SUMMIT
ENVIRONMENTAL CONSULTANTS LTD. ISO 9001 AND 14001 CERTIFIED
#17A - 100 KALAMALKA LAKE RD.
VERNON, BC V1T 7M3
TEL 250 545-3672 FAX 250 545-3654
www.summit-environmental.com

May 14, 2004

Reference: **459-01.01**

Mr. Joe Harrison
President, Area A Quality Water Association
RR1, Site 11, Comp. 15
Garden Bay, B.C.
V0N 1S0

Email: c/o bkappeli@dccnet.com

Dear Mr. Harrison:

Re: Review of hydrologic and water quality information for Hotel Lake

1.0 Introduction

Summit Environmental Consultants Ltd. (Summit) was retained by the Area A Quality Water Association (AAQWA) in April 2004 to review hydrologic information and existing documentation relevant to Hotel Lake and to provide opinions on the potential impacts associated with the transfer of two unused water licences to the Sunshine Coast Regional District (SCRD). This report presents the results of our findings.

2.0 Background

Land and Water B.C. (LWBC) has recently transferred two water licences on Hotel Lake that were not being utilized (Conditional Licences 62623 and 17526) to the SCRD. These two licences are now known as Conditional Water Licence 119342 (4,015,000 Imperial gallons per year) and Conditional Water Licence 119338 (7,300,000 Imperial gallons per year). Members of AAQWA have appealed the transfer of these two licences to the B.C. Environmental Appeal Board.

3.0 Objectives

The specific objectives of this project were:

- To review and assess previous reports and other documentation on the hydrology of Hotel Lake (Section 5.1);
- To independently examine the hydrology and water balance of Hotel Lake (Section 5.2);
- To identify and discuss potential hydrologic impacts associated with the transfer of the two water licences to the SCRD (Section 5.3);
- To comment on available water quality data for Hotel Lake, and discuss potential impacts to lake water quality associated with the licence transfer (Section 5.4);

- To identify other present-day and future factors that could impact the hydrology and water quality of the lake (Section 5.5); and
- If necessary, to develop recommendations for future work (Section 7.0).

Conclusions of the report are presented in Section 6.0 and recommendations are provided in Section 7.0.

It is important to note that this report presents an overview of the Hotel Lake documentation and hydrologic regime, rather than a detailed analysis. The work was conducted under a tight schedule and the results reflect the limited scope of the assignment. In addition, the report makes no attempt to quantitatively assess the impacts of the licence transfer on fish or aquatic resources, either in Hotel Lake or downstream of the lake.

4.0 Information reviewed

The following reports and documentation was reviewed in the course of this study:

- Hugh G. Harris and Associates Inc. (2002);
- Jacques Whitford Environment Limited (2003a, b, c, d); and
- Jacques Whitford Environment Limited (2004).

These reports and letters are listed in the Reference section of this report. In addition, other letters, press releases, and documentation relevant to the issue of water supply and use from Hotel Lake were reviewed, including AAQWA (2003a, b, and c).

5.0 Results

5.1 Review of previous documentation on Hotel Lake

5.1.1 Harris Report

The report by Hugh G. Harris and Associates Inc. (2002) (known henceforth in this report as the "Harris Report") presents and interprets short-term measurements (taken over about one year in 2001 and 2002) of some components of the lake water balance. The work was undertaken in relation to a water licence application to pump 14,000,000 Imperial gallons per year from Hotel Lake to service a new development at Daniel Point. To provide a historical context, the report also attempts to provide a lake water balance analysis using information obtained from elsewhere in the region in a particularly dry year (1985). However, the organization and language used in the report are somewhat confusing, and as a result it is difficult to follow much of the author's interpretation of the 2001-2002 data, which comprises a large proportion of the report. Its value as a technical document and impact assessment in support of water allocation decisions from Hotel Lake is limited because of a number of other deficiencies:

1. Some of the technical analyses are suspect, which limits the confidence that can be placed in them. For example:

- in Table 1, there is an error in the bathymetric data, as well as a typographical error in the drainage area of the lake.
- the report does not state whether the lake overflow weir was calibrated via measurement, or whether a standard weir equation was applied without calibration – if the latter is the case, the overflow data are suspect.
- the lake level data reported in Appendix 3 are difficult to understand – for example whereas the lake level is reported to be constant for February 12, 13, and 14, 2002, three different values of lake outflow are provided for these three dates, which doesn't make sense.

2. Uncertainty in the analyses is not well represented – the author reports far too many significant figures in his calculations, implying a degree of certainty that is not supported by the data used in the calculations.
3. The report fails to provide an analysis of a monthly lake water balance for a representative (average) year that explicitly accounts for each of the input and output components of the water balance. Only a partial water balance (not including all components) is provided (in Table 7 of the report) for a portion of one particular year (June 2001 to April 2002). Despite that fact that lake level data was collected over this period, it is not clear that it was used for the water balance calculations – rather the lake level is simply reported as "full" for most months of the year.
4. No statistical analysis is done to define a water balance in drought years with specified frequencies (such as a 1 in 5 year drought, or a 1 in 10 year drought). An attempt is made (in Table 8 of the report) to provide a monthly water balance for a specific "representative" dry year (1985), but that year is not put into a statistical context. In addition, the lake inflows reported in Table 8 in the representative "dry" year greatly exceed the values reported for 2001-2002 in Table 7, which suggests that they are in error.
5. The report fails to account for all of the existing water licences when evaluating the potential impacts of the Daniel Point 14,000,000 gallon licence application.
6. Despite the fact that climate change is now a well-documented and researched topic, the Harris Report fails to take account of the potential effects of climate change on future water supply.
7. Despite the fact that Hotel Lake is a "summit" lake, situated in the upper elevations of the Hotel Lake Creek and Mixal Lake watersheds, the Harris Report fails to consider the potential implications of withdrawals from the lake for the local groundwater regime, downgradient well users, baseflows in Hotel Lake Creek, or inflows to Mixal Lake associated with the Daniel Point licence application.

5.1.2 Jacques Whitford Reports

The first four of the five documents produced by Jacques Whitford (Jacques Whitford, 2003a, b, c, and d) relate to assessments of impacts of the Daniel Point licence application, which included an application for 14,000,000 Imperial gallons per year from the lake (equivalent to about 240 mm), combined with a proposal to add 200 mm of storage onto the lake surface. The work focused on the fish habitat characteristics of the lake and the outlet stream (Hotel Lake Creek), potential utilization of the outlet channel by fish, and on documenting fish species in Hotel Lake.

In identifying components of a lake water balance, these reports make use of a fundamental assumption that all of the water leaving the lake is accounted for by evaporation, pumping, and overflow via Hotel Lake Creek. The potential loss via seepage out the lake bottom is assumed to be zero. The analyses of potential impacts to fish and aquatic resources in Hotel Lake and Hotel Lake Creek presented in these reports are based on this important assumption, under which the total annual flow leaving the lake via Hotel Lake Creek is assumed to be about 150,000,000 Imperial gallons, and the seepage loss is assumed to be zero. Unfortunately, this assumption is not in accord with three other readily available sources of information on lake outflows:

- the Harris Report, in which the annual outflow via Hotel Lake Creek is estimated at about 19,000,000 gallons for 2001-2002;
- AAQWA anecdotal evidence, in which the annual lake outflow via Hotel Lake Creek is estimated at about 6,000,000 Imperial gallons (Harrison, 2004); and
- about 9,000,000 Imperial gallons per year, based on Fisheries and Oceans Canada data from Mixal Creek (from Harrison, 2004).

Using the Hotel Lake Creek flow estimates provided by these three sources, it appears that between about 83% and 95% of the lake outflow that is not accounted for by evaporation or pumping may occur via seepage through the lake bed. Because Hotel Lake is a summit lake, located at higher elevations than Hotel Lake Creek, Mixal Lake, Mixal Creek, and Sakinaw Lake, the seepage losses from Hotel Lake are likely important in recharging aquifers at lower elevations, in maintaining baseflows in Hotel Lake Creek and possibly Mixal Creek, and contributing to Mixal Lake inflows. This means that there could be significant implications of additional withdrawals from Hotel Lake on downstream lakes and creeks and downgradient groundwater aquifers and wells. If storage on the lake is provided to mitigate reduced groundwater recharge from the lake, these effects will be reduced. However, the Garden Bay licence transfer does not include development of additional storage on the lake. The potential impacts without developing additional storage have not been addressed in any of the Jacques Whitford documents.

The final Jacques Whitford document (Jacques Whitford, 2004) refers to the issue under examination by the present report – the appeal of the transfer of two unused licences on Hotel Lake totaling 11,315,000 Imperial gallons per year to the SCRD. That letter identifies a large "surplus" of water, but does not provide a full context for this "surplus". The report does not acknowledge the impacts of the additional drawdown that will occur in summer, the impact on reduced seepage from the lake (it assumes that both present and future seepage loss will be zero), and it does not address the implications of future changes in water supply due to climate change.

In summary, neither the Harris Report nor the various Jacques Whitford reports provide a sound, thorough, comprehensive, error-free analysis useful for making wise water allocation decisions for Hotel Lake, and in particular for making a sound decision on transferring the two Garden Bay licences to the SCRD. None of these reports consider all the factors (e.g. drought years or future changes in supply due to climate change) that should be considered in making water allocation

decisions for Hotel Lake. None of the reports take account of the possible role of Hotel Lake in supplying local groundwater aquifers via seepage from the lake bottom, or of the implications of reduced seepage from the lake on aquifers, downgradient wells, baseflows in Hotel Lake Creek and Mixal Creek, and inflows to Mixal Lake.

5.2 Approximate monthly water use and balance for Hotel Lake

We have undertaken a simple, approximate analysis of the monthly water use and balance of Hotel Lake in order to develop a basic understanding of the functioning of the lake. The results are based on several simplifying assumptions, necessitated by the short-term nature of this assignment. With additional time and resources, the assumptions could be verified and refined. The water balance analysis is summarized in Tables 1 through 5 (attached).

Table 1 shows monthly water use recorded by the SCRD in 2001 and 2002. The table illustrates that water use in 2001 was very close to the licensed value of 10,950,000 Imperial gallons, but that in 2002, water use exceeded the licensed quantity by about 10% (equivalent to about 19 mm of unlicensed withdrawal.

Table 2 distributes the existing water withdrawn from the lake for human use into SCRD, other domestic users, and agricultural users. Assumptions and sources of information are listed below the table. Existing users account for about 272 mm of withdrawal from the lake each year. The two Garden Bay licences in question would result in a further 191 mm of withdrawal, for a total of about 463 mm of drawdown each year. In addition to the sources listed in Table 2, there are anecdotal reports of several other unlicensed withdrawals from the lake, which are not accounted for in Table 2.

Table 3 provides a record of storage changes on Hotel Lake between October 2001 and September 2003, based on observations by Mr. Terry Mulligan, a local resident. The data reveal that the lake level varied by about 500 mm from its high point to its low point during this period. In addition, the ending level was lower than the beginning level of two years earlier, indicating the possibility that despite refilling each fall and winter, the lake level may drop over consecutive dry years.

Table 4 presents an approximate monthly water balance for an average year for the Hotel Lake watershed. The data are based on 30-year (1971-2000) averages of precipitation at Gibsons–Gower Point and Powell River, 30-year (1971-2000) averages of potential evapotranspiration for Gibsons-Gower Point and Powell River, and average runoff data from Obedkoff (2003) for Hydrologic Zone 27 (Western South Coast Mountains). The data indicates 1344 mm of precipitation per year, which is distributed into 744 mm of evapotranspiration and 600 mm of runoff. It is assumed that there is no long-term accumulation of either a deficit or a surplus of water. Evapotranspiration from the watershed upstream of the lake and direct evaporation losses from the lake are both estimated using the Priestley-Taylor equation. Evapotranspiration losses

from the watershed are estimated assuming a "tall forest" vegetation cover, and evaporation losses from the lake are calculated using the "open water" form of the equation.

Table 5 presents an approximate monthly water balance for Hotel Lake for an average year (i.e. for the lake only, not including the contributing watershed). The analyses assume a constant lake surface area of 27 ha (270,000 m^2), and identify and account for two specific inputs:

- runoff from the watershed upstream of the lake (75 ha); and
- direct precipitation onto the lake (27 ha).

The table also accounts for four specific outputs:

- evaporation from the lake surface,
- pumping loss,
- surface outflow, and
- seepage through the lake bed.

The table indicates several important features of the water balance of the lake:

- The total annual input to the lake (runoff from the watershed area upstream of the lake plus direct precipitation onto the lake) amounts to over 3 m of water;
- Annual losses from the lake include 811 mm lost to evaporation, 273 mm lost via pumping (not including the Garden Bay licences in question), 155 mm lost via surface outflow, and 1772 mm lost via seepage from the lake bottom, for a total exceeding 3 m (assumed equal to the water input in an average year);
- The surface outflow is ephemeral, occurring for only about 8 months of the year (November to June); and
- Seepage loss is highest in the winter when the lake level is highest, and lowest in the summer when the lake level is lowest.

It appears on the basis of this analysis that more than half of all the water lost from the lake occurs via seepage through the lake bed. Measurements of surface overflow (Section 5.1.2) suggest that seepage represents 83% to 95% of the total losses that occur via overflow and seepage. The lake is thus likely an important contributor to recharge of groundwater aquifers downgradient of the lake, a factor that was not examined in the Harris Report or the Jacques Whitford documents.

5.3 Potential hydrologic impacts associated with the two new licences

Table 6 provides an approximate monthly water balance fot Hotel Lake assuming that the two Garden Bay licences in question are being fully utilized. The analysis is simplistic because it assumes that the change caused by the two Garden Bay licences is all taken up by reductions in lake overflow and seepage, with no changes in lake levels. Table 6 is intended to demonstrate the maximum potential effect on lake outflows. In reality, the impacts of these two licences will be shared by changes in lake overflow, seepage, and lake levels (i.e. lake levels will drop as well).

If the two Garden Bay licences are fully utilized, the results will be:

- Overflow into Hotel Lake Creek: The lake will continue to fill each fall, and Hotel Lake Creek will continue to flow in the fall, winter, and spring, but overflow volumes and rates will be smaller than at present. The overflow will drop by up to about 1 million Imperial gallons per year and the period of time that the outlet is flowing will shorten by up to about two weeks. The lake will likely fill later in the fall and drop below the outlet elevation earlier in the spring compared with present-day conditions.
- Seepage losses: Seepage from the lake bottom will drop by up to about 177 mm, i.e. 10 million Imperial gallons per year, as shown in Table 6.
- Lake drawdown: The lake level will drop each summer to at most 191 mm lower than it would without the Garden Bay licences in place.

Information available for this review does not make it possible to provide a more precise estimate of the additional drawdown, or of the expected changes in volume and timing of groundwater recharge and surface outflow.

5.4 Hotel Lake water quality data and potential impacts of additional pumping

5.4.1 Phosphorus

Water sampling and analysis for phosphorus has taken place in Hotel Lake on an annual basis from 1994 to 2003, although the sampling schedule varies from year to year. Annual sample sizes range from a single sample to three samples, and data are available for two depths, one metre and nine metres below the surface (Table 8). The current B.C. water quality guidelines (WQG) for total phosphorus (MWLAP, 2001) are:

- 0.010 mg/L total P maximum for drinking water; and
- Between 0.005 (minimum) and 0.015 mg/L (maximum) total P for aquatic life protection[1].

Of the 14 samples taken at 1 m depth, seven exceed the drinking water guideline and three exceed the maximum aquatic life guideline[2]. At nine metres, nine of the 14 samples exceed the drinking water guideline and six exceed the maximum aquatic life guideline of 0.015 mg/L total P. The average concentrations were 0.010 mg/L (n=14) and 0.017 mg/L (n=14) at 1 m and 9 m depth respectively. Figure 1 shows the total P concentrations at the two depths[3]. The y-axis is arbitrarily set as days since the start of 1994 in order to illustrate the timing of the available data.

[1] For aquatic life total P concentration less than 0.005 mg/L are considered a limitation to fisheries because of effects on their food supply. The standard point of reference for the B.C. guidelines is results of sampling during spring overturn (Nordin, 1985). Most concerns in Hotel Lake relate to concentrations above the guideline maximum.

[2] The improbably high concentrations from December 1997 (Table 7) are excluded from the analyses in this report.

[3] Note: concentrations less than the detection limit of 0.005 mg/L are plotted as 50% of the detection limit, 0.0025 mg/L. This value was also used to calculate the averages.

In general, the total P concentrations are higher at 9 m depth than at 1 m depth, although the concentrations are often within 0.002 mg/L of each other, especially in the spring when the lake is likely isothermal (the same temperature at all depths). Some members of AAQWA have expressed concern that the higher frequency of above-WQG concentrations observed in 2000-2002 may represent a rising trend (Table 8 and Figure 1). The irregular sampling schedule for the available data, however, makes it impossible to confirm the presence or absence of a statistically significant trend because total P concentrations vary seasonally and the sample size is limited.

From the existing data it appears that most of the P is present as organic-P, bound in organic matter or suspended sediment, since the dissolved-P and ortho-P concentrations are mostly less than the laboratory detection limit. Total P concentrations in the spring are generally considered the best indication of the supply of P available to the lake biomass for the upcoming growing season (Nordin, 1985). The limited April to mid-June data that are available indicate that the concentrations throughout the water column do exceed the drinking water and aquatic life guidelines in the spring (e.g. 5 out of 7 samples from 9 m in April-June exceed the drinking water guideline). Therefore Hotel Lake would be classified as meso-eutrophic (Wetzel, 1983) and even small increases in phosphate could increase the frequency of algal blooms. In summer higher concentrations of total P are generally found at the 9 m depth than at 1 m. No information on the thermal characteristics of the lake at the time of sampling is available, nor are there data on P concentrations in lake bottom sediments.

The basis for the B.C. drinking water guideline is the potential for elevated P concentrations to cause algae growth, which increases the cost of water treatment (e.g. filtration) and can cause aesthetic (taste and odour) concerns (Nordin, 1985). Risks to human health are generally considered much less of a concern than these water supply and aesthetic issues, and there is no Canadian Drinking Water Guideline for phosphorus (Health Canada, 2003).

The proposed increase in water withdrawals from Hotel Lake could influence the lake phosphorus cycle in two ways:

1. by reducing the dilution effects of rainfall and runoff on P inputs from septic systems and natural processes; and
2. by altering shoreline processes.

With respect to dilution, the proposed additional withdrawal of 51,483 m^3 per year (11,315,000 Imperial gallons) represents about 3% of the average volume of the lake. Assuming no change in P inputs, the average total P concentration would therefore increase by a maximum of about 3%, which may be biologically insignificant given the large within-year variations in water column P concentrations that are experienced. However, changes in lake level brought about by the increased withdrawals (a maximum of 191 mm) could result in additional turbulence of lake sediments near the shoreline. Phosphorus release from littoral zones in small lakes as the result of turbulence can make up a more significant source of P than it would in large lakes (Wetzel, 1983), and could therefore be a source of concern in Hotel Lake.

5.4.2 Nitrogen

Available nitrate-N and nitrite-N concentrations have been consistently very low and well within the Canadian drinking water guidelines of 10 mg/L nitrate-N and 1 mg/L nitrite-N respectively. Similarly, the ammonium-N concentrations are also with the B.C. guidelines for aquatic life protection, although there are few data. The specific guideline for ammonium-N depends on temperature and pH, but even the most restrictive guideline is higher than the observed concentrations to date.

5.4.3 Summary

Summarizing the results from the available data:

1. Hotel Lake is meso-eutrophic and total P concentrations regularly exceed B.C. water quality guidelines. However it isn't possible to determine whether the total P concentrations are either increasing, decreasing, or staying the same; and
2. The impacts of additional withdrawal would be a maximum 3% increase in P concentration from reduced dilution and potentially some unknown amount from increased turbulence of lake sediments. Given the meso-eutrophic status of the lake, even a small increase like 3% could have an effect on algal populations, but it's not possible to tell without more data.

Recommendations for water quality monitoring to address these issues are provided in Section 7.0.

5.5 Other present and future factors that could impact the hydrology and water quality of the lake and downstream aquatic environments

There are several factors that could affect the water balance and water quality of Hotel Lake and downstream aquatic environments that have not been addressed in previous reports:

- unlicensed water use;
- withdrawals that exceed licensed amounts; and
- effects of climate change on water supply, the seasonal distribution of lake inflow and outflow, and water use.

5.5.1 Unlicensed water use and excessive withdrawals

Information from the AAQWA (AAQWA, 2003a) indicates that there are 8 unlicensed water users on Hotel Lake, and that each of these water users withdraws water for domestic purposes (at about 500 Imperial gallons per day). The total volume represented by these unlicensed withdrawals is about 1,460,000 Imperial gallons per year, equivalent to about 25 mm on the lake surface, which is about 10% of the total licensed water use from the lake. The presence of these (and possibly other) unlicensed users casts some doubt on the belief that LWBC has an accurate inventory of actual water use from the lake.

Second, as outlined above and shown in Table 1, in 2002 SCRD withdrew about 1,000,000 Imperial gallons more than they were licensed to withdraw (equivalent to about 17 mm on the lake). In drier years it is possible that SCRD withdraws even more.

Taken together, the unlicensed water use and the extra use in 2001 over and above licensed amounts represents about 15% of the known water use. Better knowledge of actual withdrawals and improved monitoring of licences would help to ensure an accurate inventory of water use that would provide an improved foundation for water allocation decisions.

5.5.2 Effects of a changing climate on water supply and demand

The climate of south-coastal British Columbia is changing, and it is predicted to continue to change in coming years. Table 7 presents an analysis of the expected changes in the monthly inflows to Hotel Lake based on analyses presented by Whitfield et. al. (2002). Table 7 indicates the absolute and percentage changes expected in 2020 compared with the present. As indicated in Table 7, future climate change is not predicted to significantly change the annual total runoff to Hotel Lake. However, the seasonal distribution of runoff is expected to change.

There will likely be increased inputs to the lake between November and February, and corresponding increases in seepage losses and overflows via Hotel Lake Creek. However, the opposite effect is predicted between March and June, in which inflows to the lake are likely to be smaller than at present. This will likely mean that lake levels will drop further than they do at present during spring, and outflows via seepage and Hotel Lake Creek will decrease. In the July through October period, the 2020 runoff into the lake is expected to be similar to present-day conditions.

The overall effect of these predicted changes is that the lake will likely discharge more water via overflow and seepage during winter, but will drop to lower levels in spring, summer, and early fall. The length of the period of zero surface overflow in summer and fall will likely increase, and overflow to Hotel Lake Creek and seepage through the lake bottom will both decrease in summer and fall.

The year 2020 is only 16 years away, and the water supply changes due to ongoing climate change will likely be even more significant beyond 2020. Since water licences are in place in perpetuity (unless they are cancelled), it is prudent to acknowledge the fact that the climate is non-stationary (i.e. that it is changing). It is also important to realize that due to significant research effort in recent years, the effects are somewhat predictable, and can be utilized in making water allocation decisions.

Finally, it is important to recognize that future reductions in summer runoff combined with increased water demands in the growing season due to climate change will mean increases in water demand in the future. Even if none of the existing licensed users withdraws more than their present licences allow, there are at present several unlicensed users (and there could be more in future). Unregulated, these unlicensed users could increase their water use as the

climate continues to change in the future. In addition, there will likely be additional pressures for new water licensing in the future.

None of the potential impacts of climate change on supply or demand have been considered by the Harris Report or the various Jacques Whitford reports.

6.0 Conclusions

The analyses presented in this brief report lead to several conclusions:

1. Previous documentation does not provide a sufficiently broad context or basis for making water allocation decisions for Hotel Lake. Previous analyses have not been done in a sufficiently comprehensive and error-free manner to provide confidence that the natural hydrologic regime of Hotel Lake is well understood. Historical average and specific drought-year analyses have not been done, and the effects of future changes in climate have not been accounted for.
2. The analyses presented herein suggest that seepage losses from Hotel Lake are likely important to the local groundwater regime. However, the potential effects of reduced seepage losses from the bed of Hotel Lake on downstream aquifers, wells and surface water bodies have not yet been examined.
3. The database of water use information is incomplete, which complicates decision-making about new licences or licence transfers. Records indicate that in 2002 the SCRD pumped about 10% more than their existing licence allows. In addition, there are apparently several unlicensed water users taking water out of the lake.
4. The preliminary water balance analyses undertaken for the present report indicate that further work is needed to provide a sound basis for making water allocation decisions for Hotel Lake.
5. The analyses indicate that there is a reasonable likelihood that a comprehensive evaluation of the water balance of Hotel Lake, and of the potential impacts of additional water withdrawals from the lake (including the impacts of future changes in water supply due to climate change) would conclude that the transfer of the two Garden Bay licences could result in water quality and quantity impacts to the lake itself, and to downstream flows, aquatic resources, fish habitat and groundwater levels.

7.0 Recommendations

The conclusions reported in Section 6.0 lead to several recommendations:

1. Prior to considering new licences or licence transfers, Land and Water BC should ensure (e.g. through monitoring and enforcement) that actual use does not exceed licensed use, and that licences are in place for all withdrawals (or at least that the unlicensed use has been properly documented and accounted for in licensing decisions).
2. A comprehensive water balance analysis and quantitative impact assessment should be conducted to determine whether the proposed use of the two transferred licences will result

in environmental impacts to Hotel Lake or to any downstream or downgradient water resources. The work should consist of at least the following steps:

- Determining a monthly water balance for Hotel Lake in a representative average year, and in drought years with specified frequencies (e.g. 1 in 5 year drought and 1 in 10 year drought). This work would re-evaluate the assumptions used in previous analyses and in the present preliminary analysis.
- Determining the appropriate drought frequency to use as the basis for decision-making.
- Quantifying all of the existing water use from Hotel Lake (including both licensed and unlicensed use).
- Evaluating return flows, i.e. considering to what extent withdrawals represent permanent removals from the lake and downstream aquatic environment and to what extent return flows occur.
- Considering in a quantitative manner the likely effects on water supply of future changes in climate, making use of ongoing research by Environment Canada and the University of B.C.
- Considering the potential effect of climate change on increasing the water demands, particularly from unlicensed users.
- Determining the effects of potential future withdrawals from Hotel Lake on the lake hydrograph and ecosystem, and on the aquatic ecosystems of downstream surface water resources and downgradient groundwater resources.
- Conducting a groundwater study. Estimates presented in the present report suggest that more than half of the total lake outflow occurs via seepage from the lake bed into local aquifers. The groundwater study would address the issue of seepage losses, and would also focus on downstream aquifers, groundwater wells, and groundwater quality.
- If appropriate, proposing measures that could be implemented to mitigate predicted effects of increased water withdrawals from the lake.

3. Improving the site-specific information database, in particular the lake outflow and water quality information. The lake level readings should continue, and flows in Hotel Lake Creek should be monitored. Precipitation readings should also continue. Clarification of the hazards to drinking water supply systems and aquatic life presented by the P concentrations in Hotel Lake, both under the current operating regime and if the water withdrawals increase, will require additional sampling. We suggest sampling on a weekly basis in the spring for four weeks, then on a monthly basis for the rest of the year. Sampling should continue at the same location(s) and at the same depths, and should be supplemented by temperature profiling (i.e. recording measurements at 1 m depth intervals) and Secchi dish readings (i.e. recording the depth where the disk is no longer visible). Laboratory analysis should be done for total P, dissolved P, and ortho-P. Nitrogen analyses (nitrate+nitrite-N, ammonium N, and total Kjeldahl N) are not essential but could be beneficial to confirm the previous observations, but N sampling can be limited to a spring sample (when the lake is mixed) and one from later in the year when the lake is stratified. This schedule should be re-evaluated in

two years and the annual frequency reduced, if appropriate. If an analysis of long-term trends is desired, the timing of the core sampling program must stay consistent from year to year.

I trust that this report provides the information you require at this time. Please call if you have any questions.

Yours truly,

Summit Environmental Consultants Ltd.

Brian T. Guy, Ph.D., P.Geo., P.H.
Senior Geoscientist

Attachments:
Table 1: Monthly water use from Hotel Lake by SCRD in 2001 and 2002
Table 2: Approximate monthly water use from Hotel Lake in an average year
Table 3: Record of storage changes on Hotel Lake, October 2001 to September 2003
Table 4: Approximate monthly water balance for an average year for the Hotel Lake watershed
Table 5: Approximate monthly water balance for Hotel Lake in an average year
Table 6: Approximate monthly water balance for Hotel Lake in an average year with the two Garden Bay licences in place
Table 7: Likely effect of climate change on monthly inputs to Hotel Lake
Table 8. Nutrient concentrations in Hotel Lake, 1994-2004
Figure 1. Total phosphorus concentrations at 1 m and 9 m depths in Hotel Lake

References

Area A Quality Water Association (AAQWA). 2003a. Revised Licencee Application Objection Z118466 dated September 10, 2003.

Area A Quality Water Association (AAQWA). 2003b. Supplementary Objection #1 to the Licence Application Objection Z118466 dated September 12, 2003.

Area A Quality Water Association (AAQWA). 2003c. Supplementary Licencee Application Objection Z118466 #2 dated October 14, 2003.

Harrison, J. 2004. E-mail memorandum to John Heinonen of Fisheries and Oceans Canada dated May 3, 2004.

Health Canada. 2003. Summary of guidelines for Canadian drinking water quality. Prepared by the Federal-Provincial-Territorial Committee on Drinking Water of The Federal-Provincial-Territorial Committee on Environmental and Occupational Health. Ottawa. April 2003.

Hugh G. Harris and Associates Inc. 2002. Preliminary Report – Hydrology of Hotel Lake at Pender Harbour Area Sunshine Coast, B.C. Report prepared for Sunshine Coast Engineering (1993) Ltd. May 30, 2002.

Jacques Whitford Environment Limited. 2003a. Letter to Mr. Dave Nanson of Fisheries and Oceans Canada dated April 29, 2003.

Jacques Whitford Environment Limited. 2003b. Letter to Mr. Dave Nanson of Fisheries and Oceans Canada dated May 27, 2003.

Jacques Whitford Environment Limited. 2003c. Letter to Mr. Bob Herath of Land and Water BC Inc. dated September 11, 2003.

Jacques Whitford Environment Limited. 2003d. Letter to Ms. Kristie Trainor of Land and Water BC Inc. dated November 9, 2003.

Jacques Whitford Environment Limited. 2004. Letter to Mr. Dave Nanson of Fisheries and Oceans Canada dated April 23, 2004.

Ministry of Water, Land & Air Protection (MWLAP). 2001. British Columbia Approved Water Quality Guidelines (Criteria). Victoria. Available on-line at: http://wlapwww.gov.bc.ca/wat/wq/BCguidelines/approved.html.

Nordin, R. 1985. Water Quality Criteria for Nutrients and Algae. Technical Appendix. Water Quality Unit, Ministry of Environment. Victoria.

Obedkoff. W. 2003. Streamflow in the Lower Mainland and Vancouver Island. Aquatic Information Branch, Ministry of Sustainable Resource Management. Victoria. April 2003.

Wetzel, R.G. 1983. Limnology (Second edition). Saunders College Publishing. Philadelphia. 767 pp.

Whitfield, P.H., C.J. Reynolds, and A.J. Cannon. 2002. Modelling streamflow in present and future climates: Examples from the Georgia Basin, British Columbia. Canadian Water Resources Journal 27 (4), p. 427-456.

Table 1: Monthly water use from Hotel Lake by SCRD in 2001 and 2002

	2001 Water Use				2002 Water Use			
Month	Imperial gallons	cubic metres	Annual distribution (%)	Depth on Hotel Lake (mm)	Imperial gallons	cubic metres	Annual distribution (%)	Depth on Hotel Lake (mm)
Jan	578,194	2,631	5.3	9.7	503,736	2,292	4.2	8.5
Feb	620,485	2,823	5.7	10.5	496,484	2,259	4.1	8.4
Mar	704,405	3,205	6.5	11.9	677,802	3,084	5.6	11.4
Apr	868,722	3,953	8.0	14.6	562,198	2,558	4.6	9.5
May	780,396	3,551	7.2	13.2	909,231	4,137	7.5	15.3
Jun	952,203	4,333	8.7	16.0	1,691,648	7,697	14.0	28.5
Jul	1,683,921	7,662	15.5	28.4	1,606,154	7,308	13.3	27.1
Aug	1,247,797	5,677	11.5	21.0	2,230,549	10,149	18.4	37.6
Sep	1,114,815	5,072	10.2	18.8	1,150,989	5,237	9.5	19.4
Oct	1,169,600	5,322	10.7	19.7	872,308	3,969	7.2	14.7
Nov	651,542	2,965	6.0	11.0	739,560	3,365	6.1	12.5
Dec	516,300	2,349	4.7	8.7	650,989	2,962	5.4	11.0
TOTAL	10,888,380	49,542	100	183	12,091,648	55,017	100	204
Licences	10,950,000	49,823		185	10,950,000	49,823		185

Notes:
1. Data source= SCRD
2. Depth on Hotel Lake is calculated by assuming a lake surface area of 270,000 m^2.

Table 2: Approximate monthly water use from Hotel Lake in an average year

	Existing					2 Garden Bay licences		Future (with the 2 Garden Bay licences)	
Month	SCRD (IG)	Other domestic (IG)	Agricultural (IG)	Total monthly use (IG)	Depth on Hotel Lake (mm)	Licensed volume (IG)	Depth on Hotel Lake (mm)	Total monthly use (IG)	Depth on Hotel Lake (mm)
Jan	547,500	164,300	0	711,800	12	565,800	10	1,277,500	22
Feb	657,000	197,100	0	854,100	14	678,900	11	1,533,000	26
Mar	766,500	223,000	0	996,500	17	792,000	13	1,788,500	30
Apr	876,000	262,800	95,000	1,233,800	21	905,200	15	2,139,000	36
May	985,500	295,700	190,000	1,471,200	25	1,018,400	17	2,489,500	42
Jun	1,095,000	328,500	285,000	1,708,500	29	1,131,500	19	2,840,000	48
Jul	1,642,500	492,800	475,100	2,610,300	44	1,697,300	29	4,307,600	73
Aug	1,314,000	394,200	475,100	2,183,300	37	1,357,800	23	3,541,100	60
Sep	1,095,000	328,500	285,000	1,708,500	29	1,131,500	19	2,840,000	48
Oct	876,000	262,800	95,000	1,233,800	21	905,200	15	2,139,000	36
Nov	547,500	164,300	0	711,800	12	565,800	10	1,277,500	22
Dec	547,500	164,300	0	711,800	12	565,800	10	1,277,500	22
TOTAL	10,950,000	3,285,000	1,900,300	16,135,300	272	11,315,000	191	27,450,300	463
Licence	10,950,000	3,285,000	1,900,300			11,315,000			

Notes:

1. IG = Imperial gallons
2. Garden Bay licences - (1) CL119338 = 7,300,000 IG per year; and (2) CL119342 = 4,015,000 IG per year; total = 11,315,000 IG per year
3. Values are reported to nearest 100 Imperial gallons or nearest millimetre

Assumptions:

1. Total use equal to licensed use.
2. "Other domestic" licences total 9,000 Imperial gallons per day (from LWBC website)
3. Irrigation licences total 7 AF per year (1,900,300 Imperial gallons) (from LWBC website)
4. The 2 new Garden Bay licences assumed to be for 100% domestic use
5. Per AAQWA's "revised licence objection" (Sept 10, 2003) there are also 8 unlicensed domestic users. These are not counted here. They would add 4,000 IG per day or 1,460,000 IG per year, about 25 mm on the lake.
6. Distributions of water use in an average year are based on the following table:

Month	Domestic	Agricultural
Jan	5	0
Feb	6	0
Mar	7	0
Apr	8	5
May	9	10
Jun	10	15
Jul	15	25
Aug	12	25
Sep	10	15
Oct	8	5
Nov	5	0
Dec	5	0
TOTAL	100%	100%

Based on data from SCRD (domestic) and Westbank Irrigation District (agricultural)

Table 3: Record of storage changes on Hotel Lake, October 2001 to September 2003

Year	Month	Level at beginning of month		Level and volume change during month		
		Measured (inches above benchmark)	Measurement converted to mm above benchmark	Change in lake level (mm)	Change in lake volume (m^3)	Change in lake volume (Imperial Gallons)
2001	Oct	4.5	114	97	26,100	5,728,000
	Nov	8.3	211	104	28,100	6,180,000
	Dec	12.4	315	119	32,200	7,084,000
2002	Jan	17.1	434	61	16,500	3,617,000
	Feb	19.5	495	-5	-1,400	-301,000
	Mar	19.3	490	-122	-32,900	-7,235,000
	Apr	14.5	368	8	2,100	452,000
	May	14.8	376	-30	-8,200	-1,809,000
	Jun	13.6	345	-109	-29,500	-6,481,000
	Jul	9.3	236	-71	-19,200	-4,220,000
	Aug	6.5	165	-109	-29,500	-6,481,000
	Sep	2.2	56	-97	-26,100	-5,728,000
	Oct	-1.6	-41	33	8,900	1,959,000
	Nov	-0.3	-8	132	35,700	7,838,000
	Dec	4.9	124	142	38,400	8,441,000
2003	Jan	10.5	267	91	24,700	5,426,000
	Feb	14.1	358	33	8,900	1,959,000
	Mar	15.4	391	-5	-1,400	-301,000
	Apr	15.2	386	8	2,100	452,000
	May	15.5	394	-41	-11,000	-2,412,000
	Jun	13.9	353	-48	-13,000	-2,864,000
	Jul	12	305	-140	-37,700	-8,290,000
	Aug	6.5	165	-147	-39,800	-8,742,000
	Sep	0.7	18			

Note:
Data are reported to nearest mm, 100 m^3, and 1,000 Imperial gallons

Table 4: Approximate monthly water balance for an average year for the Hotel Lake watershed

Month	Precipitation, P (mm)	Evapotranspiration, ET(mm)	Runoff, R (mm)	P-ET-R
Jan	170	0	85	85
Feb	132	10	90	32
Mar	124	36	79	9
Apr	89	70	54	-35
May	81	111	41	-71
Jun	72	126	23	-77
Jul	44	149	12	-117
Aug	49	128	6	-85
Sep	62	77	12	-27
Oct	137	31	23	83
Nov	202	6	79	117
Dec	182	0	96	86
TOTAL	1344	744	600	0

Sources:
Precipitation: based on 30-year (1971-2000) normals for Gibsons-Gower Point and Powell River
Evapotranspiration: Using Priestley-Taylor equation, average of results for Gibsons-Gower Point and Powell River, using "tall forest" vegetation type.
Runoff: Based on Obedkoff (2003) for Hydrologic Zone 27. Monthly distribution assumed similar to that of Lang Creek near Powell River.

Table 5: Approximate monthly water balance for Hotel Lake in an average year

	INPUTS						**OUTPUTS**						**NET**	
Month	Direct precip. onto lake (27 ha)	Runoff contribution from watershed upstream of lake (75 ha)			**Total inputs to lake**		Evaporation from lake, E	Surface Outflow	seepage loss	pumping (existing, see note)	**Total outputs from lake**		Input - Output	
	P (mm)	Runoff (mm)	Runoff (m^3)	Runoff (depth on lake (mm))	Volume (m^3)	**Depth (mm)**	(mm)	(mm)	(mm)	(mm)	Volume (m^3)	**Depth (mm)**	**Depth (mm)**	Volume (m^3)
Jan	170	85	63,750	236	109,650	**406**	0	30	294	12	90,750	**336**	**70**	18,900
Feb	132	90	67,500	250	103,140	**382**	12	30	316	14	100,440	**372**	**10**	2,700
Mar	124	79	59,250	219	92,730	**343**	40	30	286	17	100,830	**373**	**-30**	-8,100
Apr	89	54	40,500	150	64,530	**239**	77	30	151	21	75,330	**279**	**-40**	-10,800
May	81	41	30,750	114	52,620	**195**	120	10	90	25	66,120	**245**	**-50**	-13,500
Jun	72	23	17,250	64	36,690	**136**	136	5	46	29	58,290	**216**	**-80**	-21,600
Jul	44	12	9,000	33	20,880	**77**	161	0	-33	44	46,530	**172**	**-95**	-25,650
Aug	49	6	4,500	17	17,730	**66**	139	0	-15	37	43,380	**161**	**-95**	-25,650
Sep	62	12	9,000	33	25,740	**95**	84	0	32	29	39,240	**145**	**-50**	-13,500
Oct	137	23	17,250	64	54,240	**201**	34	0	46	21	27,240	**101**	**100**	27,000
Nov	202	79	59,250	219	113,790	**421**	8	5	266	12	78,690	**291**	**130**	35,100
Dec	182	96	72,000	267	121,140	**449**	0	15	292	12	86,040	**319**	**130**	35,100
TOTAL	1,344	600	450,000	1,667	812,880	**3,011**	811	155	1,772	273	812,880	**3,011**	**0**	0

Notes:

1. Assume inputs = outputs (lake is neither filling nor draining over the long-term).
2. Precipitation and runoff data are taken from Table 4.
3. Lake levels based approximately on Terry Milligan's lake level data for 2001-2003.
4. Surface outflows based approximately on DFO data for Mixal Creek.
5. Data are reported to nearest mm or nearest 10 m^3
6. Lake evaporation based on Priestley-Taylor equation for "open water" conditions
7. Pumping loss does not include the two Garden Bay licences in question

Table 6: Approximate monthly water balance for Hotel Lake in an average year with the two Garden Bay licences in place

	INPUTS						**OUTPUTS**						**NET**	
Month	Direct precip. onto lake (27 ha)	Runoff contribution from watershed upstream of lake (75 ha)			**Total inputs to lake**		Evaporation from lake, E	Surface Outflow	seepage loss	pumping (including the 2 Garden Bay licences)	**Total outputs from lake**		Input - Output	
	P (mm)	Runoff (mm)	Runoff (m^3)	Runoff (depth on lake (mm))	Volume (m^3)	**Depth (mm)**	(mm)	(mm)	(mm)	(mm)	Volume (m^3)	**Depth (mm)**	**Depth (mm)**	Volume (m^3)
Jan	170	85	63,750	236	109,650	**406**	0	28	286	22	90,750	**336**	**70**	18,900
Feb	132	90	67,500	250	103,140	**382**	12	27	307	26	100,440	**372**	**10**	2,700
Mar	124	79	59,250	219	92,730	**343**	40	27	276	30	100,830	**373**	**-30**	-8,100
Apr	89	54	40,500	150	64,530	**239**	77	27	139	36	75,330	**279**	**-40**	-10,800
May	81	41	30,750	114	52,620	**195**	120	9	74	42	66,120	**245**	**-50**	-13,500
Jun	72	23	17,250	64	36,690	**136**	136	4	28	48	58,290	**216**	**-80**	-21,600
Jul	44	12	9,000	33	20,880	**77**	161	0	-62	73	46,530	**172**	**-95**	-25,650
Aug	49	6	4,500	17	17,730	**66**	139	0	-38	60	43,380	**161**	**-95**	-25,650
Sep	62	12	9,000	33	25,740	**95**	84	0	13	48	39,240	**145**	**-50**	-13,500
Oct	137	23	17,250	64	54,240	**201**	34	0	31	36	27,240	**101**	**100**	27,000
Nov	202	79	59,250	219	113,790	**421**	8	4	257	22	78,690	**291**	**130**	35,100
Dec	182	96	72,000	267	121,140	**449**	0	14	283	22	86,040	**319**	**130**	35,100
TOTAL	1,344	600	450,000	1,667	812,880	**3,011**	811	140	1,595	465	812,880	**3,011**	**0**	0

Notes:

1. This is a simplistic analysis with <u>all of the change caused by the two Garden Bay licences</u> assumed to be accounted for by reductions in lake overflow and seepage, with no changes in the lake hydrograph – intended to demonstrate the maximum potential effect on lake outflows. In reality, the impacts will be shared by reductions in lake overflow, reductions in seepage, and reductions in lake levels.
2. Assume inputs = outputs (lake is neither filling nor draining over the long-term).
3. Precipitation and runoff data are taken from Table 4.
4. Lake levels based approximately on Terry Milligan's lake level data for 2001-2003.
5. Surface outflows based approximately on DFO data for Mixal Creek.
6. Data are reported to nearest mm or nearest 10 m^3
7. Lake evaporation based on Priestley-Taylor equation for "open water" conditions

Table 7: Likely effect of climate change on monthly inputs to Hotel Lake

Climate change Effect		Current conditions			2020 conditions		
Month	% change in runoff in 2020 vs 2000	Runoff input to Hotel Lake (mm)	Runoff (m^3)	Runoff (depth on lake, mm)	Runoff in 2020 (mm)	Runoff in 2020 (m^3)	Runoff in 2020 (depth on lake, mm)
Jan	8.8	85	63,750	236	92	69,340	257
Feb	5.8	90	67,500	250	95	71,390	264
Mar	-17.9	79	59,250	219	65	48,640	180
Apr	-24.1	54	40,500	150	41	30,730	114
May	-26.5	41	30,750	114	30	22,600	84
Jun	-42.0	23	17,250	64	13	10,000	37
Jul	-7.9	12	9,000	33	11	8,290	31
Aug	0.0	6	4,500	17	6	4,500	17
Sep	9.7	12	9,000	33	13	9,870	37
Oct	-2.1	23	17,250	64	23	16,890	63
Nov	9.5	79	59,250	219	86	64,860	240
Dec	12.9	96	72,000	267	108	81,290	301
	TOTAL	600	450,000	1,667	585	438,390	1,624

Notes:
1. Based on Whitfield et. al. (2002)
2. Data are reported to nearest mm or nearest 10 m^3

Table 8. Nutrient concentrations in Hotel Lake, 1994-2004.

Date	Location	Ortho-Phosphorus (P) Dissolved	Phosphorus Total Dissolved	Phosphorus-Total(P)	Nitrate Nitrogen Dissolved (N)	Nitrate+ Nitrite (N)	Nitrite Nitrogen (N)	Total Kjeldahl Nitrogen (N)	Ammonia Nitrogen (N)
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
13/10/1994	1	<0.003	<0.003	0.007					
	2	<0.003	<0.003	0.004					
04/07/1995	9M	<0.003	0.004	0.005					
09/01/1995	1M	<0.003	0.004	0.007					
18/04/1996	1M	<0.003		0.016					
	9M	<0.003		0.016					
13/04/1997	1M	<0.003	0.006	0.016				0.002	
	9M	<0.003	0.005	0.018				0.002	
11/12/1997	1M	<		0.09					
	9M	<		0.1					
05/07/1998	1M			<				<	
	9M			<				0.66	
28/10/1998	1M	<0.005		0.015					
	9M	<0.005		0.015					
22/04/1999	1M	<0.005		<0.005	<0.02	<0.02	<0.005		0.019
	9M	<0.005		<0.005	0.05	0.05	<0.005		0.173
20/12/1999	1M	<0.005		<0.005	<0.02	<0.02	0.007		<0.005
	9M	<0.005		<0.005	<0.02	<0.02	0.008		0.015
14/06/2000	1M	<0.005		0.009	<0.02	<0.02	<0.005		
	9M	<0.005		0.026	<0.02	<0.02	<0.005		
23/08/2000	1M	<0.005		0.013	<0.02	<0.02	<0.005		
	9M	<0.005		0.042	<0.02	<0.02	<0.005		
12/06/2000	1M			<0.005	<0.02	<0.02	<0.005		
	9M			<0.005	<0.02	<0.02	<0.005		
07/06/2001	1M			0.013	<0.02	<0.02	<0.005		
	9M			0.048	<0.02	<0.02	<0.005		
29/11/2001	1M			0.022	<0.02	<0.02	<0.005		
	9M			0.015	<0.02	<0.02	<0.005		
07/02/2002	1M			0.015	<0.02	<0.02	<0.005		
	9M			0.025	<0.02	<0.02	<0.005		
06/05/2003	9A			0.011	<0.02	<0.02	<0.005		

Notes:
1. Source = SCRD
2. Data obtained 11/12/1997 and 05/07/1998 are suspect, and have not been considered in the present report.

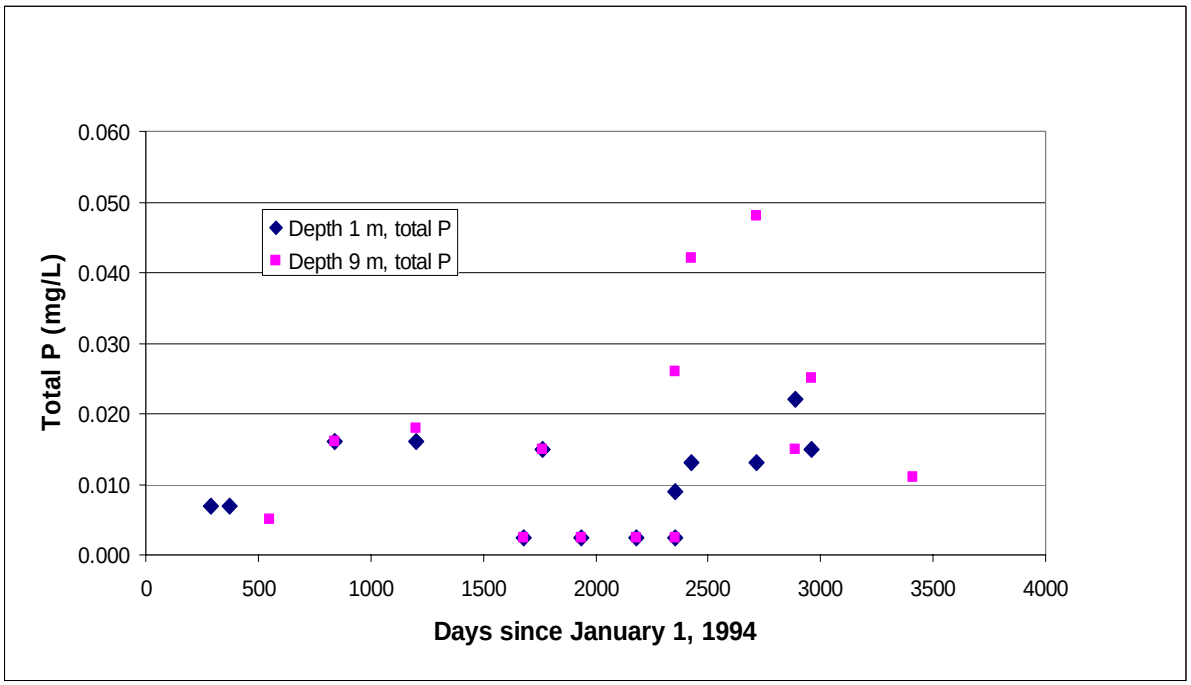

Figure 1. Total phosphorus concentrations at 1 m and 9 m depths in Hotel Lake.

Note: There are 6 data points between 500 and 2500 days on the x-axis that are superimposed – the points appear as purple circles with blue sides on a colour copy, or as indistinct circles on a black and white copy.