Trends Analyses of Total Phosphorus in the Columbia River at Birchbank

Prepared by
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Introduction

The station on the Columbia River at Birchbank is located about 24 km downstream from the community of Castlegar, and approximately 20 km north of the international boundary.

Water quality in this reach of the Columbia River is influenced by the Hugh Keenleyside dam, the Kootenay River, and several major effluent discharges (*e.g.*, Celgar pulp mill, City of Castlegar).

This report summarizes trend analyses performed on total phosphorus data collected from 1968 to the end of 1997, using nonparametric statistical tests for trend.

Methods

The analyses used in these report were performed using the following software tools on a PII running Windows 98 :

Data tabulation performed in Excel '95
Data graphing performed in Grapher 2.0
Data statistical tests performed in S-Plus 4.5, using the add-on module EnviromentalStats 1.0

Nonparametric Analyses

Nonparametric tests to detect trends in water quality have been used by many others in the past (Yu and Zou, 1993; Walker, 1991; Gilbert, 1987; Hirsch and Slack, 1984). The relative simplicity and minimal data assumptions of these tests make them a popular choice for analysis of water quality time series. Two different nonparametric tests; the seasonal Kendall's Tau and the Sen slope estimator, were used to detect and determine magnitude of trends in the total phosphorus data.

Seasonal Kendall's Tau

A rank-order statistic that can be applied to time series exhibiting seasonal cycles, missing and censored data, and indications of non-normality (Yu and Zou, 1993). For computational details see Gilbert (1987), and Hirsch and Slack (1984).

Sen Slope Estimator

This nonparametric statistic calculates the magnitude of any significant trends found. The Sen slope estimator (Sen, 1968) is calculated as follows:

$$D_{ijk} = \frac{Y_{ij} - Y_{kj}}{i - k} \quad \text{for } j = 1,\ldots,12 ; \quad 1 \le k < i \le n_j$$

The slope estimate is the median of all Dijk values. Hirsch et al. (1982) point out that this estimate is robust against extreme outliers and that since the Dijk values are computed on values that are multiples of 12 months apart, confounding effects of serial correlation are unlikely. Confidence bounds for this slope estimator are calculated as a simple percentile of the total number of calculated slopes (Gilbert, 1987).

Results

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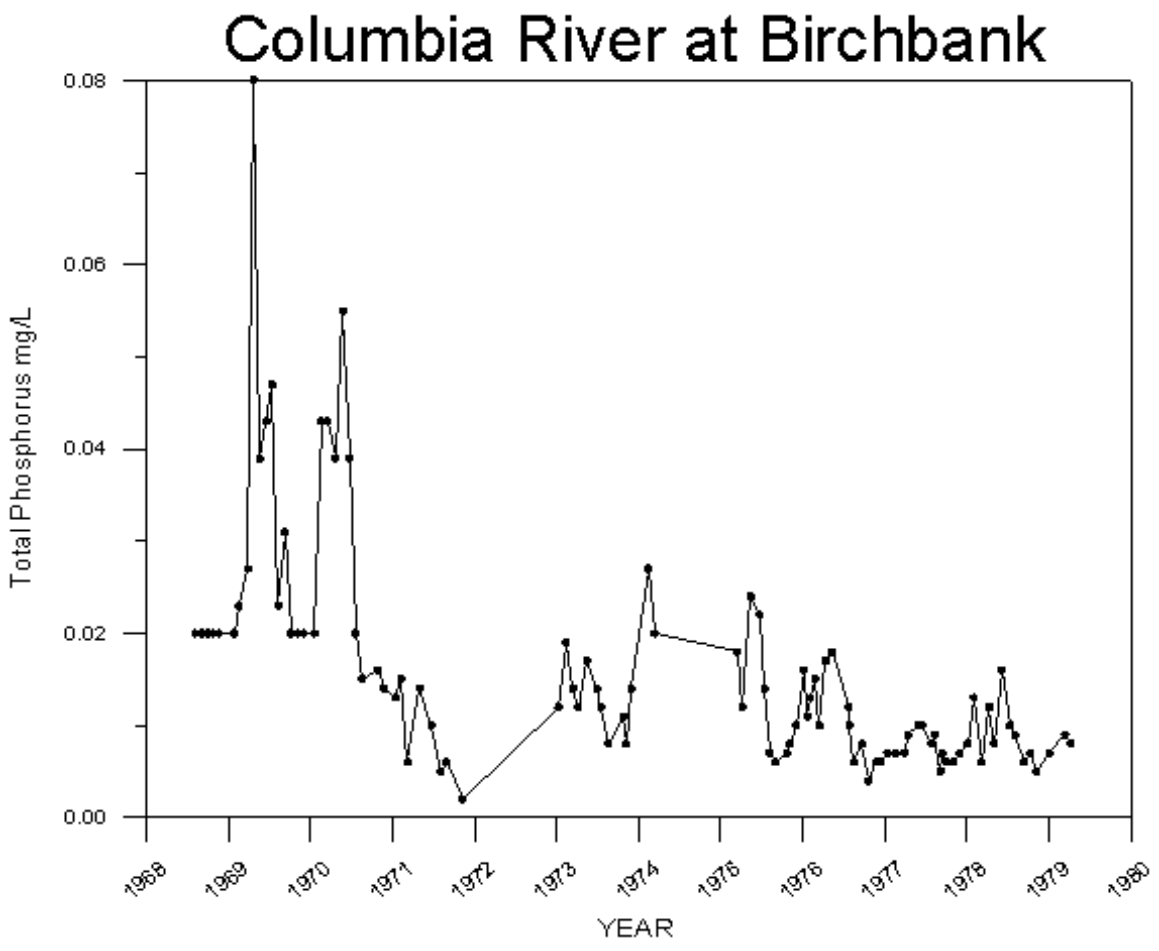

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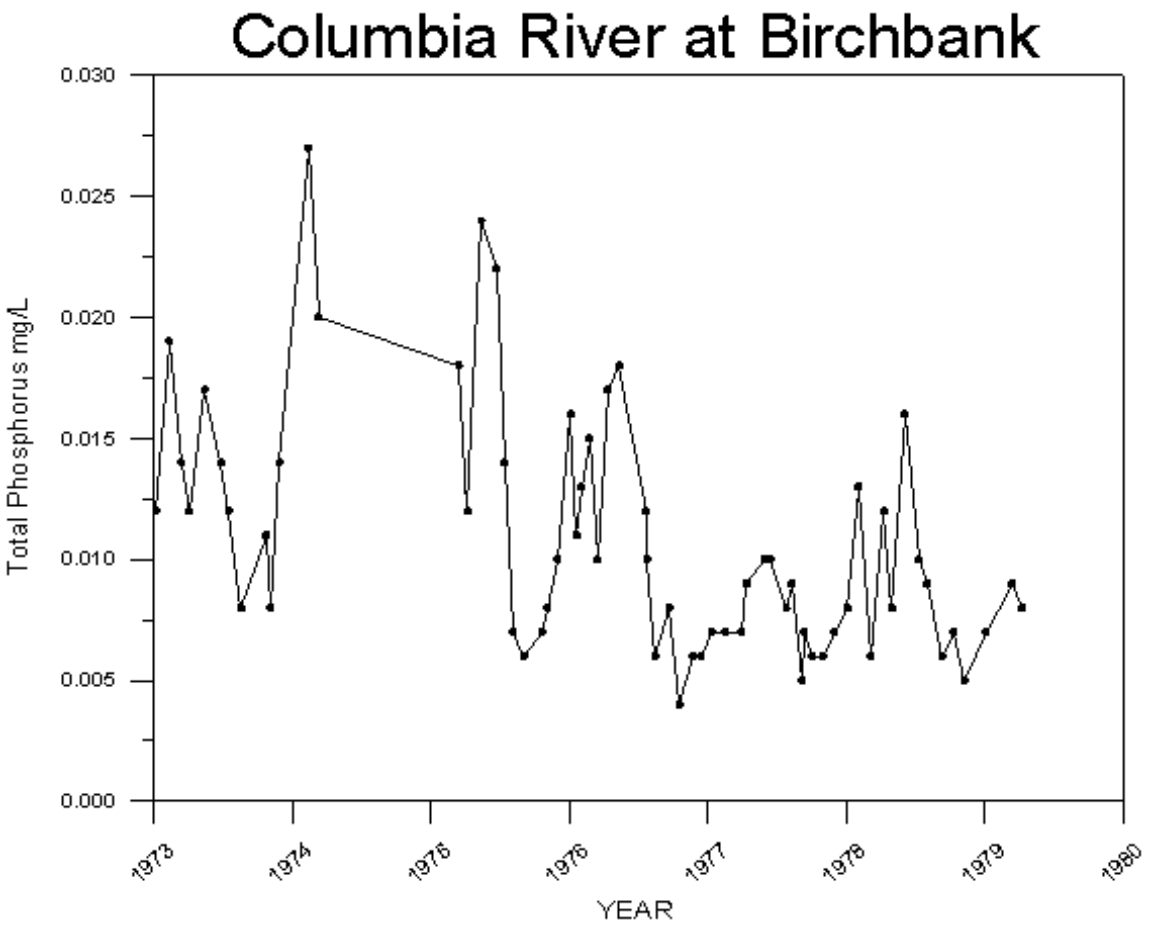

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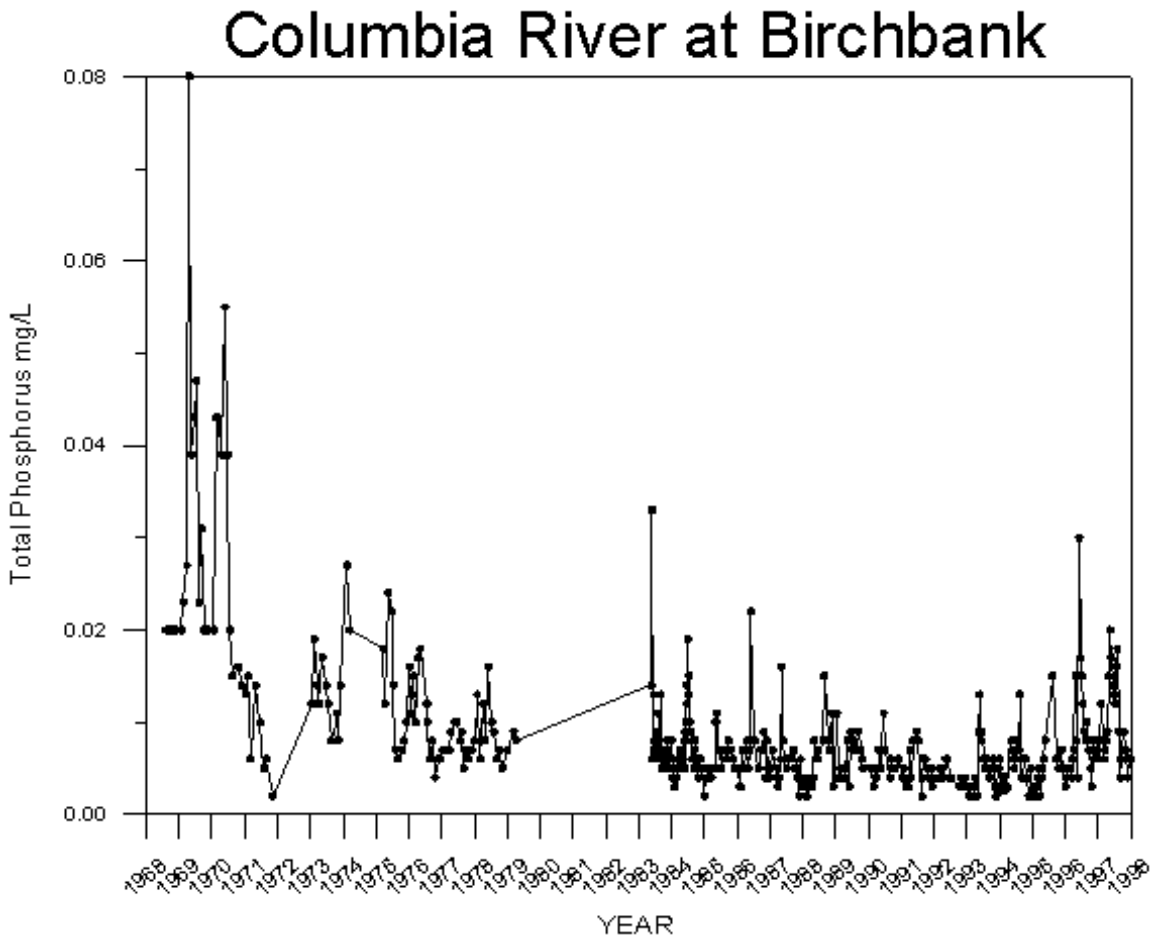

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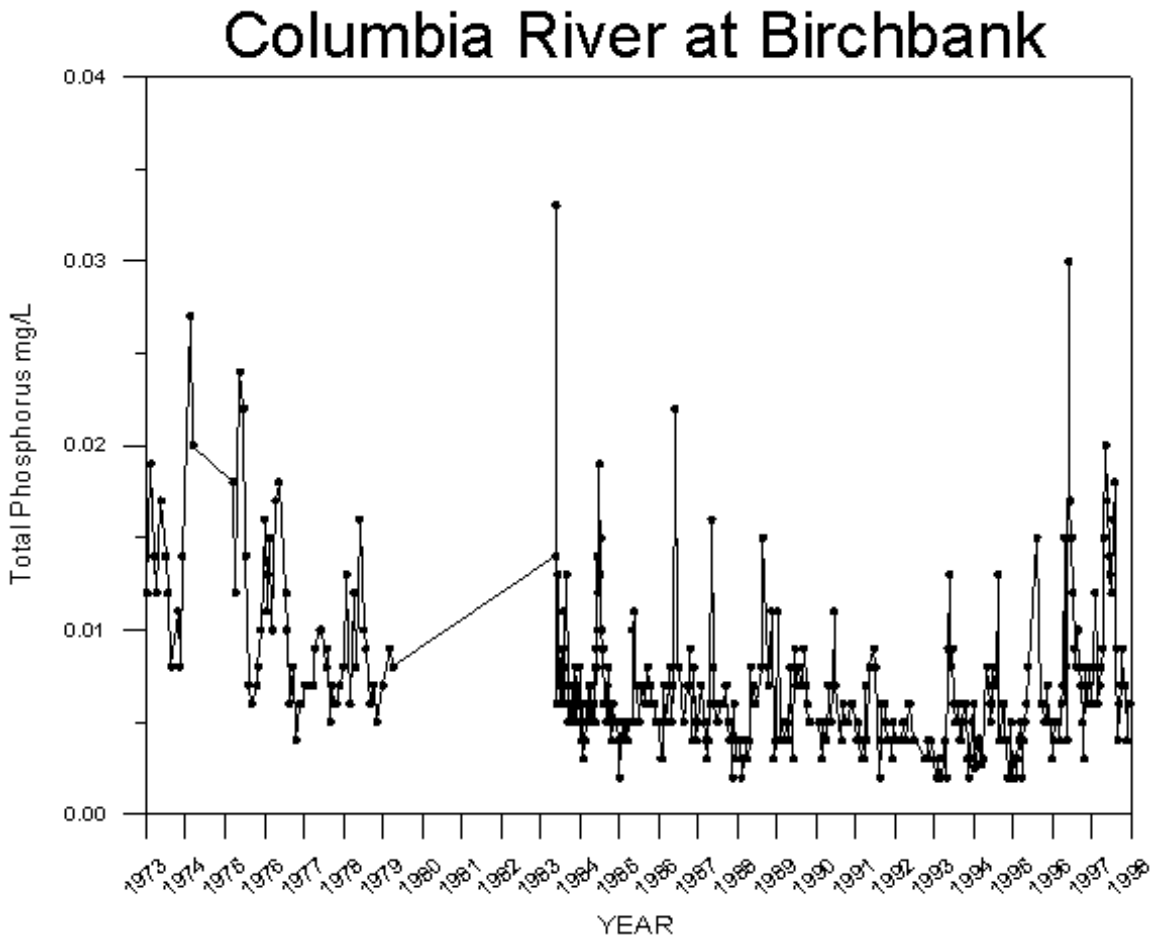

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Summary

Nonparametric tests for trend indicated strong linearly decreasing trends in total phosphorus data collected from the Columbia River at Birchbank. Separate analyses were conducted on the following subsets of data:

1968 - 1979 (EMS data only)
1973 - 1979 (EMS data only)
1968 - 1997 (EMS and Envirodat data combined)
1973 - 1997 (EMS and Envirodat data combined)

References

Gilbert, R.O., 1987. Statistical methods for environmental pollution monitoring. Van Nostrand-Reinhold, New York.

Hirsh, R.M. and J.R, Slack, 1984. A nonparametric trend test for seasonal data with serial dependence. Water Resources Research 20: 727-732.

Hirsh, R.M., J.R, Slack, and R. Smith, 1982. Techniques of trend analysis for monthly water quality data. Water Resources Research 18 (1): 107:121.

Sen, P.K., 1968. On a class of aligned rank order tests in two-way layouts. Annals of Mathematical Statistics 39, 1115-1124.

Walker, W., 1991. Water quality trends at inflows to Everglades National Park. Water Resources Bulletin 27 (1): 59-72.

Yu, Y.S. and S. Zou, 1993. Research trends of principal components to trends of water-quality constituents. Water Resources Bulletin 29(5): 797-806.

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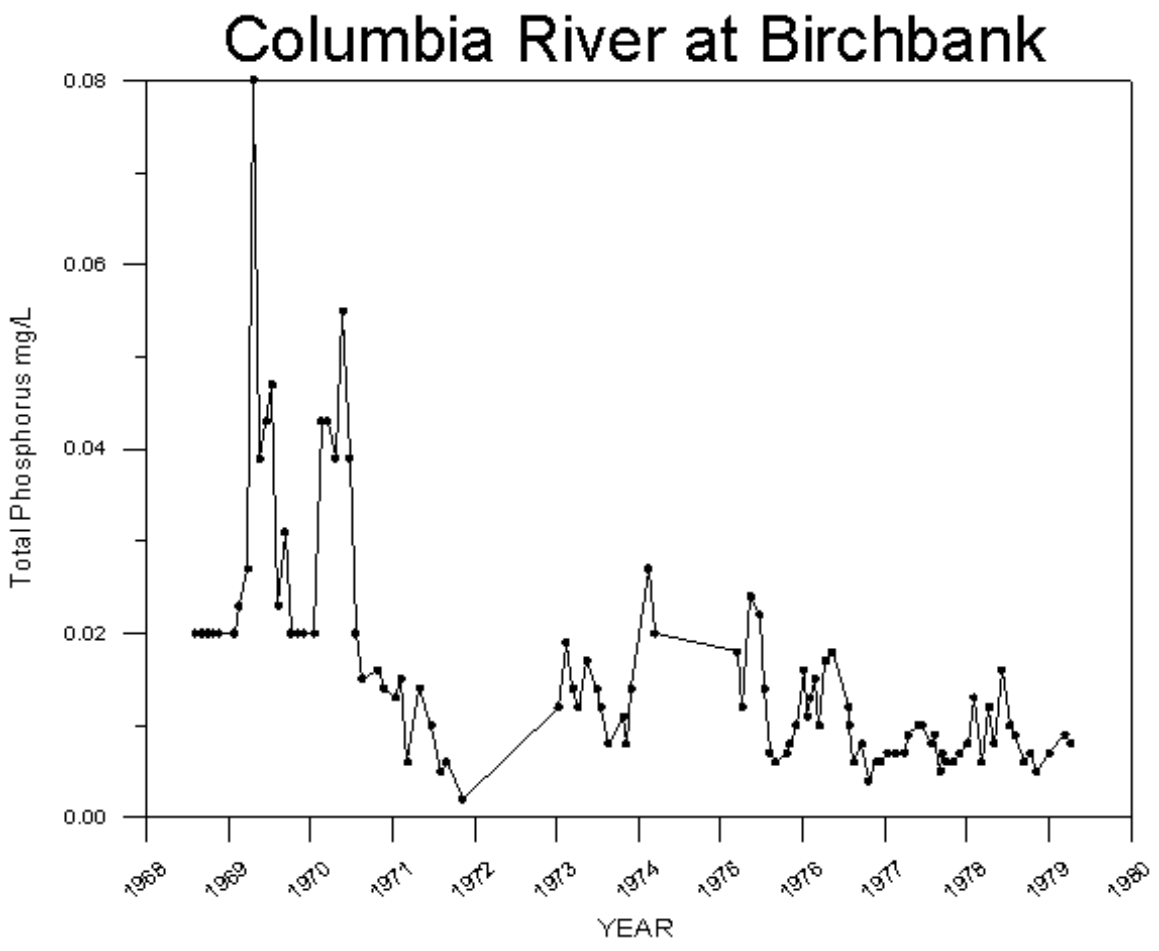

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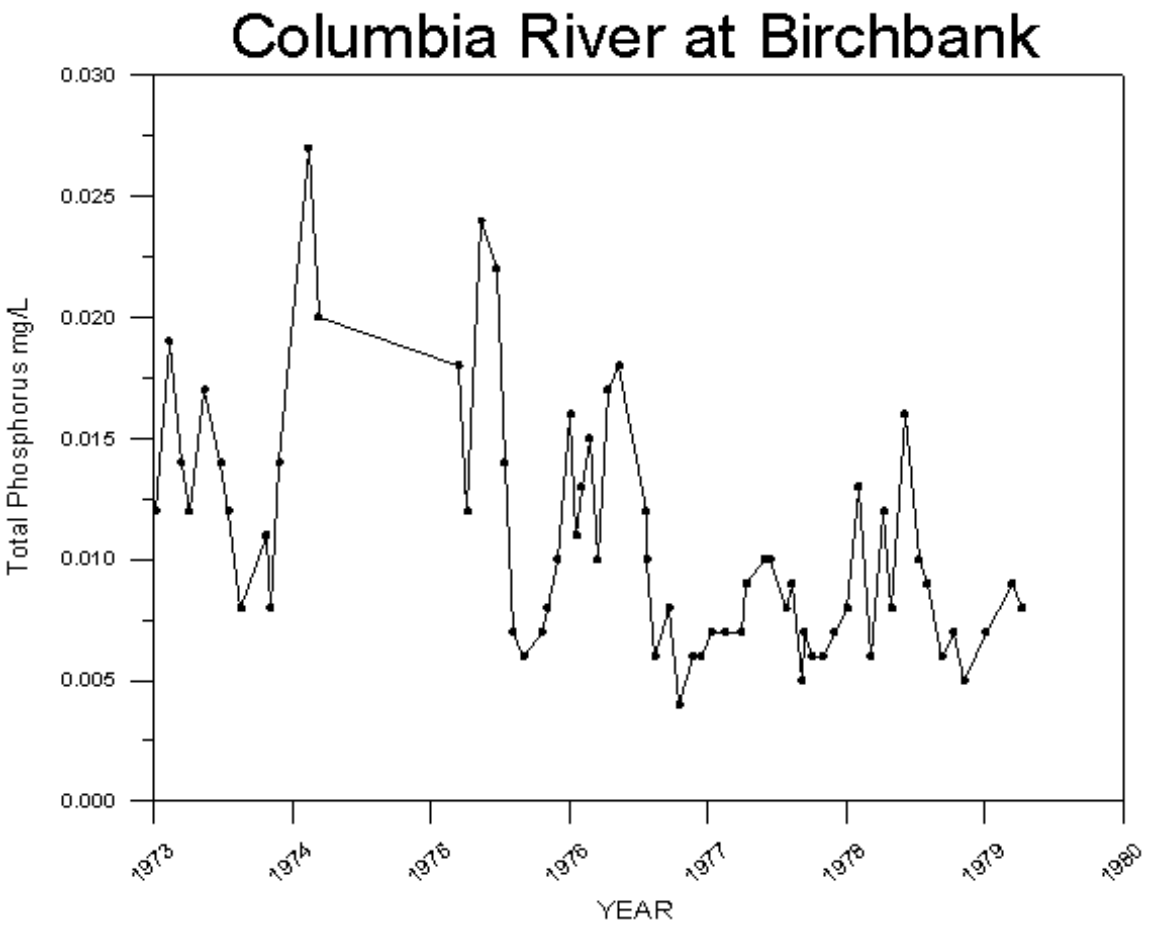

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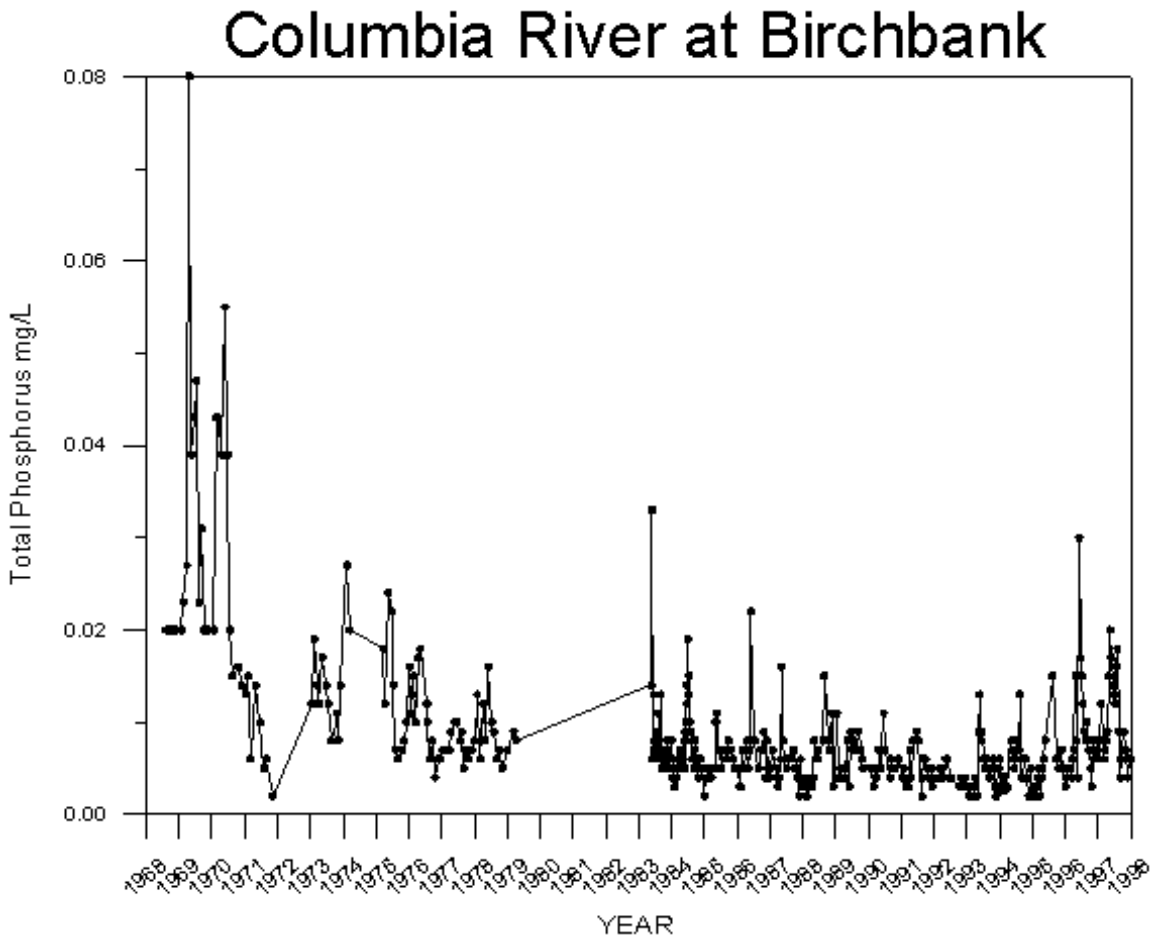

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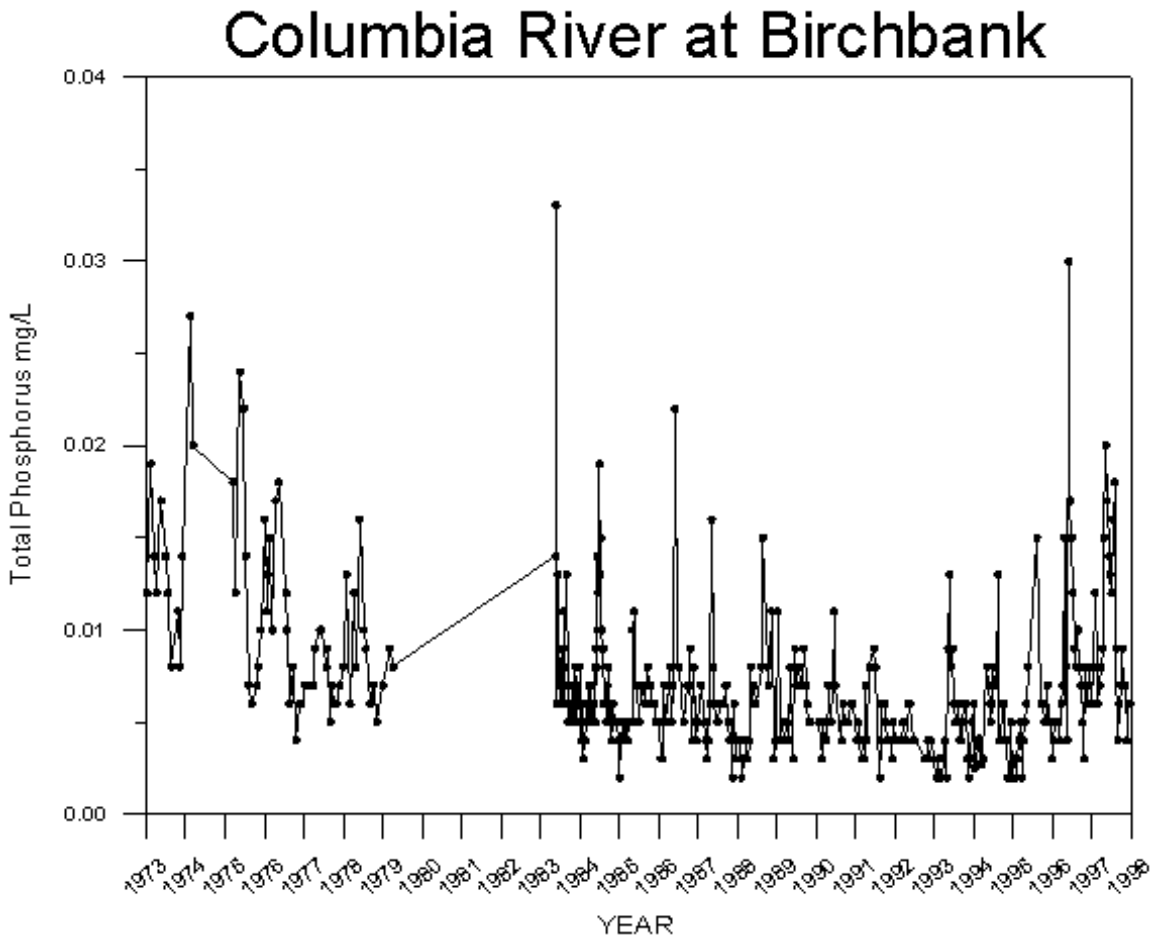

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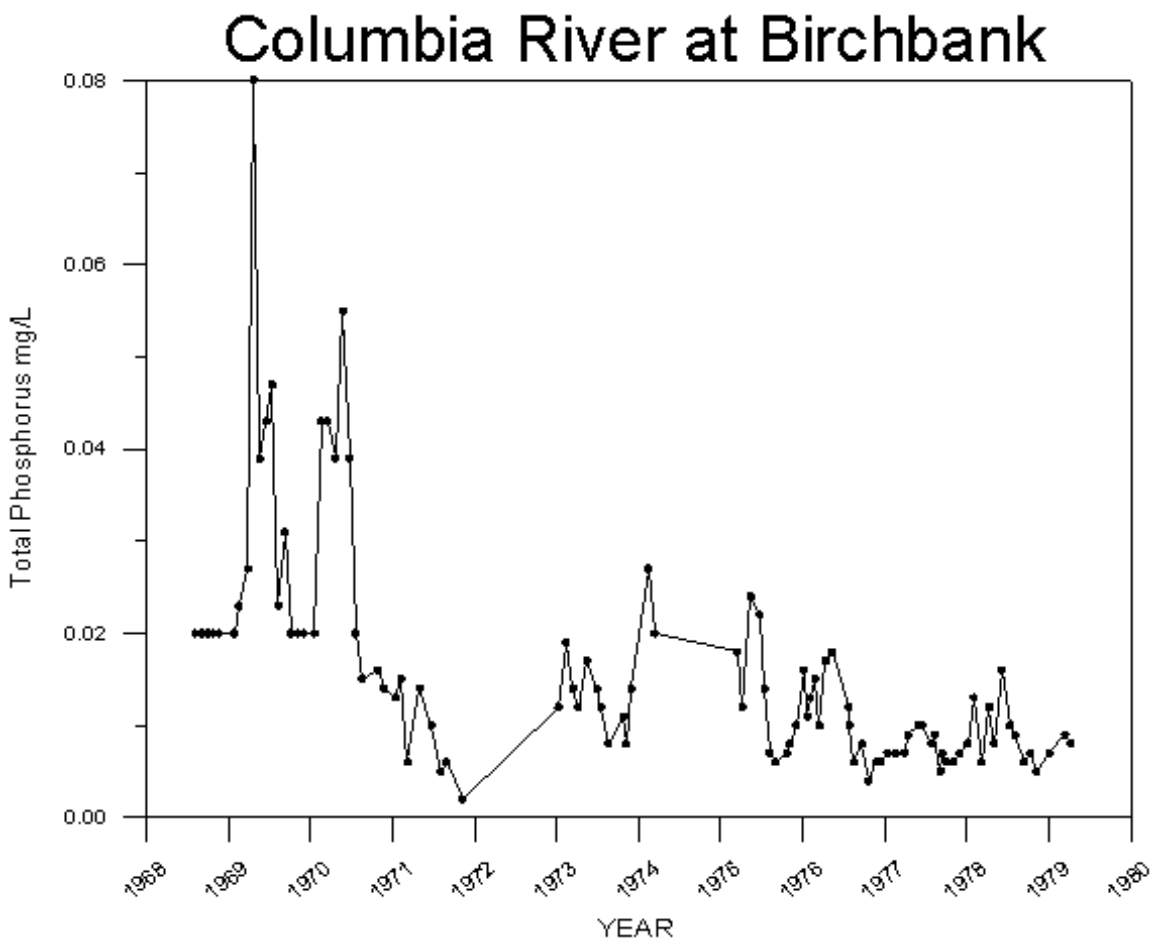

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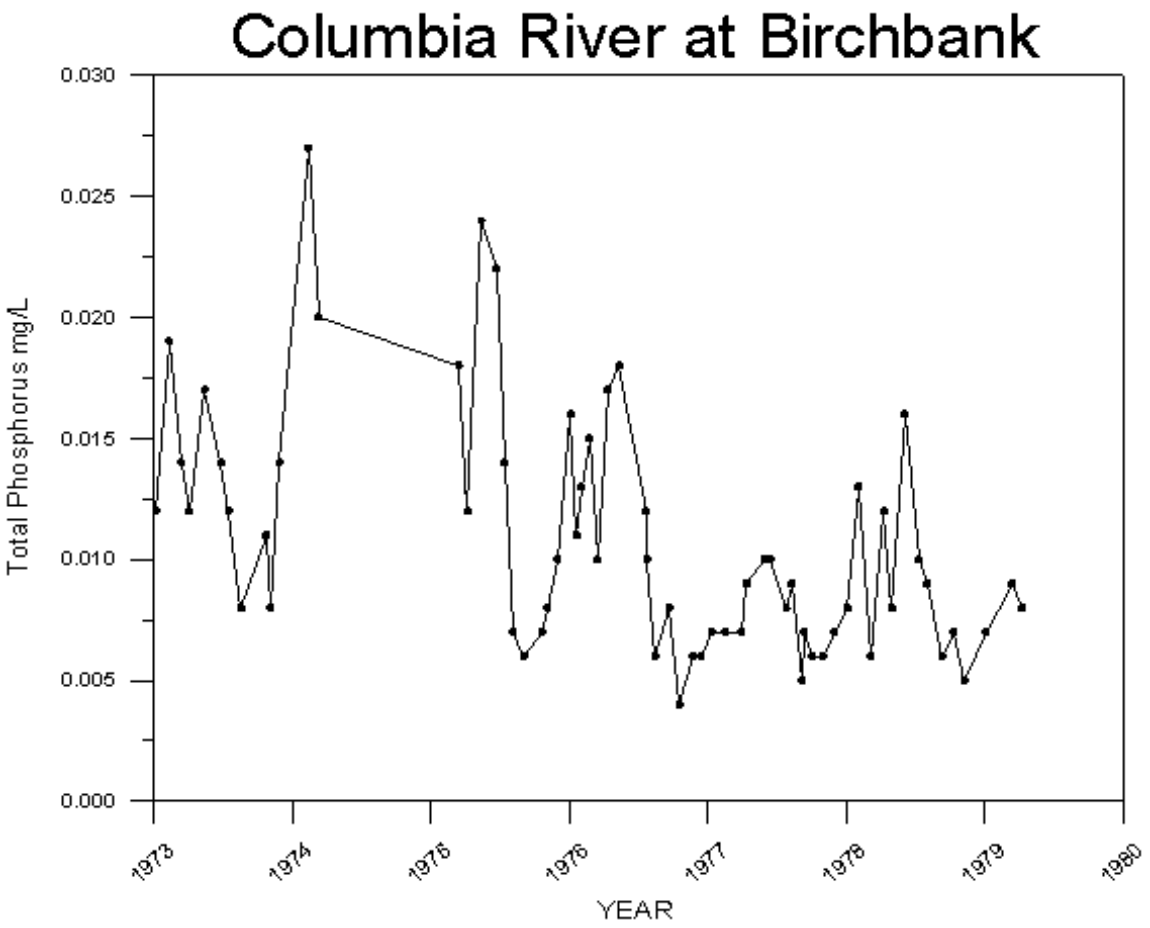

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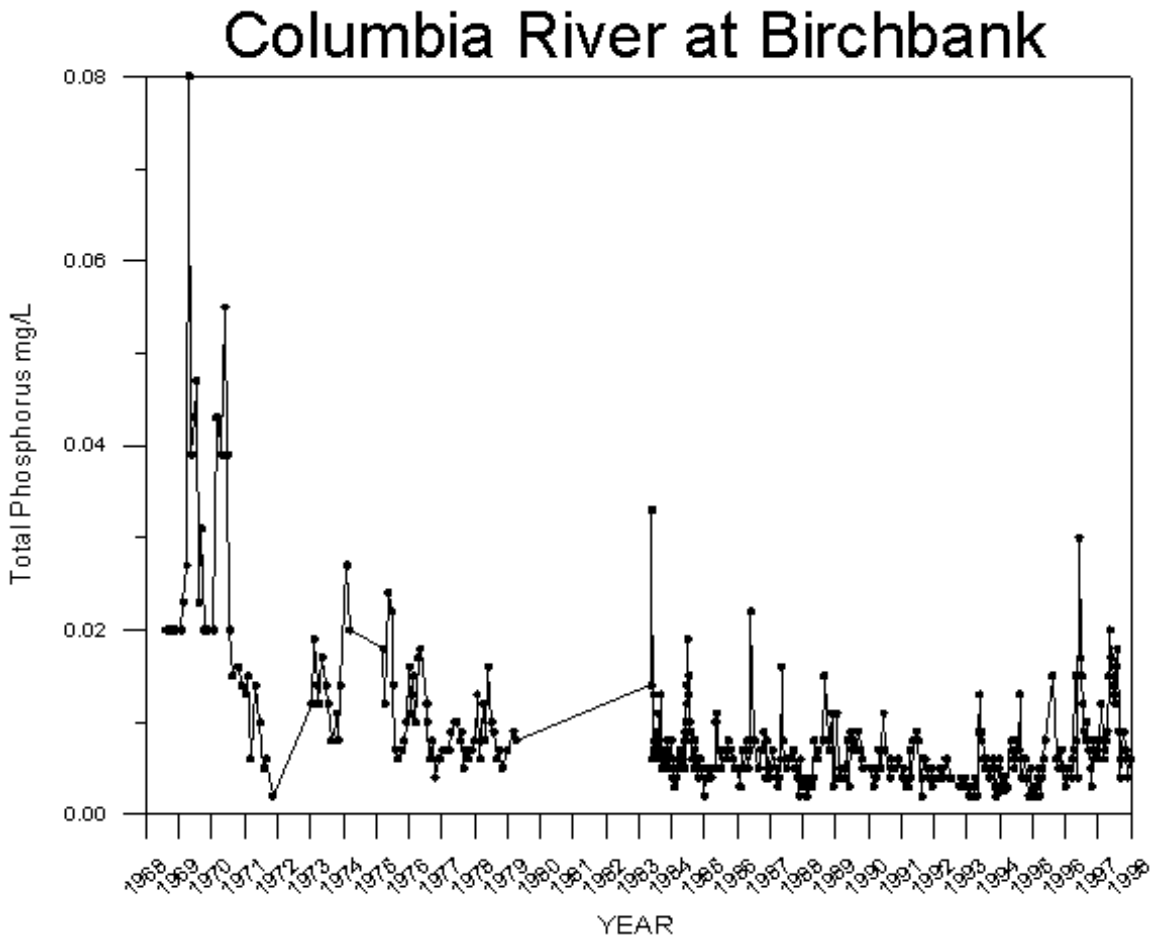

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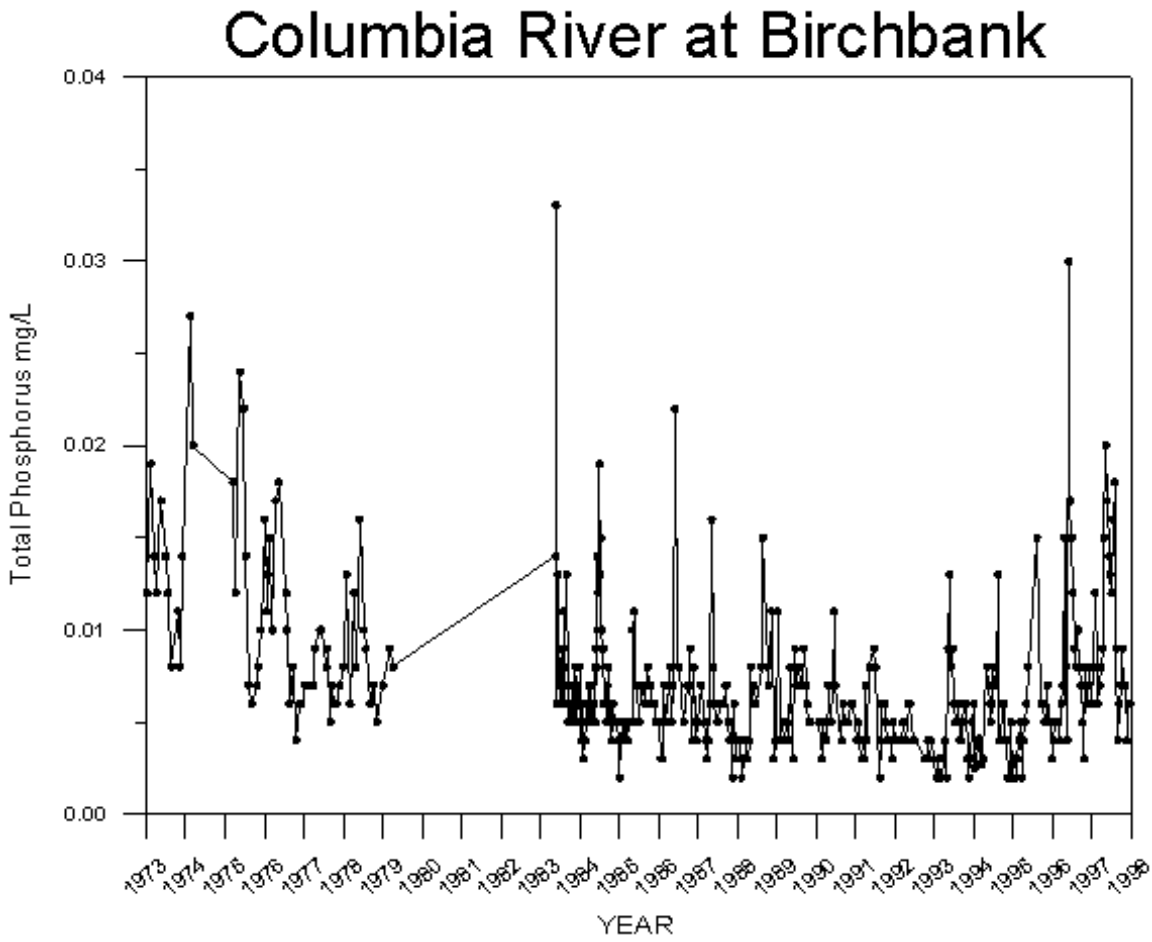

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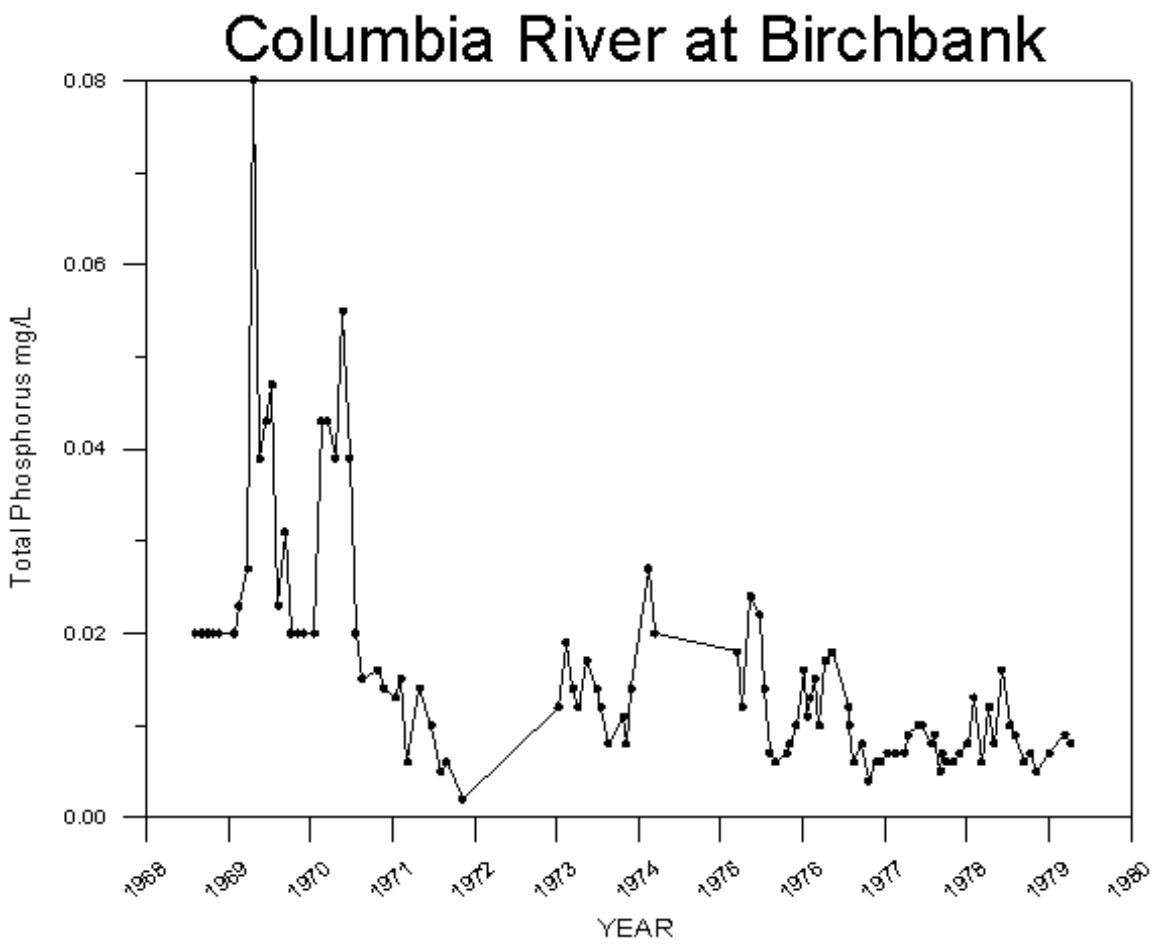

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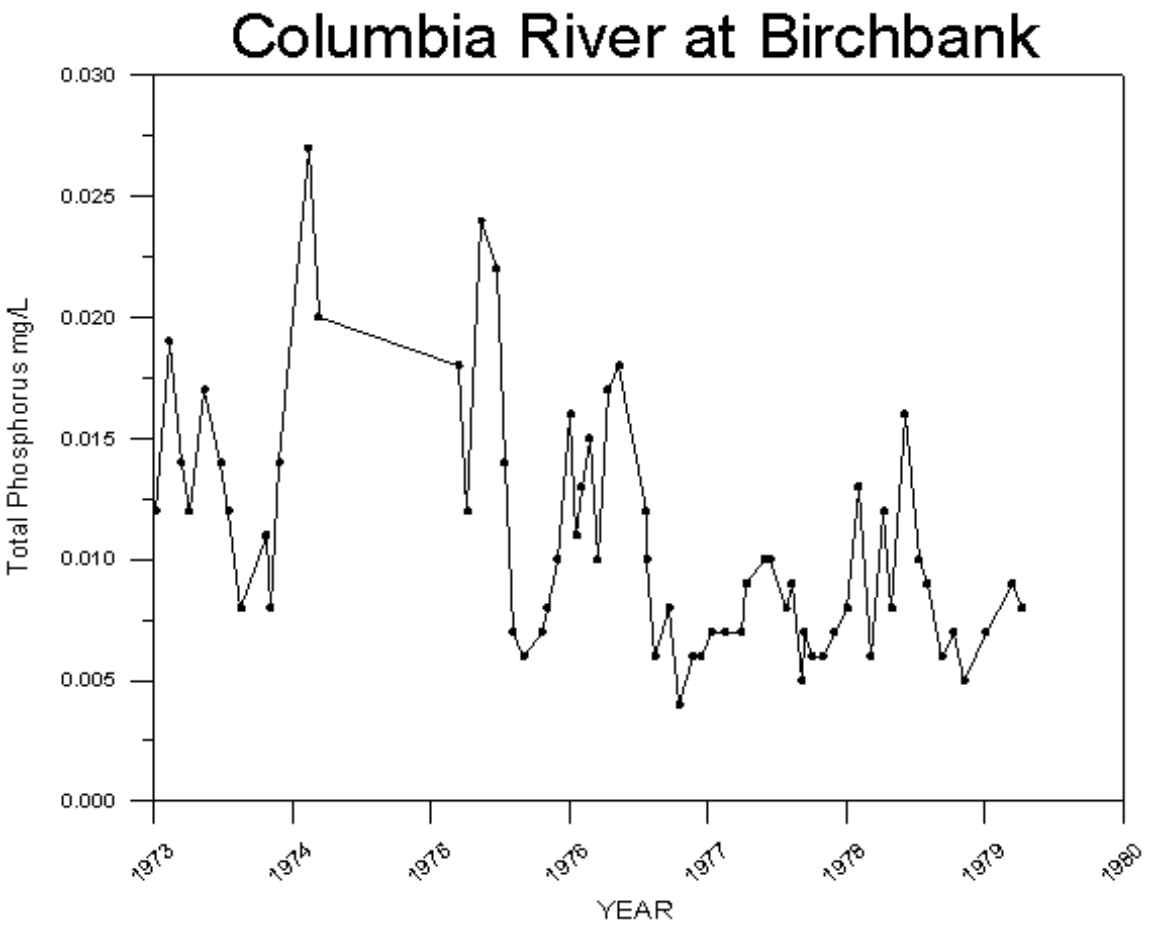

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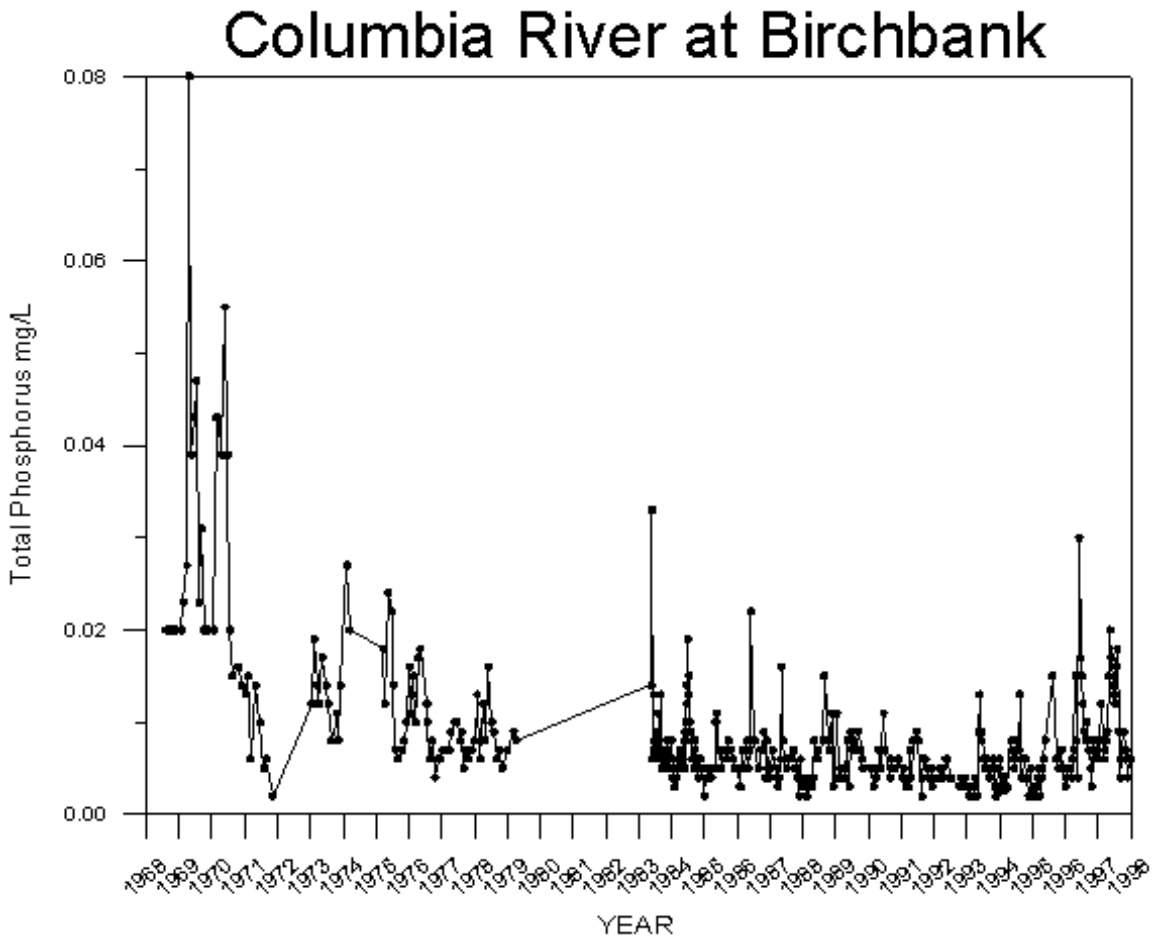

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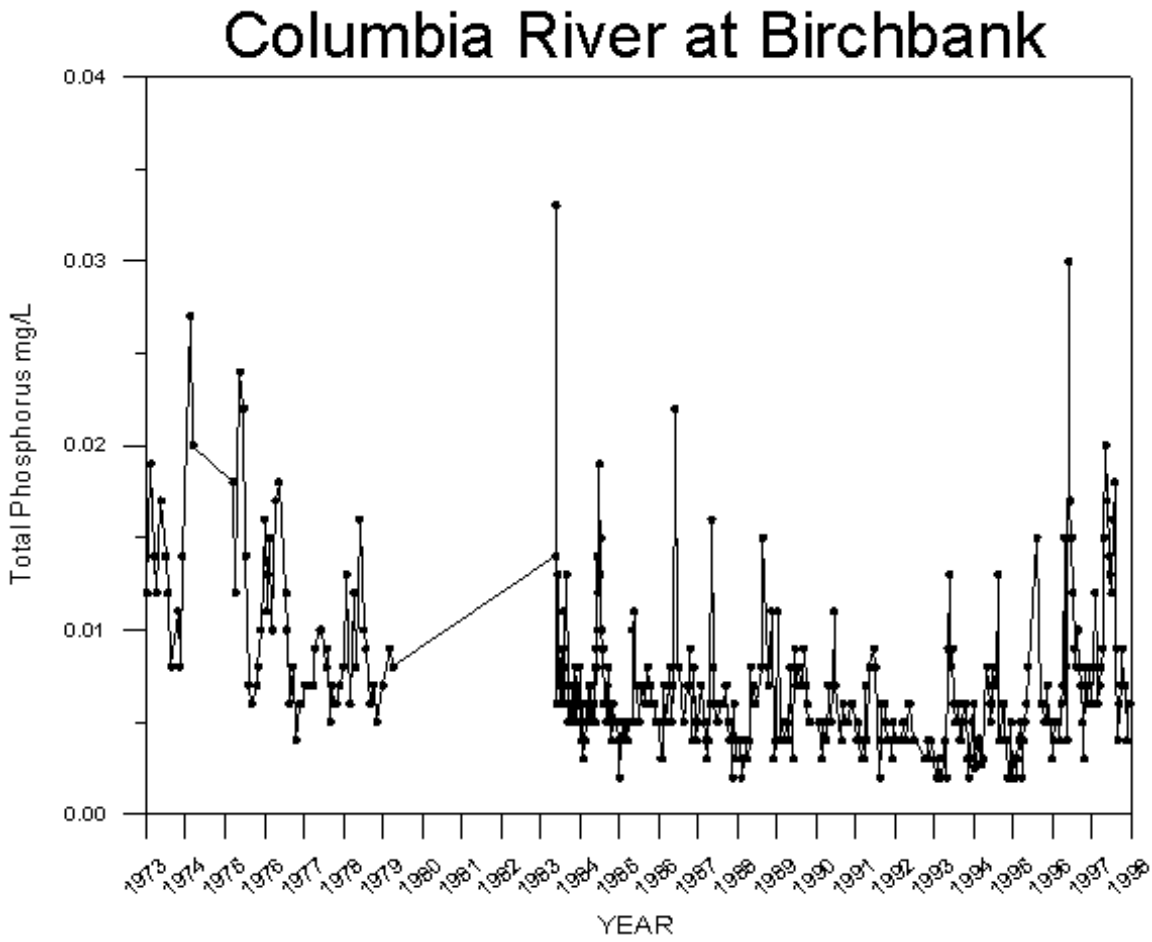

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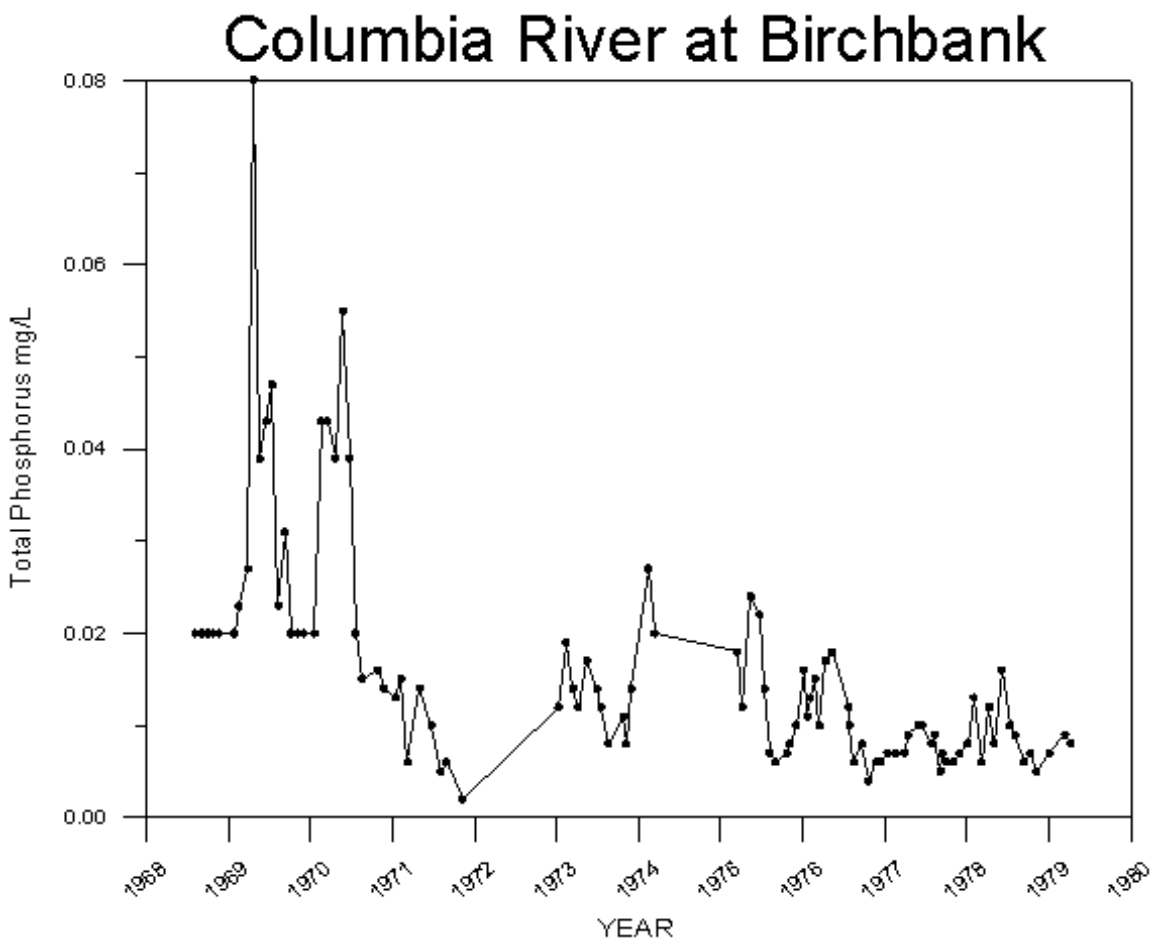

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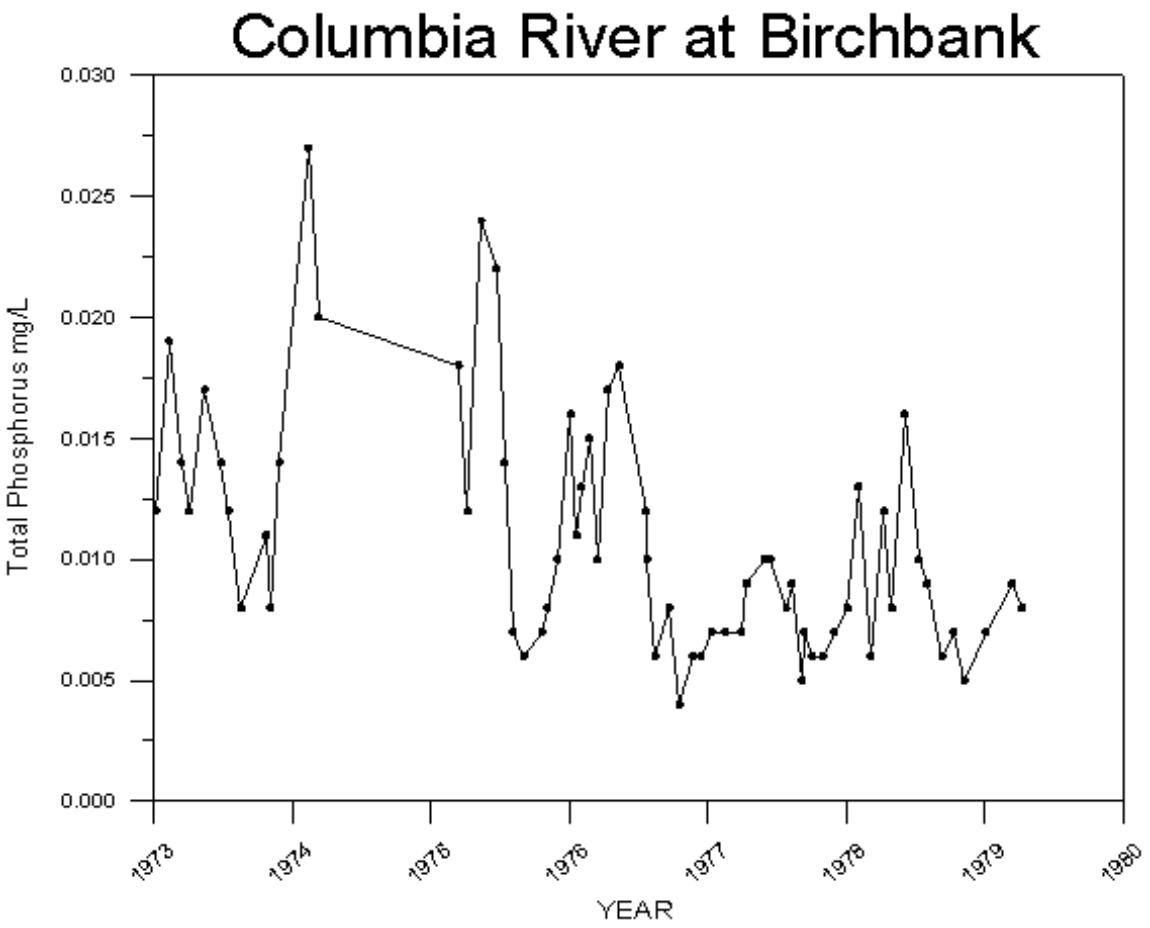

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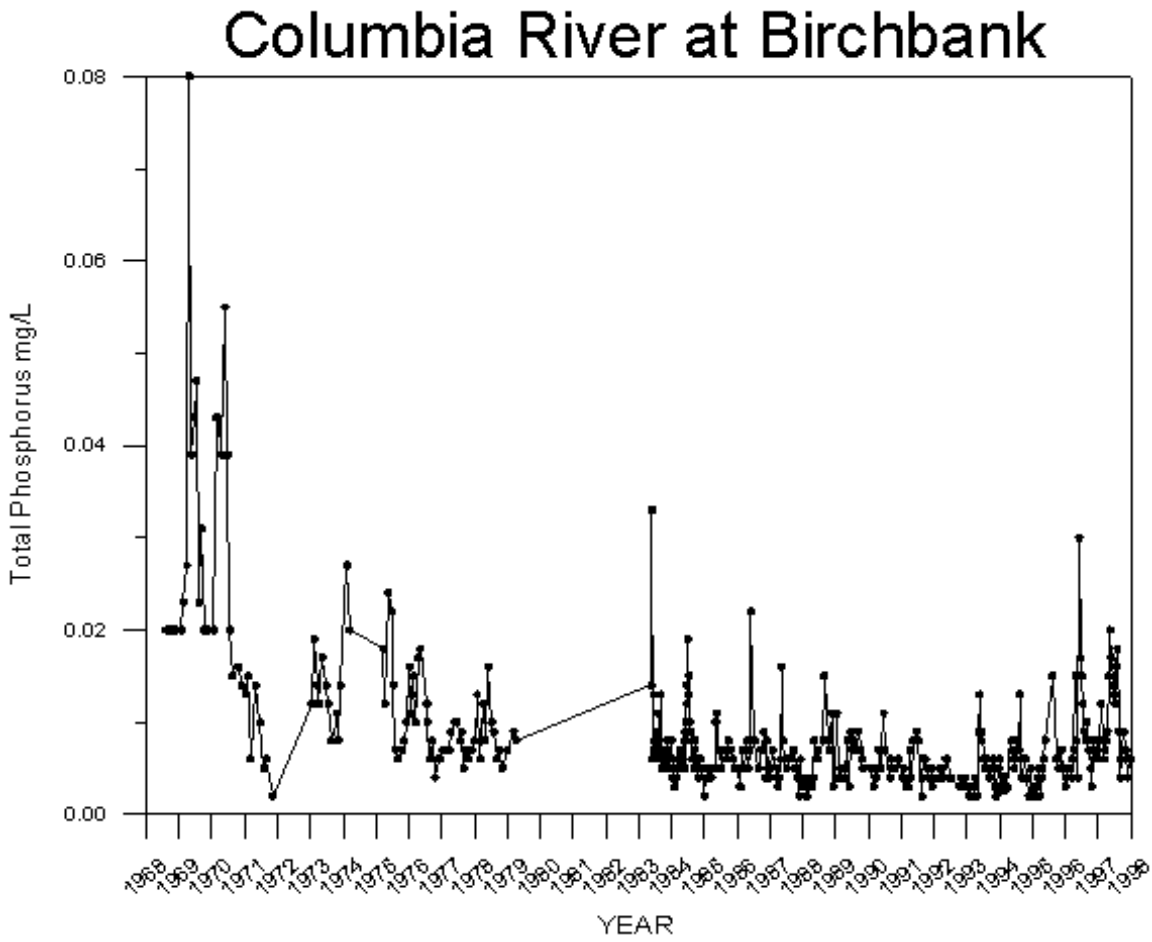

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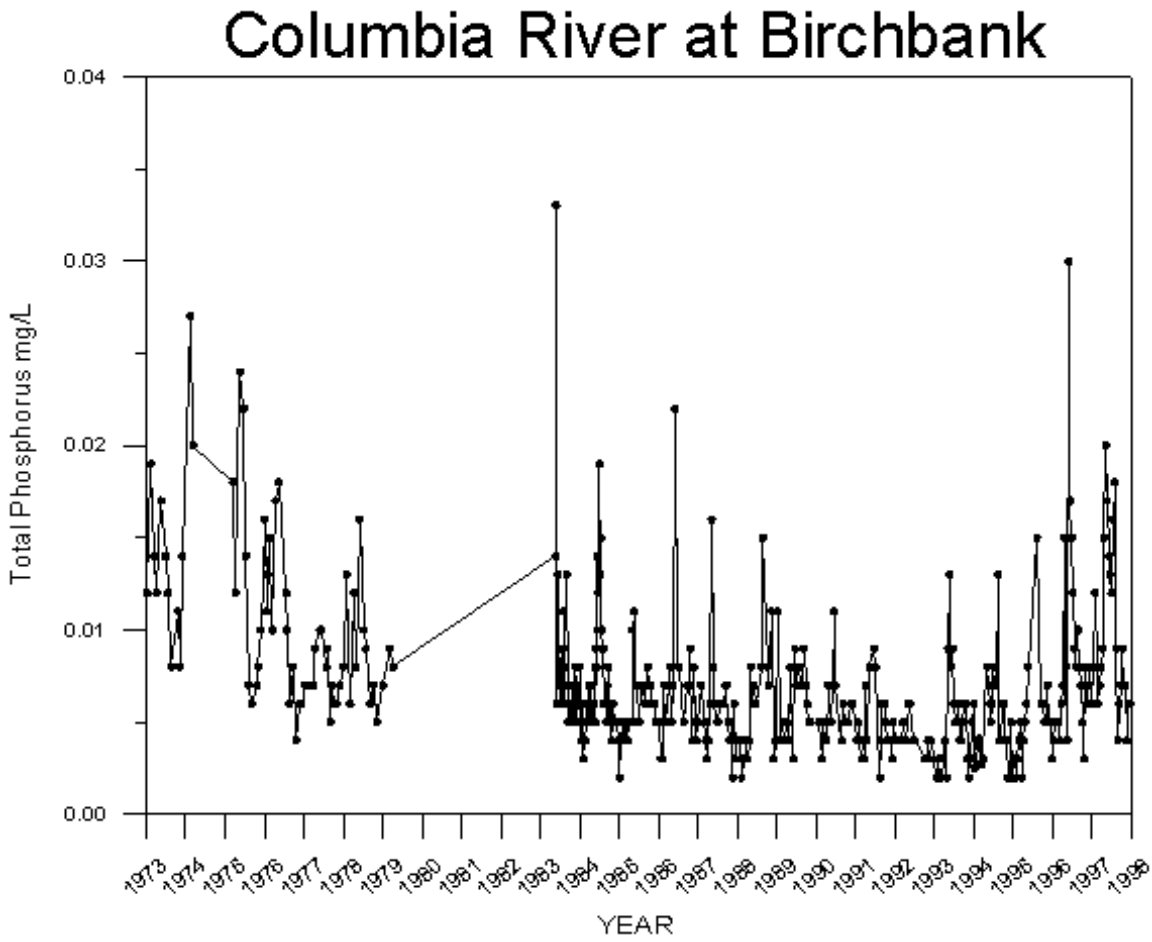

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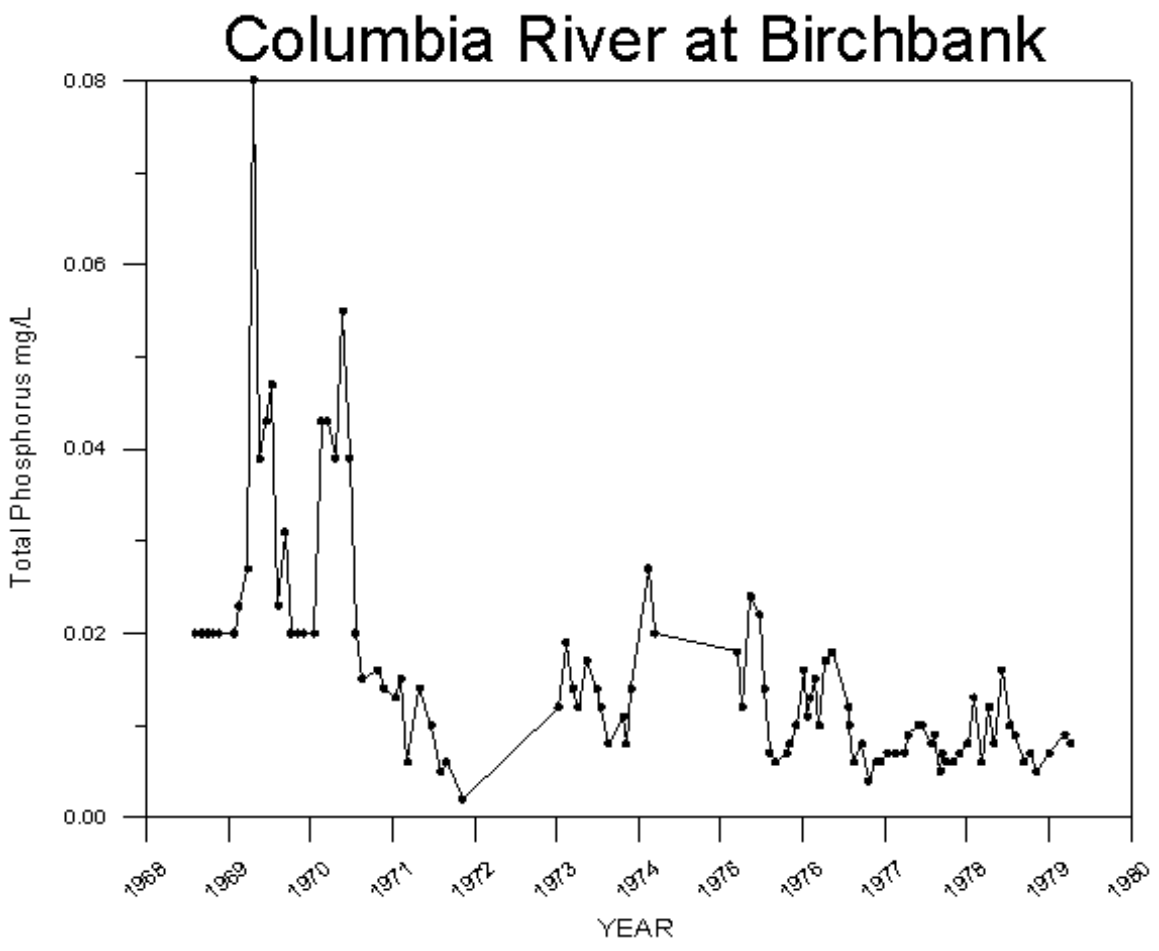

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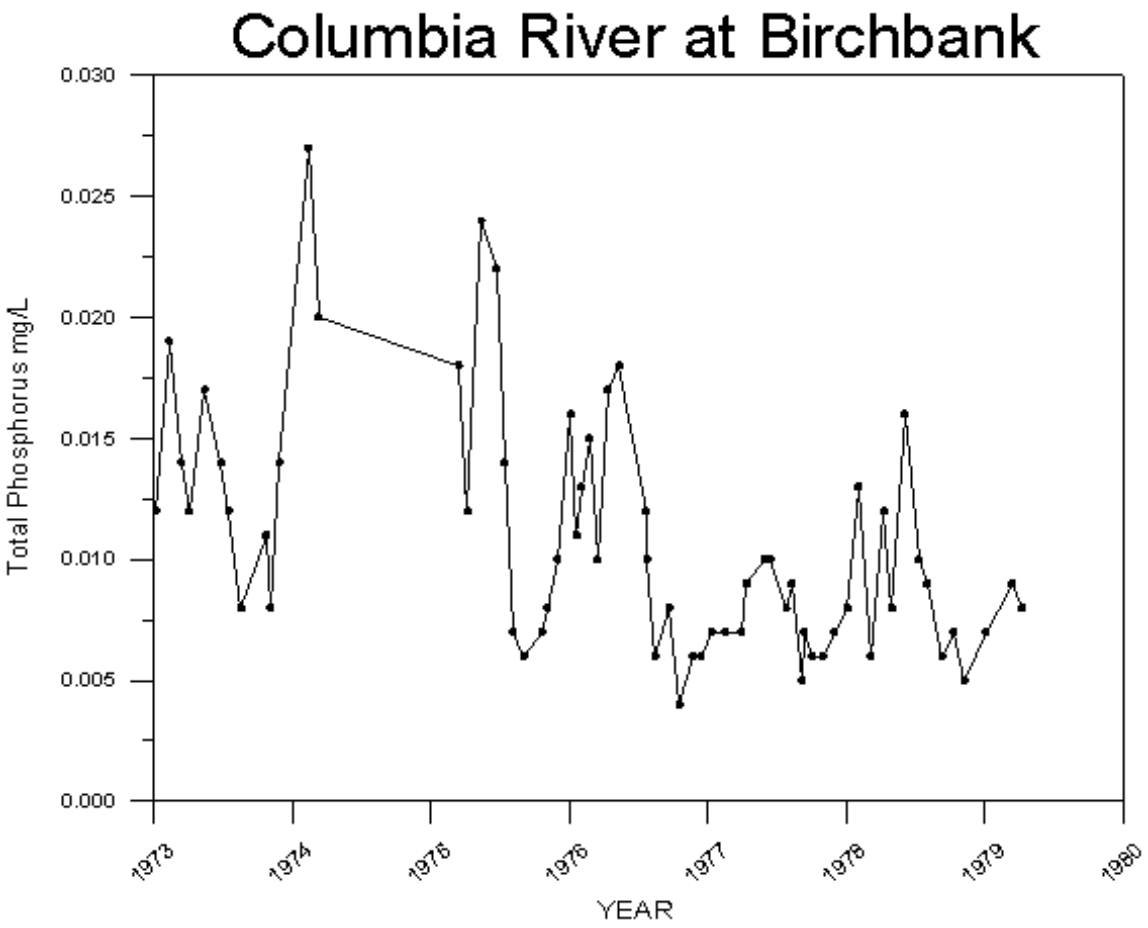
Figure 2 EMS Total Phosphorus data in the Columbia River at Birchbank 1973 - 1979.



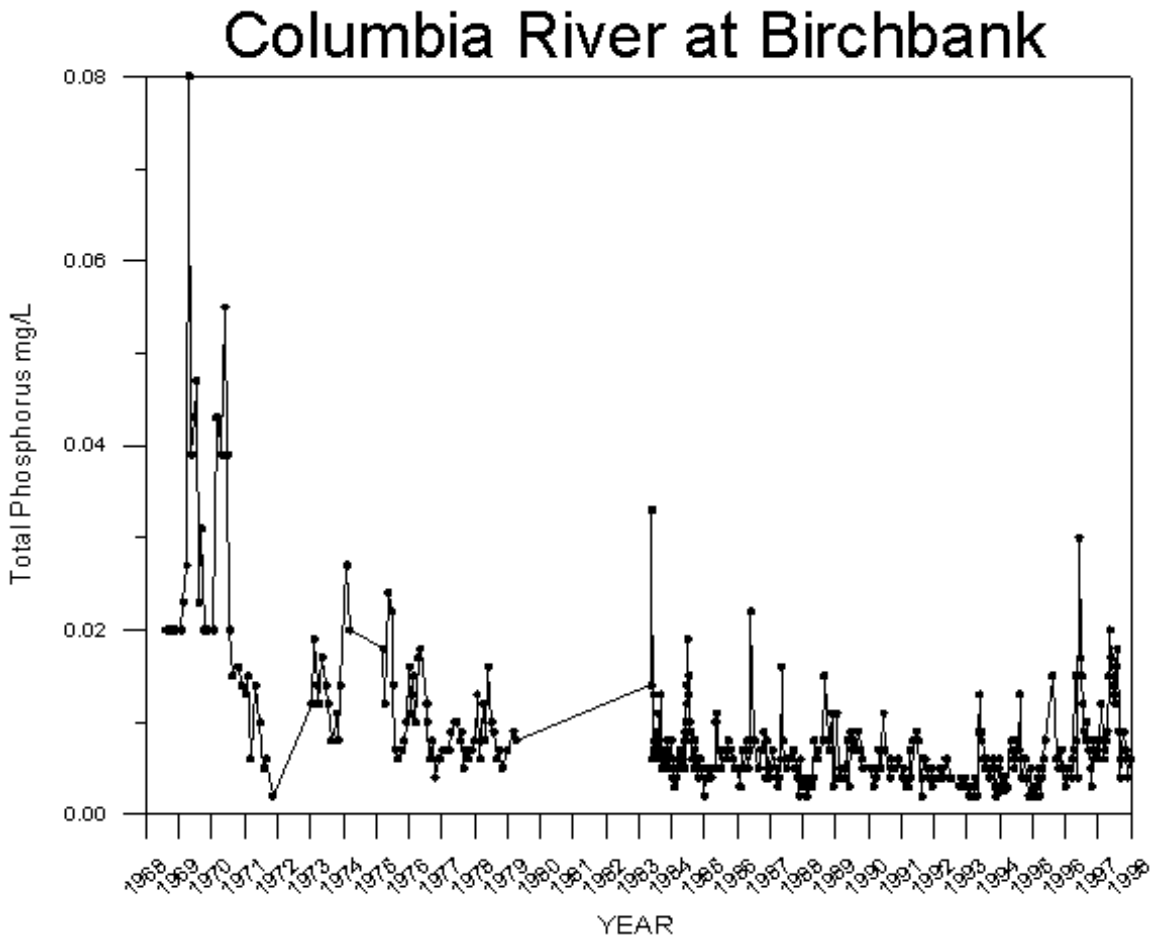
Nonparametric tests also revealed a strong linearly decreasing trend in subset (see Table 1 on page 7 of this report).

EMS and Envirodat Data Combined

1968 - 1997

This analysis combines the two database files for total phosphorus without compensating for the change of MDL early in the EMS dataset. Figure 3 shows this dataset plot.

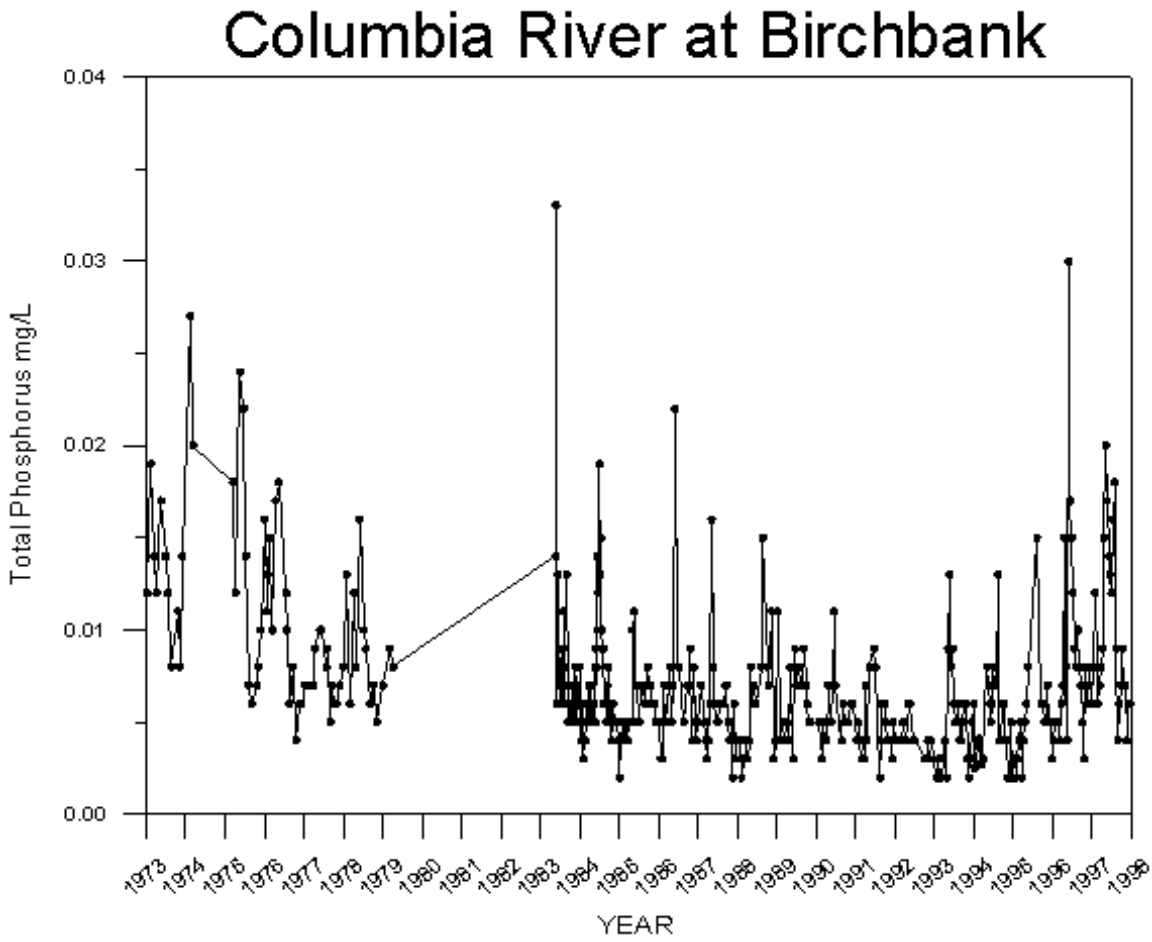
Figure 3 EMS and Envirodat Total Phosphorus data in the Columbia River at Birchbank 1968 - 1997.



Nonparametric tests revealed a strong linearly decreasing trend in this combined dataset (see Table 1 on page 7 of this report).

1973 - 1997
The final analysis was performed on this data, using a subset consisting of data from 1973 to 1997. Figure 4 shows this subset.

Figure 4 EMS and Envirodat Total Phosphorus data in the Columbia River at Birchbank 1973 - 1997.



Nonparametric tests also revealed a strong linearly decreasing trend in this subset (see Table 1 on page 7 of this report).

Table 1 Nonparametric test for trend results for total phosphorus in the Columbia River at Birchbank.

EMS 1968 - 1979		
Test	*Test Statistic*	*P-value*
SK	-7.0105	2.374e-012
SSE	-0.0018	NA
LCL	-0.0021	NA
UCL	-0.0015	NA

EMS 1973 - 1979		
Test	*Test Statistic*	*P-value*
SK	-4.0341	0.000055
SSE	-0.001	NA
LCL	-0.0018	NA
UCL	-6.6667e-4	NA
EMS & Envirodat 1968 - 1997		
Test	*Test Statistic*	*P-value*
SK	-8.5752	9.8958e-018
SSE	-0.0002	NA
LCL	-0.00025	NA
UCL	-0.00015	NA
EMS & Envirodat 1973 - 1997		
Test	*Test Statistic*	*P-value*
SK	-5.5603	2.6933e-008
SSE	-0.00011	NA
LCL	-0.00017	NA
UCL	-0.000046	NA

SK - Seasonal Kendall
SSE - Sen Slope Estimator (slope units are mg/L per year)
LCL - Lower 95% Confidence Limit for SSE
UCL - Upper 95% Confidence Limit for SSE
NA - Not Applicable