Phosphorus carried by small culverts into Cusheon Lake, Salt Spring Island.

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Background Report for the Cusheon Watershed Management Plan and Steering Committee
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Summary

(1) This study assessed seven culverts as a source of phosphorus for Cusheon Lake. These culverts cross under Horel and Cusheon Lake Roads. Phosphorus concentrations and loads were compared to those in Blackburn Creek (upstream of Blackburn Lake).

(2) Flow rates in the culverts were estimated for 20 days in 2004-05. They carry about 37% of the water that runs off the land, directly into Cusheon Lake.

(3) The water flow through the culverts averaged about 13% of the flow in Blackburn Creek.

(4) Phosphorus was measured on 10 days and estimated from partial data for 2 more days. The *concentration* of phosphorus in the culvert water was usually similar to the concentration in Blackburn Creek. However, the first two flushes of runoff had very high concentrations in the culverts -- two to three times higher than the creek. Phosphorus apparently accumulated on the land around Cusheon Lake during the dry season, and washed off with the first big rains. Presumably the higher phosphorus is related to human activity in this built-up area.

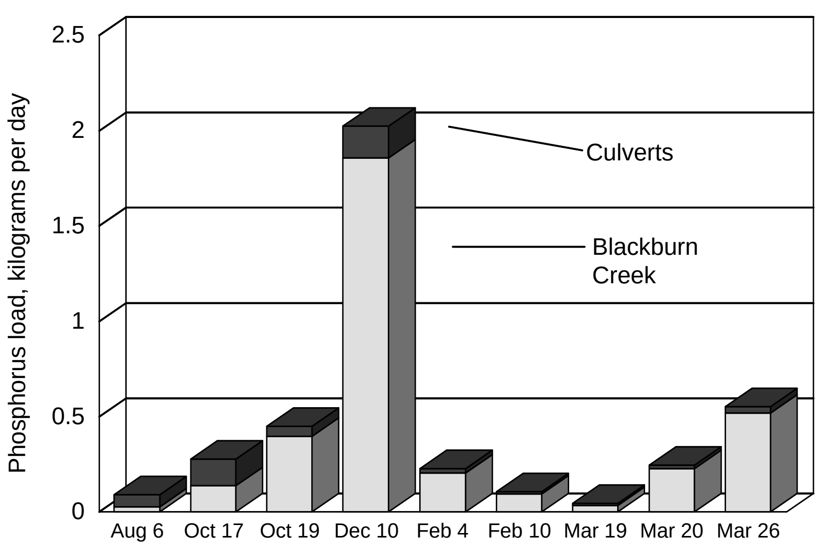

Figure 1. Comparing the loads of phosphorus in the culverts and in Blackburn Creek. Values are for nine out of ten days for which there were complete phosphorus measurements. (One day was omitted because a culvert had anomalous flows of uncertain origin.)

(5) The *load* of phosphorus moving through the culverts is the weight of phosphorus carried on a given day. It averaged only 15% of the load carried by Blackburn Creek, on the nine sampling dates shown in Figure 1.

(6) However, during the first two flushes of the wet season (August 6 and October 17) the culverts carried loads as great as, and twice as great as, the load in the creek. Because these first flushes had small flows, they did not actually contribute much of the total yearly load. Higher loading came with the heavy flows of mid-winter.

INTRODUCTION

This is a background report for the Cusheon Watershed Management Plan (CWMPSC 2007). The work was carried out under the auspices of the Cusheon Watershed Management Plan Steering Committee. The main purpose was to investigate the relative importance of small culverts as a source of phosphorus inputs to Cusheon Lake. The culverts carry local runoff water under roads, then into the lake. This water is quite obvious during the wet seasons as it runs off the land, the road surfaces, and moves through ditches to the lake. In the past, there has been speculation that the water running through the culverts was a major source of nutrients for the lake. It turns out to be a significant source, but not a major one.

The main findings are reported above in the summary. The remainder of the report provides technical details of methods, supporting data and analyses.

METHODS

Locations

Seven culverts were sampled. Six were along Cusheon Lake Road, and included all of the culverts crossing the road into the main body of the lake (upper side of Figure 2). Three of these were close together (upper right side of Figure 2). One of those three flowed out at the public parking place and dock, while the other two discharged near the waterworks pumping station.

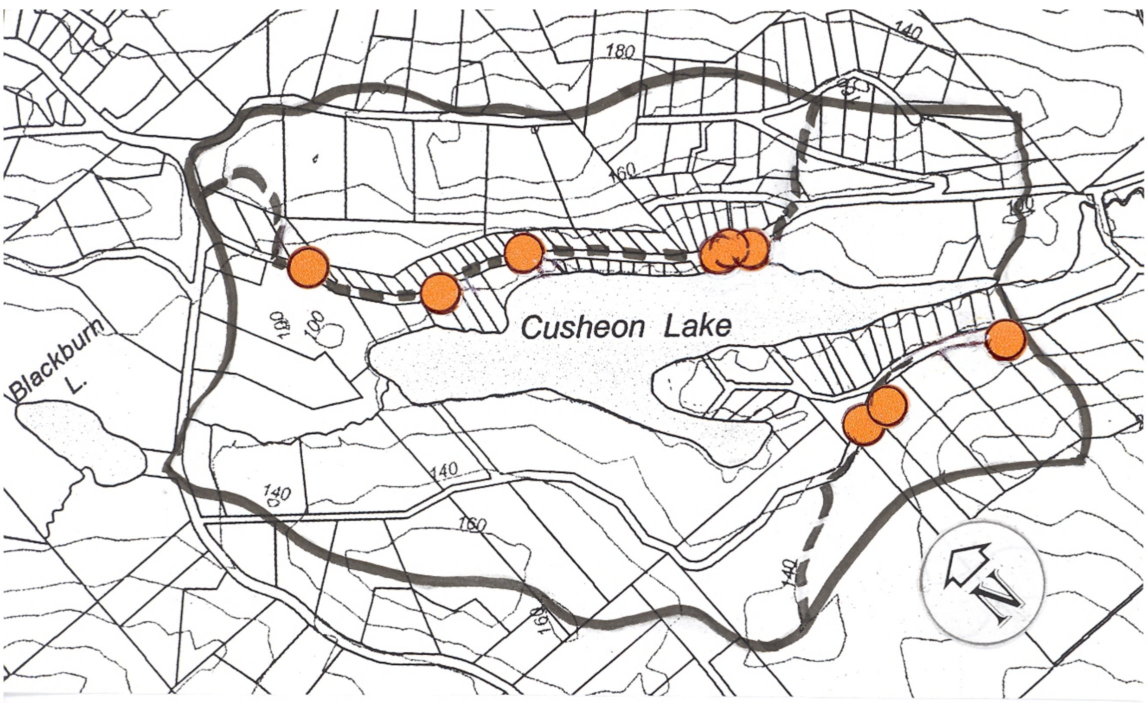

Figure 2. Locations of culverts mentioned in this report. They are indicated by circles, six on Cusheon Lake Road (north and west of the lake), and three on Horel Road (south and east of the lake). The heavy solid line is the boundary of the Cusheon sub-basin, and the heavy dashed lines show the approximate downhill boundaries of the areas drained by the culverts.

One culvert was sampled for Horel Road, the left-hand one in Figure 2. This was a five-minute walk along the road allowance beyond the end of the developed part of Horel Road. There were two other smaller culverts crossing Horel Road and shown in Figure 2. These additional points of runoff were not routinely measured and were not sampled for phosphorus analysis. They drained hillsides part way along Horel Road. Inspection at various times of the year indicated that the right-hand culvert on Horel Road had flows slightly smaller than the culvert that was sampled. The middle culvert, close to the sampled one, was small in flow and very intermittent. It was estimated that these two additional culverts had a combined flow that was approximately the same as the culvert that was sampled. Accordingly, flows measured in the single (left-hand) culvert were multiplied by two to approximate the runoff across Horel Road. Two other culverts that crossed Horel Road were not included because they did not flow to the lake, but to Cusheon Creek just downstream of the lake. These two were further to the right in Figure 2. One was at the start of Horel Road (the junction with Stewart Road), and another nearby, outside the boundary marked for the Cusheon Lake sub-basin.

In this report, “Cusheon culverts” and “Cusheon flow” are used as short names for the six culverts under Cusheon Lake Road and the water that comes out of them, and “Horel culverts” is used in similar fashion.

The lower left side of Figure 2 shows that a considerable section of local drainage to the lake was omitted from this sampling plan. That section represents a wooded area with a right-of-way for a Horel Road extension. Official maps show the extension as a road, but it is only a trail through the woods. Runoff from that wooded section of the drainage basin was not sampled, because the purpose of this study was to assess culverts draining built-up sections of the drainage basin and the roadside ditches.

The Cusheon culverts drained much of the north-westerly part of the Cusheon sub-basin, along the top of Figure 2. The Horel culverts drained a small part of the south-easterly part, along the developed section of Horel Road. Relative areas were estimated by “counting squares” on the contour map. All the culvert runoff taken together was estimated to represent approximately 36.5% of Cusheon Lake’s sub-basin. In other words, the culverts handled about 37% of “local” drainage, which does not include inputs from the upstream lakes, coming in from Blackburn Creek.

Sampling times

The culverts were dry or had only dribbles of flow for much of the year. Therefore, the sampling dates were generally during and immediately after rainfall events. Those are the times of concern for phosphorus runoff from the land. The first sample was taken on August 6, 2004, at the time of a rainfall and runoff, unusual in late summer and the first one after the dry period. The next assessment was on October 17, the first subsequent time that there was a significant rainfall event causing runoff. Thus, the study captured the first flushes of runoff from the land after the dry summer. Other dates continued through the autumn and winter until late March 2005. The snow and rainfall during this period are listed in Sprague (2007b). Most samples were collected in mid- to late morning or in early afternoon.

Flow in the culverts was estimated on twenty occasions. On thirteen of those occasions, there were direct measurements for all seven culverts. On another seven occasions, flow was measured in the six Cusheon Road culverts, but not in the Horel culvert. The total flow for the seven occasions was estimated by regression as described in a section further below.

On ten of these days there was also measurement of phosphorus concentration. There were two more days when incomplete phosphorus data were filled in by regression, as described below.

Comparison with Blackburn Creek

This study was done at the same time as a study of runoff and phosphorus in Blackburn Creek. The idea was to compare the magnitude of the load in the culverts with the load in the creek, which carried runoff from the upper part of the Cusheon watershed. Samples of the culverts were taken on the same days as samples of Blackburn Creek. All the results for Blackburn Creek are recorded in a report (Sprague 2007b). Relevant data were taken from that report, for comparison with the culverts.

The location for sampling of Blackburn Creek was at the culvert crossing Blackburn Road. This is upstream of Blackburn Lake, so the load of phosphorus in the creek does not represent exactly the load that was carried into Cusheon Lake by the lower part of the creek. It was, however, of similar magnitude (Sprague 2007e).

There are three days in January when the flows in Blackburn Creek are omitted here. The period from January 17 to 25 was a time of snow-melt, heavy rain, runoff and flooding, probably a once-a-decade event (Sprague 2007b). This event washed out the culvert on Blackburn Road and there was difficulty in measuring the flows. Because of their approximate nature they are not included here.

Methods of sampling, measurement and analysis

Flow was measured at the same time as water samples were taken for phosphorus analysis. Flow was easily measured at most culverts because they discharged at a height above the downstream gulley. A four-litre container was timed to filling with a stop-watch. Flow in litres per second was calculated later. With heavy runoff, a pail marked at eight litres was used, and for slight runoff, a 0.75-litre container.

On some occasions the flow was estimated by the velocity of the water in the culvert, assessed by a float and stopwatch. Velocity was multiplied by the cross-sectional area of water, determined from its depth and the diameter of the culvert. A factor of 0.8 was applied to any such estimates to allow for the drag on water near the walls of the culvert. This method is explained in Sprague (2007b). One culvert had difficult access so a similar procedure was followed to measure the flow in the little creek channel upstream of the culvert. Depth, width and velocity of the water were measured and a factor of 0.75 applied for bottom drag.

The flow was always measured in each of the six Cusheon culverts. These values were used to create one proportional water sample for analysis of phosphorus (see immediately below).

Water samples. Grab samples of water were taken for analysis of phosphorus. The procedures were the same as those reported in Sprague (2007b). Briefly, clean 250-mL plastic (Nalgene) sample bottles were supplied by MB Laboratories of Sidney B.C. Bottles were rinsed twice with vigorous shaking, using a small amount of the water to be tested. The bottle was drained, then nearly filled. The bottle had been pre-labelled. The sample was frozen within three hours. Later, sets of samples were carried to MB Laboratories, still frozen in a cooler.

On each occasion, one composite sample was analyzed for the six Cusheon culverts. A sample was taken from each culvert and carried to an office. There, calculations were completed for the flows in the culverts. The proportional amount of water that each culvert would contribute to the combined sample was then calculated. In other words, the amount of water from each culvert that went into the combined water sample, was calculated from the flow in that culvert as a proportion of the total six-culvert flow.

Analysis for total phosphorus was done by MB Laboratories Ltd. of Sidney B.C. Samples were analyzed by a process called *Technicon*, with reported sensitivity of 0.3 micrograms per litre (hereafter called parts per billion).

“Blind” replicate samples were supplied to the laboratory with fictitious names, and precision of analyses proved to be excellent. The average coefficient of variation was 4.2% for twelve sets of replicates (details in Sprague 2007b). Duplicate samples were also sent to the laboratory used by the B.C. Ministry of Environment, and analysed by them. The results agreed satisfactorily. Accordingly, the results given here can be tied in with past measurements by the Ministry in the Cusheon watershed.

RESULTS: ESTIMATES OF FLOW

Flows in the six Cusheon culverts.

Table 1 shows 20 days during the year when there were complete measurements of flow in each of the six Cusheon Road culverts. The measurements were totalled for the six culverts, as shown, then added to the Horel flow to yield the “Total of culverts” shown in the last column of Table 1.

The days chosen for measurement and sampling were usually at times of appreciable rainfall and runoff, because those were the days of concern for nutrient runoff. The culverts were actually dry or carried only a dribble of flow during much of the year. Two of the days in Table 1 show such zero flows in all culverts. Obviously there was great variation in flow through the culverts, from zero to a gushing maximum of about 110 litres per second at the time of January flooding. Accordingly, there were 18 days with measurable flow in the culverts, and 15 of those also had measurements in Blackburn Creek (taken from Sprague 2007b).

Limitations. The measurements at culverts should not be interpreted too closely. The data were limited to single measurements of flow taken sequentially during about 1.5 hours on any given day.

Examining the individual flow measurements at the six Cusheon culverts, it was clear that the different culverts had different runoff patterns or timing. The ratios of flow among the culverts differed appreciably from day to day, and no consistent pattern could be seen. Apparently some of the small drainage areas ran off fast, reached peak flow, and then started declining at the same time as other culverts were still building up their flow. To fully establish the relative amounts of water carried by the various culverts, an observer would have to make a series of flow measurements during and after several rainfall events.

Of course, runoff in the culverts also followed a faster pattern than the runoff and flow in Blackburn Creek (“BB Creek”). After a heavy rainfall, the early runoff through the culverts occurred several hours to many hours in advance of a peak flow in BB Creek. That must be expected since the culverts were draining relatively small areas. It took time for local runoff to reach BB creek and run downstream to the measuring point.

In view of the diversity among the six Cusheon culverts, their flows for a given day were added together, and the total was used for later analyses.

Flow in Horel culverts

The study aimed to add the runoff water crossing Horel Road to that of the six culverts crossing Cusheon Lake Road. There were 13 measurements of flow in the culvert at the end of Horel road, counting two occasions when there was zero flow. As described above in the “Locations” part of the Methods section, the Horel flows in Table 1 are twice the actual amount measured in the single culvert, to allow for the contribution of two other drainage gulleys.

There was an anomalous value for Horel culvert on November 2. On all other occasions, the measured Horel flows were one half or less of the total Cusheon Road flow. The Horel value for November 2 was more than twice the Cusheon value and the cause of this anomaly is not known. It is not thought to be an error in measurement or record-keeping. It might have resulted from some human activity upstream, where there are ponded areas. Because of the uncertainty, this anomalous value was considered an artifact and no data from November 2, from any of the culverts, were used in the analyses described below.

Table 1. **Estimates of water flow in Blackburn Creek and in culverts around Cusheon Lake.** Dates are during one year, August 1, 2004 to July 30, 2005. Data are arranged according to increasing flow in Blackburn Creek. For thirteen days, measurements in all of the culverts were complete. For seven other days, marked with asterisks, Horel Road flows and the all-culvert totals were estimated by regression. Large flows in Blackburn Creek were of uncertain magnitude for three days in January, and are not shown in the table.

Date	Flow, litres per second			
	Blackburn Creek	Six Cusheon culverts	Horel Rd culverts	Total of culverts
Sept. 11	2.0	0	0	0
July 06*	2.8	0.045	0.010*	0.055*
Aug. 06*	3.1	1.68	0.603*	2.28*
Sep. 15*	4.0	0.381	0.132*	0.513*
June 16	4.9	0	0	0
Oct. 17	15.4	6.59	0.134	6.72
Mar. 19*	21.7	1.57	0.563*	2.13*
Mar. 09*	38.4	1.04	0.370*	1.41*
Oct. 19	44.4	2.48	0.414	2.89
Mar. 02*	46.1	1.97	0.710*	2.68*
Jan. 31*	64.0	5.07	1.84*	6.91*
Mar. 20	82.7	3.22	1.71	4.94
Feb. 04	98.3	8.60	4.58	13.2
Feb. 10	129.7	9.44	3.56	13.0
Nov. 02	130.2	2.99	6.60	9.59
Mar. 26	179.4	10.6	0.503	11.1
Dec. 10	332.1	32.6	15.1	47.6
Jan. 23	--	45.7	24.8	70.5
Jan. 17	--	66.9	10.6	77.5
Jan. 18	--	76.6	34.0	110.6

Total flow of Cusheon and Horel culverts

As mentioned, there were seven days which had flow measurements for the Cusheon culverts but not for the Horel culvert (Table 1). It was desirable to have as many complete sets of data as possible for culvert runoff, and therefore an attempt was made to fill in the missing information with a predictive relationship. The attempt was successful and is described here.

A comparison was made of the total flow in all culverts (last column of Table 1), and flow in the six Cusheon culverts. The twelve data-points are shown in Figure 3.

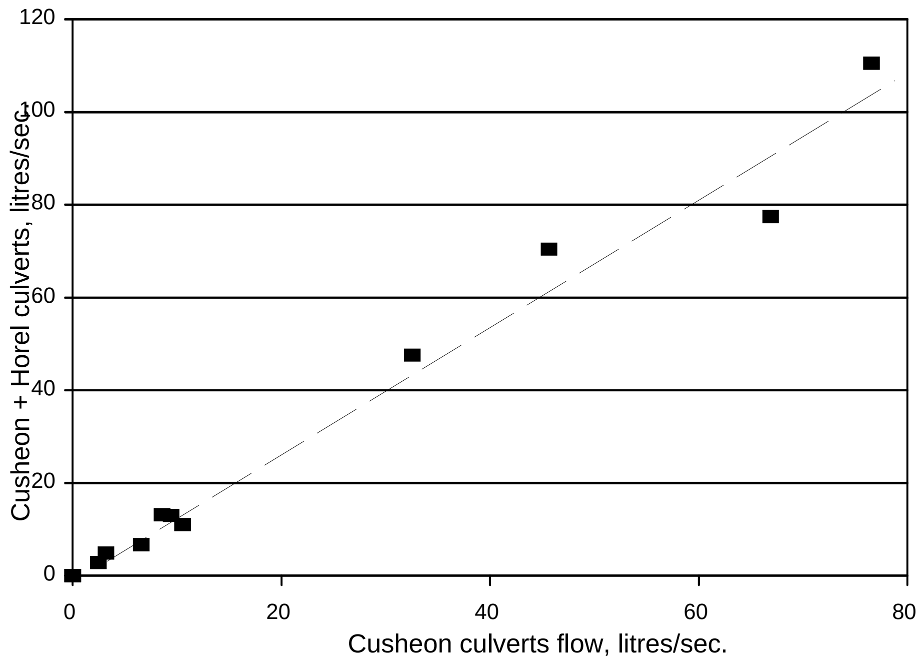

Figure 3. Total flow in all culverts compared to the combined flow of the six culverts on Cusheon Lake Road. The points represent measurements on twelve days. The line was fitted using Equation 1.

A regression was calculated for the twelve complete sets of data excluding the anomalous values of November 2 (Table 1, Figure 3). The straight-line relationship was:

Total culvert flow = (1.363475 x (Cusheon flow)) - 0.00654 (Equation 1)

The regression essentially passes through zero as shown by its line drawn on Figure 3. For the relationship, the *coefficient of determination*, or *r-squared*, is 0.98 which is considered excellent. Accordingly, the regression is considered reliable for prediction and has been used to fill in the seven missing values for total flow in the culverts. The predicted values are indicated by asterisks in Table 1 and are henceforth used as valid data.

Comments on the flows in culverts and Blackburn Creek

The calculations above complete the estimates of flow in the culverts for the year 2004-05. For 16 days, there are sets of data that include the total flow in culverts and also the flow in Blackburn Creek.

For these days, the flow in the culvert averages approximately 13% of the flow in Blackburn Creek, according to the calculated regression:

Total flow in culverts + (0.126922 x (Blackburn flow)) - 2.03199 (Equation 2)

For three other days during flooding, estimates are complete for the culverts, but values for Blackburn Creek are not given because of their uncertain accuracy. As described in the methods, the three days during the extreme storm and runoff probably represented a once-in-a-decade event.

RESULTS: ESTIMATES OF PHOSPHORUS

Phosphorus concentrations in the culverts

Measured concentrations for the six Cusheon culverts and the Horel culvert were available on ten days, and are shown in Table 2. For convenience, Table 2 repeats in columns 2 to 4, the flows from Table 1. For each day, the overall phosphorus concentration was measured for the combined flow from the six Cusheon culverts. The water sample that was measured had allowed for the relative flows in the individual culverts, as described in the methods. These 6-culvert values are shown in column 5 of Table 2 (“Cusheon culverts” column). Then the overall concentration was calculated for Cusheon plus Horel culverts, again allowing for the relative flows. These overall culvert concentrations are shown in column 7 of Table 2 (“Combined culverts” concentration).

The phosphorus load (column 8 of Table 2) was a straightforward multiplication of total culvert flow (column 4) by the combined concentration (column 7). Load is discussed further below.

There are ten sets of phosphorus measurements. They were all associated with flows that were measured, not estimated by regression. There was a very good correlation between the combined (overall) concentration and the Cusheon Road concentration, as shown in Figure 4.

Figure 4 appeared to show a straight-line relationship, so a regression was calculated for the ten sets of data. The resulting equation was:

Overall concentration in seven culverts
= (0.949555 x (concentration in Cusheon culverts)) - 6.67731 (Equation 3)

The regression had a near-perfect coefficient of determination (r-squared) of 0.991, confirming the excellent correlation.

Because of this very tight relationship, the regression was used to estimate two missing “combined” concentrations. There were two days when the Cusheon concentrations were measured, but the Horel ones were not. For those two days, the concentrations for the combined culverts were estimated from the Cusheon concentrations, using Equation 3. The estimated values for combined culverts are shown in column 7 of Table 3. The Horel concentration (column 6) was then obtained by straightforward algebra, based on (a) the phosphorus concentration in the Cusheon culverts, (b) the phosphorus in the combined culverts, and (c) the respective flows. The loading (weight of phosphorus per day, column 8 of Table 4) was also calculated by the straightforward multiplication mentioned above and will be discussed in a later section.

Table 2. Measured flows and phosphorus concentrations in the culverts. Dates are arranged in the same order as in Table 1. Some numbers do not add because of rounding.

1. Date	Flow, litres per second			Phosphorus			
				Concentration, parts per billion			Load, grams/day
	2. Cusheon culverts	3. Horel culverts	4. Total, all culverts	5. Cusheon culverts	6. Horel culverts	7. Combined culverts	8. Combined culverts
Oct. 17	6.59	0.134	6.72	245.0	46.1	241	140
Oct. 19	2.48	0.414	2.89	237.5	17.3	206	51.5
Mar. 20	3.22	1.71	4.94	53.0	17.6	40.8	17.4
Feb. 04	8.60	4.58	13.2	28.2	5.8	20.4	23.2
Feb. 10	9.44	3.56	13.0	13.8	4.9	11.4	12.8
Mar. 26	10.6	0.503	11.1	36.4	6.0	35.0	33.5
Dec. 10	32.6	15.1	47.6	55.1	9.8	40.8	168
Jan. 17	66.9	10.6	77.5	138.3	27.1	123	824
Jan. 18	76.6	34.0	111	67.2	18.7	52.3	500
Jan. 23	45.7	24.8	70.5	33.0	8.1	24.2	148

By including the two estimates of phosphorus obtained with the regression equation, there were 12 sets of data for culvert flow and the associated concentrations of phosphorus. Three of those sets of data for the culverts did not have accompanying values for flow in Blackburn Creek (during the January flooding).

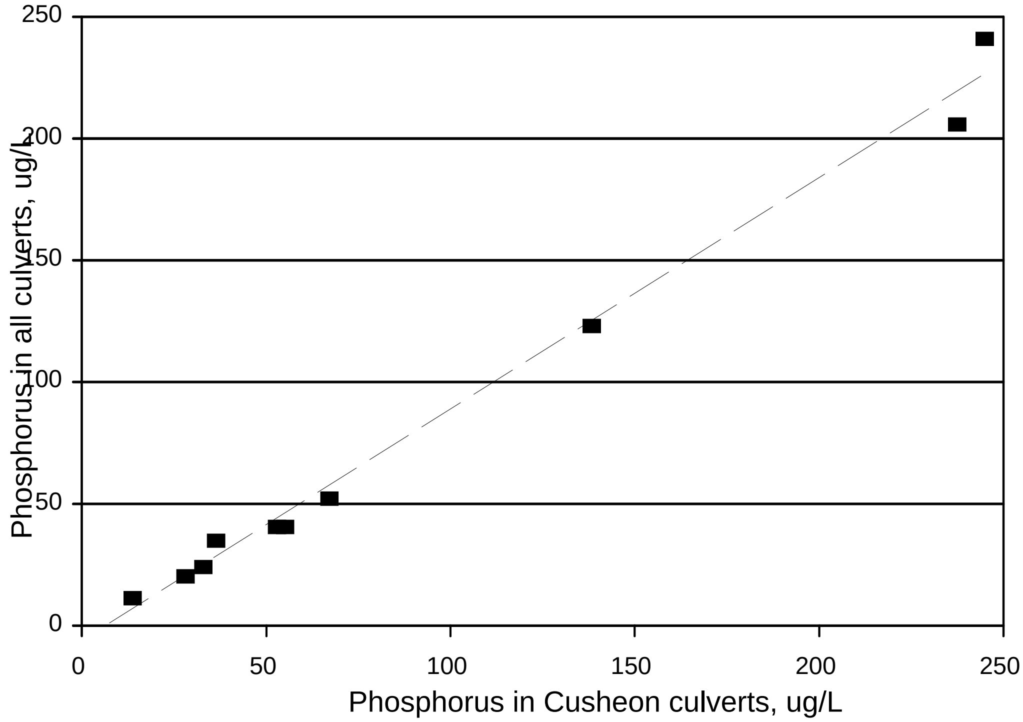

Figure 4. Concentration of phosphorus in the mixed waters of all culverts, compared to concentration in the six culverts of Cusheon Lake Road. "All culverts" represents the Cusheon plus Horel Road culverts. The ten points represent ten days when measurements were made. The line was fitted by Equation 3. Concentrations are in micrograms per litre ("parts per billion").

Table 3. Estimates of phosphorus concentration and loading in the combined culverts, for two days which lacked measurements for the Horel culverts. The estimated values (asterisks) are based on measured concentrations in the Cusheon culverts, using a regression (Equation 3) which was derived from the data shown in Table 2.

	Flow, litres per second			Phosphorus			
				Concentration, parts per billion			Load, grams/day
1. Date	2. Cusheon culverts	3. Horel culverts	4. Total, all culverts	5. Cusheon culverts	6. Horel culverts	7. Combined culverts	8. Combined culverts
Aug. 06	1.68	0.603*	2.28*	344.4	253.5*	320.4*	63.2*
Mar. 19	1.57	0.563*	2.13*	62.2	25.1*	52.4*	9.63*

Seasonal changes in phosphorus content -- nutrient runoff from developed areas

The phosphorus measurements can be arranged in a time-series to look for any obvious changes in pattern. This can be done for concentration of phosphorus in the runoff water. It can also be done for the load of phosphorus carried into the lake, that is, phosphorus concentration multiplied by volume of flow. The numbers for the culverts can be compared with those for Blackburn Creek, since those values are available (Sprague 2007b). The values for Blackburn Creek are of interest in order to make a general comparison of the culvert water with a surface creek. It must be remembered that the Blackburn samples are upstream of Blackburn Lake, and are not a measurement of the nutrient load that the creek carries into Cusheon Lake.

There are some striking features in Figure 5 which plots the 12 measurements of total phosphorus concentration from early August to late March.

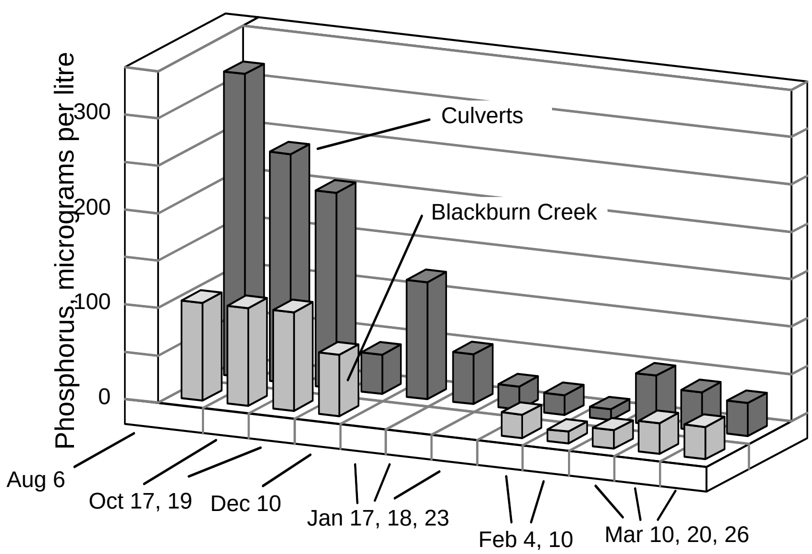

Figure 5. The relative concentrations of phosphorus in water of the culverts and Blackburn Creek on twelve days. Three January values for Blackburn Creek had extreme and uncertain flows and are absent from the graph. August 6 and October 17 were the first late-summer and autumn rainfalls causing runoff.

From Figure 5, it appears that the first flushes of runoff, after the dry summer, wash off an unusually high amount of phosphorus from the land around Cusheon Lake. In the first three measurements, concentrations are very high in the culverts, two or three times the concentration in Blackburn Creek. The highest concentration of about 300 parts per billion (= micrograms per litre) was on August 6, which was the first appreciable rainfall at the end of the dry summer. The next measurement for October 17 represented the next significant rainfall and runoff, which extended through October 19.

On those three days, Blackburn Creek was also elevated in concentration, but only to about 100 parts per billion. In other words, the lands of the general watershed upstream on Blackburn Creek do not wash off as much phosphorus in the first rainfalls, as do the lands in the Cusheon sub-basin. It seems likely that this results from the relatively large number of residences in the Cusheon sub-basin. The conclusion is that something results in a summertime accumulation of phosphorus on the surface of the soil. Lawn fertilizers would be an obvious cause, if they are used. Seepage of septic fields to the surface could be another. Ashes from “burn piles” would be a ready source of phosphorus. Another potential source might simply be an accumulation of nutrients from decayed leaves and other organic matter on the cleared land, material which could wash off easily.

Another significant item in Figure 5 is that the concentrations of phosphorus in the culverts were not excessively high during the severe runoff of January 17 to 23. Concentration went up, but only a little higher than 100 parts per billion, not nearly as high as the earlier first-flush concentrations. Apparently the earlier runoff had already carried off much of the available phosphorus.

For the rest of the samples during the wet season, the concentrations of phosphorus in the culverts were roughly similar to those in the waters of Blackburn Creek.

Relative loads of phosphorus in the culverts and Blackburn Creek

The actual *load* of nutrient carried by the culverts is the important factor for Cusheon Lake. Load is the amount or weight of phosphorus, calculated as the concentration multiplied by the amount of runoff that is flowing. Figure 1 (shown in the Summary at the start) compares the loads in the culverts with loads in Blackburn Creek for the nine days when both were available. The data for Blackburn Creek were taken from the one-year study of that creek (Sprague 2007b)

From the standpoint of load, the culverts are seen to be a relatively small source of phosphorus for the lake. For the nine occasions shown in Figure 1, the culvert load averages only about 15% of the load carried by Blackburn Creek.

Once again, however, the first flushes of runoff were high in the culverts. Although difficult to discern in Figure 1, on August 6 the culvert load was more than double the load in the creek (230%). For the second flush on October 17, the culvert load was 100% of the creek load. After that the percentages decreased sharply. The actual proportions of culvert-to-creek loads for the nine days were 230%, 100%, 13%, 9.0%, 11%, 13%, 27%, 7.7% and 6.5%. Leaving out the first two runoff events, the average for the last seven days was 9.0%. The average of 9% is about what might be expected from the small flows in the culverts, relative to the creek.

Although the culverts carried *relatively* high loads on August 6 and October 17, compared to the creek, the *absolute* loads were not that great. On August 6, the culvert load was 63.2 grams of phosphorus per day (Table 3). On October 17 the culvert load was 140 grams (Table 2). Those are appreciable, but higher loads of 824, 500, and 148 grams per day were carried by the culverts on January 17, 18, and 23 during the severe storm. During another storm event on December 10, the culverts carried 168 grams. Accordingly, the relatively high concentrations and loads in the culverts on August 6 and October 17 indicate a wash-off of surface nutrient, *but the major loading from the culverts came later in the year when there were higher runoff flows.*

In addition to that, total phosphorus loads from the culverts were about ten-fold lower than the loads in Blackburn Creek, during much of the year (Figure 1).

A relationship can be derived for phosphorus load carried by the culverts, compared to the load carried by Blackburn Creek. There are nine days with measurements of total phosphorus load in the culverts (Tables 2 and 3) and also in Blackburn Creek (Sprague 2007b). These values are shown in Table 4

Table 4. Phosphorus loads in Blackburn Creek and in the culverts of Horel and Cusheon Lake Roads. Values for the culverts are repeated from Tables 2 and 3, and values for the creek are taken from Sprague (2007b).

	Phosphorus load, grams per day	
Date, 2004-2005	Blackburn Creek	Combined culverts
August 6	27.3	63.2
October 17	137	140
October 19	35.7	9.63
December 10	399	51.5
February 4	227	17.4
February 10	205	23.2
March 19	95.7	12.8
March 20	519	33.5
March 26	1860	168

The first two dates listed in Table 4 are the days when the first culvert flushes were unusual as discussed above. For the more usual relationship on the other seven days, a regression can be calculated as Equation 4.

Load for the culverts = 0.087609 x (load in Blackburn Creek) + 3.34324 (Equation 4)

Equation 4 has a coefficient of determination (r-squared) of 0.975 which is very good. Equation 4 could be used to estimate the phosphorus load in the culverts on other days, based on the load in the creek. Despite the good r-squared value, it would be fairly speculative to use Equation 4 to predict the load from the culverts over any extended period, and that has not been done here.

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