WATER QUALITY SUMMARY REPORT NO. 28

Diel Dissolved Oxygen Monitoring of the Spokane River, During Extreme Low Flow

Kootenai County, Idaho 1992

Idaho Department of Health and Welfare
Division of Environmental Quality

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Abstract

Diel monitoring of dissolved oxygen and temperature was conducted on an impounded and free-flowing reach of the Spokane River in north Idaho, on two occasions during an extreme low flow event (less than 0.01% frequency of occurrence) in water year 1992. The low flows were a natural occurrence, the result of a mild winter with little snowpack accumulation. The objective was to document excursions from water quality criteria for dissolved oxygen and to provide insight into rates of over-night oxygen uptake or daylight oxygen production for future modeling efforts. Water column temperature and dissolved oxygen were measured on a regular interval for 24 hours at three locations in the impounded reach, and at one location downstream of Post Falls Dam. The first sample period on August 16 and 17, 1992, was characterized by marked stratification, departures from oxygen criteria in the metaliminion, and warm water temperatures. Profiles were significantly different ($P = 0.05$) from each other in time (over 24 hours) and space (from upstream to downstream), largely due to low variability of the data. The actual magnitude of the changes (less than 1.0 mg/L) was not great enough to suggest that biological processes were significantly changing dissolved oxygen levels on a 24 hour basis. Generally, water was slightly warmer and contained slightly less oxygen at downstream stations. The run of the river station demonstrated the largest diel change, possibly indicating daytime production of oxygen by attached periphyton. Following a storm event and subsequent decrease in residence time, stratification and criteria violations were not detected during the second sample event on September 8 & 9, 1992. Profiles of temperature and dissolved oxygen were still significantly different in space and time statistically, however, they were well mixed vertically and the magnitude of the changes was very small (0.3°C and 0.7 mg/L O_2). Based on this information, future water quality modeling efforts can assume that in the impounded reach of the river a large amount of organic matter is <u>not</u> in the system, and that a large amount of algae or periphyton is <u>not</u> present. Dissolved oxygen criteria violations appear to be infrequent and stratification conditions are fragile.

Introduction

Background

The Spokane River flows from Coeur d'Alene Lake, Kootenai County, Idaho into the State of Washington approximately five miles below the Post Falls Dam (Figure 1). The Post Falls Dam controls the discharge and stage of the upper six miles of the river and Coeur d'Alene Lake. The river receives the outfall of two wastewater treatment facilities year around (Coeur d'Alene and Post Falls) and receives a third wastewater treatment plant discharge (Hayden) when river flow exceeds 2,000 cfs. The largest WWTP contribution is from Coeur d'Alene, with a permitted discharge of 4.2 mgd near the outflow of Coeur d'Alene Lake, at the head of the Spokane River. Post Falls WWTP is the next largest discharge, with a permitted flow of 1.0 mgd. The Post Falls discharge is located downstream of the Post Falls Dam, in the free flowing reach of the river. Hayden is the smallest discharge, and is located approximately in the middle of the impounded reach (Figure 1). Biological oxygen demand (BOD) load is permitted on a percent removal basis for all three treatment plants. Permit renewals for these facilities have requested increased discharge flows. River frontage and islands have relatively dense residential development. Recreational use of the river has increased as well.

Water Year

Water year 1992 was characterized by low precipitation and early snowmelt. The snow pack in the Coeur d'Alene Basin was 49% of normal (SCS 1992). A warm winter and early spring advanced the snow melt event and consequently the timing and magnitude of the maximum flow of the Spokane River. Maximum mean daily stream flow was 10700 cfs on February 6, 1992. For comparison, when mean daily flows for water years 1913-1992 are averaged, the yearly maximum occurs in the month of May, with a flow of 31750 cfs (Harenburg, *et al.* 1993). As a result of early, modest runoff, flows during late summer were much lower and lasted longer than normal. The lowest mean daily flow during water 1992 was 210 cfs, on August 18, 1992 (Figure 2). For the period of record 1913 through 1992, the minimum mean daily flow is 185 cfs. The mean monthly flow for July and August 1992 was 1065 cfs and 612 cfs, respectively. The July and August monthly mean flows for the period of record are 2073 cfs and 949 cfs, respectively.

Previous Investigations

The water quality of the Spokane River was assessed in 1978, 1979 and 1989 (Yearsley 1980; Yearsley and Duncan 1989); in 1980 and 1991 (Falter and Mitchell 1982; Falter *et al.* 1992); and in 1981 by Seitz and Jones (1982). These studies were generally conducted during periods of higher discharge. Table 1 summarizes the water year conditions during previous investigations. The studies conducted during the lower water years suggest that the impounded reach of the river may stratify in those areas where depth is greater than 20 feet during low flow conditions, especially when reduced flows increase residence time to greater than 15 days (approximately 370 cfs). Two studies (Falter et al. 1992; Seitz and Jones 1982) investigated diel dissolved oxygen concentrations in the reservoir portion of the reach. Essentially no diel change in dissolved oxygen occurred during those studies. Flows in both cases were greater than during the current conditions. Departures below dissolved oxygen criteria have also been reported on occasion by researchers. Yearsley (1980) noted low dissolved oxygen levels in the bottom of Ford Rock hole, the deepest portion of the reach.

Based on low snowpack and early melt, the low discharge event anticipated during the late summer and early fall of 1992 provided a rare opportunity to characterize the water quality of the river during an extended period of minimum flow. During this period stratification was expected to occur in the deepest sections of the impounded reach. Departures from oxygen criteria, and conditions for algal growth and plant growth nutrient enrichment were also expected to be at maximum levels. Development of dissolved oxygen and oxygen demand data for this period will improve understanding of the condition of the Spokane River. Taken with the data sets cited earlier, a wide range of water quality values will be available for calibration of the Dynamic River Basin Water Quality Model (Yearsley 1991). This study was proposed in the *Low Flow Plant Growth Nutrient, Chlorophyll and Dissolved Oxygen Monitoring of the Spokane River, Idaho* monitoring plan (Harvey 1992). The additional monitoring for plant growth nutrient and algal biomass described in the plan was collected during August and September of 1992, however, the objective of that data collection effort was distinctly different: to collect data for calibration of the river model at low flow. Results will be reported in a separate document devoted to model calibration activity exclusively.

Objectives

The initial objective of the study was to characterize the water quality of the Idaho reach of the Spokane River in terms of diel oxygen fluctuation for use in a water quality model. The model, written by Yearsley (1991), is being used by DEQ to develop a Total Maximum Daily Load (TMDL) for the Idaho reach of the Spokane River. The TMDL approach is being used to guide discharge permit decisions in the face of increased wastewater treatment loading and increased public awareness as to the condition of the river. The model is a general water quality model that is capable of incorporating the physical, chemical, and biological interactions that occur in rivers or lakes. DEQ is using field data collected by Falter *et al.* (1992) for model calibration, however, the researchers did not measure sediment oxygen demand and photosynthetic growth rate. Both rate constants are adjustable in the model, however, without measured information, these rates have been left at default values. It was anticipated that during an extreme low flow event, insight into rate constant assumptions regarding sediment oxygen demand and the effect, if any, of attached periphyton on oxygen production could be obtained.

A second objective was to document stratification of the deep reaches of the impounded waters and investigate departures from dissolved oxygen criteria during the low flow conditions.

Hypotheses

Numerous physical, chemical, and biological interactions impact a stream or lake ecosystem during a 24 hour period (Wetzel and Likens 1979). During daylight hours, temperature, light, and physical properties influence algal productivity, a product of which is oxygen produced by photosynthesis. During night hours, the absence of light limits photosynthesis, hence oxygen production. Organic matter, either naturally in the system or introduced by human activity, is continually decomposed by various microorganisms, regardless of available light. This decomposition process consumes oxygen. If a large amount of organic matter is in the system, or a large amount of algae or periphyton are present, one could expect that large changes in the amount of dissolved oxygen in the water column would occur. Diel changes would be expected as a result of high oxygen production during daylight hours, high consumption at night in the absence of oxygen production, or a combination. The sampling design measured dissolved oxygen profiles (each meter from surface to bottom) through the water column many times during a 24-hour period in both the impounded and free-flowing reaches of the river. If algal populations are low and decomposition rates are low, little change in the shape of these profiles is expected. The following set of hypotheses test for productivity and decomposition:

For each station over 24 hours:

H_0: *the water column profiles are the same.*
H_1: *the water column profiles are different.*

The study design also allowed for evaluation of potential changes in dissolved oxygen from upstream to downstream. Addition of nutrients and the presence of particulate or dissolved organic matter may be anticipated as one nears Post Falls Dam. The river morphology deepens (allowing flow velocity to drop and particles to settle) and the amount of shoreline development increases. If no activity is occurring, the response observed in the oxygen profiles should be that they are the same. Continued metabolic activity would be expected to increase variability in the profiles as one moves downstream. The following set of hypotheses test for changes relative to location:

For each similar time period:

H_0: *the water column profiles are the same between stations.* $(A=B=C)$
H_1: *the water column profiles are different between stations.* $(A \neq B \neq C)$

If H_0 is rejected, then hypotheses for the direction of change can be tested. If oxygen is being consumed, the concentration of oxygen in the profiles should decrease as one moves downstream. The following hypotheses test for a decrease in dissolved oxygen downstream:

For each similar time period:

H_0: the water column profiles are the same between stations.
([up] = [B] = [down])
H_1: the water column profiles upstream are greater than profiles downstream.
([up] > [B] > [down])

There is a risk that H_0 can be accepted when the actual direction of change may be in the opposite direction of that tested by H_1. Careful comparison of graphed results and statistical test results is needed to avoid this potential error.

Materials and Methods

Sampling Design

Temperature and dissolved oxygen profiles were measured at Stations 4, 5, 6, and at the Ford Rock Hole (Figure 1) on two dates during late summer of water year 1992. Numbered stations in this reach have been used by many researchers over the years, most recently by Falter *et al.* (1992). Stations 4, 5, and Ford Rock hole represent the deepest reaches of the impounded river reach. Sampling of shallower upstream stations was not performed as stratification was not anticipated, based on information in earlier studies. Even though Coeur d'Alene WWTP discharges at the headwaters of the reach, the impact of their BOD on stratification conditions has not been documented in the upper reaches. The collected data were used to document the occurrence and the extent of stratification in the deepest areas of the impounded reach. Any departure below dissolved oxygen criteria of 3.5 mg/L instantaneous minimum (IDAPA 16.01.02276.02 in Appendix B) below the Post Falls Dam was also documented. Diel oxygen measurements were made at these stations to document any temporal departures from the criteria. The location of the stations by river mile, STORET number designation, and latitude/longitude are provided in Table 2.

Sampling Method

The diel measurements of temperature and dissolved oxygen were made using a Hydrolab Surveyor unit. Measurements were taken at least every three hours over a 24 hour period at stations 4, 5 and 6. Ford Rock Hole, representing the deepest part of the river, was measured on a less frequent interval to determine if oxygen criteria were met or exceeded in all parts of the river. Measurements at stations 4, 5, and Ford Rock Hole were vertical profiles with readings taken at one meter intervals in the water column at the location of greatest depth. Measurements of temperature and oxygen were made at the deepest location of Station 6. Since a depth of less than 1.33 meters in the free running reach was observed, measurements were recorded at every half meter. Profiles were taken to verify that complete mixing was occurring below the Post Falls Dam.

Sample locations were verified using a Global Positioning System (GPS) Pathfinder unit (Trimble Navigation; Sunnyvale, CA). Stations were located from field notes describing landmarks used during the Falter 1990-1991 study. Each station was re-visited, multiple GPS data transmitted by satellites was collected, differentially corrected for skew and downloaded to an analysis program that provided a best statistical estimate of the location. The resulting locations were compared to existing latitude and longitude information in STORET, to USGS quads, and to river mile sample locations reported by Falter *et al.* (1992).

Oxygen saturation was calculated to evaluate the impact of temperature on oxygen. Calculations compensating for elevation were performed following the methods in Wetzel (1979).

Sampling Duration

The diel measurements of temperature and dissolved oxygen were made twice during the period of low flow conditions, on August 16 and 17, 1992 and on September 8-9, 1992. The August diel measurements were taken following a long period without precipitation (22 days). Following that precipitation event flows generally decreased prior to the sample date. Flow was 229 cfs at the beginning of the August diel survey. Flow was 225 cfs at the end of the survey. Commencing with 0.88 inches of rainfall on August 22, and continuing for 4 more days, a total of 1.42 inches of rain fell in the area. Spokane River flows increased to 2180 mean daily cfs on August 24, and returned to earlier levels by August 30. Flow was 238 cfs at the beginning of the September 24 hour period and 233 cfs upon completion of the survey. Additional sampling events were not appropriate since Washington Water Power was scheduled to begin drawdown on September 10, 1992 and additional rainy weather was forecast for later in September. Flows are shown in Figure 2.

Quality Control/Quality Assurance

The Hydrolab instrument used to measure temperatures and dissolved oxygen was operated according to the manufacturer's instructions. The instrument was calibrated before and after each diel monitoring session. The unit calibrated accurately each time. No abnormal behavior (indicated by unstable readings or wild fluctuation in readings) on the part of the unit was observed during sampling. In addition, at the start of each diel sample event, readings were compared to a Yellow Springs Instrument (Model 57) temperature and dissolved oxygen meter. Readings compared within 0.1 mg/L.

Statistical Analysis

While a component of the study was a descriptive exercise intended to document violation of water quality criteria, the additional objective to evaluate dissolved oxygen fluctuation in space and time required hypothesis testing. Statistical analysis of sample variability is appropriate to determine if observation of differences between sample events and stations or observation of exceeded criteria is real or due to variability in sample collection and analysis. A two way analysis of variance (ANOVA) without replication following the methods in Sokal and Rohlf

(1981) was appropriate for testing hypotheses about differences in water column profile over the 24 hour test period or between stations. To test between stations, profiles were limited to the depth of the shallowest station, since ANOVA methods do not allow for missing values. A Student's *t* test was used to ascertain direction of changes. Example calculations for each test are shown in Appendix A.

Results

Data collected during the August and September sample runs differed dramatically (paired Figures 4 & 5,6 & 7, 8 & 9, 10 & 11). In general, August data indicate that stratification was occurring with respect to all measurements. September data show that no stratification was occurring (Table 4, and above Figures). Pool stations and Station 6, in the run-of-the-river reach below Post Falls Dam, differed greatly. The following presents results from the two sample events. For clarity, an example graph showing a single profile is provided in Figure 3.

August

During the August sample event, temperature profiles at the pool stations (#4,Ford Rock,#5) show changes with depth (Figures 4, 6, 8). A 'classic' stratification pattern (one degree Celsius change in one meter depth) is observed at Station 4 at two sample times and at Station 5 at four sample times. More gradual stratification in temperature was observed at the Ford Rock Hole. Complete mixing is observed at Station 6. Temperature at the surface decreased slightly during nighttime hours and increased throughout the day. Temperature remained relatively constant in the lower water column. A high temperature of 25.2° C was observed at Station 5 and a minimum temperature of 20.4° C was observed at the Ford Rock hole.

Statistical analysis verified that the changes with depth observed in the pool stations are significant, given the overall variability (Table 4). Within each station, the profiles were also statistically different over the 24 hour period (Table 3). Figure 20 shows the relationship between stations. Table 5 shows that for a given time period, upstream station temperature profiles are generally cooler than downstream stations.

Vertical profiles of dissolved oxygen concentration showed decreases in concentration with depth at all stations except Station 6, downstream of the Post Falls Dam. Decreases generally began below 4 meters depth. Changes of 1.0 mg/L per meter depth were observed frequently, especially at lower depths. Minimum concentration of 0.3 mg/L was detected in the bottom four meters of the Ford Rock hole (Figure 6). Minimum oxygen concentrations found at the bottom of Stations 4 and 5 were 2.3 mg/L and 4.0 mg/L, respectively (Figures 4 & 8).

Statistically, only Station 4 of the pool stations was significantly different in oxygen concentration with respect to sample time (Table 3). Ford Rock hole and Station 5 exhibited little change in oxygen profile shape and value over the 24 hours (Figures 6 & 8). Differences between pool stations were slight (<1 mg/L overall), however, a general statistical trend of decreasing concentration as one moves downstream can be observed (Table 5).

Oxygen saturation values followed a pattern similar to that of temperature and oxygen concentration (Figures 12 - 15). A decrease in surface saturation overnight is more pronounced than seen in the concentration data alone. At pool stations, a maximum percent saturation of 101.8 % was observed at surface of Station 4, in the early evening sample. Minimum percent saturation of 3.56 % was recorded at the bottom of Ford Rock hole. Saturation reached a low of 27.8 % and 49.3 % at the bottom of Stations 4 and 5 respectively.

August profiles at Station 6 fluctuated over the twenty four hour diel period more than pool stations (Figures 10 & 15). All measures were statistically different with respect to sample time (Table 3). Values were similar to those observed in the upper layers of the pool: temperature ranged from 23.0 to 24.8 degrees C; dissolved oxygen concentration ranged from 5.9 to 7.1 mg/L; percent saturation ranged from 74.7 to 93.2 percent. The water column appeared well mixed for all measured values. ANOVA shows a significant difference with respect to depth for temperature and dissolved oxygen concentration (Table 4). Changes of less than 1.0 mg/L were observed. Percent oxygen saturation demonstrated the greatest diel variation (Figure 15), with lower values observed during hours of darkness.

September

Profiles of temperature and oxygen in the pool reach were much more uniform in the water column. Temperatures were cooler than observed in August. Maximum temperature was 19.6 degrees C at Station 5; minimum temperature was 17.6° C at Station 4. Temperature change with sample time was again observed, however, little change with depth was recorded. ANOVA analysis showed that all stations had statistically the same temperature with respect to depth. Maximum change with depth was 0.3° C/meter at Station 5. Maximum surface to bottom temperature change was 1.7° C when all samples are combined.

Analysis of difference between stations shows little real difference graphically (Figure 23). ANOVA and Student's t results show that the slight difference observed was occasionally significant. The note in Table 5, however, shows that in the early morning hours, there is a difference, but, the direction of change is that of warmer water upstream.

Oxygen was also relatively uniform in the water column during the September diel data collection event. A maximum concentration of 9.3 mg/L and a minimum concentration of 7.9 mg/L were recorded in the pool stations. Maximum difference from surface to bottom was 0.7 mg/L for all pool stations at all sample times. ANOVA results detected statistically significant differences within stations with respect to sample time (Table 3), but not with respect to depth (Table 4). ANOVA and Student's t tests performed between stations showed that changes from station to station were generally not significant (Table 5).

Oxygen saturation in September was also dramatically different from that observed in August. For the pool stations, maximum saturation was 106.0 %; minimum saturation was 90.0 %.

September profiles at Station 6 are more consistent through the diel observation (Figure 11) than seen during the August sampling. Temperatures were cooler, ranging from 17.6 to 19.0 degrees C. Differences between sample times were significant, but vertical differences were not. Oxygen was also vertically mixed with slightly higher (max = 9.2 mg/L) values than seen in August. Percent saturation ranged from 89.5 to 104.8 percent (Figure 19).

Discussion

Differences Between Dates and Effect of Weather

The water conditions leading up to the diel survey in August of 1992 were extremely unusual. A 7-day mean flow of 330 cfs or less occurs less than 0.01% of the time, based on historical records (7Q0.01 flow = 330). The seven day mean flow observed during the week preceding the August sample date was 245 cfs.

Falter *et al.* (1992) state that residence time of water in the pool reach of the Spokane River of 15 days or greater is required to establish stratification. A flow of 370 cfs is required to obtain this residence time. Mean daily flows had been less than 1000 cfs for 20 days (Figure 2) prior to the August 16 sample date; mean daily flows had been less than 370 cfs for 10 days. Stratification likely took some time to establish after flows dropped below 370 cfs. The timing of the diel survey in August, during a low flow year, at the end of a long dry period and immediately before a storm event likely captured worst case conditions that could be expected to occur in the Spokane River. Under these conditions, thermal stratification is moderate, occurring below 4-5 meters depth at a gradual rate. The traditional limnological definition of stratification, a change of 1°C per meter of depth, or 1.0 mg/L oxygen per meter of depth was occasionally observed during the August survey only, at 8 and 9 meters depth at Station 4, 12 to 13 meters depth at Ford Rock hole, and at five to six meters depth at Station 5. Oxygen remained saturated above the thermocline, and complete oxygen depletion is found in only the deepest locations.

Following the August survey, a precipitation event caused flows to increase to 2180 cfs, reducing residence time in the pool reach to approximately one day. These flows undoubtedly destroyed the thermal and oxygen stratification. The September diel survey was delayed in an attempt to capture the longest period of residence following the flush associated with the storm. Flows were less than 370 cfs for 8 days before the September diel sample. Even with flows reduced to pre-storm levels, cooler ambient temperatures and the mixing associated with increased flows following the storm did not allow stratification to re-establish in the three weeks between surveys.

24 Hour Changes

All stations showed slight diel patterns of reduced temperature, oxygen concentration, and saturation during hours of darkness and increased values during the day. The influence of solar radiation on surface temperature is noticeable. Deeper water temperatures remained relatively constant. Oxygen concentration also decreased following the same pattern: reduced oxygen during nighttime hours at the surface. Saturation should increase with cooler temperatures. The fact that less oxygen was present in the water column during darkness and cooler conditions indicates some biological activity is present. Either photosynthesis is increasing oxygen during daylight hours, decomposition of organic material is consuming oxygen, or, more likely, a combination is occurring. The magnitude of these shifts in oxygen, while statistically significant, does not appear to be biologically significant. The low variability observed in the data is the reason that statistical significance is observed. Oxygen concentration and saturation remain within 1.0 mg/L and 10 % respectively in the surface layers of the impounded reach of the river. The free running reach below Post Falls Dam exhibited the same diel pattern. Saturation values remained greater than 70 %.

The larger diel changes observed in the free running reach is most likely a result of increased photosynthetic activity, rather than sediment oxygen demand. Attached periphyton is very evident along the river banks at low flow. The shallower depth would place the entire substrate area in the euphotic zone, allowing plant growth across the entire reach. While not measured in this study, discharge from Post Falls WWTP may contribute additional nutrient load to this reach. The increased current velocity observed in this reach makes settling of organic matter much less likely. Consequently, estimation of photosynthesis rates for model use should account for a larger oxygen production in this lower reach than instream values of chlorophyll *a* reported by Falter *et al.* would suggest. Additionally, instream values of chlorophyll *a* may not be an appropriate indicator of nutrient enrichment in this reach.

<u>Differences Between Stations</u>

Differences in profiles between stations in the impounded reach of the Spokane River were discernable, both statistically and graphically. Temperature generally increased slightly, and oxygen content generally decreased. Biologically, the magnitude of change ($< 1°C$ and ,1 mg/L O_2) is probably insignificant. Again, the low variability in the data contributes to a finding of statistical significance. The decrease in oxygen concentration and saturation in a downstream direction makes sense, given the increase in temperature. The temperature increase can be expected at extreme low flows as slow moving water is heated for a longer time.

Station 6 differed from stations in the impounded reach with respect to temperature and oxygen, due to the difference in physical character of the river at that location. Mixing and re-aeration from spilling over the Post Falls Dam and over shallow rapids kept oxygen levels higher. The low flows being released partially explain the increase in temperature and the increase fluctuation in response to heating and cooling associated with daylight and night. The shallow depth would allow the entire water column to be heated.

<u>Comparison to Other Studies</u>

Falter *et al.* (1992) found no stratification of either dissolved oxygen or temperature (Figures 2 & 3) during a diel monitoring event conducted during August 12-13, 1991. Slight changes with depth and over 24 hours are discernable, however, complete mixing with essentially no stratification is apparent. Mean daily flows on August 12 and 13, 1991 were 1450 and 1460 cfs, respectively (Harenburg, *et al.* 1992). Temperatures were slightly cooler during the 1991 diel, as compared to the surface temperatures observed during the August 1992 diel, possibly reflecting the increased flow regime during water year 1991.

Seitz and Jones (1982) measured single vertical profiles for temperature and dissolved oxygen at Stations 4, Ford Rock and 5. Mean daily flows of 608 and 622 cfs (Seitz and Jones 1982) were observed during their measurements on August 27 and 28 of 1981. Again, essentially no change with depth was observed, indicating a well mixed system. The low flows (< 370 cfs) necessary for stratification to establish did not occur during WY 1981.

Yearsley and Duncan (1989) did observe stratification and oxygen depletion in Ford Rock hole in August of 1988. Values of less than one were observed at two stations: one at river mile 102.2, just above the Post Falls dam, and another at the Ford Rock hole at river mile 103.1. River flow during August of 1988 was also low. Mean daily lows were less than 400 cfs for 23 days of the month. A thermocline was also seen in waters seven meters deep or deeper. As with the present study, unusual water flow conditions increased temperatures and decreased mixing, to the point where oxygen depletion occurred. An extended period of low flow allowed stratification to establish.

Falter *et al.* (1992) described this system as mesotrophic on the basis of chlorophyll *a* and water clarity values. Some biological activity in the form of photosynthesis and decomposition should be expected in a mesotrophic water body. The slight surface changes and pattern at Station 6 indicate some biological activity is present in the system, however, not enough change to indicate classification as more eutrophic than described by Falter.

Water Quality Standards

The applicable sections of the *Idaho Water Quality Standards and Wastewater Treatment Requirements* are: definition of a hypolimnion (16.01.02003,21), designated uses of the Spokane River (16.01.02110,01.pp), general surface water criteria regarding oxygen demanding materials (16.01.02200,06), specific use classification criteria for temperature and oxygen for warm and cold water biota (16.01.02250,02.b & c), temperature and oxygen criteria for salmonid spawning (16.01.02250,02.d) and oxygen criteria below dams (16.01.02250,02). These sections are included in Appendix B.

Some of the sections of the Water Quality Standards are more explicit regarding dissolved oxygen than others, especially as applied to the Spokane River. Criteria for free-flowing rivers are most explicit. Therefore, determinations as to whether or not criteria are being met are easiest for temperature, salmonid spawning, and dissolved oxygen criteria downstream of Post Falls Dam.

Below Post Falls Dam

During the August diel monitoring, instantaneous temperatures and daily average temperatures exceeded criteria of 22 and 19 degrees C respectively at all stations, depths, and times. Conversations with Idaho Department of Fish and Game personnel indicate that above Post Falls Dam, few cold water biota are in the Spokane River Reach during summer months (Davis 1992). Cutthroat enter the river in spring (high flow) to spawn and rear, then return to the main body of Coeur d'Alene Lake. Below the dam, a brown trout (*Salmo trutta*) fishery exists. Again, Fish and Game verbal information indicates that a major impact on the fishery is flow. Dam operation isolates spawning beds and juvenile fish, limiting recruitment (Davis 1992). DEQ staff collecting data observed several fishermen using the area near the USGS gauge during the August diel sampling. In spite of warm water temperatures, the fishery appears that it can maintain itself.

Numeric values for salmonid spawning dissolved oxygen and temperature criteria (noted in Appendix B) were exceeded during this study, however, as noted above, spawning occurs at higher water flows during spring. Salmonid spawning criteria in the regulations limit the criteria to the period of spawning and incubating for the species of interest.

Dissolved oxygen criteria for cold water biota apply to the free running reach between Post Falls Dam and the Idaho-Washington border. Measurements slightly below the criteria of 6 mg/L dissolved oxygen (5.94 mg/L) were observed during the early morning hours of August 18. Flow may have contributed to this condition. WWP operates to maintain flows of 300 cfs downstream of the dam. Flows were 227 cfs, according to the USGS stage recorder located at Station 6. Had flow been higher, more mixing may have occurred and temperature would have

Organic material may also have contributed to the 5.94 mg/L dissolved oxygen observation. Post Falls Waste Water treatment plant discharges slightly upstream from Station 6. Biological decomposition of organic material does consume oxygen. This possibility was not addressed by this study.

The *Idaho Water Quality Standards* §16.01.02276 addresses dissolved oxygen concentrations below dams. All waters below existing dams from June 15 through October 15 must contain an instantaneous minimum of 3.5 mg/L dissolved oxygen. This criteria, in addition to the 30 day mean and seven day minimum, was met at station 6, below Post Falls dam.

Above Post Falls Dam

The Spokane River reach upstream of Post Falls Dam is obviously impounded and consequently acts as a reservoir during some flow regimes, and acts more like a river under other flow regimes. At high flow times of the year, the impoundment gates are open, and the dam has little effect on river dynamics. Deciding whether river or reservoir criteria apply largely depends on how the reach is behaving physically. This same interpretation is used to interpret criteria on the run-of-the-river dams on the Snake River in southern Idaho (Litke, 1992). The standards allow for some exceptions to the cold water biota dissolved oxygen criteria in lakes and reservoirs, recognizing that natural stratification will occur in water bodies strictly due to physical processes. Two of the exceptions may apply to the Spokane River, namely: a) the bottom 20% of depth for natural lakes or reservoirs less than 35 meters deep or, b) waters of the hypolimnion.

During the diel study, Post Falls Dam impacted the river and created an impounded reach. A true hypolimnion, according to the regulatory and generally accepted limnological definition (the deepest zone in a stratified body of water, under the thermocline), was only observed in the bottom of the Ford Rock hole in August. These waters constitute a relatively small volume of water. Water quality standards exempt this small part of the Spokane River from aquatic criteria.

In the epilimnion, water quality criteria for dissolved oxygen were met. Generally the epilimnion was above four or five meters. The metalimnion, or thermocline, was where standards were generally not met, if one applies the 20% rule noted above. The bottom twenty percent of depth at Station 4 was below 8 meters on average. Dissolved oxygen was consistently in the 4 mg/L range at 8 meters depth during the August diel sampling event. The bottom twenty percent of depth at Station 5 was below seven meters. Dissolved oxygen at seven meters depth ranged from 4.8 to 5.2 meters at Station 5. An approximate calculation of the volume of water not meeting criteria (estimated by that volume between 4.5 meters and 8 meters depth for waters 8 meters or deeper) comes to 3.69% of the total volume of the impounded reach.

Conclusions

1) Under worst case conditions of water year and associated low flow, combined with longest available period of extended residence time during the warmest season, it appears that stratification in the Spokane River is relatively short-lived, fragile, and moderate in nature. Conditions of complete anoxia exist only in a small volume of water found in the deepest portion of the river -- Ford Rock hole.

2) The slight changes in the oxygen content over 24 hours were statistically significant due to low variability in the data. Little decomposition of organic matter appears to be taking place overnight, typical of a mesotrophic system.

3) Slight temperature increases and associated oxygen decreases are observed as one moves downstream. Given the extreme low flows and warming of water as it moves downstream, some decrease in oxygen concentration and saturation is expected.

4) The study agrees reasonably well with findings by Falter *et al.* (1992), Seitz and Jones (1982), and Yearsley and Duncan (1989). Stratification and oxygen depletion are only found in the Spokane River under very low flow regimes, in the deepest locations, and for a short period. Very little diel variation occurs.

5) Large changes in the diel oxygen profiles were not observed. Estimates for water quality model inputs that relate to oxygen dynamics in the impounded reaches of the river can therefore assume that organic matter is not significant and that respiration by algae or periphyton is not, for modeling purposes, significant. Hence, sediment oxygen demand rate constants can be set at low values, and chlorophyll *a* measurement is, for now, an adequate indicator of the amount of algae present in the system. The free-running reach of the river, below Post Falls dam, merits a higher rate of photosynthesis than a rate based strictly on water column chlorophyll *a* values. Investigation into the effect of attached periphyton on oxygen dynamics in this reach should be investigated. The objective of better characterizing oxygen sources and sinks for modeling purposes has been met.

6) During periods of extreme low flow, State *Water Quality Standards* for the Spokane River do not meet criteria. During these rare situations (0.1% occurrence), a small volume of the impounded reach does not meet criteria for dissolved oxygen and a slight exceedence of oxygen criteria may be expected overnight in the free-flowing reach below Post Falls Dam. Focus on dissolved oxygen as a parameter of concern should be shifted to other water quality components since criteria violations are unusual occurrences and affect a small portion of the system.

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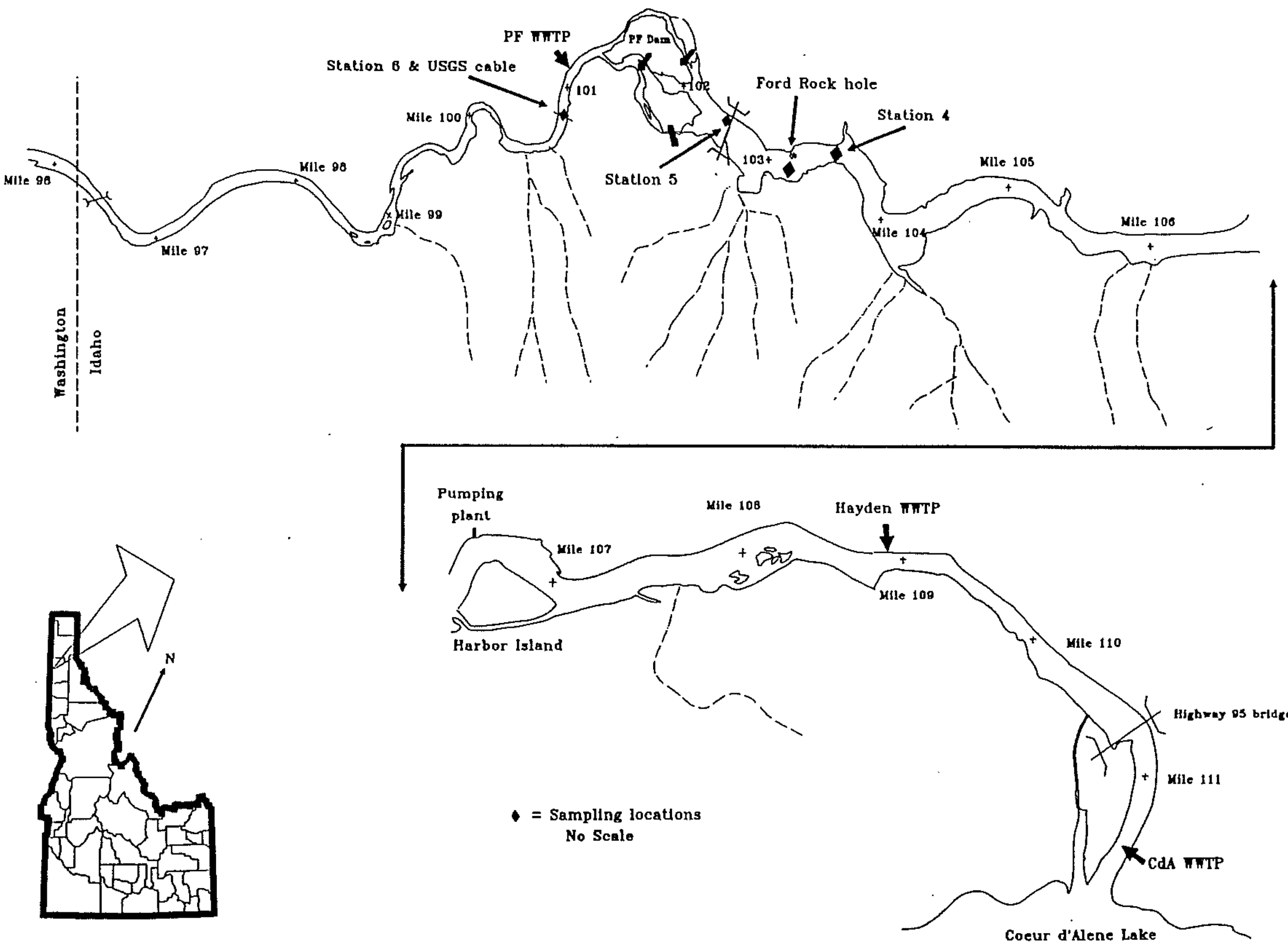
Figures


PF WWTP
PF Dam
Station 6 & USGS cable
101
102
Ford Rock hole
Station 4
Mile 100
Station 5
103+
Mile 105
Mile 96
Mile 98
Mile 99
Mile 104
Mile 106
Mile 97
Washington
Idaho
Pumping plant
Mile 108
Hayden WWTP
Mile 107
Mile 109
Harbor Island
Mile 110
N
Highway 95 bridge
Mile 111
♦ = Sampling locations
No Scale
CdA WWTP
Coeur d'Alene Lake

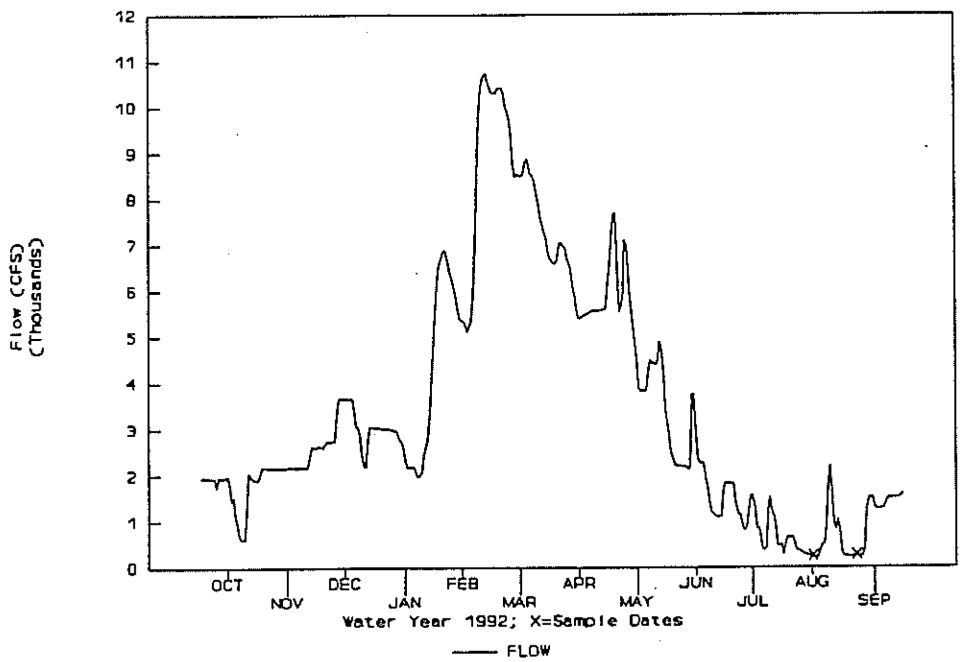


Figure 2. Mean daily Spokane River flows for Water Year 1992 at Post Falls USGS gauge, showing sample dates (Harenburg *et al.* 1993).

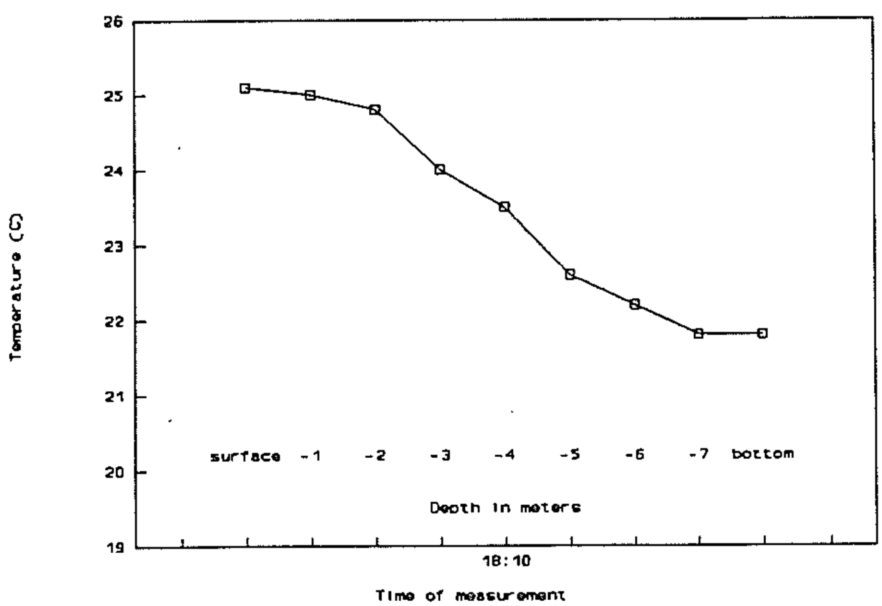


Figure 3. Example of diel profile graphic presentation.

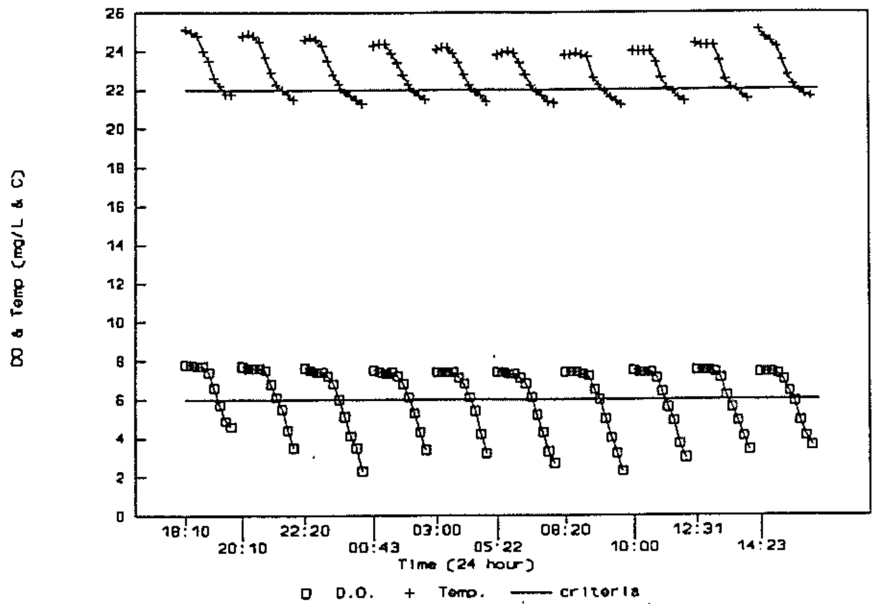


Figure 4. Temperature and dissolved oxygen profiles taken at Station 4 (RM 103.5) on August 16 and 17, 1992.

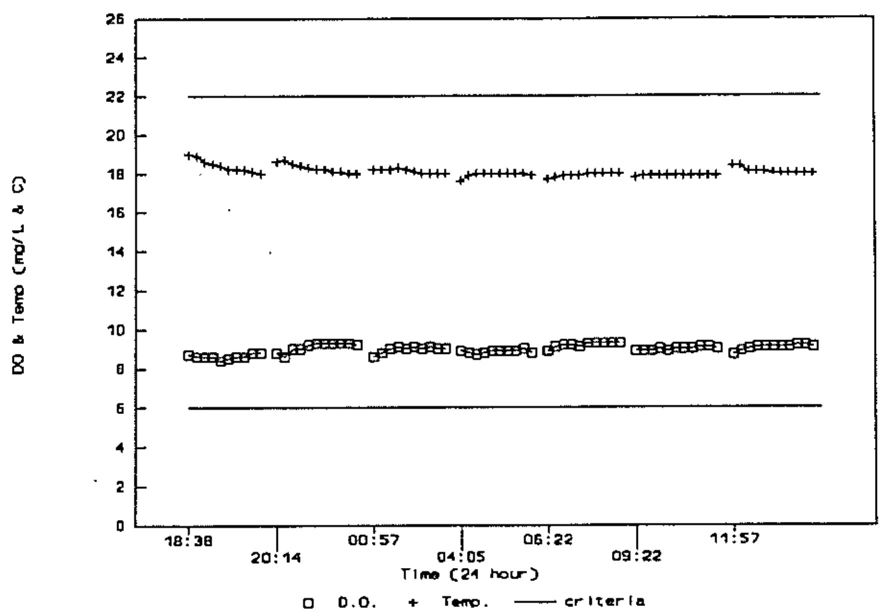


Figure 5. Temperature and dissolved oxygen profiles taken at Station 4 (RM 103.5) on September 8 & 9, 1992.

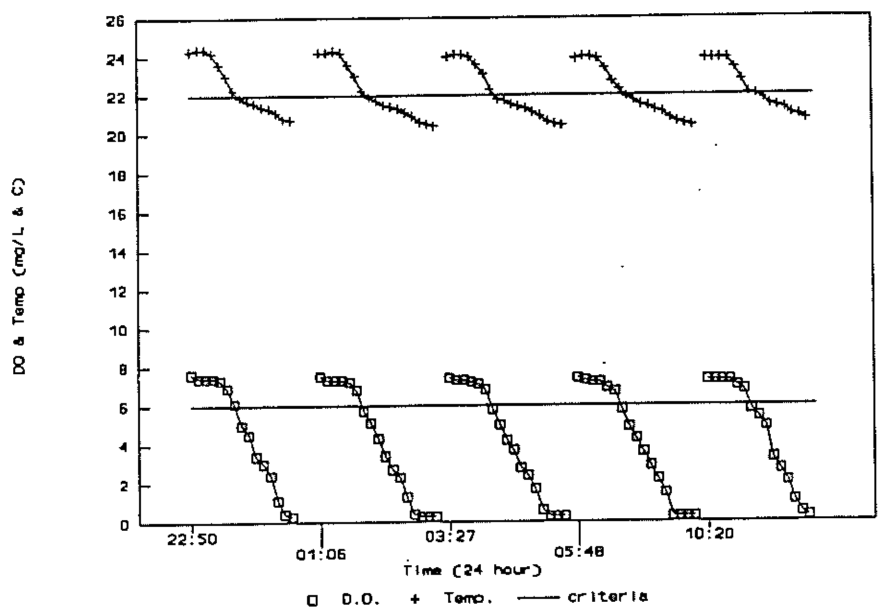


Figure 6. Temperature and dissolved oxygen profiles taken at Ford Rock hole (RM 103.2) on August 16 & 17, 1992.

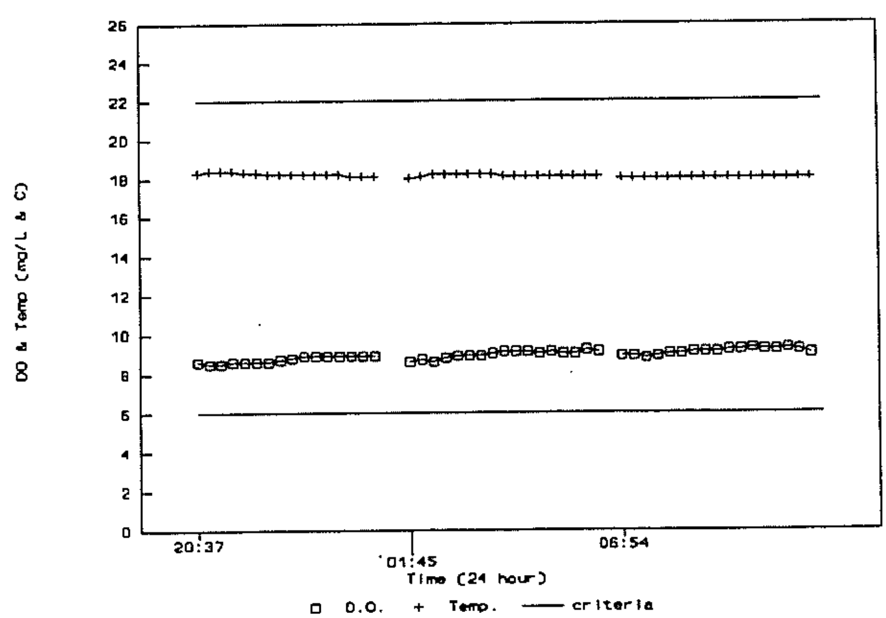


Figure 7. Temperature and dissolved oxygen profiles taken at Ford Rock hole (RM 103.2) on September 8 & 9, 1992.

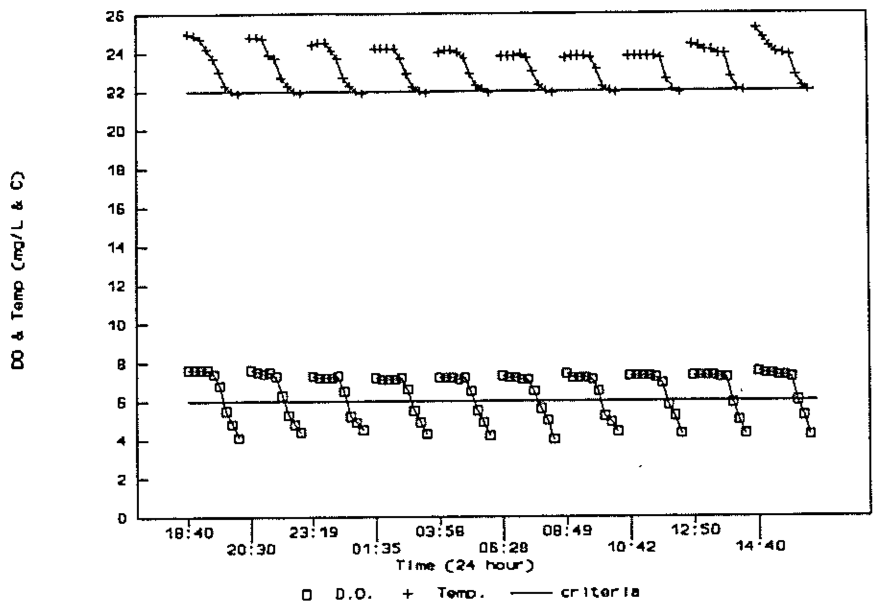


Figure 8. Temperature and dissolved oxygen profiles taken at Station 5 (RM 102.4) on August 16 & 17, 1992.

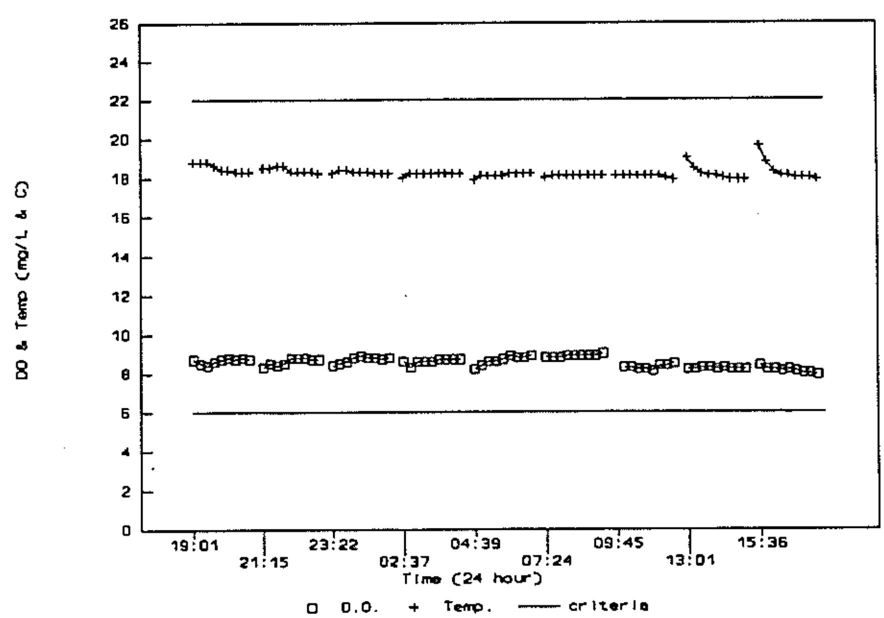


Figure 9. Temperature and dissolved oxygen profiles taken at Station 5 (RM 102.4) on September 8 & 9, 1992.

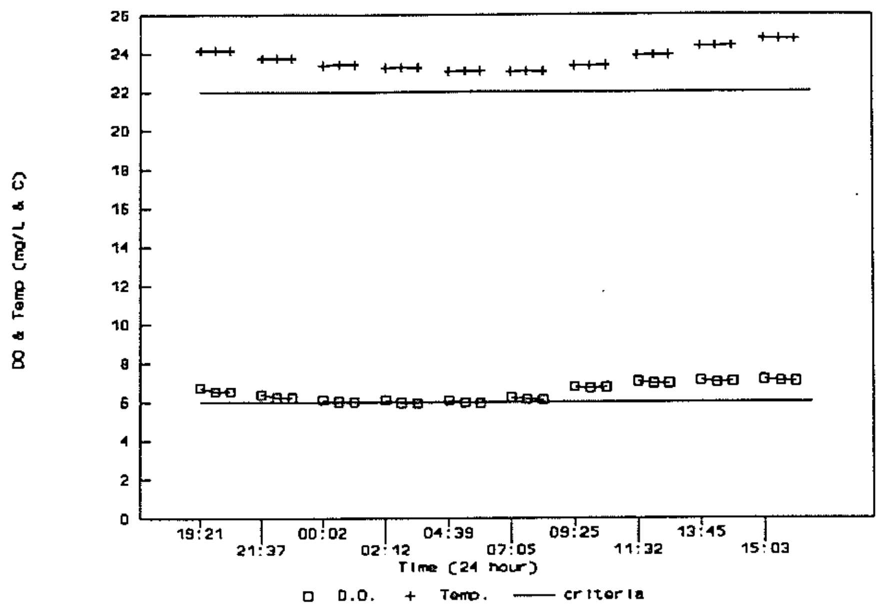


Figure 10. Temperature and dissolved oxygen profiles taken at Station 6 (RM 100.9) on August 16 & 17, 1992.

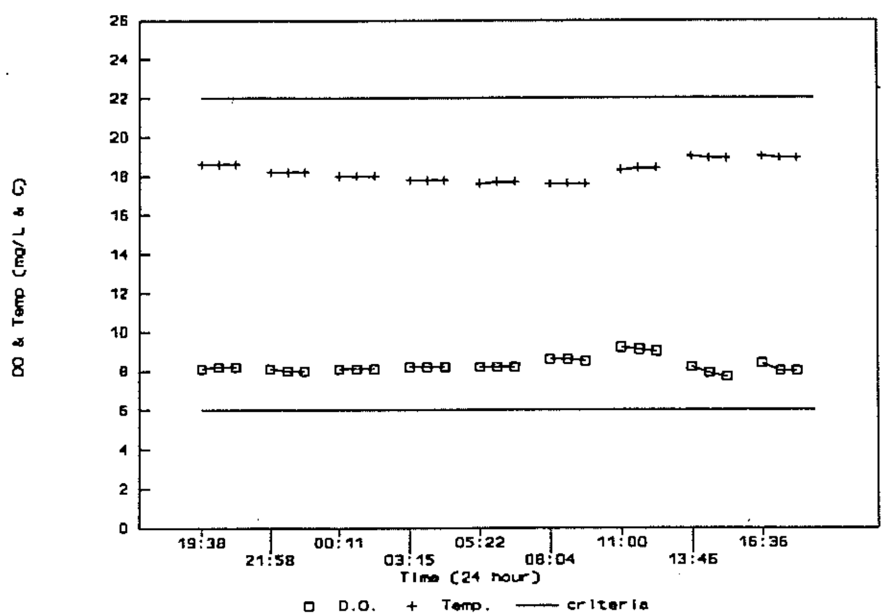


Figure 11. Temperature and dissolved oxygen profiles taken at Station 6 (RM 100.9) on September 8 & 9, 1992.

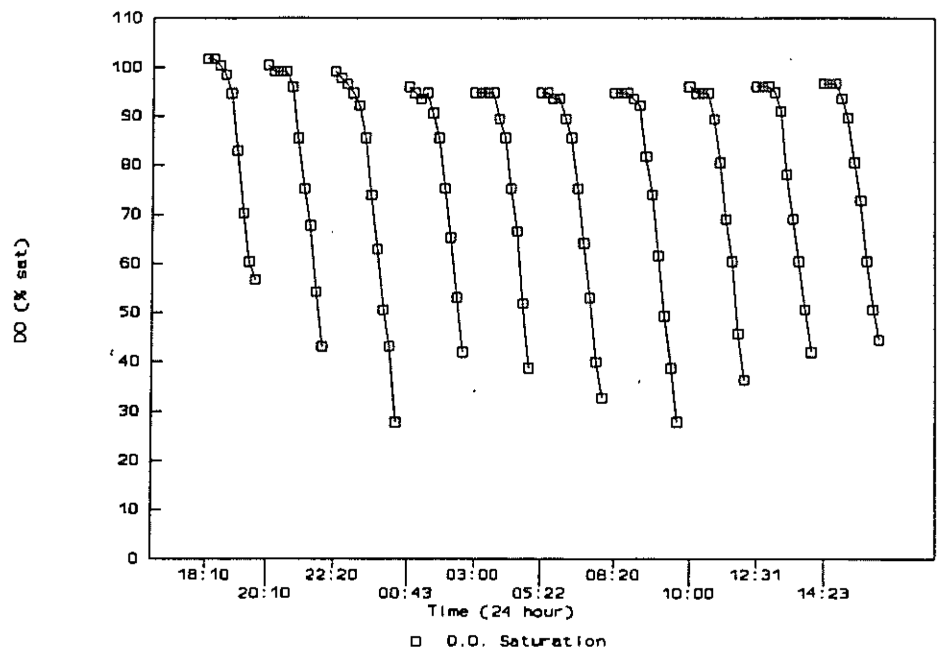


Figure 12. Percent saturation at Station 4 (RM 103.5) during August 16 & 17, 1992 diel study period.

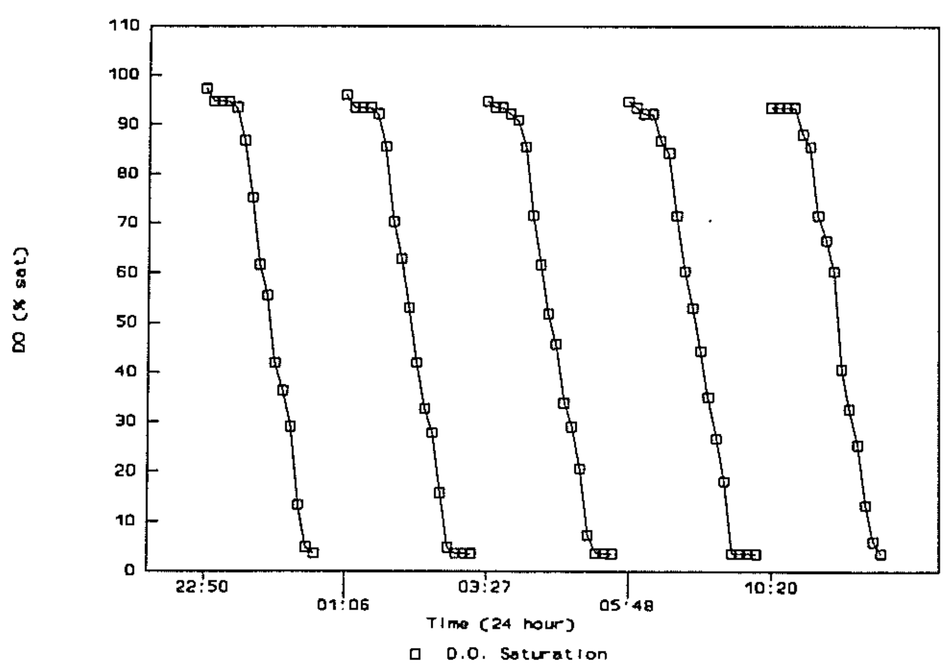


Figure 13. Percent saturation at Ford Rock hole (RM 103.2) during August 16 & 17 diel study period.

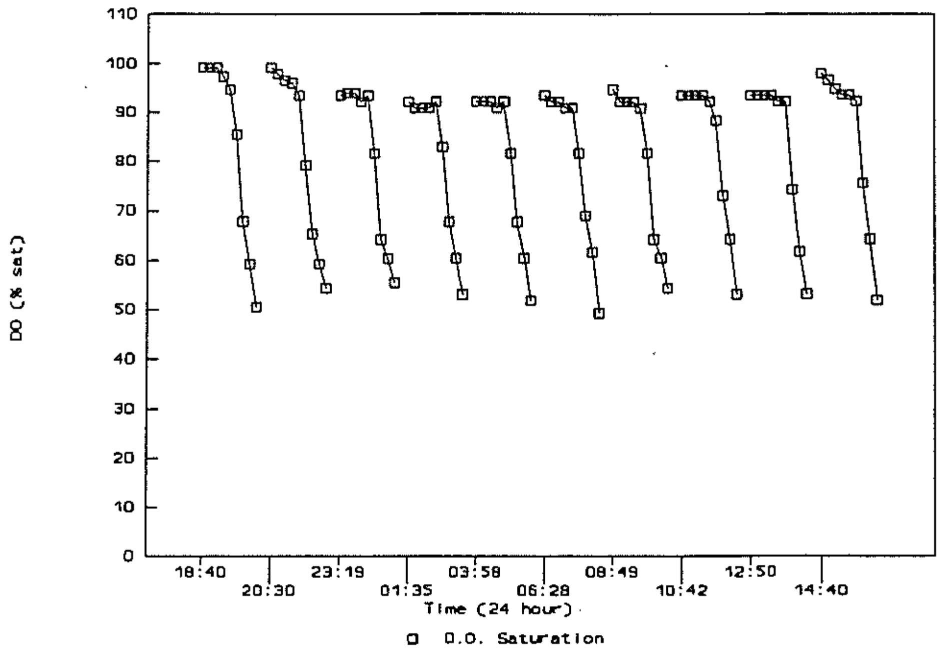


Figure 14. Percent saturation at Station 5 (RM 102.4) during August 16 & 17 diel study period.

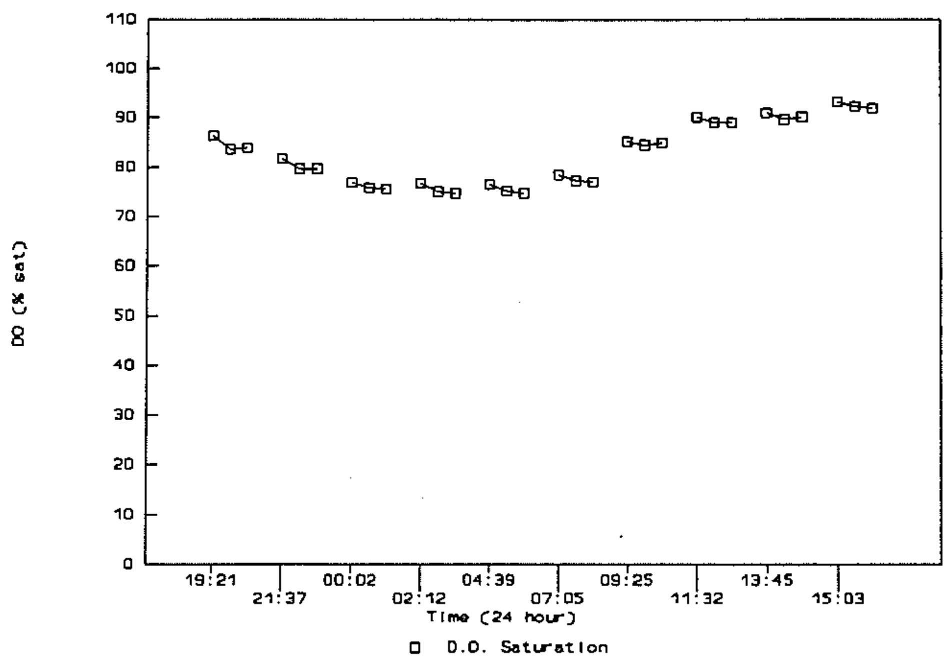


Figure 15. Percent saturation at Station 6 (RM 100.9) during August 16 & 17 diel study period.

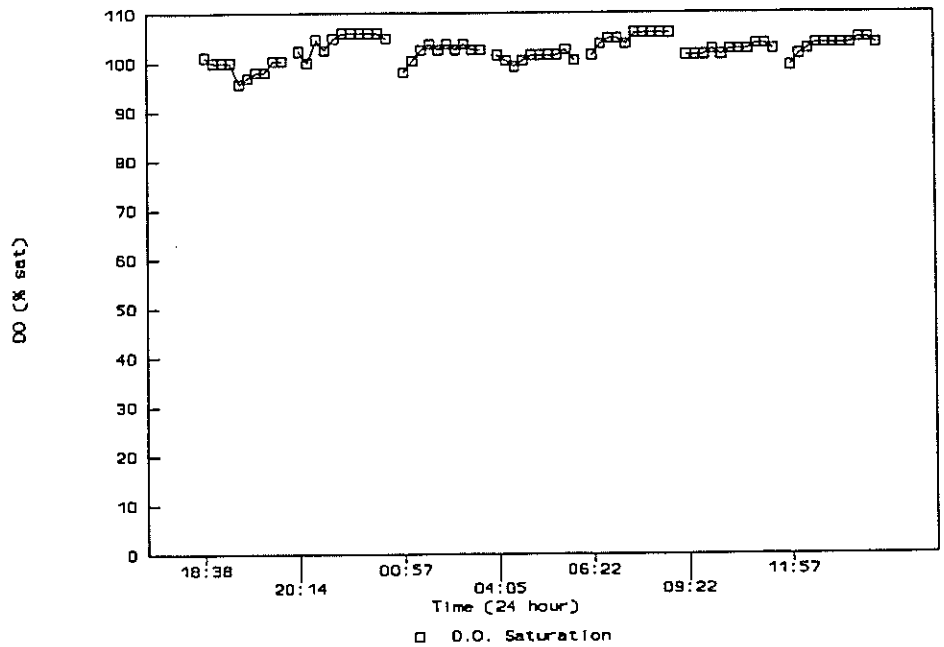


Figure 16. Percent saturation at Station 4 (RM 103.5) during September 8 & 9, 1992 diel study period.

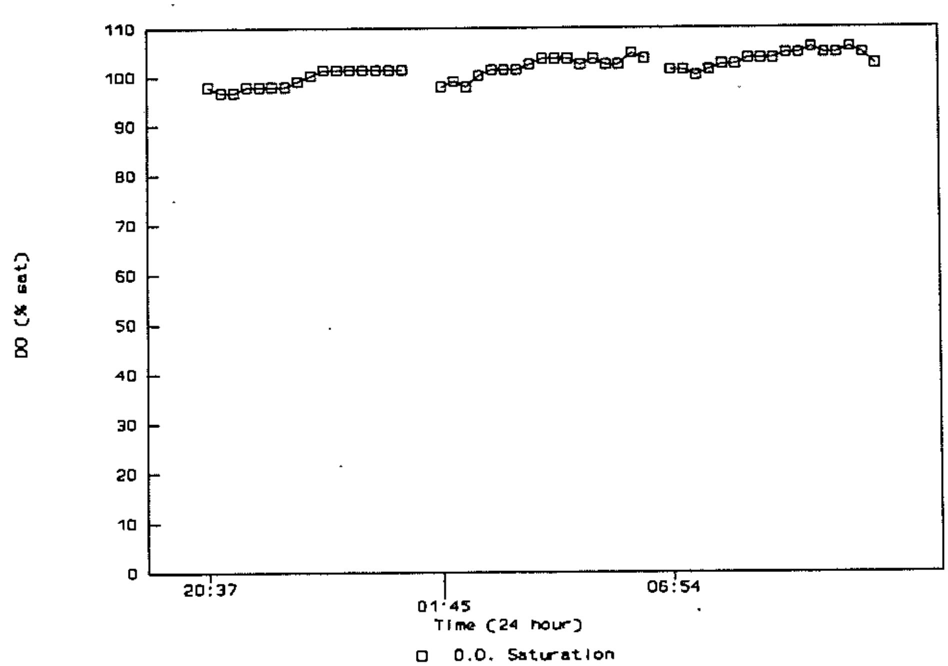


Figure 17. Percent saturation at Ford Rock hole (RM 103.2) during September 8 & 9, 1992 diel study period.

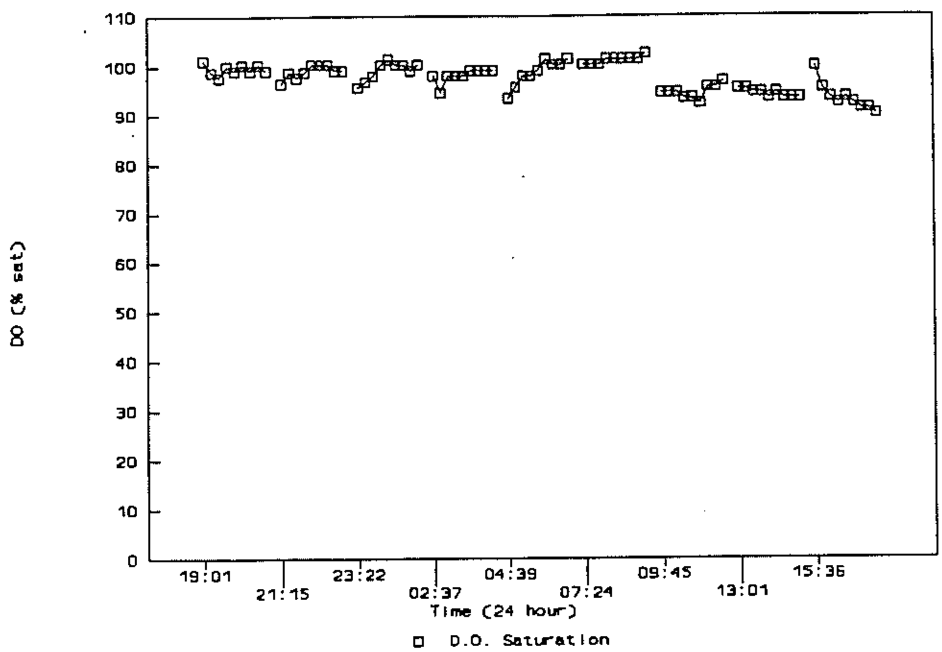


Figure 18. Percent saturation at Station 5 (RM 102.4) during September 8 & 9, 1992 diel study period.

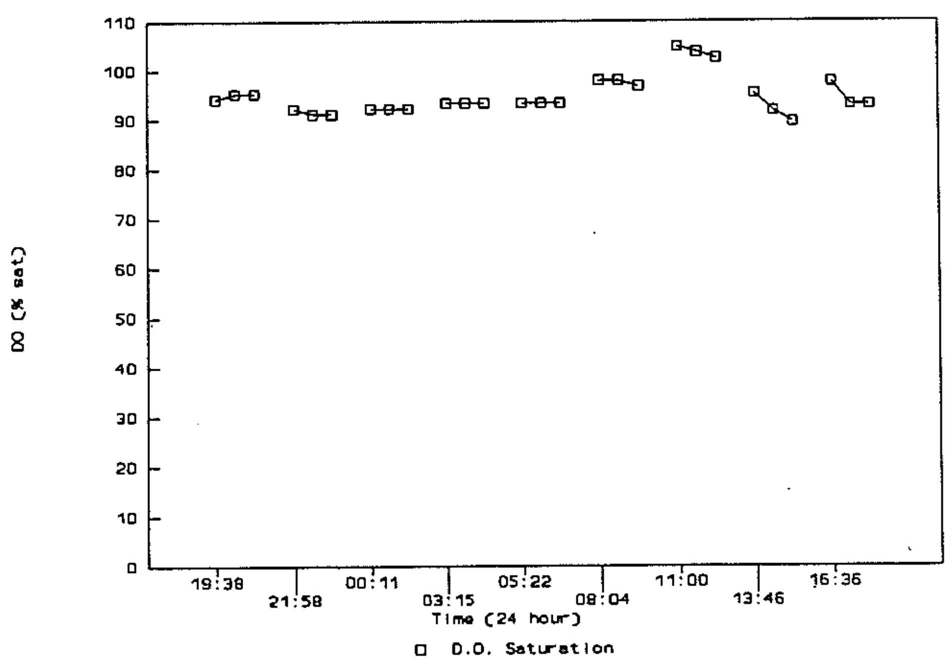


Figure 19. Percent saturation at Station 6 (RM 100.9) during September 8 & 9, 1992 diel study period.

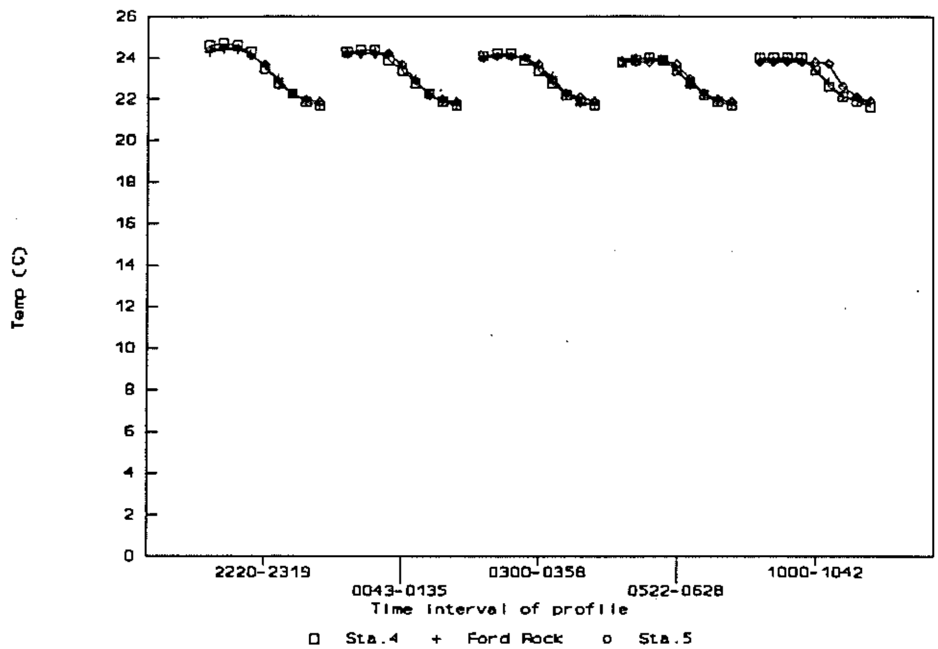


Figure 20. Comparison of temperature at equivalent depths between pool stations during August 16 & 17, 1992 diel study.

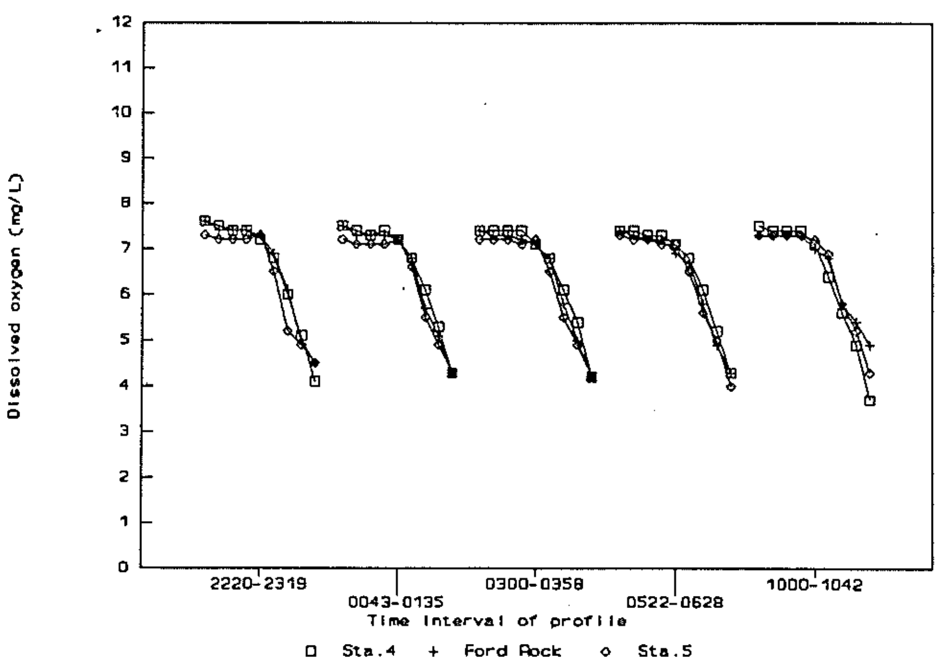


Figure 21. Comparison of dissolved oxygen at equivalent depths between pool stations during August 16 & 17, 1992 diel study.

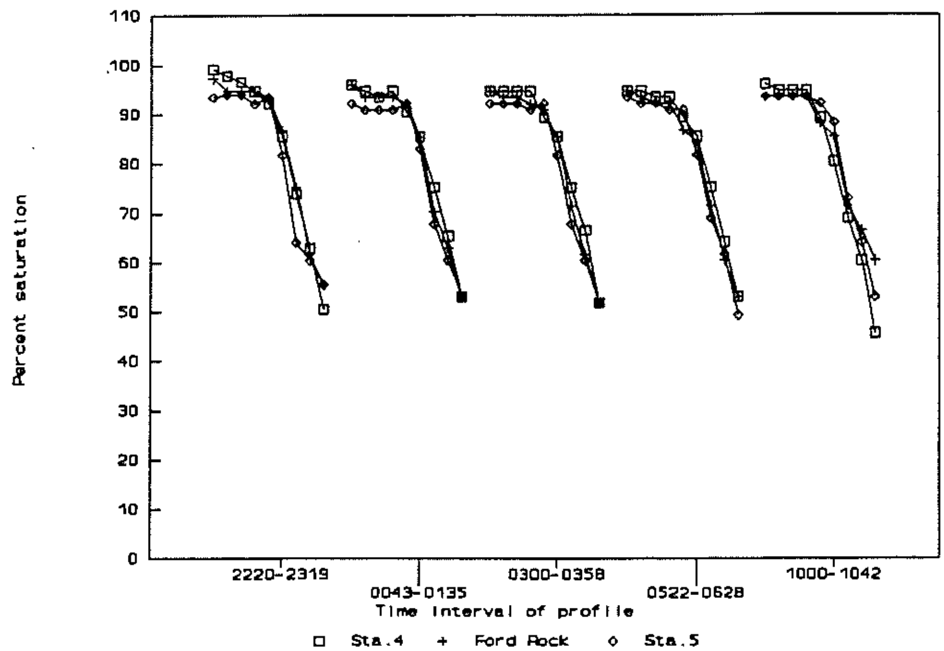


Figure 22. Comparison of oxygen saturation at equivalent depths between pool stations during August 16 & 17, 1992 diel study.

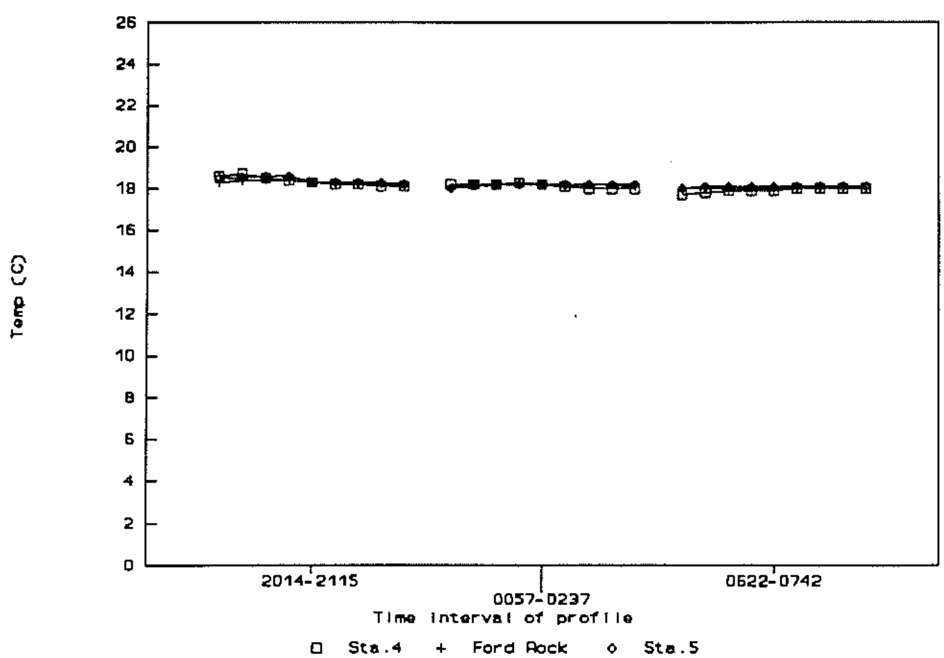


Figure 23. Comparison of temperature at equivalent depths between pool stations during September 8 & 9, 1992 diel study.

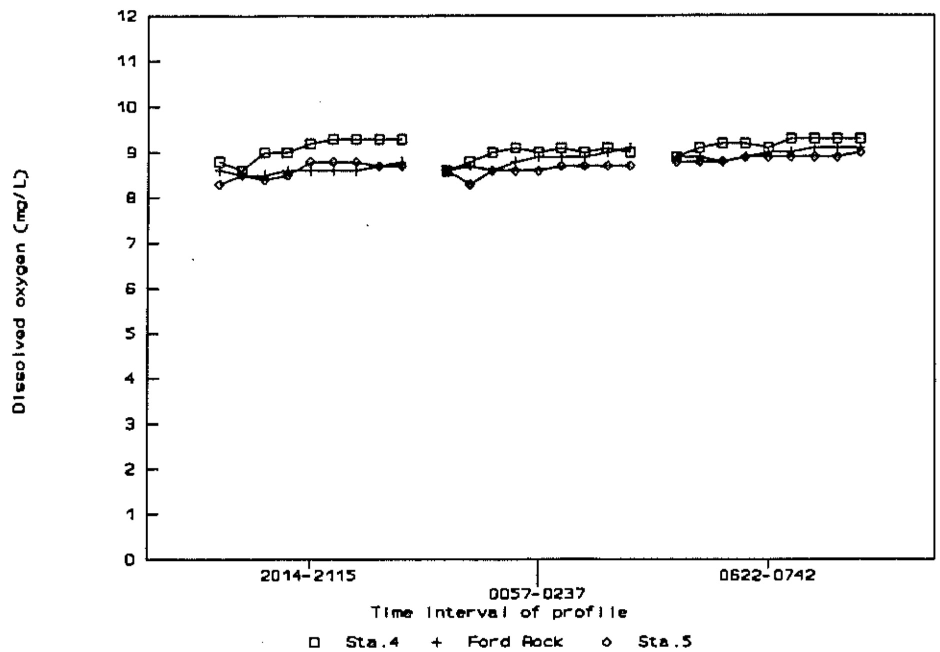


Figure 24. Comparison of dissolved oxygen at equivalent depths between pool stations during September 8 & 9, 1992 diel study.

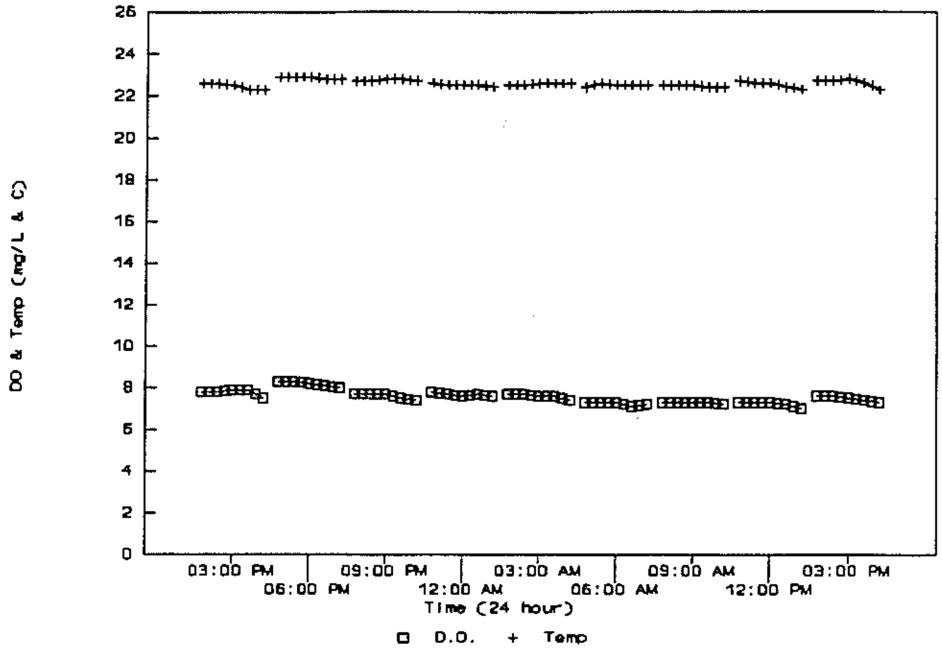


Figure 25. Temperature and dissolved oxygen profiles taken by Falter *et al.* (1992) at Station 4 (RM 103.5), on August 12-13, 1991.

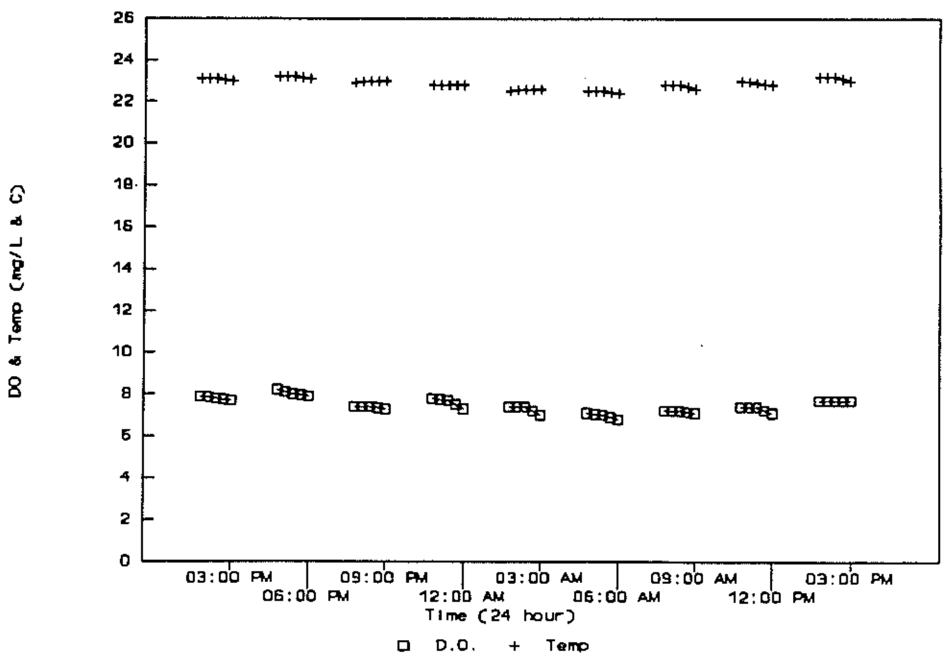


Figure 26. Temperature and dissolved oxygen profiles taken by Falter *et al.* (1992) at Station 5 (RM 102.4), on August 12-13, 1991.

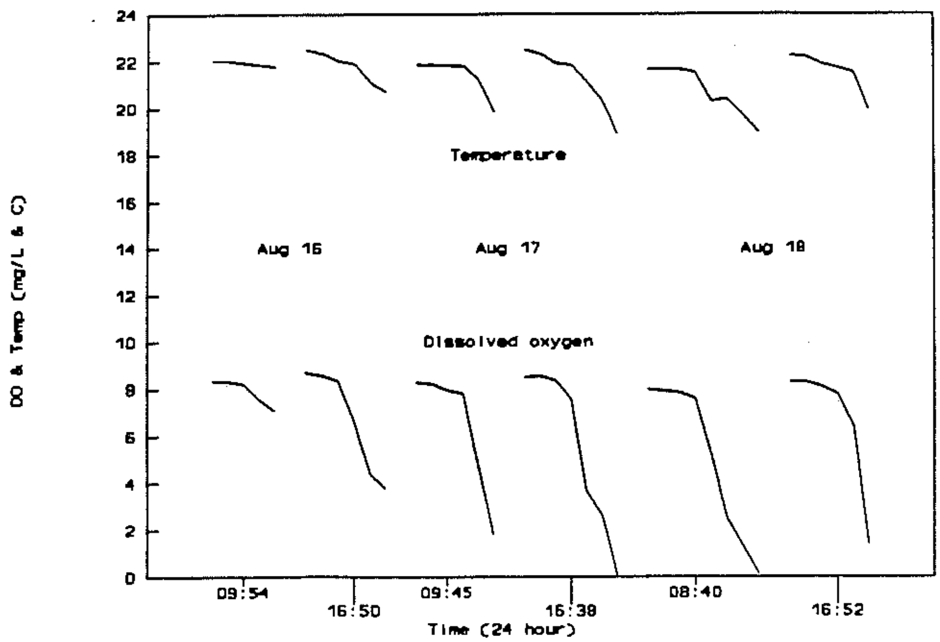


Figure 27. Temperature and dissolved oxygen profiles taken by Yearsley and Duncan (1989) at Ford Rock hole (RM 103.2), on August 16-18, 1988.

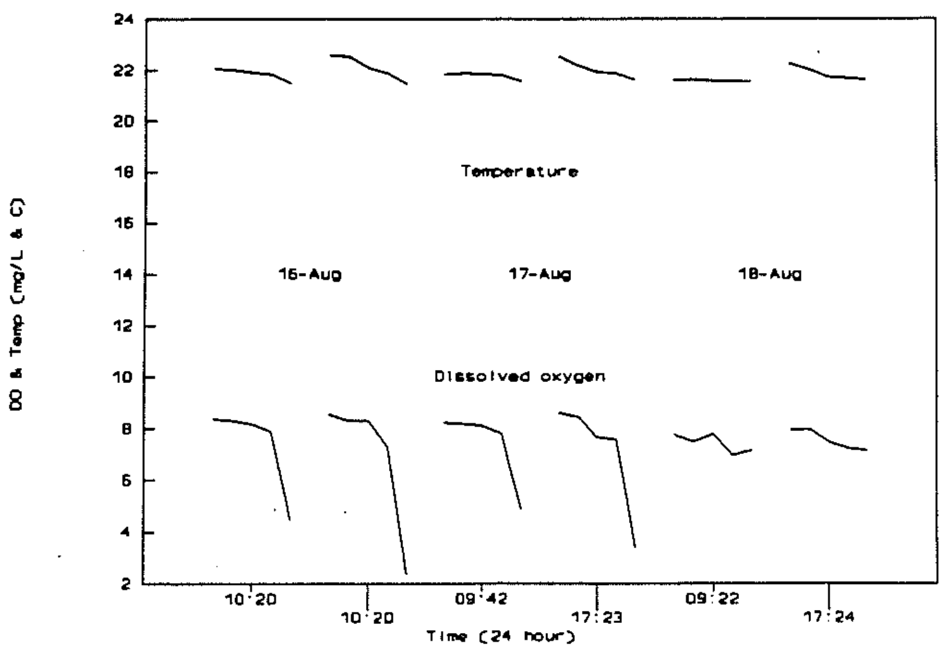


Figure 28. Temperature and dissolved oxygen profiles taken by Yearsley and Duncan (1989) at Post Falls dam forebay (RM 102.2), on August 16-18, 1988.

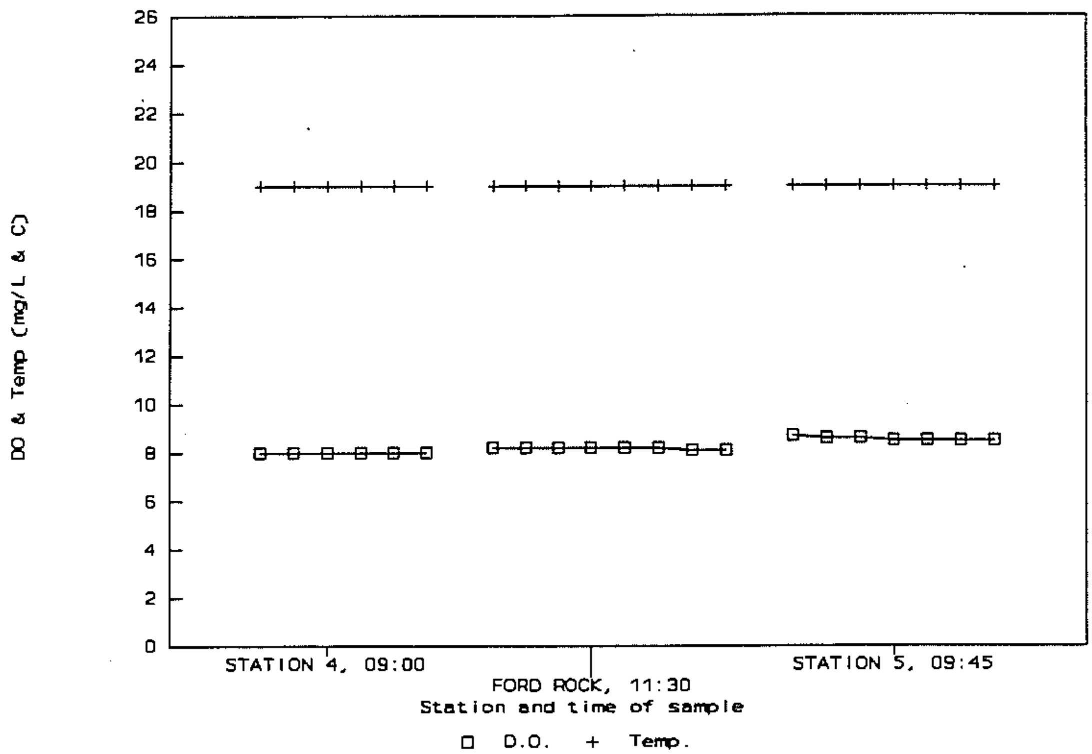


Figure 29. Temperature and dissolved oxygen profiles taken by USGS (Seitz and Jones 1982) on August 27, 1980. Flow = 1730 cfs.

Tables

Table 1. Summary of water year data during current and previous studies.

Water Year	Max mean daily flow (cfs)	Min mean daily flow (cfs)	Mean annual flow (cfs)	Study author and report
1992	10700	210	3455	present study, 1994
1990,1991	24200, 22800	340, 370	7820, 8006	Falter *et al.*,1992
1988	20000	317	3480	Yearsley, 1989
1981	25700	597	6246	Seitz and Jones, 1982
1980	18100	696	4610	Falter & Mitchell, 1982
1979,1980	30100,18100	258, 696	5055, 4610	Yearsley, 1980

Table 2. Locations, STORET numbers and revised latitude, longitude for sample stations.

Station	River Mile	Storet Number	Latitude	Longitude
4	103.5	2000310	47°42'05"	116°55'41"
Ford Rock	103.2	NA	47°42'01"	116°56'06"
5	102.4	2000311	47°42'17"	116°56'56"
6	100.9	2000313	47°42'18"	116°58'23"

Table 3. One way ANOVA acceptance P levels for H1: Station profiles are different over 24 hours.
Format: Temperature/O_2 concentration

Date	Station 4	Station 5	Ford Rock hole	Station 6
Aug. 17-18	0.05/0.05	0.05/NS	0.05/NS	0.05/0.05
Sept. 8-9	0.05/0.05	0.01/0.05	0.05/0.05	0.05/0.05

Table 4. One way ANOVA acceptance P levels for change of parameter with depth.
Format: Temperature/O_2 concentration.

Date	Station 4	Station 5	Ford Rock hole	Station 6
Aug. 17-18	0.05/0.05	0.05/0.05	0.05/0.05	NS/0.05
Sept. 8-9	NS/0.05	NS/NS	NS/0.05	NS/NS

Table 5. Student's *t* test P levels for H_1: upstream O2 values are >, & temperature values are <, downstream values. Format: temperature/O_2 concentration/O_2% saturation

Date	Time	Station 4:Ford Rock hole	Ford Rock hole:Station 5	Station 4:Station 5
Aug. 17	2200-2319	0.05/0.05/0.05	0.05/0.01/0.01	0.05/0.01/0.01
Aug. 18	0043-0135	0.05/0.01/0.05	0.05/NS/NS	0.05/NS/NS
	0300-0358	0.05/0.01/0.01	0.05/0.01/0.01	0.05/NS/0.01
	0522-0628	0.05/NS/NS	0.05/0.01/0.05	0.05/NS/NS
	1000-1042	0.05/0.05/0.05	0.05/0.05/0.05	0.05/0.05/0.05
Sept. 8	2014-2115	0.05/NS/NS	0.05/error*/error*	0.05/NS/NS
Sept. 9	0057-0237	0.05/0.01/0.01	0.05/NS/NS	0.05/NS/NS
	0622-0740	Error*/NS/NS	Error*/NS/NS	Error*/NS/NS

* From review of graph results, the direction of change is the opposite of what H_1 tests.

Appendix A: Statistical Calculation Examples

Two Way ANOVA Without Replication: August 17-18; Location = Station 4; Temperature (degrees C)

	profile time										
Depth(m)	18:10	20:10	22:20	00:43	03:00	05:22	08:20	10:00	12:31	14:23	sum
0	25.1	24.8	24.6	24.3	24.1	23.8	23.8	24	24.4	25.1	244
-1	25	24.9	24.7	24.4	24.2	23.9	23.8	24	24.3	24.7	243.9
-2	24.8	24.8	24.6	24.4	24.2	24	23.9	24	24.3	24.5	243.5
-3	24	24.5	24.3	23.9	23.9	23.9	23.8	24	24.3	24.2	240.8
-4	23.5	23.7	23.5	23.4	23.4	23.4	23.7	23.4	23.5	23.5	235
-5	22.6	22.9	22.8	22.8	22.8	22.8	22.6	22.6	22.5	22.7	227.1
-6	22.2	22.3	22.3	22.3	22.2	22.2	22.2	22.1	22.1	22.2	222.1
-7	21.8	22	21.9	21.9	21.9	21.9	21.9	21.9	22	21.9	219.1
-8	21.8	21.8	21.7	21.7	21.7	21.7	21.6	21.6	21.7	21.7	217
sum	210.8	211.7	210.4	209.1	208.4	207.6	207.3	207.6	209.1	210.5	2092.5

Squared column totals:

44437	44817	44268	43722	43431	43098	42973	43098	43723	44310

Squared row totals:

59536
59487.21
59292.25
57984.64
55225
51574.41
49328.41
48004.81
47089

Squared observations:

630.01	615.04	605.16	590.49	580.81	566.44	566.44	576	595.36	630.01
625	620.01	610.09	595.36	585.64	571.21	566.44	576	590.49	610.09
615.04	615.04	605.16	595.36	585.64	576	571.21	576	590.49	600.25
576	600.25	590.49	571.21	571.21	571.21	566.44	576	590.49	585.64
552.25	561.69	552.25	547.56	547.56	547.56	561.69	547.56	552.25	552.25
510.76	524.41	519.84	519.84	519.84	519.84	510.76	510.76	506.25	515.29
492.84	497.29	497.29	497.29	492.84	492.84	492.84	488.41	488.41	492.84
475.24	484	479.61	479.61	479.61	479.61	479.61	479.61	484	479.61
475.24	475.24	470.89	470.89	470.89	470.89	466.56	466.56	470.89	470.89

Two Way ANOVA Without Replication continued

1) Grand total = 2092.5

2) Sum of squared observations = 48757.77

3) Sum of squared column totals divided by sample size of a column = 48652.99

4) Sum of squared row totals divided by sample size of a row = 48752.17

5) Grand total squared and divided by the total sample size = correction term = 48650.62

6) SS_{total} = quantity 2-quantity 5 = 107.145

7) SS_a {SS of columns (profile time)} = quantity 3-quantity 5 = 2.367222

8) SS_b {SS of rows (depths)} = quantity 4-quantity 5 = 101.548

9) SS_{error} (remainder) = quantity 6-quantity 7-quantity 8 = 3.229777

ANOVA table

	df	SS	MS	Fs	significance
col(times)	9	2.367	0.263	5.863	F[9,72] ***
row(depths)	8	101.550	12.694	282.957	F[8,72] ***
error	72	3.230	0.045		
total	89				

Student's *t* Test With No Replication
August 17-18
temperature
time = 2220-2319

1) Data

Depth(m)	Station 4	Ford Rock Hole	Station 5
0	24.6	24.3	24.4
-1	24.7	24.4	24.5
-2	24.6	24.4	24.5
-3	24.3	24.2	24.1
-4	23.5	23.6	23.7
-5	22.8	23	22.7
-6	22.3	22.3	22.3
-7	21.9	21.9	22
-8	21.7	21.7	21.9

2) Differences

4-FORD	FORD-5	4-5
0.3	-0.1	0.2
0.3	-0.1	0.2
0.2	-0.1	0.1
0.1	0.1	0.2
-0.1	-0.1	-0.2
-0.2	0.3	0.1
0	0	0
0	-0.1	-0.1
0	-0.2	-0.2

3) Differences squared

4-FORD	FORD-5	4-5
0.09	0.01	0.04
0.09	0.01	0.04
0.04	0.01	0.01
0.01	0.01	0.04
0.01	0.01	0.04
0.04	0.09	0.01
0	0	0
0	0.01	0.01
0	0.04	0.04

3) Test statistic calculation

	4-FORD	FORD-5	4-5
n	9	9	9
sum D	0.6	-0.3	0.3
mean d	0.066666	-0.03333	0.033333
sum D^2	0.28	0.19	0.23
ct	0.04	0.01	0.01
SS	0.24	0.18	0.22
sD^2	0.03	0.0225	0.0275
sd bar	0.057735	0.05	0.055277
t	1.155	-0.667	0.603

Student's *t* Test With No Replication continued

5) Evaluate significance

Compare	4-FORD	FORD-5	4-5
P<.05 (t[.05,8] = 1.860)			
Ho:u1=u2 H1:u1>u2	accept	accept	accept
P<.01 (t[.01,8] = 2.896)			
Ho:u1=u2 H1:u1>u2	accept	accept	accept

Appendix B:
Relevant sections of the Idaho Water Quality Standards

01.2003, DEFINITIONS AND ABBREVIATIONS. For the purpose of the rules contained in Title 1, Chapter 2, the following definitions and abbreviations apply: (1-30-80)

21. Hypolimnion. The deepest zone in a thermally-stratified body of water. It is fairly uniform in temperature and lies beneath a zone of water which exhibits a rapid temperature drop with depth of at least 1° < C per meter. (1-30-80)

01.2200, GENERAL WATER QUALITY CRITERIA. The following general water quality criteria apply to waters of the State, both surface and underground, in addition to the water quality standards set forth for specifically classified waters. Idaho Department of Health and Welfare Rules and Regulations Sections 01.2200,04. -- 01.2200,06. will, however, apply only to surface waters. As provided in Idaho Department of Health and Welfare Rules and Regulations Sections 01.2300,01., 02. and 03. for point source discharges, failure to meet general or specific water quality criteria is a violation of the water quality standards. As provided in Idaho Department of Health and Welfare Rules and Regulations Section 01.2300,04.a. for non-point source activities, failure to meet general or specific water quality criteria, or failure to fully protect a beneficial use, shall not be considered a violation of the water quality standards for the purposes of enforcement. Instead, water quality monitoring and surveillance of non-point source activities will be used to evaluate the effectiveness of best management practices in protecting beneficial uses as stated in Idaho Department of Health and Welfare Rules and Regulations Sections 01.2050,06. and 01.2300,04.b. As a result of man-caused point or non-point source discharge, waters of the State must not contain: (3-3-87)

06. Oxygen-Demanding Materials. Oxygen-demanding materials in concentrations that would result in an anaerobic water condition. (1-30-80)

01.2110 PANHANDLE BASIN. The waters found within the Panhandle hydrologic basin are designated for use as follows:

01. Designated Uses Within Panhandle Basin - Table

DESIGNATED USES

Legend
Protected for General Use
* Protected for Future Use
X Use Protected Above Mining Impact Area

Map Code	Waters	Domestic Water	Agricultural Water Supply	Cold Water Supply	Warm Water Biota	Salmonid Spawning Biota	Primary Contact Recreation	Secondary Contact Recreation	Special Resource Water
pp. PB-40s	SPOKANE RIVER - Coeur d'Alene Lake outlet to Ida-Wash border	#	#	#	#	#	#	#	

(10-15-85)

01.2250, SPECIFIC WATER QUALITY CRITERIA FOR USE CLASSIFICATIONS. The following water quality criteria apply to waters of the State, both surface and underground in addition to the water quality criteria set forth for specifically classified waters. As provided in Idaho Department of Health and Welfare Rules and Regulations Sections 01.2300,01., 02., and 03. for point source discharges, failure to meet general or specific water quality criteria is a violation of the water quality standards. As provided in Idaho Department of Health and Welfare Rules and Regulations Sections 01.2200 and 01.2300,04.a. for nonpoint source activities, failure to meet general or specific water quality criteria, or failure to fully protect a beneficial use, shall not be considered a violation of the water quality standards for the purposes of enforcement. Instead, water quality monitoring and surveillance of nonpoint source activities will be used to evaluate the effectiveness of best management practices in protecting beneficial uses as stated in Idaho Department of Health and Welfare Rules and Regulations Sections 01.2050,06. and 01.2300,04.b. (3-3-87)

03. Warm Water Biota. Waters designated for warm water biota are to exhibit the following characteristics: (1-30-80)

a. Dissolved oxygen concentrations exceeding 5 mg/L at all times. In lakes and reservoirs this standard does not apply to: (1-30-80)

i. The bottom twenty percent (20%) of the water depth in natural lakes and reservoirs where depths are thirty-five (35) meters or less. (1-30-80)

ii. The bottom seven (7) meters of water depth in natural lakes and reservoirs where depths are greater than thirty-five (35) meters. (1-30-80)

iii. Those waters of the hypolimnion in stratified lakes and reservoirs. (1-30-80)

c. Water temperatures of 33° C or less with a maximum daily average not greater than 29° C. (1-30-80)

04. Cold Water Biota. Waters designated for cold water biota are to exhibit the following characteristics: (1-30-80)

a. Dissolved Oxygen Concentrations exceeding 6 mg/L at all times. In lakes and reservoirs this standard does not apply to: (1-30-80)

i. The bottom twenty percent (20%) of water depth in natural lakes and reservoirs where depths are thirty-five (35) meters or less. (1-30-80)

ii. The bottom seven (7) meters of water depth in natural lakes and reservoirs where depths are greater than thirty-five (35) meters. (1-30-80)

iii. Those waters of the hypolimnion in stratified lakes and reservoirs. (1-30-80)

c. Water temperatures of 22° C or less with a maximum daily average of no greater than 19° C. (1-30-80)

05. Salmonid Spawning. Waters designated for salmonid spawning are to exhibit the following characteristics during the spawning period and incubation for the particular species inhabiting those waters: (1-30-80)

a. Dissolved Oxygen concentrations exceeding 6 mg/L or ninety percent (90%) of saturation, whichever is greater. (1-30-80)

b. Hydrogen Ion Concentration (pH) values within the range of 6.5 to 9.0. (1-30-80

c. Water temperatures of 13° C or less with a maximum daily average no greater than 9° C. (1-30-80)

01.2276, DISSOLVED OXYGEN STANDARDS FOR WATERS DISCHARGED FROM DAMS, RESERVOIRS, AND HYDROELECTRIC FACILITIES. Under the terms specified under this section, waters discharged from dams, reservoirs and hydroelectric facilities shall not be subject to the provisions of Idaho Department of Health and Welfare Rules and Regulations Section 01.2250,04.a. or 01.2250,05.a. (1-10-86)

02. Dissolved Oxygen Concentrations Below Existing Facilities. As of the effective date of these regulations, and except as noted in Idaho Department of Health and Welfare Rules and Regulations Sections 01.2276,03. and 01.2276,04., waters below dams, reservoirs, and hydroelectric facilities shall contain the following dissolved oxygen concentrations during the time period indicated:

mg/L Dissolved Oxygen

Time Period (annually)	30-day Mean	7-Day Mean Minimum	Instantaneous Minimum
June 15-Oct 15	6.0	4.7	3.5

(12-31-91)