District of Lake Country Source to Tap Assessment of Okanagan Lake Intake – July 2010.

Executive Summary

The objectives of this assessment of the DLC Okanagan Lake Intake were to characterize the lake and its immediate watershed, identify current and forecast future drinking water hazards and vulnerabilities, characterize the risk posed by each hazard and provide recommendations to reduce potential impacts on the intake.

This assessment characterized natural and man-induced hazards to drinking water quality as physical, chemical or biological. Fortunately, Okanagan Lake is one of the most studied lakes in BC, making background information available to this assessment. Existing research was augmented by field studies of water currents near the intake and lab studies on the fall rates of particulate contaminants. This research was used to define a proposed Intake Protection Zone (IPZ), based on a two hour travel time of water currents to the intake. The hazard assessments were then divided into those occurring inside the IPZ and those occurring outside the IPZ. The same hazard occurring outside the IPZ was given a lower risk rating than that hazard presented within the IPZ where there is less dilution and less time to react to a contaminant.

Specific recommendations and action plans were developed: (1) source protection for mid-North Basin Okanagan Lake (2) water treatment and system protection plan and (3) future large expenditure improvements to the DLC Okanagan Lake water system. Key recommendations include: applying for a License of Occupation over the Intake Protection Zone; having DLC Planning staff and Water System staff work closely with the Lakestone developers to relocate the Lakestone Marina and the storm water outfall or otherwise mitigate the aquatic impacts of the project; modifying the water quality monitoring to comply with IHA filtration deferral; and consider extending the intake.

This assessment confirms what we all know; source protection is important to preserving low-cost safe drinking water and it requires the co-operation of every Okanagan resident.

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Disclaimer: This report is based on limited, cost-constrained research on complex lake systems. Larratt Aquatic Consulting Ltd and its associates have made a best attempt at accuracy in data collection and presentation. No liability is incurred by LAC or DLC for accidental omissions or errors made in the preparation of this report.

Figures, Tables and Appendices

1.0 Introduction

1.1 Study Background

On-going monitoring and research can be used to meet most of the criteria for the IHA requested Modules 1, 2, 7 and 8 of the Drinking Water Source to Tap Assessment for District of Lake Country's 33 m Okanagan Lake Intake. Because Lake Country is proactive, monitoring and research on their intakes has been in progress for years. All of the information from their intake studies and the extensive data base collected by Ministry of the Environment and other ministries can be brought to bear on this source to tap assessment. Additional innovative research was undertaken to round out the data base for this Source to Tap Assessment. This report is intended for both scientific and regional planning audiences.

1.2 Study Purpose

This report compiles new research and known data into the Source to Tap Assessment format for use identifying District of Lake Country's lake intake strengths, its liabilities and to allow for water quality protection and improvement planning. The most sensitive designated use of the water from Lake Country's Okanagan Lake intake is as domestic drinking water, as part of a public water supply.

1.3 Study Plan

This report was written using the Okanagan Lake studies 2008 - 2009 commissioned by Lake Country and by studies of the adjacent proposed GEID intake commissioned by Glenmore Ellison Improvement District and used with their kind permission. Reports created by Provincial agencies including Ministry of Environment were reviewed. Several reports prepared for the City of Kelowna by Hay and Company were also utilized.

The research/sampling component of this source to tap report was completed in 2009 and it involved:

- Collecting sediment samples from beneath the intake for total coliforms and *E. coli*
- Sediment traps were deployed near the intake for 7 months (Oct - May)
- A caffeine analysis from the raw water to identify the presence/absence of dilute human outfall/septic wastes
- A drogue study of long-shore currents near the DLC Okanagan Intake to clarify local water current conditions
- Inclusion of cyanobacterial, thermistor chain, water quality, microfloral and sediment data for the intake area from Deep Okanagan Lake Biology Study 2009

1.4 Definitions

The following terms are defined as they are used in this report.

ALGAE BLOOM: A superabundant growth of algae. Many species are capable of coloring the water or covering the surface of a lake.

ANAEROBIC or ANOXIC ZONE: A zone that develops along the sediments where algal decomposition consumes oxygen faster than it is supplied by the surrounding water. Anaerobic zones accumulate color, nutrients, THM precursors and taste & odor compounds.

BENTHIC: Organisms that dwell on or are associated with the sediments.

BIOFILM: A thin usually resistant layer of microorganisms, such as bacteria, that form on and coat surfaces such as water pipes.

BLUE-GREEN ALGAE (CYANOBACTERIA): The family of bacteria-like algae having cyanochrome as the main photosynthetic pigment and chlorophyll as a secondary pigment. Many members of this family reproduce rapidly and some cause algae blooms. They are notorious for taste and odor problems.

CONDUCTIVITYY: Electrical conductivity *of* water samples is used as an indicator of how salt-free, ion-free, or impurity-free the sample is; the purer the water, the lower its conductivity.

DIATOMS: The family of algae containing chlorophyll as the primary photosynthetic pigment and having hard, silica-based "shells" (frustules). Diatoms affect filtration and produce a range of taste and odors.

DROGUE: Float used to track current paths at a depth below the water surface determined by the position of vanes (or other surface to intercept currents) suspended beneath the float.

EUTROPHIC: Refers to a nutrient-rich, biologically productive water body where concentrations of mineral and organic nutrients have reduced dissolved oxygen, producing environments that frequently favor plant over animal life.

Lake Classification by Trophic Status Indicators

Trophic Status	Chlorophyll-a ug/L	Total P ug/L	Total N ug/L	Secchi disc m	Primary Production mg C/m^2/day
Oligotrophic	0 – 2	1 – 10	<100	> 6	50- 300
Mesotrophic	2 – 5	10 – 20	100 – 500	3 – 6	250 – 1000
Eutrophic	>5	> 20	500 - 1000	< 3	>1000

After Nordin 1985

FALL OVERTURN: In fall, surface waters cool and sink, eroding the thermocline until a wind storm mixes the entire water column.

FRESHET: Freshet is commonly refered to as “spring runoff” and is the period when accumulated winter snow melts, causing substantially increased stream flow.

GENERA: The usual major subdivision of a family or subfamily in the classification of organisms, usually consisting of more than one species.

GREEN ALGAE: The large family of algae containing chlorophyll as the primary photosynthetic pigment.

IRON RELATED BACTERIA: Non-disease-producing bacteria that grow in water and use dissolved iron as part of their metabolism.

LIMITED, NUTRIENT LIMITATION: In any environment, a nutrient or other growth requirement will limit or restrict the potential growth of organisms. For example, phosphorus usually limits algae production in lakes; if there is an increase in all of the other nutrients, no increase in algae growth will result because phosphorus is the bottleneck. Conversely, even a small increase in the phosphorus supply will result in increased algae growth.

LIMNOLOGY: The study of freshwater; physical and chemical considerations such as lake thermal behavior, nutrient cycling, basin morphology, sediment structure, etc.

MACRONUTRIENT: Macronutrients are the major constituents of cellular protoplasm and usually limit biological production. They include nitrogen, phosphorus, carbon, hydrogen and sulphur.

METALIMNION: The water layer containing the thermocline that is between the surface epilimnion and the bottom hypolimnion.

MICRONUTRIENT: Relatively minute amounts of a micronutrient are required to maintain plant growth within its environmental constraints. These include; Mn, Fe, Co, Zn, Cu, Mo etc.

MONOMICTIC: Refers to a lake that experiences only one period of mixing that extends from fall, through the winter to early spring.

NANNOPLANKTON: Minute algae that pass through the mesh of fine (No. 20) bolting cloth. Most are less than 5 microns in their largest dimension.

OXIC: Refers to an environment with oxidizing conditions and can be used synonymously with aerobic which refers to an environment with free oxygen.

PHYTOPLANKTON: Algae that float, drift or swim in standing water.

PHOTIC ZONE: The zone in a water body that receives sufficient sunlight for photosynthesis.

PLANKTON: Organisms that float or swim in water. Phytoplankton refers to plants; zooplankton to animals.

RIPARIAN: A riparian zone or riparian area is the interface between land and a stream or lake. Plant communities along the river margins are called riparian

SECCHI DEPTH: The depth to which a 20 cm disk with alternate black and white quadrants can be seen through the water column

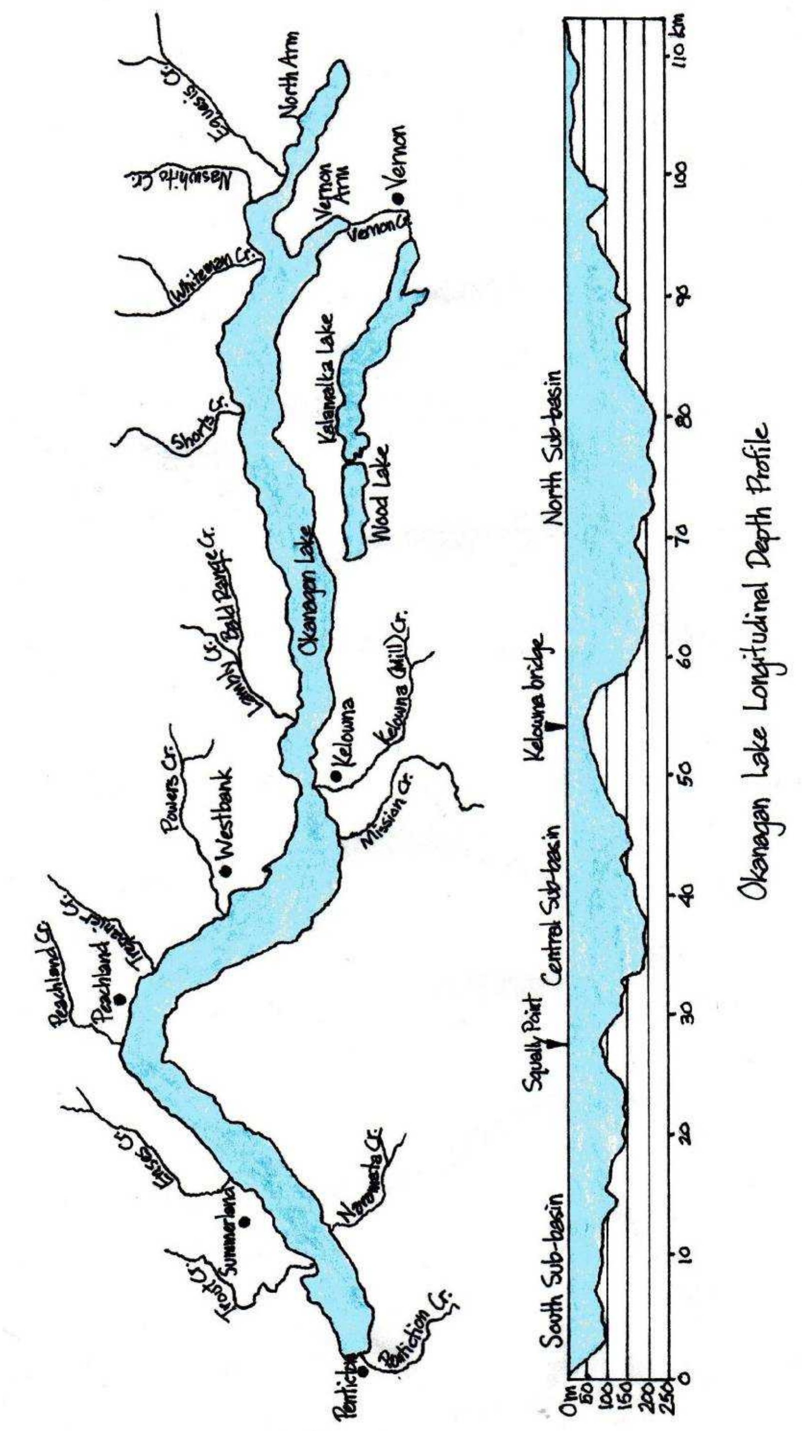
SEICHE: Wind-driven tipping of the water layers during the summer. Seiches cause the water layers to oscillate for days after a wind storm.

THERMOCLINE: The zone of greatest change in water temperature with depth (> $1^{o}C/m$) that separates the surface water (epilimnion) from the underlying cold hypolimnion.

ZOOPLANKTON: Minute animals that graze algae, bacteria and detritus.

Report abbreviations: *DLC = District of Lake Country; MoE = Ministry of Environment:*
LAC = Larratt Aquatic Consulting; GEID = Glenmore-Ellison Irrigation District;
C of K= City of Kelowna; GVW = Greater Vernon Water OBWB= Okanagan Basin Water Board
UBC-O= UBC Okanagan campus IHA=Interior Health Authority

FIGURE 2.1 Okanagan Lake Longitudinal Depth Profile



Okanagan Lake is divided into three sub-basins by an underwater sill at Squally Point and another sill at the Bennett (Kelowna) Bridge.

2.0 DLC Okanagan Lake Intake Module 1: Characterization of Source

2.1 Okanagan Lake Limnology and Watershed

Okanagan Lake is located in south central British Columbia. It has a watershed catchment area of over 6,000 km^2 and is the largest of the five main and interconnected lakes in the Okanagan Valley (Bryan and Jensen, 1989). Okanagan Lake is the most important and valuable lake in BC and is therefore one of the most studied lakes in the province (Nordin, 2005).

Okanagan Lake is approximately 135 km long, 1 to 5 km wide, and has a surface area of 35,000 hectares. It takes about 53 years to replace all of the water in the lake, based on outflow. Its maximum depth is 230 m with a mean depth of 76 m. It receives flow from Kalamalka Lake in the north via Vernon Creek and releases water to the south through Okanagan River to Skaha Lake (Bryan and Jensen, 1989). It receives water from numerous tributaries of which Mission Creek, Trout Creek and Lambly (Bear) Creek are the largest.

The water that comes into Okanagan Lake is primarily from tributary stream inflows (89%) and secondarily from the precipitation that falls directly onto the lake surface (11%). Average losses of water from the lake are from outflows via Okanagan River (56%) and evaporation from the lake surface (40%) and water intakes to supply irrigation and drinking water demands (4%) (Ward and Yassien, 2000; Nordin, 2005). As of 2005, there were 1085 licenses issued on Okanagan Lake (Patschke, pers comm. 2010) Evaporation from the lake surface removes almost a meter of water in an average year. Of the water that is used for irrigation and domestic consumption, about 50 to 65% of it returns to Okanagan Lake as groundwater and as treated sewage (Nordin 2005). On an annual basis, the outflow from Okanagan Lake is very small – only 2% of the lake's total volume, while the amount retained in the lake is 98%.

Okanagan Lake is divided into three basins by underwater sills. The Lake Country intake is located in the largest and deepest of the three basins, the North Basin (Figure 2.1). Okanagan Lake has distinct water chemistry differences in each of the three basins and there is water movement among the three but not equally in all directions or towards the southern outlet. The differing physical and chemical characters of the three basins results in distinctive biological profile as well. The three basins could be separate lakes in terms of the sum of their differences.

There is a general nutrient gradient in Okanagan Lake from moderate nutrient concentrations in the North Arm to more nutrient-poor conditions throughout the balance of the lake, with localized higher nutrient conditions near creeks and urban areas.

In the late 1960's a number of important studies were conducted in response to public concern about deteriorating water quality in the Okanagan Valley, culminating in the Okanagan Basin Study. Even a lake the size of Okanagan Lake was experiencing nuisance algae growth in response to increasing nutrient loads from municipal outfalls, watershed impacts on creeks, and near-shore developments.

Okanagan Lake forms distinct water temperature layers during the spring and remains stratified through the summer. The water layers erode during the fall until a wind storm mixes the water column, usually in November. The lake remains fully mixed top to bottom until stratification commences again in early May. Okanagan Lake is therefore monomictic (one mixing). Its surface temperatures reach 20°C during most summers. The thermocline occurs at 10-15 m in early to mid summer, and deepens to 15-20 m in early fall (Andrusak et al., 2005; Hayco 2000). The entire lake has only had complete ice cover 3-4 years in the past 100 years, in the early 1900's. Partial freezing of sheltered areas such as the North Arm occurs more frequently (Bryan and Jensen, 1996).

2.2 Description of Intake: location, design, construction and maintenance

The intake and main pipeline was constructed in 1968 by Hiram-Walker Distillery as their source of process water. The intake pipe size is 45".

Lake Country's Okanagan Lake intake is 33 m deep and approximately 60 m long (out from the shore) at N50.0137 W119.442. This intake is located on a steep rocky shoreline. The 60 m intake length is very short and close to shore for an intake of this depth (Figure 2.2). The position of the inlet is only 40 m from shore
Because it is on a cliff and fitted with an elbow, there is excellent (5m) clearance of the intake from the substrate.

Cross Section of Intake

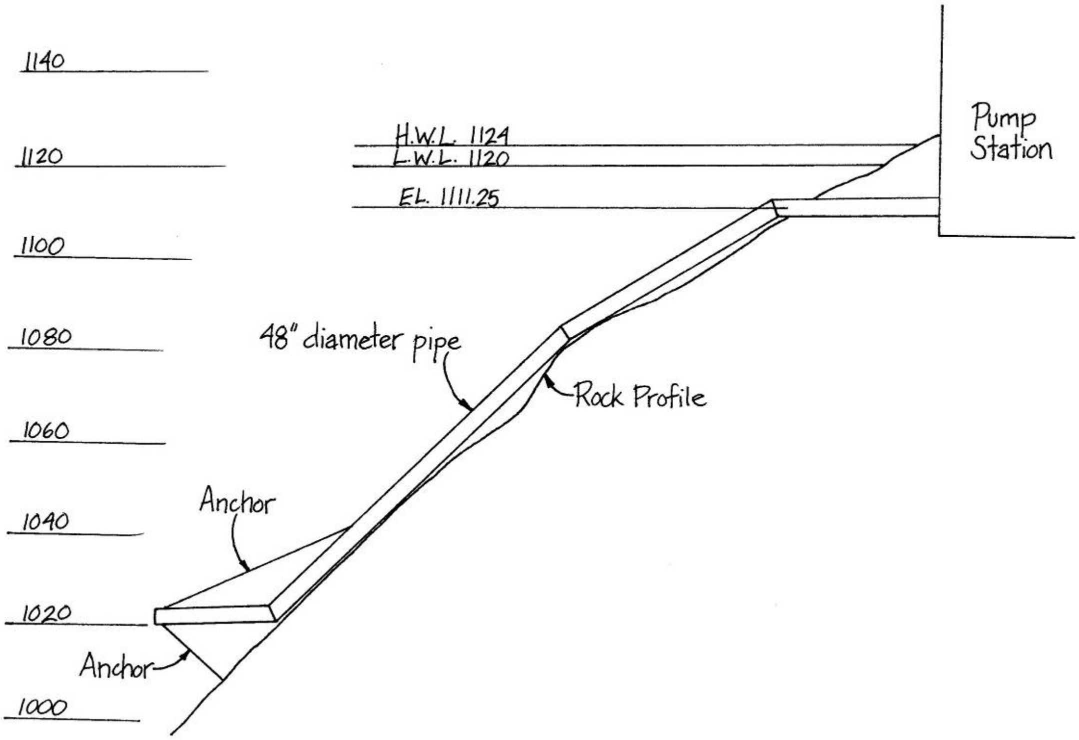
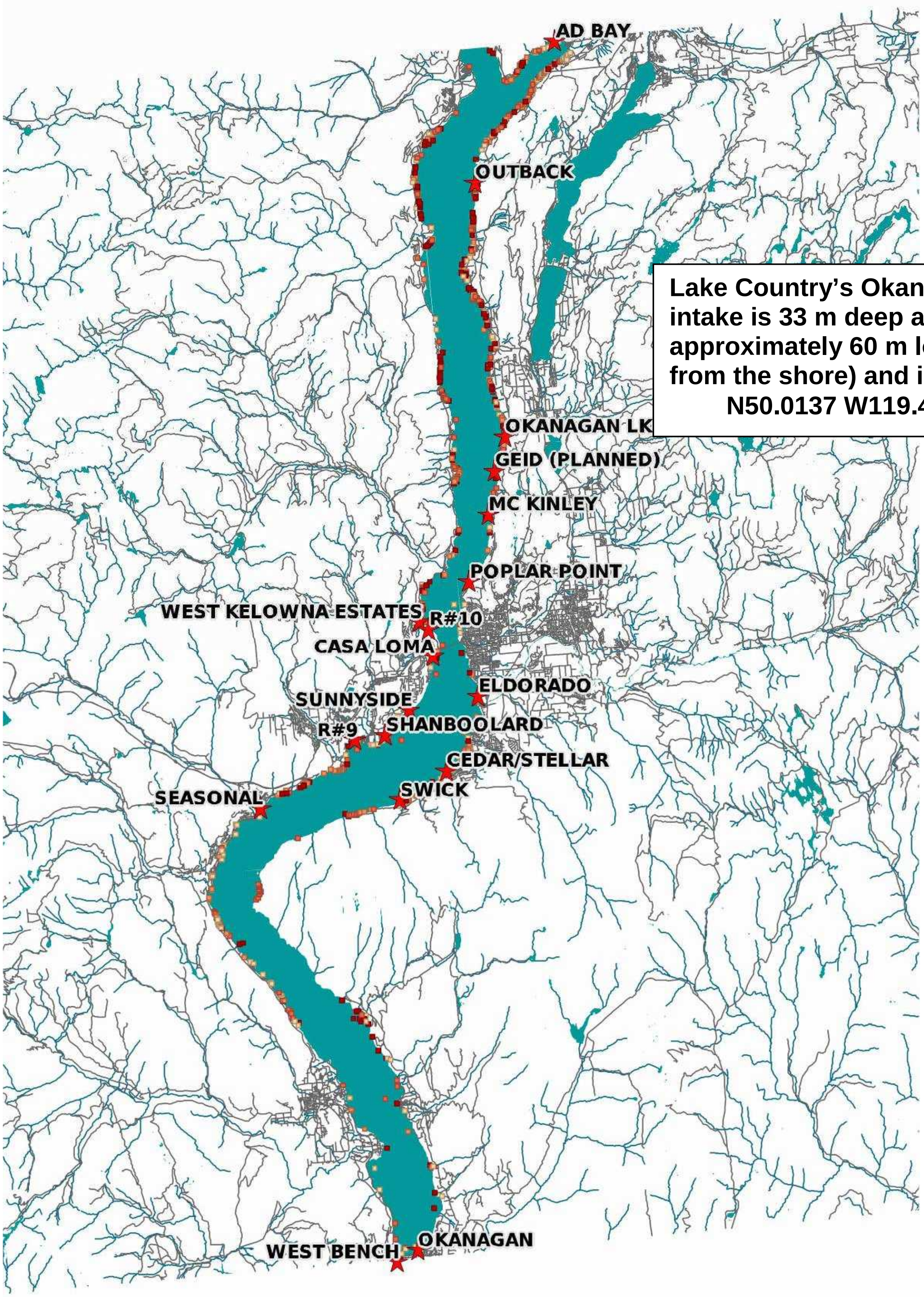


Figure 2.2:
GIS Image of Okanagan Lake Showing Okanagan Intake Location
–GIS by Aaron Hahn (GEID)



Lake Country's Okanagan Lake intake is 33 m deep and approximately 60 m long (out from the shore) and is located at:
N50.0137 W119.442

2.3 Okanagan Lake Limnology – Thermal Data, Seiches, Light Penetration

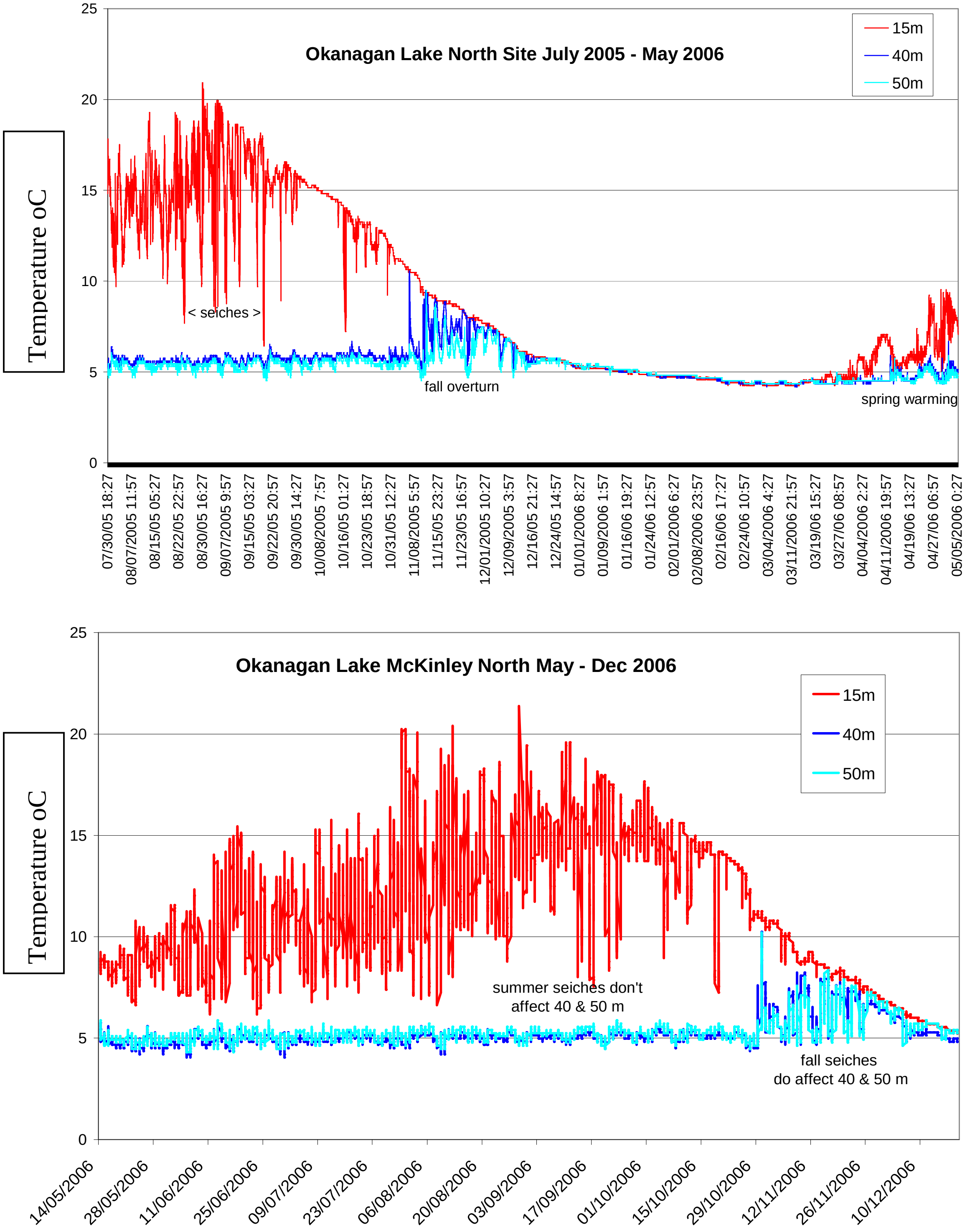
Like most large lakes, Okanagan Lake experiences internal waves called seiches during the stratified season (late May – early November). Figures 2.3 and 2.4 illustrate seiching. During seiches, intakes collect alternately cold deep water and warm surface water as the internal waves travel back and forth past an intake after a wind event. Overall, deep intakes draw colder water and experience fewer seiches while shallow intakes draw warm water during the summer and experience many powerful seiches.

Within Okanagan Lake, these seiches, upwellings and water currents direct the movement of “water parcels”- discrete inflows that gather in localized areas and travel as a mass while gradually mixing with an increasing volume within Okanagan Lake. For example, creek plumes often travel into Okanagan Lake as a “river of water” within the lake (Figure 2.10). These water movements also impact the flux of nutrients horizontally within the lake’s three basins, and vertically between the water layers during the stratified season.

Comparing current thermal data to a detailed study performed in 1939 shows slight warming in the thermal regime of Okanagan Lake (Clemens et al., 1939). This could be related to climate change or merely the result of the particular temperatures captured in 1939 and 2007-2009. Detailed thermal data from GEID’s thermistor lines located near McKinley Landing in the North Basin of Okanagan Lake is presented in Figure 2.3 and Figure 2.4. Abrupt temperature shifts illustrate seiches in these graphs.

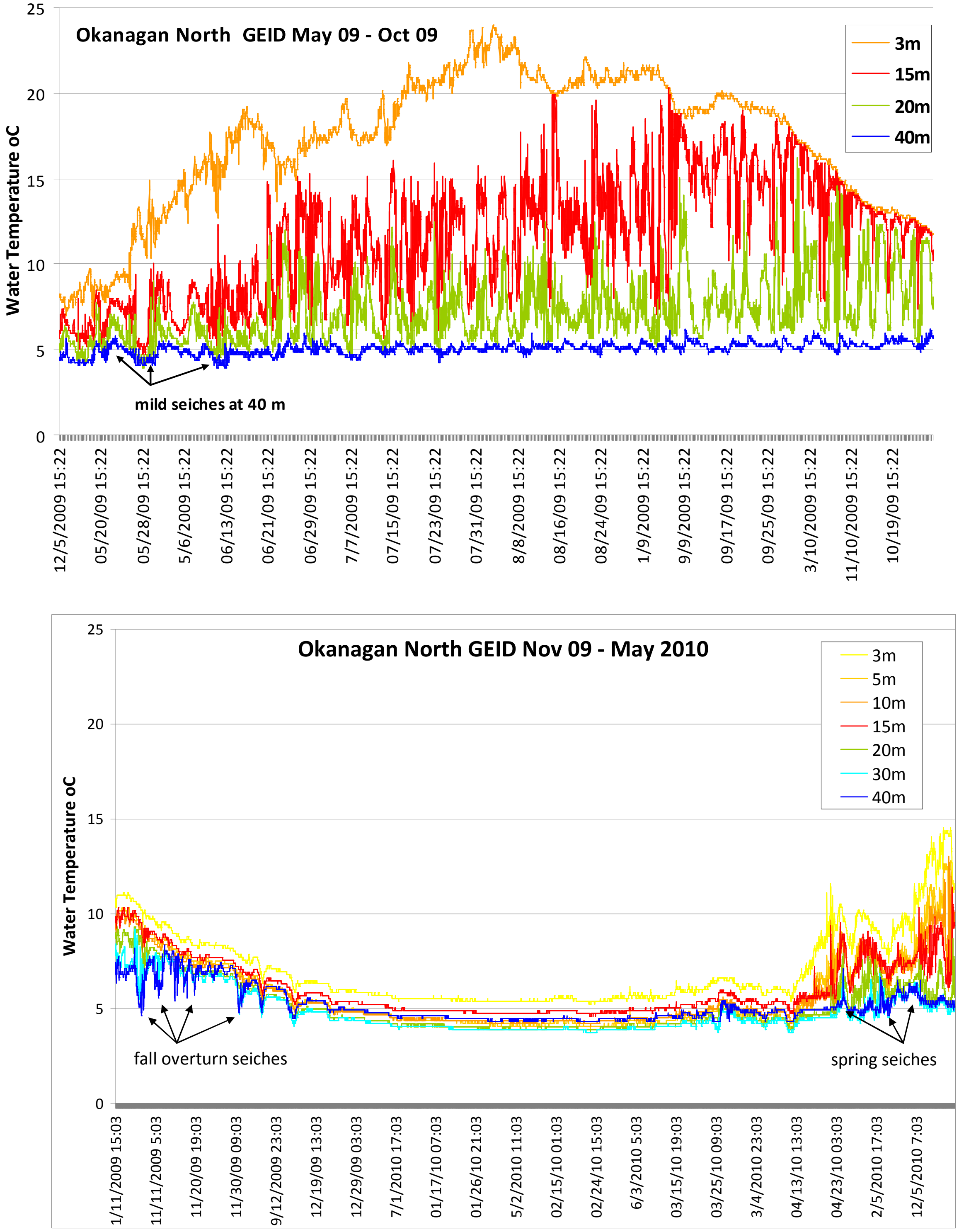
Thermistors at the exposed GEID intake site showed rapid oscillations in water temperature at the 15 m and 20 m thermistor and several seiches per week, particularly in the early and late summer. Spring mixing ends in late April (+- 3 weeks depending on weather) and thermal stratification begins. Seiches penetrate to 40 and 50 m in the spring and fall, but are less frequent and milder than the seiches occurring in shallower water layers.

Figure 2.3:
Thermistor Data for Proposed Okanagan Lake Intake, GEID North Site



COMMENTS: Even 40 and 50 m depths show seiche-induced temperature fluctuations of 3-5^{o}C during fall overturn. The 40/50 m depths are not affected by summer seiches.

Figure 2.4 Thermistor Data for Proposed Okanagan Lake Intake 2009-2010



COMMENTS: The exposed GEID Intake site showed rapid oscillations in water temperature at the 15 m and 20 m thermistor and several seiches per week, particularly in the early and late summer. Seiches penetrate to 40 and 50 m in the spring and fall, but are less frequent and milder than the seiches occurring in shallower water layers.

Okanagan Lake establishes a thermocline in May and mixes deeper into the water column as the year progressed. The depth where the thermocline is located on any given sampling date was affected by seiches that can "move" the thermocline by more than 20 m vertically.

A 10 m intake at this location would experience seiches constantly and draw from the surface water layer throughout the summer. A 20 m intake at this location would be impacted by 2-3 seiches/week from mid-April to mid-November. The temperature fluctuations caused by passing seiches in Okanagan Lake decrease with depth according to the following table (no data available for South Basin):

Table 2.1: Maximum Seiche-Induced Temperature Fluctuations at Okanagan Lake Intake Depths

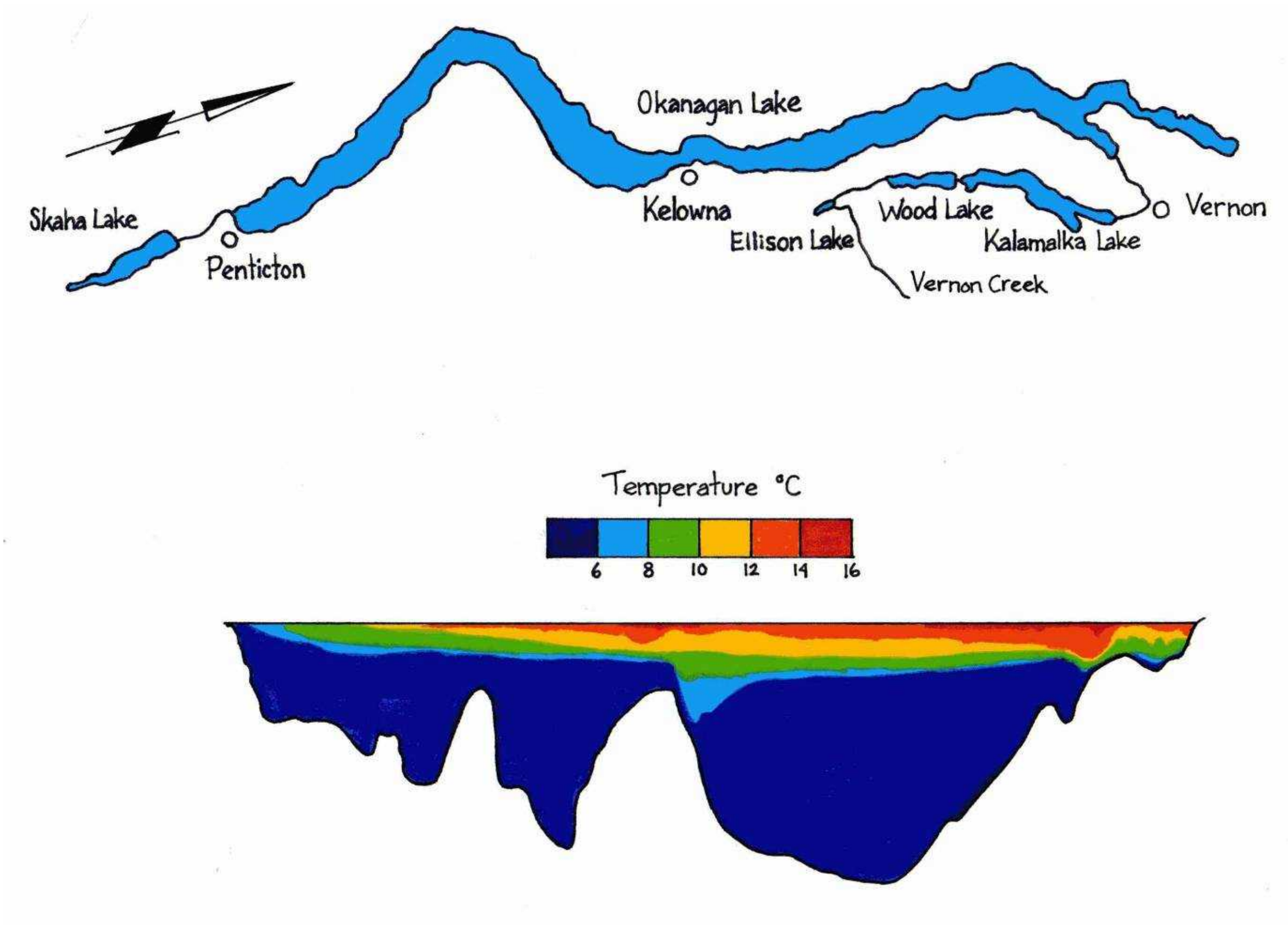
Intake Depth (m)	**Modeled: Central Basin** Temp. fluctuation ^{o}C and (Min – Max temp)	**Measured: North Basin** Temp. fluctuation ^{o}C and (Min - Max temp)
< 20	**13 (5 – 18)**	**13 (5 – 18)**
25	**10 (5 – 13)**	**9 (4 – 13)**
30	**7 (5 – 12)**	**7 (5 – 12)**
40	**5 (5 – 10)**	**5 (5 – 10)**
50	**3 (5 – 8)**	**4 (4 – 8)**
> 60	**< 3 (4 – 6)**	**< 3 (4 – 6)**
	Modeled by Hayco	Measured by LAC

The Okanagan Lake intake at 33 m is affected by seiches that can temporarily raise water temperature to 13.6 ^{o}C as surface water is drawn down to the intake depth (Meger et al., 2006). Seiches may also be responsible for elevated turbidity and water color (max = 69 PtCo) in intake samples collected by DLC.

The 40 m depth has a satisfactory temperature regime (5-10 ^{o}C) for most water treatment plants. 40 m evades summer seiches and is briefly affected by October/November seiches (Figure 2.2). 40 m is also suitable for SCUBA diver maintenance of an intake. Diving up to 40 m is air-diving and is less expensive (4000.00/day for diving crew diving Dynamics Kelowna 2009 estimate). Diving from 40 to 47 m requires additional equipment and is more expensive (10,000 – 12,000/day for diving crew plus chamber). Diving 48 m to 80 m is theoretically possible but would require mixed gas, specialist crews from Vancouver, and is very expensive due in part to increased risk for the divers.

Figure 2.5 shows the summer seiche penetration and how the seiches are disrupted and re-organized by the sills separating the three basins of Okanagan Lake. (The water layers are not parallel to the lake surface because of wind-driven seiches).

Figure 2.5: Summer Seiches in a Cross Section Illustration of Okanagan Lake
(After Hayco, 2000)



Comments: The map and the cross section have been lined up vertically to show the positions of the sills that separate Okanagan Lake into three basins. The cross section shows the North basin as the deepest and largest of the three basins. It also shows the depths involved in summer stratification. In the cross section, a seiche is occurring where the water layers tip and are “caught” on the sills and shallow areas of the lake.

2.4 General Okanagan Lake Water Chemistry

Okanagan Lake has distinct water chemistry in each of the three basins and there is water movement among the three but not equally in all directions and neither is there a net movement towards the southern outlet. Only about 2% of the water is exchanged in Okanagan Lake in any given year. The differing physical and chemical characters of the three basins results in distinctive biological profile as well.

The DLC Okanagan Intake is located in the Northern basin and the water quality discussion will focus on this basin. Water quality near the DLC Okanagan intake is fairly uniform with depth. Most of the changes in water quality occur in the upper 10 m (Nordin, 2009, pers. comm., Wetzel, 2001). Since the 1970's, urban and residential activities have been consistently identified as imposing the largest impact on Okanagan Lake, while prior to that time, agriculture was deemed to have the largest impact (OBA, 1973).

pH

Okanagan Lake water is basic with the pH ranging from 8.0 in January to 8.5 in August. Photosynthesis increases pH, accounting for greater pH during the summer months.

Water transparency

Water transparency can be measured with a secchi disk (a 17 cm disk with alternate quarters of black and white). The secchi depth is shortest in the spring when the spring diatom bloom is at its height. It can be as little as 5.8 m, while in the low productivity winter months, the secchi depth can be as much as 16.5 m. Okanagan Lake secchi depths averaged 8 to 10 m during the summer months, yielding a photic depth of approximately 20 m – unchanged from research conducted in 1939 (Clemens et. al., 1939).

TSS

Ministry of Environment data from the 1970s and 1980s records an average total suspended solids at the intake depth of 10 – 12 mg/L. There was very little change in the TSS with the seasons or through the years of study (Nordin, 1988).

Nutrients

There is a general nutrient gradient in Okanagan Lake from moderate nutrient concentrations in the North Arm to more nutrient-poor conditions throughout the balance of the lake, with localized higher nutrient conditions near creeks and urban areas. Overall, Okanagan Lake is classified as oligotrophic or nutrient-poor (Andrusak and Sebastian, 2000). Its typically low nitrogen concentrations give a competitive advantage to the cyanobacteria because they can utilize atmospheric nitrogen and they can persist in low light conditions in deep water. MoE data from the intake depth gave a range of total nitrogen of 0.13 – 0.35 mg/L as N and a total phosphorus of 0.06 – 0.10 mg/L as P (Nordin, 2005).

Chlorophyll-a and TOC

Chlorophyll-a is a photosynthetic pigment found in most algae and is a means of measuring lake productivity. MoE measured chlorophyll-a as a surface-5 m-10 m composite and their measurements averaged 0.8 – 2.0 ug/L or moderate.
Total organic carbon measured at GVWs Outback Intake in the North basin ranged from 5.3 – 6.9 mg/L TOC or moderate in the fall/winter of 2009.

2.5 Water Chemistry Relevant to Drinking Water Safety

Algae Analyses

With climate change and eutrophication, the frequency and intensity of cyanobacteria growth is increasing in Canada. In Okanagan Lake, conditions have biased the lake towards blue-green production for at least 70 years (Andrusak et al., 2005; Clements et al., 1939). Bloom-forming surface types require high concentrations of nitrogen (N) and phosphorus (P). Increased nutrient concentrations would stimulate their growth. Research suggested that eutrophication increased the occurrence of microcystin-producing cyanobacteria, raising the risk of toxic bloom formation (Rantala et al, 2006; H&W Canada, 1992). Minimizing nitrogen loading from storm water with its lawn fertilizer N is important, as is watershed protection on the major tributaries, and management of municipal outfalls. The MoE nutrient loading targets should be met consistently for Okanagan Lake.

Most cyanobacteria grow best in nutrient-rich warm water, but Okanagan Lake is not the only nutrient-poor large lake to be dominated by cyanobacteria – there are many other examples world-wide (Rojo and Cobelan, 1999). In fact, *Planktothrix rubescens*, the species having the highest microcystin concentration per cell of all known cyanobacteria, occurs primarily in the metalimnion of oligotrophic and deep lakes, and can persist during the winter (Reynolds and Walsby, 1975; Reynolds, 1987; Humphries and Lyne, 1998). *Planktothrix* is the dominant deep lake species in Okanagan Lake.

Like most large temperate lakes, Okanagan Lake experiences peak algal production in the spring when nutrients and dissolved organic material are circulated to the surface water by spring turbulence. Diatoms, flagellates and cyanobacteria dominate the spring algae community (Stockner, 2003). The physical size of the spring diatoms in Okanagan Lake samples collected for this study were all very large for algae, and would settle out in distribution systems. The same dominant types were present in this study as there were in 1939,1973 and 2006-2007 studies (*Asterionella, Cyclotella, Fragilaria Melosira, Stephanodiscus and Tabellaria*) suggesting stability in the lake system. Their annual densities depend on nutrient concentrations. Unlike most lakes, Okanagan Lake deviates from the typical summer algae populations of flagellates and green algae and instead develops colonial blue-green dominance by late June (Stockner, 2003). Mid-summer algae populations decline as nutrients are depleted, creating a “clear water period”. Cyanobacteria counts increase again in the fall as turbulence returns nutrients to the surface water.

Averaged over an entire year, cyanobacteria dominate Okanagan Lake algae, followed by diatoms, and then a diverse group of small flagellates. Cyanobacteria usually account for about half of the phytoplankton community in summer and they can increase to 60% of both algal density and biomass in the fall (Stockner, in Andrusak et al., 2003). Average annual algae densities vary by as much as 50% from 2600 – 5400 cells/mL (Andrusak et al., 2005); individual intake samples collected in 2009 ranged from 200 to 5650 cells/mL. At the DLC Okanagan Intake peak algae counts are encountered in May and can reach 3800 cells/mL, 3000 cells of which are cyanobacteria (Larratt et al.,2009) ,

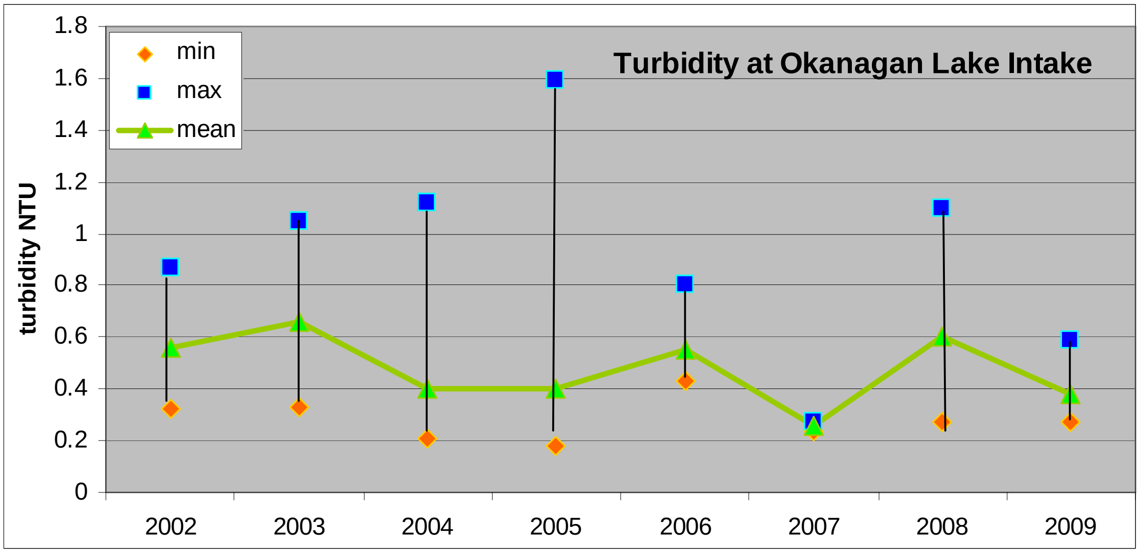
Taste and Odor

Taste and odor events in water drawn from DLC Okanagan intake are very rare. Occasionally the spring diatom densities are large enough to impart a mild grassy, musty or astringent odor, but most people cannot discern it after chlorination. No taste and odor complaints have ever been received on this system.

Turbidity

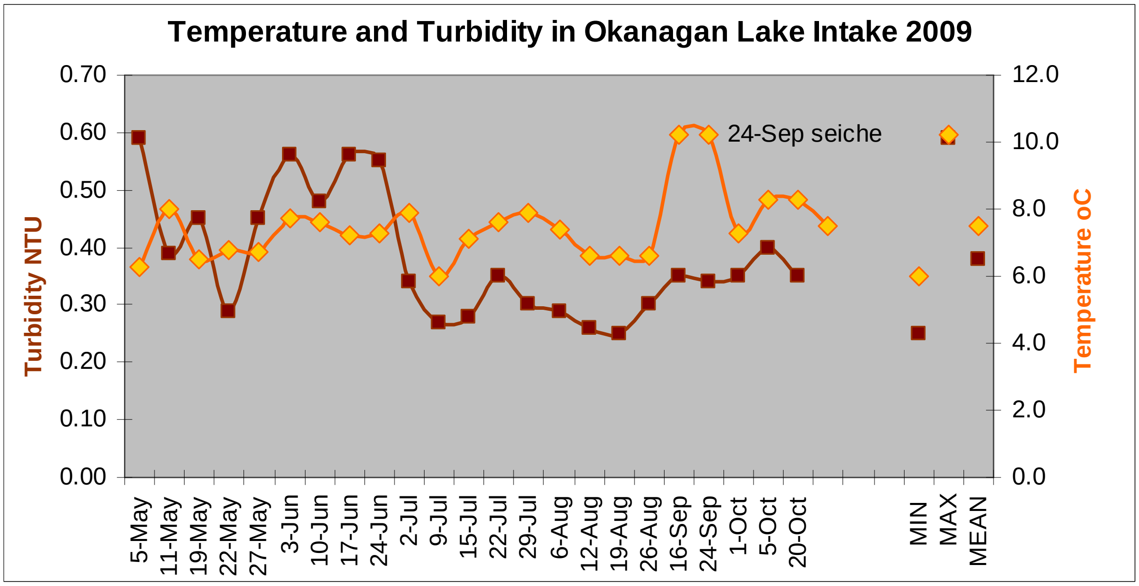
Turbidity is generally low in Okanagan Lake water in the area and depth of DLC's intake. Over the years and season of operation, average annual turbidity has ranged from 0.3 to 0.65 NTU – indicating very low overall turbidity (Figure 2.6). The dates where turbidity exceeded 1.0 NTU are very rare and isolated, usually only one or two dates per year and they have occurred in August, September and October. These dates correspond to the fall seiches that lead to the fall overturn in November.

Figure 2.6 Average Annual Turbidity at DLC Okanagan Lake Intake



When the temperature and turbidity data for 2009 are compared, dates with elevated turbidity also tended to have elevated water temperature, again suggesting seiche activity (data from DLC) (Figure 2.7).

Figure 2.7 2009 Water Temperature and Turbidity showing a Seiche



UV transmissivity

UV transmissivity was monitored in 2009 and ranged from 84.8% to 91.7% with an average of 87.6% The lowest readings occurred in the spring during the mild annual diatom bloom. These algae are very large in May (up to 100 microns in the longest dimension). UV disinfection would be effective on the DLC Okanagan Lake intake as a secondary disinfection process.

2.6 Calculation of Intake Protection Zone for DLC Okanagan Lake Intake

> *An intake protection zone defines the area where the intake should take precedence over every other use or consideration and defines the areas of land and water where special care must be taken in the use and handling of potential contaminants to prevent them from accidentally entering the lake and affecting the intake.*

The decision on the size of an intake protection zone should be based on the existing and potential hazards, and on the speed with which they can be transported to the intake, both horizontally and vertically. Vertical transport is dominated by fall rates and seiches while horizontal movement in lakes is dominated by wind-driven currents and inflow plumes. The default intake protection zone defined by IHA is a 100 m radius around the end of the intake. The protection zone should be modified from a circle to reflect consistent influences on water travel near the intake such as stream inflows, water currents and seiche patterns. A second layer of protection zone could be imposed on adjacent land development where subsurface (waste water; irrigation water management) and surface (storm water) flows delivered to the intake protection zone would be significantly impacted by the land development.

The minimum intake protection zone safety factor recorded in the Lake Ontario Source to Tap Study is 2 hours and 1 km radius (Stantec ,2007). Lake Ontario is a large lake with heavy industrial use; and not analogous to Okanagan Lake. None the less, a decision must be made on the acceptable time-safety factor that would give DLC a reasonable timeframe to react to an emergency such as a spill. The maximum speed of water transport at the surface and at the intake depth are then used to estimate the intake protection zone (IPZ).

Drogue Water Current Studies

Drogues can be used to measure water currents. They consist of a large surface to intercept and be carried by lake currents, attached to a small float. Drogues were released and tracked by GPS for several hours under a range of wind conditions. Currents in Okanagan Lake show a seasonal variability that is strongly related to wind speed. Wind speeds were average on the study dates, ranging from 2 – 15 km/hr. The relationship between wind speed and water current speed was measured by the drogues and it was very close to the general energy transfer estimate of 1.3 - 2% (Wetzel, 2001), and is close to the energy transfer estimate of 2-3% used in Hayco's modeling.

The stretch of Okanagan Lake near the DLC intake experiences fast-moving water currents parallel to shore. Horizontal water currents are strongest in the top 5 meters of Okanagan Lake, particularly in front of a point of land. During a storm, they can reach speeds of up to 9.5 cm/s (342 m/hr) (Figure 2.8).

The drogue studies conducted as part of this report measured water currents in the immediate vicinity of the intake. Drogues were deployed on September 14 and October 7, 2009 adjacent to the pump house and on July 10, 2009 at a site 700 m to the south (Figure 2.8). In all cases movement was towards the south or slightly east of south (towards shore).

On Sept 14, 2009 one 10 m drogue moved in a SE direction (towards shore) at 25 m/hr while a second 10 m drogue moved SSE at 56 m/hr. The second drogue was started closer to shore, indicating the impact of the shoreline in directing movement and increasing water current speed (Figure 2.8). Generally water movement was fastest near the surface and decreases with depth. One exception occurred on Sept 14, when the 20 m drogue moved at the same speed as the faster of the 10 m drogues (56 m/hr). On all three dates, the thermocline was at 15 m.

When wind direction reversed during a drogue run, the surface water layer reacted first by slowing and reversing direction. Deeper water layers reacted slowly. Hayco modeling and this drogue study agree that water layers within Okanagan Lake can travel in different directions from each other, creating turbulence between the layers.

Current speed diminishes with depth. Drogue speeds at 5 m were 91-158 m/hr, at 10 m were 25-56 m/hr and at 20 m were 20-56 m/hr. These speeds are very close to the model predictions of <144 m/hr at a 5 m depth, <72 m/hr at 20 m and deeper (Hayco, 1999). At the intake depth of 33 m, the Hayco model predicts 18 -36 m/hr during non-storm, winter conditions.

Although in this study the drogues always traveled south, direction of travel would be reversed, under different winds but that was never observed during the 2009 drogue runs.

Table 2.2: Drogue Results for DLC Okanagan Lake Intake 2009

	July 10		Sept 14		Oct 7	
Depth m	m/hr	direction	m/hr	direction	m/hr	direction
5	146	S	140	S	115	SSE
5	110	S	158	S	91	SSE
10	224	S	56	S	54	S
10	196	S	25	SE	47	S
20			56	S	20	SSE
30	23	SE				

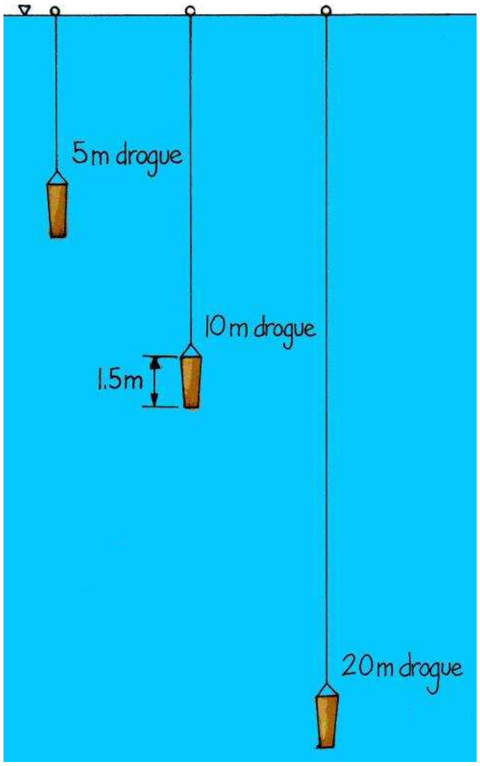
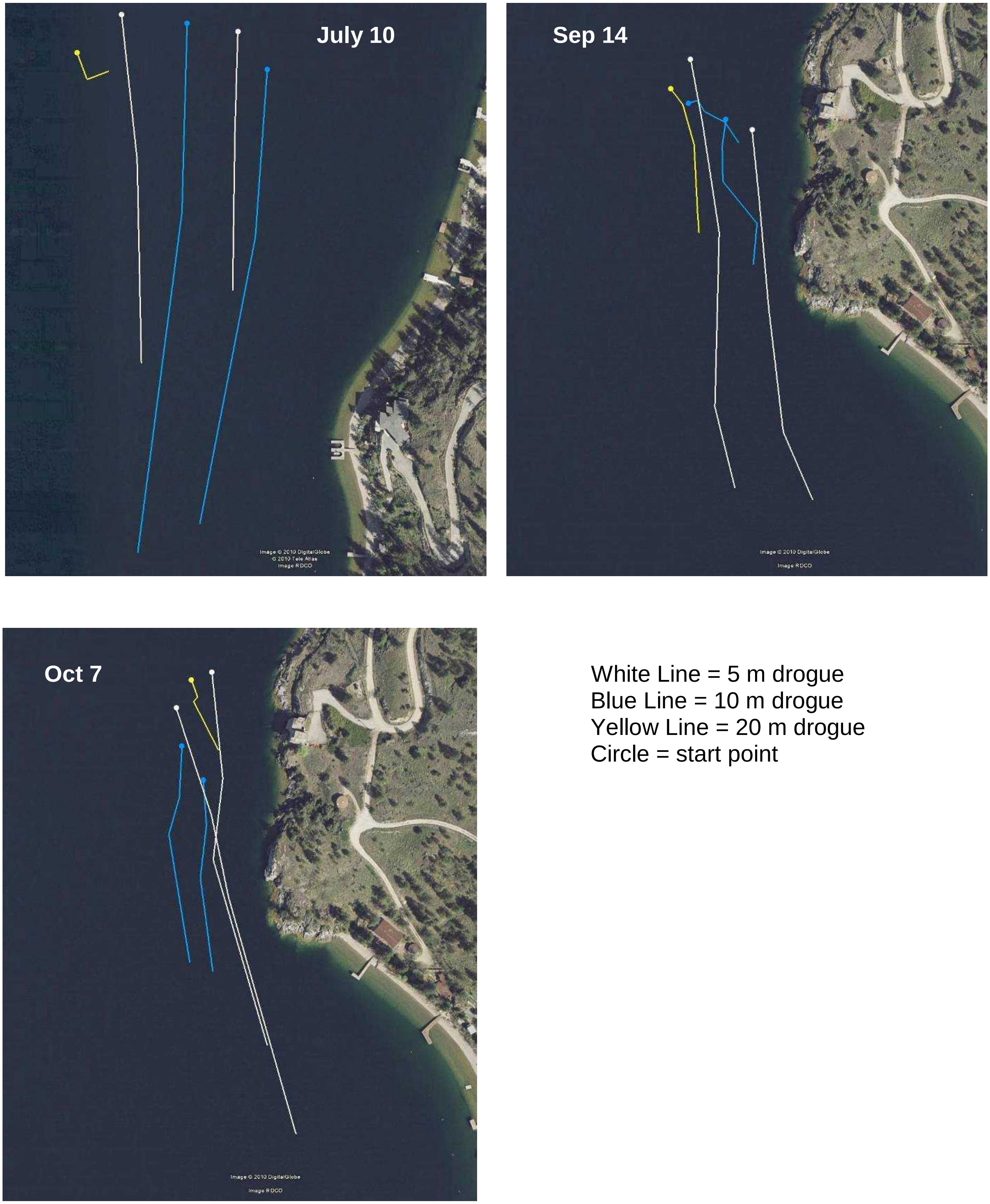


Figure 2.8: Okanagan Lake Drogue Trials 2009



White Line = 5 m drogue
Blue Line = 10 m drogue
Yellow Line = 20 m drogue
Circle = start point

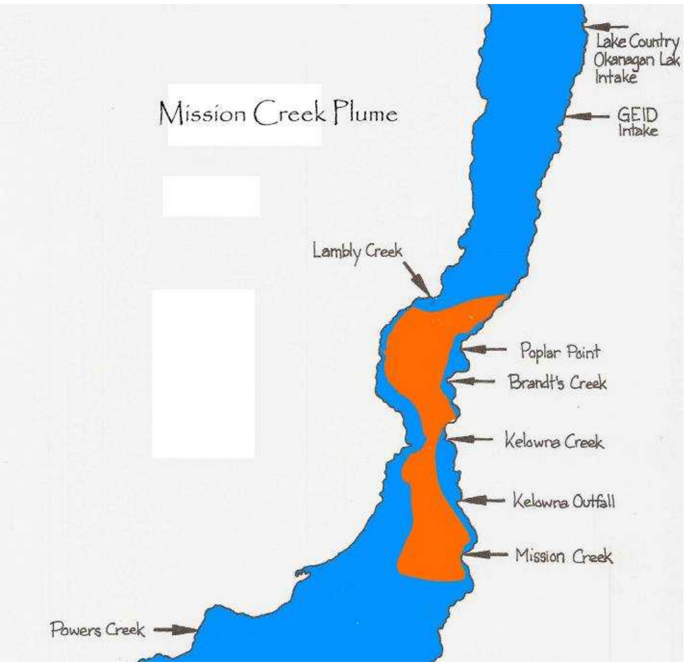
Water Movement Near Lake Country Okanagan Lake Intake

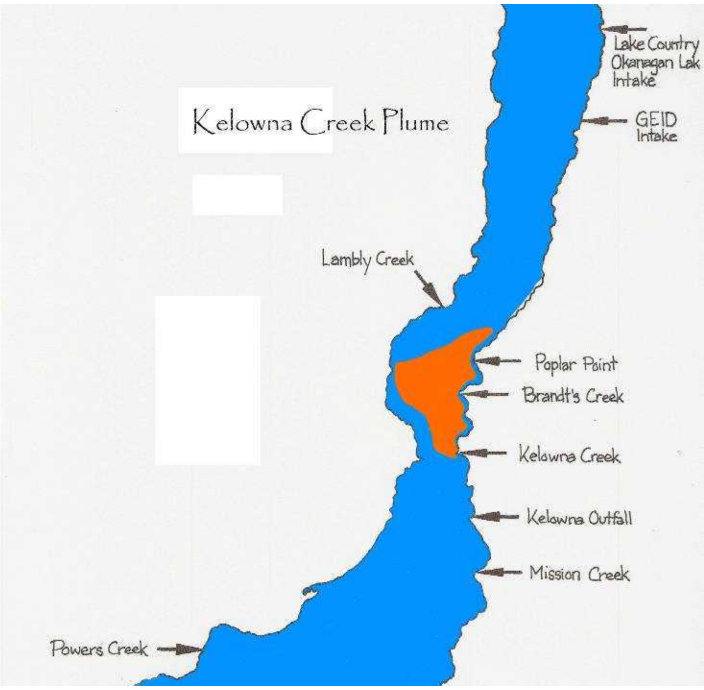
Inflow plumes often stay as a discrete current at a depth dictated by the densities of the plume water and the receiving lake water. Water density is determined by temperature, dissolved and suspended solids. Coriolis force moves the current to the right in the Northern hemisphere (right-hand facing in the direction of flow) (Hilton et al.1986). These plumes are then moved and deflected by the water currents depicted by the drogues (Figure 3.8 and 2.9). Particulate matter gradually settles as plume energy is gradually lost by mixing with the lake water.

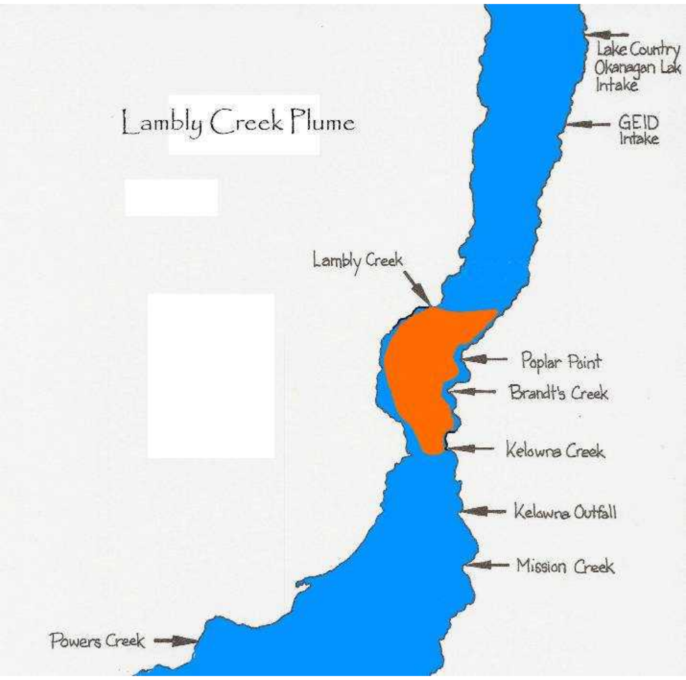
Creek Plumes:

There are three creek plumes that can potentially affect the DLC Okanagan intake. They are; Lambly (Bear) Creek, Kelowna (Mill) Creek and Brandt's Creek. These creek plumes travel extensively through the lake. Creek plume travel at the 23 to 26 m depth is depicted in Figure 2.9 and is more confined than surface plume travel under different lake conditions.

Figure 2.9: Examples of Creek Plumes at Intake Depths in Okanagan Lake







These maps show the extent of creek plumes that could theoretically affect the DLC intake when they are deflected northward by wind and water currents. Most of the flow pattern shown in orange is deeper than 20 m. The natural sill under the Bennett Bridge helps protect DLC intake from Kelowna , Brandt and Mission Creek plumes; it is unlikely that any creek plumes will reach the intake.

(After Hayco, 2000)

Lambly Ck (9.4 km from DLC intake) The main creek plume into the North Basin of Okanagan Lake is Lambly (Bear) Creek with a mean annual inflow of 49,000 ML or 8.5% of the total tributary inflow to Okanagan Lake on a yearly basis (Nordin, 2005). Lambly watershed has a long history of logging activities and since 2002 with the declaration of a motorized recreation emphasis RMZ under the LRMP process, riparian damage in the watershed has escalated (Dobson, 1999). Since the creek water is frequently more dense than lake water, creek inputs tend to sink. In the Hayco modeling, the Lambly Creek plume sank and was trapped at 10 m during the stratified period but would penetrate deeper into Okanagan Lake in the spring unstratified period. The Lambly Creek plume can contain *Cryptosporidium, Giardia* and other pathogens because it does carry *E. coli* (LID monitoring at their head-gate).

Brandt's Ck (14.2 km from DLC intake) Brandt's Creek is is periodically impacted by the Brandt's Creek Treatment plant that treats SunRype and winery wastes. When the plant effluent is within permit limits, it discharges to Brandt's Creek. For example, in 2002, 72,800 m^3 were discharged with a phosphorus load of 0.05 tons to Okanagan Lake (Nordin, 2005). This water is usually warmed by industrial processes and is likely to travel high and far within Okanagan Lake (Figure 2.9). It can carry numerous contaminants because it also receives storm water from at least 30 outfalls (Swain, 1990).

Kelowna Ck (16.1 km from DLC intake) Kelowna (Mill) Creek plume could also theoretically affect the DLC intake and it has a mean annual inflow of 18,700 ML or 3.2% of the tributary inflow (Nordin, 2005). Plume water travels the 3.2 km from Kelowna Creek to Poplar Point Intake an average 51 times per year (Hayco 2000). Kelowna Creek travels through agricultural areas to the north of the City of Kelowna and its final reaches traverse the urbanized areas of Kelowna. It receives storm water from urban, light industrial and residential developments and can carry numerous contaminants (Figure 2.9). At least 22 storm water outfalls discharge into Kelowna Creek (Swain, 1990).

Mission Creek (20 km from DLC intake) Although Mission Creek is the furthest from DLC intake, it is the largest tributary to Okanagan Lake at an average discharge of 6.3 m3/s. It has moderate agricultural impacts and receives some storm water. Even in a storm, with SW winds, by the time the Mission Creek plume reached DLC intake it would be very dilute.

Municipal Outfall Plumes:

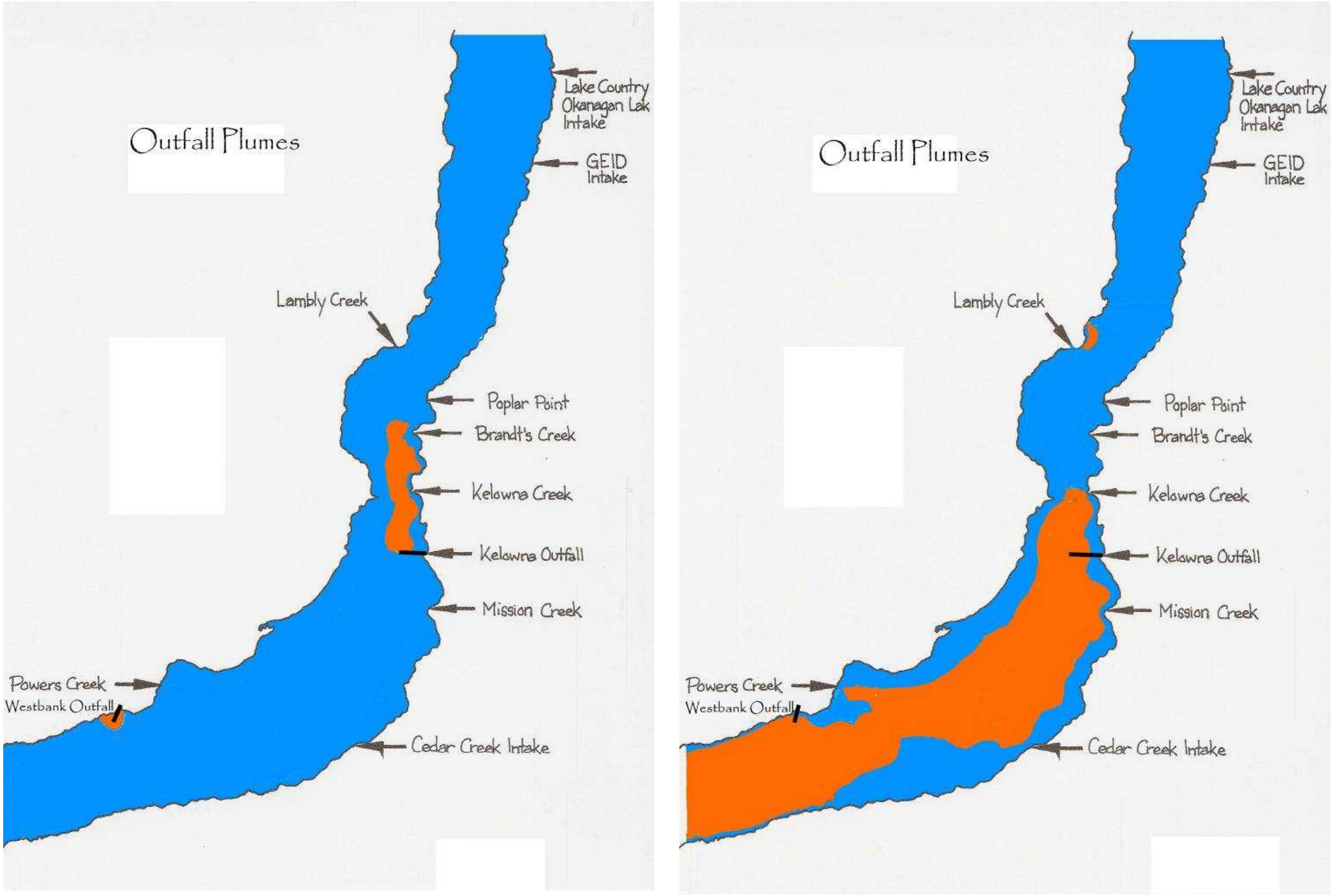
The main municipal outfall plume that can theoretically reach the Lake Country Okanagan Lake intake is the Kelowna outfall (Figure 2.10). It is injected at 60 m and the plume travels upward because it is warmer than the receiving lake water. It will travel within the lake at varying depths and directions depending on the condition of the water layers in Okanagan Lake.

The outfall plume consists of about $0.31m^3/s$ of water treated with the Bardenpho tertiary process since 1983 (Bryan, 1990). The total outfall load of phosphorus to the lake in 2002 was 1.5 tons and the total nitrogen load was 42 tons. Even with tertiary treatment in Okanagan Lake, the reduction of nutrient discharge may have been offset by increasing load (City of Kelowna population doubled from 1975 to 2005) and/or by an increase in non-point source loading such as erosion in watersheds (Dobson, 2009). The plume is often deflected by horizontal currents as it rises such that the waste field spans the water column from the surface down to depths near the outfall (Hayco, 2000).

Approximate travel of the large Kelowna outfall plume at intake depths is depicted in Figure 2.10 (after Hayco, 2000). The direction and depths at which it travels are dependent upon the vertical and horizontal water currents. This large plume can pass the sill under Bennett Bridge and travel into the North Basin of Okanagan Lake.

Figure 2.10: Examples of Outfall Plumes at Intake Depths in Okanagan Lake with variable summer conditions

(after Hayco, 2000)



The depth of the outfall plume travel is usually below the thermocline in the summer months but will be less confined by depth during the winter. Modelling by Hayco suggests that it is unlikely that contaminants from either outfall could reach the DLC intake under normal conditions. Even in a storm, the outfall plume would be very diluted by the time it travelled to the DLC intake.

Storm Water The closest storm water inflow to the DLC intake is the proposed Lakestone outfall, located 220 m along the shore to the south in a small bay and it will discharge at a 10 m depth. This depth will discharge into the surface water layer above the thermocline during most of the summer, but the 10 m depth is subject to 2 - 3 seiches per week from mid-April to mid-November. Seiches and associated turbulence will mix the storm water deeper into the lake. Although the drogues showed only southward water currents, the plume will reverse and travel northward under a wind from the south.

Storm water routinely carries bacteria, PAHs salt and nutrients. The storm water plume will behave like a creek inflow plume. If the particulate load is heavy during the “first flush” of materials off the streets into the storm water, then the inflow may form a density plume that travels along the lake bottom like a dirty cloud. After the initial flush, the storm water plume should be trapped by the thermocline and remain in the surface water during the summer. It will travel parallel to the shore dropping large particulates quickly while finer particulates will travel further.

During the non-stratified winter period, the storm water can form a pool in front of the outfall intake and travel as a packet of water, diluting as it travels. The depth that the pool can form at will be deeper in the fall/winter than in the summer, and is the most immediate potential source of contaminants to the 33 m deep DLC intake after November. At present, this intake is only operated until December, but more extended winter use is probable in the future. The 33 m depth of the intake provides more protection than a shallower intake would because water movements are much smaller.

Distributed Runoff Runoff from the land that is not collected into a storm water outfall can affect this intake because the length of the DLC intake pipe from the shoreline is only 60 m. Similarly, material that is torn off the lake bottom or suspended by wave turbulence has a greater effect on this intake than it would on an intake that is 200 m offshore. Long-shore water currents driven by wave action are temporary and frequently reverse the angle that they are striking the shore, making them a weak transporter of potential contaminants over great distances (Hayco, 1999). The shoreline in front of the intake has the greatest potential to donate contaminants.

Vertical Transport – Fall Velocity When solutions are introduced to a lake, the dissolved materials remain suspended indefinitely and diffuse, while particulate materials settle out according to their fall velocity. Large particles of sand introduced by creek plumes settle out almost immediately while finer sand/silt is transported on the freshet plume far out into Okanagan Lake. Very small particles remain suspended even longer, including algae and microbes such as *Cryptosporidium* and *Giardia* cysts.

The fall velocity of fine clay is small 0.0011cm/s (0.04 m/hr or about 1 m/day) and for *E. coli* bacteria it is far smaller at 0.00000410 cm/s (0.00354 m/day) (Hayco, 2009; USGS 2007). It will take several weeks for clay to settle through the water column; less as it clumps with other materials (larger sediment particles, organics). Bacteria take even longer to settle but they readily clump with other organics, and settle out of the water column gradually over a period of months. It could take years for bacteria to settle out based strictly on fall velocity. Bacteria can also be consumed by zooplankton and deactivated by sunlight or aging (Wetzel, 2007). Fall rates are presented in Table 2.3

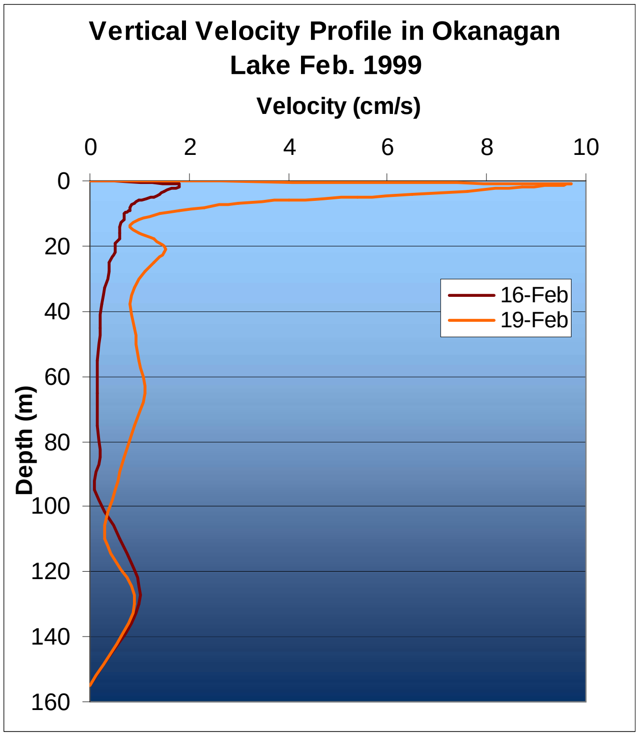
Table 2.2: Size and Fall Velocity Estimates for Kalamalka Lake Particulates

Material	Size	Fall velocity
Inorganic		
Sand	>63 – 100 microns	> 100 m/day
Silt	4 – 63 microns	21 m/day
Clay	0.1 – 4 microns	1 m/day
Marl	<1.5 microns	0.6 m/day
Biological		
Organic clumps	> 100 microns	>100 m/day
Large algae and diatoms	22 – 70 microns	< 50 m/day
Small algae	6 – 14 microns	<1 m/day
Lg filament cyanobacteria	5 x 200 microns	0.1 m/day
Sm filament cyanobacteria	1 x 100 microns	>0.007 m/day
Giardia / crypto cysts	4 – 8 microns	0.02 - 0.1 m/day
Bacteria – *E. coli*	0.7 – 10 microns	>0.0035 m/day

(Dia and Boll, 2006; USGS 2007; Hayco, 2009; Larratt 2010)

Fall rates are important when considering the settling of particulates out of storm water and the re-suspension of settled particulates off the lake bottom. Fall rates are affected by water movement and temperature (Figure 2.11). Vertical currents generated by a strong wind event can reach 10 m/s at the surface (5 m/s in deeper water) and can counteract the sediment fall velocity with enough energy to transport fine sediments disturbed from the lake bottom upward (Hayco, 2009). Like horizontal water currents, vertical water currents are strongest near the surface of Okanagan Lake. There are no persistent vertical currents in a lake; the direction of the vertical currents oscillates following the upward and downward water motions in the lake.

Figure 2.11: Modeled Vertical Water Current Velocity in Okanagan Lake



(After Hayco, 2009)

Seiches also complicate particulate travel and fall rates by tipping the surface water layer down closer to the intake. The DLC 33 m deep intake experiences fewer and less powerful seiches than a shallower intake would but this intake is still not immune to seiches (Figures 2.5 - 2.7).

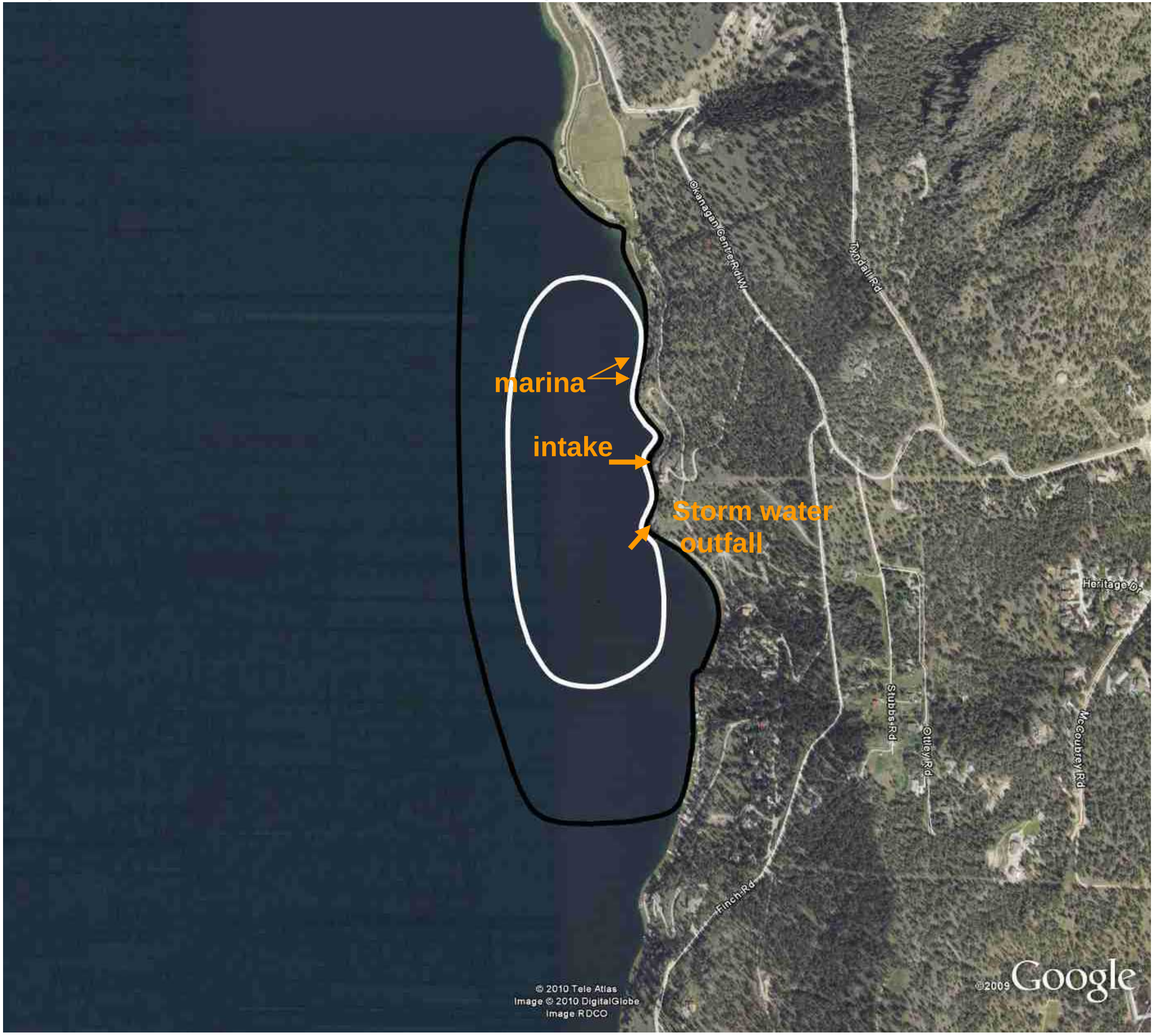
Calculation of the Intake Protection Zone (IPZ)

The preceding investigation of vertical and horizontal water currents in Okanagan Lake and their capacity to transport contaminants, allows the calculation of the Intake Protection Zone for the DLC Okanagan Lake Intake.

The minimum intake safety factor recorded in the Lake Ontario Source to Tap Study is 2 hours and 1 km (Stantec, 2007). A surface contaminant could travel at 342 m/hr according to the Hayco Model, in which case a surface contaminant could cover a 100 m intake protection zone in less than 20 minutes. Doubling the wind speeds that were measured by the drogues covers 80% of the wind events expected in a year. To achieve the two hour guideline, the intake protection zone radius would have to be 900 m long based on doubling the speed of the fastest drogue (Figure 2.12). The shape of the intake protection zone should be modified from a circle by prevailing directions of water travel and the locations of potential contaminant introduction and their fall velocities. For the DLC Okanagan Lake intake, the drogue patterns show water currents travel parallel to the shore, and contaminants are far more likely from the shore side than from the open lake side suggesting that the IPZ should be oval. A second layer of protection zone could be imposed on adjacent land development where subsurface (waste water; irrigation water management) and surface (storm water) flows would be delivered to the intake protection zone from the Lakestone Development.

This estimate of the appropriate size and shape of the intake protection zone does not account for major storm events where water travel would be faster. Hayco concluded that there is a substantial reduction of risk resulting from an increase in the depth of the intakes. If one assumes that water deeper than 30 m is “safe” during non-storm events, then an intake at 100 m is “safe” from the 1 – 10 year storm and an intake at 135 m is “safe” with respect to the 1 in 100 year storm (Hayco, 2000). From these calculations it is clear that a major storm can move diluted contaminants from as far away as Kelowna and mix them into the North Basin. It becomes the responsibility of all residents to protect Okanagan Lake. We are all “downstream” of the contaminants we produce.

Figure 2.12: Proposed DLC Okanagan Lake Intake Protection Zone



The white oval encompasses the area that the fastest drogues (they were at the 10 m depth) traveled in two hours with light winds at the time of sampling.

The black oval encompasses the area water currents can travel in two hours with 80 % of the wind events that occur on Okanagan Lake and is the recommended Intake Protection Zone (IPZ). This estimate does not include major storms that occur every year.

The intake protection zone does not encompass the entire area capable of impacting the intake, rather it delineates the "highest risk" area. In a severe storm, a spill anywhere on Okanagan Lake could theoretically impact DLC's intake. An intake protection zone based on two hours of water travel under normal wind conditions represents the minimum safety factor recommended in this study. An IPZ should be understood as a critical protection area nested into a larger area of concern (North Basin) and finally into the entire area of concern – Okanagan Lake and its watershed.

2.7 Hazards and Contaminants Impacting the DLC Okanagan Lake Intake Protection Zone

Contaminants that are injected within the intake protection zone have the greatest potential to imminently impact the intake water quality and have the least available dilution. Lake or basin-wide threats to water quality in Okanagan Lake tend to be slower and longer term and include:

- Nutrient loading – accelerates algae and microflora production
- Personal Care products – injected by municipal outfall, septic fields, grey water, spills
- Watershed damage – alters hydrology, also nutrient, silt and contaminants transfers to the lake

2.7.1 Fecal Bacteria and *E. coli*

Total coliforms are a broad category of bacteria that include soil bacteria and along with background colonies, they indicate the amount of bacterial loading in the water. Fecal coliforms are found in warm-blooded animal wastes and they serve as an indicator of recent fecal contamination (WSDH, N.D.). Unfortunately, there are non-fecal bacteria that can give false positive fecal readings such as *Klebsiella*, *Enterobacter* and *Citrobacter,* leading to declining reliance on the fecal coliform assay in the water industry (Doyle et al., 2006). *E. coli* (*Escherichia coli*) are the most common type of true fecal coliforms. Only a few of the thousands of *E. coli* strains are disease-causing, however, if *E. coli* are present, recent fecal contamination is probable. The presence of other pathogenic bacteria such as *Campylobacter* may be correlated, while *E. coli* counts do not correlate well with viruses or other pathogens (Carter et al. 1986; Keith et a, 1999).

The criteria set by IHA for source/raw water is (1) No more than 10% of source/raw water *E. coli* samples exceed 20 cfu/100 mL *E. coli* within any 6 month period. (2) No more than 10% of source/raw water total coliform samples exceed 100 cfu/100 mL total coliform within any 6 month period (Filtration Deferral Document, IHA).

The Okanagan water system is operated by DLC during the frost-free period (May to Oct-Dec). They installed a raw water sample line in 2009 that allowed bacteriological monitoring of incoming raw water. Total coliforms were moderate with a range of 5 to 20 cfu/100 mL (one additional sample was overgrown) and total coliforms average 12.5 cfu/100 mL. For *E. coli*, there were three positives out of 19 sample dates, each with 1 or 2 *E. coli* /100mL. These results meet the raw source water criteria set by IHA.

Open water samples from Okanagan Lake rarely carry bacteria. The vast majority of bacteria in Okanagan Lake occur in the surface sediments or are carried in by recent inflows to the lake. In the Deep Lake Biology Study 2009, the majority of the bacterial samples contained <1 colony forming unit CFU/100 mL. The samples with significant total coliform results were collected in July 2008 and May 2009. Creek inflow plumes, storm water plumes or turbulence may have contributed these higher bacteria numbers to the water column. Even when total coliforms exceeded the countable numbers in May 2009, *E. coli* remained non-detectable. The few detectable *E. coli* counts were usually in samples where sediments were deliberately disturbed during sampling. In a lake, 99% of the bacteria population will be associated with the upper few centimeters of sediment. The sediments act as a bacterial reservoir and *E. coli* are capable of persisting, but not reproducing, in Okanagan Lake sediments. Events that could reasonably suspend sediments will deliver more bacteria to the DLC intake in the raw Okanagan Lk water.

2.7.2 Sediment Contaminants

The steep cliff-like shoreline near the intake limits the accumulation of sediments and therefore restricts contaminant re-suspension of sediments laid down in the 1930s to 1970s when numerous toxic substances were in use that have since been banned. For example, fish tissue measurements of mercury and DDT have been dropping since the 1970s (Nordin et al., 1988)

Pathogenic bacteria such as some strains of *E. coli* can persist in sediments. The 3 positive out of 19 samples for *E. coli* indicate that substrate may be lifted to the intake during sediment disturbance by turbulence. The DLC intake may be too close to the lake bottom to evade sediment re-suspension. Alternately, the *E. coli* may have been recently introduced by storm water or another contaminant source.

A sediment sample was collected on September 14th from the sediments that are easily suspended from the intake area. This sample was submitted to Caro labs for bacterial analysis. As with other natural lake sediments, the coliform bacteria result came back as "too numerous to count" while both fecal coliforms and *E. coli* came back at <1 CFU/100mL. The sediments below the intake also contained significant amounts of benthic cyanobacteria so it is fortunate that the intake has 5 m clearance.

The sediment trap captured a very low sediment accumulation rate because there was no sediment source such as a stream or a storm water outfall nearby (Table 2.4). The trapped material demonstrated a very low accumulation rate of 1.9 g/m^2/yr of which 19.6% was volatile (organic).

Table 2.4 Sediment Under Okanagan Lake Intake and Sediment Trap Data

Sediment Sampling Under Intakes for Microflora - 2009

		14-Sep	14-Sep	17-Sep
	frequency data	Ok Lk LC	Kal-GVW	Kal-LC
	DIATOMS			
	Asterionella formosa		L (dead)	L (dead)
	Cocconeis		P	
	Cyclotella		C	C-D
	Cymbella sp	L (dead)	L (dead)	L (dead)
	Fragilaria capucina		VL (dead)	
	Fragilaria crotonensis	VL (dead)	M (dead)	L (dead)
	Melosira italica	P (dead)	L	C (dead)
	Navicula sp.	L	L (dead)	P
	Stephanodiscus niagarae	VL (dead)	L (dead)	L (dead)
	Synedra acus var radians			
	Synedra ulna		P (dead)	
	Siruriella elegans		L (dead)	
	Tabellaria fenestrata	L (dead)		P (dead)
TOXINS	**BLUE-GREEN ALGAE**			
x	Aphanocapsa sp.			**P**
x	Anacystis cyanea	**C-D**		
X	Aphanocapsa sp.	**C**		
X	Planktolyngbya limnetica	**M**		
	Limnothrix redekeii			
x	Oscillatoria sp. smooth	**L**		
	OTHER			
	micro-flagellates	M	L	VL
	Large flagellates	L	C	
	bacteria	D	**D**	**C**
	detritus	M	**L**	**L**
	silt	L	C	D
	SUM			

P=Present L= Low M=Moderate C=Common D=Dominant

Sediment Trap Samples 2009-2010

Deployed Sept 14/09 - Collected May 25/10

(15 cm dia; 175 cm^2 surface area)

	Ok Lk LC	Kal-GVW	Kal-LC
% solids	0.1	0.7	0.2
% volatile solids	19.6	13.1	15.2
dry weight (g)	0.222	7.250	2.503
volatile weight (g)	0.038	0.859	0.320
accum rate g/m^2/yr	1.9	62	21
volatile accum g/m^2/yr	0.33	7.4	2.7

2.7.3 Trihalomethanes (THMs)

Trihalomethanes (THMs) are generated when combinations of total organic carbon, water temperature, contact time and chlorine dose are high (Larratt, 2007). There are many Okanagan water supplies that do not meet the THM criteria. THM's are higher during the summer months when microfloral production is high than they are in the winter months. Almost all of the THM produced in the distribution system will be chloroform ($CHCl_3$). At DLC Okanagan intake, the TTHMs would be expected to be highest in the spring. None of the DLC Okanagan Lake intake samples collected to date exceeded the 0.10 mg/L total THM guideline. To date, intake samples have averaged 0.030 to 0.057 mg/L Total THMs and met the guideline of 0.100 mg/L CDWG (Meger et al. 2006, 2007)

2.7.4 Cyanobacteria

In Okanagan Lake, conditions have biased the lake towards blue-green cyanobacteria production for at least 70 years (Andrusak et al., 2005, Clements et al., 1939). Like most large temperate lakes, Okanagan Lake experiences peak algal production in the spring when nutrients and dissolved organic material are circulated to the surface water by spring turbulence. Diatoms, flagellates and very small cyanobacteria dominate the spring algae community (Stockner, 2003). But unlike most lakes, Okanagan Lake deviates from the typical summer algae populations of flagellates and green algae and instead develops colonial blue-green dominance by late June (Stockner, 2003).

Averaged over an entire year, cyanobacteria dominate Okanagan Lake algae, followed by diatoms, and then a diverse group of small flagellates. Cyanobacteria usually account for about half of the phytoplankton community in summer and they can increase to 60% of both algal density and biomass in the fall (Stockner, in Andrusak et al., 2003).

Most cyanobacteria grow best in nutrient-rich warm water, but Okanagan Lake is not the only nutrient-poor large lake to be dominated by cyanobacteria – there are many other examples world-wide (Rojo and Cobelan, 1999). The dominant cyanobacteria in DLC samples was *Planktothrix rubescens*, the species having the highest microcystin concentration per cell of all known cyanobacteria, occurs primarily in the metalimnion of oligotrophic and deep lakes, and can persist during the winter (Reynolds and Walsby, 1975; Reynolds, 1987; Humphries and Lyne, 1998).

Problems caused by cyanobacteria include:

- Toxicity from a variety of cyanotoxins
- Taste and odor production
- Increased organic carbon (TOC), thus reduced UV transmissivity
- Contribution of organic material to feed re-growth biofilms within the distribution system (Niquette, et al., 2001; Servais and Savoir, 2001)
- Trihalomethane (THM) production following chlorination
- Increased cost to treat the water for domestic use

Exposure to an acute and possibly fatal dose of cyanotoxins would require contact with a concentrated surface scum of cyanobacteria and would be very rare on Okanagan Lake. A chronic low dose which develops over long periods of exposure through domestic water use is much more probable and the health impacts can include neurological damage and liver cancer (Kuiper-Goodman et al., 1999; Larratt, 2009).

Figure 2.13: Surface Cyanobacteria “Bloom” in Okanagan Lake

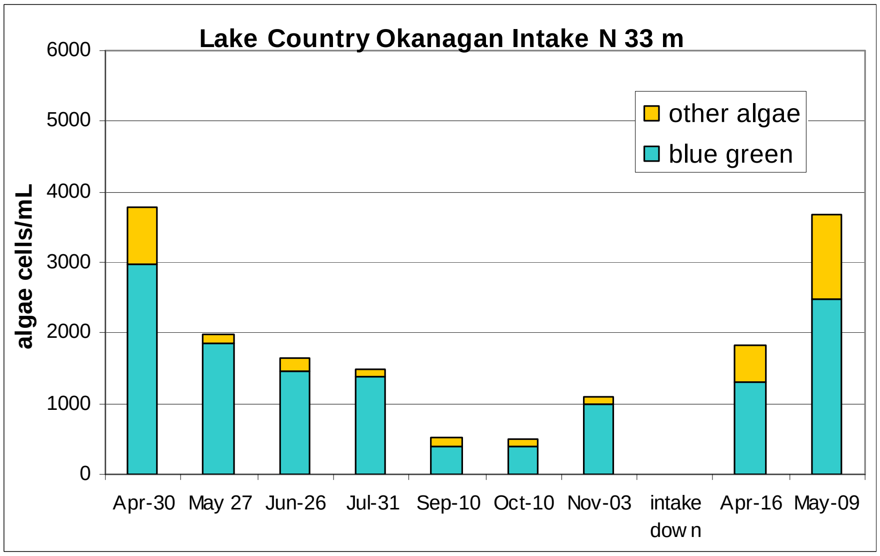
In June 1975, an *Anabaena* bloom degraded drinking water quality in the Vernon Arm of Okanagan Lake. Tap water was described as foul-smelling. There have been two documented and potentially toxic blue-green algae blooms on Okanagan Lake in the last decade and one on Skaha Lake in the winter of 2008/2009. The last one on Okanagan Lake occurred in 2004 and was caused by *Microcystis aeruginosa (pictured above)*. There was a small bloom the north sub-basin in July 2009, detected near the intake in the surface water layer. It involved *Anabaena* and *Microcystis*. Small blooms are probably more frequent than current records indicate because they often go unnoticed.

Potentially toxic cyanobacteria (blue-green algae) grew throughout the water column of Okanagan Lake. Cyanobacteria species including *Planktothrix* growing in the deep waters tolerate very low light and low nutrient concentrations. Unlike surface-blooming types such as *Anabaena* that pose a rare but significant risk to shallow intakes, *Planktothrix, a* species with high microcystin concentrations, occur specifically in the mid water column of deep lakes including Okanagan Lake.

There were no incidents where counts exceeded the 15,000 cell/mL threshold of toxin threat in 2009 samples from the North Basin. Samples with more than 2000 cyanobacteria cells/mL were most common in the 10-30 m depth range in April and May (Figure 2.14). Among the Okanagan Lake intakes deeper than 30 m, the Penticton intake at 36 m gave the lowest overall cyanobacterial counts, while Lake Country’s 33 m intake gave the highest counts, perhaps due to its position in the North basin.

The risk these cyanotoxins present to the DLC intake is dependent on dose and toxin mixture. Chronic low dose exposure to cyanotoxins that can be produced by cyanobacteria found in Okanagan Lake can cause a range of diverse effects including skin irritation, inflammatory response, liver and kidney damage, DNA damage, tumor promotion and cancer, nervous system disruption and promotion of neurological degenerative diseases. The most vulnerable people are the immune-compromised, children and the elderly. The cyanobacterial numbers found in this study correspond to a very low risk of acute toxicity and a low risk of chronic low dose toxicity based on cyanobacteria numbers (toxin assays were not performed).

Figure 2.14: Proportions of Blue-Green Algae (cyanobacteria) and Other Algae in Samples from the District of Lake Country Okanagan Intake, 2009



NOTE:

DLC's Okanagan Lake Intake has high overall and blue-green algae counts in Apr/May each year - the only time the counts exceed the 2000 cells/mL threshold of concern

Diatom counts in the spring samples were high enough to cause a mild musty taste and odor

During the rest of the year, algae counts were very low

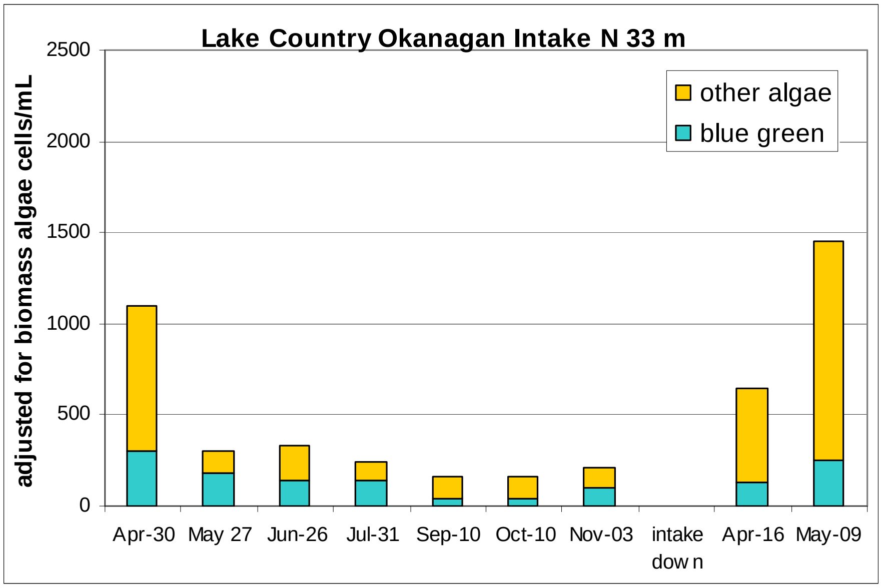


Table 2.5 contains the list of common cyanobacteria in Okanagan Lake found in this study. Rare types were not included because they do not affect water quality.

Table 2.5: Problems Caused by Okanagan Lake Cyanobacteria

Common Okanagan Lake Cyanobacteria	Toxins	Taste and Odor when Moderate / Abundant
Anacystis /Microcystis*	LPS MC BMAA	grassy /septic
Anabaena circinalis, planktonica*	LPS CYL MC ATX BMAA NEO SAX	musty / septic Geo
Anabaena flos-aquae *very toxic*	LPS CYL MC ATX BMAA NEO SAX	musty / septic
Aphanocapsa sp.	LPS MC	
Aphanothece sp.	None known	
Aphanizomenon dispersus	LPS CYL MC ATX BMAA NEO SAX	musty / septic Geo
Chroococcus sp.	None known	
Coelosphaeria sp.	None known	
Gomphosphaeria spp.*	None known	grassy / grassy
Limnothix redekei*	None known	mildly musty
Planktolyngbya*	LYN APL LPS CYL SAX BMAA	MIB
Merismopedia sp.	None known	
Oscillatoria spp.*	LYN APL LPS MC ATX BMAA SAX	grassy / musty, spicy Geo MIB
Planktothrix spp.* *very toxic*	LYN APL LPS MC ATX BMAA SAX	grassy / musty, spicy Geo MIB
Phormidium spp.	LPS MC ATX BMAA	Musty / musty Geo MIB
Pseudanabaena sp.*	LPS MC	musty / musty Geo MIB
Rhaphidiopsis sp.	LPS CYL ATX	
Spirulina spp.	None known	
Synechococcus sp.*	LPS MC BMAA	musty Geo MIB
Synechocystis sp.	LPS MC BMAA	

Cyanobacteria marked with * are dominant types and many of these were identified in (Clemens et al. 1939)

Dermal toxins = LYN lyngbyatoxin-a; APL aplsiatoxins; LPS lipopolysaccharides
Liver toxins = CYL cylindrospermopsins; MC microcystins; NOD nodularins
Nerve toxins = ATX anatoxins; BMAA B-N-methylamino-L-alanine;
NEO neosaxitoxins; SAX saxitoxins

The seven toxins most likely to be contacted in Okanagan Lake include: lyngbyatoxin-a, aplisiatoxin, microcystin, cylindrospermopsins, saxitoxins, lipopolysaccharides and BMAA.

Taste-and-Odor = GEO geosmin; MIB 2-methylisoborneol

Geosmin and 2MIB are detectable at less than 5-10 ng/L among sensitive individuals. 10 nanograms per liter is far below the detection limit of most lab assays, however, taste alone is not considered to be a reliable indicator of cyanotoxin presence. (Falconer et al., 1999; Graham et al., 2008).

2.7.5 Septage / Sewage / Grey-water

Septage and sewage routinely carries pathogens, organic matter, nitrates, heavy metals, inorganic salts, pharmaceuticals & personal care products (PPCPs), cleaners, paints, auto wastes, PAHs and more, hence the need to isolate it from drinking water sources. The modeling work by Hayco demonstrates how far a dilute municipal outfall plume can travel in Okanagan Lake even at 23-26 m depth (Figure 2.10).

Caffeine can be used as a marker for human sewage and septage because no other animal excretes it. This test is much more definitive if caffeine is detected than if it is below detection because caffeine is broken down by bacteria (Seiler et al., 1999). A caffeine sample was collected from the intake depth near the Kalamalka Lake intake on September 29 and shipped to ALS Labs Edmonton. The results were below the detection limit of <0.20 ug/L caffeine and indicate that there is a low likelihood of threat from human sewage/septage in the vicinity of the intake under normal lake conditions. As the septic systems are removed from service by the municipal sewer system, their impact on subsurface drainage should diminish. This test does not rule out sewage/septage impacts.

Flooding events are unusual on Okanagan Lake because the water level is regulated by the control structure on Okanagan River in Penticton. Freshet inflows are accurately forecasted but flooding has occurred in the last 30 years when June was wetter than expected and lake levels rose. Flooding increases the impacts from old septic fields or informal disposal sites at properties located adjacent to the lake.

Another potential source of septage is improper disposal from houseboats, yachts and cabin cruisers. Numerous complaints of improper houseboat sewage disposal have been reported, including human feces washing up on shore (ref)

Most of these boats do not retain grey water from sinks showers, dishwashers, washing machines and hot tubs; it is disposed of directly to the lake. Grey water contains detergents, dyes, personal care products and can contain heavy bacterial loads comparable to domestic sewage (MoE, 2010). A 2008-09 study funded by MOE and Interior Health on Shuswap Lake, "indicated that the presence of houseboats is correlated to the chance of detecting fecal coliforms, that grey water discharges contribute endocrine disruptors to the lake and houseboat discharges are a consistent source of fecal bacteria. (These problems led the BC Ministry of Environment to implement a phased-in compliance with the provincial Environmental Management Act Sec. 13 which prohibits the discharge of both black and grey water from any vessel into any inland or coastal marine water).

A final potential source of sewage contamination is a failure of a lift station or force main. This occurred at the Coldstream Creek Sewage Lift Station in 2009. A power failure caused a pump disruption, allowing a small raw sewage spill into Kalamalka Lake on February 11, 2009. A back-up generator has since been installed in the lift station.

2.7.6 Storm Water

Storm water routinely carries bacteria, PAHs salt and nutrients. Excess nutrients carried in during storm events stimulate periphyton growth in the vicinity of the storm water outfall. The increased growth can become an attached or planktonic algae bloom and include cyanobacteria, increasing a localized risk.

Storm water may also carry other contaminants when people illegally dispose of materials down storm drains. Outfall locations must be distant from the intake and preferably, they should be replaced with alternatives such as soak-away zones, retention for irrigation, etc.

2.7.7 Biofilm Development

Warm water rich in organic material will develop biofilm in a distribution system. Biofilms in distribution pipelines contain a build-up of precipitated material and microorganisms (bacteria, fungi, yeasts). Biofilms are dislodged from pipe walls during periods of high flow. Most Okanagan water supplies develop biofilms during the summer when the warmer water accelerates bacterial growth.

Okanagan Lake water from 33 m provides one of the coolest water supplies available in the Okanagan. From 2004 to 2009, the maximum summer temperatures ranged from 10 to 12.3 ^{o}C with a peak of 13.5 ^{o}C measured in the distribution system. The temperatures within the distribution system stay below the 15 ^{o}C CDWG limit at all times. These cool temperatures do not encourage biofilm.

2.7.8 Turbidity

Turbidity is low at all times in DLCs Okanagan Lake Intake, rarely exceeding 1 NTU. Turbidity does not represent a threat to this water supply.

2.7.9 Water Infrastructure

The main pipeline and intake was installed in 1968.
The system has a back-up water supply in case of emergency – it can be switched to Vernon Creek.

Low water levels could theoretically strand water intake wet wells. The normal operating level of Okanagan Lake is HWL 1124 – LWL 1120' (above sea level) and the wet well is at 111.25' or 8' (2.4 m) below the normal low water level. Water levels would have to drop 2.4 m below normal low water to strand the wet well. Current Okanagan Lake water levels are at record lows and we have no control over the major inflows and outflows. Drought can affect intake withdrawal capacity. The main inflow from the watershed tributary creeks to Okanagan Lake occurs in May and June (freshet). The year-to-year variation is high with extremes in runoff volume spanning more than an order of magnitude difference – from a low flow of 130 Mm^3 in 1970 to a high inflow of 1,401 Mm^3 in 1997 (Symons, Nordin, 2005). In addition, there is some evidence from climate models that water availability will decease in the coming decades (Leith and Whitfield, 1988). Increasing demand for domestic water may require different release and conservation strategies.

2.7.10 Monitoring Routine and Emergency Planning

Routine intake sampling by Lake Country Staff includes sampling for free chlorine conductivity, pH, temperature, turbidity, as well as total coliforms and *E. coli*. These bacterial parameters were invalidated by the chlorine already in the water. A raw water sample line has been in place since 2009 and allows a true estimate of the raw water bacterial counts. In 2009, sampling was conducted weekly while the intake was operating (frost-free period).

The SCADA system at the Okanagan Lake intake measures free chlorine, turbidity and 11 other operational parameters.Monthly monitoring reports are e-mailed to the Interior Health Drinking Water Officer.

In the event of a water emergency involving the Okanagan Lake system, the Vernon Creek supply can be used to feed this portion of the DLC system. Either system can act as the sole supply for both distribution lines. The Okanagan Lake system is limited in what it can supply by infrastructure limitations (PR station) in the distribution system (Hansen, pers. comm.).

District of Lake Country has plans in place for releasing water quality advisories and boil water alerts but they do not have a formal emergency response plan that details contacts and procedures in the event of a water emergency. The plan should be developed and could use the GVW plan as a template (GVW have given their permission).

Vernon's All Hazards Emergency Response Plan was prepared by: Public Safety Consultants Northwest, LLC Seattle, Washington. Vernon's plan follows the guidelines of the BCERMS standards for response and incident management using the Incident Command System. The water utility Manager is responsible to review the entire Plan on an annual basis, co-ordinating the revision of the plan as needed, maintaining records of the revisions, and administering the overall plan.

To meet IHAs requirements, the emergency plan must include:

- Emergency contact numbers
- Steps to follow
- Agencies to notify
- Protocols to follow for public notice

2.8: MODULE 1 Hazard and Contaminant Table – Okanagan Lake Intake

Report section	Drinking Water Hazard	Possible Effects	Existing Preventative Measures/Barriers
	Physical		
2.6 3.1.1	Creek and Outfall plumes	Introduction of TSS, pathogens, nutrients, PPCP PAHs	Some riparian protection through watershed
2.7.2	Sediment re-suspension from the substrate	Increased turbidity can compromise disinfection, potentially causing illness if contaminants are present	>4m Clearance of intake from Okanagan Lake substrate
2.7.9	Drought low water levels or shoreline flooding	Wet well stranded in low water Flooding of septic fields, yards, etc causes introduction of contaminants	Drought planning outlet flow control
3.1.4	Marinas existing and proposed	Alter long-shore currents, refueling spills, septage spills	Existing marinas are 3 km away; proposed marina is 180 m N of intake
	Chemical		
3.1.2	Storm water outfall	Transport of nitrogen, pesticides, road surface contaminants, pathogens, salt	New Lakestone outfall is 220 m to the south
3.1.3	Municipal Sewage Outfall/septic fields	Exposure to: pathogens, organic matter, nitrates, heavy metals, inorganic salts, personal care products cleaners, paints, medications, auto wastes, PAHs	Caffeine analysis was negative
3.1.4	Hydrocarbons -PAHs	Deliberate or accidental spill or use of 2 stroke gas-powered boats	Dilution; depth of intake; location of intake
2.7.8	Turbidity	Reduces disinfection efficiency	Turbidity is low (avg 0.5 NTU)
3.2	Taste/odor chemicals	Reduce acceptance of supply	Rare, mild, only in spring
2.7.2	Heavy Metals	Bioaccumulation through chronic exposure	Levels are dropping in lake with reduced usage
2.7.5	Personal Care Products/Herbicides/	Chemical interaction and reaction with chlorine may impact human health	Dilution; depth of intake; location of intake
	Biological		
2.7.4 3.2	Cyanobacteria	Chronic low-dose exposure to cyanotoxin; health impacts vary with toxin type, can include skin rashes, hepatic cancer, nerve damage	33 m depth of intake; chlorination provides some protection; local nutrient loading is low
2.7.3	THM precursors (algae organic material)	Organic material (TOC) can react with chlorine to create THMs	Intake never exceeds 0.1 mg/L Total THM (IMAC)
2.7.5	Viruses	Acute Illness through water-borne exposure	Chlorination
2.7.1 2.7.5 3.1.3	Bacteria	Illness through water-borne exposure	Chlorination
2.7.5 3.1.3	Protozoa	Illness through water-borne exposure	Chlorination
2.7.7	Biofilm	Shields pathogens from disinfection – low risk at this intake	Pipeline flushing

3.0 DLC Okanagan Lake Intake Module 2: Contaminant Inventory

3.1 Anthropogenic Potential Water-Borne Hazards to DLC Intake

A wide range of human activity occurs within the vicinity of the Lake Country Intake on Okanagan Lake, including lakeshore residential, boat-based recreation, municipal roads, light industrial (Kelowna) and low-density residential subdivisions. The degree to which they can affect the intake is based on their proximity and their potential to generate an emergency.

3.1.1 Major Inflows

Transport for discrete inflows such as creeks or outfalls enter the layer in Okanagan Lake with a matching density. Larger inflows such as Lambly Creek travel as a plume that is still "intact" when it reaches Poplar point on the opposite shore (Figure 2.9). Kelowna Creek and Brandt's Creek can also affect this intake (please refer to section 2.6). Whole-lake effects such as nutrient loading and non-settling particulates such as viruses and bacteria from these distant creeks have the potential to affect the DLC Okanagan Intake.

Similarly, the outfall plume from Kelowna's Bardenpho plant is large and rises until it matches the density of the lake water. The plume travels in Okanagan Lake at variable depths and directions depending on water layers and currents (Section 2.6). This is a large input and it can flow into the North Basin of Okanagan Lake where the DLC intake is located, but it is very dilute by the time it reaches the intake area. The contaminants of concern from this dilute outfall include nutrients and non-settling pathogens.

A final method of water-borne contaminant introduction to Okanagan Lake is via overland flow and subsurface drainage. Land use within several hundred meters of Okanagan Lake has the highest potential to impact water quality and is covered in Section 3.1-5. Contaminants such as heavy metals, pesticides, PAHs, nutrients and accidental spills can impact the intake area on Okanagan Lake.

3.1.2 Storm Water Outfalls

Transport for distributed shoreline sources such as local runoff or storm water outfalls would behave similarly to a creek input (Hayco, 2000). Inflows can pool below the outfall and travel as a discrete packet of water, diffusing as it travels. For example, an inflow of storm water can pool near the outfall and be transported by currents. It is therefore unwise to count on dilution with the available volume in the region of the intake when water-borne contaminants are considered. Creeks receiving storm water in the City of Kelowna contained *E. coli* from ducks, dogs songbirds, deer, humans, cows, horses, gulls, and Canada geese (Appendix 3).

Historically there were no storm water outfalls in the vicinity of the DLC Okanagan Intake. There is limited low density residential development in the area with limited inflow along natural drainage courses that may flow into the bay immediately south of the intake. Currently, the closest storm water inflow to the DLC intake is the proposed Lakestone outfall, located 220 m along the shore to the south in a small bay and extending to about 10 m deep. Storm water routinely carries bacteria, PAHs salt and nutrients. The storm water plume will behave like a creek inflow plume. If the particulate load is heavy during the "first flush" of materials off the streets into the storm water, then the inflow may form a density plume that travels along the sides of the lake like a dirty cloud. After the initial flush, the storm water plume should be trapped by the thermocline and remain in the surface water during the summer. It will travel parallel to the shore dropping large particulates quickly while finer particulates will travel further. During the non-stratified winter period, the storm water can form a pool in front of the outfall intake and travel as a packet of water, diluting as it travels. The depth that the pool can form at will be deeper than in the summer, and is the most immediate potential source of contaminants to the 33 m deep DLC intake after November. At present, this intake is only operated until December, but more extended winter use is probable in the future. The 33 m depth of the intake provides more protection than a shallower intake would because water movements are much smaller.

The Lakestone Resort storm water outfall plans include the use of a storm water treatment involving a D20 ConTech storm water treatment unit that should remove oil and grit and is designed for the one in ten year storm. Storms with less intensity than the 1 in 10 year event are handled by a soak-away ground water recharge system (no details available). The planned outfall would discharge at 8 m or above the thermocline for most of the stratified period.

Okanagan Centre Road comes down to the lakeshore 1200 m north of the intake and is 30 m from the lake for 3.3 km to the North, along beaches where people often swim Storm water run-off from the road would be directed to the lake without treatment. The possibility of a hazardous spill from hauling along the route would include septic trucks, fertilizer and the PAHs represented by the vehicles themselves.

Very little storm water treatment has been developed in the Okanagan Centre area. Most storm water reports to the nearest watercourse without treatment. Localized on-site soak-away disposal could be considered for street run-off as well as rainwater barrels and rain gardens for roof drains. Rain water should be captured as an asset rather than allowing it to degrade into an expensive (storm water) liability.

3.1.3 Sewer Infrastructure and Septic Fields

The nearest existing residential area to the DLC intake Is Okanagan Centre. It will have aging septic systems in older areas. It is not currently serviced by sewer. All subsurface drainage will be toward Okanagan Lake from that community. Raw sewage pumped from the septic tanks can be dumped at the Biosolids Composting Facility in Lake Country, located off Beaver Lake Road, where it is composted with wood wastes and used to create Ogogrow.

Properly functioning septic fields should not release pathogens but they will release nutrients and pharmaceuticals and personal care products (PPCPs) to the groundwater or subsurface flow. Recent research has shown that wastewater treatment plants and septic systems only partially remove pharmaceuticals, so these chemicals end up in groundwater and have been measured in adjacent rivers and lakes (Knox County, ND) In addition to functioning systems, improperly functioning septic systems will allow even greater concentrations of PPCPs to pass. Septic system contamination can severely impact surface and ground water (USEPA, 2007).

Ascertaining the minor risk from Okanagan Centre septic systems to the DLC Okanagan Lake intake would be prohibitively complex and beyond the scope of this report. A far more immediate concern would be the proposed Lakestone development immediately upslope of the intake.

Proposed New Lakestone Resort Sewer infrastructure

All of the planned Lakestone Development is to be connected to the sanitary sewer collection system by a series of lift stations and force mains to DLC Waste water treatment plant. Emergency plans for a catastrophic failure must be in place. It is unlikely but the consequence of a failure of a sewer main or lift station to the DLC intake must be considered. Appropriate containment strategies should be included in the Emergency Response Plan.

3.1.4 Moorage, Docks and Powerboat Recreation

The closest existing boat launch/marina facility to the LDC Okanagan Intake is called Okanagan Safe Boat Harbor. It is located at Okanagan Centre and is 3 km north of the intake. It consists of two boat launches, parking and a large dock and break-water. There are no facilities on the docks but there are pump-out washrooms located 30 m from the shore. There is a public beach south of the boat harbor.

The proposed marina for the Lakestone Resort is only 180 m north of the intake and plans include extensive dock facilities with 100 boat slips, 272 boat grotto with boat relay service, tiered decks, a casual outdoor restaurant, “swimming pool” in the lake, and a boutique beach house hotel on-the-water-fueling and presumably septage facilities or connection to sewer (Figure 3.1). This facility presents a far greater risk to the intake than the Okanagan Centre boat harbor.

Figure 3.1: Proposed Lakestone Marina and Hotel Complex (180 m N of intake)

THE BEACH HOUSE

Accidental spills during refueling at marinas are routine and PAHs accumulate in the sediments. Leakage from boat motors is also routine while they are moored. No moorage, marinas, boat launches or large dock facilities should be considered within the Intake Protection Zone without intensive precautions and planning.

The Okanagan Shuswap Land and Resource Management Plan (LRMP) was approved by the Provincial government in 2001. An overall objective of the LRMP was to minimize and reduce impacts on foreshore areas. The LRMP emphasized that on the foreshore of large lakes, there is a continuing need to ensure that existing developments and future proposals respect the foreshore. The magnitude and potential impacts of this marina appear to be in contradiction with the intent of the LRMP.

The risks presented by the Lakestone Marina must be weighed carefully against the benefits of such a project and include:

- Increased introduction of PAHs during normal motor operation and by accidental spills; (A liter of gasoline can contaminate 750,000 liters of water (Kerr Wood Leidel, 2008).
- Risk of leaks and spills from on-lake fuel storage
- Increased use of the lakes with boats equipped with on-board septic holding tanks (many of which can be opened at will and verified reports of human feces washed up on shore near houseboat moorage have occurred in the Okanagan);
- Seasonal pump-out stations at marinas can fail – for example the August 14, 2009 spill of raw sewage from the Westbank Yacht Club into Gellatly Bay, Okanagan Lake. Storm water deluged a manhole and overflow of storm water and raw sewage flowed into the lake for 45 minutes (Appendix 1).
- More intensive use of the area above the intake by power boats

A proposal to relocate this marina away from the intake or mitigate these concerns is urgently needed.

A clean-up kit for a hydrocarbon spill into Okanagan Lake should be stored with the Lake Country Fire Department and at Lakestone if the development proceeds. Spills should be reported and cleaned up in accordance with the Spill Reporting Regulation (B.C. Reg.263/90). Lake Country may wish to consider encouraging non-motorized recreation by planning facilities that promote sailing, kayaking, canoeing, all of which have far less potential to impact intake water quality.

3.1.5 Adjacent Land Use

Land use within several hundred meters of Okanagan Lake has a greater potential to impact water quality than land use distant from the lake. Shoreline properties have the highest potential to impact the lake. Overland flow from these properties is the most serious, followed by subsurface drainage which is slower and offers some in situ treatment. Both of these routes for contaminant travel are diffuse and are unlikely to impact the intake water quality directly, however, overland flow and groundwater contamination both contribute to the contaminant and nutrient loads reaching Okanagan Lake. Although shoreline flooding is rare on this regulated lake, no toxic materials should be shored near the high water mark.

Along the proposed Intake Protection Zone, current development is limited to single family residential and municipal roads.

Like the storm water generated from residential properties, overland flow and seepage to ground can carry fertilizers, pesticides, pathogens, detergents and solvents from residential properties bordering the lake. The impact would be determined by the type volume and the location of the contaminant introduction. Lakeshore owners should be encouraged to preserve a shrub belt between their properties and the lake to intercept drainage. It is illegal to modify the natural shoreline because of its protective value and fisheries value. Best practices management of properties within the Intake Protection Zone is more important to the DLC intake than management of properties remote from the intake, but all are important.

The proposed Lakestone Development represents a massive change to the semi-rural land use to this time. It includes residential subdivisions, a hotel, marina complex, a golf course and roads (Figure 3.2). It is unfortunate that this development plans to put a storm water outfall on one side of the intake, and a marina on the other. Although the intake's 33 m depth provides some protection, its short 60 m length (43 m out from shore) keeps it in the higher risk near-shore area.

Figure 3.2: Lakestone Master Plan

ARCHITECTURE BUILT IN HARMONY WITH THE LAND

The hazards and potential contaminants that Lakestone represents to the intake include:

- Storm water discharge (can carry fertilizer, pesticides, pathogens, road surface contaminants, PAHs, particulates and salt) – *Very Serious Risk*
- Fertilizer and lawn care chemicals from the golf course and residences reporting to ground water and subsurface flow along the shoreline near the intake (can increase localized algal growth)
- Accidental spills of boat septage or PAHs
- Accidental spills of sewage (force-main failure) from development

3.1.6 Vandalism

Deliberate spills into Okanagan lakes through ignorance or spite are recorded (Appendix1). For example, 20 gallon pails of hydraulic oil and motor oil were deliberately spilled into Okanagan Lake near Poplar Point in 2009, necessitating an expensive clean-up. While vandalism can be difficult to predict, obvious hazardous targets such as fuel storage or portable outhouses should be protected. The risk of human activity to Okanagan Lake is dependent upon the behavior of all residents and users.

There are already many laws and bylaws prohibiting deliberate and accidental pollution of water bodies, but enforcement efficiencies are needed. Direction from the OBWB is desirable.

3.2 Natural Contaminants

Not even pristine watersheds and lakes provide completely risk-free drinking water. Natural conditions in and near Okanagan Lake also affect the water quality it provides. The most important of these are covered in this section.

While cyanobacteria densities in the DLC Okanagan Lake intake water never exceeded the WHO and AWWA recommended guidelines, they may still allow a risk of chronic low dose exposure to cyanotoxins. Fortunately, one of the most likely cyanotoxins that can be produced by cyanobacteria in Okanagan Lake is degraded by chlorine but at twice the dose required for disinfection and pH must be near neutral (Hitzfield et al., 2000). UV disinfection is also helpful but again, the UV dose to deactivate microcystins is greater than the dose for water disinfection (Hudnell (ed) 2007). Infrequent surface cyanobacteria blooms have been noted in the vicinity of the intake and could be transported down to the intake by seiches or near-shore turbulence. These blooms are dominated by *Anabaena and Anacystis* and may become more common if localized nutrient loading from the Lakestone development occurs (Larratt, 2009).

3.3 SUMMARY MODULE 2: Contaminant Source Inventory Table

Contaminant Source and Type	Owner/ Jurisdiction	Location	Distance to intake	Possible Contaminants	Contaminant Transport Mechanism	Comments
Inflows						
Lambly Creek plume	n/a	N 49.9266 W119.5084	9.4 km	nutrients bacteria viruses	Currents seiches	Dilute risk at intake
Kelowna Creek plume	n/a	N 49.8804 W119.5035	16.1 km	nutrients pathogens spills	currents seiches	Flow direction & volume varies
Brandt's Creek	n/a	N 49.8958 W119.5020	14.2 km	nutrients pathogens process chemicals	Currents seiches	Creek inflow can be very warm
Overland flow / flooding	n/a			sediment pathogens fertilizers pesticides	currents	Only in storms; flooding rare
Sewage /Grey Water						
Lift Station sewer mains	DLC	near pump-house	Not avail.	sewage*	overland flow	Rare event; very high risk
Septic fields	OK Centre		3-4 km	septage*	Subsurface seepage	Hazard, esp. old systems
C of Kelowna outfall	C of K	N 49.8622 W119.4994		sewage*	Currents seiches	Very dilute when reaches intake
Boat grey and black water	MoE	variable	variable	sewage* detergents dyes PPCP bacteria	Currents Seiches	Risk dependent on boaters
Storm Water						
Ok Centre Rd	DLC	N of intake	1200m-4000m	PAH salt pathogens accidental spills;	ditches seepage	Some discharge directly to lake
Lakestone Developments		above intake	70 m +	PAH salt bacteria nutrients pesticides	Outfalls seepage	Outfalls should not occur in IPZ
Marinas						
Ok Centre Safe Harbor	OK Centre	N 50.0405 W119.4504	3 km	PAHs	currents	Very low risk
Lakestone Resort Marina		N 50.0154 W119.4422	180 m	PAHs, septage, fuel spill	Currents seiches	Very high risk
Land Use						
Lakestone Developments		Above intake	70 m +	fertilizers pesticides	Currents Seiches	
Existing Residential	D.L.C.		100 m+	fertilizers pesticides spills	Currents seiches	
Okanagan Centre	OK Centre		3 km	septage* fertilizers historc pesticides	Currents seiches	Very dilute when reaches intake
Natural						
Cyanobacteria	BC	throughout	n/a	cyanotoxins	seiches	Apr-May had highest counts
Benthic algae and plankton algae	BC	Near shore	n/a	organic material for biofilm, THM precursors	Currents near shore turbulence	May/June and summer

Pesticides includes: herbicides, insecticides, fungicides, rodenticides, and avicides; Many pesticides are highly toxic and are mobile in sub-surface flows

PAHs includes: fuels, oil, grease, asphalt (auto wastes also include: transmission fluid, antifreeze, battery acid)

***Septage/sewage** includes: pathogens, organic matter, THM precursors, nitrates, nutrients, heavy metals, inorganic salts, pharmaceuticals, personal care products, cleaners, paints, medications, auto wastes, PAHs

Pathogens includes: bacteria, viruses, fungi, protozoan parasites

3.4 Summary MODULE 2: Hazard from Contaminants Identification Table

Contaminant Source and Type	Possible Contaminants	Existing Preventative Measures and Barriers	Possible Preventative Measures and Barriers
Inflows			
Lambly Creek plume	nutrients bacteria viruses	MoF cooperation with LID in watershed protection	Enhanced watershed protection esp motorized recreation
Kelowna Creek plume	nutrients pathogens spills	New development not allowed to discharge SW Public education (chlorine)	Improved storm water management
Brandt's Creek	nutrients pathogens process chemicals	Monitoring, release only when meets criteria	Improved process water management
Overland flow / flooding	sediment pathogens fertilizers pesticides	Some silt curtains during construction (chlorine)	Discourage over watering with metering, high water rates
Sewage			
Lift Station sewer mains	sewage*	Not known	Need spill plan; overflow alarms SCADA, back up power genset
Septic fields	septage*	Small number near intake	May be decommissioned
C of Kelowna outfall	sewage*	Extensive dilution occurs under most circumstances	Improved treatment to remove more nutrients and PPCP
Boat grey and black water	sewage* detergents dyes PPCP bacteria	BC MoE Envi Management Act Sec 13 (stops dumping)	Equip boats with secured grey and black water holding tanks
Storm Water			
Ok Centre Rd	PAHs salt pathogens accidental spills;	None –chlorination of supply	Direct storm water to ditches opposite from lake where possible
Lakestone Developments	PAHs salt bacteria nutrients pesticides	DL 20 ConTech storm water treatment unit	Relocate outfall or monitor outfall; direct to water features or ponds
Marinas			
Ok Centre Safe Harbor	PAHs	Long distance from intake	None needed at present
Lakestone Resort Marina	PAHs, septage, fuel spill	None	Relocate marina
Land Use			
Lakestone Developments	fertilizers pesticides	Not known	Limit use of fertilizers, ban pesticides on property
Existing Residential	fertilizers pesticides spills	Very low density	Limit use of fertilizers, ban pesticides on property; green belt
Okanagan Centre	septage* fertilizers historic pesticides	None, long distance from intake	Encourage shoreline protection, planting a green belt
Natural			
Cyanobacteria	cyanotoxins	Monitoring done, chlorination	Limit nutrient sources; extend intake to 40-50 m
Benthic algae and plankton algae	organic material for biofilm, THM precursors	None except sewer systems and tertiary treatment	Limit nutrient sources in seepage and storm water

Pesticides includes: herbicides, insectides, fungicides, rodenticides, and avicides; Many pesticides are highly toxic and are mobile in sub-surface flows

PAHs includes: fuels, oil, grease, asphalt (auto wastes also include: transmission fluid, antifreeze, battery acid)

Sewage includes: pathogens, organic matter, nitrates, heavy metals, inorganic salts, personal care products cleaners, paints, medications, auto wastes, PAHs

Pathogens includes: bacteria, viruses, fungi, protozoan parasites

4.0 Okanagan Lake Intake Module 7: Risk Characterization and Analysis

The intent of Module 7 is to connect the contaminant hazards identified in Modules 1 and 2 with an evaluation of the existing source protection and water treatment barriers. The focus of this report is on the Okanagan Lake intake and water source. Module 7 uses the following set of tables to assign risk.

Table 4.1: IHA Module 7 Hazard and Risk Tables

Qualitative Measures of Hazard

Level of Risk	Descriptor	Description	Probability of occurrence within next 10 years
A	Almost certain	Is expected to occur in most circumstances	>90%
B	Likely	Will probably occur in most circumstances	71-90%
C	Possible	Will probably occur at some time	31-70%
D	Unlikely	Could occur at some time	10-30%
E	Rare	May only occur in exceptional circumstances	<10%

Qualitative Measures of Consequence

Level	Descriptor	Description
1	Insignificant	Insignificant impact, no illness, little disruption to normal operation, little or no increase in operating cost
2	Minor	Minor impact for small population, mild illness moderately likely, some manageable operation disruption, small increase in operating costs
3	Moderate	Minor impact for large population, mild to moderate illness probable, significant modifications to normal operation but manageable, operating costs increase, increased monitoring
4	Major	Major impact for small populations, severe illness probable, systems significantly compromised and abnormal operation if at all, high level of monitoring required
5	Catastrophic	Major impact for large population, severe illness probable, complete failure of systems

Qualitative Risk Analysis Matrix

Likelihood	**Consequences**				
	1 Insignificant	**2 Minor**	**3 Moderate**	**4 Major**	**5 Catastrophic**
A almost certain	Moderate	High	Very High	Very High	Very High
B likely	Moderate	High	High	Very High	Very High
C possible	Low	Moderate	High	Very High	Very High
D unlikely	Low	Low	Moderate	High	Very High
E rare	Low	Low	Moderate	High	High

Risk Characterization and Analysis

The proximity of the DLC Okanagan intake to the Lakestone Development makes it more vulnerable to contamination than an intake in the upland watershed water supplies. The risks within the intake protection zone (IPZ) are generally higher than the risks presented by the same hazard occurring outside the IPZ. Tables 4.2 and 4.3 summarize the hazards and assign a risk level based on likelihood and consequence of each hazard, along with existing and proposed improvements to the barrier(s) guarding the DLC Okanagan Lake Intake. For ease of assessment, the hazards have been grouped as physical, chemical, biological and water system risks. An overview of the protective barriers follows this hazard-by-hazard assessment is presented in Table 4.4.

Physical Risks The physical risks presented by Okanagan Lake include inflows that can carry contaminants, transport of contaminants within the lake and re-suspension of settled contaminants.

Chemical Risks Inevitable anthropogenic risks are caused by: storm water, septage and PAHs. Preventable anthropogenic risks include pesticides, fertilizers and accidental spills. Hopefully increasing societal awareness will continue to diminish the risk presented by these chemicals. The most catastrophic human impact on DLC's Okanagan intake is fortunately extremely unlikely and that is a spill of sewage or toxic chemical within the Intake Protection Zone (IPZ).

Biological Risks The naturally occurring biological risks to the intake occur throughout Okanagan Lake and they involve algae blooms and cyanobacterial blooms. These naturally occurring threats are exacerbated by human activities that add nutrients to the lake system. Population growth will necessitate increasingly sophisticated water treatment to prevent increased nutrient loading. Pathogens are also naturally occurring, but human travel has greatly increased the range of pathogens and their frequency in the Okanagan region.

Water System Risks After water from the 33 m depth in Okanagan Lake enters the DLC system, it is chlorinated and monitored. The distribution system is subject to aging, settling of suspended materials, accidental line breaks. etc. The pump-house and main were completed in 1970, but the distribution system was installed in 1995. On-going maintenance, repairs and monitoring are vital to any water distribution system. This water system has had very few maintenance problems (Allingham, pers comm.). An emergency response plan aids in providing an appropriate and swift response to an emergency.

Risk Characterization Table: Part 1: Risks Within Intake Protection Zone

Table 4.2 Risks Inside Intake Protection Zone (IPZ) with the Potential to Impact the DLC Okanagan Intake

Drinking Water Hazard	Likelihood Level	Consequence Level	Risk Level	Comments/ Assumptions
Physical				
1 Adjacent land use impacts	**A**	**2**	High	Lakestone Development must observe BMP for riparian areas and IPZ
2 Sediment re-suspension	**C**	**1**	Low	Can occur during seiches; no *E. coli* found in sediment under intake
3 Flooding and subsurface inflow	**D**	**3**	Mod	Okanagan R prevents most flooding; subsurface flow to IPZ is important
Chemical				
4 Storm water plume to intake	**A**	**3**	VHigh	Storm water carries many contaminants, no outfalls should occur in IPZ
5 Sewage leak or spill	**B**	**4**	VHigh	Impact determined by size of spill within IPZ, can be very serious
6 PAH spills in marina	**B**	**3**	High	Impact determined by size of spill within IPZ, can be serious
7 THM precursors	**D**	**2**	Low	All results to date are less than 0.100 mg/L T-THM guideline
8 Heavy Metals (from sediments)	**E**	**2**	Low	Seiche disturbance can release metals to lake water
9 Pesticides (overland or seepage)	**D**	**3**	Mod	Toxicity and persistence of pesticides varies; no storage within IPZ rec'd
10 Fertilizers (overland or seepage)	**C**	**2**	Mod	Localized algae bloom may result, trace metal contamination is possible
11 Spills (road, boats, homes)	**E**	**4**	High	Depending on spill location and type, emergency response may be needed
Biological				
12 Algae blooms	**A**	**1**	Mod	Algae increase TOC, THM precursors, odor, chlorine consumption
13 Cyanobacteria blooms	**B**	**3**	High	Chronic low-dose exposure to cyanotoxins >2000 cells/mL in May
14 Viruses- pathogenic	**C**	**4**	VHigh	Protect IPZ from storm water, septage, boat spills. Viruses do not settle
15 Bacteria- pathogenic	**C**	**4**	VHigh	Protect IPZ from storm water, septage boat spills. Bacteria slow to settle
16 Protozoa – pathogenic	**E**	**4**	High	Protozoan cysts will settle in calm conditions
Water System				
17 Physical system failure	**E**	**3**	Mod	Disruption of service probable; may have break/spill reach the lake with Cl
18 Treatment / Monitoring failure	**E**	**3**	Mod	Water quality advisory probable
19 Emergency response plan failure	**B**	**3**	High	No formal Emergency Response Plan is in place; DLC relies on skill of operators to handle and notify appropriate authorities

Risk Characterization Table: Part 2: Risks Outside the Intake Protection Zone

Table 4.3: Risks Outside the Intake Protection Zone (IPZ) With the Potential to Impact the DLC Okanagan Intake

Drinking Water Hazard	Likelihood Level	Consequence Level	Risk Level	Comments/ Assumptions
Physical				
20 Creek Plumes	**B**	**2**	Mod	Lambly Creek is the most likely influence
21 Adjacent land use impacts	**A**	**1**	Mod	All Okanagan residents must recognize their responsibility
22 Sediment re-suspension	**B**	**1**	Mod	Sediment re-suspension is common but the amount here is small
23 Flooding / subsurface inflow	**D**	**2**	Low	Flooding, subsurface inflow remote from IPZ are unlikely to exert impact
24 C of K Outfall plume	**D**	**3**	Mod	Greater transport of nutrients pathogens to N basin during wind storms
Chemical				
25 Storm water plume to intake	**C**	**2**	Mod	Current transport of storm-water packet to the intake is probable in winter
26 Septage and sewage spill	**D**	**3**	Mod	Spills remote from IPZ will be diluted with some pathogen deactivation
27 Hydrocarbons PAHs spill	**D**	**2**	Low	Spills remote from IPZ will be diluted
28 THM precursors >0.10 mg/L	**D**	**2**	Low	All results to date are less than 0.100 mg/L T-THM
29 Heavy metals (from sediments)	**D**	**1**	Low	Sediment disturbance outside IPZ unlike to create measurable impact
30 Pesticides(overland or seepage)	**D**	**2**	Low	Toxicity/persistence of pesticides varies; golf course/gardens may donate
31 Fertilizers (overland or seepage)	**C**	**1**	Low	Large nutrient inflows could increase the algae production of N Ok Lake
32 Spills (Ok Centre Rd)	**D**	**3**	Mod	Depending on contaminant spilled, emergency clean-up needed ASAP
Biological				
33 Algae blooms	**A**	**1**	Mod	Algae blooms can be transported around lake by currents
34 Cyanobacteria blooms	**C**	**2**	Mod	Chronic low dose is greatest concern in spring (May)
35 Viruses – pathogenic	**C**	**2**	Mod	Low volume of viral introduction unlikely to impact intake
36 Bacteria- pathogenic	**C**	**2**	Mod	Bacteria can be deactivated or consumed as they travel in lake water
37 Protozoa- pathogenic	**E**	**2**	Low	Long distance transport of cysts through lakes is unlikely
Water System				
38 Physical system failure	**E**	**3**	Mod	Disruption of service probable to small population;
39 Treatment/ monitoring failure	**E**	**2**	Low	Water quality advisory probable
40 Emerg. response plan failure	**B**	**2**	High	No formal Emergency Response Plan is in place;

4.1 Condition of Source

Okanagan Lake in the vicinity of the DLC intake provides excellent quality drinking water with no color, moderate hardness, low iron and no taste and odor events. Okanagan Lake is not under the control of the District of Lake Country, but water quality relies on every user of the resource. Adjacent urban centers put pressure on the lake as a whole and the Lakestone Development will put pressure on the areas of the lake near the intake.

The DLC Okanagan water supply has a back-up supply because the system can be switched to Vernon Creek. This is a 100% redundant back-up system, but there would be a noticeable reduction in water quality to the rate payer.

4.2 Physical Integrity of Intake, Treatment and Distribution System

The Okanagan Lake intake was completed in 1968 and currently serves 926 domestic connections and 60 acres (24 ha) of irrigated land. This use will expand to 2000 if the Lakestone development proceeds as planned, however, the Lakestone plans are under review.

The distribution system is in good condition, with significant recent upgrades including new pump stations, reservoirs and pipelines over the past seven years Upgrades to the system are performed based on priority. In 2008/9, the main intake pumps were replaced and a raw water sample line was installed.

Maintenance involves draining cleaning and chlorine- shocking balancing reservoirs, proactive line flushing, connection checks, etc. DLC employs full-time operators with Level I and Level II training and the water manager has Water Distribution Level III. Operators have additional certifications and receive on-going training from DLC (Meger et al., 2006, 2007).

4.3 Risk Assessment for Healthy and Health-compromised Individuals

On the whole, water quality from Okanagan Lake is enviable and meets the needs of healthy individuals. People with compromised immune systems could benefit from another pathogen barrier such as UV disinfection or boiling their drinking water. One area of concern would be the chronic low dose exposure to cyanotoxins for people battling cancer, those with neurological conditions or those with hepatic conditions. Based on in-place monitoring of pathogens and THMs, the risk posed by these materials is below the guidelines that themselves usually have a ten-fold safety margin built into them.

4.4 Strength/Weakness Opportunities/Threats SWOT Analysis

A SWOT analysis provides a summary overview of the balance between the major positive and negative aspects of the DLC Okanagan Lake Intake that supplies the DLC distribution system. Only those aspects with the greatest potential to influence DLC water quality at present and into the future are considered in Table 4.4.

Strength/Weakness Opportunities/Threats Analysis Summary for DLC Okanagan Lake Intake

Strengths	Weaknesses
▪ The large size and depth of oligotrophic Okanagan Lake maintains constant water quality (low color odor turbidity THM bacteria) ▪ The 33 m depth of the intake provides more protection from surface contaminants than shallower intakes ▪ Low concentrations of cyanobacteria occur most of the year; ▪ Algae counts were very low except during the spring ▪ Existing urban areas are not close to the intake ▪ The Drinking Water Protection Act and other regulations help protect source water ▪ FIM and SHIM Inventory mapping are underway for Okanagan Lake and its main tributaries ▪ Dedicated staff and council on water issues ▪ SCADA system records turbidity, Cl, level ▪ Back-up water supply is available in Vernon Creek	▪ Although the intake is deep, it is only 60 m from shore, exposing it to shoreline activities and seiche upwelling ▪ The plumes from Kelowna STP, Bear Creek, Kelowna Creek reach the intake every year (in a diluted state) ▪ Diatom counts are high enough in the spring to cause a mild musty taste and odor ▪ Lack of DLC control over Okanagan Lake and adjacent land use planning ▪ Small number of connections limits funds for system improvements ▪ Recreational and land development pressures on Okanagan region are increasing ▪ Cyanobacteria counts exceeded 2000 cells/mL in the spring at the intake depth dominated by *Planktothrix* which produces cyanotoxins including microcystin

Opportunities	Threats
▪ Apply for License of Occupation from ILMB over the intake protection zone ▪ Establish a no-build no-disturb set-back bylaw for foreshore protection from future development based on the 1-100 yr storm ▪ Develop storm water master plan for DLC; consider re-routing storm water away from IPZ; consider opportunities for re-use for irrigation ▪ Public education on shoreline protection ▪ UV disinfection would be effective on this high-quality water ▪ Develop emergency response plan ▪ Put alarm on sewer mains for loss of pressure ▪ Extending the intake to 47 m would provide optimal water quality with >3 m clearance from the substrate ▪ Add temperature to the SCADA system	▪ Proposed Lakestone shoreline development including a marina (180 m away) and a storm water outfall (220 m) within the intake protection zone ▪ Cyanobacteria counts may be increasing with eutrophication and climate change ▪ Spill to Okanagan Lake from Lakestone or Ok Centre Road could cause an emergency ▪ Several years of drought could lower the water level below the depth of the wet well, disrupting service ▪ Increasing development in the central Okanagan is increasing the net load of nutrients to Okanagan Lake ▪ Inadequate enforcement of recreation polluters and foreshore development violators ▪ Mountain pine beetle is altering hydrology of Okanagan Lake's watershed

5.0 Okanagan Lake Intake Module 8: Recommendations

The summation of Modules 1, 2 and 7 lead to the recommendations to improve DLC Okanagan Lake Intake and Water System presented here as Module 8. This section presents three action plans addressing 1) source protection, 2) the existing water treatment system, and 3) future large expenditure system improvements. The hazards from Table 4.2 and 4.3 addressed by each recommendation are shown in the Risk box. Additionally, there would be great value in a comprehensive source water assessment on the mainstem lakes that could evaluate cumulative impacts on water quality, carrying capacity for quality and quantity, identify point source contaminants, storm water in stream flows etc., Partners such as OBWB Regional Districts, municipalities, First Nations could pool funding and existing studies.

5.1 Source Protection Action Plan

The only items worth placing into a source protection action plan are those that can be realistically achieved both from a financial and practical standpoint. Improvements that provide the best cost-benefit for risk reduction are itemized below. Additional protection measures intended to protect unimpaired areas are also provided.

5.1-1 Protect Intake Protection Zone (IPZ)

Risk	Action	Who?	Cost	Timeframe	Outcome
1 4 6 11 15	Apply for License of Occupation for IPZ	DLC apply to ILMB	Staff time	2010	Stronger source water protection

DLC apply to Integrated Land Management Bureau (ILMB) through Front Counter BC for a License of Occupation over the Intake Protection Zone. This License could pre-empt or set limits on future developments (e.g. marinas, house boat moorage) and proposed adjacent uses would be flagged for DLC comment. The IPZ could be added to the Official Community Plan (OCP) for DLC and that would give the intake further protection. Signage including maps of the Intake and the IPZ could be posted at parks and boat launches in the area to remind residents that their drinking water is drawn 40 m offshore. Some property adjacent to the southern end of the IPZ may be within the City of Kelowna boundary and they should be informed of the IPZ proposal.

5.1.2 Bylaw to Protect Okanagan Lake Foreshore within DLC and C of K

Risk	Action	Who?	Cost	Timeframe	Outcome
1 4 5	Develop bylaw	DLC CofK	Staff time	2010	Okanagan Lk protection

The DLC land use planning department could use other jurisdiction's foreshore policies to draft enforceable (no-build, no-disturb) set-backs from the high water mark on Okanagan Lake. A voluntary pesticide ban on all lakeshore properties should also be considered and a restriction on impervious surfacing. Best Management Practices should always be utilized and a checklist is provided in Appendix 2.

5.1.3 Storm Water Outfall Exclusion/Improvement

Risk	Action	Who?	Cost	Timeframe	Outcome
4 10 11 1	Exclude storm water outfalls from IPZ	DLC staff and council	unknown	Commence in 2010	Prevent SW contaminants from reaching IPZ

Ideally no storm water outfalls should discharge within the intake protection zone or within two hour's transport during maximum current velocity, whichever is greater. The DLC may need to develop a plan with the developer for re-routing outfall(s) that can threaten the intake. The main storm water outfall proposed by CTQ consultants needs relocating, perhaps following Ok Center Road to the north by 900 – 1000 m from the intake. The storm water outfall planned for the phase adjacent to the lake may be able to safely discharge if a series of swale / soak-away area(s) are planned. Land owners in the area should be encouraged to limit impervious surfaces, and incorporate "rain gardens"

5.1.4 Safeguard Sewer Mains

Risk	Action	Who?	Cost	Timeframe	Outcome
5 26	Alarm all sewer mains	Lakestone	???	During development	Protection from main breaks, etc.

Lakestone should provide alarms on the sewer mains and a back-up power source such as a Gen-set for the mains with the potential to spill to Okanagan Lake.

5.1.5 Relocate Lakestone Marina

Risk	Action	Who?	Cost	Timeframe	Outcome
5 6 11 1 4 10	Plan to relocate marina outside IPZ	DLC staff and council	unknown	Commence in 2010	Prevent marina contaminants from reaching IPZ

A major marina such as the proposed Lakestone marina located 180 m from an important domestic water intake is a very high risk. Relocating the marina outside the IPZ is strongly recommended. Compensating for the suite of risks the current marina plans present to the DLC intake would be very difficult.

5.1.6 Public Education

Risk	Action	Who?	Cost	Timeframe	Outcome
1 11	1 day survey, update	DLC	Staff time	annual	Knowledge of changes

Public education through open houses, e-mailings, directed billings to lakeshore owners, signage and other initiatives can help encourage responsible public behaviour and is key to preserving Okanagan Lake quality. The Water Supply Association BC, Kelowna Joint Water Committee and the Lake Stewardship Society would be useful allies.

5.1.7 Regular Inspection of Lakestone Development for Unexpected Impacts

Risk	Action	Who?	Cost	Timeframe	Outcome
1 4 6 9 10	Continue public education on OK Lk	DLC and NGO, MoE	low	On-going	Better voluntary control of contaminants to Ok Lk

A brief annual survey of the intake shoreline area and an update from the planning department would allow an annual overview of changes to the lake and adjacent land use that have the potential to impact water quality at the intake.

5.1.8 Discussions with DLC on Okanagan Center Rd Drainage Maintenance

Risk	Action	Who?	Cost	Timeframe	Outcome
4 6 11	Get culverts/ditches inspected	DLC	Staff time	2010	Better risk abatement

DLC should review drainage maintenance on the 3 km section of Okanagan Centre Rd. within 30 m of Okanagan Lake shoreline. There may be opportunity to have appropriate emergency spill containment measures for septage spills provided to DLC by the Provincial Emergency Program.

5.1.9 Large Scale Source Water Source to Tap Assessments on Mainstem Lakes

Risk	Action	Who?	Cost	Timeframe	Outcome
20 21 27 30 31 32	Water Assessment as appendix of OBWB supply study	OBWB FN Purveyors Reg.districts	Staff time	2010 >	Better understanding of cumulative impacts, carrying capacity

MoE suggested doing larger scale source water assessments on the mainstem lakes (i.e. Okanagan Lake, Kalamalka Lake, Skaha Lake, & Osoyoos Lake). Key partners could include OBWB, the 3 regional districts plus major water purveyors, Transport Canada, FN etc. The assessments could look at cumulative impacts, carrying capacity, point source contamination etc.

5.2 Water Treatment and System Protection Plan

Preventative measures and corrective action for critical hazards to the Okanagan Lake Intake and DLC water system are laid out in this section.

5.2.1 All Hazards Emergency Response Plan

Risk	Action	Who?	Cost	Timeframe	Outcome
19 17	Plan preparation	DLC student	wages	Start in 2010	Better reaction to emerg.

Lake Country needs an All Hazards Emergency Response Plan. The plan should include emergency contact numbers, steps to follow, agencies to notify, protocols to follow for public notice, etc. This could be prepared by a Water Quality Tech. summer student using the GVW plan as a guide.

5.2.2 THM sampling

Risk	Action	Who?	Cost	Timeframe	Outcome
7 18	Increased THM sampling	DLC	???	2010	Compliance with IHA filtration deferral

Seasonal THM samples should be collected for three years and then dropped down to once annually during the season when the highest total THMs are expected: Spring, Summer and Fall THM samples should be collected from location(s) furthest from treatment. This sampling is expected to meet all criteria i.e. generate a “good news” outcome. THM precursor sampling could be conducted at 30 and 50 m if extending the intake is considered.

5.2.3 Enhanced water quality sampling

Risk	Action	Who?	Cost	Timeframe	Outcome
2 4 5-8 13 16	More WQ sampling	DLC	???	2010	Compliance with IHA filtration deferral

Upgrade routine sampling to include:
Quarterly - algae/cyanobacteria sampling including April, May, August, October
Monthly – protozoa – *Cryptosporidium* and *Giardia* for filtration deferral (may not need to continue this sampling intensity indefinitely, based on results)
Bi-weekly – alkalinity, hardness, TOC
Weekly - color, UV transmissivity as per the IHA Filtration Deferral guidelines

Okanagan Lake – Raw Water

1 sample per week: (4 per month)

- Total Coliform/E.coli, True colour and UVT (125mL bottle or 2 - 50 mL)
- **Water chemistry:** NTU, temp, pH, cond., appt col, hardness
- On-line WQ equipment verification check

Distribution System

1 sample per week: (4 per month)

- Total Coliform/E.coli
- 1 sample collected within system (approximately 20 sites - some seasonal or water chemistry only): ensuring that adequate sampling occurs at dead-ends/intermediary/end of line
- 1-2 other locations per week testing water **chemistry ONLY**.
- **Water chemistry:** Free & Total Chlorine, NTU, temp, pH, cond, appt col.
- 1 P/A Sample/month

5.2.4 Add Temperature to SCADA system

Risk	Action	Who?	Cost	Timeframe	Outcome
4 20 25	Add temp probe to SCADA on Ok intake	DLC	2000	2010	Detailed information on seiches that impact the Okanagan DLC intake

There may be cost efficiencies to adding temperature to both the Kalamalka and Okanagan DLC intake at one time. These probes are very reliable at other locations and provide excellent data on seiche activity and hoe that correlates to changes in turbidity, TOC and other water quality parameters relevant to water treatment.

5.3 Future Large Expenditure Improvements to Lake Country Okanagan System

This final section of recommendations covers the large expenditure items that require extensive preparation and planning.

5.3.1 Intake Extension

Although DLCs Okanagan Lake Intake is one of the deepest in Okanagan Lake currently, the distance to extend the intake into the best possible water (45-50 m) would only be an extension of about 50 m of intake pipe.

Based on cyanobacteria numbers, the best depths for an intake are 30-40 m in the south sub-basin, 40-45 m in the central sub-basin and 45-50 m in the north sub-basin (Larratt, 2009). These results follow the nutrient and turbulence gradients typical in the three sub-basins. Locating intakes deeper than these recommended depths will not provide further protection from cyanobacteria. Depths exceeding 40 m also had a satisfactory temperature regime for most water treatment plants. Intakes located deeper than 40 m would experience a gradually decreasing risk of seiches (temperature fluctuations) with increased depth (Figure 5.1).

When all measured physical, chemical and biological parameters are considered, from many research sources, the advantages of a 47 m intake extension located >3m off the bottom from the current 33 m intake located >3m off the bottom are:

- Reduced seiche impact, transport of surface contaminants
- Maximum temperature deviation during a seiche would be lowered to <1 –3 °C
- Lower overall water temperature
- Lower turbidity, suspended sediments
- Lower transmissivity during fall overturn
- Lower cyanobacterial counts
- Lower algae production Lower total coliforms and possibly pathogens
- A theoretically lower risk of contaminants from land-based activities
- Opportunity to give intake better clearance from substrate (minimum 3 m vertically above substrate)
- Increase the vertical distance between the storm water outfall and the intake
- Smaller Intake Protection Zone that would incorporate less shoreline

..

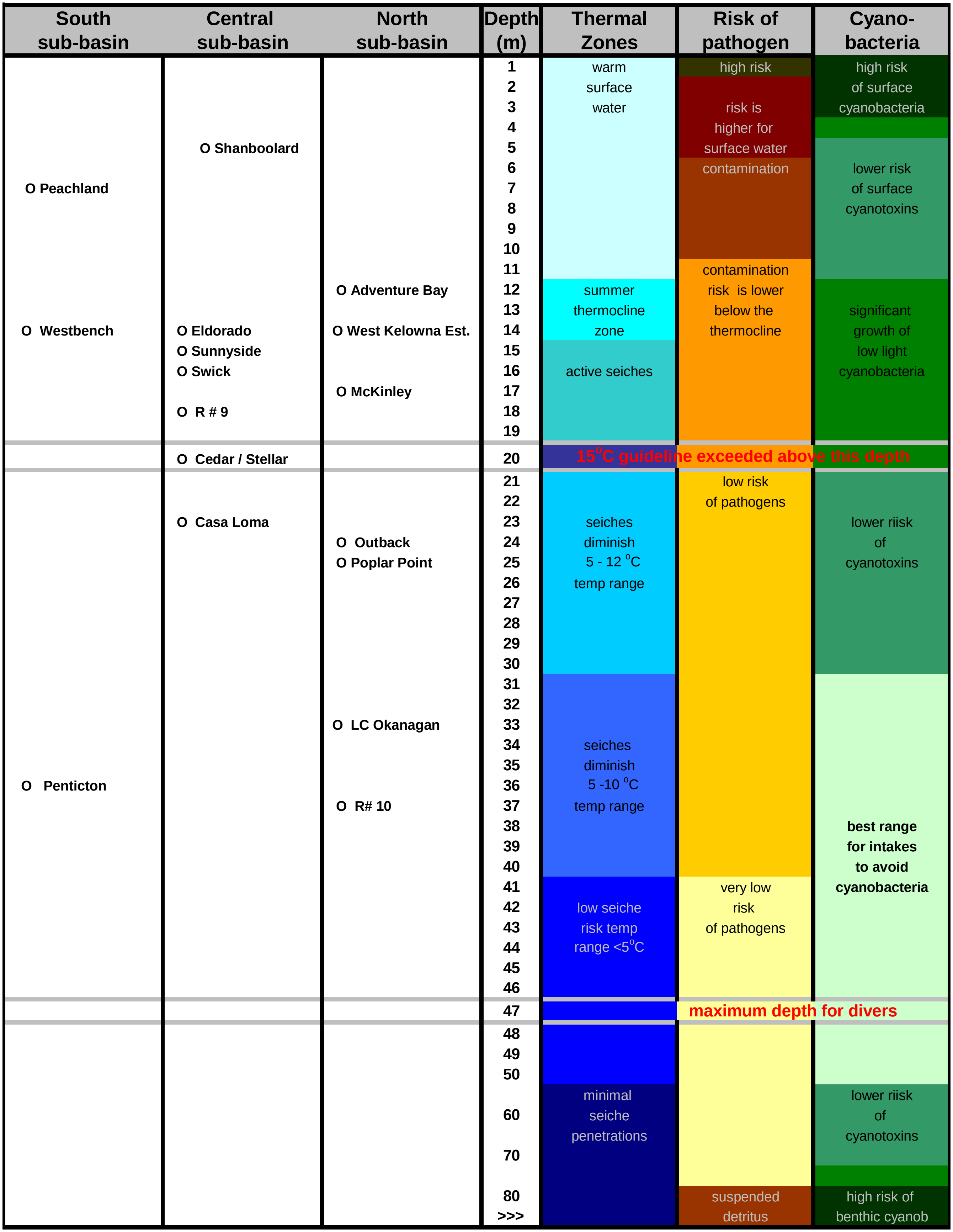
There is a substantial reduction of risk resulting from an increase in the depth of the intakes (Hayco, 2000). The area that can contribute contaminants to an intake shrinks as the intake depth increases and the Intake Protection Zone would also shrink.

5.3.2 Addition of UV Disinfection

The IHA Filtration Deferral document calls for a second method of disinfection in addition to chlorination. UV disinfection would be appropriate because the range of UV transmissivity measured thus far in Okanagan Lake have all been in the acceptable range for UV disinfection. UV-based systems adapt well to small water systems and are cost-effective. The system used by City of Kelowna at Poplar Point could be reviewed for efficiency and costs. UV treatment may also help deactivate cyanotoxins.

Figure 5.1: Overview of Major Okanagan Lake Intakes; their Depth and Influences

The first three columns provide the depths of the intakes by sub-basin
The last three columns demonstrate the approximate change in risk with depth for water temperature, pathogen and cyanobacteria; concerns



South sub-basin	Central sub-basin	North sub-basin	Depth (m)	Thermal Zones	Risk of pathogen	Cyano-bacteria
			1	warm	high risk	high risk
			2	surface		of surface
			3	water	risk is	cyanobacteria
			4		higher for	
	O Shanboolard		5		surface water	
			6		contamination	lower risk
O Peachland			7			of surface
			8			cyanotoxins
			9			
			10			
			11		contamination	
		O Adventure Bay	12	summer	risk is lower	
			13	thermocline	below the	significant
O Westbench	**O Eldorado**	**O West Kelowna Est.**	14	zone	thermocline	growth of
	O Sunnyside		15			low light
	O Swick		16	active seiches		cyanobacteria
		O McKinley	17			
	O R # 9		18			
			19			
	O Cedar / Stellar		20	**15^{o}C guideline exceeded above this depth**		
			21		low risk	
			22		of pathogens	
	O Casa Loma		23	seiches		lower riisk
		O Outback	24	diminish		of
		O Poplar Point	25	5 - 12 ^{o}C		cyanotoxins
			26	temp range		
			27			
			28			
			29			
			30			
			31			
			32			
		O LC Okanagan	33			
			34	seiches		
			35	diminish		
O Penticton			36	5 -10 ^{o}C		
		O R# 10	37	temp range		
			38			**best range**
			39			**for intakes**
			40			**to avoid**
			41		very low	**cyanobacteria**
			42	low seiche	risk	
			43	risk temp	of pathogens	
			44	range <5^{o}C		
			45			
			46			
			47		**maximum depth for divers**	
			48			
			49			
			50			
				minimal		lower riisk
			60	seiche		of
				penetrations		cyanotoxins
			70			
			80		suspended	high risk of
			>>>		detritus	benthic cyanob

COMMENTS: The thermal, pathogen and cyanobacterial risks depicted in this chart are generalized;
every intake is affected by sub-basin and location (proximity to creek plumes, outfalls, storm water etc.)

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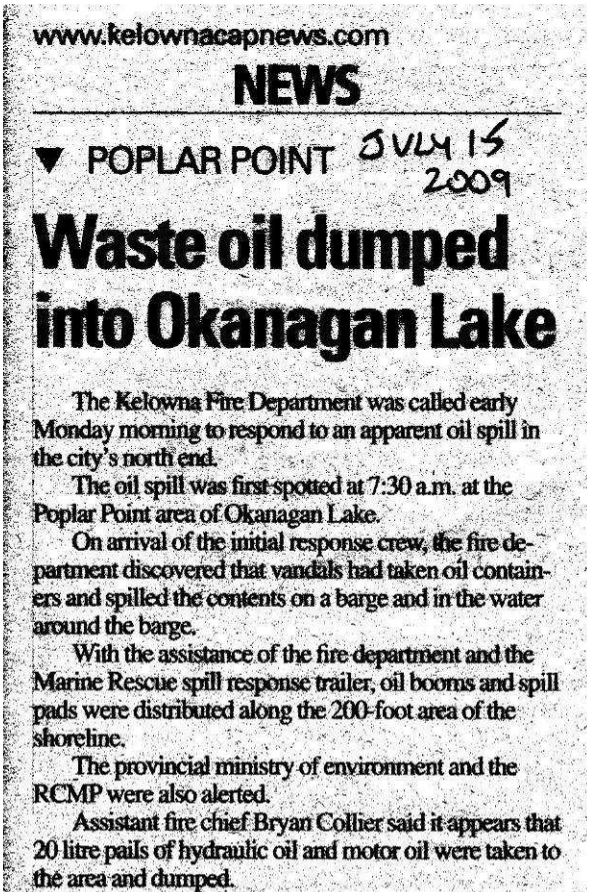
Appendix 1: Supporting Documentation



www.kelownacapnews.com

NEWS

▼ POPLAR POINT JULY 15 2009

Waste oil dumped into Okanagan Lake

The Kelowna Fire Department was called early Monday morning to respond to an apparent oil spill in the city's north end.

The oil spill was first spotted at 7:30 a.m. at the Poplar Point area of Okanagan Lake.

On arrival of the initial response crew, the fire department discovered that vandals had taken oil containers and spilled the contents on a barge and in the water around the barge.

With the assistance of the fire department and the Marine Rescue spill response trailer, oil booms and spill pads were distributed along the 200-foot area of the shoreline.

The provincial ministry of environment and the RCMP were also alerted.

Assistant fire chief Bryan Collier said it appears that 20 litre pails of hydraulic oil and motor oil were taken to the area and dumped.

AUG 15 2009

Sewage leaks into lake

Raw sewage has leaked into Okanagan Lake at the Westbank Yacht Club boat launch on Gellatly Road in West Kelowna.

The leak occurred Friday morning during a downpour. 14th

CORD spokesman Chris Radford said that surface water deluged a manhole, causing it to overflow at 9 a.m. Aug. 14. Runoff into Okanagan Lake continued for approximately 45 minutes. "It was a combination of raw sewage and storm water," said Radford.

As a result the boat launch at Gellatly Bay is closed indefinitely. Water samples from the Gellatly Bay boat launch were being taken Friday. As of press deadline Interior Health and the B.C. Ministry of Environment were working to determine when it would be safe to reopen the launch.

For more information, visit www.districtofwestkelowna.ca.

www.kelownacapnews.com

Wednesday, June 23, 2010 capital news A3

NEWS

▼ KELOWNA

Authorities quick to control gasoline leak into lake

SEAN CONNOR/CAPITAL NEWS

KELOWNA FIREFIGHTERS work Monday afternoon at Kerry Park to contain a gasoline fuel tank leak into Okanagan Lake.

Jennifer Smith
STAFF REPORTER

A gasoline leak from a land-based tank had the City of Kelowna, the fire department and Petro-Canada staff hopping Monday morning as fuel spilled into Okanagan Lake.

It is not known exactly how much gasoline leaked into the water, but city staff say they believe they caught it early and are hoping the damage is minimal.

"We discovered a very small leak, actually in the wall (along the shore)," said Todd Cashin, City of Kelowna's environment division.

To the point where city officials were called in, Cashin said he believes the spill only contained about a water bottle's worth of gasoline, perhaps 200 milliliters; although, all of the details are still under investigation.

The municipality was contacted by concerned citizens who smelled gas in the downtown area at approximately 8 a.m. and city crews were on scene almost immediately.

The Integrated Land Management Bureau, the provincial Ministry of Environment and the federal Ministry of Environment were all contacted as fire crews set up a boom and absorbent pads to contain the spill.

While the exact source of the leak is under investigation, the city could say the spill's source is around a fuel tank used by Kelowna Marina that is buried under Kerry Park. Details on who is responsible for the tank, its maintenance and so forth have yet to be released, though Cashin confirmed the tank itself is a relatively new one.

The site is complicated because it sits on territory once occupied by ferry docks, so the crews working in the area must go slowly to ensure they don't disrupt live infrastructure lines or hit dormant ones once used to service the docks.

A Petro-Can truck was brought in to siphon off the remains of the gas in the tank Monday morning, leaving the tank empty, but crews are still poking around to ascertain whether more fuel leaked into the ground and exactly what caused the leak.

Fire crews used a silly putty-like sealant to damn the leak spilling into the lake upon arrival.

Unfortunately, gasoline, even in small amounts, does diffuse very quickly, meaning a clean up effort will be required.

Kerry Park sits right beside the brand new Stuart Park where the native riparian shoreline is being restored, but the good news Tuesday was that the lake had been entirely protected.

City officials said more information would be forthcoming Wednesday as the exact source of the leak becomes clear.

jsmith@kelownacapnews.com

Fire-Fighting Stormwater Contaminates Mill Creek and City Beach, Kelowna

Fire's toxic chemical trail leaves questions

Aug 4, 2010

Kathy Michaels
CONTRIBUTOR

When fire crews attacked flames overtaking Stewart Centre Saturday night, their focus wasn't on how local waterways would suffer from the toxic mixture of chemicals they unleashed.

Now, as beaches are cordoned off and images of dead fish rising to the top of local streams make the rounds, the environmental impact is front and centre.

"This might be a wake-up call for everyone to step back and look at our procedures and do the things we need to do to protect fish waterways and ensure safe water for wildlife and people," said Patrick Whittingham, vice-president of the Oceola Fish and Games Club.

"That (dead) fish was a canary in the coal mine. We see the fish that have died off, but we don't know enough about the smaller organisms and what impact this will have on them now, and down the road."

Trouble is, as his club co-hort Rick Simpson put it, you're "damned if you do, damned if you don't."

"What were those guys supposed to do, let the whole block burn down?" he said.

According to Jason Brolund, assistant chief of the Kelowna Fire Department, his crews had a good idea about the chemicals they'd be dealing with and their potential hazard, when they headed into the blaze.

"We knew it was going to take water, and that the water would come out contaminated, but the fire department and province at large follows the B.C. emergency response management system," explained.

That set of principles prioritizes the safety of responders first, then the preservation of life, protecting public life, government infrastructure, property, then the environment comes into play.

"The decisions we made that night were tough," he said.

"It was about keeping people safe and fighting the fire—things were flying left, right and centre and we made decisions about protecting exposures on either side… there were 30 to 40 other busineseses that were saved and they could be impacted if we didn't use water to put it out."

With the decision made to deluge flames a call was made to city crews to mitigate the impact of the pesticide, nitrate and glycol mixture that started to trickle into the storm drain system upstream near Lindahl Street, between Springfield Road and Sutherland Avenue.

Their vacuum trucks were on scene, sucking up waste 45 minutes after the first blaze broke.

Unfortunately, they didn't realize they hadn't stopped the flow until the next morning when a resident along Mill Creek noticed the water had changed colour.

Others noticed dead fish on the banks, and as the situation became clear, beaches were closed to swimming.

"In catastrophic situations like that, even the measures the city has in place won't help deal with that volume of water that quickly," said Rick Wagner, environmental emer-

SEAN CONNOR/CAPITAL NEWS

WADING UP to his waist in Mill Creek near the entrance to Okanagan lake, an environmental remediation worker nspects and removes debris from the creek after hazardous chemicals from the Stewart Centre fire on Saturday night vere washed into the creek through the city's drainage system from the water used to douse the blaze.

See Toxic A4

Appendix 2:
Activities Impacting the Intake Protection Zone Checklist

Municipal

- Minimize shoreline clearing for beaches especially with adjacent grassed areas (attracts geese)
- Re-locate storm water outfalls to discharge outside of intake protection zone
- Encourage developers to capture and use storm water on their properties
- Stop or limit the use of fertilizers, pesticides on municipal spaces

Residential Yard Maintenance, Landscaping & Gardening

- Minimize the disturbance of shoreline areas by maintaining natural vegetation cover.
- Minimize high-maintenance grassed areas.
- Replant lakeside grassed areas with native vegetation.

. Do not import fine fill or sand for beaches.

- Use paving stones instead of pavement.
- Stop or limit the use of fertilizers, pesticides.
- Don’t use fertilizers in areas where the potential for water contamination is high, such as sandy soils, steep slopes, or compacted soils.

Agriculture

- Locate confined animal facilities away from water bodies and storm water system. Divert incoming water and treat outgoing effluent from these facilities.
- Construct adequate manure storage facilities.
- Do not spread manure during wet weather, on frozen ground, in low-lying areas prone to flooding, within 3 m of ditches, 5 m of streams, 30 m of wells, or on land where runoff is likely to occur.
- Install barrier fencing to prevent livestock from grazing on stream banks.
- If livestock cross streams, provide graveled or hardened access points.
- Provide alternate watering systems, such as troughs, dugouts, or nose pumps for livestock.
- Maintain or create a buffer zone of vegetation along a stream bank, river or lakeshore and avoid planting crops right up to the edge of a water body.
- Limit the use of fertilizers and pesticides

Onsite Sewage Systems

- Inspect your system yearly, and have the septic tank pumped every 2 to 5 years
- Use phosphate-free soaps and detergents.
- Avoid septic additives and house-hold cleaning chemicals
- Don’t put toxic chemicals (paints, varnishes, thinners, waste oils, photographic solutions, or pesticides) down the drain because they can kill the bacteria at work in your onsite sewage system and can contaminate water bodies.
- Conserve water: run the washing machine and dishwasher only when full and use only low-flow showerheads and toilets.

Auto Maintenance

- Use a drop cloth if you fix problems yourself.
- Recycle used motor oil, antifreeze, and batteries.
- Use phosphate-free biodegradable products to cleanyour car. Wash your car over gravel or grassy areas, but not over sewage systems.

Boating

- Do not throw trash overboard or use lakes or other water bodies as toilets.
- Use biodegradable, phosphate-free cleaners instead of harmful chemicals.
- Conduct major maintenance chores on land.
- Use four stroke engines, which are less polluting than two stroke engines, whenever possible. Use an electric motor where practical.
- Keep motors well maintained and tuned to prevent fuel and lubricant leaks.
- Use absorbent bilge pads to soak up minor oil and fuel leaks or spills.
- Recycle used lubricating oil and left over paints.
- Check for and remove all aquatic plant fragments from boats and trailers before entering or leaving a lake.
- Do not use metal drums in dock construction. They rust, sink and become unwanted debris. Use
polystyrene (completely contained and sealed in UV-treated material) or washed plastic barrel floats.
- When within 150 m of shore adjust your speed accordingly to prevent waves from eroding banks. Adhere to British Columbia’s Universal Shoreline Speed Restriction which limits all power-driven vessels to 10 km/hr within 30 m of shore. Exceptions to this restriction include:• vessels traveling perpendicularly to shore when towing a skier, wakeboard, etc.

-After BC Lake Stewardship Society 2008

Appendix 3: *E. coli* Source Tracking in City of Kelowna Creeks Receiving Storm Water and at Beaches

City of Kelowna Creeks with Storm Water 2006
E. coli Bacterial Source Tracking

Probable Source	Count	Percent
Human	3	13
Canine	6	25
Bovine		0
Horse		0
Song birds		0
Gulls	1	4
Duck	7	29
Canada Goose	1	4
Racoon		0
Deer	4	17
Unknown	2	8
SUM	24	100

City of Kelowna Creeks and Beaches 2006
E. coli Bacterial Source Tracking

Probable Source	Count	Percent
Human	8	8
Canine	15	14
Bovine	1	1
Horse		0
Song birds	14	13
Gulls	18	17
Duck	20	19
Canada Goose	16	15
Racoon	4	4
Deer	5	5
Unknown	4	4
SUM	105	100

City of Kelowna Creeks with Storm Water 2008
E. coli Bacterial Source Tracking

Probable Source	Count	Percent
Human	3	5
Canine	2	3
Bovine	6	9
Horse	2	3
Song birds	14	21
Gulls	5	8
Duck	7	11
Canada Goose	12	18
Racoon	1	1
Deer	6	9
Unknown	8	12
SUM	66	100

City of Kelowna Creeks and Beaches 2008
E. coli Bacterial Source Tracking

Probable Source	Count	Percent
Human	10	5
Canine	13	6
Bovine	21	10
Horse	11	5
Song birds	44	21
Gulls	18	8
Duck	18	8
Canada Goose	26	12
Racoon	6	3
Deer	19	9
Unknown	28	13
SUM	214	100

Courtesy of City of Kelowna, Analyses performed at UVic

-------------End of Report-------------------