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December 11, 1991

TO: Will Kendra

FROM: Dave Hallock

SUBJECT: Trends in Pend Oreille River Ambient Monitoring Data

Your memo to Dick Cunningham of September 27, 1991, requested that I evaluate ambient monitoring data from the Pend Oreille River for trends in various water quality constituents. In subsequent discussions, Randy Coots expressed an interest in nutrient limitation and the effects of upstream nutrient sources on downstream water quality. This memo presents my analysis of ambient monitoring data from two stations, Pend Oreille River at Newport and Pend Oreille River at the International Boundary, with emphasis on the above questions.

## METHODS

The Pend Oreille River at Newport, station number 62A150 (RM 88.2), has been monitored monthly by the Ambient Monitoring Section (AMS) from WY76 to the present, excluding WY77. The Pend Oreille River at the International Boundary, 62A080 (RM 16.1), was monitored monthly by USGS from February 1974 through June 1981. The data sets during these periods are moderately complete. AMS's usual suite of conventional water quality constituents (see Hopkins, et al., in press) were monitored at both stations with the following exceptions: the downstream station has no fecal coliform bacteria data, and oxygen and total suspended sediment data are missing prior to 1977. The upstream station has no fecal coliform bacteria, pH, or total suspended sediment data prior to about 1978.

Inconsistent sampling and analytical methods reduce confidence in trend data interpretations. Unfortunately and inevitably for any long-term monitoring program, changes in protocols occur that have the potential to affect data. In our case, the older data (pre-1980) was particularly subject to potentially significant changes, especially the nutrients. These changes were considered qualitatively when interpreting statistical results. As a result, trends in nutrient data, even when highly significant statistically, are assigned lower confidence.

Trends were evaluated using a Seasonal Kendall Test for Trend without correction for serial correlation. For station 62A150 (Pend Oreille at Newport) only, where serial correlation was present, the Seasonal Kendall Test for Trend with correction was used. The data set at the lower station was not sufficiently long to perform the test with correction; as a result, less confidence should be placed in trends at this station for those constituents where serial correlation was present.

Correlation with flow and time of collection was evaluated prior to analysis for trends. Where the constituent of interest was correlated with flow or time of collection, the test for trend was performed on the residuals of the regression of the con stituent and flow or time. This removes the effect of flow or time on the constituent which might otherwise mask or exaggerate trends.

The significance of differences between the two stations was evaluated by testing whether the 95% non-parametric confidence interval on the quarterly medians included zero. The year was divided into quarters beginning in Jan-Mar, Feb-Apr, or Mar-Feb depending on which choice exhibited the greatest seasonal variation.

Methods for collection and analyses of samples and a discussion of AMS's quality assurance/quality control program are discussed in Hopkins, et al., (in press). Statistical and graphical analysis was done using WQHYDRO (Aroner, 1991).

## RESULTS AND DISCUSSION

### Differences Between Stations

Quarters where the difference between the upstream and downstream station was significantly (95% level) different from zero are shown in Table 1. There was no difference between the two stations for most quarters and most constituents. Turbidity was greater at the upstream station during all quarters for unknown reasons. Oxygen was greater at the upstream station during the summer quarter and lower during the spring (Figure 1), perhaps because of greater net productivity during the growing season above the upper station, or perhaps because of different bypass regimes at the dams above the two stations. Both upstream and downstream stations are about one mile below dams (Albani Falls and Boundary Dam, respectively) with another dam, Box Canyon, in between. These impoundments will affect water quality and make interpretations of upstream/downstream data difficult.

### Trends in the Differences Between Stations

Trends in specific constituents are shown in Table 2. Trends at the two stations should not be compared directly because of the different periods of record used in the analysis. For example, one should not conclude that oxygen at the downstream station is decreasing relative to the upstream station. The declining trend in oxygen at the lower station, although visually dramatic,

Table 1. Significant differences (95%) in water quality constituents between the Pend Oreille River at Newport and at the international boundary by quarter. (Upstream results greater than downstream results = '+'.)

| Constituent | Quarter | Upstream minus Downstream |
|---|---|---|
| Temperature | Dec-Feb | + |
| Conductivity | Apr-Jun | + |
| Oxygen | Apr-Jun | - |
| | Jul-Sep | + |
| Percent Sat. | No differences | |
| pH | No differences | |
| Total Ammonia | Feb-Apr | + |
| Total Phosp. | Jun-Aug | - |
| Turbidity | All quarters | + |

Table 2. Trends in water quality parameters at Ambient Monitoring Stations on the Pend Oreille River at the International Boundary (62A080) and at Newport (62A150), and the difference between those stations. Two arrows indicates a high degree of confidence, one arrow indicates lower confidence, and a dash indicates no trend (see text). A decreasing trend in the difference between stations indicates the upstream station is decreasing relative to the downstream station.

| Parameter | 62A080 | 62A150 | Difference |
|---|---|---|---|
| Oxygen | ↓ 95% s | -- | -- |
| Temperature | -- | -- | -- |
| Conductivity | -- | -- | -- |
| Percent Sat. | -- | -- | -- |
| pH | ↑↑ 99% s | -- s | -- |
| Total Susp. Solids | NA | ↑ 90% | NA |
| Total Ammonia | ↓ 90% | ↓↓ 99% s | ↓ 90% |
| Total Phosphorus | ↑ 99% | ↓ 90% s | -- |
| Turbidity | -- f | ↓ 99% s | -- |
| Fecal Coliform | NA | ↓↓ 95% s | NA |
| Flow | ↓↓ 99% | ↓↓ 90% s | NA |

s = significant serial correlation; serial correlation was compensated for at 62A150 but not at 62A080.
f = significant flow correlation, residuals used
NA = Not available, insufficient data

is based on only three years of data (Figure 2). Oxygen at the upstream station during these same three years also experienced a significant downward trend, although there was no significant trend when all dates were included. Similarly, although pH at the downstream station increased sharply between 1974 and 1981 (Figure 3) with no significant trend at the upstream station, there was no measurable change in the difference between the stations. Part of the problem in detecting trends in differences between the stations is the short period of overlapping data. Five years of overlapping data is available for most constituents, the minimum desirable for conducting trends. However, oxygen, pH, and percent saturation have four or fewer years of overlapping data. A trend in the difference between stations would have to be very large indeed to be detected in these constituents.

The only measurable trend in the difference between stations was a weak downward trend in total ammonia (Figure 4). Ammonia decreased significantly during the periods evaluated at both stations (Table 2) but the decrease during the overlapping period was greater at the upper station than the lower.

Because there are only a few years of overlapping data, and because the quality of pre-1980 nutrients is questionable, the effect of upstream nutrients on downstream water quality cannot be assessed using historical ambient monitoring data. In WY94, barring budget cuts, we will be monitoring the Pend Oreille at Newport and at Metaline Falls and may be able to revisit this issue at that time.

**Trends at Each Station**

Turbidity at the lower station (62A080) showed a decreasing trend (95%), but turbidity was correlated with flow ($r=0.6$), and flow also exhibited a decreasing trend. The residuals of a linear (the best fit in this case) regression of turbidity and flow exhibited no trend. In other words, any changes in turbidity at the lower station can be attributed to changes in flow, and not to changes in the underlying processes contributing to turbidity (such as land uses). At the upper station, turbidity was not correlated with flow (neither was suspended sediment) and the downward trend may be attributed to upstream processes. The lack of a relationship between turbidity (or suspended sediment) and flow at the upstream station may be because that station is close to Lake Pend Oreille, which would buffer effects of flow on water quality constituents.

Overall, most water quality constituents at the upper station have been improving over the last 15 years. (There is insufficient data at the lower station to evaluate recent changes.) Fecal coliform bacteria showed a strong negative trend--mostly due to higher counts in the late '70s and early '80s--but counts were never very high (Figure 5). Oddly, although turbidity at the upper station showed a strong decrease, total suspended solids showed a weak increase. These two constituents were positively correlated, but the relationship was not strong.

Total Nitrogen : Total Phosphorus Ratio

Total nitrogen (TN = Kjeldahl nitrogen + $NO_2$ + $NO_3$) and total phosphorus (TP) data were collected intermittently between 1978 and 1981 at the lower station only. The TN:TP ratio can be used as an indicator of nutrient limitation, although the actual boundary values between nitrogen and phosphorus limitation are a subject of debate. Nitrogen limitation is defined here as being indicated at TN:TP ratios less than seven, while phosphorus limitation is indicated at TN:TP ratios greater than 17. Between 1978 and 1981, TN:TP ratios approached nitrogen limitation during late-winter to early spring, moving into clear phosphorus limitation during the growing season (Figure 6). Whether or not this is still the case is unknown.

## LITERATURE CITED


Aroner, E. 1991. WQHYDRO. Olympia, WA.

Hopkins, B., D. D. Hallock, R. James. In Press. 1990 Ambient Monitoring Annual Freshwater Data Report. Environmental Investigations and Laboratory Services, Washington State Department of Ecology, 1991.


cc: Dick Cunningham
Randy Coots

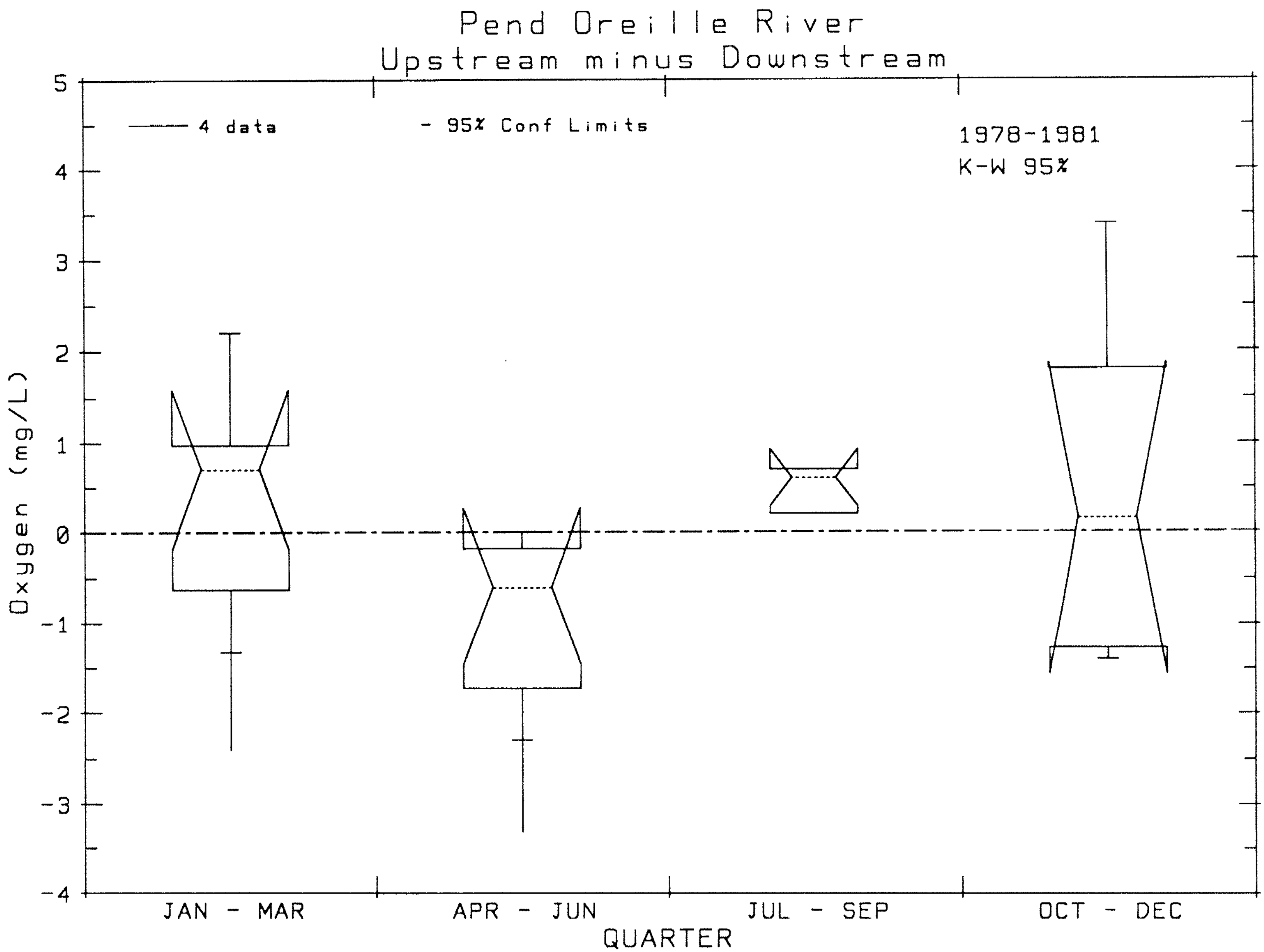


Figure 1. Pend Oreille River, Dissolved Oxygen - Upstream minus Downstream.

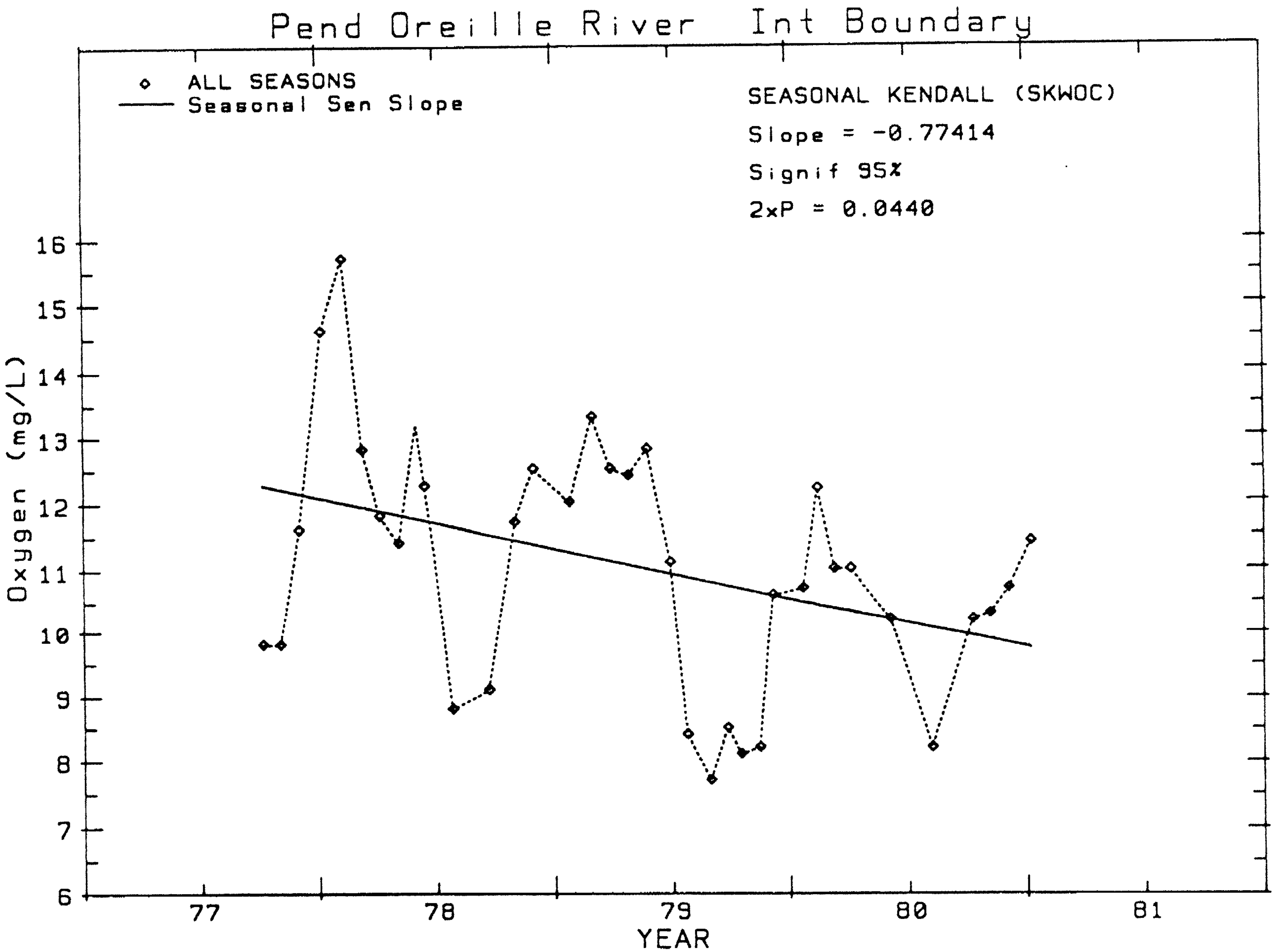


Figure 2. Pend Oreille River, International Boundary - Dissolved Oxygen Trends.

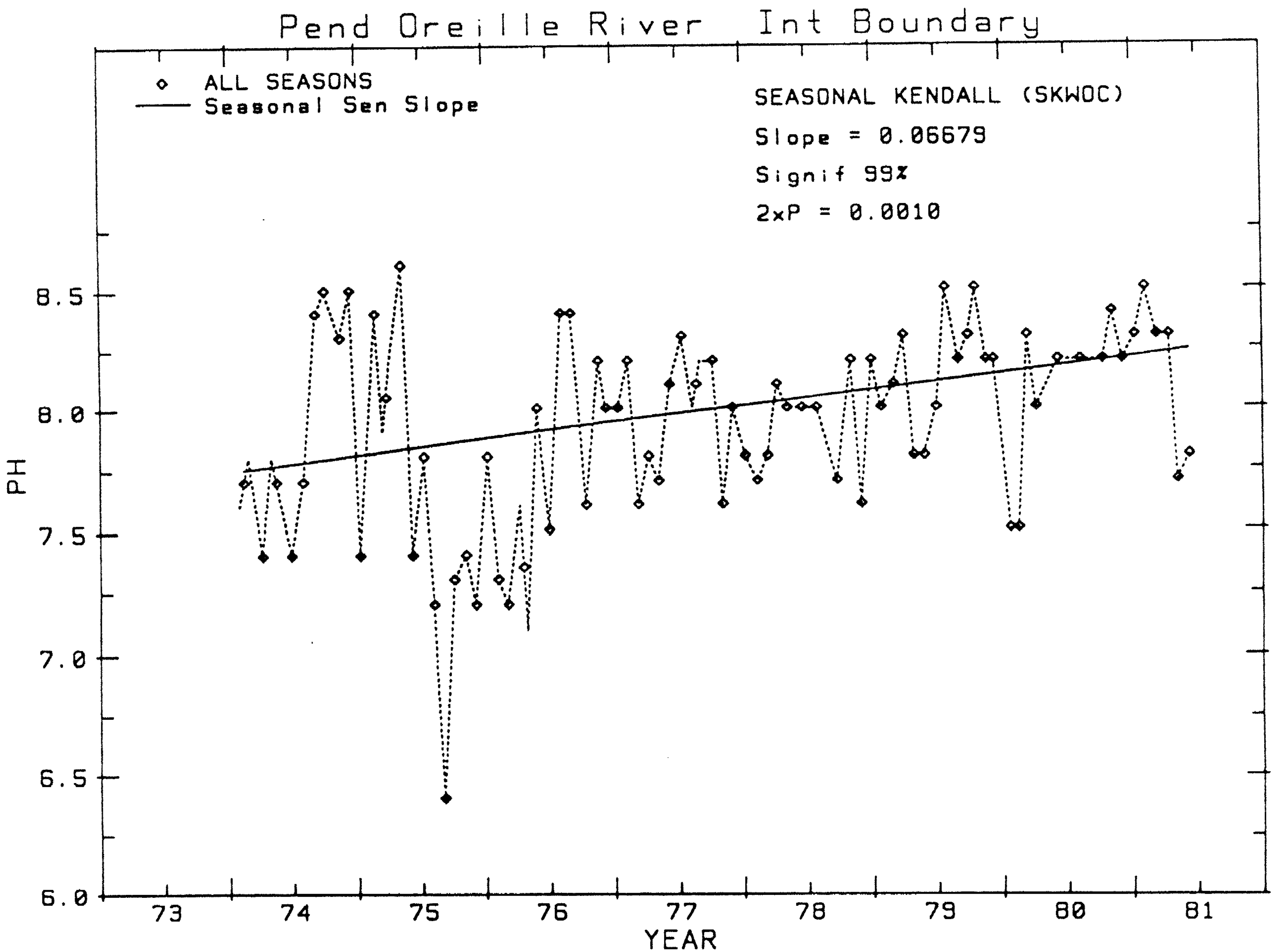


Figure 3. Pend Oreille River, International Boundary - pH Trends.

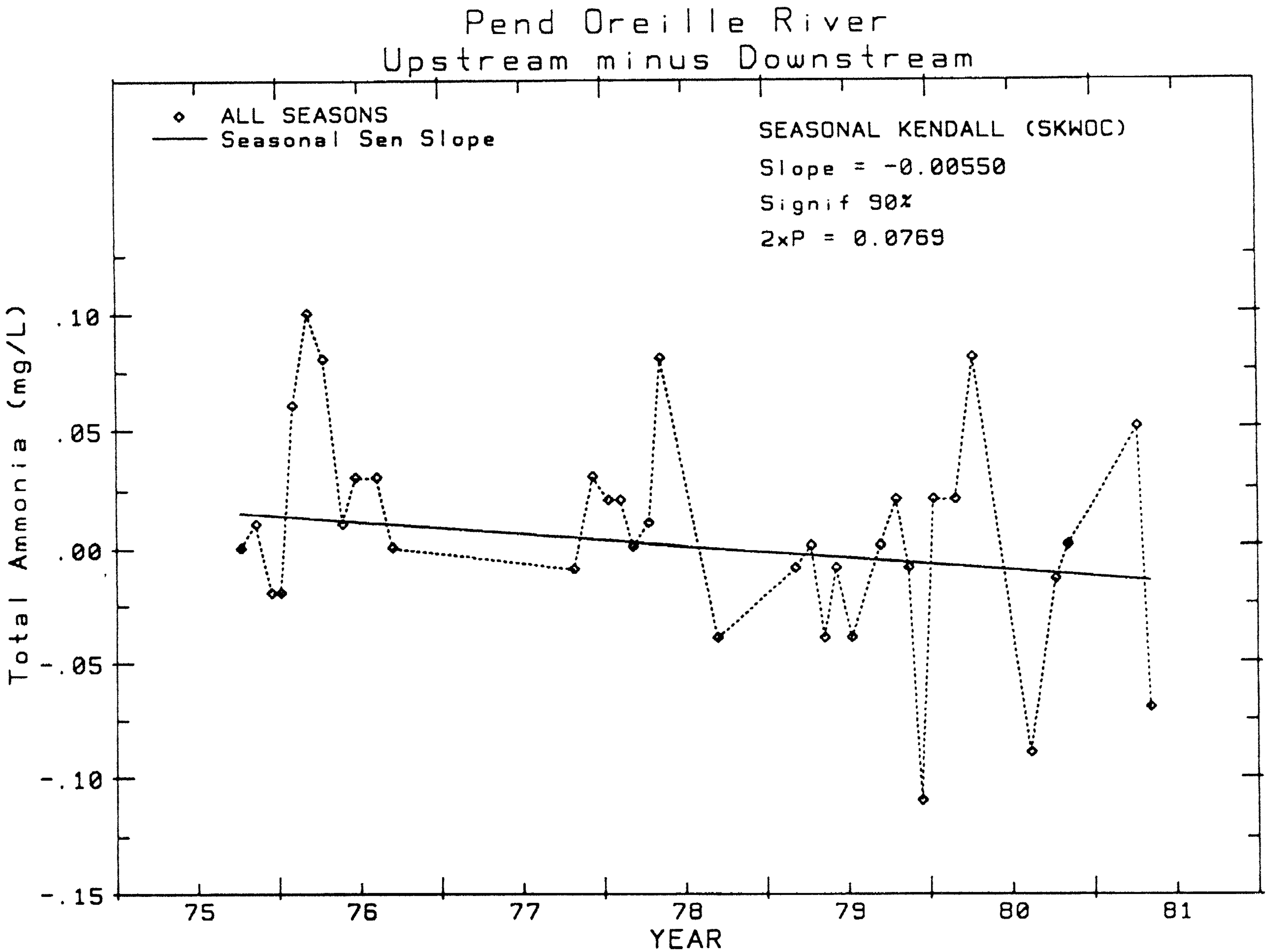


Figure 4. Pend Oreille River, Upstream minus Downstream - Total Ammonia Trends.

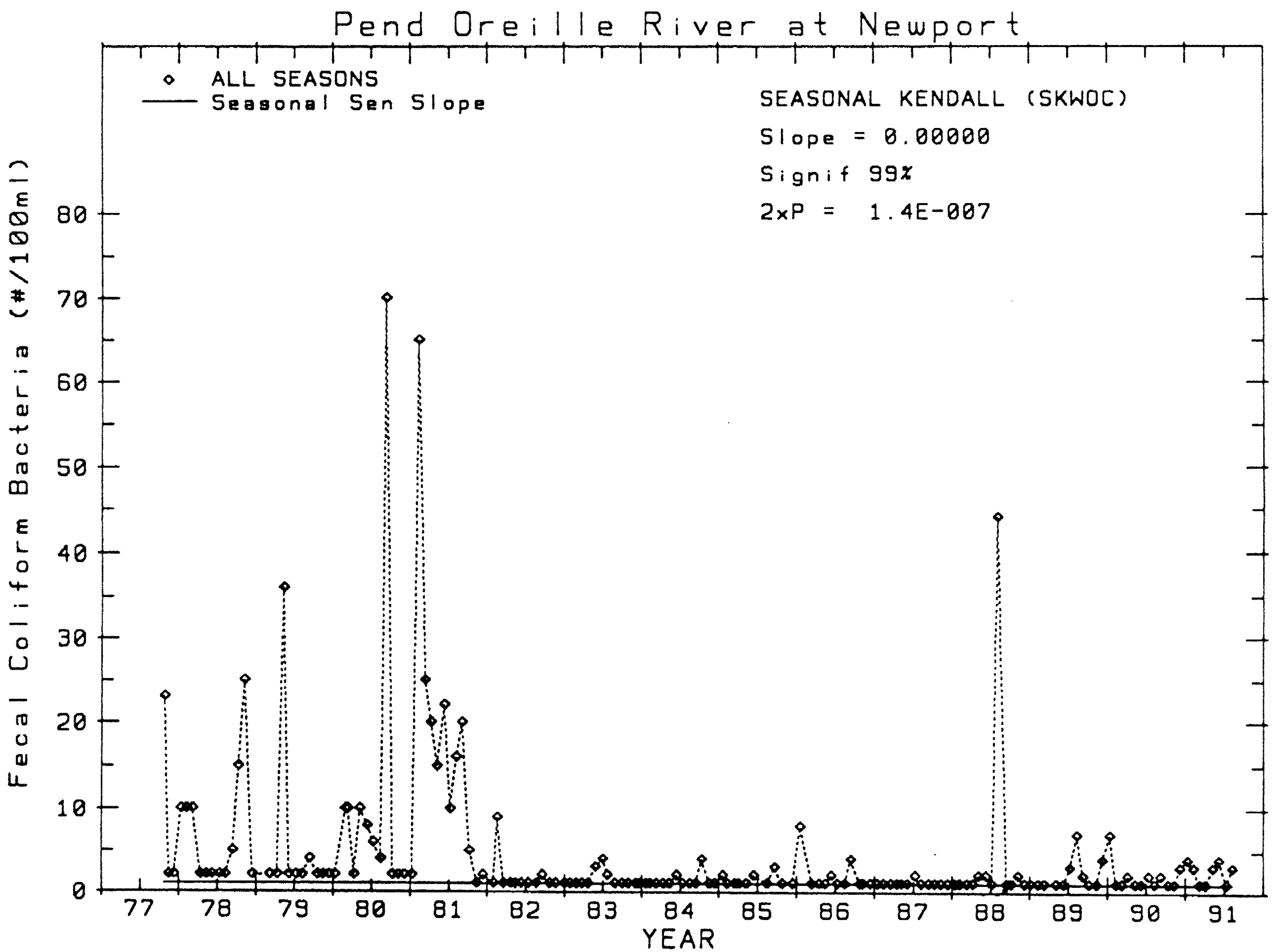


Figure 5. Pend Oreille River at Newport, Fecal Coliform Bacteria Trends.

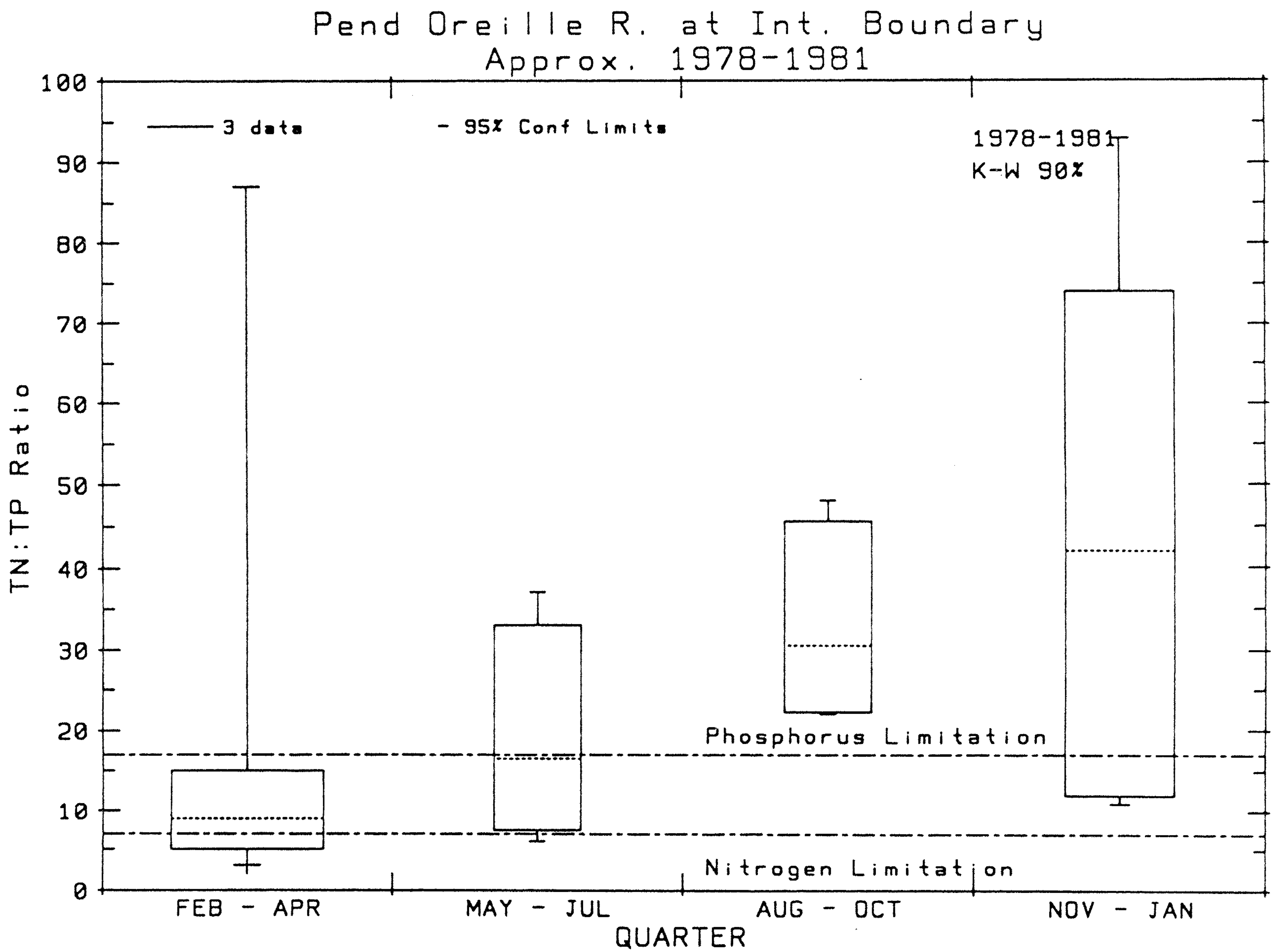


Figure 6. Pend Oreille River, International Boundary - TN:TP Ratio.