Non-parametric Trend Analyses of Annual Spring-Overturn Total and Total Dissolved Phosphorus, and Mean Secchi Depth in Williams Lake, British Columbia

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Introduction

The BC Ministry of Environment, Lands and Parks has recently reviewed long-term water quality time series to identify any potential trends. Included in these time series were the data for total and total dissolved phosphorus recorded at the spring overturn, and mean Secchi depths in Williams Lake, British Columbia.

This report summarizes the statistical analyses of the time series for total and total dissolved phosphorus concentrations, and mean Secchi depths in this lake.

Background information on this lake can be obtained by contacting the BC Ministry of Environment, Lands and Parks, Pollution Prevention, Williams Lake, BC.

Methods

Exploratory Data Analysis (EDA)

Exploratory data analysis procedures are the `initial look' at a dataset, providing a researcher with tools to select appropriate statistical tests and modeling techniques. Apart from computing basic summary statistics (means, medians, minimums, maximums, number of observations), EDA procedures are best represented by graphical displays of the data. Time series plots were used in the initial data explorations.

Non-Parametric Tests

Non-parametric 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 non-parametric tests, the *Kendall Test for Trend* and the *Sen slope estimator* were used to detect and determine magnitudes of any trends in the water quality data.

Kendall Test for Trend

To perform this non-parametric test, Kendall's S statistic is computed from the data (see Millard, 1997, or any good introductory non-parametric statistics text for details). The null hypothesis of no trend is rejected when S is significantly different from zero. Hirsch et al. (1982) note that this test is appropriate even in the presence of missing observations and censored values.

Sen Slope Estimator

This non-parametric statistic calculates the magnitude of any significant trends found. The Sen slope estimator (Sen, 1968) is calculated as follows (Y is the variable of interest; X is the time at which the i^{th} observation was taken) :

$$D_{ij} = \left[\frac{Y_j - Y_i}{X_j - X_i} \right] \text{ for } i < j, \; X_i \neq X_j$$

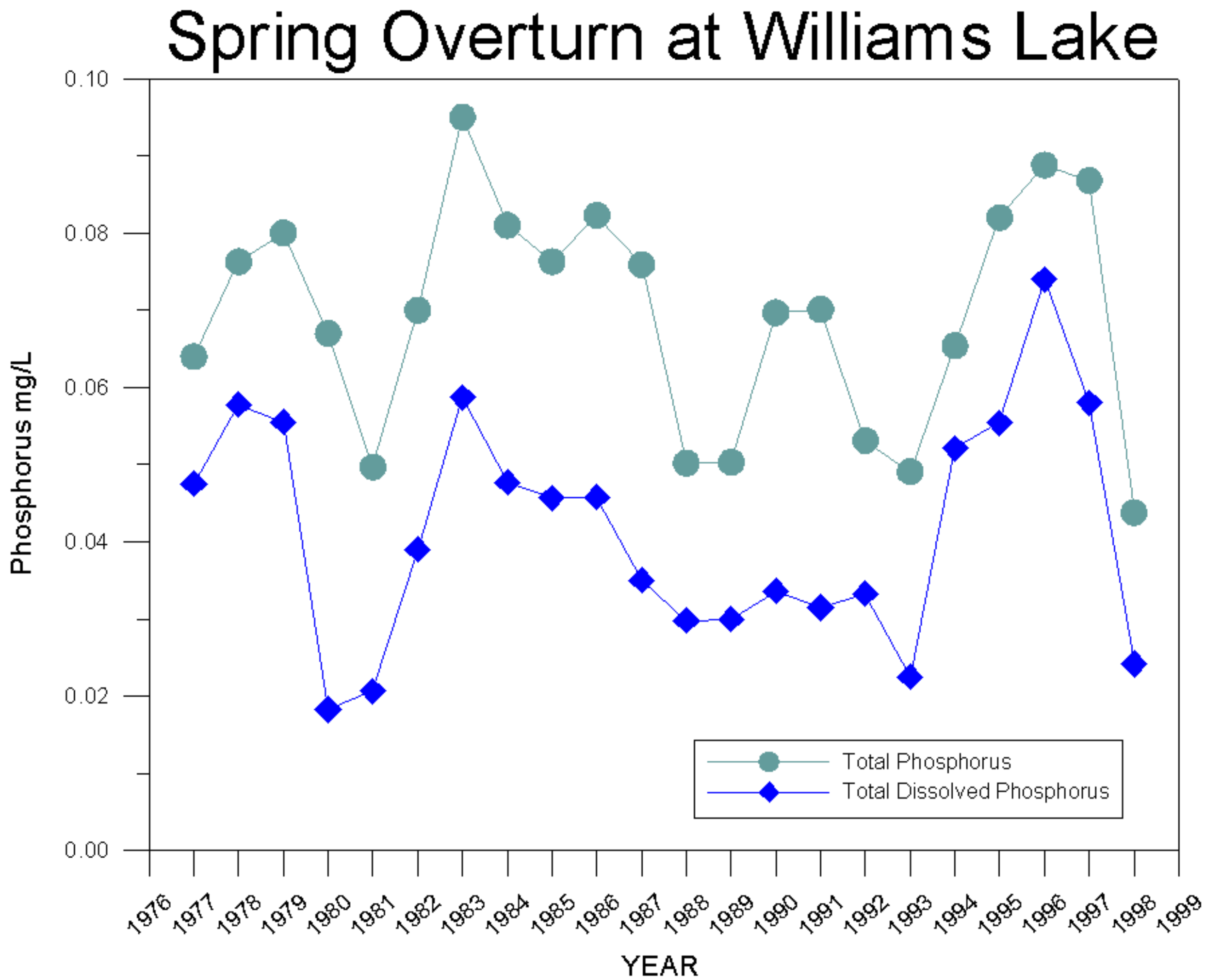
The slope estimate is the median of all D_{ij} values. Hirsch *et al*. (1982) point out that this estimate is robust against extreme outliers. Confidence bounds (95%) for this slope estimator are calculated as a simple percentile of the total number of calculated slopes (Gilbert, 1987).

Results and Discussion

Total Phosphorus and Total Dissolved Phosphorus

The data sets for total and total dissolved phosphorus in Williams Lake during spring overturn spanned 22 years, from 1977 to 1998 (Figure 1). Each sample represents a whole-lake average at annual spring overturn.

Figure 1 Time series plot of total and total dissolved phosphorus recorded at spring overturn in Williams Lake, 1977 - 1998.



Non-parametric tests indicated no evidence of any trends in either data set, with the Kendall test statistics having p-values much greater than 5% (see Table 1). Also, the 95% confidence bounds on the Sen Slope estimators included zero which further supports the finding of no trends (see Table 1).

Table 1 Non-parametric results for mean spring overturn total and total dissolved phosphorus data for Williams Lake 1977 - 1998.

	Total Phosphorus		Total Dissolved Phosphorus	
	statistic	*p-value*	*statistic*	*p-value*
Kendall Trend	-0.1976	0.8435	-0.1128	0.9102

Sen Slope	-5.0E-5	N/A	-1.412E-4	N/A
Upper CI	8.8653E-4	N/A	0.0011	N/A
Lower CI	-0.0016	N/A	-0.0016	N/A

Secchi Mean Depths

The data set for the Secchi Mean Depths in Williams Lake also spanned 22 years, from 1977 to 1998, although measurements were missing for 9 years from 1978 to 1986 (Figure 2).

Figure 2 Time series plot of Secchi mean depths for Williams Lake, 1977 - 1998.

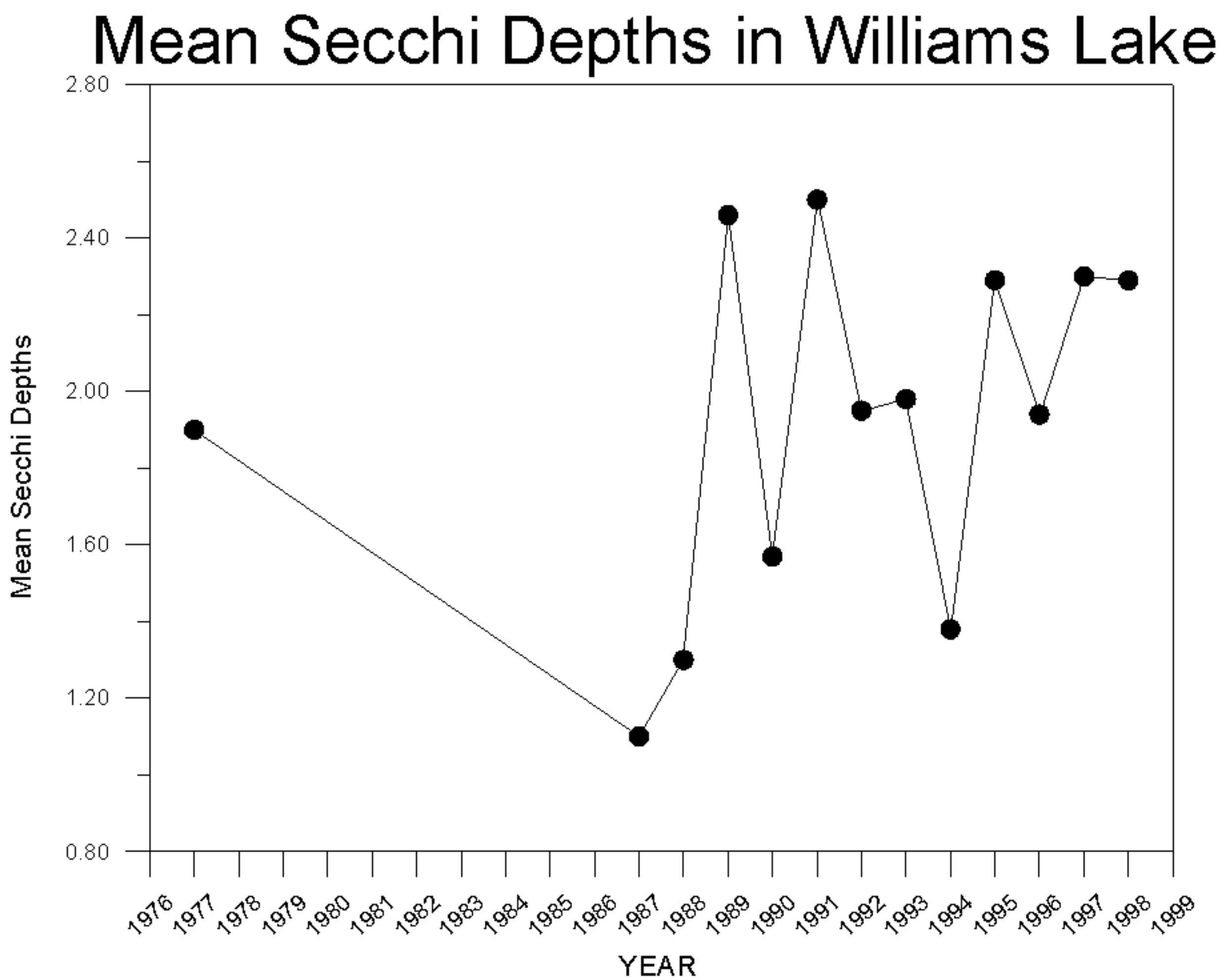


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Table 2 Non-parametric results for mean Secchi depth data for Williams Lake 1977 - 1998.

	Mean Secchi Depth	
	statistic	***p-value***
Kendall Trend	1.4669	0.1424
Sen Slope	0.0448	N/A
Upper CI	0.1360	N/A
Lower CI	-0.0189	N/A

Summary

Non-parametric trend analyses on total phosphorus, total dissolved phosphorus, and mean Secchi depths data collected in Williams Lake gave no evidence of any trends.

References

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

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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.

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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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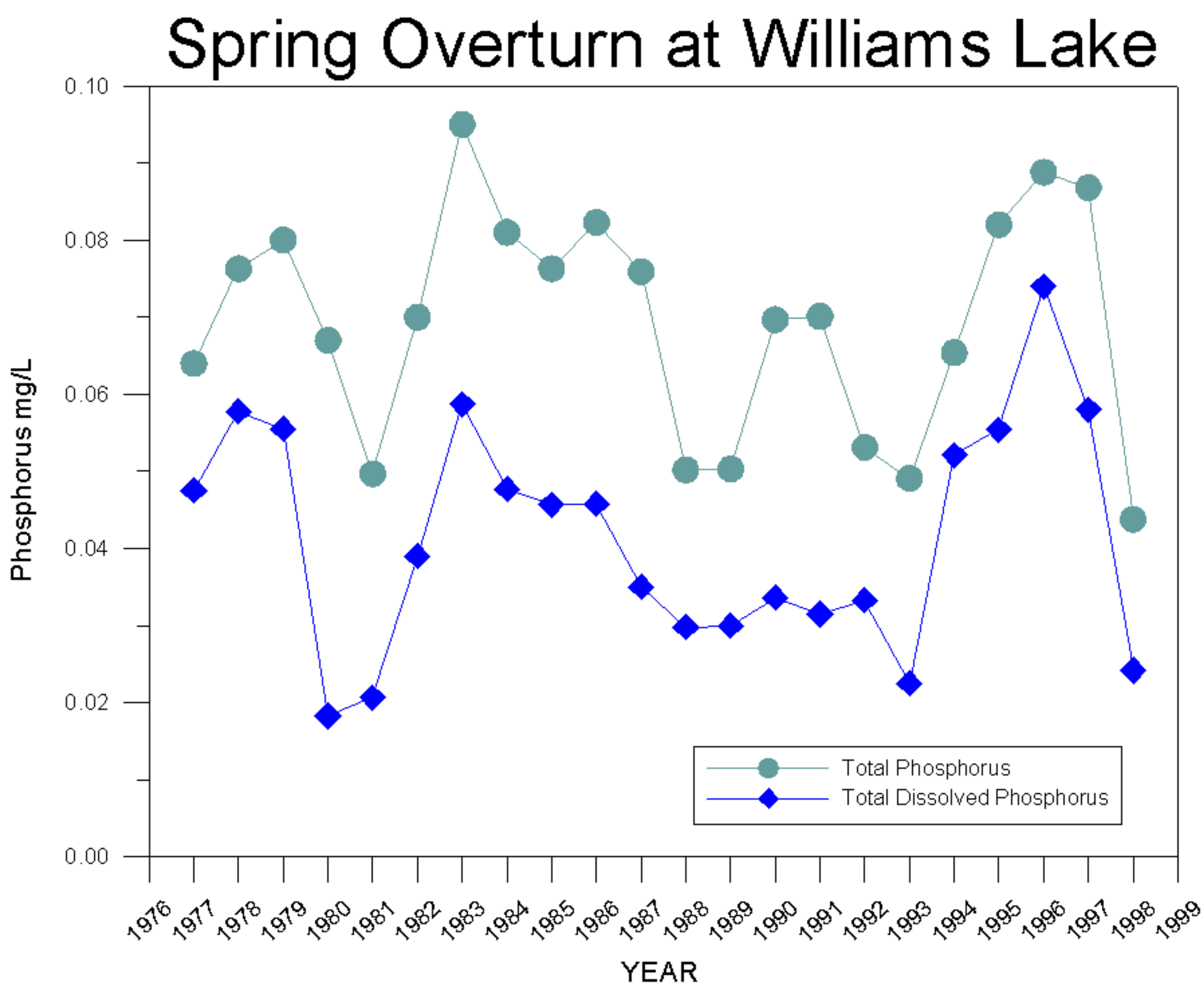

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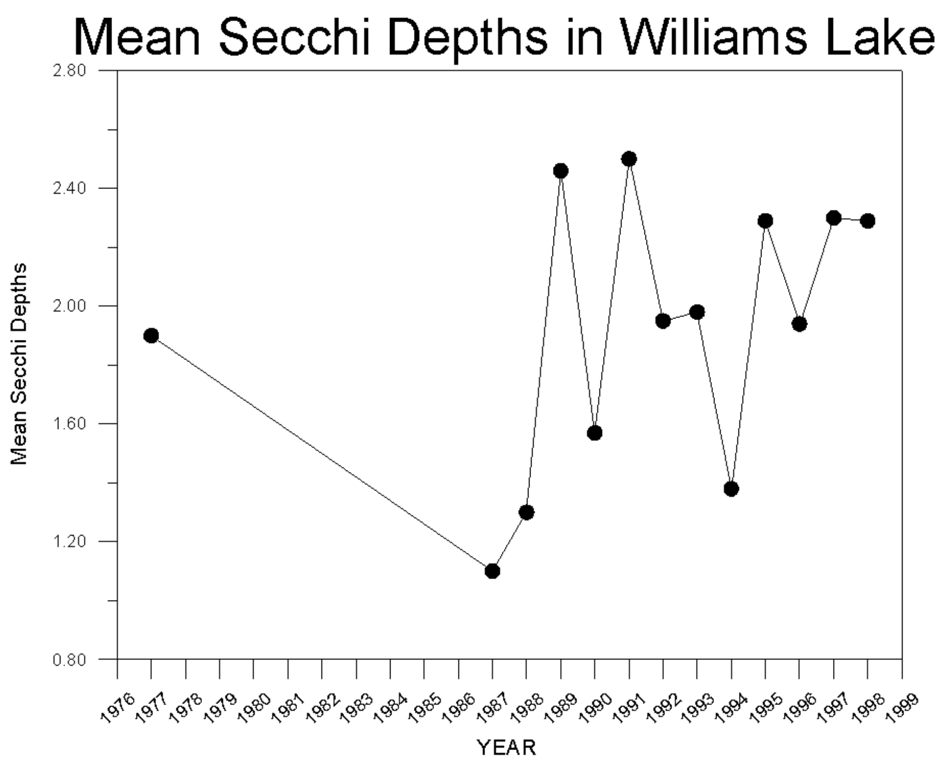

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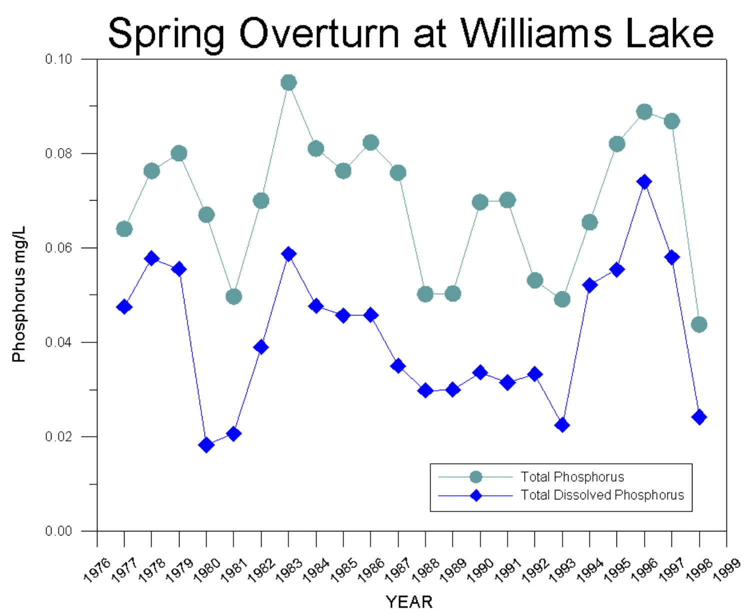

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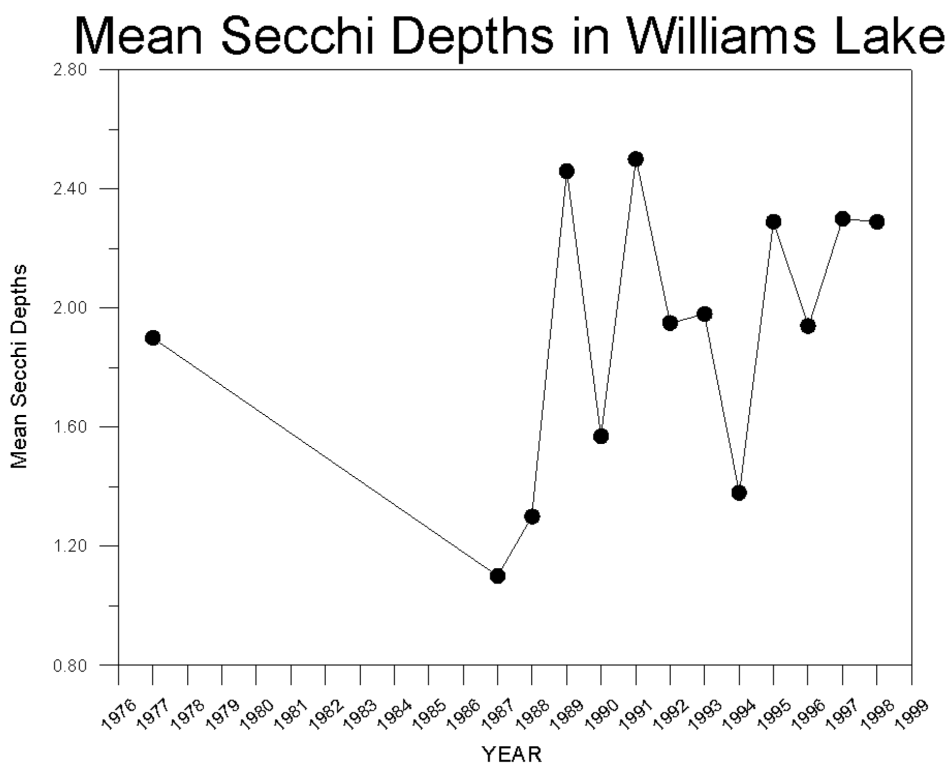

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