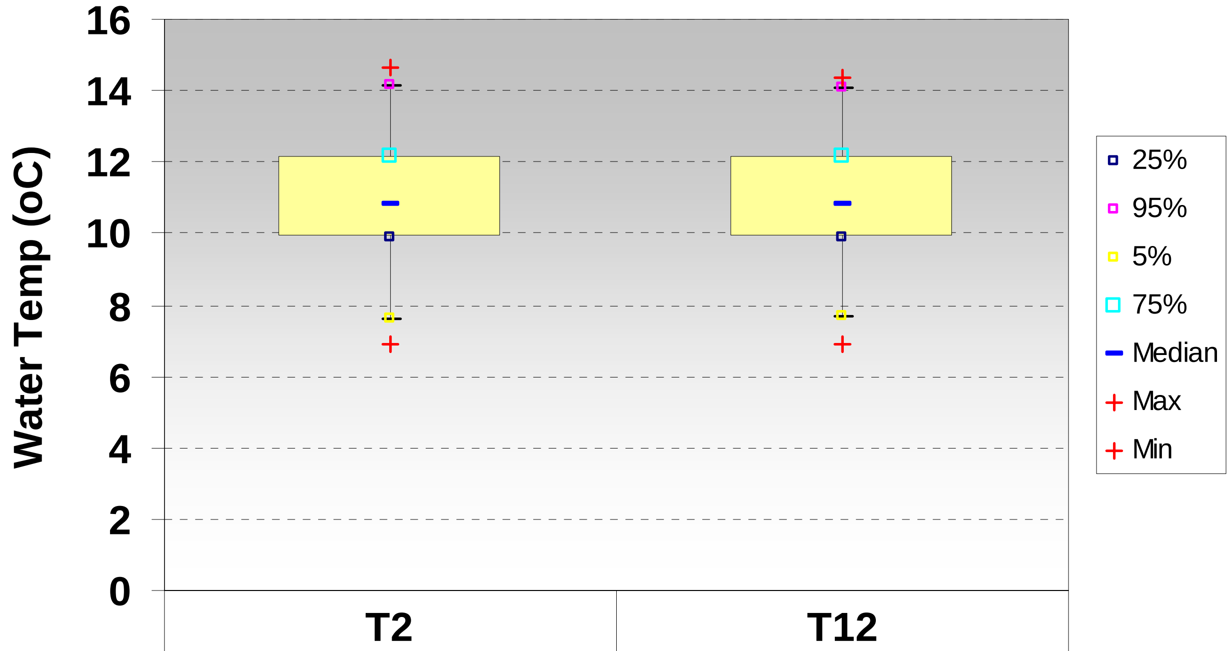


Figure 29
T17 Hourly Temperature and Precipitation Data
Temperature
Precipitation
5.2
5
4.8
4.6
4.4
4.2
4
3.8
16
14
12
10
8
6
4
2
0
Precipitation (mm)
06/10/02
06/22/02
07/05/02
07/17/02
07/30/02
08/11/02
08/24/02
09/05/02
09/18/02
Date

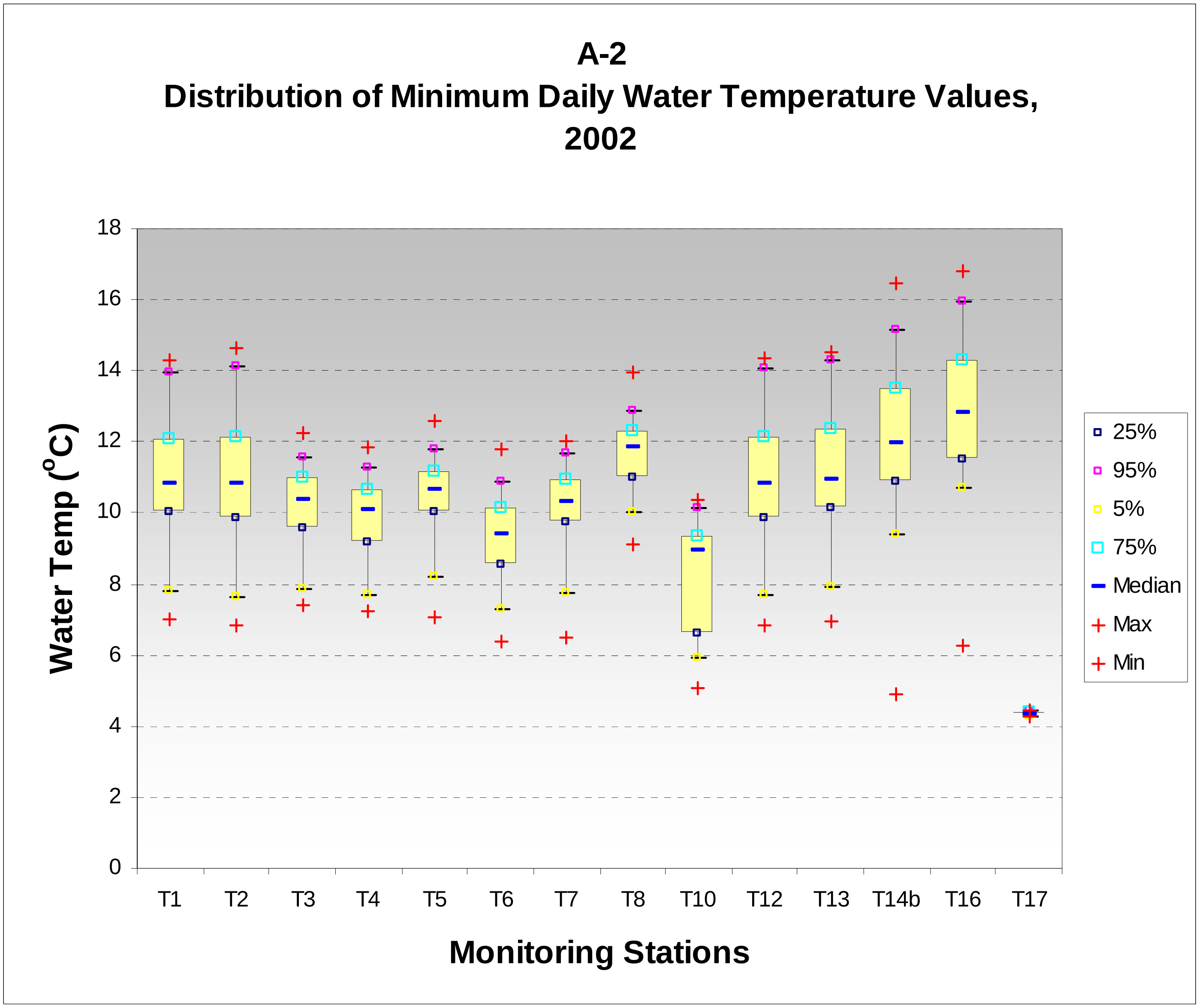
Appendices

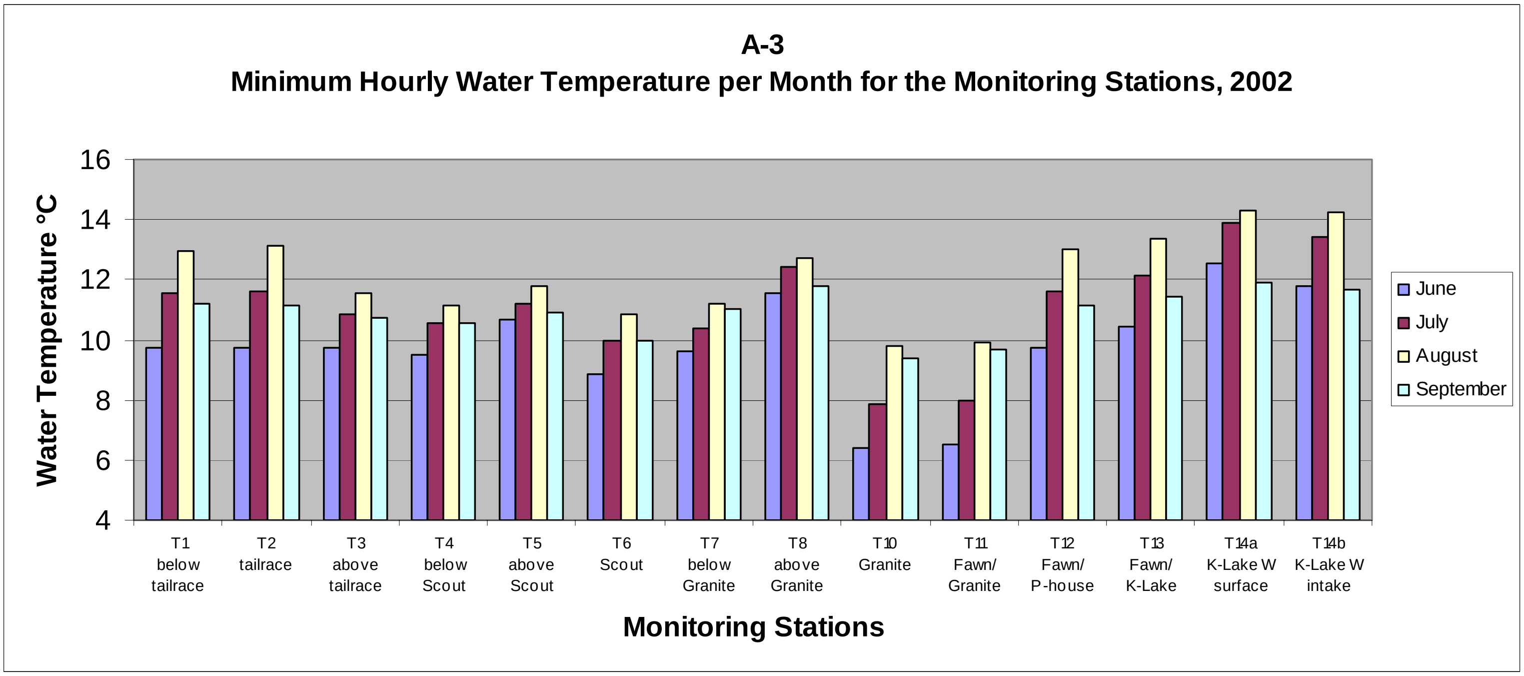
Appendix A – Supporting Figures

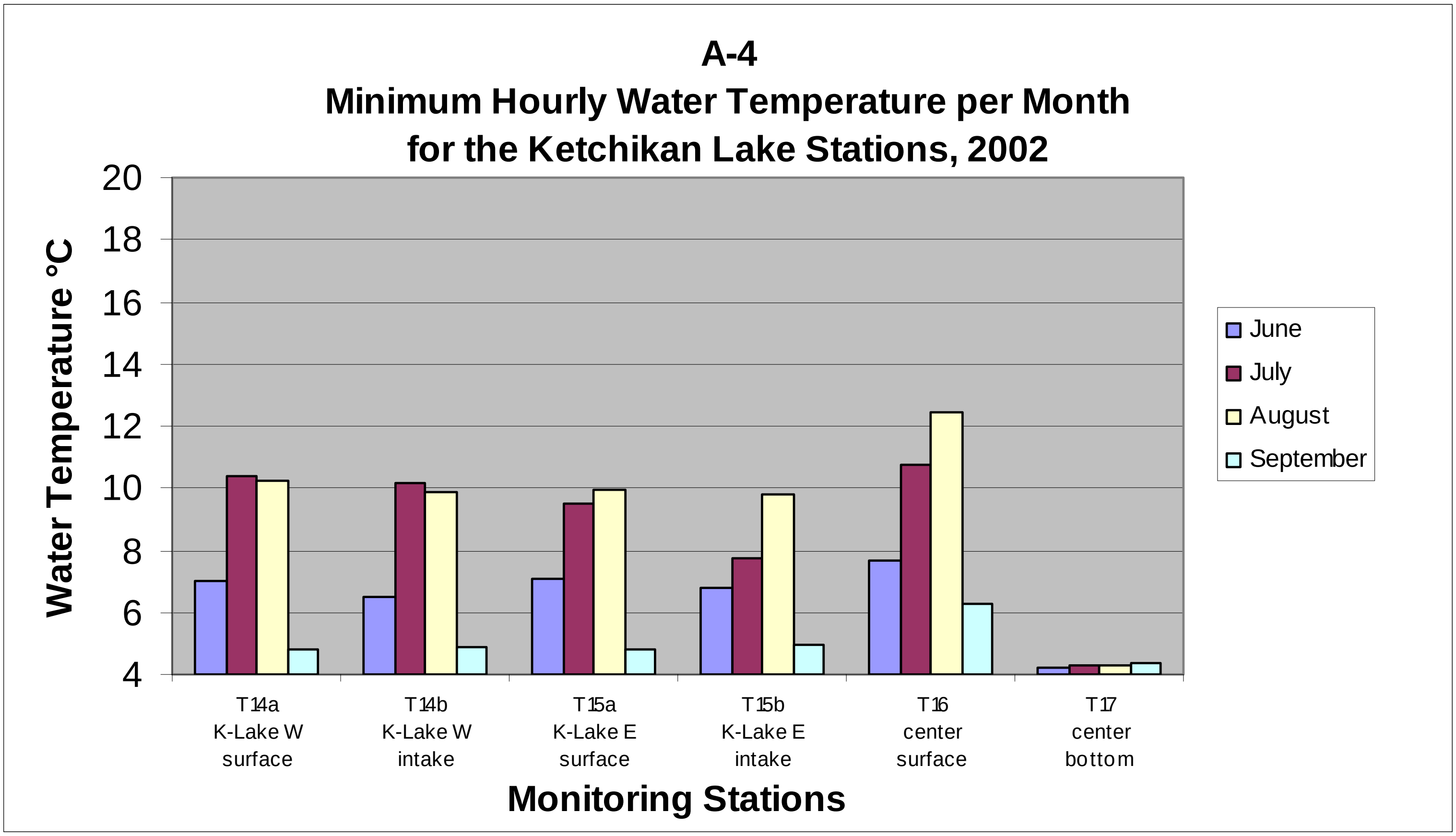
A-1
Comparison of T2 to T12 Maximum Daily Water Temperature Values, 2002



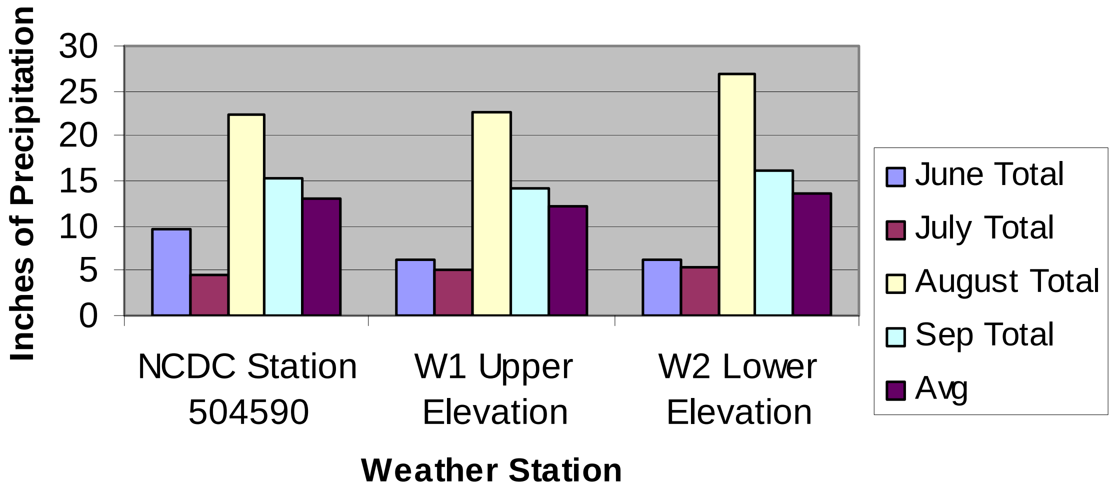
	T2	T12
25%	9.853888889	9.853888889
95%	14.13959183	14.04483333
5%	7.641777778	7.679444444
75%	12.14666667	12.14666667
Median	10.80944444	10.80944444
Max	14.64888889	14.33722222
Min	6.863888889	6.863888889


A-2
Distribution of Minimum Daily Water Temperature Values, 2002
Water Temp (°C)
18
16
14
12
10
8
6
4
2
0
T1
T2
T3
T4
T5
T6
T7
T8
T10
T12
T13
T14b
T16
T17
Monitoring Stations
25%
95%
5%
75%
Median
Max
Min

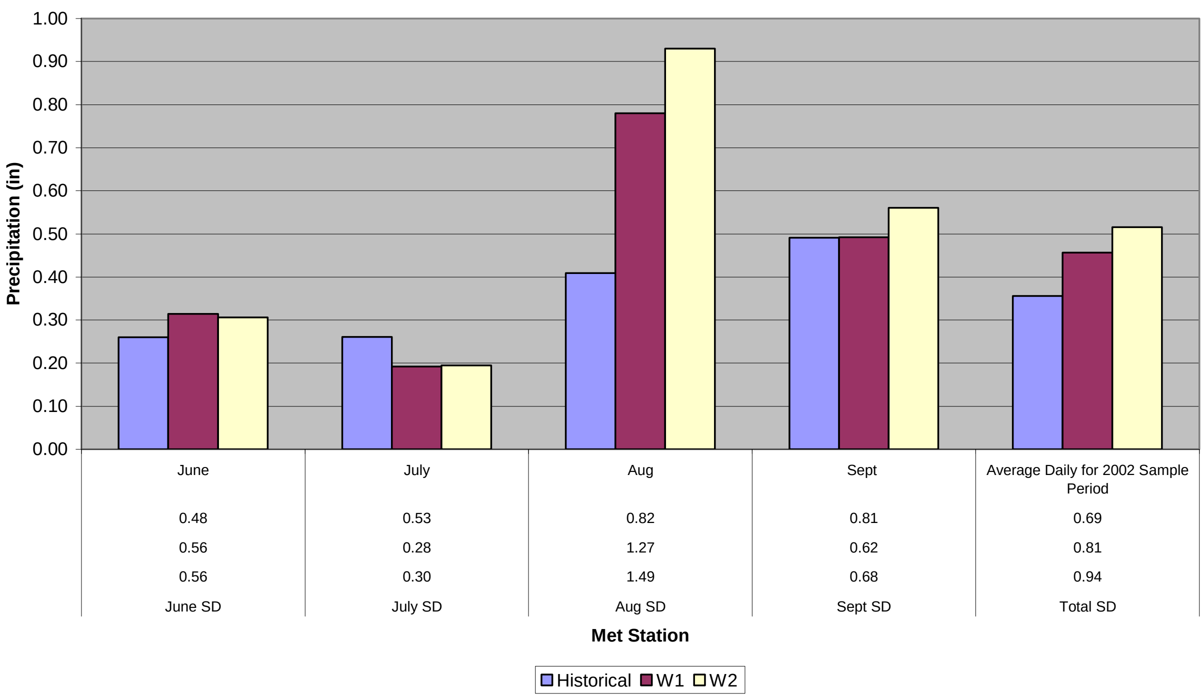

A-3
Minimum Hourly Water Temperature per Month for the Monitoring Stations, 2002
Water Temperature °C
16
14
12
10
8
6
4
T1 below tailrace
T2 tailrace
T3 above tailrace
T4 below Scout
T5 above Scout
T6 Scout
T7 below Granite
T8 above Granite
T10 Granite
T11 Fawn/ Granite
T12 Fawn/ P-house
T13 Fawn/ K-Lake
T14a K-Lake W surface
T14b K-Lake W intake
Monitoring Stations
June
July
August
September


A-4
Minimum Hourly Water Temperature per Month
for the Ketchikan Lake Stations, 2002
Water Temperature °C
20
18
16
14
12
10
8
6
4
June
July
August
September
T14a K-Lake W surface
T14b K-Lake W intake
T15a K-Lake E surface
T15b K-Lake E intake
T16 center surface
T17 center bottom
Monitoring Stations

A-5
Total Monthly Precipitation for the W1, W2, and Historical Stations for the 2002 Sample Period



A-6
Average Daily Precipitation for the W1, W2, and Historical Stations for the 2002 Sample Period



Appendix B – Anomalies

Isolated Events or Anomalies

It was determined sometime after the temperature loggers were retrieved that data from T2 placed in an outlet from the KPU powerhouse was compromised during a small portion of the data collection period. There are three outlets from the powerhouse for each hydro including kpg3, kpg4, and kpg5 that all feed into the tailrace. T2 was located in kpg3 and, according to KPU records, this outlet did not receive flow on August 7 or from August 15-20, 2002, because the hydro turbine unit was not in use. T2 was not collecting water temperature data during this time, which verifies the anomalies observed on those days in August.

KPU must discharge a minimum flow of 47 cfs from the tailrace. Average daily flows below the tailrace in Ketchikan Creek are the same as would occur without the powerhouse with the exception of the 10 cfs of water removed to supply water to the city (KPU 1998). However, minimum monthly flows below the powerhouse are increased compared to what would occur during dry periods. During periods of high flow or peak flow, the average monthly flow is frequently reduced by the project. As indicated in the Environmental Assessment (EA) for the Ketchikan Lakes Hydroelectric Project from 1998, there are no significant losses of flow that occur as a result of the project operation. Rather, the concern for this study is how the alternate flow regime may affect Ketchikan Creek temperatures not the amount of flow. Flow is conserved from Ketchikan Lakes, Granite Basin, and Fawn Lake to the powerhouse. Only the 10 cfs for water supply is lost from the main channel downstream of the powerhouse and the minimum of 4.7 cfs supplied to the hatchery is not available until returned from the outfall below the hatchery. The management of flow provides a higher than average summer flow in the reach below the powerhouse, which is a sensitive time for fisheries.