Final Report

CITY OF VERNON

Environmental Impact Study

Effluent Discharge to Okanagan Lake

URBAN systems

June 2013 / 1085.0034.01

Suite 200 – 286 St. Paul Street,
Kamloops, BC V2C 6G4

Contact: Dr. Joanne Harkness, R.P.Bio.
T: | 250.374.8311
jharkness@urbansystems.ca

urbansystems.ca

VIA EMAIL

URBAN systems

June 28th, 2013

File: 1085.0034.01

City of Vernon
3400 30th Street
Vernon, BC V1T 6E6

VIA EMAIL: gthompson@vernon.ca

Attention: **Greg Thompson**

RE: FINAL REPORT – ENVIRONMENTAL IMPACT STUDY FOR DISCHARGE TO OKANAGAN LAKE

Please find attached the final report for the environmental impact study to assess the discharge of effluent from the sewage treatment plant to Okanagan Lake. The outcomes of the environmental impact study were presented at the June 11th Liquid Waste Management Plan committee meeting.

Please do not hesitate to contact us, if you have any questions or require further discussion on the environmental impact study.

Sincerely,

URBAN SYSTEMS LTD.

Joanne Harkness

Dr. Joanne Harkness, R.P. Bio.
Water and Wastewater Specialist

Ehren Lee, P.Eng.
Water Consultant/Principal

JH/crg

Encls.

cc: Jeffrey Rice, Urban Systems Ltd.

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EXECUTIVE SUMMARY

The City of Vernon last completed a Liquid Waste Management Plan (LWMP) in 1999 and from the BC Ministry of Environment recommendation, the City is currently undertaking a review of the LWMP. As part of the LWMP review, there is the need to assess the options for effluent release to the environment. Under the current practices, the City's effluent is used for irrigation on surrounding agricultural lands. Through the LWMP review, an environmental impact study is required to evaluate the potential to formalise the lake discharge, which would result in effluent being directed to Okanagan Lake on a more regular basis. The primary aim of the environmental impact study is to assess the discharge of effluent to Okanagan Lake while developing effluent criteria which will protect public health and the environment, with the primary focus being on nutrients and bacteriological indicators.

Dilution analyses were performed to provide an indication of the dilution potential and the factors which will affect mixing between the effluent and lake water. The analyses were completed for combinations of lake conditions, effluent temperatures and discharge rates. The two discharge rates that were analysed were an effluent flow rate of 16,700 m^3/d, which is the 20 year design flow, and 10,160 m^3/d, which assumes the optimisation of irrigation. The dilution ratio at the end of the initial dilution zone (IDZ) was determined to be between 23:1 and 230:1 for an effluent flow rate of 16,700 m^3/d and between 29:1 and 314:1 for an effluent flow rate of 10,160 m^3/d. In all cases, the available dilution is higher than the minimum 10:1 dilution which is indicated in the BC Municipal Wastewater Regulation. Additional dilution is achieved before the plume reaches the closest shoreline, which is approximately 1,300 m away, if the plume moves in the direction of the closest shoreline. The dilution ratio at the shoreline was determined to be between 70:1 and 820:1 for an effluent flow rate of 16,700 m^3/d and between 88:1 and 1,118:1 for an effluent flow rate of 10,160 m^3/d. These dilution ratios are considered to be conservative, as wind-driven mixing was ignored in the analysis. Wind and waves can easily generate more mixing and increased dilution, regardless of the season.

The highest dilution ratios occur during the winter months, as the lake is not stratified which allows a greater potential for mixing to occur between the effluent and lake water. However, due to the lack of stratification, the effluent is likely to move to the surface of the lake. The lowest dilution ratios occur during the summer months, as the effluent is trapped below the thermocline. However, this means that the effluent will not rise to the surface of the lake in the summer months.

Even though it is recognised that the City is under a LWMP, not the BC Municipal Wastewater Regulation, the outfall assessment was based on the conditions of the BC Municipal Wastewater Regulation, as this is the standard legislation in BC with respect to the discharge of sewage effluents. The outfall assessment indicated that the current outfall location generally satisfies the conditions of the MWR, except with respect to effluent rising to the surface. This condition is unavoidable at this location (or any other location within the lake) during the winter when stratification is absent. The current location of the outfall does minimize this condition.

Modelling was completed in order to determine resulting concentrations of effluent parameters at the end of the IDZ and at the closest shoreline. The assessment was completed for effluent flow rates of 16,700 m^3/d and 10,160 m^3/d for both summer and winter effluent discharge conditions. The assessment indicated that, for an effluent which is consistent with the requirements of the operational certificate, as indicated below, it is unlikely that there would be any negative impacts with respect to these parameters:

Carbonaceous 5 day biochemical oxygen demand ($CBOD_5$)	≤ 10 mg/L
Total suspended solids (TSS)	≤ 10 mg/L
Total nitrogen	≤ 6.0 mg/L
Total phosphorus (annual average)	≤ 0.25 mg/L
Faecal coliforms	≤ 50 CFU or MPN/100 mL

For an effluent release during the summer months, when the lake is stratified, there is less dilution potential, but the effluent will be trapped below the surface. The greatest risk for an effluent discharge under these conditions would be to intakes, although greater dilution will have been achieved by the time the plume reaches an intake, in the case that there are any intakes in the direction of the plume and at the same depth as the plume. The risks associated for these intakes relate primarily to the presence of faecal micro-organisms. However, the high disinfection rate achieved further minimises the potential of risk.

For an effluent release during the winter months, when the lake is not stratified, there is a higher dilution potential but the effluent will likely surface due to the lack of stratification. There is little risk to recreational use, due to the time of year. There is also little risk with respect to aesthetics due to the low concentrations of nutrients which are being released, the greater potential for dilution and the low ambient temperatures which will impede the potential for algal growth.

As the condition of the existing outfall and status of diffuser ports (i.e. which ports are functioning) is not known at this time, it is recommended that the City undertake diver inspection of the outfall system. The depth to the tops of the diffusers should also be confirmed during the inspection.

With respect to the reliability category, given the high hydraulic residence time for Okanagan Lake, there is a risk that a process upset will result in impacts as a result of the low flushing rate. If the City is to rely on a lake discharge as the sole means of effluent management, a category I is recommended to further protect Okanagan Lake. If effluent reuse remains a key component of the effluent discharge strategy, a relaxation in the reliability category could be pursued. In this case, there is the opportunity to divert effluent away from the lake to irrigation in the case of a process upset. The available storage in MacKay Reservoir is an alternative to redundancy for a disinfection process and irrigation is not sensitive to BOD_5, TSS and the presence of nutrients. In fact, the presence of nutrients in irrigation water is beneficial for plant growth, although application rates and the need to manage run-off can become of greater importance. Therefore, if the irrigation approach remains a priority, and the operations are balanced appropriately, it is possible that the treatment facility could be reduced to a reliability category III.

Amendments to the monitoring of the effluent have been recommended, and consider the conditions of the current operational certificate, the Municipal Wastewater Regulation, the Federal wastewater regulation and the parameters which were of specific interest through this environmental impact study. The effluent monitoring recommendations are outlined in Table 9.1 of this report. Toxicity testing of the effluent is not being recommended until this becomes a requirement of the Federal wastewater regulation in 2015.

In addition to effluent monitoring, in 2012, the City also provided a financial contribution to the Okanagan Lake monitoring program, which is administered by the BC Ministry of Environment. If the effluent from the City of Vernon is to be discharged to Okanagan Lake, it is recommended that the City continues to provide financial support to this monitoring program, in lieu of undertaking a City directed receiving environment monitoring program. Considerations for the future development of this monitoring program have been made. It is recognised that the development of a monitoring program is complex and there are many factors to be considered, including the parameters, frequencies and sampling timing and depths. It is understood that not all desires can be incorporated into a monitoring program, as the monitoring program must remain both practical and cost effective to implement.

1.0 INTRODUCTION

The City of Vernon last completed a Liquid Waste Management Plan (LWMP) in 1999 and from the BC Ministry of Environment recommendation, the City is currently undertaking a review of the LWMP. As part of the LWMP review, there is the need to assess the options for effluent release to the environment. Under the current practices, the City's effluent is used for irrigation on surrounding agricultural lands. Through the LWMP review, an environmental impact study is required to evaluate the potential to formalise the lake discharge, which would result in effluent being directed to Okanagan Lake on a more regular basis. The primary aim of the environmental impact study is to assess the discharge of effluent to Okanagan Lake while developing effluent criteria which will protect public health and the environment, with the primary focus being on nutrients and bacteriological indicators.

In addition to the BC legislation and policies with respect to effluent and receiving water quality, the implications of the Canada-wide Municipal Wastewater Strategy and the Federal municipal wastewater regulation will also be considered, as these documents were developed to address sewage effluent discharge to surface waters in Canada.

2.0 REGULATORY OVERVIEW

2.1 BC Legislation

2.1.1 Liquid Waste Management Plan

The City of Vernon's first LWMP was completed in 1985 and focused on spray irrigation for effluent release rather than a discharge to Okanagan Lake. The LWMP was further updated in 1995 and completed in 1999. A LWMP is a powerful document which is based on the current legislation. The process involves consultation with all relevant government agencies, members of the public and key interest groups in order to develop a site-specific approach to the management of liquid wastes within a community. Once completed, the LWMP must be signed by both the City and the BC Minister of Environment, resulting in the plan becoming a legal document. The completion of a LWMP results in a document which takes precedence over any existing permit or the BC Municipal Wastewater Regulation (MWR). Although the MWR is the basis for the legislation of sewage in BC and a LWMP must recognize this, the development of a LWMP has the ability to allow for flexibility compared with the requirements of the MWR.

Once complete, a LWMP can be implemented by a community without the need for further consultation or approvals from the BC Ministry of Environment or from members of the community.

2.1.2 BC Ministry of Environment Operational Certificate

Once a LWMP is complete, an operational certificate is developed and issued by the BC Ministry of Environment. Therefore, the City's wastewater treatment and discharge is governed by operational certificate ME-12215, that was last updated on January 14th, 2008.

Under the conditions of the certificate, the maximum month flow for the Vernon Water Reclamation Centre (VWRC) is 27,000 m^3/d. In addition, the operational certificate indicates the volume of effluent which can be discharged from the VWRC to MacKay Reservoir. This volume is listed for each year from 2007 to 2016, with the volume increasing for each year. For the years from 2012 onwards, under the operational certificate, the maximum authorized daily volume of reclaimed water discharged from the VWRC to MacKay Reservoir, averaged on a monthly basis, is:

2012 – 24,900 m^3/d

2013 – 25,700 m^3/d

2014 – 26,500 m^3/d

2015 – 27,300 m^3/d

2016 – 28,100 m^3/d

The effluent can be pumped to MacKay Reservoir for storage before reuse or may be pumped directly from the VWRC to the reuse area. Different effluent quality criteria apply, depending on whether the effluent is stored before use.

In the case where the effluent is stored for a long time in MacKay Reservoir before reuse, the following effluent criteria apply:

5 Day Biochemical Oxygen Demand (BOD_5)	≤ 26 mg/L
Total Suspended Solids (TSS)	≤ 25 mg/L

(The operational certificate does not indicate if the BOD_5 concentration is in the form of total BOD_5, which was the standard criterion at the time of developing the operational certificate, or carbonaceous BOD_5 – $CBOD_5$, which is the current standard for both Federal and Provincial legislation. It is assumed that, as there is no reference to the BOD_5 being in the form of total BOD_5, that there is flexibility within the operational certificate for the BOD_5 to be considered as $CBOD_5$.)

In the case where the effluent is used directly for irrigation from the VWRC, the effluent must be filtered and disinfected (by UV disinfection), and the following effluent criteria apply (Table 2.1), depending on whether the irrigation lands are designated as having “restricted public access” or “unrestricted public access”:

Table 2.1: Effluent Quality Summary – Direct Reuse from the VWRC

Parameter	Effluent Quality Requirements	
	Unrestricted Public Access	**Restricted Public Access**
BOD_5	≤ 10 mg/L	≤ 10 mg/L
TSS	≤ 10 mg/L	≤ 10 mg/L
pH	6-9 pH units	6-9 pH units
Faecal Coliforms	2.2 CFU (or MPN)/100 mL	200 CFU (or MPN)/100 mL
Turbidity	2 NTU	N/A

The reuse of effluent is the main discharge route for the City of Vernon. However, in addition to effluent reuse by irrigation, the City of Vernon is permitted to discharge effluent to Okanagan Lake by the deep lake outfall in the case of an emergency. There are two emergency conditions which are identified in the operational certificate:

- The City is not able to pump effluent to MacKay Reservoir, as a result of an event such as a mechanical failure, power outage or pipeline failure.
- The level of the effluent in MacKay Reservoir increases, so that it exceeds 1,935 feet (589.8 m) above mean sea level and it is projected to rise to 1,939 feet (591 m) above mean sea level prior to the start of the next irrigation season.

The operational certificate governs the flow and effluent conditions for discharge to Okanagan Lake. As quoted from the operational certificate, for flow, the maximum monthly flow is 27,000 m^3/d and, for the years 2012 to 2016, the maximum authorized daily volume, averaged on a monthly basis, is:

2012 – 24,900 m^3/d

2013 – 25,700 m^3/d

2014 – 26,500 m^3/d

2015 – 27,300 m^3/d

2016 – 28,100 m^3/d

In addition, the operational certificate indicates that if the effluent is being directed to Okanagan Lake as a result of issues with the reservoir level, the maximum discharge must not exceed 150% of the volume needed to prevent the reservoir level from exceeding 1,939 feet (591 m) above mean sea level prior to the start of the next irrigation season.

The effluent quality requirements for discharge to Okanagan Lake are summarised in Table 2.2. Under the conditions of the operational certificate, this route of discharge is only intended to be used in an emergency, with the intent being that the City is to make all reasonable efforts to maximise the beneficial reuse of the effluent for irrigation.

Table 2.2: Effluent Quality Summary – Discharge to Okanagan Lake

Parameter	Effluent Criteria
BOD_5	≤ 10 mg/L
TSS	≤ 10 mg/L
Total Phosphorus as P:	
Not to exceed	≤ 2.0 mg/L
99 percentile	≤ 1.5 mg/L
90 percentile	≤ 1.0 mg/L
Annual average	≤ 0.25 mg/L
Level to strive for	≤ 0.01 mg/L
Total Nitrogen	≤ 6.0 mg/L
Faecal Coliforms	≤ 50 CFU or MPN/100 mL

2.1.3 BC Municipal Wastewater Regulation

The Municipal Wastewater Regulation (MWR) is the regulatory framework for management of sewage in British Columbia. The MWR was published in April 2012, and replaced the Municipal Sewage Regulation, which was promulgated in 1999. The MWR indicates the effluent quality standards and discharge requirements for municipal sewage.

Of particular relevance to this environmental impact study, for a lake discharge for effluent flow rates > 50 m^3/d and for a lake with a surface area ≥ 100 hectares, as is the case for Okanagan Lake, the MWR indicates the following effluent criteria:

- Carbonaceous BOD_5 ($CBOD_5$) ≤ 45 mg/L
- TSS ≤ 45 mg/L
- pH range 6-9
- Total phosphorus ≤ 1.0 mg/L
- Orthophosphate ≤ 0.5 mg/L
- Ammonia to be below chronic concentrations at the end of the initial dilution zone
- Faecal coliforms to be ≤ 200/100 mL for recreational waters.

However, Section 97 of the MWR indicates that discharges to the Okanagan Basin require advanced treatment. This section of the MWR indicates that the total annual average phosphorus concentration of the effluent should be ≤ 0.25 mg/L and the total nitrogen concentration should be ≤ 6 mg/L. Given these more stringent criteria, and the effluent quality requirements in the operational certificate, it is also reasonable to assume that there would be a case for requiring more stringent effluent concentrations for $CBOD_5$, TSS and faecal coliforms for a discharge to Okanagan Lake under the MWR.

2.2 Federal Legislation

2.2.1 Canada-wide Municipal Wastewater Strategy

In February 2009, the Canada-wide Municipal Wastewater Strategy was approved by the Canadian Council of the Ministers of the Environment (CCME). This Strategy was the first step in a country-wide approach to sewage, and focused on discharges to surface waters. As a member of the CCME, by signing off on the Strategy, the Province of BC has agreed to implement the Canada-wide Municipal Wastewater Strategy. The direction set by the Strategy will need to be considered in the LWMP process, in the context of discharge to the Okanagan Lake. In addition, the Strategy is the basis of a new Federal wastewater regulation, which was developed by Environment Canada under the Federal Fisheries Act. The new Federal wastewater regulation is discussed further in Section 2.2.2.

2.2.2 Federal Wastewater Regulation

This is a new regulation which was published in July, 2012. The Federal wastewater regulation (the Wastewater Systems Effluent Regulations) applies to any surface water discharges in Canada. There are National Performance Standards which are outlined in the CCME Strategy and will be enforced through the regulation. The Standards are:

- Average $CBOD_5$ ≤ 25 mg/L
- Average TSS ≤ 25 mg/L
- Average total residual chlorine concentration ≤ 0.02 mg/L
- Maximum concentration of un-ionised ammonia to be < 1.25 mg/L

Ammonia can be present in two forms – ionised and un-ionised ammonia. It is the un-ionised form of ammonia which is toxic to fish. The proportion of these two forms of ammonia is dependent on temperature and pH, with the un-ionised form predominating as the pH increases.

The regulation defines the monitoring frequency and time period for calculating the average and maximum values stipulated in the Standards. Both the frequency and the time period are based on the size of the facility, which is determined using the average annual daily flows from the sewage treatment plant. This approach is also consistent with the principles set out in the Canada-wide Municipal Wastewater Strategy. For the City of Vernon, assuming a continuous effluent release, sampling would be required every two weeks, with the period for averaging the concentration being based on data for each quarter.

Although the regulation has been published, the regulatory aspects are to be phased in over the next few years, starting in January 2013 with facility registration and effluent monitoring.

3.0 THE CITY OF VERNON SEWAGE TREATMENT PLANT

3.1 Overview

The sewage treatment plant and effluent discharge consists of the following processes:

- Influent pumping and screening,
- Grit removal,
- Primary clarifiers,
- A modified Johannesburg biological nutrient removal (BNR) treatment process, which includes pre-anoxic, anaerobic, anoxic and aerobic bioreactors,
- Secondary clarifiers,
- Effluent storage in MacKay Reservoir, prior to irrigation. In this case, effluent directly from the clarifiers is pumped to the reservoir with the intent being to allow natural die-off of micro-organisms to occur over the minimum 60 day residence time in the reservoir. The effluent is chlorinated immediately before it is released for irrigation;
- Effluent filtration and UV disinfection in the event that the effluent is used for irrigation without prior storage in MacKay Reservoir; and
- Outfall with diffuser in Okanagan Lake, which is intended to be used in an emergency.

The sludge process train consists of a fermenter, which receives sludge from the primary clarifiers, a dissolved air flotation unit which thickens the waste activated sludge, and centrifuges which are used to dewater the thickened sludge. The dewatered solids are then trucked to the Ogo-Grow site for composting.

The sewage treatment plant serves primarily the City, although the service area extends beyond the City boundary to include some parts of the District of Coldstream. Although the incoming wastewater is mainly domestic in nature, the system also receives industrial wastewater from the Okanagan Springs Brewery, located in the centre of the City of Vernon.

3.2 Sewage Treatment Plant – Flows

The design capacity of the sewage treatment plant is 27,000 m^3/d. The influent flows to the VWRC are summarised in Table 3.1, and include data from 2006 to the end of 2011. For this time period, the average influent flow was approximately 12,500 m^3/d. For this time period, the lowest day flow was measured in December, 2011 (9,852 m^3/d) and the maximum day flow was recorded in June, 2007 (17,335 m^3/d).

Table 3.1: Sewage Treatment Plant Flow Data Summary (2006 to 2011)

Year	Flow (m^3/d)		
	Minimum	**Maximum**	**Average**
2006	11,444	14,985	13,117
2007	10,900	17,335	12,877
2008	11,032	13,792	12,487
2009	10,605	16,997	12,809
2010	10,315	15,480	12,014
2011	9,852	14,670	11,869

Table 3.2 summarizes the release of effluent from MacKay Reservoir for irrigation, for the 2009 to 2011 time period. The data indicate that there is a difference between the volume of effluent which is diverted to MacKay Reservoir, compared with the volume which is used for irrigation. Based on these data, the irrigation rate exceeds the volume of effluent which is being diverted to the reservoir. This discrepancy could be due to the influence of local drainage/run-off to MacKay Reservoir, or could be indicative of an on-going drawdown of the reservoir into the stored effluent. Since 2009, there has been a decrease in the volumes which have been used for irrigation.

Table 3.2: Irrigation Flow Data Summary (2009 to 2011)

Year	Total Annual Irrigation Flow (m^3)	Total Number of Days Irrigating	Average Daily Flow (m^3/d)
2009	5,200,000	156	33,333
2010	4,830,000	184	26,250
2011	4,500,000	162	27,777

Irrigation is the main route for effluent release, with a discharge to the lake only being allowed in an emergency. The last discharge to Okanagan Lake occurred in 1998, for a period of 88 days from (February 22 to May 21). During this time period, approximately 1,000,000 m^3 was discharged (Urban Systems Ltd., 2011), which equates to approximately 11,400 m^3/d.

3.3 Sewage Treatment Plant – Effluent Quality

The current process was designed to operate in three different modes, with the effluent criteria varying depending on the plant operational mode. The three different effluent design criteria were: discharge to land with unrestricted public access, discharge to land with restricted public access and discharge to Okanagan Lake. The effluent design criteria for each operational mode are summarised in Table 3.3 and range from the less stringent criteria required for the discharge to lands designated as having access restrictions to the public through to the need to operate as a BNR facility in order to reduce nitrogen and phosphorus concentrations to very low levels. There are slight differences between the original design criteria and the current operations. The current facility is operated to allow 4 different effluent scenarios: direct discharge from the sewage treatment plant to land designated as restricted access, direct discharge from the sewage treatment plant to land designated as unrestricted access, discharge from the reservoir for application to land and discharge to the lake.

Table 3.3: Effluent Design Criteria

Parameter	Operational Mode		
	Discharge to Land – Unrestricted Public Access	**Discharge to Land – Restricted Public Access**	**Discharge to Okanagan Lake**
BOD_5 (Note 1)	< 10 mg/L	< 45 mg/L	< 10 mg/L
TSS	< 5 mg/L	< 45 mg/L	< 10 mg/L
Total Phosphorus	N/A	N/A	< 0.25 mg/L
Total Nitrogen	N/A	N/A	< 6 mg/L
Faecal Coliforms	< 2.2/100 mL	< 200/100 mL	< 200/100 mL
Level of Treatment	Filtration or 60 days storage	Secondary	Advanced BNR

Note 1: Assumed to be total BOD_5.

Table 3.4 summarizes the average effluent data from 2009 to 2011, using data which were used as the basis of the City's data submission reports to the BC Ministry of Environment. The effluent is sampled at the VWRC before being piped to the MacKay Reservoir, with the sample site being either immediately after the secondary clarifiers or, for samples taken during the irrigation season, immediately after UV disinfection. Therefore, samples taken after UV disinfection will also have passed through the sand filters. The plant is only operated in the full BNR mode, so that if a lake discharge is required, the effluent will be in compliance with the conditions of the operational certificate.

Table 3.4: Effluent Data Summary (2009 to 2011)

Date	Total BOD_5 (mg/L)	TSS (mg/L)	Total Nitrogen (mg/L)	Total Kjeldahl Nitrogen (mg/L)	Organic Nitrogen (mg/L)	Ammonia (mg/L)	Un-ionised Ammonia (mg/L)	Nitrate (mg/L)	Nitrite (mg/L)	Total Phosphorus (mg/L)	Total Dissolved Phosphorus (mg/L)	Orthophosphorus (mg/L)	pH	Total Coliforms (MPN/100 mL)	Faecal Coliforms (MPN/100 mL)
January	<5	3	3.63	1.59	1.48	0.11	0.0010	2.04	0.007	0.25	0.16	0.11	7.28	N/A	N/A
February	<5	4	3.42	1.91	1.82	0.09	0.0003	1.48	0.030	0.26	0.17	0.09	7.31	N/A	N/A
March	8	3	4.46	2.77	1.71	1.06	0.0029	1.62	0.075	0.26	0.16	0.11	7.28	N/A	N/A
April	9	5	4.20	2.27	2.09	0.18	0.0008	1.73	0.205	0.31	0.16	0.14	7.32	N/A	N/A
May	<5	<1	3.34	1.64	1.50	0.14	0.0009	1.67	0.030	0.23	0.20	0.08	7.51	6	<1
June	<5	<1	3.15	1.47	1.44	0.03	0.0004	1.67	0.010	0.21	0.17	0.08	7.73	185	<1
July	<5	2	3.66	1.46	1.40	0.06	0.0011	2.20	<0.005	0.27	0.24	0.10	7.80	32	3
August	<5	<1	2.64	1.09	1.04	0.05	0.0009	1.56	<0.005	0.25	0.21	0.11	7.78	313	15
September	<5	2	2.92	1.35	1.38	0.06	0.0007	1.57	0.010	0.25	0.25	0.08	7.72	14	<1
October	<5	2	2.49	1.36	1.31	0.05	0.0007	1.12	0.007	0.24	0.17	0.13	7.71	7	N/A
November	<5	2	3.33	1.61	1.51	0.10	0.0011	1.73	<0.005	0.25	0.13	0.08	7.59	N/A	N/A
December	<5	3	2.58	1.50	1.43	0.06	0.0007	1.08	<0.005	0.25	0.19	0.08	7.65	N/A	N/A
Minimum	**<5**	**<1**	**2.49**	**1.09**	**1.04**	**0.03**	**0.0003**	**1.08**	**<0.005**	**0.21**	**0.13**	**0.08**	**7.28**	**6**	**<1**
Maximum	**9**	**5**	**4.46**	**2.77**	**2.09**	**1.06**	**0.0029**	**2.20**	**0.205**	**0.31**	**0.25**	**0.14**	**7.80**	**313**	**15**
Average	**6**	**2**	**3.32**	**1.67**	**1.51**	**0.17**	**0.0010**	**1.62**	**0.033**	**0.25**	**0.18**	**0.10**	**7.56**	**95**	**4**
Count	**36**	**36**	**36**	**36**	**35**	**35**	**35**	**36**	**36**	**36**	**35**	**36**	**36**	**16**	**16**

The data in Table 3.4 represent actual values with the exception of organic nitrogen, total nitrogen and un-ionised ammonia, which are calculated values. The concentrations of organic nitrogen and total nitrogen were calculated using the respective measured concentrations of the different forms of nitrogen. Un-ionised ammonia is one of the parameters which will be regulated under the new Federal wastewater regulation, with the effluent concentration having to be < 1.25 mg/L. The concentration of un-ionised ammonia was calculated using the methodology outlined in the Federal wastewater regulation, which uses the measured concentration of total ammonia, the measured pH of the sample and the standard temperature of 15^{o}C. (The standard temperature of 15^{o}C is the temperature at which the LC50 rainbow trout bioassay is undertaken in order to determine acute toxicity.) In cases where the data point was below the analytical detection limit, half of the detection limit was used for the purpose of generating statistics. As expected for a BNR sewage treatment plant, which is the operational mode used as standard by the City of Vernon regardless of whether the effluent is being directed for irrigation or to the lake, the data indicate a high quality of effluent, with low concentrations of BOD_5, TSS, nitrogen (due to nitrification and denitrification) and phosphorus (due to biological phosphorus removal). There are no occasions when the calculated un-ionised ammonia concentration exceeded 1.25 mg/L, which is expected for a BNR facility, due to the high nitrification rates which can be achieved. The data for total and faecal coliforms focused on the summer months only, which is consistent with the reuse of effluent for irrigation. The effluent had been disinfected, hence the low concentrations of faecal coliforms.

3.4 Future Direction for the Vernon Water Reclamation Centre

The current sewage treatment plant has a design capacity of 27,000 m^3/d, although the influent is only in the order of 12,000 m^3/d. Through the LWMP process, the 20 year average annual flow for the community has been estimated at 16,700 m^3/d.

As noted, under the current operations, the facility is operated as a BNR plant, regardless of the route of discharge for the effluent. With the exception of a small amount of effluent which is directed to the Rise Golf Course during the irrigation season, the effluent is pumped up to the MacKay Reservoir on a daily basis, throughout the year. The effluent is stored in the reservoir over the winter months and is used for irrigation during the growing season. Therefore, theoretically, the need for effluent release to Okanagan Lake would be more likely required during the non-irrigation season, due to the effluent demands for irrigation during the warmer months of the year. However, under the current operations, BC Hydro offers the City of Vernon a reduced rate of 50% for their electricity use during winter months. Given the significant costs associated with pumping the effluent from the sewage treatment plant to MacKay Reservoir, from an operational standpoint, it is more cost effective for the City to pump effluent to MacKay Reservoir during the winter versus the summer months. Therefore, this could lead to the scenario where effluent is released to Okanagan Lake during the summer months, allowing the effluent which is stored over the winter period in MacKay Reservoir to be used for irrigation.

For the purposes of this environmental impact study, consideration will be made for effluent discharge to Okanagan Lake throughout the year, for a maximum discharge rate of 16,700 m^3/d, which is consistent with the projected 20 year design flows.

In addition, through the LWMP, one direction which is being discussed is an alternative approach where effluent irrigation is maximised but, until new customers are in place, for a portion of the year, there would be the need to divert excess flows to Okanagan Lake. Under this scenario, the maximum flows which would need to be discharged to the lake would be in the order of 10,160 m^3/d.

4.0 OKANAGAN LAKE

4.1 Background Information

Okanagan Lake is situated in the Okanagan Valley in South Central British Columbia. This area is classified as the Interior Douglas Fir Very Dry Hot Okanagan variant (IDFxh1) biogeoclimatic zone (BC Forest Service, 2012). This zone is characterised by a warm, dry climatic regime with a relatively long growing season and less extreme winter temperatures. Vegetation is dominated by stands of Douglas fir and yellow pine that form open forests, with a sparse understory of birch-leaved spirea, snowberry, pinegrass and bluebunch wheatgrass. The habitat provided in this area is important to bear, deer, rodents and many bird species.

The average daily temperature in the Vernon area ranges from -4.2 to 19.6 ˚C. Annually, Vernon receives approximately 410 mm of precipitation with approximately 308 mm being in the form of rainfall and 103 mm being in the form of snowfall (Environment Canada, 2012).

Okanagan Lake is an important resource to the communities in the Okanagan Basin. The lake has many uses including recreational, fisheries resources and a water source for many different purposes. The importance of this lake has resulted in many studies being completed since the late 1960's, to increase the understanding of the lake so as to assist with developing long-term strategies which help to manage and protect this valuable resource.

Okanagan Lake is a long, deep, oligotrophic (nutrient limited) water body. The lake is the largest of six main interconnected lakes in this basin, which flow from Ellison Lake in the northern part of the valley to Osoyoos Lake in the southern part of the valley. The flow of water into Okanagan Lake is from Kalamalka Lake by Vernon Creek and the outflow is to Skaha Lake by the Okanagan River in the south (Figure 4.1).

Okanagan Lake spans more than 110 km in length and ranges in width from approximately 1 km to 5 km. The lake has a surface area greater than 350 km^2 with a maximum depth of 242 m and a mean depth of 76 m (Habitat Wizard, 2012). Three major population centres are located along Okanagan Lake shores: the City of Vernon at the north end, the City of Kelowna at the mid-point and the City of Penticton at the south end. The lake is comprised of three basins: a north basin which is located by Vernon, a mid-basin which is located in the Kelowna area and a southern basin which is located in the Penticton area. The outfall from the City of Vernon's Water Reclamation Centre is located in the northern part of Okanagan Lake, at the mouth of the Vernon Arm in the main body of Okanagan Lake. The outfall is located at an approximate depth of 60 m midway along the diffuser manifold.

ENVIRONMENTAL IMPACT STUDY

URBAN systems

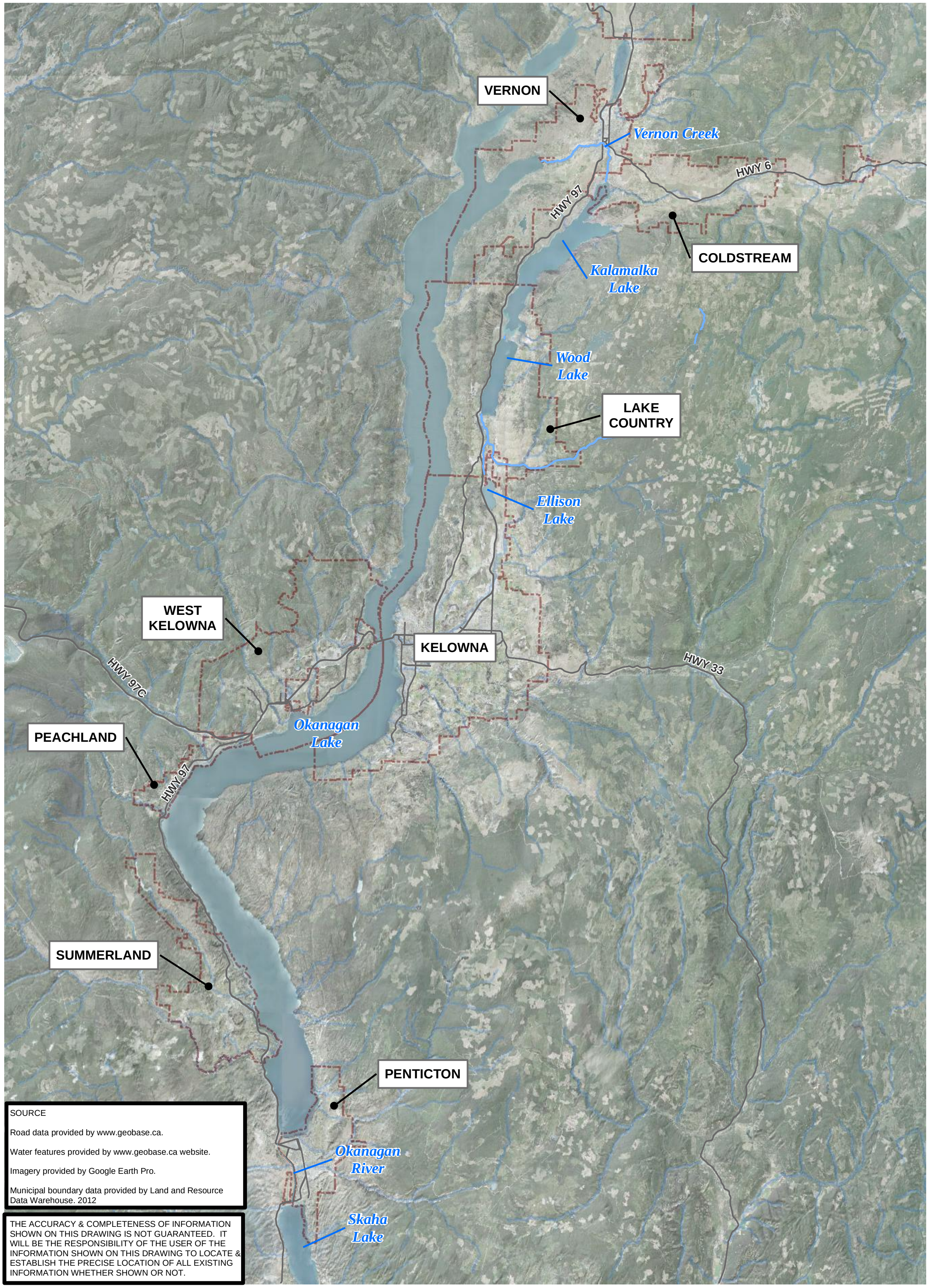
DATE: DECEMBER 2012

CITY OF VERNON

1:450,000

Legend

Municipal Boundary



SOURCE

Road data provided by www.geobase.ca.

Water features provided by www.geobase.ca website.

Imagery provided by Google Earth Pro.

Municipal boundary data provided by Land and Resource Data Warehouse. 2012

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U:\Projects_KEL\1085\0034\01\D-Drafting-Design-Analysis\GIS\Projects\MXD\Current\FIG 4.1.mxd

LOCATION AND KEY FEATURES OF OKANAGAN LAKE

FIGURE

4.1

For the northern part of Okanagan Lake, there are 5 main tributaries. Irish Creek, Deep Creek, Equesis Creek and Naswhito Creek all feed into the Armstrong Arm (Figure 4.2). Vernon Creek is the only main tributary to the Vernon Arm, and contributes approximately 8.6% of the inflow to Okanagan Lake. Vernon Creek is the third largest source of inflow to Okanagan Lake, with Mission Creek in the Kelowna area and Trout Creek, located north of Penticton, being the only single greater inputs to Okanagan Lake (Nordin, 2005).

4.2 Limnology

Okanagan Lake is considered to be a low-nutrient, or oligotrophic, water body with an average depth of about 76 m. With this depth, the lake experiences temperature stratification during the summer period, normally overturning and mixing once a year (monomictic) beginning in the fall. During the summer, a very cold, dense layer of water sits on the bottom of the lake while an upper layer of warm, less dense water sits on top. These water layers are called the *epilimnion* and *hypolimnion*, respectively. A *thermocline*, or region of rapid change in water temperature and density, lies between these two layers, creating a barrier. As a result of this barrier, any effluent that is discharged to the hypolimnion remains in the lower depths of the lake, and the ability of this effluent to rise to the water surface will either be limited or prevented. As the water at the surface of the lake cools in the winter, it becomes more dense and sinks to the bottom, while the water at the bottom of the lake circulates up to the surface. As long as the lake remains ice free, this circulation breaks up the thermocline through the winter until it reforms in the spring, as the surface water again warms up. With the break-up of the thermocline, the temperature and density of the entire water column is approximately the same. As a result, effluent plumes can rise to the surface during the winter months. During those few years when ice forms over the surface of the lake (for the whole lake, this has only occurred three or four times in the last 100 years), the lake becomes dimictic, overturning once in the early summer and again in the late fall, instead of just once.

Due to the sheltered nature of the Vernon Arm, partial freezing of the surface of the water can occur in cold winters, resulting in this part of the lake being dimictic during cold winters but monomictic during warm winters (Nordin, 2005). However, typically, the water in the Vernon Arm stratifies in spring and has strong stratification from June through to October. The water temperature below the thermocline during these conditions will be in the 4 to 6 ^{o}C range. By contrast, the surface water temperatures in the summer are approximately 20 °C in open water and may exceed 25 °C in shallow areas (Nordin, 2005). During the fall, as the water temperature in the Vernon arm decreases, the thermocline deepens and the lake becomes vertically mixed. Due to the lack of thermal stratification in the Vernon Arm throughout the winter, the lake water

URBAN systems

ENVIRONMENTAL IMPACT STUDY

DATE: DECEMBER 2012

CITY OF VERNON

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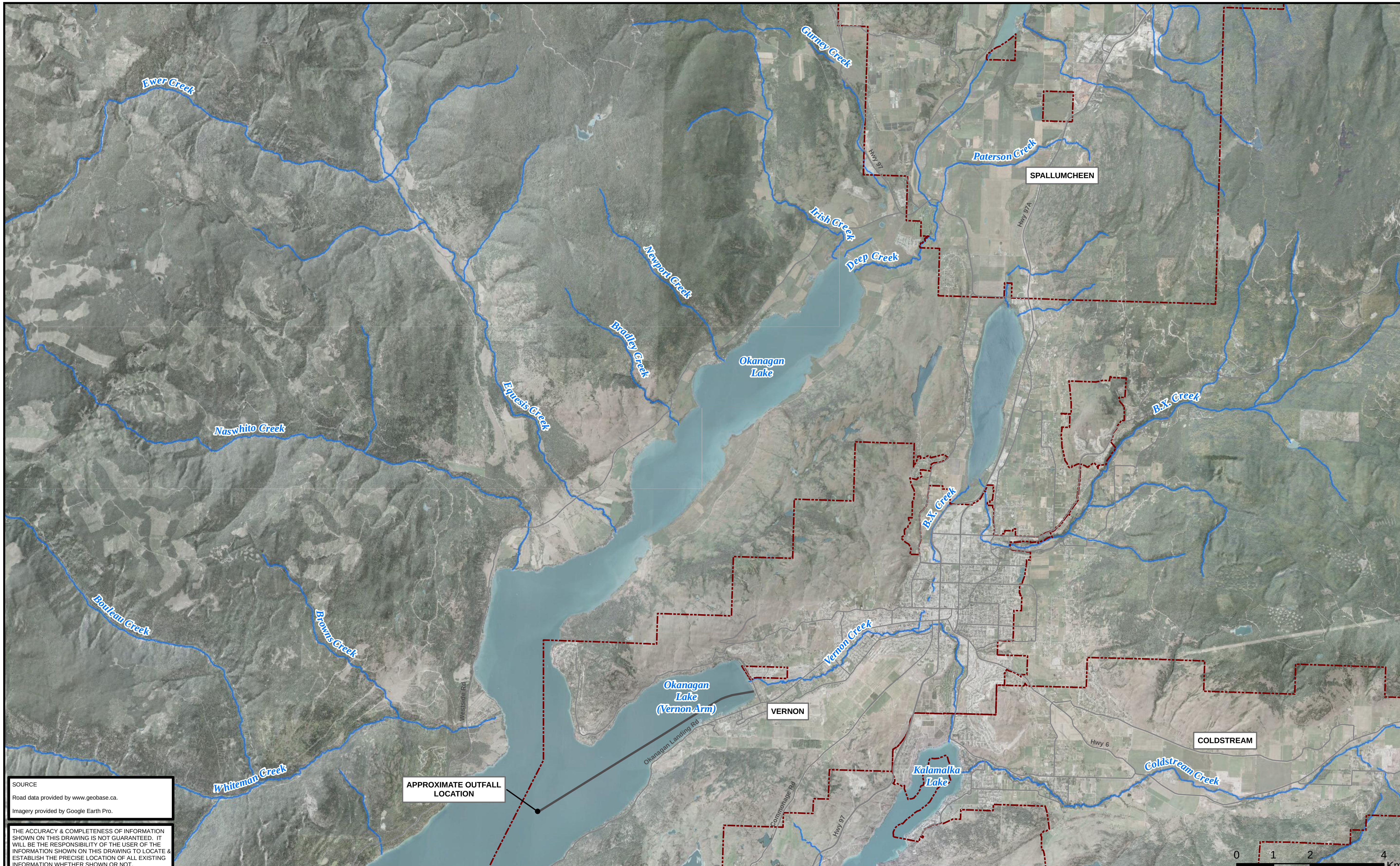

Legend

Municipal Boundary

VERNON ARM AND LOCALIZED TRIBUTARIES AND FEATURES

FIGURE

4.2

mixes (both horizontally and vertically) throughout the winter period. As long as the lake surface is not frozen, during the winter, the temperature over the entire water column will typically be in the 4 to 6 °C range.

The average hydraulic residence time of Okanagan Lake is about 53 years, which means that only about 2% of the lake's volume is discharged at the south-end outlet (at Penticton) each year. Thus, although there are inflows to the lake, and there is an outlet at Penticton, there is no real "flow" within the lake. As a result, average flow through the lake is small compared to its volume, generating essentially no directional flow (i.e. currents) in the lake. Currents within the lake are generated more by weather conditions (winds) than by the general movement of water along a hydraulic gradient. The effects of weather conditions will result in complex current patterns within Okanagan Lake. Due to the orientation of Okanagan Valley, winds tend to blow the length of the lake. These winds, as opposed to water flow, are the main forcing mechanism for lake circulation and hence for mixing. For example, winds will tend to generate surface currents along the lake which then sets up return currents in deeper water. When stratified in the summer, internal seiching (that is, water oscillations at the thermocline) occurs in response to surface disturbance by winds and also induces currents at deeper levels. In any case, complex current patterns are set up in Okanagan Lake due to its size, configuration, hydrology and weather. These current patterns provide both horizontal and vertical mixing within the lake and, thus affect plume dispersion, including at the Vernon outfall site.

Okanagan Lake consists of three basins, each with distinct biological, chemical and physical (hydrologic) conditions. The City of Vernon outfall, which is situated just on the west end of Vernon Arm, is part of the North Okanagan Centre basin. Compared to the entire lake, the Vernon Arm is relatively shallow at less than 30 m deep, however the outfall diffuser is located in about 60 m of water as the lake bottom drops steeply into the main body of the lake, where depths can exceed 120 m. Figure 4.3 shows the lake profile, along with the approximate depth of the City's outfall.

The City of Vernon's outfall extends along the length of Vernon Arm, about 6.5 km, into the deep trench of the main lake. Temperature profiles are available from the BC Ministry of Environment database, with temperature data being recorded to a depth of 50 m in the Vernon Arm. This is approximately 10 m above the location of the City's outfall. Figure 4.4 summarises the plot of temperature profiles at the City of Vernon's outfall based on data from the BC Ministry of Environment. The data indicate that the City's outfall is located well below the thermocline, which is at a depth of 10 to 25 m. At the thermocline, the temperature changes rapidly from the higher temperatures recorded at the surface to a fairly constant 4 to 5 °C year-round temperature. Therefore, seeing as the City of Vernon outfall is located at a depth of approximately 60 m, this will be located below the thermocline when the lake is stratified.

URBAN systems

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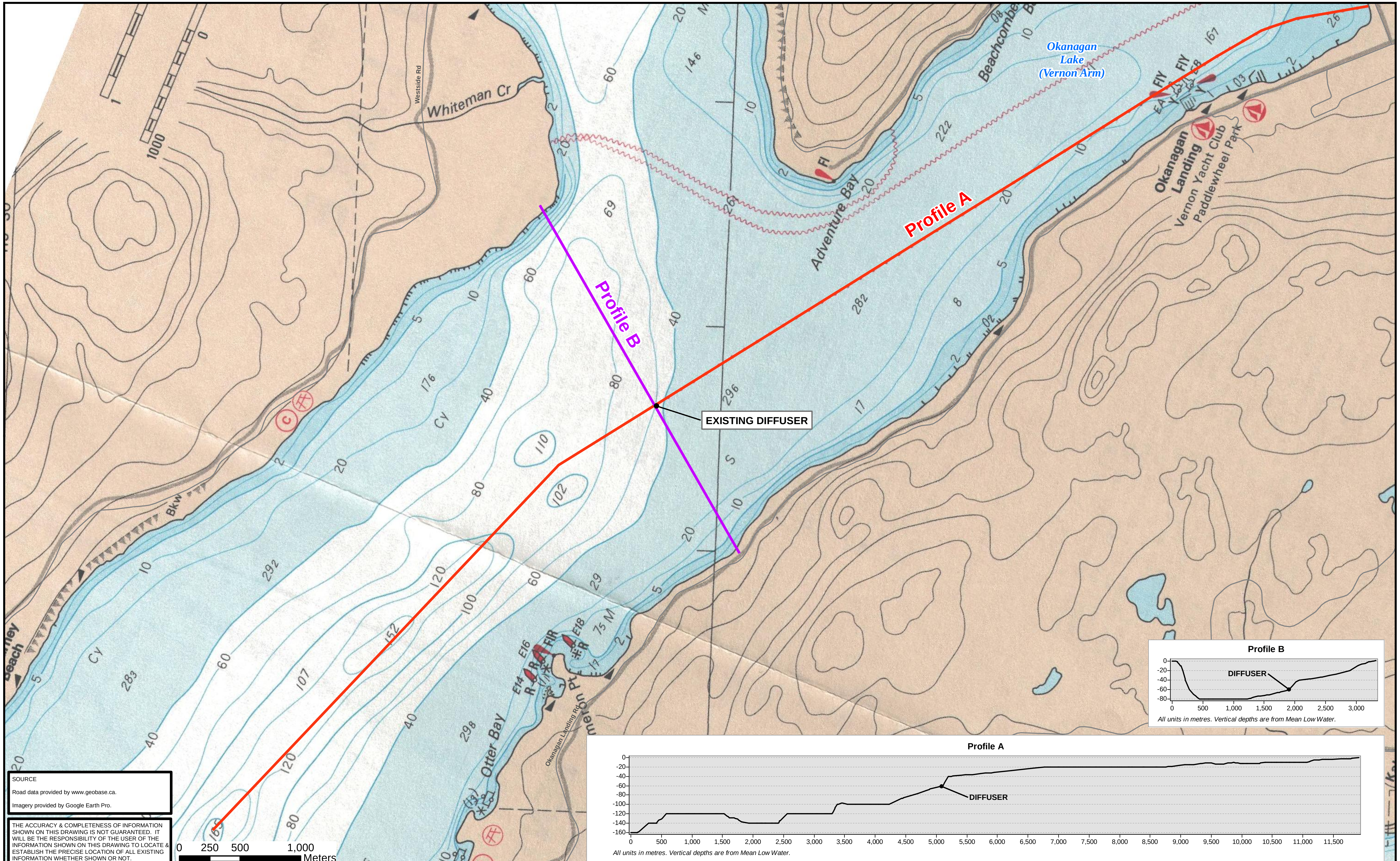
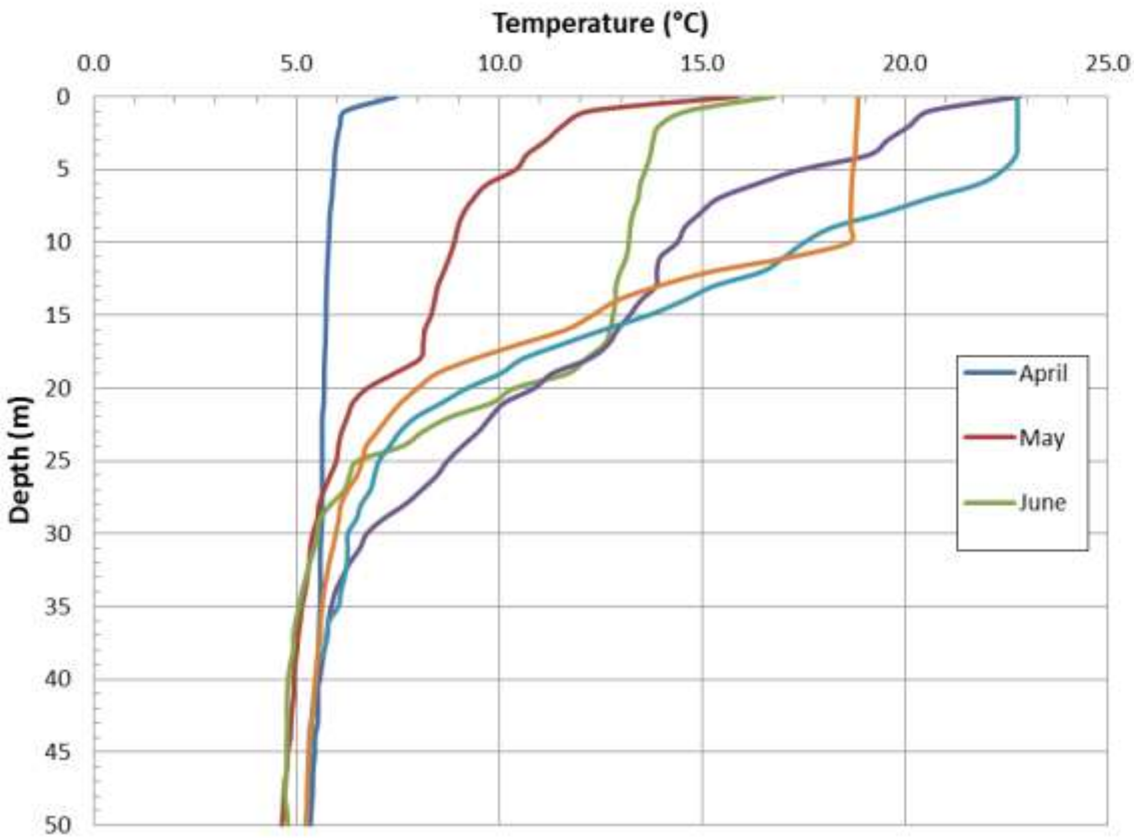


LAKE BOTTOM PROFILES AT VERNON OUTFALL

FIGURE 4.3

Figure 4.4: Temperature Profiles for Okanagan Lake in the Vicinity of the City of Vernon Outfall (2012 Data)



Under stratified conditions, the temperature of the water in the hypolimnion will be in the 4 to 6 ^{o}C range, but the temperature of the effluent as it is released will be higher than this, say in the 18 to 20 ^{o}C range, if not higher. Although there is a temperature difference between the effluent and the lake water, and higher temperature is less dense and will rise, there is little risk that the effluent will break through the thermocline. Given the distance from the outfall to the thermocline, the effluent will be at the ambient water temperature of 4 to 6 ^{o}C, before it reaches the thermocline.

4.3 Water Licences

Water supply is one of the three main uses of Okanagan Lake (Nordin, 2005), and there are over 1,000 water licences for the extraction of water from Okanagan Lake.

With respect to the Vernon area, there are 186 current licences identified on Okanagan Lake within a 5 km radius of the City of Vernon's outfall. Of those licences, the uses are identified as domestic (140), waterworks (19), irrigation (20), enterprise (3), fire protection (2) and land improvement (2). The outfall is located approximately 1.2 km from the closest water licence (C114085). Under water licence C114085, Pechet, E. Howard, *et al*. is permitted to withdraw 2.273 m^3/d of water from Okanagan Lake for domestic use. There are no current water licences within a 1 km radius of the outfall.

Figure 4.5 outlines a 1 km and 5 km radius of the outfall and the water licences which are located in this part of Okanagan Lake.

4.4 Discharges to Okanagan Lake

The MWR indicates that only municipalities are allowed to discharge sewage effluent into the Okanagan Basin. There are 4 authorisations from the BC Ministry of Environment for discharges directly into Okanagan Lake. These authorisations are from the following communities and are summarised in Table 4.1, below.

District of Central Okanagan (RDCO) for the facility located in West Kelowna – authorised under operational certificate 11652, dated 2011.

District of Summerland – authorised under operational certificate 13627, dated 1998.

City of Kelowna – authorised under operational certificate 12211, dated 2013.

City of Vernon – authorised under operational certificate 12215, dated 2008.

The City of Penticton also discharges to Okanagan Lake, but the point of discharge is to the outflow channel which connects Okanagan and Skaha Lakes. As the outflow channel flows from Okanagan Lake to Skaha Lake, no further consideration will be made to this point source release.

In addition to point sources, there are a number of non-point sources of pollution into Okanagan Lake. However, unlike point sources, there are challenges with respect to identifying the inputs through non-point sources. Currently, non-point sources are considered to be the major inputs of pollutants to the lake, and include inputs from urban storm run-off, agricultural activities, past logging operations, past mining activities, poorly maintained and/or located septic tank or tile field systems and dustfall/precipitation (Nordin, 2005).

URBAN systems

ENVIRONMENTAL IMPACT STUDY

DATE: DECEMBER 2012

CITY OF VERNON

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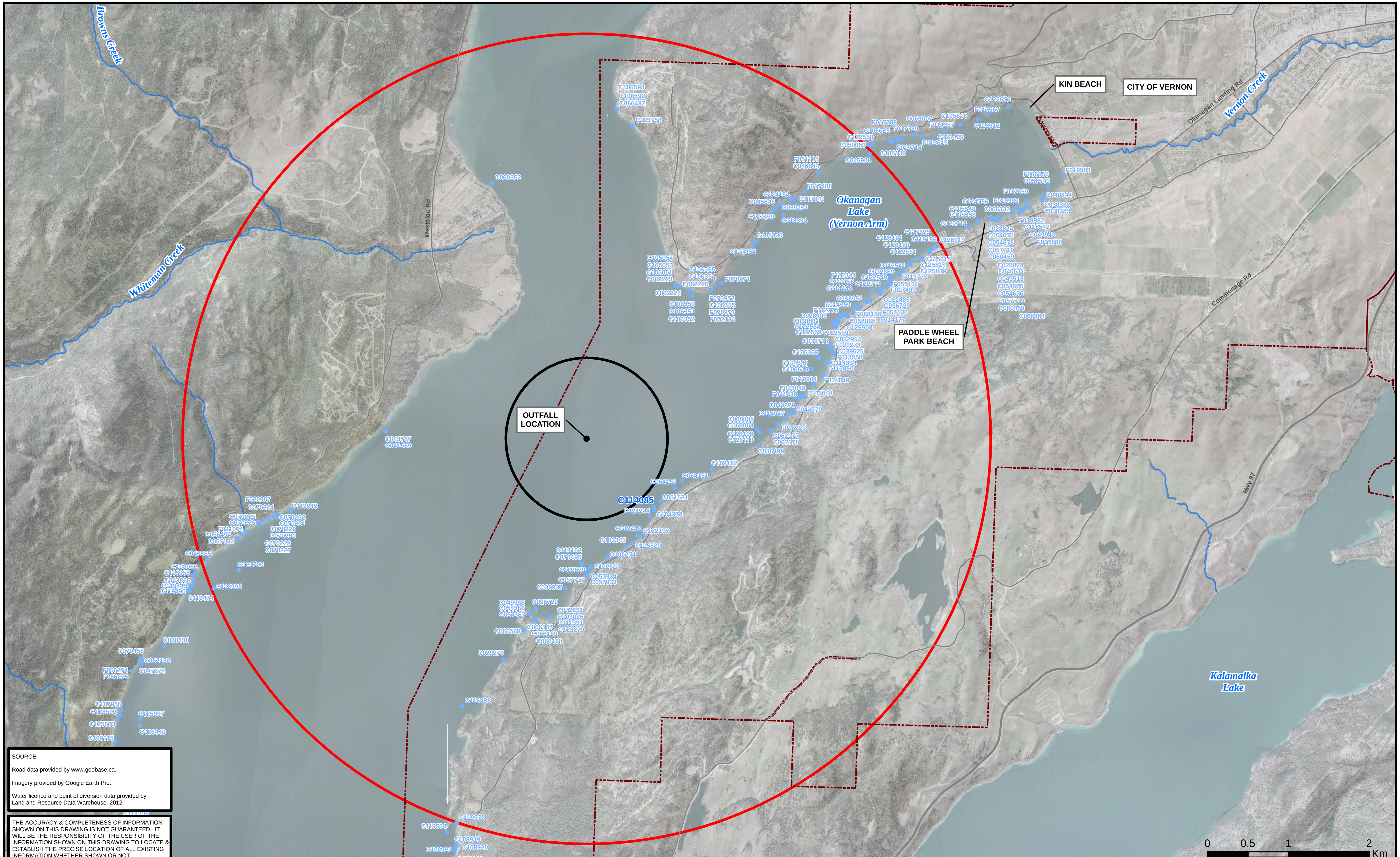

SOURCE

Road data provided by www.geobase.ca.

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Water licence and point of diversion data provided by Land and Resource Data Warehouse. 2012

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Legend

- Municipal Boundary
- Current Water Licence
- 5 Km Outfall Radius
- 1 Km Outfall Radius

WATER LICENCE POINTS OF DIVERSION

FIGURE

4.5

Table 4.1: Summary of Permitted Sewage-Related Discharges to Okanagan Lake

Parameter	Effluent Criteria			
	Vernon	Kelowna	RDCO	Summerland
Maximum Flow (m^3/d)	27,000	50,454	48,000	4,000
BOD_5 (mg/L)	10	10	10	10
TSS (mg/L)	10	10	10	10
Total Phosphorus as P (mg/L):				
Not to exceed	2.0	2.0	2.0	2.0
99 percentile	1.5	-	-	1.5
90 percentile	1.0	-	-	1.0
Annual average	0.25	0.25	0.25	0.25
Level to strive for	0.01	Lake background level	0.01	0.01
Total Nitrogen (mg/L)	6.0	10 (max) 6.0 (av)	10 (max) 6.0 (av)	6.0
Faecal Coliforms (CFU or MPN/100 mL)	50	50	50	50

4.5 Recreational Use

Recreational use is also one of the three main uses of Okanagan Lake (Nordin, 2005), with the main recreational uses being swimming, sunbathing, water skiing, boating, hiking and fishing.

The Vernon Arm of Okanagan Lake is home to more than 25 beaches (Love, 2010). These beaches range in size from very small with minimal access to large, well-used beaches with a variety of amenities. The larger beaches include Paddlewheel Park and Kin Beach. With the number of boat launches and beaches in the Vernon area, the easy access to Okanagan Lake provides the ideal opportunity for the numerous recreational activities supported by the lake.

From the information shown on Figure 4.5, while there are no beaches within a 1 km radius of the outfall, there is shoreline within the 5 km radius of the outfall, and it is likely that beaches can be found within this shoreline area. It is also reasonable to assume that primary contact recreational use (i.e. swimming) will be likely to occur at most of these beaches, but it is also reasonable to assume that there will be some people swimming from the boats within the radii shown on Figure 4.5.

4.6 Fisheries Resources

Aquatic life is one of the three main uses of Okanagan Lake. The fisheries values associated with Okanagan Lake are high, with the lake providing important habitat for a wide variety of fish species. The City of Vernon's outfall is located at the mouth of Vernon arm in the northern portion of Okanagan Lake. This section of the lake is a popular area for angling, especially during the summer months.

The species which are known to be present in the lake, as identified by the BC Ministry of Environment Fisheries Inventory Data Queries website (BC Ministry of Environment, 2012), are summarised in Table 4.2, along with the Provincial and Federal status. The BC Conservation Data Centre listing is an advisory and management tool, and is not a legal designation in the province. The rankings or provincial listing categories describe the species that require special attention. There are three different rankings:

- **Red**: any indigenous species that is extirpated, endangered, or threatened in BC. Extirpated elements no longer exist in the wild in BC, but do occur elsewhere. Endangered elements are facing imminent extirpation or extinction. Threatened elements are likely to become endangered if limiting factors are not reversed.
- **Blue**: any indigenous species considered to be vulnerable in BC. Vulnerable elements are of special concern because of characteristics that make them particularly sensitive to human activities or natural events. Blue-listed elements are at risk, but are not extirpated, endangered or threatened.
- **Yellow**: indigenous species which are not at risk in British Columbia.

On the Federal level, species ranking is conducted by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) established under Section 14 of the *Species at Risk Act* (SARA). COSEWIC is a committee of experts that assesses and designates, under Sections 15 to 21 of the SARA, those wild species of animal, plant or other organisms that are in danger of disappearing from Canada. Below is a listing of the status categories used by COSEWIC to rank or list a species:

- **Extinct**: a species that no longer exists.
- **Extirpated**: a species no longer existing in the wild in Canada, but occurring elsewhere.
- **Endangered**: a species facing imminent extirpation or extinction.

- **Threatened**: a species likely to become endangered if limiting factors are not reversed.
- **Special Concern**: a species that is particularly sensitive to human activities or natural events, but is not an endangered or threatened species.
- **Data Deficient**: a species for which there is inadequate information to make a direct, or indirect, assessment of its risk of extinction.
- **Not At Risk**: a species that has been evaluated and found to be not at risk.

For the fish which are recorded as being present in Okanagan Lake, although some species were identified as being Blue Listed (chiselmouth and cutthroat trout), there were no Red Listed species recorded as being present and no species have been designated a status under the SARA.

Table 4.2: Fish Species Present in Okanagan Lake

Common Name	Scientific Name	Status in BC	SARA Status
Brook trout	*Salvelinus fontinalis*	Exotic	None
Burbot	*Lota lota*	Yellow	None
Carp	*Cyprinus carpio*	Exotic	None
Chiselmouth	*Acrocheilus alutaceus*	Blue	None
Cutthroat trout	*Oncorhynchus larkia*	Blue	None
Kokanee	*Oncorhynchus nerka*	Yellow	None
Lake trout	*Salvelinus namaycush*	Yellow	None
Lake whitefish	*Coregonus clupeaformis*	Yellow	None
Largescale sucker	*Catostomus snyderi*	Yellow	None
Leopard dace	*Rhinichthys falcatus*	Yellow	None
Longnose dace	*Rhinichthys cataractae*	Yellow	None
Longnose sucker	*Catostomus catostomus*	Yellow	None
Mountain whitefish	*Prosopium williamsoni*	Yellow	None
Northern pikeminnow	*Ptychocheilus oregonensis*	Yellow	None
Peamouth	*Mylocheilus caurinus*	Yellow	None
Prickly sculpin	*Cottus asper*	Yellow	None
Pumpkinseed	*Lepomis gibbosus*	Exotic	None
Pygmy whitefish	*Prosopium coulterii*	Yellow	None
Rainbow trout	*Oncorhynchus mykiss*	Yellow	None
Redside shiner	*Richardsonius balteatus*	Yellow	None

Table 4.2: Fish Species Present in Okanagan Lake (continued…)

Common Name	Scientific Name	Status in BC	SARA Status
Slimy sculpin	*Cottus cognatus*	Yellow	None
Yellow perch	*Perca flavescens*	Unknown	None

The history of the fisheries resource of Okanagan Lake goes back to the initial settlers and native peoples for food sources. A commercial fishery is also recorded to have existed as early as the 1920's. A number of studies on the fisheries resources for Okanagan Lake have been conducted, dating back to the 1930's , when Clemens *et al.* concluded that very little data were available on the population of kokanee, with the primary concern being the low fish productivity (Clemens *et al.*, 1939, as quoted by Nordin, 2005)

Additional data were gathered for the 1971 Okanagan Basin Study and indicated that 15 species of fish were reported to be present in Okanagan Lake (Nordin, 2005). Later studies indicated the introduction of carp in 1971, lake trout in 1971 and lake whitefish in 1994. The stocking of non-indigenous fish species began as early as 1984 when 1,500,000 lake whitefish were stocked in Okanagan and Kalamalka Lakes (Nordin, 2005).

The Okanagan Lake Water Quality Objectives report (Nordin, 2005) identified kokanee as being the most valued species in Okanagan Lake, especially with respect to sport fishing. The kokanee populations have fluctuated in the past with the most recent decline in the late 1980's. The 1980's decline was thought to be caused by many factors such as loss of historical spawning habitat (both stream and lake), direct competition for food with other fish species/*Mysis* shrimp and low water levels.

A fisheries assessment was completed by Urban Systems Ltd. and Chara Consulting on August 16th, 2012, in order to assess the fisheries values in the area close to the City of Vernon's outfall. During the fisheries assessment, a visual site assessment of the known kokanee shoreline spawning habitat was observed, in addition to discussions regarding the known fisheries resources in the Armstrong Arm and the immediate area surrounding the outfall. To the east of the outfall location, excellent kokanee shore spawning habitat exists, as characterised by the angular substrate, low algae and vegetation presence (Figure 4.6) along with frequent westerly winds, which occur in this immediate area.

Figure 4.6: View of Preferred Kokanee Spawning Habitat along the East Shore of Vernon Arm

High densities of lake-rearing kokanee aged 0+ and 1+ years are present within the Vernon Arm. Results from past kokanee and *Mysis* surveys indicate the presence of kokanee in the Vernon Arm in the general location of the outfall (Chara Consulting, 2012). Hydro-acoustic and trawl net fish surveys have been conducted on Okanagan Lake for each fall (September/October) since 1988, with the focus being to monitor the kokanee population in Okanagan Lake. A summary is presented by Sebastian *et al.* (2006) in the Okanagan Lake Action Plan Year 10 Report. During the fall period, the lake is still stratified, with the thermocline being at the approximate depth of 15 m (Rae and Wilson, 2006). The annual studies conducted by Sebastian *et al.* (2006) for depths from 5 to 50 m. Most fish were found to be present at the 10 to 35 m depths. Below the thermocline, the majority of fish that were found were kokanee, although a limited number of lake whitefish, pygmy whitefish, pike minnow and sculpins were also present. With respect to the kokanee population, fry were the most common age group found near to the thermocline, with the older fish being evenly distributed through the range of depths.

During the first phase of the studies which were conducted as part of the Okanagan Lake Action Plan (starting from 1996), the data indicated that there was a decline in the kokanee population. This decline was considered to be due to the reduced spawning habitat and reduced in-lake survival rates, potentially related to an imbalance in the concentrations of the nutrients: nitrogen and phosphorus. However, the data from 2000 through to 2005 indicated that there has been a significant increase in the kokanee population over this time. The reason for this increase in the kokanee population was not clear, as it appears to be contrary to the data from the limnological studies which were also completed as part of the Okanagan Lake Action Plan for this time period. The main limitations to the kokanee population in Okanagan Lake are indicated to be a function of food quality and the potential for heavy predation. The greatest vulnerabilities lie with the fish aged 2+ years, as these fish have the greatest energy requirements (Sebastian *et al*., 2006).

The Okanagan Lake Action Plan (OLAP) has now completed a decade of investigations into reasons why there was such a precipitous decline in kokanee during the 1970's through the 1990's. In the later years of this study, the focus was on understanding the nitrogen to phosphorus (N:P) imbalance, but the studies have included research into a number of different technical areas including limnology, water quality and fisheries studies. With respect to the N:P imbalance, the OLAP indicated that the lake appears to be primarily nitrogen limited during the growing season. In addition, the report indicates that for the last nine years, the N:P ratio is out of balance for the growth of algae which are preferred by macrozooplanktors that are in turn preferred as a food source by kokanee. The report indicates that there has been a considerable decrease in nutrient concentrations, which have in turn resulted in extremely low algal production. The phytoplankton "collapse" is believed to have occurred due to chronic nutrient depletion of both nitrogen and phosphorus. The report indicates that, despite the 2005 kokanee escapements being the highest in two decades, the numbers of kokanee in Okanagan Lake are still far below the levels recorded in the 1970's and early 1980's (Andrusak *et al.*, 2006)

For mountain whitefish, even though little is known of their populations and eating habits, the shoreline east of the outfall is also known to provide important spawning habitat for this species in late November (Chara Consulting, 2012). It is likely that a high number of adult rainbow trout and burbot use the general area of the Vernon Arm for feeding, based on the high concentrations of an important food source (kokanee). In addition, higher than normal densities of northern pike minnow are likely to exist, with predation of kokanee occurring (Chara Consulting, 2012).

Very few fish are found in the deeper parts of Okanagan Lake. Data from the annual hydro-acoustic and trawl net fish surveys indicate that, at the deepest trawl depths of 50 m, the density of fish is approximately 1/hectare (Sebastian *et al.*, 2006). At these depths, light and food will be limited, which will not encourage the presence of fish. The City of Vernon outfall is located at an approximate depth of 60 m, which is deeper than the hydro-acoustic and trawl net fish surveys. If fish are present at these depths in the immediate vicinity of the outfall location, the numbers are likely to be limited, and the species are more likely to be burbot and lake trout, rather than kokanee. However, although food sources may be limited at such depths in the lake, it is possible that any release from the outfall could result in a localised nutrient supply which may attract fish at these depths.

4.7 Water Quality

4.7.1 Overview

Okanagan Lake is described as having relatively low biological productivity (oligotrophic). However, the two shallower areas of Okanagan Lake (i.e. Vernon Arm and Armstrong Arm) have poorer water circulation resulting in higher nutrient levels and greater plankton abundance (Nordin, 2005).

Water quality objectives have been developed for Okanagan Lake by the BC Ministry of Environment. The first water quality objectives report was published in 1985, with an update published in 2005.

Water quality objectives are developed to provide direction on water quality where designated water uses may be threatened and aim to protect the most sensitive designated water use at a specific location. The water quality objectives are developed in order to consider the following generic water uses:

- Raw drinking water, public water supply and food processing;
- Aquatic life and wildlife;
- Agriculture (livestock watering and irrigation);
- Recreation and aesthetics; and
- Industrial water supplies.

The multiple demands on Okanagan Lake provide a good example of the need to balance the various water uses and the point and non-point source discharges for this water source. As is consistent with the intent of developing water quality objectives, the water quality objectives for Okanagan Lake were set to protect the most sensitive water use from deterioration.

The most recent water quality objectives report (Nordin, 2005) is an update and expansion of the 1985 document produced by the BC Ministry of Environment. With respect to assigning water quality objectives, Okanagan Lake was separated into four divisions (north basin, south basin, central basin and Armstrong Arm). The City of Vernon and the outfall is located within the north basin. The parameters of particular focus for Okanagan Lake are identified as being Secchi disk (water clarity), dissolved oxygen, total nitrogen, total phosphorus, nitrogen to phosphorus (N:P) ratio, chlorophyll *a*, phytoplankton, zooplankton, trace contaminants in biota and bacterial indicators. The water quality objectives are summarised in Table 4.3, with further comments on these parameters as a water quality objective outlined below:

- Secchi disk: The Secchi disk is a simple way to measure water clarity and provides guidance with respect to determining the trophic status (through identifying if the water is cloudy due to the presence of phytoplankton – i.e. algae). A water quality objective is proposed for all four divisions of the lake, and is based on the long-term seasonal averages while taking into account the inter-annual variation due to inflow to the lake. (There tends to be a reduction in water clarity in wetter years, due to the increase in nutrient loading to the lake as a result of increased flows to the lake.) For the Vernon area, the intent of the objective is to protect the water clarity from deteriorating from its current level, with the primary focus being to protect recreational and drinking water uses.
- Dissolved oxygen (DO): The water quality objective applies to the Armstrong Arm only, as data from this area indicate concerns with respect to depletion of DO in the deeper waters. There are no concerns with respect to the DO concentration in the north basin, where the City and outfall are located.
- Total phosphorus: Important water uses for Okanagan Lake are aquatic life, recreation and drinking water. However, lower concentrations of phosphorus are required in order to preserve water quality for drinking water and recreational uses. Increases in phosphorus concentrations can result in an increase in biological activity, which will increase water cloudiness. Fisheries resources need nutrients, and higher concentrations of phosphorus can result in increased productivity and fisheries resources. Phosphorus was the only water quality objective indicated in the 1985 report, and the objective for the Vernon area has been amended from the proposed 12 µg/L in the 1985 report to 8 µg/L, based on a year with average inflow although this may need to be amended during years when there is a high volume of inflow. Phosphorus objectives have been set for all four divisions, but may be amended further, depending on influences from nutrient ratios (e.g. N:P).
- Total nitrogen: Nitrogen concentrations will also influence algal growth, with nitrate being the form of nitrogen which is the most readily used by phytoplankton. Data indicate that there has been an increase in the nitrate concentrations during the spring, with the trend being more apparent in the southern basin, rather than the Vernon area. The concentrations are expected to decrease through the summer as a result of uptake by phytoplankton, however, there are concerns that the low concentrations of nitrate could result in an imbalance in the nutrients which could allow cyanobacteria to grow. Objectives

for nitrogen have been set for all four divisions of the lake, with the focus being a total nitrogen concentration of < 230 µg/L.

- N:P ratio: The ratio of these two important nutrients can influence the algal species which will grow and dominate a surface water, although it is also recognised that there are a range of other factors such as light, temperature, pH, etc. which also will affect the algal speciation. For Okanagan Lake, the TN:TP ratio is currently in the order of 28:1 and appears to not encourage the proliferation of cyanobacteria, the presence of which can result in concerns with respect to recreational use (mainly swimming), drinking water sources and the enhancement of fisheries resources. A proposed water quality objective for the N:P ratio of > 25:1 is proposed to help protect these three water uses for Okanagan Lake.
- Chlorophyll *a*: This is used as a measurement to determine the amount of phytoplankton (algae) which are present. While algal growth can result in benefits with respect to fisheries resources, concerns with respect to recreational water use, water intakes and aesthetics all apply. Objectives have been proposed for all four divisions of the lake, including the Vernon area, and focus on the phytoplankton growth in the upper depths of the lake (the epilimnion).
- Phytoplankton: Phytoplankton (both in terms of quantity and community composition) are commonly used as an indicator for environmental quality and ecological conditions. For Okanagan Lake, the relatively consistent phytoplankton community structure is desirable for both drinking water and fisheries uses. As such, a water quality objective has been set for all four divisions of the lake in order to maintain the current balance which is found in the lake.
- Zooplankton: As with phytoplankton, zooplankton can also be used as environmental indicators. A healthy population of zooplankton can increase productivity and the associated fisheries resources. A zooplankton objective was proposed for all four divisions of the lake, with the inclusion that there should be no significant change in dominant species.
- Tissue contaminants: The use of tissue contaminants was raised as a water quality guideline due to the potential for a wide range of contaminants to have accumulated in the lake sediments over the years. Some of these contaminants could have the potential to become incorporated into the food chain, and fish from Okanagan Lake are used for human consumption. As a result, a water quality guideline has been set for all four divisions of the lake. The primary focus for tissue contaminants in Okanagan Lake includes mercury, dioxins and furans, DDT and the metabolites of DDT, PCBs and miscellaneous agricultural chemicals.

- Bacteriological indicators: This objective focuses on the need to protect drinking water intakes and beaches used for bathing and, as such, the objective varies, depending on the water use for the area.

Other parameters that were considered with respect to water quality objectives were dissolved ions (total dissolved solids, conductivity and chloride) and periphyton. In the future, a recommendation may be made to include these parameters as a water quality objective for Okanagan Lake.

Table 4.3: Summary of the 2005 Proposed Water Quality Objectives – Okanagan Lake

Parameter	Proposed Water Quality Objective			
	North Basin	**Central Basin**	**South Basin**	**Armstrong Arm**
Secchi Disk Transparency (m) (growing season average)	6		7	5
Dissolved Oxygen	No objective set			Minimum of 5 mg/L in bottom waters
Total Phosphorus (µg/L) (maximum at spring overturn)	8		7	10
Total Nitrogen (µg/L) (maximum)	230			
N:P ratio (spring weight ratio)	> 25:1			
Chlorophyll-a (µg/L) (maximum seasonal average)	4.5		4	5
Phytoplankton Structure (heterocystous cyanobacteria by numbers)	< 5%			
Phytoplankton (growing season average biomass)	< 0.75 g/m^3			
Zooplankton (designated species mix minimum biomass)	50 µg/m^3			

Table 4.3: Summary of the 2005 Proposed Water Quality Objectives – Okanagan Lake
(continued . . .)

Parameter	Proposed Water Quality Objective			
	North Basin	**Central Basin**	**South Basin**	**Armstrong Arm**
Zooplankton Structure (minimum of cladocera by numbers)	5%			
Contaminants in Fish Tissue and *Mysis* Tissue	Below human consumption and wildlife protection guidelines			
Bacteriological Indicators	Dependent on localised water use: For areas close to drinking water intakes: faecal coliforms < 10 counts/100 mL; *E. coli* < 1 count/100 mL. For recreational areas: faecal coliforms ≤ 200 counts/100 mL; *E. coli* ≤ 77 count/100 mL, both as a geometric mean of 5 samples taken over a 30 day period.			

4.7.1 Monitoring Data Summary

The water quality and biology of Okanagan Lake have been much studied over the years. In addition, the update to the water quality objectives for the lake resulted in further monitoring recommendations. A number of sites are currently monitored under a range of existing programs, and the City of Vernon has recently started to contribute financially to the BC Ministry of Environment's monitoring programs, in the aim of increasing the understanding of lake characteristics in the Vernon area.

There are data available from the BC Ministry of Environment monitoring program in the vicinity of the City of Vernon outfall. In 2012, sampling events took place once a month for the time period April through to September. Samples were collected at two depths; surface (1 to 10 m deep) and 20 to 45 m deep. The samples were sent to Maxxam Analytics in Burnaby for analysis. In the field, samples were analysed for conductivity, dissolved oxygen and temperature. The water quality data are summarised in the following sections, the primary focus being the relationship to the water quality objectives (where applicable) for the North Basin, although the BC Water Quality Guidelines for the protection of aquatic life are also considered, if appropriate.

4.7.2 Nutrients - Nitrogen

The data for the nitrogen parameters are shown in Table 4.4. The data represent measured values, with the exception of total Kjeldahl nitrogen (TKN), which was calculated by the laboratory. For the north basin of Okanagan Lake, there are water quality objectives for total nitrogen, but there are no water quality objectives for TKN, organic nitrogen, ammonia, nitrate, and nitrite. However, there are BC water quality guidelines for ammonia, nitrate and nitrite.

Table 4.4: Nitrogen Water Quality Data Summary

Parameter	Concentration (mg/L)					
	April 17	May 15	June 12	July 17	August 14	September 17
Depth 1 to 10 m						
Total Nitrogen	0.228	0.197	0.369	0.274	0.294	0.222
TKN	0.197	0.192	0.367	0.274	0.294	0.222
Total Organic Nitrogen	0.179	0.176	0.354	0.247	0.294	0.222
Total Ammonia	0.0180	0.0160	0.0130	0.0270	<0.0050	<0.0050
Nitrate + Nitrite	0.0310	0.0049	0.0023	<0.0020	<0.0020	<0.0020
Depth 20 to 45 m						
Total Nitrogen	0.218	0.254	0.240	0.235	0.213	0.236
TKN	0.180	0.220	0.206	0.176	0.158	0.179
Total Organic Nitrogen	0.173	0.179	0.164	0.156	0.153	0.179
Total Ammonia	0.0069	0.0400	0.0420	0.0200	0.0052	<0.0050
Nitrate + Nitrite	0.0376	0.0346	0.0340	0.0590	0.0542	0.0573

The proposed water quality objective for total nitrogen in the north basin is 0.230 mg/L (230 µg/L). Three of the 1 to 10 m deep samples (months of June, July and August) and four (May, June, July and September) of the 20 to 45 m deep samples exceeded the objective. However, the objective is intended to focus on conditions at the spring overturn, which typically occurs in the February to March window (Rae and Wilson, 2006). All the 2012 samples were taken after the spring overturn. However, data relating to the month of April were also included in the Water Quality Objectives report, with respect to conditions at the spring overturn (Nordin, 2005). Using this approach, during the April event, the total nitrogen concentration at both depths was in line with the water quality objectives.

For ammonia, the BC Water Quality Guidelines focus on the protection of aquatic life and relate to both a maximum (acute) concentration and an average (chronic) concentration, which is intended to be based on 5 data points taken over a 30 day period. For each ammonia data point, the maximum and average ammonia concentration is identified using tables in the BC Water Quality Guidelines which correlate the ammonia concentration to the measured pH and temperature at the time of sampling. For each sampling event, the temperature and pH were measured at depth intervals of 1 m from the surface of the lake through to a depth of 50 m. Taking the maximum temperature and pH for each of the two depth ranges for each month, the corresponding guideline ammonia concentration was identified for both the acute and chronic conditions. The data are summarised in Table 4.5. The tables in the BC Water Quality Guidelines only provide ammonia concentrations up to a maximum temperature of 20 ^{o}C and a pH of 9.0. Some of the values recorded during the monitoring events exceed these conditions. Therefore, the resulting guideline ammonia concentration has been referred to as “less than” the closest tabled value for conditions when either the temperature exceeded 20 ^{o}C or the pH exceeded 9.0. In all cases, the recorded concentrations of ammonia from the monitoring events were below the acute and chronic guideline values. (Note that in the case for chronic conditions, the BC Water Quality Guidelines refer to an average of 5 data points taken over a 30 day period, not a single monthly sample, as is the case for the Okanagan Lake data.) Of interest are the pH data recorded for the lower depths for the month of June. The pH decreased through the depth profile from approximately pH 8.6 at a depth of 1 m through to approximately pH 6.8 at a depth of 50 m. The lowest pH for the whole data set was 6.57, recorded at an approximate depth of 30 m. This trend was not observed for any of the other months.

Table 4.5: Summary of Data Relating to Ammonia Water Quality Guidelines

Parameter	Date					
	April	May	June	July	August	September
Depth 1 to 10 m						
Maximum Temperature (^{o}C)	7.46	15.88	16.77	22.83	22.77	18.84
Maximum pH	8.20	9.24	8.58	9.05	8.58	8.83
Measured Ammonia Concentration (mg/L)	0.0180	0.0160	0.0130	0.0270	< 0.0050	< 0.0050
Acute Guideline Ammonia Concentration (mg/L)	3.83	< 0.711	1.55	< 0.752	< 1.57	1.06
Chronic Guideline Ammonia Concentration (mg/L)	0.736	< 0.128	0.259	< 0.102	< 0.213	0.154

Table 4.5: Summary of Data Relating to Ammonia Water Quality Guidelines *(continued…)*

Parameter	Date					
	April	May	June	July	August	September
Depth 20 to 45 m						
Maximum Temperature (^{o}C)	5.63	5.98	6.50	8.72	7.03	6.62
Maximum pH	7.88	8.02	8.23	8.41	6.76	8.08
Measured Ammonia Concentration (mg/L)	0.0069	0.0400	0.0420	0.0200	0.0052	< 0.0050
Acute Guideline Ammonia Concentration (mg/L)	7.25	6.08	3.83	2.41	23.6	4.80
Chronic Guideline Ammonia Concentration (mg/L)	1.39	1.17	0.736	0.464	1.90	0.922

For nitrate, there are guidelines for a range of water uses: drinking water, aquatic life, livestock watering, wildlife and recreation/aesthetics. The most stringent guidelines relate to drinking water and recreation/aesthetics, both for a maximum concentration of 10 mg/L. In addition, the chronic guidelines for the protection of aquatic life indicate a concentration of 3 mg/L, which is intended to be a 30 day average consisting of 5 samples, rather than a single monthly sample. The data from the sampling events relate to combined nitrate/nitrite, but indicate that the concentrations were below any of the guideline values. For the 1 to 10 m depth, the data were below the analytical detection limit (0.002 mg/L) for the months of July, August and September.

For nitrite, there are guidelines for a range of water uses: drinking water, aquatic life, livestock watering, wildlife and recreation/aesthetics. The most stringent guidelines relate to the protection of aquatic life indicate a maximum concentration of 0.06 mg/L and an average concentration of 0.02 mg/L, based on a 30 day average (rather than a single monthly sample) and is dependent on the chloride concentration. The data from the sampling events relate to combined nitrate/nitrite, and there are no chloride data available. However, given the concentrations recorded during the monthly monitoring events, there is a high confidence that the concentrations of nitrite would be below the guidelines for the protection of aquatic life.

4.7.3 Nutrients - Phosphorus

The data for the phosphorus parameters are shown in Table 4.6. For the north basin of Okanagan Lake, there are water quality objectives for total phosphorus, but there are no water quality objectives for dissolved phosphate or orthophosphate. In addition, there are also no BC water quality guidelines for either of these two parameters.

The proposed water quality objective for total phosphorus in the north basin is 0.008 mg/L (8 µg/L). There was only one occasion when the objective was exceeded: May for the 1 to 10 m deep sample. However, the objective is intended to focus on conditions at the spring overturn, which typically occurs in the February to March window (Rae and Wilson, 2006). All the 2012 samples were taken after the spring overturn. However, data relating to the month of April were also included in the Water Quality Objectives report, with respect to conditions at the spring overturn (Nordin, 2005). Using this approach, during the April event, the total phosphorus concentration for both sample depths was below with the water quality objectives.

For the dissolved phosphorus data, there was one occasion (June 1 to 10 m depth) when the concentration was below the analytical detection limit (0.002 mg/L) and for orthophosphate, there were three occasions (July and August for the 1 to 10 m depth; July for the 20 to 45 m depth) when the concentrations were below the analytical detection limit (0.001 mg/L).

Table 4.6: Phosphorus Water Quality Data Summary

Parameter	Concentration (mg/L)					
	April 17	May 15	June 12	July 17	Aug 14	Sept 17
Depth 1 to 10 m						
Total Phosphorus	0.0066	0.0104	0.0055	0.0056	0.0059	0.0048
Dissolved Phosphorus	0.0049	0.0031	<0.0020	0.0029	0.0036	0.0030
Orthophosphate	0.0017	0.0019	0.0013	<0.0010	<0.0010	0.0023
Depth 20 to 45 m						
Total Phosphorus	0.0066	0.0065	0.0056	0.0041	0.0058	0.0042
Dissolved Phosphorus	0.0057	0.0022	0.0023	0.0027	0.0042	0.0028
Orthophosphate	0.0012	0.0022	0.0036	<0.0010	0.0015	0.0016

The concentration of total phosphorus can also be used to provide an indication of the trophic status of a body of water. The definition of oligotrophic (nutrient limited) is when the total phosphorus concentration is between 0.004 and 0.010 mg/L. Above this concentration range, a surface water would be classified as mesotrophic and below this concentration range, a surface would be classified as ultra-oligotrophic (CCME, 2011). Based on these definitions, the north basin of Okanagan Lake would be classified as oligotrophic, with the exception of the May data point from the 1 to 10 m depth, which is just higher than the oligotrophic range.

4.7.4 N:P Ratio

The ratio of nitrogen to phosphorus (N:P) provides an indication of the nutrient limitation within a system, and is one of the water quality objectives for the north basin (TN:TP > 25:1 based on the spring weight ratio). The TN:TP ratios for the 6 monitoring events are shown in Table 4.7. The data indicate that the TN:TP ratio ranged from 19:1 to 67:1 for the 1 to 10 m depth and from 33:1 to 57:1 for the 20 to 45 m depth. There was one occasion when the TN:TP was below 25:1. This was for the 1 to 10 m depth in the month of May, and was a factor of the unusually high total phosphorus concentration. The intent of the water quality objective for the TN:TP ratio is that this parameter would apply to the spring overturn. For Okanagan Lake, the spring overturn occurs in the February to March time period (Nordin, 2005), however, data relating to the month of April were also included in the Water Quality Objectives report, with respect to conditions at the spring overturn. Using this approach, during the April event, the TN:TP ratio was in line with the water quality objectives.

Table 4.7: Total Nitrogen to Total Phosphorus Ratio – 2012 Data Set

Sample Date	TN:TP	
	1 to 10 m	20 to 45 m
April 17th	35:1	33:1
May 15th	19:1	39:1
June 12th	67:1	43:1
July 17th	49:1	57:1
August 14th	50:1	37:1
September 17th	46:1	56:1

4.7.5 Secchi Disk Readings

Table 4.8 summarises the Secchi disk readings taken over the 2012 monitoring period. The proposed water quality objective for the Secchi reading is a depth of 6 m as an average over the growing season. There were two occasions when the Secchi depth was below 6 m (May and July), however, assuming that the growing season is from April to September, the average Secchi depth over this period was 6.1 m, which met the proposed objective for the north basin of Okanagan Lake.

Table 4.8: Summary of Secchi Disk Reading – 2012 Data

Sample Date	Secchi Depth (m)
April 17th	7.8
May 15th	3.3
June 12th	6.2
July 17th	4.6
August 14th	7.6
September 17th	6.9
Average	**6.1**

4.7.6 Phytoplankton

The water quality objective for chlorophyll *a* for the north basin of Okanagan Lake is 4.5 µg/L as a maximum seasonal average, with the value representing the growing season average for the epilimnion. There were 6 sampling events for chlorophyll *a* in 2012, with two samples being taken for each month from the epilimnion. The data are summarised in Table 4.9, with half the detection limit being used to calculate the average concentrations. As the concentration of chlorophyll *a* for all samples was below the proposed objective of 4.5 µg/L, the resulting seasonal average was below the objective concentration for this parameter. The average chlorophyll a concentration for the growing season was 1.47 µg/L.

Table 4.9: Summary of Chlorophyll *a* Concentrations (2012)

Sample Date	Chlorophyll *a* Concentration (µg/L)		
	Sample 1	Sample 2	Average
April 17th	1.28	1.67	1.48
May 15th	1.42	2.23	1.83
June 12th	1.74	2.18	1.96
July 17th	1.34	1.68	1.51
August 14th	0.96	1.61	1.29
September 17th	1.22	<0.50	0.74

At the time of developing this report, there were no data available on the species of algae present over the 2012 monitoring. Therefore, no comments can be made with respect to the objective criterion and the presence of cyanobacteria.

4.7.7 Zooplankton

Zooplankton are an important part of the aquatic ecosystem, and are one of the keys to a healthy population structure. Within the food chain, zooplankton graze on micro-algae and, in turn, act as a food source for many species of fish. If there is an inadequate or unsuitable population of micro-algae, e.g. through a cyanobacterial bloom, the numbers of zooplankton will decrease, resulting in less food available for the higher aquatic organisms. In conditions where excessive phytoplankton growth can occur, zooplankton are considered to be key in the management of these blooms through top-down control grazing. The reverse is also considered to be true – if there are low numbers of zooplankton, there are concerns that phytoplankton blooms could occur. The type of zooplankton is also important, as some species are preferred as a food source within the food chain to other species. Therefore, high numbers of zooplankton may not be sufficient to result in a flourishing population of fish. As a result, over the years, zooplankton populations have been included in the many studies on Okanagan Lake, in order to increase understanding on the role of this part of the food chain in maintaining a healthy ecosystem. Zooplankton have also been included as one of the proposed water quality objectives, with the objective including not only the mass of these types of organisms but also the types which are present.

The importance of zooplankton within the food chain was discussed as part of the OLAP 10 year report. Stockner (2002) indicated that an imbalance between nitrogen and phosphorus could result in concerns with respect to zooplankton populations, through the potential for the N:P ratio to influence the micro-algal population, with a low N:P ratio increasing the risk of growth of cyanobacteria, which are not a suitable food source for zooplankton. Within the zooplankton population, a high proportion of cladocera was also considered to be important, as this is important for fish production.

The Okanagan Lake water quality objectives report (Nordin, 2005) identifies that sampling for zooplankton dates back as early as the mid 1930's. Sampling for zooplankton was included in the early/mid 1970's as part of the Okanagan Basin Study which was being undertaken at that time. The early data have been used to form the basis of our understanding of the zooplankton community in Okanagan Lake, and have been used as the point reference for subsequent sampling. Using the earlier data, Pinsent and Stockner (1974) identified 13 species of zooplankton in Okanagan Lake, with 89% of these zooplankton being found in the top 50 m of lake water. The zooplankton numbers were observed to increase by a factor of 3 to 5, when comparing the 1935 data to the 1969-70 data. This increase was considered to be a factor of the increased nutrient loading to the lake over this time period.

There is a good set of data available for zooplankton populations in Okanagan Lake, as the data have been collected twice annually (spring and fall) on a continuous basis from 1979 through to 1994. With respect to the settled volume, there appears to be little change in the zooplankton biomass during this time period (Nordin, 2005). A comparison of zooplankton density by McEachern (1998) indicates that there has been an increase in the density of the zooplankton population from the 1971 through to 1998. For the data from the Vernon Arm, the average seasonal (May to October) biomass of cladocern and copepod zooplankton during the period 1999 to 2001 was 61 µg/L, which was close to the data for the whole lake (65 µg/L). However, more recent data indicates that there has been a decrease in the zooplankton density of the main lake since 1998 (Nordin, 2005). Sampling for zooplankton was completed in 2012 for the Vernon area, but the data were not available at the time of developing this report.

4.7.8 Additional Objective Criteria

There are also objective criteria for contaminants in fish and *Mysis* tissues, and bacteriological indicators, defined as faecal coliforms and *E. coli*. There were no data available from the 2012 monitoring period for either of these criteria. Therefore, no comments can be made with respect to the status of these criteria and the proposed water quality objectives for the north basin of Okanagan Lake.

4.8 Discussion on Factors Influencing the Water Quality of the North Basin

4.8.1 Influences from Sewage Treatment Plants

There are four points of discharge from sewage treatment plants to Okanagan Lake, with the discharge from the City of Vernon only operating in the case of an emergency. One of the key goals for the management of Okanagan Lake was to reduce the phosphorus inputs to the lake in order to protect the water quality, as phosphorus was identified as one of the major influences on the algal growth and water clarity – two aspects of water quality which are easy to distinguish visually. Sewage treatment plants were the primary consideration for this approach, as the discharges from a sewage treatment plant are relatively easy to manage and control, compared with non-point sources of inputs to the lake, although inputs through industry and agriculture were also considered. The ultimate goal was to reduce the phosphorus inputs to Okanagan Lake by 90%, compared with the inputs which were occurring in the early 1970's (Nordin, 2005).

From the studies which were completed in the late 1960's, municipal sewage effluents were identified as being the major point sources of phosphorus to Okanagan Lake. At this time, the City of Vernon was also contributing to the phosphorus inputs to the Vernon Arm, as the point of discharge was to Vernon Creek. In 1977, the City of Vernon ceased discharge to the creek and diverted the effluent to spray irrigation. Table 4.10 summarises the reduction in phosphorus loadings to the lake over time, based on the information presented by Nordin (2005) and the BC Ministry of Environment (date unknown).

Table 4.10: Summary of Reduction in Phosphorus Loadings by Point Sources

Year	Estimated Phosphorus Loading (tonnes/year)
1970	44
1980	15
1990	5
1994	2.6
2001	2.1
2003	2.3

With the data from the more recent years, the decrease in the phosphorus loading appears to have stabilised, indicating that there is likely little more that can be achieved through the management of sewage treatment plant effluents. In addition, information from the Nordin report (2005) indicates that the decrease in the phosphorus loading from the point sources may have been off-set by similar increases from non-point source inputs.

Of interest is the discussion on the potential differences between effluent entering the lake overland versus entry directly into a deep part of the lake. Earlier information indicated that there was the potential for over-irrigation to occur, in the aim of ensuring that there was no requirement for a lake discharge. Irrigating at rates which are higher than the soil capacities will result in the production of run-off, and effluent was observed to be flowing overland, surfacing and entering ditches (Forty, 1995, as quoted by Nordin, 2005). Given the rate of the run-off, it was considered likely that some of the phosphorus from the effluent would be reaching the lake. As a result, further consideration was given to compare an effluent input to the lake via run-off versus an input through an outfall located deep in Okanagan Lake, in this case at 60 m which is the approximate depth at which the City's outfall is located. Inputs through run-off will be entering the lake at the edge, where the water depth is shallow. As a result, there will be a direct contribution to the biological activity in the surface and shoreline waters, which could cause increased growth in the attached algae and plants located in these shallow shoreline areas. Such growth will result in impacts to aesthetics, recreational use, intakes either through fouling or tainting of water, and aquatic habitat for spawning and rearing. These impacts would not necessarily occur for a deep lake discharge, especially if the effluent is trapped below the thermocline.

Further discussion in Nordin (2005) indicates that the influences of a periodic discharge from the City of Vernon appear to have a relatively minor influence on the phosphorus concentrations in the open water of Okanagan Lake. This is based on the data collected in 1998, when an effluent discharge to the lake was required. The report indicates that the discharge of a tertiary treated effluent at a depth of 60 m near the confluence of Vernon Arm and the main body of Okanagan Lake would likely not have a measurable effluent on the water quality of Vernon Arm. It was considered that the wet weather and loading from Kalamalka Lake and the non-point sources will have a greater ability to influence the phosphorus concentrations in the Vernon Arm (Nordin, 2005).

Although the primary focus has been nutrient inputs to Okanagan Lake, sewage effluents can also contribute a range of other substances. In more recent years, there has been an increased awareness of the presence of endocrine disrupting substances and personal care products as a result of sewage effluents being discharged to surface waters. This is discussed further in Section 5.

4.8.2 Influences from Vernon Creek

As Vernon Creek is the main tributary to the Okanagan Lake in the Vernon area, and given the low flow characteristics of Okanagan Lake, it is possible that there could be influences from the creek which could result in impacts to the water quality of Okanagan Lake. Water quality objectives have been developed for Vernon Creek (Swain, 1993), in recognition of the salmonid species which are present in Lower Vernon Creek. The water quality objectives which were developed also recognised other creek uses, not just aquatic life. These uses were indicated to be: drinking water sources, primary contact recreation, irrigation, livestock water and wildlife. The direction for the development of the water quality objectives for the creek focus on the creek uses, not the potential for impacts to Okanagan Lake.

At the time of developing the water quality objectives report, both point source and non-point source pollution was identified for Lower Vernon Creek. An evaluation of the available water quality data indicated that there were periodic elevated concentrations of aluminium, iron, lead and phosphorus, with periodic depressions in the dissolved oxygen concentration. Water quality objectives were set for the following parameters: faecal micro-organisms (faecal coliforms, *E. coli*, *Enterococci*), suspended solids/turbidity, ammonia, nitrate, nitrite, chlorophyll *a* and dissolved oxygen.

4.8.3 Influences from Recreational Activities

Beach activities are one of the main uses of Okanagan Lake, and with the economic benefits from tourism, such activities are encouraged and will continue to be encouraged in the future. Inputs to the lake through beach activities are hard to evaluate, and could range in nature including substances such as faecal micro-organisms, nutrients, etc. from many different sources, e.g. animal faeces (from geese, dogs, etc.), and oils etc. from skin products, lotions and sunblock. It is also possible that the contributions from these sources may be low, compared to the inputs and the lake volume. However, localised areas may be affected more significantly from these inputs due to the very nature of bathing areas: high bather usage, shallow water leading to higher water temperatures, and embayment of the area.

5.0 ENDOCRINE DISRUPTING SUBSTANCES

5.1 Introduction to Endocrine Disrupting Substances

In the mid-1990's, concerns were first raised regarding the impact of certain substances on the normal functioning of endocrine (hormone) systems. These substances have been termed endocrine disrupting substances. The endocrine system consists of complex mechanisms which are responsible for the co-ordination and regulation of the internal communication among cells. Endocrine systems release hormones which act as chemical messengers, interacting with cells to control normal biological functions such as growth, embryonic development and reproduction. These processes are complex, and much still needs to be understood with respect to the interference of endocrine disrupting substances on the endocrine system. Examples of endocrine-related problems include:

- Exposure to industrial chemicals and certain insecticides has been associated with deformities and embryo mortality in birds and fish;
- Effluents from pulp and paper mills have impaired the reproduction and development in fish;
- Exposure to anti-fouling substances used in the ship industry has resulted in abnormal reproduction in snails; and,
- Reports have indicated a higher incidence of fish feminisation near municipal effluent outlets.

It is thought that the principal cause of feminised responses in wild fish populations worldwide is related to the presence of endocrine disrupting substances in sewage effluents (Filby *et al*., 2010).

It is understandable that with the wide variety of sources and substances which are potentially able to disrupt the endocrine system, and the low concentrations which may be present, the subject of endocrine disrupting substances is a challenge to environmental managers in industry and government worldwide. As such, there is a global aspect to the whole subject of endocrine disrupting substances, their impact and the development of management criteria.

5.2 Background to Endocrine Disrupting Substances Related to Sewage

The subject of endocrine disrupting substances has been researched in some depth, although there are still many questions which need to be answered. There have been many research projects on the potential effects to the endocrine system as a result of sewage and sewage effluents, including research to help understand the fate of endocrine disrupting substances as they pass through a sewage treatment plant. The subject of endocrine disrupting substances has reached a high profile in the public domain, but this can also lead to confusion and misunderstandings, due to the technical and complex nature of this subject.

It is important to understand how the issue of endocrine disrupting substances first came to be recognised. This was through research undertaken in the UK on fish populations located downstream of effluent releases indicating that the male fish were becoming feminised. In all cases, these observations were made on rivers that contained nearly 100% effluent, from various municipal and industrial sources. In the UK today, some rivers still contain 100% effluent, especially during the summer months. The presence and effect of endocrine disrupting substances is a great concern where there is little potential for dilution of an effluent (Johnson and Sumpter, 2001). The situation in the UK is very different to many of the discharges in British Columbia, where there can be a significant potential for dilution and mixing between a receiving environment and an effluent.

There are a wide number of substances which have been identified as potentially being able to disrupt the endocrine system, from both anthropogenic (man-made) and naturally-occurring sources. These are found in a wide number of sources, including industrial, agricultural and municipal wastes.

The presence of hormones, either from natural or synthetic sources, is one of the main considerations for sewage effluents. Although hormones can be produced by both male and female humans, the primary focus has been the female-related hormones, as these substances can be found in higher concentrations in sewage and there is a general acceptance that the estrogenic hormones are the largest problem or risk with respect to endocrine disruption. By contrast, there are low concentrations of the androgenic chemicals (i.e. hormones which mimic male hormones) in sewage, both as a result of the low concentrations which are excreted by humans and the low usage of these hormones for pharmaceutical purposes.

There are several forms of estrogens (female hormones) associated with sewage, from both natural and synthetic sources: estrone (E1), estradiol (E2), estriol (E3) and 17α-ethinylestradiol (EE2). The interaction between the different forms of estrogens is complex. It is interesting to note that the form in which estrogens enter a sewage treatment plant has a low potential to disrupt the endocrine system (Johnson and Sumpter, 2001), as the estrogen hormone has been metabolised before excretion. However, it is possible for the metabolised form of the estrogen to be degraded during sewage treatment, which could result in the production of the parent hormone. As a result, it is possible for the concentration of estrogens in an effluent to be higher than those measured in an influent. This demonstrates the complexity associated with the estrogenic substances and the interactions which can result in unexpected changes through biological sewage treatment.

With respect to the different types of estrogens, E1 is a metabolite of E2 and has half the potency of E2, but it is present in an effluent at twice the concentration of that typically associated with E2. E2 is the most potent naturally occurring estrogen. It is the synthetic hormone EE2 which is of particular concern with respect to the endocrine disrupting effects of this family of hormones. EE2 is used commonly for birth control and has the greatest potency and persistence, but data indicate that there are good removal rates of EE2 during sewage treatment, so it is likely to have less of an overall impact on the estrogenicity of an effluent. However, EE2 can be difficult to measure at low concentrations, which can result in uncertainties with respect to data reliability and treatment capabilities. There are relatively few concerns with E3, which is produced mainly during pregnancy. While this form of estrogen may be found in an effluent, it has a low potency (Johnson and Sumpter, 2001; Filby *et al*., 2010).

With respect to municipal sewage, the potential effects of pharmaceuticals and personal care products (PPCPs) have received particular focus regarding to the potential for disrupting the endocrine system, as these substances are found in sewage as a result of these substances being commonly used in society, mainly for medical purposes. These substances can include a vast range of medications and related substances, such as antibiotics, anticancer drugs, anticonvulsants, barbiturates, smoking deterrents, non-steroidal anti-inflammatory drugs such as ibuprofen (Onesios *et al*., 2009). These substances are important in maintaining health and allowing some humans to be able to function with everyday life. These types of endocrine disrupting substances are complex and it is hard to predict how these substances can be broken down during treatment. In addition, these substances are often chemically complex, which could result in a slow rate of degradation.

Surfactants are man-made compounds used for cleaning and are another concern for endocrine disruption. The main surfactants of concern are alkylphenol polyethoxylates. Surfactants can be hard to break down because of their recalcitrant nature and hydrophobicity, and, once broken down, the breakdown product may even have a greater concern with respect to endocrine disruption (Johnson and Sumpter, 2001) than the original parent compound. Many surfactants are man-made, so their production and entry into a sanitary sewer system has the ability to be controlled, rather than focusing on how these substances can be treated during the sewage treatment process. Research has also indicated that, although alkylphenolic substances have the ability to cause endocrine disruption on their own, the interaction with the steroid estrogens can result in an additive effect on fish – i.e. the endocrine disrupting effect on fish can be exacerbated due to the presence of alkylphenolic substances.

5.3 Standard Treatment – Typical Sewage Treatment Processes

There are two main mechanisms by which endocrine disrupting substances can be removed during the sewage treatment process. These mechanisms are sorption and biodegradation, and are discussed further below.

5.3.1 Treatment Pathways – Sorption

In wastewater treatment, sorption is the attachment of a substance to the solids or sludge, and is an important mechanism for the removal of endocrine disrupting substances (Oulton *et al*., 2010; Pileggi *et al.*, 2010). Sorption occurs with substances which are hydrophobic in nature, as this type of substance does not like being associated with water, so it naturally moves away from sewage which mainly consists of water, to being attached to the sludge. The reduction in the concentration of the endocrine disrupting substance is purely a physical reaction of the substance moving from the liquid to the solid phase during sewage treatment.

Although sorption is a simple physical action, there are a few factors which will affect the rate and extent to which sorption occurs. These factors include the hydrophobicity of the substance, the charge associated with the sludge, the type of sludge (with a primary sludge having a greater sorption rate than secondary sludge), temperature, sludge age and pH (Oulton *et al*., 2010; Pileggi *et al.*, 2010). The understanding of these factors is also limited, sometimes with conflicting information. For example, some research indicates that a longer sludge age results in increased sorption, however, other research has indicated that a shorter sludge age is more important (Pileggi *et al.*, 2010).

As indicated above, sorption is a simple physical reaction. Attachment of the substance to the sludge does not necessarily mean that the sorbed substance will be degraded once it has become attached to the sludge. However, attachment to the sludge could encourage biodegradation to occur (Pileggi *et al.*, 2010). Sorption does decrease the concentration of some endocrine disrupting compounds in the liquid effluent which is discharged to the receiving environment.

5.3.2 Treatment Pathways – Biodegradation

Biodegradation is the breakdown of a substance through a biological process, with the ultimate biodegradation being the conversion of the substance to carbon dioxide and water (aerobic biodegradation) or methane, carbon dioxide and water (anaerobic biodegradation). Therefore, unlike sorption, biodegradation results in the transformation of a substance into other substances.

Many endocrine disrupting substances have a complex nature and it is hard to understand or predict the pathway by which biodegradation can or will occur. There are also many variable factors which can affect the rate and extent of biodegradation. These factors include sludge age, temperature, biomass diversity, the fraction of active biomass which is present, floc size, the structure of the chemical to be degraded, the hydraulic retention time and biomass concentration (Onesios *et al*., 2009; Oulton *et al*., 2010; Pileggi *et al*., 2010). It is also possible to have conflicting results on how these factors can affect the rate and extent of biodegradation. For example, higher ambient temperatures during the warmer months of the year have been reported to result in a greater removal of endocrine disrupting substances, but the reverse has also been reported (Onesios *et al*., 2009). The conflicting research information further reiterates the complexity of endocrine disrupting substances.

The variability in the conclusions which have been drawn with respect to the biodegradation of endocrine disrupting substances could be due to the focus being on the removal of the original substance. There are instances where a substance may actually increase in concentration as it moves through a sewage treatment plant. Although this could be due to the evaporation of water in warm climates or sampling constraints, the increase in the concentration may also be due to the release of endocrine disrupting substances which are attached to particulate faecal material or the conversion of substances which have been transformed by metabolism in the human body back to the parent compound (Onesios *et al*., 2009).

It is also possible that a substance could be removed without being biodegraded. For example, the substance may be sorbed onto the sludge, but not degraded. In addition, it is often assumed that biodegradation will result in a “harmful” substance being transformed to one which is “benign”. However, due to the complexity of endocrine disrupting substances, this may not always be the case, and it is possible for some intermediate by-products to be formed which have a higher endocrine disrupting potential than the original substance which entered the sewage treatment plant.

Secondary (biological) treatment is considered to provide the greatest contribution to the removal of endocrine disrupting substances during the sewage treatment process (Oulton *et al*., 2010). However, much is still not known about the biodegradation which occurs during biological treatment. The complex nature of endocrine disrupting substances causes difficulties in the ability to predict the biodegradation pathways and the nature of the intermediate by-products which form during biodegradation. There is also the risk of incorrectly extrapolating data and information gained from the laboratory into the real world (Onesios *et al*., 2009).

5.3.3 Abilities of Standard Sewage Treatment Processes

There are still significant knowledge gaps on the treatment or removal of endocrine disrupting substances during the wastewater treatment process. Many different studies have been conducted to increase the understanding of how to optimise standard sewage treatment processes to treat endocrine disrupting substances. While some of these studies have been conducted on full-scale sewage treatment plants, many have focused on laboratory or pilot-scale work, mainly due to the need to simplify this complex subject. Caution is needed when considering the outcomes of laboratory and pilot-scale studies, as these outcomes may not necessarily be translated directly to full-scale sewage treatment plant operations.

Some sewage treatment plants have primary treatment as part of the overall treatment process. Primary treatment is a simple approach to separating solids from the liquid portion of the sludge through settlement. There have been few studies on the ability of primary processes in sewage treatment plants to treat endocrine disrupting substances. As such, the potential for primary processes to provide treatment is based mainly on studies completed at water treatment plants. The studies indicate that the use of primary processes at a sewage treatment plant will be limited to the sorption of hydrophobic compounds to suspended organic matter/sludge and will only provide limited treatment for endocrine disrupting substances (Oulton *et al*., 2010).

By contrast, there have been significant studies on the ability of secondary biological sewage treatment processes to remove endocrine disrupting substances. Many of these studies have focused on activated sludge plants, which is one of the most common approaches to biological wastewater treatment in the world. Activated sludge plants remove the bulk of organic compounds which enter the sewage treatment plant, however, early research indicated that while removal can occur, this did not necessarily relate to complete biodegradation (Johnson and Sumpter, 2001). Hydrophobicity and recalcitrance of the compound play an important part on the effectiveness of treatment, and lack of removal is not necessarily related directly to a failing of the sewage treatment processes. There are some aspects of the activated sludge treatment process which can result in an increased reduction in the concentration of endocrine disrupting substances. These aspects include:

- Hydraulic retention time, with the general concept being that the hydraulic retention time should be around 14 hours (Johnson and Sumpter, 2001), or even up to 25 hours (Pileggi et al., 2010). However, others indicate that increasing the hydraulic retention time is only able to affect the treatment rate of endocrine disrupting substances up to a certain level (Oulton *et al*., 2010). Hydraulic retention time should not be considered on its own. Other factors can also affect the degree of treatment achieved. For example, a lower hydraulic retention time can be balanced with a good microbial population in order to achieve treatment of endocrine disrupting substances (Onesios *et al*., 2009).

- Sludge retention time, with a greater removal of the more complex and recalcitrant endocrine disrupting substances occurring as the sludge retention time increases. Proposed sludge retention times vary from 30 days (Lishman *et al*., 2006), through to a range of 5 days to 80 days (Onesios *et al*., 2009). The concept is that a high sludge retention time will allow for greater microbial diversity, the development of slow growing populations, acclimatisation to the complex organics in the sewage, longer exposure times, an increase in number of pathways for degradation, and a greater potential for sorption and biodegradation to occur (Pileggi *et al*., 2010). However, as with the hydraulic retention time, increasing the solids retention time is only considered able to affect the treatment rate of endocrine disrupting substances up to a certain level (Oulton *et al*., 2010).
- Temperature was not found to be a factor in some cases (Lishman *et al*., 2006), but was important with others (Pileggi *et al*., 2010). With respect to ambient temperature, greater removal of endocrine disrupting substances has been associated with the summer than the winter, although this is also thought to be dependent on the type of compound, as other research shows that there is no difference in the degree of treatment, regardless of the season (Onesios *et al*., 2009).
- Tank configuration. A number of plug flow tanks was observed to be better for the treatment of endocrine disrupting substances than a complete mix tank. This is thought to be due to the reaction kinetics for the biological transformation of endocrine disrupting substances (Pileggi *et al*., 2010).
- Biomass diversity, with a greater diversity resulting in a greater potential for treatment (Pileggi *et al*., 2010).
- Fraction of active biomass, with a higher portion of active biomass yielding a greater potential for treatment (Pileggi *et al*., 2010).
- Floc size, with larger floc sizes yielding a greater potential for treatment (Pileggi *et al*., 2010).

Some typical modifications to the standard activated sludge process include nitrification, biological nutrient removal and the membrane bioreactor. Consideration of the ability to increase the removal of endocrine disrupting substances as a result of process modification has also been discussed in the scientific literature. There are conflicting outcomes in all cases. Research indicates that the use of extended aeration activated sludge processes, activated sludge with nitrification, biological nutrient removal and membrane bioreactors do not provide any significant improvement in the removal of endocrine disrupting substances over the standard activated sludge process (Pileggi *et al*., 2010), although it is possible that membrane bioreactors may provide increased treatment for specific compounds where there is the potential for biodegradation of an intermediate by-product due to the higher sludge concentration which is maintained in the membrane bioreactors (Oulton *et al*., 2010).

The activated sludge process is considered to provide up to 99% removal of endocrine disrupting substances (Johnson and Sumpter, 2001), although this will vary depending on the type of substance which is present (Lishman *et al*., 2006; Oulton *et al*., 2010). While it may be possible to increase the efficiency of the activated sludge process for the treatment of endocrine disrupting substances, this may not be financially or practically feasible (Johnson and Sumpter, 2001).

The ability of other biological treatment processes has also been researched, although to a lesser extent, compared with the activated sludge process. Aerated or facultative lagoons can show equivalent or better removal rates of endocrine disrupting substances than activated sludge plants, but this is dependent on the type of substance present (Lishman *et al*., 2006; Pileggi *et al*., 2010). Treatment of endocrine disrupting substances in a lagoon is thought to occur by a variety of different pathways including biodegradation, sorption, deconjugation and photodegradation. It is also possible that volatilisation may also occur during times when there is no ice cover (Lishman *et al*., 2006).

There is limited information available on the trickling filter, which is the generic biofilm biological treatment process. Generally, the treatment capabilities of the trickling filter were considered to be lower than that achieved by an activated sludge type process, but better than that achieved in a primary settlement tank (Oulton *et al*., 2010; Pileggi *et al*., 2010). However, the very nature of a biofilm process could increase the biodegradation of recalcitrant substances due to the presence of an immobilised stable bacterial population (Oulton *et al*., 2010).

5.4 Advanced Treatment Options

Although it is possible that the activated sludge process could provide up to 99% removal of endocrine disrupting substances, this is not the case for all substances. In addition, since standard sewage treatment plants are not designed specifically to treat endocrine disrupting substances, there is the possibility that additional processes may be required to allow adequate treatment to occur or to remove all endocrine disrupting substances from an effluent. These additional processes are discussed further below.

5.4.1 Activated Carbon

Activated carbon is used as a standard process for the treatment of drinking water. Organics, such as endocrine disrupting substances, can be removed from water through the attachment to the activated carbon media by sorption. Although there have been many studies with respect to the use of activated carbon for the treatment of drinking water, the studies relating to sewage effluents are limited, and are largely extrapolated from the understanding of the drinking water studies. From the research which has been conducted on sewage effluents, activated carbon has the potential to be a highly effective treatment process for endocrine disrupting substances (Filby *et al*., 2010).

The efficiency of the activated carbon process to remove endocrine disrupting substances is affected by a number of factors, including the surface area, porosity, pore-size distribution, and surface acidity/basicity which affects pH and charge. Activated carbon is not a selective process, and any organic matter will theoretically attach to the activated carbon substrate. Therefore, the presence of organic matter in sewage effluents will bind to the activated carbon, regardless of whether these organics have the potential to be endocrine disrupting or not. As a result, there will be competition for the activated carbon binding sites, and the miscellaneous organic matter which is found in sewage effluents has the potential to further impede the removal of endocrine disrupting substances by blocking access to the pores (Oulton *et al*., 2010).

Activated carbon only has a limited useful life. Once this is reached, regeneration or disposal is needed, as no further removal of organics can occur. Both disposal and regeneration (which requires high temperatures) are expensive and, with the amount of organic matter which is present in sewage effluents compared with a drinking water source, frequent replacement of the activated carbon medium will be required if it is used to treat sewage effluents (Pileggi *et al*., 2010). The high costs associated with the use of activated carbon for the treatment of endocrine disrupting substances has made this approach unfavourable for sewage effluents (Johnson and Sumpter, 2001).

5.4.2 Chemical Oxidation

Chemical oxidation is the use of highly active chemicals to breakdown compounds through a simple chemical reaction. Any highly reactive chemical can be used in chemical oxidation, with the most common ones being ozone or chlorine.

Both ozone and chlorine have the potential to be highly effective with respect to reducing the concentration of endocrine disrupting substances which are present in sewage effluents. However, in addition to the capital and operational concerns with both of these chemicals, there are also concerns with respect to the potential production of by-products during the chemical oxidation process. These by-products are known to be toxic and it may be necessary to add yet another treatment process to reduce the by-products in order to protect against negative effects to the environment (Filby *et al*., 2010; Pileggi *et al*., 2010)

Chemical dose and contact time are important for chemical oxidation to be successful (Pileggi *et al*., 2010) and, as treatment by chemical oxidation is not necessarily specific to endocrine disrupting substances, higher doses may be required to accommodate the chemical reaction which will occur with any of the miscellaneous substances which are present in sewage effluents, including organic material, micro-organisms and ammonia. However, in addition to the increase in concerns relating to toxic by-products, higher dosage rates could result in unreasonable capital and operational costs. The alternative, which is to reduce the chemical dosage rate, will also result in higher concentrations of endocrine disrupting substances (Filby *et al*., 2010).

Although there is a general lack of specificity with the use of chemical oxidation to treat endocrine disrupting substances, research has shown that ozone will react preferentially with some substances over others and, therefore, not all endocrine disrupting substances will be targeted by the use of ozone (Oulton *et al*., 2010).

5.4.3 Ultra-violet (UV) Light

Light can result in the photolytic decay of organic compounds and may occur naturally through sunlight or as part of a designed UV process. In order for photolysis to occur, high energy light such as that produced during UV disinfection must be absorbed by the compound, and the energy of the light must be sufficient to break chemical bonds. There is some information on the potential to use UV light for the treatment of endocrine disrupting substances in drinking water, but it is assumed that the complex organic nature of a sewage effluent would result in less removal of endocrine disrupting substances due to the higher concentrations of organic matter present and the potential for other light scattering or light absorbing constituents (Oulton *et al*., 2010).

It was originally thought that UV light could provide a treatment approach which would result in a significant reduction in endocrine disrupting substances, but concerns were raised with respect to high process costs (Johnson and Sumpter, 2001). However, more recent data indicate that photolytic decay from either natural sunlight or a UV treatment process is not expected to achieve significant reductions in endocrine disrupting substances (Pileggi *et al*., 2010).

5.4.4 Volatilization

This is the removal of substances through rapid aeration, and results in the substance being transferred from a liquid into the air. The success of this approach is reliant on the substance being volatile in nature, so it is capable of moving out of the liquid phase. While aeration, such as that which occurs during standard biological wastewater treatment, may result in the loss of some organic compounds, many endocrine disrupting substances are not volatile in nature, and little removal would be expected as a result of using air stripping (Pileggi *et al*., 2010).

5.4.5 Sand Filtration

The theory behind using sand filtration in sewage treatment is to provide additional effluent polishing before discharge through removal of suspended solids and turbidity, after biological treatment has been achieved. Sand filtration has also been evaluated for its potential to provide additional treatment for endocrine disrupting substances.

It is possible to achieve some additional removal of endocrine disrupting substances through the use of sand filters. The mechanism of treatment can either occur as a result of a physical process (filtering of endocrine disrupting substances if they are attached to solids) or through a biological process (biodegradation of endocrine disrupting substances through interaction with the biofilm in the sand). Although some removal of endocrine disrupting substances is possible, the potential for removal by sand filtration is considered to be low. There is also little consensus on the operational conditions which could control the degree to which removal occurs. These operational conditions include the hydraulic retention time, hydraulic loading rate and the incoming effluent quality (Oulton *et al*., 2010).

5.4.6 Membrane Filtration

High pressure membranes and reverse osmosis (RO) are used for advanced water reclamation processes. The theory behind these processes is a simple physical filtering of contaminants, where molecules that are bigger than the pore size cannot pass through the membrane and become concentrated on the untreated side of the membrane. In the case of endocrine disrupting substances, some of these compounds can also become adsorbed onto the membrane or may be prevented from passing though the membrane as a result of electrostatic repulsion.

The efficiency of a membrane system for the removal of endocrine disrupting substances can be affected by a range of factors such as membrane size, molecule size and charge, and effluent characteristics. Operational factors such as trans-membrane pressure and permeate flux rate will also have an effect on the efficiency (Oulton *et al*., 2010). Membrane processes are capable of providing a high level of treatment, but have high capital and operational costs (Pileggi *et al*., 2010), and there is still the requirement to manage membrane fouling and handle the residual wastewater stream, which will contain concentrated substances.

5.4.7 Summary

Standard sewage treatment processes are known to provide treatment for endocrine disrupting substances, although the level to which this is achieved will vary due to a number of factors, including the complexity of each endocrine disrupting substance. While a high treatment rate can be achieved for some substances, this is not necessarily the case for all substances. In addition, given the very low concentrations which can cause endocrine disrupting effects, it is possible that a high level of treatment may not be sufficient to guarantee that an effect will not be seen. The ability for dilution and dispersion in the environment is important with respect to eliminating the potential for negative effects of endocrine disrupting substances.

Options to upgrade a sewage treatment plant to enhance the removal of endocrine disrupting substances treatment processes, compared with a typical standard treatment process (i.e. activated sludge) has conflicting opinions. There is a lack of consistent research data to indicate that upgrading to nitrification, extended aeration, biological nutrient removal or even a membrane bioreactor will result in a level of treatment which is acceptable for all types of endocrine disrupting substances. There are additional treatment options available, but the considerations (including capital costs, operational costs, level of efficiency and risk of toxic by-products) do not result in a simple solution to this complex problem. Again, it is important to reiterate that it is the combination of treatment processes and discharge characteristics that need to be considered in order to reduce the harmful risks to acceptable levels.

5.5 Status in Canada and British Columbia

Although there are concerns with respect to the potential effect of endocrine disrupting substances, including pharmaceuticals in sewage effluents, the complexity associated with this subject has resulted in little action with respect to Federal and Provincial regulations. Before such direction can be taken, much needs to be understood with respect to the level of treatment which can be achieved, the extent of the effects in a receiving environment and the resulting capital and operational costs which may need to be borne to achieve required effluent concentrations of these substances.

This lack of willingness to implement regulatory requirements based on the current understandings has been demonstrated recently at both the Federal and Provincial levels. In July 2012, the publication of the new Federal wastewater regulation contained no requirement for endocrine disrupting substances or pharmaceuticals, but focused on the standard parameters associated with sewage effluents – TSS, BOD_5, ammonia and chlorine. The same is also the case for Provincial legislation. In April 2012, the Municipal Sewage Regulation was repealed and replaced with the Municipal Wastewater Regulation. As with the Federal approach, the focus for the MWR was the standard parameters associated with sewage effluents, although in this case, the parameters were extended to include additional nitrogen parameters, phosphorus and faecal coliforms. There are no effluent quality requirements for endocrine disrupting substances or pharmaceuticals in either regulation. In addition, there are no monitoring requirements for endocrine disrupting substances or pharmaceuticals in either regulation. This is likely a factor of the complexities which exist for monitoring these substances. These complexities include:

- The cost of the analyses,
- Limitation of testing associated with effluent samples, due to the presence of solids and organic matter,
- The inability to test for all parameters which may have an endocrine disrupting effect which includes the vast number of unknown by-products which can be produced during degradation,
- The limitations with respect to the analytical detection limits and the potential for effects to occur below these detection limits,
- The issues of increased affects as a result of interactions between the different types of endocrine disrupting substances, and
- Concerns with the ability to translate measured concentration into risks associated with biological effects.

The complexity with endocrine disrupting substances and pharmaceuticals does not mean that there has been silence. On the contrary, measures have been implemented at the Federal, Provincial and local government levels in order to take the first steps towards managing these substances.

For example, from the Federal level of government, nonylphenols and related substances were declared toxic to the environment under the Canadian Environmental Protection Act (CEPA). The main focus of this declaration was based on the endocrine disrupting potential of these substances. It was recognised that these substances are man-made and were being released to the sanitary sewer system through both industrial and domestic activities. Once declared toxic under the CEPA, management strategies need to be developed. The focus of the resulting management strategies was on the production and use of nonylphenols, rather than requirement for treatment at a sewage treatment plant. This was in recognition that these substances are wholly man-made and that there is the potential to control, and even eliminate, their production and use, replacing these substances with a more acceptable alternative.

From the Provincial level of government, a water quality guideline has been set for EE2. This has been set based on the protection of aquatic life, with the guideline concentrations being 0.5 ng/L as a 30 day average concentration and 0.75 ng/L as a maximum concentration (Nagpal and Meays, 2009).

With respect to pharmaceuticals, source control and public education is important. There are many pharmaceuticals which are flushed down the toilet, and exacerbate any issues with respect to the presence of endocrine disrupting substances at the sewage treatment plant. There are alternative programs available for the disposal of expired or excess pharmaceuticals, through the simple handing over of these medications to pharmacists who are part of the BC Medications Return Program. Under this program, the pharmaceuticals are transported for disposal at an appropriate facility, thus reducing the amounts of such substances which are disposed to the sanitary sewer system. This program is promoted at both the Provincial and local government levels.

Management of substances through source control is a key alternative to treatment at a sewage treatment plant, and is especially important based on the recalcitrance of some of the substances which are disposed to sewer and the likelihood that these substances will pass through the sewage treatment plant and remain in the effluent. Approaches to source control can include sewer use and related by-laws, collection and disposal programs and educational programs (Waller *et al*., 2010).

5.6 Area Specific Information – Studies Being Undertaken in the Okanagan

Research is being conducted on the discharges and receiving environments for the large sewage treatment plants in the Okanagan Valley. This research is being completed by UBC-Okanagan and was the focus of an article in the Kelowna Capital News on November 21st, 2012. Limited information is available on this research for two reasons – the amount of study which has been completed and the need for the researchers to publish the information. To elaborate on both of these reasons, the research is still in the early stages and the researchers acknowledge that much still needs to be known before conclusions can be drawn. Secondly, with respect to the information which has been interpreted, this is the basis of a master’s thesis and articles which will be published in peer-reviewed scientific journals.

Discussions were held with both of the senior academic contacts for the studies: Dr. Jeff Curtis and Dr. Bruce Mathieson, with respect to the research which has been completed, the intended future direction of the research and the information which they are able to discuss at this time. The research aims to increase the understanding of the endocrine disrupting substances which are present in the effluent of the large biological nutrient removal plants in the Okanagan and evaluate the potential impacts on the receiving environments. The receiving environments included Okanagan Lake and, for the specific case of the City of Vernon, MacKay Reservoir, where the effluent is currently stored before it is used for irrigation. These two receiving environments are very different in nature. Given the volume of effluent which is discharged to Okanagan Lake and the size of the lake, there is the potential for significant dilution and dispersion to occur, in addition to the potential for endocrine disrupting substances to also undergo further transformations (e.g. adsorption and biodegradation) after release to the lake. As a result, it was harder to detect the presence of endocrine disrupting substances in the lake water, and the data indicated that the movement of the plume may not be consistent with predictive modelling. By contrast, data from MacKay Reservoir was relatively easy to collect, as the reservoir consists primarily of effluent and there is little opportunity for dilution and dispersion of the endocrine disrupting substances. It was also easier to identify effects on fish which are present in the reservoir, due to these fish being unable to avoid the effluent plume.

With these two scenarios, Okanagan Lake and MacKay Reservoir, it is the latter which is more representative of the classic early work on endocrine disrupting substances which emerged from the UK – i.e. a receiving environment which consists mainly of effluent with little opportunity for dilution and dispersion. As a result, it is not overly surprising that the initial data from the MacKay Reservoir studies indicate that there is the potential for the effluent from the City of Vernon sewage treatment plant to contain endocrine disrupting substances at concentrations which could cause feminisation of fish. However, the initial data also indicate the potential for further changes in the nature and concentration of the endocrine disrupting substances during the time of storage in the reservoir. It is thought that these changes are primarily due to adsorption and biodegradation.

The research which is being conducted by UBC-Okanagan is in the very early stages, but has the potential to significantly increase the understanding of the potential for impacts and changes in endocrine disrupting substances to our local environment.

5.7 Summary

The effects of endocrine disrupting substances are of concern world-wide, and direction on the management of these substances needs to be set by higher levels of government (i.e. in Canada, the Federal and Provincial levels of government), rather than the municipal government. However, at the municipal level, there is the need to be aware that action may be required in the future with respect to the management of endocrine disrupting substances, as and when the understanding of the issue allows. Certainly, the issue of public education at the municipal level can improve the situation with respect to reducing the amounts of endocrine disrupting substances that are put into the sanitary sewer system.

The City of Vernon operates a sewage treatment plant which is one of the most sophisticated of its kind. As a result, a high effluent quality is achieved for a range of different design parameters. Although there are no design parameters for endocrine disrupting substances, given the research information in scientific literature, it is reasonable to expect that the City of Vernon's sewage treatment plant will achieve a substantial reduction in the endocrine disrupting substances which can be removed by standard sewage treatment processes. This may not necessarily translate to 100% removal of all endocrine disrupting substances which are present in sewage. At this point in time, from the research information which is available, further upgrades to the City's sewage treatment plant, e.g. through the addition of activated carbon or chemical oxidation, would not be advised. However, the subject of endocrine disrupting is dynamic, and when scientific research results in the development of effluent criteria which are supported by the Federal and Provincial governments, then upgrades to this environmental impact study should be undertaken with respect to the identification of appropriate treatment requirements.

6.0 OUTFALL ASSESSMENT

6.1 Current Outfall Summary

Based on the information provided by the City of Vernon (record drawings, dated December 1987), the outfall is approximately 6,100 m in length[1] and consists of 750 mm diameter steel pipe, with the last 31 m being the diffuser manifold. The outfall pipe is laid directly on the lake bottom. The 750 mm diameter diffuser section contains 15 ports each 100 mm in diameter, spaced at 2 m intervals, plus a single 150 mm diameter port at the outfall end. The diffuser section is steel pipe while the ports are Schedule 60 polyethylene pipe with blind flanges bolted to the tops. The first nine ports were installed with the flanges in closed position while the deepest seven ports were installed with the flanges bolted in an open position. The depth along the diffuser section varies from about 56.2 m to 61.2 m, measured at the tops of the ports. The condition of the outfall, diffuser and diffuser ports are unknown. The City has anecdotally corroborated that the terminus port and the other deepest six ports are currently in the "open" position.

6.2 Historical Documentation and Reports

There are no known historical reports for this outfall. The outfall has apparently been inspected by divers, but this information was not available at the time of the assessment.

6.3 Outfall Assessment

The MWR is the standard legislation for regulating sewage discharges in British Columbia, including outlining the expectations with respect to outfall conditions and design. The conditions with respect to outfall design include:

- The definition of the initial dilution zone (IDZ), which is the area located immediately around an outfall where a zone of degradation of water quality is acceptable.
- The outfall is to be located to maximize mixing and minimize the surfacing of effluent or the tendency of the effluent to move towards a shoreline.
- The outfall is to be located in a place which will allow the predominant current to be intercepted.
- The diffuser is to provide a minimum dilution ratio of 10:1 within the initial dilution zone.

[1] Underwater within the lake only; an additional 750 m of outfall is installed in an on-shore trench.

- For outfalls located within the Okanagan Basin, the outfall depth must be at least 40 m below the mean low water.
- Specific depth, flow and distance requirements with respect to the diffuser and diffuser ports in cases where the discharge is to a lake with a surface area greater than 100 hectares.

Although it is recognised that the City is under a LWMP, which will supersede the requirements of the MWR, the MWR outfall and mixing guidelines were used as a basis for assessing the existing outfall. The results of the assessment are outlined below.

6.3.1 Dilution Analysis

The dilution analysis was performed using spreadsheet "desktop" models; the models implement the same near- and far-field dispersion equations used in the U.S. Environmental Protection Agency's "VisualPlumes" software, an industry standard for such analyses, except with various simplifying assumptions (e.g., constant thermal gradient within the water column during stratification). Further, the spreadsheets implement static conditions with no consideration for time series analysis.

For the assessment, wind forced mixing was ignored; this yields a conservative analysis with respect to dilution ratios as winds will tend to induce additional mixing. Analyses were completed for combinations of lake conditions, effluent temperatures and discharge rates:

- Stratified (summer) and non-stratified (winter) lake conditions;
- Very small current (0.03 m/s) in the vicinity of the point of discharge;
- Warm effluent temperature range in the summer (18 and 23 ^{o}C) and cold effluent temperature range in the winter (11.5 and 14 ^{o}C);
- An effluent discharge rate ranging between 5,000 and 40,000 m^3/d, with a 16,700 m^3/d design rate, which is in line with the 20 year projected flows.

At the time the analysis was completed, the available information from the City indicated that the diffuser had 15 ports and was located at a depth of about 60 m; dilution computations were performed using these values. Subsequently, the record drawings became available which indicated there were instead 16 ports at about 60 m depth. The greater number of ports will tend to increase the dilution values as originally computed while the slightly shallower depth will tend to decrease the dilution values as originally computed. It was judged that, given the lack of current corroboration from an in-field inspection and the simplified computational approach utilized for the analysis, these differences cancel each other out.

6.3.2 Initial Dilution Zone – IDZ

The MWR defines an IDZ as a 3-dimensional zone around a point (or points, when part of a diffuser) of discharge where mixing of the effluent and receiving water occurs. Using the concepts listed in the regulation, the IDZ for the City of Vernon's current outfall location and diffuser configuration is ellipsoid in plan view, extending 100 m from all points along the diffuser. The full depth of the lake at the diffuser location (about 60 m) is available for dilution within this IDZ plan view; the available dilution volume is thus about 1,891,100 m^3. Figure 6.1 shows the approximate location of the initial dilution zone for the existing outfall.

The MWR also indicates where the IDZ is to be located with respect to other water uses, specifically, the MWR indicates that the edge of the IDZ must be located at least 300 m away from recreational areas, shellfish harvesting areas, domestic and agricultural water intakes and other sensitive areas as identified by the BC Ministry of Environment. There are no shellfish harvesting areas in Okanagan Lake, but there are recreational uses and domestic and agricultural water intakes. However, as distance from the last diffuser port to the nearest shoreline is approximately 1,300 m, none of these situations would be in contravention of the MWR limits.

Using desktop, spreadsheet-based models for lake plume dilution computations, dilution ratios along the plume centreline at the edge of the IDZ and at 1,300 m for discharge rate of 10,160 m^3/d and the 20 year design discharge rate of 16,700 m^3/d under various conditions were computed and are summarised in Table 6.1.

Table 6.1: Estimated Dilution Ratios for Various Environmental Conditions (Design Effluent Discharge = 16,700 m^3/d and 10,160 m^3/d)

Distance from Outfall	Summer (stratified)		Winter (unstratified)	
	Low Effluent Temperature (18 °C)	High Effluent Temperature (23 °C)	Low Effluent Temperature (11.5 °C)	High Effluent Temperature (14 °C)
Effluent Discharge Rate 16,700 m^3/d				
At Edge of IDZ	23:1	30:1	187:1	230:1
At 1,300 m from Outfall	70:1*	95:1*	730:1	820:1
Effluent Discharge Rate 10,160 m^3/d				
At Edge of IDZ	29:1	38:1	259:1	314:1
At 1,300 m from Outfall	88:1*	121:1*	1,012:1	1,118:1

* *Theoretical; with stratification present in summer, plume would normally not surface.*

URBAN systems

ENVIRONMENTAL IMPACT STUDY

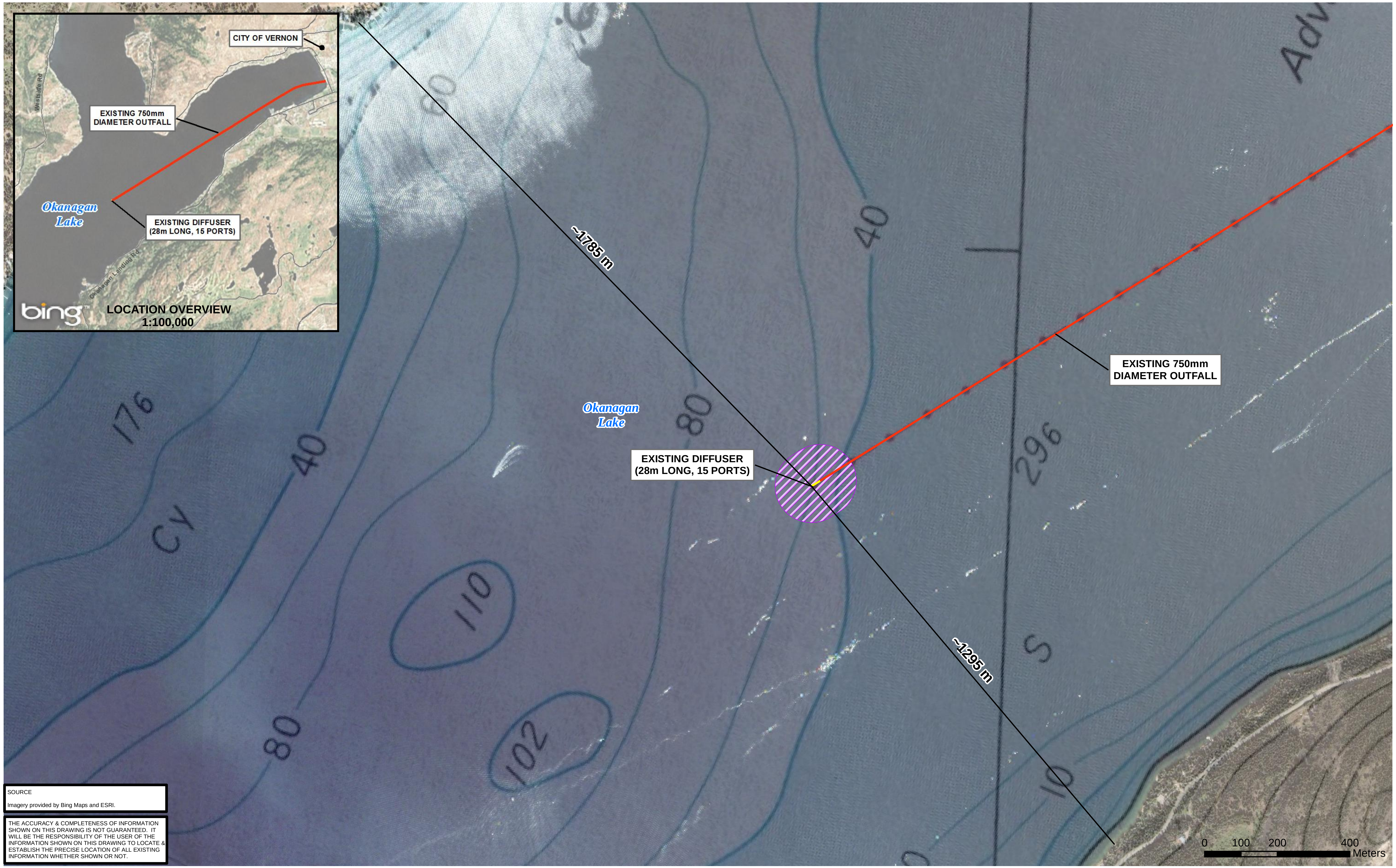
DATE: NOVEMBER 2012

CITY OF VERNON

1:10,000

Legend

- Existing Diffuser
- Existing Outfall
- Initial Dilution Zone (IDZ)



SOURCE

Imagery provided by Bing Maps and ESRI.

THE ACCURACY & COMPLETENESS OF INFORMATION SHOWN ON THIS DRAWING IS NOT GUARANTEED. IT WILL BE THE RESPONSIBILITY OF THE USER OF THE INFORMATION SHOWN ON THIS DRAWING TO LOCATE & ESTABLISH THE PRECISE LOCATION OF ALL EXISTING INFORMATION WHETHER SHOWN OR NOT.

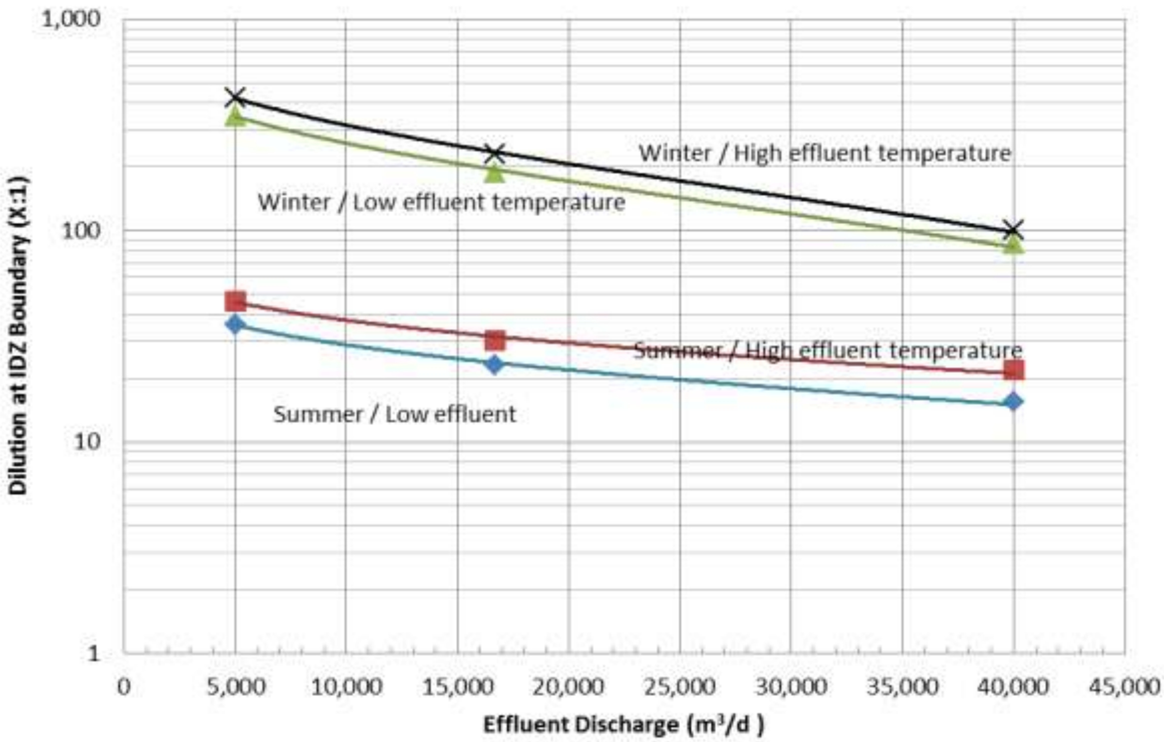
EXISTING OUTFALL SHOWING INITIAL DILUTION ZONE

FIGURE

6.1

Figure 6.2 provides a plot showing the dilution ratios for a range of discharges (5,000 to 40,000 m^3/d).

Figure 6.2 Dilution Ratios for a Range of Effluent Discharges



As noted above, wind-driven mixing was ignored in the analysis and the results can be considered conservative with respect to dilution ratios. Wind and waves can easily generate more mixing and increased dilution, regardless of the season.

6.3.3 Outfall Design

The MWR indicates the following key points with respect to outfall design in a freshwater lake environment:

a. The outfall design must meet the following requirements:

   i. Meet the definition of the initial dilution zone

   ii. Prevent air entrapment

   iii. Have adequate weighting to prevent movement

iv. Protect the outfall from corrosion

Based on the record drawings of the existing outfall and diffuser, the IDZ zone definition is met. Further, as the steel outfall pipe is coated and lined, it is likely to be corrosion resistant, although its current condition is not known. The outfall was laid at a continuous downward gradient from the shore and 17 underwater air release valves were installed at equal spacing along the length of the outfall to prevent air entrapment. It is not known what method(s) were used to prevent outfall pipe movement, although the use of steel pipe which is heavy will inhibit displacement.

b. The outfall diffusers must be located at a sufficient depth to maximize the frequency of trapping of the effluent below the surface of the water body.

The current diffusers are placed approximately 60 m below mean low water, which is well below the thermocline present during the stratified (summer) period (typically located at 10 to 25 m below the water surface); thus effluent will normally be trapped below surface during warm weather. However, during the winter when thermal stratification is normally absent, the effluent plume will normally rise to the surface. Moving the diffuser to deeper water would not alter this condition.

c. The outfall location must intercept the predominant current and avoid small currents that tend to move in toward the shore.

The diffuser is placed in the lake's central trough and in line with the likely general direction of currents within the lake.

d. The diffuser is to be designed to provide a minimum 10:1 dilution ratio within the initial dilution zone.

There are no concerns with the current outfall location and the ability to meet this criterion for flows up to the 20 year design discharge rate of 16,700 m^3/d.

e. The outfall must be protected from wave, boat and marine activity.

The outfall consists of a steel pipe placed along the bottom of the lake and well away from shore.

f. In the Okanagan Basin, outfalls must be at least 40 m below mean low water.

At approximately 60 m deep, the current diffuser satisfies this requirement.

g. The discharge is not to cause water quality parameters outside of the initial dilution zone to exceed known water quality guidelines.

For the existing outfall, the computations indicate that for a discharge rate of 16,700 m^3/d with the presence of a small current, the dilution ratios range between 23:1 and 230:1 at the IDZ boundary and between 70:1 and 820:1 at 1.3 km from the diffuser (see Table 6.1). Further evaluation on the resulting water quality is discussed in Section 7 of this report.

h. For lakes with surface area greater than 100 ha, the discharge rate must not exceed a critical flow value determined based on the depth of the diffuser and its distance to the nearest shore.

For the depth of 60 m below the mean low water and a distance of 1,300 m from mean low water at the shore, the critical flow value is calculated to be 47,069 m^3/d, which is greater than the design discharge of 16,700 m^3/d.

6.4 Summary

The current outfall location generally satisfies conditions of the MWR, except with respect to effluent rising to the surface. This condition is unavoidable at this location (or any other location within the lake) during the winter when stratification is absent and the current outfall location does minimize this condition from occurring. On the other hand, the modelling indicates that it is during the winter months when maximum dilution occurs, as compared to the summer months, when the effluent is trapped in the lower depths of the lake due to thermal stratification. The lowest centreline dilution ratios at the edge of the initial dilution zone are estimated to be 23:1 to 30:1 and 730:1 to 820:1 for summer stratified and winter unstratified conditions, respectively, depending on the temperature of the effluent. A very small current has been assumed in all cases. The presence of stronger wind-driven currents will generally serve to increase dilution ratios. For the lower flow rate of 10,160 m^3/d, the dilution ratio will increase, in all cases.

7.0 ASSESSMENT OF POTENTIAL IMPACTS DUE TO EFFLUENT RELEASE

7.1 Modelling of Potential Effluent Impacts

Modelling is required to determine the potential for impacts and will assess the predicted concentration at the end of the IDZ and at the shoreline. The concept of an initial dilution zone is to allow an area where there will be deterioration in water quality, as a result of an effluent release. However, through dilution and dispersion, the expectation is that the water quality will be consistent with the appropriate guidelines or objectives outside of the initial dilution zone, as would be the case when the effluent reaches the shoreline.

Modelling has been completed in order to predict the potential for impacts both at the edge of the IDZ and at the closest shoreline, which is located approximately 1,300 m from the City's outfall. In each case, the potential for impacts has been evaluated using an effluent flow rate of 16,700 m^3/d, which is consistent with the 20 year flows set through the LWMP process, and 10,160 m^3/d, which is consistent with the partial discharge approach. The following assumptions and conditions have been developed in order to undertake these evaluations.

For evaluations relating to conditions at the end of the IDZ, which is defined as a distance of 100 m from the end of the diffuser:

- Condition 1 – Summer. In the summer, the lake will be stratified and the effluent will be trapped below the thermocline, which is located at a depth between 10 and 25 m (typical depth 15 m). The dilution ratios of 23:1 and 29:1 have been selected for the evaluation, depending on the effluent flow rates. These dilution ratios are presented in Table 6.1 and are the worst case out of the two temperature scenarios shown, assuming an effluent temperature of 18 ^oC.

- Condition 2 – Winter. Although in cold winters it is possible for the lake to remain stratified, it is assumed that the lake is monomictic, which is the most common expectation for this part of the lake. Therefore, it is assumed that the lake is fully mixed and there is no thermocline, resulting in the possibility of the effluent rising to the surface of the lake. The dilution ratios of 187:1 and 259:1 have been selected for the evaluation. These dilution ratios are presented in Table 6.1 and are the worst case out of the two temperature scenarios shown, assuming an effluent temperature of 11.5 ^oC, which is reasonable given the potential for sewage to cool as it passes through the sewage treatment plant.

For evaluations relating to conditions at the shoreline, which is defined as a distance of 1,300 m from the end of the diffuser:

- Condition 1 – Summer. In the summer, as the lake is stratified, the effluent will remain trapped below the thermocline and will not reach the surface of the lake. Therefore, the main consideration in this case will be the potential for impacts to water intakes located at the shoreline. Although the nearest water intake to the outfall is used for domestic purposes, it is possible that the plume may not move towards this intake, depending on the currents which set up within the lake. However, for the purposes of a worst case scenario, it will be assumed that the closest water intake will be located 1,300 m away from the outfall, that the use of the intake is for domestic purposes and that the intake is at a depth which will be affected by the plume. Dilution ratios of 70:1 and 88:1 have been selected for the evaluation, and are the worst case out of the two temperature scenarios as they assume an effluent temperature of 18 ^{o}C.

- Condition 2 – Winter. Again, it is assumed that the lake is not stratified and that the effluent is able to rise to the surface of the lake. Therefore, the main consideration in this case will be the potential for impacts on a beach located at the shoreline. It is assumed that the nearest beach at the closest point on the shoreline from the diffuser and, therefore is 1,300 m away from the outfall, although it is possible that depending on shoreline characteristics and that the movement of the plume may not be towards the closest beach, depending on the currents which set up within the lake. Dilution ratios of 730:1 and 1,012:1 have been selected for the evaluation, and are the worst case out of the two temperature scenarios as they assume an effluent temperature of 11.5 ^{o}C.

During the summer months, as the lake is stratified, the greatest risks relate to any water uses which are located below the thermocline. This could include water intakes and fisheries resources. During the winter months, as the lake is fully mixed, the greatest risks relate to any water uses which are located at the surface. These include primary contact recreational use (bathing, water-skiing) and fisheries resources. It is also reasonable to assume that there will be limited primary contact recreational use in Okanagan Lake during the winter months.

In addition, the following were considered when evaluating the potential for impacts as a result of the effluent release:

- The Federal wastewater regulation, which applies to all discharges to surface waters, regardless of whether they are continuous or intermittent.
- The conditions of the operational certificate.
- The design of the sewage treatment plant for discharge to Okanagan Lake.

- The water quality objectives for Okanagan Lake and, if necessary, the BC Water Quality Guidelines.

7.2 5 Day Biochemical Oxygen Demand

For a surface water discharge, such as Okanagan Lake, the following effluent quality criteria apply:

- Under the conditions of the operational certificate, maximum BOD_5 concentration must be less than or equal to 10 mg/L.
- Under the Federal wastewater regulation, the average $CBOD_5$ concentration must be less than or equal to 25 mg/L.

The sewage treatment plant is designed to produce an effluent BOD_5 concentration of less than 10 mg/L. Given the current plant design and that the conditions of the operational certificate are more stringent than the Federal wastewater regulation, the focus will be for an effluent BOD_5 concentration of 10 mg/L, and no further consideration will be made with respect to the Federal wastewater regulation. In addition, given that the standard for both the Federal and Provincial approach is now $CBOD_5$, rather than total BOD_5, this form of BOD_5 will be the primary focus of the evaluations.

The increase in the concentration of $CBOD_5$ in Okanagan Lake is shown in Table 7.1, for both effluent discharge rates and winter and summer conditions. In this instance, as there are no $CBOD_5$ data available for the lake, it is not possible to predict the resulting final concentration, but it is reasonable to assume that there will be little difference between the resulting concentration and the predicted increase in concentrations, due to the low $CBOD_5$ concentrations which are associated with surface waters and the limitations of the analytical detection limit for this parameter.

The predicted increase in $CBOD_5$ concentrations range from 0.039 mg/L to 0.435 mg/L at the end of the IDZ, and 0.010 mg/L to 0.143 mg/L at the shoreline. The higher concentrations are associated with the summer conditions, due to the lower potential for dilution, as the effluent is trapped under the thermocline. It is reasonable to assume that the current $CBOD_5$ concentrations in the lake are below the detection limit (5 to 10 mg/L, depending on the laboratory used), and in each case, the predicted change in the concentration would not be detectable analytically. Therefore, there would be no resulting change in the quality of water with respect to $CBOD_5$ at the edge of the initial dilution zone or at the nearest shoreline, regardless of whether the discharge occurs in the winter or summer months.

Table 7.1: Predicted Change in Conditions - $CBOD_5$

Distance from Outfall	Summer (stratified) Concentration (mg/L)		Winter (unstratified) Concentration (mg/L)	
	Flow at 16,700 m^3/d	Flow at 10,160 m^3/d	Flow at 16,700 m^3/d	Flow at 10,160 m^3/d
At Edge of IDZ	0.435	0.345	0.053	0.039
At 1,300 m from Outfall	0.143	0.114	0.014	0.010

There are no water quality objectives for $CBOD_5$ for Okanagan Lake, nor are there any water quality guidelines for this parameter. However, there is a relationship between BOD and dissolved oxygen, as BOD has the potential to decrease the dissolved oxygen concentrations as it biodegrades in a natural environment. With respect to dissolved oxygen, the water quality objective for Okanagan Lake relates to the Armstrong Arm only. For the BC Water Quality Guidelines, the dissolved oxygen concentration focuses on the protection of aquatic life and relates to both instantaneous minimum values and 30 day average concentrations, depending on the life stages of fish which are present. For conditions at the shoreline, where spawning is expected to occur around the Vernon Arm, the dissolved oxygen concentration should be ≥ 9 mg/L, with the 30 day mean being ≥ 11 mg/L. For conditions within the water column, the BC Water Quality Guidelines indicate that the concentration should be ≥ 5 mg/L, with the 30 day mean being ≥ 8 mg/L.

In 2012, each month from April to September, the water column was profiled in the vicinity of the City's outfall from the surface through to a depth of 50 m. From these data, the average dissolved oxygen concentrations for each profiling event above the thermocline ranged from 7.9 mg/L to 11.7 mg/L, with the concentration decreasing as the summer progressed. Below the thermocline, the dissolved oxygen concentrations ranged from 11.5 mg/L in April through to 9.4 mg/L in September. There were no records of the concentration being below 5 mg/L and, although the data only relate to a single sampling event each month, there is no reason to believe that the concentration would be lower than 8 mg/L over this time period (April to September), as a 30 day mean. Given the current dissolved oxygen concentrations and the predicted increase in the $CBOD_5$, it is reasonable to assume that the potential for a decrease in the dissolved oxygen concentration in Okanagan Lake as a result of the effluent release is unlikely.

Although the potential for a measurable change in water chemistry is unlikely, it is still possible that there would be a change in the biology, given that Okanagan Lake is a slow moving body of water with a long hydraulic residence time. For a release during the summer, the $CBOD_5$ concentration in the area influenced by the effluent release will be higher than the winter conditions, due to the lower dilution potential, but the effluent will be trapped below the thermocline, where the water temperature will be in the order of 4 to 6 ^{o}C. During the winter, although the effluent is expected to surface, it will be at a lower concentration compared with the summer conditions, due to the potential for increased mixing at this time of year. For both winter and summer conditions, if there are any changes in the lake biology, this would relate to any zooplankton or fish which are living below the thermocline in the summer, and throughout the lake body in the winter, assuming that the zooplankton or fish access the effluent plume. The result would likely be an increase in number and size, as a result of organic matter being present, if there are any changes observed. If there is a change, this could ultimately result in more fish, which are larger in size.

7.3 Total Suspended Solids

For a surface water discharge, such as Okanagan Lake, the following quality criteria apply:

- Under the conditions of the operational certificate, maximum TSS concentration must be less than or equal to 10 mg/L.
- Under the Federal wastewater regulation, the average TSS concentration must be less than or equal to 25 mg/L.

The sewage treatment plant is designed to produce an effluent TSS concentration of less than 10 mg/L. Given the current plant design and that the conditions of the operational certificate are more stringent than the Federal wastewater regulation, the focus will be for an effluent TSS concentration of 10 mg/L, and no further consideration will be made with respect to the Federal wastewater regulation.

The increase in the concentration of TSS in Okanagan Lake is shown in Table 7.2, for both effluent discharge rates and winter and summer conditions. The predicted increase in concentrations range from 0.039 mg/L to 0.435 mg/L at the end of the IDZ, and 0.010 mg/L to 0.143 mg/L at the shoreline. The higher concentrations are associated with the summer conditions, due to the lower potential for dilution, as the effluent is trapped under the thermocline. There were no TSS data available for the 2012 dataset but, given the low concentrations of TSS associated with the effluent, the predicted concentrations as a result of dilution and the typical laboratory analytical detection limits for TSS (e.g. approximately 3 mg/L, depending on laboratory capabilities), it is reasonable to state that, in each case, the predicted change in the concentration would not be detectable analytically. Therefore, there would be no resulting change in the quality of water with respect to TSS at the edge of the initial dilution zone or at the nearest shoreline, regardless of whether the discharge occurs in the winter or summer months.

Table 7.2: Predicted Change in Conditions – TSS

Distance from Outfall	Summer (stratified) Concentration (mg/L)		Winter (unstratified) Concentration (mg/L)	
	Flow at 16,700 m^3/d	Flow at 10,160 m^3/d	Flow at 16,700 m^3/d	Flow at 10,160 m^3/d
At Edge of IDZ	0.435	0.345	0.053	0.039
At 1,300 m from Outfall	0.143	0.114	0.014	0.010

There are no water quality objectives for TSS for Okanagan Lake, but there are water quality objectives for water clarity (as measured by the Secchi disk). These water quality objectives indicate that the average Secchi depth over the growing season should be 6 m. Given the predicted low change in the lake TSS concentration as a result of the effluent release, it is reasonable to assume that there would be no change in the Secchi disk reading as a direct result of the effluent TSS.

There are also guidelines in BC for TSS in surface waters, with the aim being to protect several water uses including aquatic life, recreational use and drinking water sources. With the exception of the protection of recreational use, which relates to a minimum Secchi disk reading of 1.2 m (note this is much lower than the expectations for Okanagan Lake, where direction for higher water clarity has been set), the guidelines relate to an increase over background TSS concentrations (or turbidity), with the acceptable increase also increasing with higher background levels of suspended solids. Given the predicted changes in the TSS concentration, it is reasonable to assume that there would be no concerns with respect to unacceptable changes in any of the guidelines for TSS, regardless of the water use (water source, aquatic life or recreational).

As with $CBOD_5$, although the potential for a measurable change in water chemistry is unlikely, it is still possible that there would be a change in the biology, given that Okanagan Lake is a slow moving body of water with a long hydraulic retention time. This is based on the assumption that the TSS is organic and could be utilised as a food source by zooplankton and fish. For a release during the summer, the TSS concentration in the area influenced by the effluent release will be higher than the winter conditions, due to the lower dilution potential, but the effluent will be trapped below the thermocline, where the water temperature will be in the order of 4 to 6 ^oC. During the winter, although the effluent is expected to surface, it will be at a lower concentration compared with the summer conditions, due to the potential for increased mixing at this time of year. For both winter and summer conditions, if there are any changes in the lake biology, this would relate to any zooplankton or fish which are living below the thermocline in the summer, and throughout the lake body in the winter, assuming that the zooplankton or fish access the effluent plume. The result would likely be an increase in number and size, as a result of organic matter being present, if there are any changes observed. If there is a change, this could ultimately result in more fish, which are larger in size.

7.4 Nitrogen

There are several different forms of nitrogen, of which four will be considered with respect to the proposed effluent release from the City of Vernon: total nitrogen, ammonia, nitrate and nitrite. In addition, further discussion on the potential impacts to the TN:TP will be discussed in Section 7.6.

7.4.1 Total Nitrogen

The sewage treatment plant is designed to produce an effluent with a total nitrogen concentration of < 6 mg/L for discharge to Okanagan Lake. This is consistent with the requirements of the operational certificate (≤ 6 mg/L as total nitrogen). In addition, the water quality objective for total nitrogen for Okanagan Lake in the Vernon area is 0.230 mg/L (maximum). There are no BC Water Quality Guidelines for total nitrogen. In addition, total nitrogen is not a parameter which is regulated under the Federal wastewater regulation.

The predicted increase in the concentration of total nitrogen in Okanagan Lake is shown in Table 7.3, for both effluent discharge rates and winter and summer conditions. The predicted increase in the concentrations range from 0.023 mg/L to 0.261 mg/L at the end of the IDZ, and 0.006 mg/L to 0.086 mg/L at the shoreline. The higher concentrations are associated with the summer conditions, due to the lower potential for dilution, as the effluent is trapped under the thermocline. There is also little difference between a discharge rate of 10,160 m^3/d and 16,700 m^3/d.

Table 7.3 also shows the predicted resulting concentration of total nitrogen, based on the average total nitrogen data from the 2012 dataset. The total nitrogen data from below the thermocline have been used to estimate the resulting total nitrogen concentration in the summer months, as the effluent will be trapped below the thermocline for this discharge scenario. The total nitrogen data from above the thermocline have been used to estimate the resulting total nitrogen concentration in the winter months, as the effluent is predicted to rise to the surface for this discharge scenario. In all cases, the resulting concentration will be above the water quality objective, which is to be expected, considering that the average concentration in the lake is already higher than the objective concentration. There is little difference between the resulting concentrations and the two effluent flow rates. However, there are predicted lower concentrations during the winter months, regardless of the effluent flow rate, due to the higher dilution which is possible during this time period.

The evaluations discussed above and summarised in Table 7.3 focus on the whole dataset from 2012. However, the intent of the water quality objective is to focus on a maximum total nitrogen concentration of 0.230 mg/L at the spring turnover, which is defined as the February to March period for Okanagan Lake (Rae and Wilson, 2006). Although, for 2012, there were no data for the February to March period, there was one data point for above the thermocline and one data point for below the thermocline for the month of April, which has also been included within the time period of the spring turnover (Nordin, 2005). For the both the summer and winter discharge scenarios, and taking the April 2012 data only (0.218 mg/L for the summer discharge and 0.228 mg/L for the winter discharge), the resulting predicted total nitrogen concentration was above the water quality objective in all cases. This was a factor of the measured total nitrogen concentrations being close to the objective concentration and the inability to achieve sufficient dilution.

Table 7.3: Predicted Conditions – Total Nitrogen

Distance from Outfall	Summer (stratified) Concentration (mg/L)		Winter (unstratified) Concentration (mg/L)	
	Flow at 16,700 m^3/d	Flow at 10,160 m^3/d	Flow at 16,700 m^3/d	Flow at 10,160 m^3/d
Predicted Increase Over Current Conditions				
At Edge of IDZ	0.261	0.207	0.032	0.023
At 1,300 m from Outfall	0.086	0.068	0.008	0.006
Predicted Resulting in Concentration Based on 2012 Data				
At Edge of IDZ	0.494	0.440	0.296	0.287
At 1,300 m from Outfall	0.319	0.301	0.272	0.264

The predicted increase in the total nitrogen concentration will result in a concentration of total nitrogen in Okanagan Lake which will be higher than the water quality objective. In terms of water chemistry, given the influences from field and analytical variability, it is likely that the change in the total nitrogen concentration would not be measurable, although this may not be the case for the concentration at the end of the initial dilution zone for summer conditions, due to the low dilution ratio which is expected under these conditions. During the summer months, the effluent will be trapped below the thermocline, compared with the winter where the effluent is expected to move to the surface of the lake. However, in both the summer and winter conditions, any increase in the total nitrogen concentration at the shoreline is expected to have no measurable effect on the water quality, based on the predicted concentration change and the influences of field and laboratory variability. Therefore, no impacts are expected with respect to water quality and shoreline uses (beach or shoreline fisheries resources for the winter when the effluent surfaces and intake/water licences during the summer when the effluent will remain at depth).

Even in conditions when there is no likely measurable change in water chemistry, it is still possible that there would be a change in the biology, given that Okanagan Lake is a slow moving body of water with a long hydraulic residence time. Nitrogen can influence productivity, through increasing algal growth rates which can then indirectly increase in the productivity and mass of zooplankton. Theoretically, these factors can all have the potential to result in enhanced fisheries resources. However, an increase in nitrogen does not necessarily result in an increase in productivity, as phosphorus tends to be the limiting nutrient. Therefore, there is a low potential for the increase in nitrogen to result in biological effects, as long as phosphorus remains the limiting nutrient. This will be discussed further in Section 7.6, in terms of the TN:TP ratio.

7.4.2 Ammonia

Ammonia is the form of nitrogen which is most predominant in raw sewage. Therefore, in sewage treatment plants where there is no treatment for ammonia (i.e. nitrification or biological ammonia treatment), ammonia remains the predominant form of nitrogen in the effluent. For a BNR facility, such as the one utilised by the City of Vernon, the process is designed to nitrify and, therefore, the concentrations of ammonia in the effluent will be low and it is also likely that ammonia will no longer be the predominant form of nitrogen in the effluent.

Due to the potential for aquatic toxicity, ammonia is one of the key parameters of concern for a sewage effluent. Ammonia is present in two forms: ionised and un-ionised, the proportion of which is dependent on pH and temperature. It is the un-ionised form of ammonia which is of particular interest, as this is the form which is toxic to fish. Due to the concerns with ammonia in a sewage effluent, this substance is included in both Provincial and Federal legislation.

For the City of Vernon's sewage treatment plant, there is no stipulated requirement with respect to ammonia in the effluent. Instead, the operational certificate focuses on total nitrogen. This is an expected approach, given the ability of the sewage treatment plant to remove not only ammonia, but also nitrate. With respect to the Federal approach, the Federal wastewater regulation was developed using the principles of the CCME Canada-wide Municipal Wastewater Strategy. The Federal wastewater regulation indicates a National Performance Standard for un-ionised ammonia in the effluent of < 1.25 mg/L. This concentration will ensure that the effluent is not acutely toxic to fish. However, the Federal wastewater regulation also recognises the concept of an initial dilution zone, based on the ability for ammonia to be assimilated within a natural environment. Therefore, in conditions when the effluent is acutely toxic because of ammonia, nitrification is not necessarily required for compliance with the Federal wastewater regulation, as long as a concentration of ≤ 0.016 mg/L as un-ionised ammonia is reached at the end of the IDZ.

Taking the data presented in Table 3.4 regarding the summary of the City's effluent quality (data from 2009 to 2011), the un-ionised ammonia concentration was calculated based on the corresponding pH data and a standard temperature of 15 ^{o}C, which is the temperature used for the LC50 96 hour rainbow trout bioassay. In all cases, the concentration was below the National Performance Standard of 1.25 mg/L, with the calculated concentration ranging from 0.0003 mg/L to 0.0029 mg/L. Therefore, there are no concerns with respect to acute ammonia toxicity and the City's effluent. In addition, all concentrations were below the chronic concentration of 0.016 mg/L, so the effluent would also not be expected to result in chronic toxicity without dilution (note this is comparing effluent ammonia concentrations with corresponding effluent pH and a temperature of 15 ^{o}C. Chronic evaluations are intended to take the environment temperature and pH and evaluate the resulting ammonia concentration after taking into account the background levels for ammonia).

Given the significant rates of nitrification which can be achieved by the City's current process, and the lack of concern with the ability of this effluent to meet a pre-discharge concentration of 1.25 mg/L (as un-ionised ammonia), there will be no further consideration given for ammonia.

7.4.3 Nitrate

For the City of Vernon's sewage treatment plant, there is no stipulated requirement with respect to nitrate in the effluent. Instead, the operational certificate focuses on total nitrogen. There is no requirement in the Federal wastewater regulation with respect to an effluent nitrate concentration.

Nitrate is only found in trace amounts, if at all, in raw sewage. However, in sewage treatment plants where nitrification occurs, there can be a significant increase in the nitrate concentration in the effluent, unless the treatment process is also designed for denitrification. As standard, a BNR plant is designed for both nitrification and denitrification. Therefore, low concentrations of nitrate are found in the effluent. The information in Table 3.4 indicates that, from the 2009 to 2011 dataset, the nitrate concentration in the City's effluent ranged from 1.08 mg/L to 2.20 mg/L, with an average concentration of 1.62 mg/L.

Table 7.4 summarises the change in the lake nitrate concentrations, assuming an effluent nitrate concentration of 2.20 mg/L, which is the maximum concentration for the 2009 to 2011 time period. From the 2012 lake monitoring events, there were no measurements for nitrate directly, but only for combined nitrate/nitrite. These data indicated that the concentrations of nitrate/nitrite ranged from < 0.002 mg/L to 0.031 mg/L in the upper part of the lake and 0.034 mg/L to 0.059 mg/L in the lower part of the lake. There are no water quality objectives for Okanagan Lake for nitrate, but there are water quality guidelines for the protection of different water uses. Even if the most stringent guideline was taken (maximum of 10 mg/L based on drinking water and recreation/aesthetics, or the chronic guideline of 3 mg/L for the protection of aquatic life – which is intended to be a 30 day, not a single concentration), and taking into consideration the nitrate concentrations already present in the lake, the resulting nitrate concentrations in Okanagan Lake as a result of the release are significantly less than the guideline values.

Table 7.4: Predicted Change in Conditions – Nitrate

Distance from Outfall	**Summer (stratified) Concentration (mg/L)**		**Winter (unstratified) Concentration (mg/L)**	
	Flow at 16,700 m^3/d	**Flow at 10,160 m^3/d**	**Flow at 16,700 m^3/d**	**Flow at 10,160 m^3/d**
Predicted Increase Over Current Conditions				
At Edge of IDZ	0.096	0.076	0.012	0.008
At 1,300 m from Outfall	0.031	0.025	0.003	0.002

7.4.4 Nitrite

For the City of Vernon's sewage treatment plant, there is no stipulated requirement with respect to nitrite in the effluent. Instead, the operational certificate focuses on total nitrogen. There is no requirement in the Federal wastewater regulation with respect to an effluent nitrite concentration.

Nitrite is only found in trace amounts, if at all, in raw sewage, but can be produced during both nitrification and denitrification, as it is an intermediate product in both biochemical processes. However, the concentrations of nitrite in the effluent are typically low, unless there is a process upset which is affecting either the nitrification or denitrification process. The information in Table 3.4 indicates that, from the 2009 to 2011 dataset, the nitrite concentration in the City's effluent ranged from < 0.005 mg/L to 0.205 mg/L, with an average concentration of 0.033 mg/L.

Table 7.5 summarises the change in the lake nitrite concentrations, assuming an effluent nitrite concentration of 0.205 mg/L, which is the maximum concentration for the 2009 to 2011 time period. From the 2012 lake monitoring events, there were no measurements for nitrite directly, but only for combined nitrate/nitrite. These data indicated that the concentrations of nitrate/nitrite ranged from < 0.002 mg/L to 0.031 mg/L in the upper part of the lake and 0.034 mg/L to 0.059 mg/L in the lower part of the lake. There are no water quality objectives for Okanagan Lake for nitrite, but there are water quality guidelines for the protection of different water uses, with the most stringent being for the protection of aquatic life. The concentration of nitrite for the protection of aquatic life is based on the chloride concentration. Although there are no chloride data available from the 2012 lake monitoring events, there is a high confidence that the concentrations of nitrite as a result of the effluent release would be below the guidelines for the protection of aquatic life (maximum concentration of 0.06 mg/L and an average concentration of 0.02 mg/L, based on a 30 day average).

Table 7.5: Predicted Change in Conditions – Nitrite

Distance from Outfall	Summer (stratified) Concentration (mg/L)		Winter (unstratified) Concentration (mg/L)	
	Flow at 16,700 m^3/d	Flow at 10,160 m^3/d	Flow at 16,700 m^3/d	Flow at 10,160 m^3/d
Predicted Increase Over Current Conditions				
At Edge of IDZ	0.0089	0.0071	0.0011	0.0008
At 1,300 m from Outfall	0.0029	0.0023	0.0003	0.0002

7.5 Phosphorus

The sewage treatment plant is designed to produce an effluent with a total phosphorus concentration of < 0.25 mg/L for discharge to Okanagan Lake. This is consistent with the requirements of the operational certificate, although the operational certificate also indicates the discharge requirements in terms of maximums, percentiles and level to strive for. The level to strive for is 0.01 mg/L, which was set based on the background total phosphorus levels in Okanagan Lake. Phosphorus is not a parameter which is regulated under the Federal wastewater regulation. There is also a water quality objective for total phosphorus for the Vernon area: 0.008 mg/L as a maximum during the spring turnover.

There is no requirement in the operational certificate or the Federal wastewater regulation with respect to effluent orthophosphorus concentrations. In addition, there is no water quality objective for orthophosphorus for Okanagan Lake, nor is orthophosphorus an identified parameter in the BC Water Quality Guidelines.

The increase in the concentration of total phosphorus and orthophosphorus in Okanagan Lake is shown in Table 7.6, for both effluent discharge rates and winter and summer conditions. For total phosphorus, an effluent concentration of 0.25 mg/L has been assumed, which is the design concentration for the process and the average annual concentration identified in the operational certificate. For orthophosphorus, a concentration of 0.14 mg/L has been assumed, as this was the maximum concentration recorded in the 2009 and 2012 effluent data. The minimum and average effluent orthophosphorus concentrations for this same time period were 0.08 mg/L and 0.10 mg/L, respectively.

The predicted increase in the concentrations is the highest for the summer stratified conditions. For both total and orthophosphorus, regardless of the effluent discharge rate, it is possible that the change in concentration may be detectable analytically, although the influence of field variability would still apply for this discharge scenario. In all other cases, given the analytical variability in addition to the field variability, plus with some concentrations for the higher dilutions being below the analytical detection limit, it is unlikely that the change in the phosphorus concentration would be measureable chemically.

Table 7.6: Predicted Change in Conditions – Phosphorus

Distance from Outfall	Summer (stratified) Concentration (mg/L)		Winter (unstratified) Concentration (mg/L)	
	Flow at 16,700 m^3/d	Flow at 10,160 m^3/d	Flow at 16,700 m^3/d	Flow at 10,160 m^3/d
Total Phosphorus				
At Edge of IDZ	0.0109	0.0086	0.0013	0.0010
At 1,300 m from Outfall	0.0036	0.0028	0.0003	0.0002
Orthophosphorus				
At Edge of IDZ	0.0061	0.0048	0.0007	0.0005
At 1,300 m from Outfall	0.0020	0.0016	0.0002	0.0001

Focusing on total phosphorus, the information presented in Table 7.6 indicates that with the exception of the summer discharge concentrations at the end of the IDZ, all resulting concentrations either at the end of the IDZ or at the shoreline would be below the water quality objective of 0.008 mg/L. However, this does not take into consideration the background concentration of total phosphorus in the lake. Table 7.7 indicates the potential resulting concentration in the total phosphorus levels and assumes the average total phosphorus data from below the thermocline for the summer discharge period and the average total phosphorus data from above the thermocline for the winter discharge period (2012 lake dataset). For the winter data, the resulting concentrations of total phosphorus are below the water quality objective, regardless of whether the concentration is at the end of the IDZ or at the shoreline. For the summer data, the reverse was the case; with the exception of the shoreline concentration for a discharge rate of 10,160 m^3/d where the resulting concentration was the same as the water quality objective, all resulting concentrations were higher than the water quality objective.

The evaluations discussed above and summarised in Table 7.7 focus on the whole dataset from 2012. However, the intent of the water quality objective is to focus on a maximum total phosphorus concentration of 0.008 mg/L at the spring turnover, which is defined as the February to March period for Okanagan Lake (Rae and Wilson, 2006). Although, for 2012, there were no data for the February to March period, there was one data point for above the thermocline and one data point for below the thermocline for the month of April, which has also been included within the time period of the spring turnover (Nordin, 2005). For both the summer and winter discharge scenarios, and taking the April 2012 data only (0.0066 mg/L in both cases), the resulting predicted total phosphorus concentration was above the water quality objective for all summer releases but lower than the water quality objective for all winter releases. However, for the summer releases, the effluent will be trapped under the thermocline, unlike the winter releases when the effluent will move to the surface. In the summer, due to the depth of the thermocline, it is reasonable to assume that there would be a low potential for impacts as a result of the phosphorus concentration. Light penetration through the water column will be a limiting factor for algal growth, and may also be further impeded by the water temperature which will be in the 4 to 6 ^oC range. In addition, the risks to water intakes located at these depths as a result of algal growth would also be expected to be minimal, due to the factors which will restrict algal growth at these depths, even if additional biologically available phosphorus is available. During the winter months, when the effluent will move to the surface, the potential for impacts is also considered to be low. With the cold water temperatures during the winter, both suspended and attached algal growth would be expected to be limited by temperature, with further limitations on the growth of periphyton (attached algal growth) at the shoreline as a result of snow and ice cover.

Table 7.7: Predicted Conditions – Total Phosphorus

Distance from Outfall	**Summer (stratified) Concentration (mg/L)**		**Winter (unstratified) Concentration (mg/L)**	
	Flow at 16,700 m^3/d	**Flow at 10,160 m^3/d**	**Flow at 16,700 m^3/d**	**Flow at 10,160 m^3/d**
Predicted Resulting in Concentration Based on 2012 Data				
At Edge of IDZ	0.0164	0.0141	0.0077	0.0074
At 1,300 m from Outfall	0.0091	0.0083	0.0067	0.0066

7.6 Total Nitrogen to Total Phosphorus (TN:TP) Ratio

The TN:TP is one of the water quality objectives for the north basin, with the objective being a TN:TP > 25:1 based on the spring weight ratio. This focuses on the desire to reduce the risk of the TN:TP reducing to levels which are indicative of nitrogen limitation. This imbalance in the nitrogen and phosphorus concentrations could result in the growth of cyanobacteria, which is not an optimal food source for aquatic organisms. Data from the 2012 dataset indicated that the TN:TP was in the order of 34:1, for the April sampling event which is at the tail end of the spring turnover period.

Table 7.8 summarises the expected TN:TP ratio at the end of the IDZ and at the shoreline for the two effluent releases under summer and winter conditions. Given the requirements of the operational certificate and the design of the sewage treatment plant, it is expected that the effluent TN:TP will be in the order of 24:1, which is just below the objective for this parameter. However, after mixing with the lake water, it is predicted that the TN:TP ratio will increase to the 27:1 to 34:1 range, with all predicted ratios being higher than the 25:1 water quality objective.

Table 7.8: Predicted Changes in the TN:TP Ratio

Discharge Conditions	Total Nitrogen Concentration (mg/L)	Total Phosphorus Concentration (mg/L)	TN:TP
Discharge Rate 16,700 m^3/d			
Summer at IDZ	0.479	0.0175	27:1
Summer at shoreline	0.304	0.0102	30:1
Winter at IDZ	0.260	0.0079	33:1
Winter at shoreline	0.236	0.0069	34:1
Discharge Rate 10,160 m^3/d			
Summer at IDZ	0.425	0.0152	28:1
Summer at shoreline	0.286	0.0094	30:1
Winter at IDZ	0.251	0.0076	33:1
Winter at shoreline	0.234	0.0068	34:1

7.7 Bacteriological Concentrations and Disinfection

7.7.1 Effluent Bacteriological Concentrations

The potential for pathogenic micro-organisms to be present as a result of a sewage effluent release is determined, as standard, by measuring the concentration of faecal coliforms. Faecal coliforms are a sub-group of total coliforms that are associated with faecal material. The development of the use of faecal coliforms as an indicator of faecal contamination was based on the ubiquitous nature of total coliforms in the natural environment and that the presence of total coliforms did not necessarily relate to faecal contamination. The test for faecal coliforms allows the focus to be on the presence of coliforms which are predominantly present in the intestines of humans and/or warm blooded animals. While faecal coliforms may not necessarily result in public health issues, this group of bacteria provide a good indication as to whether there may be other enteric micro-organisms present which may have the potential to cause sickness or disease.

There are limitations with respect to the use of faecal coliforms as an indicator organism, due mainly to the wide number of micro-organisms which are within the faecal coliform group and the potential for false positive outcomes to occur in the data. As a result other bacteria can be used as indicator organisms, with the most common being *E. coli* and *Enterococcus*. As with faecal coliforms, these species have a high probability of being present when there is contamination from faecal material and both the numbers at which these micro-organisms may be present plus their survival rate in a natural environment is reasonable enough for these species to be a suitable indicator organism. However, as these micro-organisms are a single genera rather than a consortium, there is the risk that they may be present in such low numbers that isolation during the indicator test may not be possible, thus increasing the risk that there is an adequate understanding of whether or not there is contamination from faecal material.

With respect to the regulatory approach, faecal coliforms remain the standard for sewage effluents. This is not only the focus of the Municipal Wastewater Regulation, but is also a condition of the City's operational certificate, with the effluent faecal coliform concentration to be ≤ 50 counts/100 mL. With respect to process design, the sewage treatment plant is designed to produce an effluent quality of < 200 counts/100 mL for faecal coliforms, and recent operational data from the 2009 to 2011 time period indicate that the effluent faecal coliform concentration ranged from < 1 through to a maximum of 15 counts/100 mL (average of 4 counts/100 mL over this time period).

There are no requirements for disinfection in the Federal wastewater regulation.

There are water quality objectives set for the Okanagan Lake in the Vernon area. These objectives indicate following criteria:

- For locations near intakes, the faecal coliform concentration < 10 counts/100 mL and *E. coli* < 1 count/100 mL.
- For recreational areas, the faecal coliform concentration ≤ 200 counts/100 mL and *E. coli* ≤ 77 counts/100 mL, both being based on a geometric mean of 5 samples taken over a 30 day period.

The information in Table 7.9 indicates the predicted faecal coliform concentration at the end of the IDZ and the shoreline, for an effluent release of 50 counts/100 mL. In each case, the resulting concentrations are low, regardless of whether the concentration is at the end of the IDZ or whether additional dilution is incorporated for consideration at the shoreline. There are no recent data available with respect to the faecal coliform concentration in the lake, but with these low predicted concentrations, it is reasonable to assume that the water quality objectives would not be exceeded as a result of the effluent discharge from the City of Vernon.

Table 7.9: Predicted Change in Conditions – Faecal Coliforms

Distance from Outfall	Summer (stratified) Concentration (#/100 mL)		Winter (unstratified) Concentration (#/100 mL)	
	Flow at 16,700 m^3/d	Flow at 10,160 m^3/d	Flow at 16,700 m^3/d	Flow at 10,160 m^3/d
At Edge of IDZ	2.17	1.72	0.27	0.19
At 1,300 m from Outfall	0.71	0.57	0.07	0.05

For interest, in order to meet a faecal coliform concentration of 200 counts/100 mL at the end of the IDZ, and assuming that there are no faecal coliforms as a lake background concentration, the effluent discharge at a rate of 16,700 m^3/d would need to be in the order of 4,600 counts/100 mL for the summer conditions and 37,500 counts/100 mL for the winter conditions. This would result in a shoreline concentration of approximately 66 counts/100 mL during the summer and 51 counts/100 mL during the winter. For an effluent discharge at a rate of 10,160 m^3/d, the discharge faecal coliform concentration would need to be in the order of 5,800 counts/100 mL for the summer conditions and 52,000 counts/100 mL for the winter conditions in order to meet a faecal coliform concentration of 200 counts/100 mL at the end of the IDZ. Again, the resulting shoreline concentration would be approximately 66 counts/100 mL during the summer and 51 counts/100 mL during the winter. Therefore, there is a wide safety margin for an effluent criterion which is set at 50 counts/100 mL for faecal coliforms.

With respect to the effluent discharge from the City of Vernon, the risks with respect to faecal micro-organisms would relate to intakes during the summer, as the effluent is trapped below the thermocline, and recreational use in the winter, as the effluent has the potential to surface. However, the risks to public health as a result of recreational use during the winter months are expected to be minimal as a result of the low ambient air and water temperatures.

Unlike the release of chemicals, such as nitrogen and phosphorus, to a surface water, bacteria have the potential to die-off or grow, depending on the conditions which are experienced after release. In most cases, die-off is expected, as faecal bacteria are acclimated to survival in the intestine, not a surface water. Die-off can be a factor of many different factors such as temperature, lack of available nutrients, the inability to compete with indigenous species for nutrients and the effect of UV light. Viruses cannot replicate without being inside a suitable host. Therefore, viruses do not increase in numbers after release to a surface water, but are more likely to die-off through factors such as UV light from the sun. In addition, an infectious dose is required for an illness to occur as a result of ingesting water which contains faecal micro-organisms, on the proviso that the micro-organism capable of causing illness or disease is present. Although the infectious dose varies depending on the type of micro-organism and the health of the potential host, the infectious dose is often in the tens of thousands.

From the above discussion, the resulting faecal coliform concentrations for a discharge of 50 counts/100 mL, plus with an understanding of the factors associated with faecal micro-organisms which can affect public health, there is a low risk associated with a discharge which is consistent with the conditions of the operational certificate.

7.7.2 Use of Chlorine

The City currently uses ultra-violet light for disinfection, however, disinfection can be achieved using different processes. Chlorination is a common process to achieve disinfection, but has been used to a lesser extent due to the technological advances with UV light for the disinfection of sewage effluents and the concerns with respect to the use of chlorine and the risks of toxicity to aquatic life. Both Provincial and Federal regulations include conditions with respect to the use of chlorine for disinfection of sewage effluents.

With respect to Provincial legislation, the Municipal Wastewater Regulation indicates that chlorination must not be used unless other disinfection alternatives have first been considered. In the event where chlorination is used for disinfection, the resulting effluent must be dechlorinated and the effluent total residual chlorine concentration must be less than 0.02 mg/L. Although the

City is in the process of a LWMP review, and there is no mention in the operational certificate with respect to the effluent conditions should chlorine be used for disinfection, it is reasonable to assume that conditions in the MWR would likely be written into an amended operational certificate for the City of Vernon, should chlorine be incorporated into the treatment process for disinfection purposes.

The effluent total residual chlorine concentration is also a National Performance Standard and, therefore, is recognised in the guidance municipal wastewater strategy and in the Federal wastewater regulation. In both cases, the effluent total residual chlorine concentration must be less than or equal to 0.02 mg/L.

Therefore, in the case that chlorination is used for disinfection, dechlorination will be required to ensure that the effluent total residual chlorine concentration does not exceed 0.02 mg/L.

7.8 Miscellaneous Parameters

In addition to the parameters outlined above, there are water quality objectives for Okanagan Lake in the Vernon area with respect to chlorophyll *a*, phytoplankton (community structure and numbers), zooplankton (community structure and numbers) and fish contaminants. Predictions on changes in algal and invertebrate populations are challenging to make, due to the number of variables which can affect their growth. However, with the low concentrations proposed in the discharge, there is a reasonable confidence that there would be no unacceptable change in population for either phytoplankton or zooplankton.

There are no recent data available with respect to fish contaminants, but it is reasonable to assume that, given the nature of a typical sewage effluent, there is a low risk of substances being present which would cause concerns with respect to the tainting of fish flesh or the bioaccumulation within the tissues. Some metals can accumulate within fish flesh, e.g. mercury, but it is unusual to observe elevated concentrations of metals in a sewage effluent, as a result of the tendency of metals to migrate and accumulate in the biosolids.

7.9 Impacts to Sediments

The primary focus of this report is the projected impact on water quality as a result of an effluent release from the City of Vernon. However, brief consideration is made with respect to the sediments in the near vicinity to the outfall.

It is possible that there could be substances associated with the effluent which could accumulate in the sediments around the outfall. These substances could include particulate matter, substances which are hydrophobic in nature and substances which have a natural tendency to move from the aqueous phase to bind with solids, such as metals. The risk associated with an unacceptable accumulation of these substances in the lake sediments is low, due to the low solids concentration of the effluent and the increased likelihood that hydrophobic substances and metals will have already become associated with the sludge in the sewage treatment plant, as a natural part of the treatment process.

It is also possible that microbial growth could occur in the very near vicinity of the outfall, as preferentially, micro-organisms will attach to surfaces (e.g. the lake bottom or outfall structure) as this will increase the survival potential of the micro-organism, due to the tendency for there to be a higher concentration of nutrients at a solid/liquid interface. Again, the risk that the resulting microbial growth would occur to an unacceptable level is low, based on the low solids concentration of the effluent and the low nutrient concentration in the blended effluent/lake water.

7.10 Summary of Recommended Effluent Criteria

For an effluent which is consistent with the requirements of the operational certificate, as indicated below, there is a low risk to unacceptable conditions arising in the Okanagan Lake, for the Vernon area:

$CBOD_5$	≤ 10 mg/L
TSS	≤ 10 mg/L
Total Nitrogen	≤ 6.0 mg/L
Total Phosphorus (annual average)	≤ 0.25 mg/L
Faecal Coliforms	≤ 50 CFU or MPN/100 mL

For an effluent release during the summer months, when the lake is stratified, there is less dilution potential, but the effluent will be trapped below the surface. The greatest risk for an effluent discharge under these conditions would be to intakes, although greater dilution will have been achieved by the time the plume reaches an intake, in the case that there are any intakes in the direction of the plume and at the same depth as the plume. The risks associated for these intakes relate primarily to the presence of faecal micro-organisms. However, the high disinfection rate achieved further minimises the potential of this risk.

For an effluent release during the winter months, when the lake is not stratified, there is a higher dilution potential, but the effluent will likely surface due to the lack of stratification. There are few risks to recreational use, due to the time of year, and it is unlikely that there is a significant risk with respect to the fisheries resources due to the low concentrations of nutrients which are being released, the greater potential for dilution and the low ambient temperatures which will impede the potential for algal growth.

8.0 RELIABILITY CATEGORIES

The City operates under a LWMP. However, conditions outlined in the MWR with respect to the reliability category should be considered. There are three categories outlined in the MWR:

Category I relates to receiving environments which could be permanently or unacceptably damaged through the release of inadequate effluent over the short term. This includes discharges near shellfish waters and recreational waters in which direct human contact occurs.

Category II relates to receiving environments which could be permanently or unacceptably damaged through the continued release of inadequate effluent over a period of several days. This includes recreational waters.

Category III relates to treatment works not otherwise designated as Category I or Category II.

Given the dynamics of the thermocline and the factors affecting the effluent plume through the year, there is a low risk with respect to recreational use as a result of an unacceptable effluent quality over a short period of time. However, the high hydraulic residence time for Okanagan Lake should also be considered. If the City is to rely on a lake discharge as the sole means of effluent management, a category I is recommended, to further protect the Okanagan Lake. If the effluent reuse approach remains a key component of the effluent discharge strategy, a relaxation in the reliability category could be pursued, as there would be the opportunity to divert effluent away from the lake to irrigation in the case of a short-term process upset. The available storage in MacKay Reservoir is an alternative to redundancy for a disinfection process and irrigation is not sensitive to BOD_5, TSS and the presence of nutrients. In fact, the presence of nutrients in irrigation water is beneficial for plant growth, although application rates and the need to manage run-off can become of greater importance. Therefore, if the irrigation approach remains a priority, and the operations are balanced appropriately, it is possible that the treatment facility could be reduced to a reliability category III.

Under the conditions of the operational certificate, for a discharge to Okanagan Lake, the requirement is to have a process which is still capable of full disinfection with one unit being out of operation. This is quite stringent and there may be an opportunity to relax this redundancy requirement, due to the use of MacKay Reservoir and the use of effluent in areas which have restricted access to the public.

9.0 MONITORING RECOMMENDATIONS

Monitoring requirements are outlined in the operational certificate and, for a discharge to a surface water, additional monitoring requirements will come into effect starting in January 2013 with respect to the Federal wastewater regulation. Effluent monitoring recommendations are outlined in Table 9.1, and take into consideration the following:

- Monitoring outlined in the operational certificate;
- The minimum monitoring requirements outlined in the Municipal Wastewater Regulation – Table 12 which focuses on an effluent discharge to a surface water;
- The monitoring requirements from the Federal wastewater regulation; and
- Parameters which have been of specific interest through this environmental impact study process.

Table 9.1: Effluent Monitoring Recommendations – Discharge to Okanagan Lake

Parameter	Monitoring Recommendation
Flow	Daily – using standard automated equipment
Temperature	
pH	
$CBOD_5$	Weekly
TSS	
Total Nitrogen	
Total Phosphorus	
Faecal Coliforms	
Ammonia	Monthly
Nitrate	
Nitrite	
TKN or Organic Nitrogen (note 1)	
Orthophosphate or total dissolved phosphorus (note 2)	

Note 1: Either of these two parameters (TKN or organic nitrogen) is to be measured in the laboratory, which will allow the other parameter to be calculated if ammonia is measured for the same sample.

Note 2: Either orthophosphate or total dissolved phosphorus should be measured to provide an indication of the soluble reactive phosphorus component. The preference is for orthophosphate, as this is the true definition of soluble reactive phosphorus, but it is also important that the parameter measured in the effluent is consistent with any phosphorus parameters that are measured in the receiving environment.

In addition to the parameters outlined in Table 9.1, toxicity testing will become a requirement through the Federal wastewater regulation, starting in January 2015. For the effluent flow rate category > 2,500 m^3/d but ≤ 50,000 m^3/d, toxicity testing in the form of an LC50 96 hour rainbow trout bioassay will be required on a quarterly basis, assuming that there is a continuous release of effluent to Okanagan Lake. A reduced frequency of testing may be possible, if the discharge rate is intermittent. The test methodology can be either the standard LC50 test (EPS 1/RM/13) or the pH moderated test (EPS 1/RM/50). Given the effluent ammonia concentrations, and the low risk of failure if the pH is not moderated, the recommendation would be for the standard LC50 test method to be used, which has the lower cost out of the two test methodologies. Toxicity testing of the effluent is not recommended until this becomes a requirement of the Federal wastewater regulation in 2015.

In addition to effluent monitoring, in 2012, the City also provided a financial contribution to the Okanagan Lake monitoring program, which is administered by the BC Ministry of Environment. If the discharge to Okanagan Lake is to be implemented, it is recommended that the City continues to provide financial support to this monitoring program, in lieu of undertaking a City directed receiving environment monitoring program.

It is assumed that the aim of the existing Okanagan Lake monitoring program is to evaluate the applicability of the water quality objectives and to allow the objectives to be reviewed and updated, as required, in the future. From the data which were received from the 2012 program, the monitoring program is significant and is providing a sound and relevant basis for data on Okanagan Lake. With the potential for an on-going release of effluent from the City of Vernon sewage treatment plant to the lake, the following may also be considered with respect to the lake monitoring program:

- The need to include monitoring through the winter months, if the discharge is to occur during the winter months;
- As the City is regulated for an effluent faecal coliform concentration for discharges to Okanagan Lake, and in recognition that this is one of the water quality objectives for Okanagan Lake, consideration should be made with respect to including faecal coliforms in the monitoring program, although at a reduced frequency compared with other parameters.
- The monitoring program focuses on monthly monitoring frequencies at two different depths during the summer months. Consideration should be made with respect to additional

monitoring during the February/March period in order to assist with any water quality objectives which are based on conditions at the time of spring turnover.

- Consideration should be made as to if and when monitoring for emerging contaminants, such as endocrine disrupting substances, should be implemented. Given the current status of these substances, the recommendation is that no monitoring should be undertaken for endocrine disrupting substances at this time.

The development of a monitoring program is complex and there are many factors to be considered, including the parameters, frequencies and sampling timing and depths. It is understood that not all desires can be incorporated into a monitoring program, as the monitoring program must remain both practical and cost effective to implement.

10.0 SUMMARY AND RECOMMENDATIONS

Dilution analyses were performed to provide an indication of the dilution potential and the factors which will affect mixing between the effluent and lake water. The analyses were completed for combinations of lake conditions, effluent temperatures and discharge rates. The dilution ratio at the end of the IDZ was determined to be between 23:1 and 230:1 for an effluent flow rate of 16,700 m^3/d and between 29:1 and 314:1 for an effluent flow rate of 10,160 m^3/d. In all cases, the available dilution is higher than the minimum 10:1 dilution which is indicated in the BC Municipal Wastewater Regulation. Additional dilution is achieved before the plume reaches the closest shoreline, which is approximately 1,300 m away, if the plume moves in the direction of the closest shoreline. The dilution ratio at the shoreline was determined to be between 70:1 and 820:1 for an effluent flow rate of 16,700 m^3/d and between 88:1 and 1,118:1 for an effluent flow rate of 10,160 m^3/d. These dilution ratios are considered to be conservative, as wind-driven mixing was ignored in the analysis. Wind and waves can easily generate more mixing and increased dilution, regardless of the season.

The highest dilution ratios occur during the winter months, as the lake is not stratified which allows the greater potential for mixing to occur between the effluent and lake water. However, due to the lack of stratification, the effluent is likely to move to the surface of the lake. The lowest dilution ratios occur during the summer months, as the effluent is trapped below the thermocline. However, this means that the effluent will not rise to the surface of the lake in the summer months.

Even though it is recognised that the City is under a LWMP, not the MWR, the outfall assessment was based on the conditions of the MWR, as this is the standard legislation in BC with respect to the discharge of sewage effluents. The outfall assessment indicated that the current outfall location generally satisfies the conditions of the MWR, except with respect to effluent rising to the surface. This condition is unavoidable at this location (or any other location within the lake) during the winter when stratification is absent, but the current outfall location does minimize this condition from occurring.

Modelling was completed in order to determine resulting concentrations of effluent parameters at the end of the IDZ and at the closest shoreline. The assessment was completed for effluent flow rates of 16,700 m^3/d and 10,160 m^3/d for both summer and winter effluent discharge conditions. The assessment indicated that, for an effluent which is consistent with the requirements of the operational certificate, as indicated below, it is unlikely that there would be any negative impacts with respect to these parameters:

BOD_5	≤ 10 mg/L
TSS	≤ 10 mg/L
Total Nitrogen	≤ 6.0 mg/L
Total Phosphorus (annual average)	≤ 0.25 mg/L
Faecal Coliforms	≤ 50 CFU or MPN/100 mL

For an effluent release during the summer months, when the lake is stratified, there is less dilution potential, but the effluent will be trapped below the surface. The greatest risk for an effluent discharge under these conditions would be to intakes, although greater dilution will have been achieved by the time the plume reaches an intake, in the case that there are any intakes in the direction of the plume and at the same depth as the plume. The risk associated for these intakes relate primarily to the presence of faecal micro-organisms. However, with the high disinfection rate achieved, followed by dilution, it is estimated that the increase in the faecal coliform concentration will be less than 1 count/100 mL, at the closest shoreline.

For an effluent release during the winter months, when the lake is not stratified, there is a higher dilution potential but the effluent will likely surface due to the lack of stratification. There is little risk to recreational use, due to the time of year. There is also little risk with respect to the aesthetics, due to the low concentrations of nutrients which are being released, the greater potential for dilution and the low ambient temperatures which will impede the potential for algal growth.

As the condition of the existing outfall and status of diffuser ports (i.e. which ports are functioning) is not known at this time, it is recommended that the City undertake diver inspection of the outfall system. The depth to the tops of the diffusers should also be confirmed during the inspection.

11.0 REFERENCES

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