Lake Sawyer Water Quality

A Report on Water Quality Monitoring Results
for Water Year 2011 at Lake Sawyer

Lake Sawyer

Prepared for the City of Black Diamond
by the King County Lake Stewardship Program

December 21, 2011

King County

Overview

The King County Lake Stewardship Program (KCLSP) collaborated with citizen volunteers to monitor Lake Sawyer between 1993 and 2004. Since 2006, the City of Black Diamond has contracted with KCLSP to continue monitoring Lake Sawyer. Water quality monitoring is done on a schedule of once per month between May and October, versus the typical schedule of every other week for other lakes in the program. The water quality data indicate that currently the lake has moderate productivity (low mesotrophic) with good water quality.

There is a public boat launch and a large regional park adjacent to the lake that allows members of the public to access for recreation and to launch boats. Lake users should track aquatic plants growing near shore to monitor Eurasian watermilfoil and to catch early infestations of Brazilian elodea or other noxious weeds.

This report refers to two common measures used to predict water quality in lakes. The Trophic State Index or TSI (Carlson 1977) is a method of calculating indicators from collected data that allows comparison between different parameters and predicts the volume of algae that could be produced in the lake. A second measure is the nitrogen to phosphorus ratio (N:P), which is used to predict what groups of algae may become dominant in the lake during certain periods. Both the TSI and N:P ratios have been calculated using the available data collected through the volunteer monitoring program.

The discussion in this report focuses on the 2011 water year. Specific lake data used to generate the charts in this report can be downloaded from the King County Lake Stewardship data website at:

http://www.metrokc.gov/dnrp/wlr/water-resources/small-lakes/data/default.aspx.

Or can be provided in the form of excel files upon request.

Physical Parameters

Secchi clarity and water temperatures were gathered by volunteers from May through October 2011. Physical parameters were recorded each time water samples were collected through the sampling season.

Secchi transparency is a common method used to assess and compare water clarity. It is a measure of the water depth at which a black and white disk disappears from view when lowered from the water surface.

For Lake Sawyer, Secchi transparency values ranged from 2.4 m to 4.8m, averaging 3.5 m (Figure 1). These values suggest that Lake Sawyer is clearer than 2010 and definitely much clearer than the values from the mid to late 1990s after diversion of the experimental sewage plant.

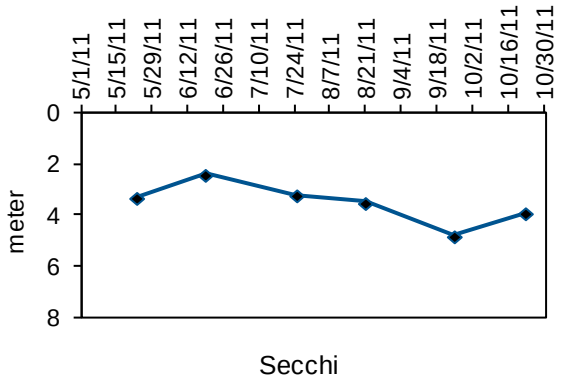

Figure 1. Lake Sawyer Secchi Transparency

Water temperatures during the sample period followed a pattern similar to other lakes in the region, with temperatures warming to summer maximum temperatures occurring between mid-July and mid-August, and temperatures cooling in the fall. The temperatures through the sampling season ranged from 14.0 degrees Celsius to 23.0 degrees Celsius with an average of 18.3 (Figure 2). The maximum temperature was in late August, reflecting the slow warming that happened in the region this year following a cool and wet spring/early summer.

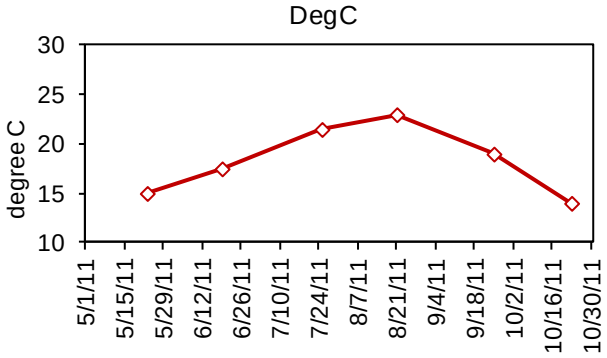

Figure 2. Lake Sawyer Water Temperatures

Nutrient and Chlorophyll Analysis

Phosphorus and nitrogen are naturally occurring elements necessary in small amounts for both plants and animals. However, many activities associated with residential development can increase concentrations of these nutrients beyond natural levels. In lakes of the Puget Sound lowlands, phosphorus is often the nutrient in least supply, meaning that biological productivity is often limited by the amount of available phosphorus. Increases in phosphorus concentrations can lead to more frequent and dense algae blooms–a nuisance to residents and lake users, and a potential safety threat if blooms become dominated by species that can produce toxins. Samples collected by volunteers

are analyzed for total phosphorus (TP) and total nitrogen (TN) concentrations at one meter depth.

In 2011, the TN started at its maximum, then decreased, followed by a peak in late July then decreased again through fall sampling (Figure 3). TP values followed a similar pattern, but started low and peaked in late July, then decreased and varied very little through the fall.

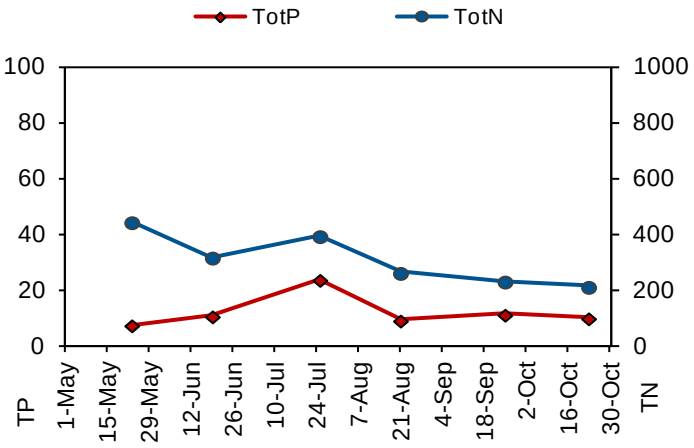

Figure 3. Lake Sawyer Nutrients

The ratio of nitrogen (N) to phosphorus (P) can be used to determine if conditions are favorable for the growth of cyanobacteria (bluegreen algae) that can impact beneficial uses of the lake. When N:P ratios are below 20, cyanobacteria often dominate the algal community due to their ability to take nitrogen from the air. Total phosphorus and total nitrogen remained in relatively constant proportion to each other through the sampling period, ranging from 20.6 to 60.0 with an average of 30.7, which suggests that conditions were generally less favorable for nuisance bluegreen growth. However, ratios were either at or very close to 20 in the fall, and this could indicate that conditions in future years could be conducive to cyanobacteria blooms in the fall.

Chlorophyll *a* values were relatively low throughout the monitoring season in Lake Sawyer (Figure 4), with the maximum value occurring in late June. The low levels reflect phytoplankton volumes in the surface water mid-lake, but do not preclude the possibility of accumulations of buoyant algae colonies along shores that are downwind. Pheophytin (degraded chlorophyll) remained near the level of detection throughout the majority of the season.

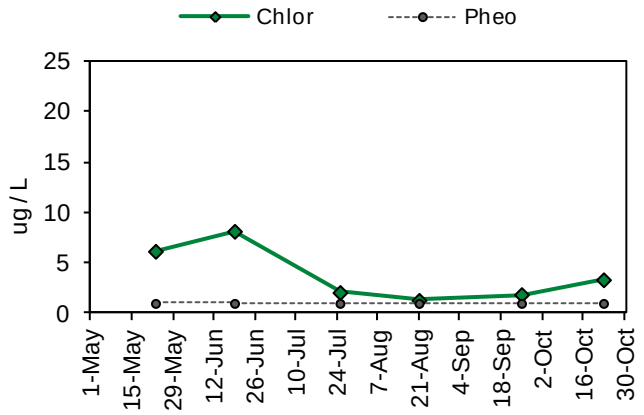

Figure 4. Lake Sawyer Chlorophyll *a* and Pheophytin Concentrations

Profile temperature data indicate that thermal stratification was present early in the season (by May) and persisted through the summer (Table 1). In the bottom samples in both May and August there were elevated levels of Total Phosphorus, as well as NH3 (ammonia) present, indicating that the hypolimnion (bottom water) of Lake Sawyer is low in oxygen early in the summer season and progresses towards anoxia, causing release of phosphorus from the sediments. This internal loading was quite apparent in the August bottom sample, in which Total P was significantly higher than it was in May. In addition, dissolved phosphate (OPO4) was present in the hypolimnion in August, further demonstrating that the anoxic conditions in the bottom water were causing internal phosphorus release from the sediments.

Table 1. Lake Sawyer Profile Sample Analysis

Lake name	Date	Secchi	Depth	DegC	Chlor-a	Pheo	Total N	NH3	Total P	OPO4	UV254	Total Alk
Sawyer	5/23/11	3.3	1	15.0	6.2	<MDL	0.444	0.0	0.0074	<MDL	0.096	53.5
Sawyer	5/23/11		8	8.0	1.9	<MDL	0.538		0.0090			
Sawyer	5/23/11		16	7.0			0.584	0.014	0.0126	<MDL		
Sawyer	8/21/11	3.5	1	23.0	1.3	<MDL	0.262	0.006	0.0091	<MDL	0.068	59.5
Sawyer	8/21/11		8	19.5	6.6	<MDL	0.475		0.0175			
Sawyer	8/21/11		16	7.5			0.556	0.198	0.0516	0.0150		

The UV254 values are indicative of clear water, suggesting that there very little dissolved organic carbon in the lake. The alkalinity value is moderate and suggests that lake is able to buffer pH changes better than the softest water lakes in the region.

TSI Ratings

A common method of tracking water quality trends in lakes is by calculating the "Trophic State Index" (TSI), developed by Robert Carlson in 1977. TSI values predict the biological primary productivity of the lake, based on measurements of water clarity (Secchi) and concentrations of Total P and chlorophyll *a*. There are 3 categories of productivity: oligotrophic (low productivity, below 40 on the TSI scale); mesotrophic (moderate productivity, between 40 and 50); and eutrophic (high productivity, above 50).

TSI-indicators are created by averaging all 1m data collected for May through October. The TSI for Total P was lower than the other two indicators, placing in the high

oligotrophic range, similar to a few of previous years (Figure 5), although it showed a small increase from 2010. The average TSI for Secchi increased slightly, though the TSI for chlorophyll decreased; both are in the mid to low mesotrophic range. The average of the indicators in 2011 placed the lake just above the mesotrophic threshold, very similar to where it has been since 1998.

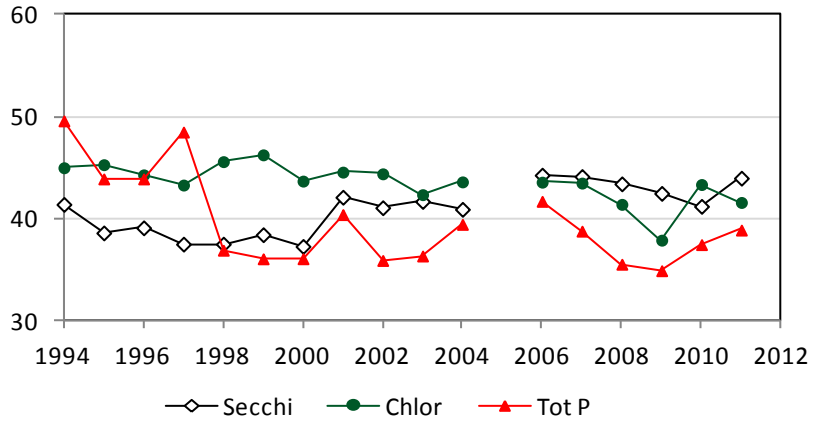

Figure 5. TSI Values at Lake Sawyer

TMDL

The Total Maximum Daily Load for Lake Sawyer set by the Washington Department of Ecology in 1993 defined a goal of an average of 16 ug/L total phosphorus concentration for the lake, but did not include the time period or water volume for which this was to be calculated. A wasteload allocation of zero was set in accordance with the removal of the Black Diamond wastewater treatment plant discharge to Rock Creek. A total annual influx of 715 kg phosphorus was estimated to meet the 16 ug/L average concentration target. Load allocations for tributary input was set at 511 kg/yr and internal loading input at 124 kg/yr, with 80 kg/yr allowed for other sources such as direct runoff and dust fall.

Onwumere (WDOE publication 02-02-054 December 2002) found that Lake Sawyer appeared to be meeting the TMDL target as a long term average, but noted that it might not be meeting a maximum in-lake mean summer target. The Lake Sawyer Water Quality Implementation Plan (June 2009) noted that significant urban growth was scheduled for the area and that such development had the potential for impacting water quality in the lake.

The long term data set collected by King County and trained volunteer monitors begins in 1985 and continues to the present, with a one year gap in 2005. Average June–September 1m values (Figure 6) show that there were a number of years around the time of the decommissioning of the sewage treatment plant when summer average phosphorus concentrations were higher than previously measured and were generally above the TMDL goal. However, since 1998 the values have been similar to the late 1980s and have shown no cause to believe that the lake is not meeting the standard set in the TMDL. There have been small increases each year over the last 4 years, but this is not a long enough length of time to predict an upward trend overall.

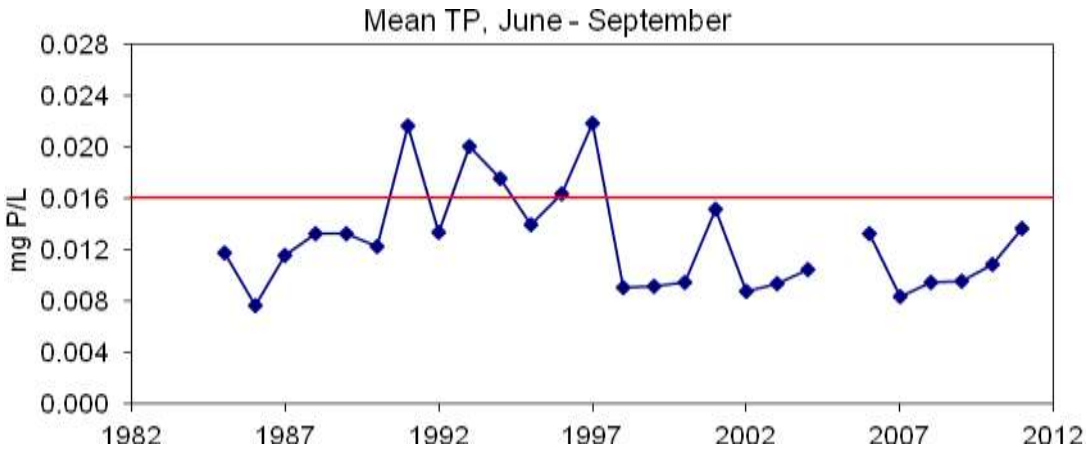

Figure 6. Summer average total phosphorus at 1m depth at Lake Sawyer

The data continue to be encouraging in that it suggests that currently Lake Sawyer is meeting the TMDL and has been doing so for over 10 years. However, because significant land development in the watershed is expected to occur in the near future, it is important to continue monitoring to look for changes as it proceeds, as well as for some time afterwards, in order to be sure that the permit controls are consistent with meeting water quality goals and targets.

Inlet Water quality

A second monitoring effort beginning in 2006 has focused on the water quality of the major streams flowing into Lake Sawyer: Rock Creek (station LSIN1) and Ravensdale Creek (station LSIN9). The program consists of sampling once a month by volunteers at the creek mouths during the wet season (generally November through May) when both creeks are flowing heavily. At the same time, water flowing from the lake at the outlet weir is also sampled (LSIN10). An additional goal was set of sampling one storm a year if possible, but this has not been accomplished in all years.

Volunteers were trained to take the routine samples and were provided with prepared sample bottles and equipment. Samples were submitted to the King County Environmental Laboratory for analysis. Parameters measured included specific conductivity and total alkalinity as indicators of development, total phosphorus and orthophosphate for TMDL monitoring, total suspended solids, temperature and water stage for flow calculations. For storms, oil and grease are measured for 3 stations of the 8 stations.

Total alkalinity and Specific Conductivity

Specific conductivity measures the amount of dissolved salts in water that can carry an electrical current at 25 degrees Celsius. Total alkalinity, also known as acid neutralizing capacity, measures the amount of calcium carbonate equivalents in the water that act as a buffer, thus moderating pH changes. It is closely related to the “hardness” of the water.

In general, both specific conductivity and total alkalinity are tied to the soil types and rocks found in the drainage basin. Both parameters generally increase as a basin is developed because of soil disturbance, as well as concrete emplacement. Because of this, they can be used as indicators of development over time.

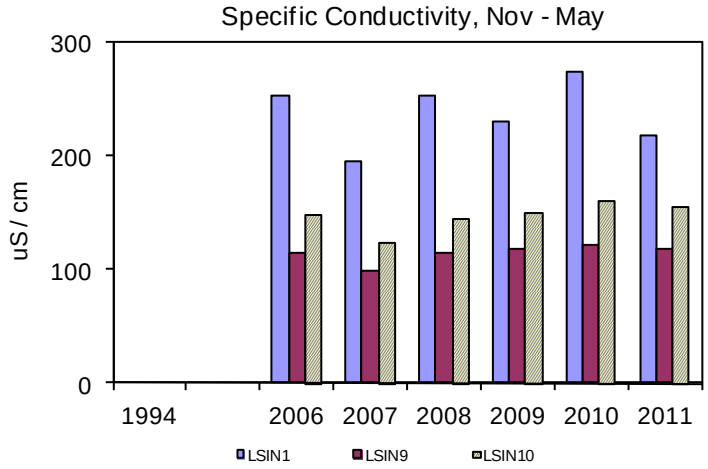

Figure 7. Wet season average of specific conductivity for Lake Sawyer and inlets

Rock Creek (LSIN1) is higher in specific conductivity than Ravensdale each year (Figure 7), while water from Lake Sawyer at the outlet appears to be a mixture of the two, but is somewhat closer to Ravensdale in value. The hydrological model constructed in the 1990s for the Lake Management Plan assigned more inflow from Ravensdale than Rock Creek, based on the measurements taken in 1993-1994. Therefore, the water from Ravensdale that has lower specific conductivity would have a greater effect on the specific conductivity of the lake than the smaller inflow from Rock Creek. This is also consistent with present land use in the two basins; in particular it should be noted that Rock Creek drains a currently inactive coal mining site that includes bare soils and rock outcroppings and in the future may receive surface water flows from several large planned developments in the watershed. Unfortunately, specific conductivity and total alkalinity were not measured before 2006, so a long-term comparison cannot be made to the time period when the experimental sewage treatment plant was operating.

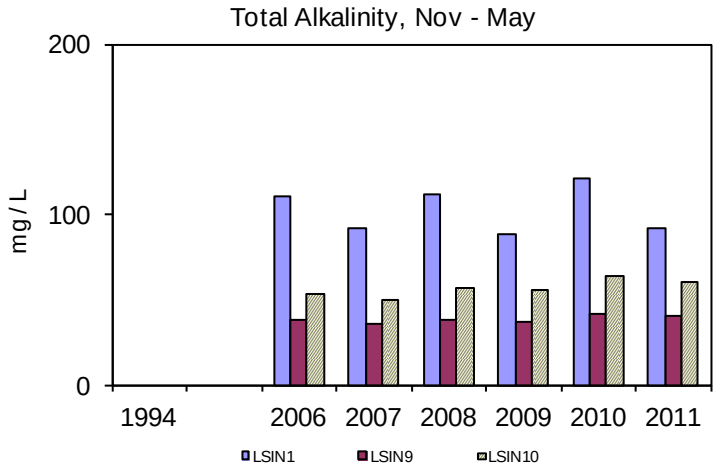

Figure 8. Wet season average of total alkalinity for Lake Sawyer and inlets

Total alkalinity, which is a measurement of the acid buffering capacity of the water, follows the same general pattern as specific conductivity (Figure 8). Alkalinity in the lake is higher than in Ravensdale Creek, but significantly lower than Rock Creek. Alkalinity values can be impacted by development of forested land due to factors such as ongoing leaching of concrete structures, soil horizon disturbances, and emplacement of foreign materials as fill to contour landscapes. As development proceeds, monitoring will document changes in water alkalinity that should reflect increased activities.

Phosphorus

Inputs of both total phosphorus and orthophosphate were also measured on a monthly basis from November through May. Total phosphorus is a measure of all phosphorus in a sample, in both dissolved and particulate form, while orthophosphate is comprised of dissolved, inorganic phosphate that is readily available for immediate uptake as a nutrient for algae and aquatic plants. While theoretically all phosphorus could be available for biological growth over time, in practice a certain amount entering the lake is likely to be buried in the sediments and never reach the water column in an available form or alternatively may flow out of the lake in the outflow, particularly in winter when the lake water is mixed thermally and the lake has a low water residence time.

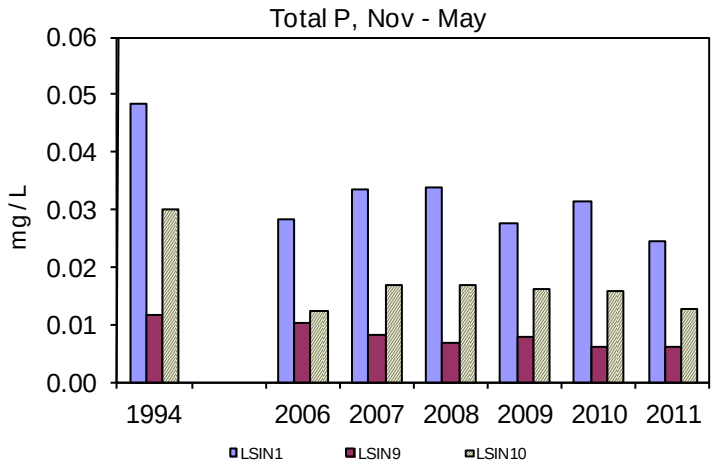

Figure 9. Wet season average of total phosphorus for Lake Sawyer and inlets

Total phosphorus is clearly lower at all three sampling sites when compared to the 1994 water year (Figure 9), with the most dramatic decline occurring in Rock Creek, consistent with the diversion of sewage effluent from the wetland as called for in the TMDL for phosphorus reduction. A significant decline has occurred in the Lake Sawyer outlet as well, and this may reflect a decrease in the pool of sedimentary phosphorus recycled internally with the fall overturn. However, this data represents winter flows and lake concentrations, while the state-adopted TMDL is does not delineate the time period to be used for evaluation.

There is a well-documented relationship between winter phosphorus concentrations in temperate lakes and spring/summer algae production, so that lower winter P values may be used to predict algae production the next growing season. There is a lag time for most Pacific Northwest lakes between when the most phosphorus enters lakes (winter) and

when it is utilized (summer). This is due to the seasonal variation in climate, which delivers most inflow to water bodies during the winter, while summer tends to produce very low base flows with little water delivery to lakes, as well as little outflow. The result is that summer nutrient inputs may actually be very small though the concentrations in the inlet waters may be high. Thus, the decrease in winter phosphorus concentrations is a good indicator for Lake Sawyer that suggests that algae may also be reduced, and the data so far are encouraging in terms of the future prognosis for the lake.

A similar pattern was found for orthophosphate (OPO4, Figure 10). The apparent increase over the 3 years 2006-2008 should not cause alarm, as some variation between years can be expected based on flows and the randomized nature of sampling dates, and since 2008 the value has dropped. Trends generally cannot be reliably calculated until a minimum of 8 consecutive years of data have been collected; however, the 6 years collected to date suggest that no trend is suggested so far either in the lake or Ravensdale Creek. In 2011, the OPO4 average was a little higher than in 2010 for Rock Creek and the lake outlet, while Ravensdale remained essentially the same.

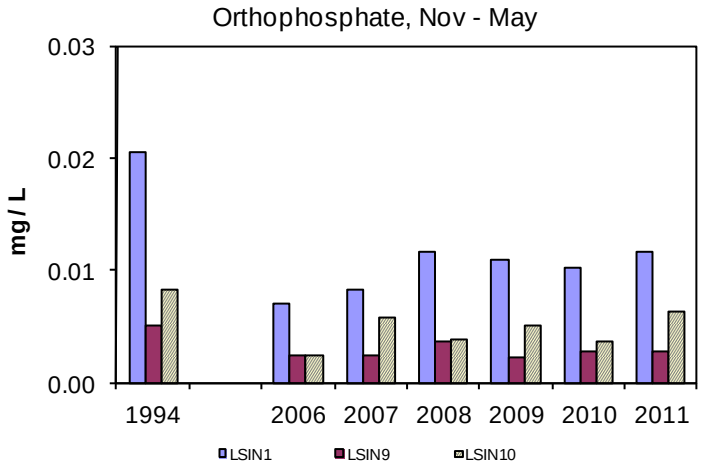

Figure 10. Wet season average of orthophosphate for Lake Sawyer and inlets

Storm water samples

The technical services contract between Black Diamond and King County called for sampling 1–2 storm events each year during November–May, but in the past it has been difficult to match up the meeting of storm criteria with volunteer availability and the operational hours of the King County Environmental Laboratory.

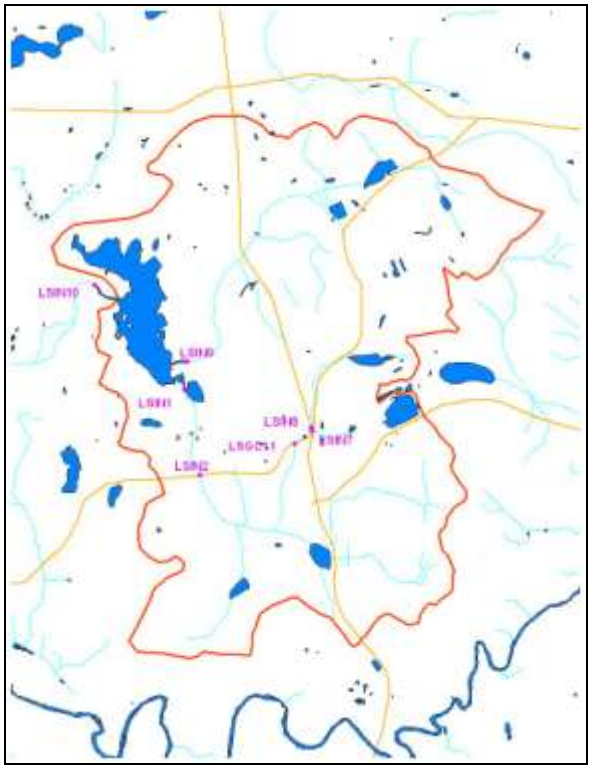

Figure 11. Location of storm sample sites on Ginder Creek, Rock Creek, Ravensdale Creek and the Lake Sawyer outlet

In 2010 and 2011, staff from the city of Black Diamond agreed to sample stream sites during business hours if a precipitation event met the storm criteria, and this resulted in storm events sampled on 28 May 2010 and 13 January 13 2011 at seven sites (Figure 11). Storm samples were taken by collecting a single grab sample from each site as soon as possible after the criterion of 1' of rain in 24 hours had been met.

The measured parameters were the same as for the routine sampling, with the addition of "Hem:oil and grease" measurements (Hem stands for hexane extractable materials) at 3 stations: LSIN1 (mouth of Rock Creek), LSIN9 (mouth of Ravensdale Creek), and LSIN10 (outlet of Lake Sawyer). All three samples were below the minimum detection level of 2.1 – 2.3 in the January storm, while they were below or just barely above detection levels in 2010. This suggests that there were no extraordinary sources of oil and grease to the surface water during either storm event. At present, there are no state water quality standards for oil and grease concentrations.

The following discussion includes the data from 3 previous storm events, dated 5 November 2006 and 24 March 2007, which were sampled by volunteer monitors, and for 28 May 2010 sampled by city staff.

Total alkalinity and Specific Conductivity

Comparing values among stations for alkalinity or conductivity can point to a particular stretch of waterway where inputs are entering the stream from increased development, such as building new structures or increased soil disturbance. A jump in value for either

of these parameters can occur in stormwater running over impervious surfaces or exposed soils and subsoils.

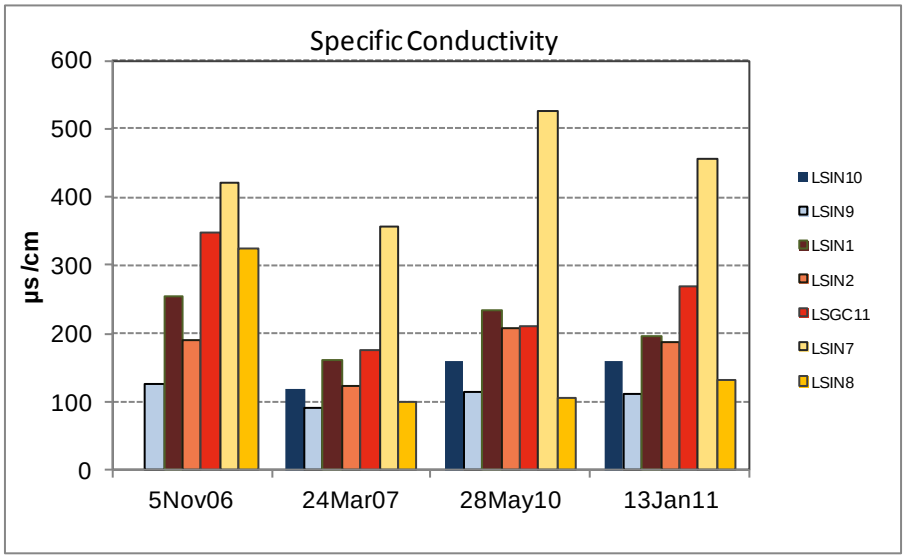

Figure 12. Specific Conductivity at 7 sites for 4 specific storm events in the lake Sawyer watershed.

In Figure 12 and the subsequent figures representing storm samples, the dark blue bar represents the outlet from Lake Sawyer, while light blue is the lower station on Ravensdale Creek. The yellow, orange, and brown bars represent tributaries and stations along Rock Creek's path from upstream to the mouth, from the Ginder Creek crossing under Highway 169 (site LSIN8 and tributary LSIN7 before it enters Ginder) downstream to the creek crossing under Roberts Drive (LSCG11) flowing south. Rock Creek site (LSIN2) is where it crosses under Roberts Drive flowing north to Lake Sawyer, while LSIN1 is the routine monitoring site at the mouth just before Rock Creek empties into Lake Sawyer. See the map in Figure 12 for geographic relationships.

There is a distinct pattern reflected in all 4 events, even though storm sampling by taking single grab samples is notoriously variable in results. LSIN7 consistently has the highest value of all the samples, which likely relates to the nature of the mine site on the property that it drains. When it combines with water in Ginder Creek, the resulting water is between the two upper stations in value, but generally still higher than LSIN2, which includes water from three other tributaries that dilute the Ginder Creek input. There is a consistent increase in conductivity between LSIN2 and LSIN1 where the water flows through a large gravel operations site.

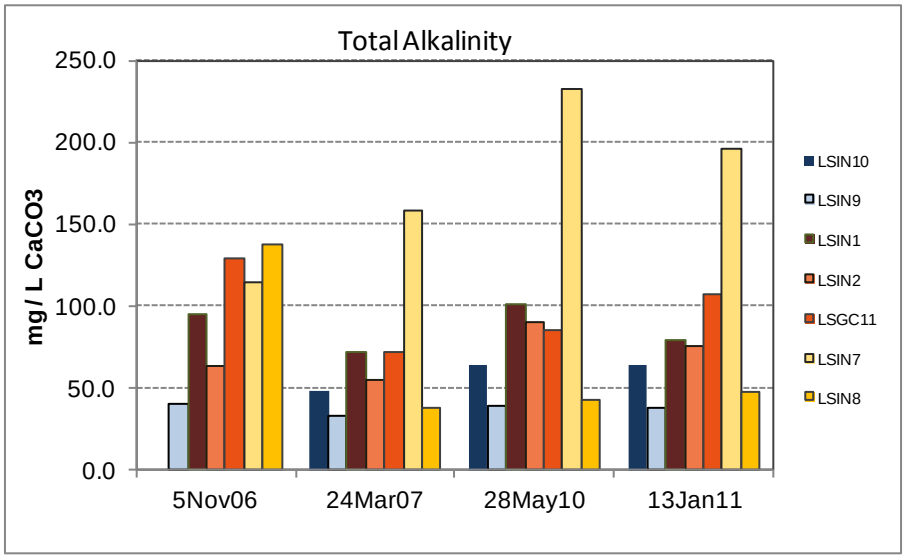

Figure 13. Total Alkalinity at 7 sites for 4 specific storm events in the lake Sawyer watershed.

Total alkalinity (acid neutralizing capacity) tells a generally similar story, with the difference that in the 2006 event, higher alkalinity was measured in the upper Ginder Creek sample than the mine site tributary, but in subsequent storms upper Ginder was consistently very low in alkalinity. A disturbance above the confluence or an unusual input related to the storm may have been responsible for the high value for LSIN8 in 2006, as that high value has not been repeated in the subsequent storm samples. It is interesting that while the conductivity for the 2006 event was not higher in LSIN8 than in LSIN7, it still was unusually high, so the two measurements tell a similar story.

Total Suspended Solids

Total suspended solids is a measure of the amount of particulate material carried in the water . It can be especially high during storm events through erosion of banks or side channels by increased flows and through excess runoff flowing over the land surface instead of infiltrating soils, picking up particles as it moves. Increases in nutrients carried by streams during storms are often attributable to the content of suspended solids in the water. Wetlands and stormwater facilities are often designed with the idea of detaining water long enough to allow the suspended solid load to settle out of the water before it proceeds downstream, thus removing a portion of the nutrient load.

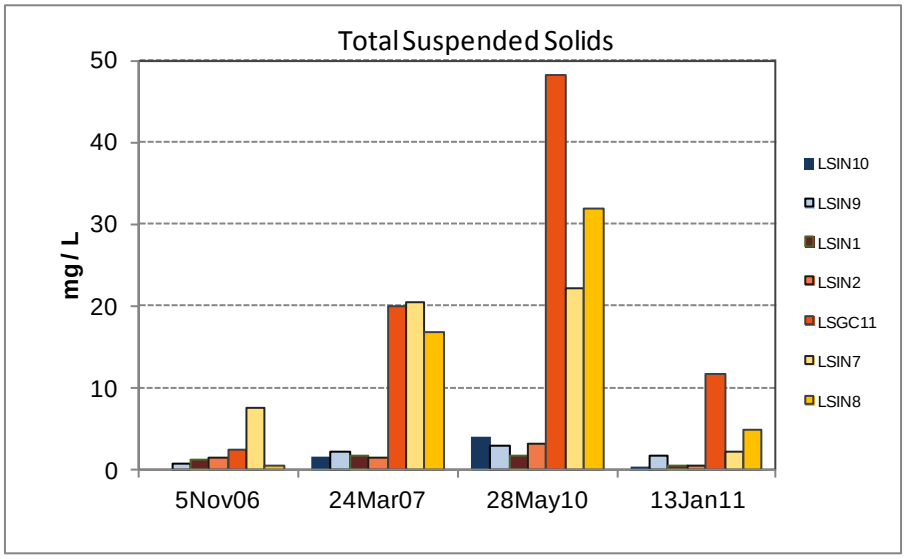

Figure 14. Total suspended solids at 7 sites for 4 specific storm events in the lake Sawyer watershed.

Data from storm events in the Lake Sawyer watershed (Figure 14) are consistent with these ideas. Samples from stations along Ginder Creek in the upper watershed carry a much higher sediment load than samples from the Rock Creek stations located in the flat, wetland-dominated lower portion of the creek close to entering the lake. Either the other inlets are diluting the heavily laden waters of Ginder Creek before reaching the LSIN2 station or the wetlands are serving the function of detaining water long enough for sediment to fall out of suspension, thus reducing the input to Lake Sawyer. An interesting result from the May 28,2010 storm is that total phosphorus in the lake water is actually higher than in either Ravensdale or Rock Creeks, probably due to algae populations in water exiting the lake.

Phosphorus

Both total phosphorus and orthophosphate were measured for storm events. In general, for storm samples the amount of total phosphorus varies in relationship with the amount of total suspended solids in the water, while orthophosphate is more independent of suspended materials and should vary less with the degree of storm erosion.

While all of the Ginder and Rock Creek samples are higher in phosphorus than the Ravensdale Creek samples (Figure 15), the pattern between stations along the Rock Creek drainage is not as consistent as it was for total suspended solids. It is possible that there may be a change in make-up of the sediments between the stations, with some upper stations carrying more large inorganic particles than the lower stations in the watershed, because of differences in rates of settling. Fine organic particles are often lighter and do not settle as quickly as mineral or rock fragments when water velocities decrease. However, this cannot be determined without measuring total organic carbon for each sample, which was not done.

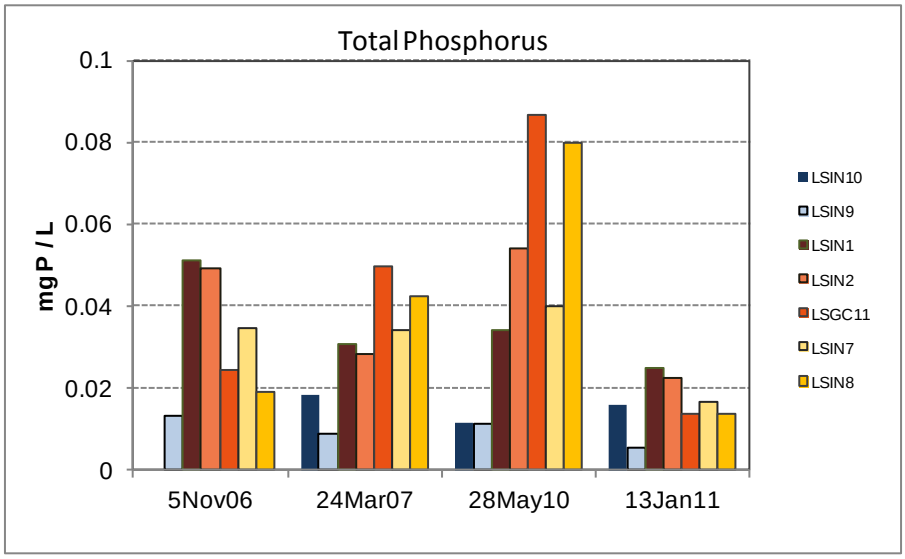

Figure 15. Total phosphorus at 7 sites for 4 specific storm events in the lake Sawyer watershed.

It is interesting to note that the 2006 and the 2011 storms show a pattern of increase as the samples move from the upper to lower reaches of the Rock Creek system, while the reverse is shown for 2007 and 2010. There could be some relationship to the timing of the grab samples in relationship to the storm hydrograph or that a pulse of peak erosion was captured by the sampling, but this information is not available.

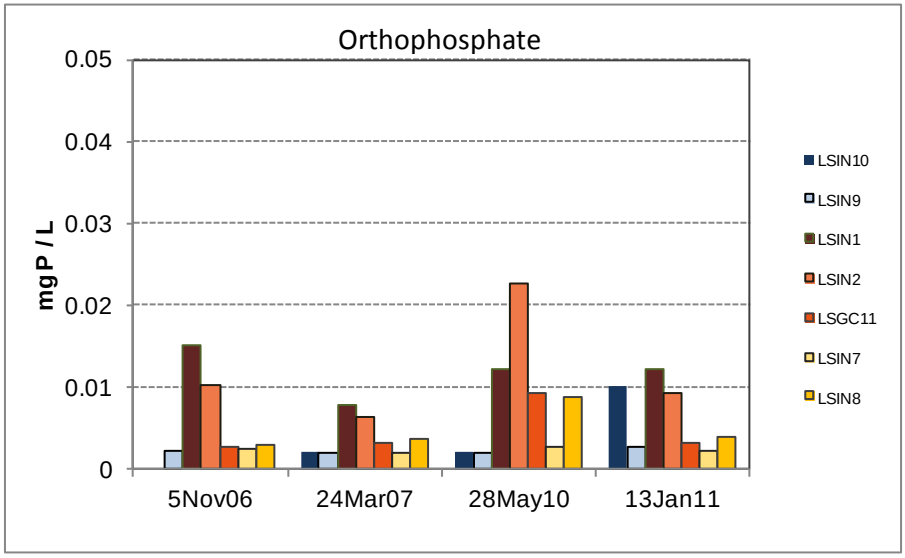

Figure 16. Orthophosphate at 7 sites for 4 specific storm events in the lake Sawyer watershed

In contrast, orthophosphate, which is found dissolved in water and is readily available for algal uptake as a nutrient, was nearly always found at lower concentrations in the water from the Ginder Creek stations than in the downstream Rock Creek stations. However, it is important to note that the maximum concentrations are still much lower than for total phosphorus for all of the samples. The high phosphate value in the lake outlet is characteristic of water from lakes in mid-winter when there are small numbers of algae present and the lake is thermally mixed.

Conclusions and Recommendations

Based on May–October monitoring data, water quality in Lake Sawyer has appeared to be relatively stable over the last decade. The nutrients in the lake varied a small amount during the sampling season and the N:P ratios were generally greater than 20 in 2011, which indicated that conditions in the lake are often unfavorable for bluegreen algae blooms, but there might be times of the year when they can be found in the lake, particularly if concentrated against a shoreline by wind.

The inlets have showed a decline in phosphorus since the 1990s, but insufficient data has been collected as yet to calculate long term annual trends for the routine monitoring carried out since 2006. Baseline values of total alkalinity and specific conductivity are being set to use as references as development in the watershed occurs. Continued monitoring should be carried out to assess conditions and to ensure that water quality remains consistent in Lake Sawyer as the area continues to be developed.

Storm sampling carried out to date suggests that more erosion is taking place during storms in the upper watershed of Ginder Creek than in the lower portion of Rock Creek, particularly from the tributary flowing from the mine site property. However, the flat topography of the downstream portion of Rock Creek may be catching some of the sediments before they enter the lake. It appears from two storm samples that hexane-extractable oil and grease may not be a concern at this time.