LARRATT AQUATIC

Attention: Liisa M. Bloomfield, P.Eng., PMP Regional District of Okanagan Similkameen
Proposal for Vaseux Lake – Land Use and Water Quality Assessment 2017-PW-43

The Larratt Aquatic team is pleased to present the following proposal in answer to your invitation. Our project team has provided details on how we would perform the sampling, analytical and reporting components required to produce a study that will serve many planning purposes in addition to meeting the requirements laid out in the RFP 2017-PW-43. We have also provided optional programs for RDOS consideration. These are:

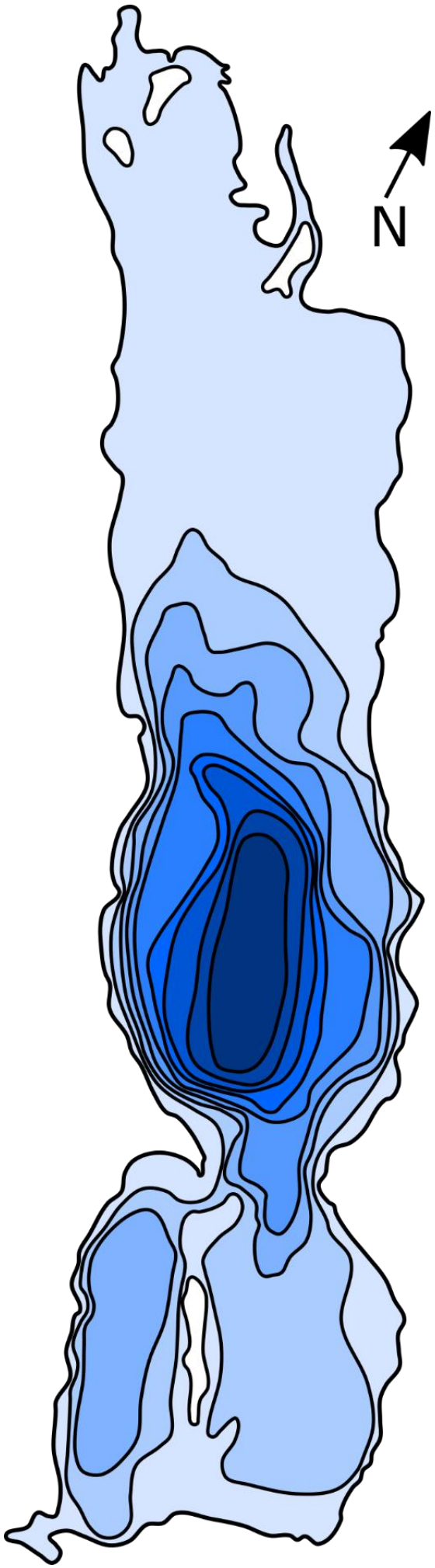
- Full foreshore inventory mapping (FIM)
- Long-term annual sampling proposal

Larratt Aquatic has over 35 years' experience with water quality improvement through altering lake hydrology (lake aeration, algae control, macrophyte control). Thanks to our mine aquatic reclamation work, we have more experience with lake modification and remediation than all other Okanagan environmental firms. LAC has conducted the WWTP Permit sampling of Vaseux Lake since 2013, allowing a unique cost efficiency for RDOS. Ecoscape Environmental Consultants are widely recognized FIM and aquatic macrophyte mapping experts. Mr. Allard has over 30 years of experience as a hydrogeologist, including 18 years as a consultant in the Okanagan. He has worked on several projects within the RDOS area, including many directly for the regional district. All team members consistently complete projects on time and on budget.

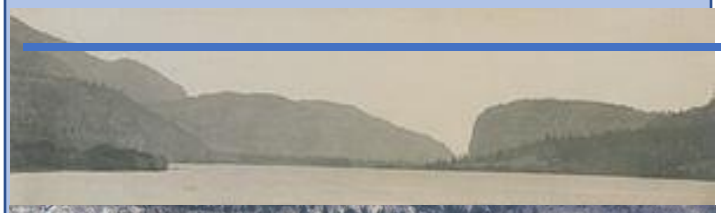
We have the capacity to commence study immediately following contract award in September 2017, to capture the late summer phase in Vaseux Lake. All equipment and supplies are already on hand allowing us to mobilize rapidly. We are pleased to submit this proposal to RDOS. Please feel free to contact us with any questions or for further clarification.

Respectfully submitted,
Larratt Aquatic Consulting Ltd.

Heather Larratt Honors B.Sc., R.P.Bio



Proposal for: Vaseux Lake - Land Use and Water Quality Assessment 2017-PW-43



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1.0 PURPOSE OF STUDY

The main objective of the Vaseux Lake Land Use and Water Quality Assessment is to determine likely sources of nutrients and sediment contributing to the increased milfoil and algae growth observed over the past few years in Vaseux Lake. These four important, interlinked concerns are addressed by the proposal presented here.

In Phase 1, targeted investigations on the interactions between land use and water quality begin. This involves the initial monitoring and sampling program on two dates in 2017-18 to measure the influences of surrounding land uses on the water quality and sedimentation of Vaseux Lake. Phase 2 will involve continued sampling on three dates in 2018, the further development of a Vaseux Lake database, and statistical data analyses. Phase 1 and 2 tasks are summarized in section 2.5 and presented in detail in sections 3 through 7.

1.1 Unique LAC Consulting Team Attributes

We are uniquely qualified to support our sampling program with excellent statistical analyses and to undertake lake remediation under the constrains of the multiple uses of Vaseux Lake. Further, the LAC team includes outstanding GIS and groundwater experts, ensuring a quality product. We have extensive experience successfully implementing lake enhancement techniques. These team attributes will ultimately allow RDOS to address the excessive Vaseux Lake productivity and endorse the lake enhancement plan to address the causes. Additionally, the Team already has all equipment and supplies on-hand and are proficient in their use.

1.2 Deliverables

The deliverables (reports, GIS mapping, database) will become Regional District of Okanagan-Similkameen (RDOS) property. The following are discussed in detail in this proposal.

Interim Phase 1 Report An interim report will be prepared after Phase 1 is complete to allow review of the results thus far and revision of plans for Phase 2 if required. It will be suitable for submission to OBWB as part of their required grant reporting.

Final Report One concise report will be prepared comparing the water quality, sediment quality, sedimentation rates, and milfoil growth results from Phase 1 and Phase 2 of this study to previous results in order to identify areas of significant change and any threats. particularly those arising from land use. The report will present a viable lake enhancement plan and include a 3-page summary report suitable for general audiences. A presentation of this report to Councils or the public will be offered to RDOS as a public service.

GIS Mapping The report will include detailed GIS mapping of Vaseux Lake, sample sites and well/piezometer locations, the later used to sample shallow groundwater. It will locate any contaminant point sources identified in the sampling. Most importantly, a complete map of aquatic plant growth (milfoils, pondweeds, etc) will be prepared by R. Wagner – an innovative GIS specialist.

Database We propose to compile all available water chemistry and limnological data for Vaseux Lake into an Excel (“R” friendly) database together with data arising from this study, Phase 1 and Phase 2. All data entered will be assessed by a data screening tool developed by LAC.

1.3 Fees and Disbursements

The total cost of the proposed work for the Vaseux Study, Phase 1 is **$ 22,745** and for Phase 2 is **$ 17,406**. To meet the requirements of the OBWB Grant Program, all work will be completed and invoicing will be submitted prior to March 31, 2019. Our completion target of January 2019 provides a buffer should the project encounter delays.

The costing of optional program elements can be refined following Phase 1 and 2:
Option 1: Foreshore Inventory Mapping (FIM) **$ 7,170**
Option 2: Long-Term Sampling (2019 onwards**) ~$ 9,013**

Detailed professional fees and disbursements are provided in Section 11

1.4 Schedule

The award date of September 22, 2017 allows for 2 sampling periods (late summer, through ice) in 2017/2018 as part of Phase 1 and 3 sampling periods (ice-off, freshet, summer) in 2018 as part of Phase 2. The Project Schedule is presented in Section 10. This intensive sampling will supply the data needed to provide answers to RDOS' concerns. The data analyses and development of recommendations, preparation of the final report by January 2019 will be a priority.

1.5 Project Consulting Team

Consulting Team: The Consulting Team will consist of the following:
Larratt Aquatic: Jamie Self, Heather Larratt
Ecoscape Environmental: Jason Schleppe, Rob Wagner, Mike Schutten
Piteau Associates: Remi Allard

Resumes: Brief resumes for each team member are provided in Appendix 1 and full CV's are available upon request. While we do not expect the need for this, Project Team members will only be replaced with the written approval of the Regional District.

Project Manager: Heather Larratt will act as Project Manager. She will be responsible for professional supervision of this project and will be the primary liaison with RDOS. Report signoff will include H Larratt 1st Hons. B.Sc. RP Bio, J. Schleppe M.Sc. RP Bio, and Remi Allard P.Eng, M.Eng.

Ownership: We agree that all background materials owned by the RDOS together with the Project reports and database will remain solely its property and should not be disclosed by the consultant team without express written permission. We further commit to not disseminating reports we may author on behalf of RDOS at any time without express written permission.

Conflict of Interest: There are no actual or potential conflicts of interest between RDOS and the consulting team. Existing business relationships include the WWTP discharge sampling performed by LAC for RDOS from 2013 to present, however this work is not in conflict with the RFP works, but compliments it.

Terms and Conditions: We accept all the terms and conditions set out in the RFP, including those that follow and that are included in all appendices and any Addenda. We do not require modifications and /or deletions to the terms and conditions set out in the RFP.

1.6 Consultant References

1.5.1 Larratt Aquatic Consulting Ltd. (LAC):

- Dr. Mike Sokal Ph.D. Environmental Impact Assessment Biologist Ph: 250-490-2284 Mike.Sokal@gov.bc.ca (LAC has conducted complex monitoring programs, and statistical analyses on behalf of BC MoE)

- Peter Martell P.Chem Superintendent of Environment and Community Affairs, Highland Valley Copper (HVC) Peter.Martell@teck.com Ph: 250-523-3518 (LAC is the aquatic reclamation specialist for HVC)

- Zee Marcolin, P.Eng. Manager – Utility Operations GVW Ph: 250-550-3660 zee.marcolin@rdno.ca (LAC has conducted long-term sampling and assessment of Kalamalka Lake for RDNO)

- Greg Buchholz Director of Infrastructure Services; Ph: 250-766-6677 gbuchholz@lakecountry.bc.ca (LAC has resolved water quality issues for Lake Country)

- Ed Hoppe B.Sc., P.Chem. Water Quality and Customer Care Supervisor City of Kelowna Ph: 250-470-0686 ehoppe@kelowna.ca (LAC did emergency lake monitoring of sediment deposition following a watershed failure)

1.6.2 Ecoscape Environmental Consultants Ltd.

- Tracy Thomas, Assistant Regional Manager, Thompson Fraser Basin Council Ph: 250-314-9660 tthomas@fraserbasin.bc.ca

- Todd Cashin, Subdivision, Agriculture, and Environment Services Manager, City of Kelowna Ph: 250-469-8470 tcashin@kelowna.ca

- Bob Harding, Habitat Partnership and Stewardship Coordinator, Fisheries and Oceans Canada Ph: 250-851-4918 Bob.Harding@dfo-mpo.gc.ca

- Sangita Sudan, Development Services Manager, Regional District Central Kootenay Ph: 250-352-8157 SSudan@rdck.bc.ca

1.6.3 Piteau Associates:

- Mr. Sky Thomson, FLNRO Penticton, phone: (250) 490-8276,
  Email: Skye.Thomson@gov.bc.ca

- Mr. Stephen Juch, Subdivision Supervisor, RDOS, phone: (250) 490-4133 ,
  Email: sjuch@rdos.bc.ca

- Mr. Nelson Jatel at Okanagan Basin Water Board, phone: (250) 469.6295,
  Email: nelson.jatel@obwb.ca

1.7 Consultant Experience

1.7.1 LAC

Long-term Water Quality Trends, Nutrient Budgets, and Cyanobacteria Blooms as they Affect the Kokanee Fishery of Wood Lake For: BC MoE and BC FLNRO 2016

This report answers questions posed by MoE surrounding the issue of nutrient loading including: calculation of a nutrient budget for Wood Lake; determining short term and long term water quality trends; quantifying the relationship between nutrient loading and cyanobacteria blooms; calculating historic baselines to assist development of future site-specific water quality objectives; and calculating the kokanee carrying capacity of Wood Lake. In this study, internal phosphorus loading was found to account for up to 99% of the annual bioavailable phosphorus budget, and this internal loading is a major contributor to Wood Lake cyanobacteria blooms. LAC determined that the 2011 kokanee die-off occurred because the anaerobic zone occupied over 50% of the entire volume of Wood Lake, due to late ice-off and cyanobacteria blooms from 2009-2011.

Near-Shore Water Quality and Periphyton Production in the Cosens Bay Cottage Development Area of Kalamalka Lake, YEAR II, 2015 For: RDNO

This BACI (a statistical design using before/after and control/impacted sampling) study determined that the impact of cottage development on Cosens Bay water quality was minor and not statistically significant, using two years of water chemistry and periphyton samples. Periphyton (attached algae including filamentous green algae) production is more sensitive to environmental change than water chemistry. LAC determined that the impact of the current level of cottage development on the near-shore area periphyton during the summer high-use period was measurable but not disruptive of community structure. Similarly, near-shore effects on nutrients, pH, turbidity were detected, but generally, the results from Cosens Bay were within the range seen in the main lake volume. Water quality results did not show significant differences between Cosens Bay foreshore and the control foreshore of Kalamalka Lake Provincial Park.

Aquatic Research and Reclamation of Highland Valley Copper Mine Ponds and Assessment of Adjacent Lakes - 2016 Report For: Teck - Highland Valley Copper

LAC has been the aquatic research and reclamation consultant for HVC for over 18 years. Aquatic research and reclamation at HVC is focused on developing techniques for converting water bodies left by mining to valuable habitat that also improves water quality. This work involves: determining the factors controlling microflora production in pit lakes to increase their bioreactor and fishery capability; developing passive sulphate-reducing bacteria treatment, evaluating the benefits of a non-mixing bottom water layer to pit lake bioreactor function; planting and monitoring riparian plots and trialing planting strategies in seasonally wetted areas and tailings ponds; determining the impact of incomplete spring overturn at various HVC lakes. Background research involves limnology, water chemistry, tailings piezometers, plant tissue chemistry, microcosms, sediment coring, microflora identification, etc.. Cost-effective techniques (nutrient or growth factor additions, artificial upwelling, bio-rafts and plant or invertebrate introductions) were successfully developed and achieved long-term benefits.

Logan Lake Enhancement Research and Plan 2008 For: District of Logan Lake

Like Vaseux Lake, Logan Lake is a small, shallow lake, with extensive shallows. It is a mildly eutrophic, phosphorus-limited lake that experiences nuisance filamentous algae production among the extensive native milfoil beds located at both ends of the lake. The full range of available lake management techniques were reviewed and a management plan developed. For example, nutrient removal by sediment capping, alum or iron treatment; and aquatic plant management by substrate barriers, rototilling, and winter draw-downs were evaluated. LAC identified the exclusion

of game fish from the weedbeds due to high daytime water temperatures and low nighttime dissolved oxygen concentrations in Logan Lake.

1.7.2 Ecoscape

Central Okanagan Wetland Inventory and Management Strategy
for: Okanagan Basin Water Board/BC Wildlife Federation

Ecoscape developed a new GIS-based application to carry out detailed wetland inventories, classifications, and evaluations. Using this new application, Ecoscape completed an extensive inventory, classification, evaluation and mapping project covering over 200 wetlands and associated low flood bench riparian sites within the municipal boundaries of the City of Kelowna. The primary objectives of this project were to identify, inventory, and map all wetlands and habitat features within the municipal limits of Kelowna for incorporation into existing development permit mapping. The methodology and development of a wetland-specific database was designed by Ecoscape to incorporate spatial and biological data with assessment of the functional condition of the various wetland types. This data collection and database design concept can be applied to any inventory project. It allows a more integrated approach to local resource management and planning.

Source Water Assessments
For: District of Lake Country, South East Kelowna Irrigation District

Ecoscape carried out watershed assessments to identify and characterize intrinsic and anthropogenic hazards within three Okanagan watersheds. These assessments were comprehensive, including elements of watershed condition, forestry, recreation, land ownership, livestock, etc. The effect of all identified parameters was critically evaluated for their impact on water quality and water quantity. Assessment responsibilities included field inventories, stakeholder coordination/liaison, orchestrating public meetings, data analysis, interpretation, and report preparation.

Sensitive Habitat Inventory and Mapping (SHIM and Foreshore Inventory mapping (FIM))
For: Various levels of government

Ecoscape has mapped over 2,500 km of shoreline and watercourses within BC for municipal, provincial, and federal clients including the District of Squamish, Fisheries and Oceans Canada, City of Kelowna, Regional District Central Okanagan, Regional District Central Kootenay, Regional District Okanagan-Similkameen, Okanagan Collaborative Conservation Program, and the Columbia Shuswap Regional District. Subsequent to completion of these inventories, Ecoscape has authored comprehensive Watercourse Catalogues and Watercourse Habitat – Condition Evaluations and completed restoration analysis using the data to identify priorities and functional specifications.

Large River Inventory and Mapping and Aquatic Habitat Index (Eagle River, Lower Shuswap River, South Thompson River, Lower Nicola River) For: Department of Fisheries and Oceans/Splatsin First Nation/Fraser Basin Council

Ecoscape developed a new GIS-based application adapting Sensitive Habitat Inventory and Mapping (SHIM) standards to carry out detailed large river inventories, classifications, and evaluations. Using this new application, Ecoscape has completed comprehensive inventories, classification, evaluation and mapping of the Lower Shuswap River, Eagle River, and South Thompson River. The primary objectives of these projects are to identify, inventory, and map the river morphology, riparian and floodplain communities, and habitat features (including salmonid spawning areas) within the river(s). Subsequent to the collection and processing of field data, Ecoscape developed an Aquatic Habitat Index which is now being used by Fraser Basin Council, the Department of Fisheries and Oceans Canada, and Provincial and Municipal governments as well as First Nations.

1.7.3 Piteau

Review of Ambient Groundwater Quality Monitoring Networks in the Okanagan/Kootenay Region for the Ministry of Forests Lands and Natural Resource Operations. Mr. Allard was the project manager and principal hydrogeologist on this project completed in 2011. The work included detailed spatial and temporal analysis of several years of water quality data collected by the province and recommendations to optimize sampling networks for three aquifer areas including Grand Forks, Oliver/Osoyoos and Eagle Rock.

Groundwater Supply Potential for OCP Update For Electoral Area D1. Mr. Allard was the project manager and principal hydrogeologist on this project completed in 2014. The work included the development of preliminary water budgets for all catchments within the electoral area and comparison against current levels of groundwater use to derive estimates of areas where groundwater use was under or over developed.

Okanagan Water Supply and Demand Project – Groundwater Objectives 2 and 3. Mr. Allard secured this work and initiated the project as team leader, project manager and principal hydrogeologist in 2009. The work involved the development of preliminary water budgets for all catchments within the entire Okanagan Basin.

1.8 Safety Plan, WCB, Insurance

Safety The consulting team all have exemplary safety records and detailed safety plans, available upon request, and the consulting team will meet or exceed at all times, the requirements as detailed in the RDOS Health & Safety Manual. Prior to any onsite work, safety plan reviews and a safety tailboard will take place.

WCB All members of the consulting team are in good standing with WCB, and letters of clearance are available.

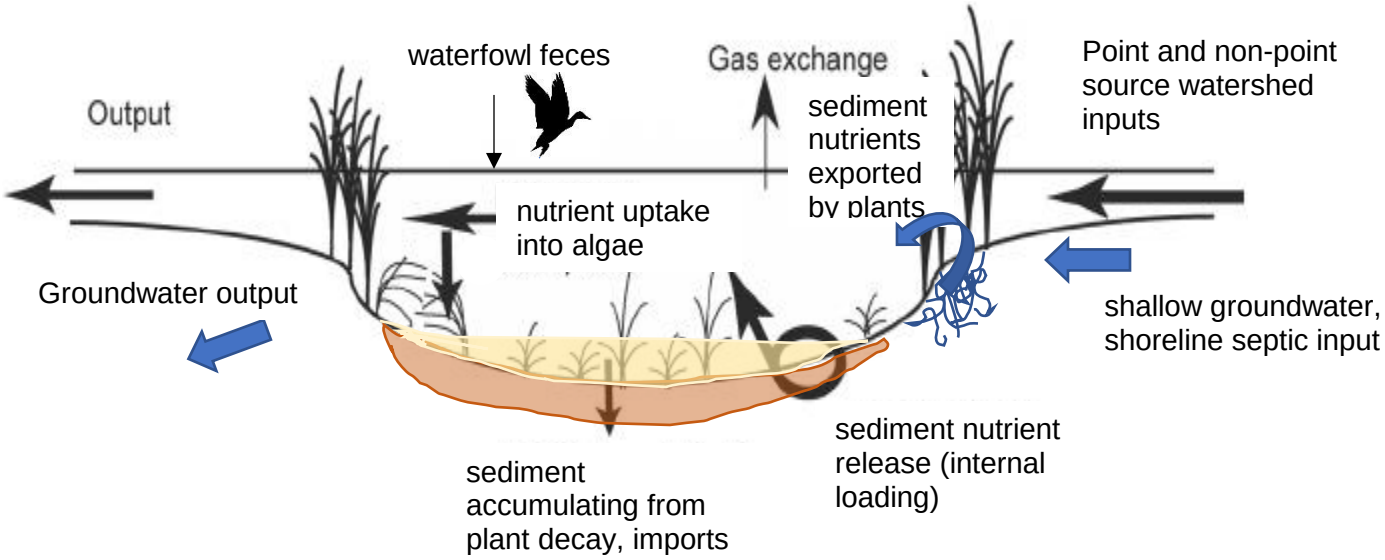
Insurance Comprehensive General Liability Insurance with insurance limits of not less than $ 5,000,000.00 is carried by Larratt Aquatic Consulting Ltd., Ecoscape Environmental Consultants Ltd. and Piteau Associates. All three firm's insurance are inclusive per occurrence for bodily injury and property damage and shall include coverage for: 1. premises, activities and operations liability 2. blanket contractual liability 3. cross liability 4. contingent employer's liability 5. owners and consultants protective liability 6. employees as additional insureds 7. personal injury 8. broad form loss of use 9. owned and non-owned automobile liability 10. The Regional District would be named as an additional insured upon contract award.

1.9 Study Background

Vaseux Lake is a small, productive lake, located near the downstream end of the Okanagan Valley mainstem lakes. Its extensive shallows support excessive growth of the introduced and invasive Eurasian water milfoil (*Myriophyllum spicatum*) and filamentous green algae. It functions as a migratory bird sanctuary, a wildlife area, a fishery and recreation resource. Problems with excessive milfoil and algae growth in Vaseux Lake were reported back into the mid-1970s (Figure 2), but increasing sedimentation near the mouth of the lake has been observed in recent years and the productive growth seems to be increasing again according to long-time residents. Milfoil control using rototilling was discontinued about a decade ago and may be contributing to the perceived increase (J. Littley OBWB pers comm).

While imported nutrients and sediment can trigger nuisance growths, nutrient enrichment trials conducted in the 1970's concluded that, "Vaseux Lake has always been a productive lake and the extensive weed growth covering much of the lake's surface will remain an integral part of the lakes' environment regardless of a varying nutrient input from Okanagan River." (OBA, 1973). This apparent contradiction can be resolved by calculating a nutrient budget. Figure 1 depicts a shallow lake nutrient budget. This study will estimate point source and non-point source external loading from shoreline activities, upstream sources, etc. and from internal loading from anaerobic sediment release, plant export, etc.

Figure 1: Graphic of Vaseux Lake nutrient-sediment budget

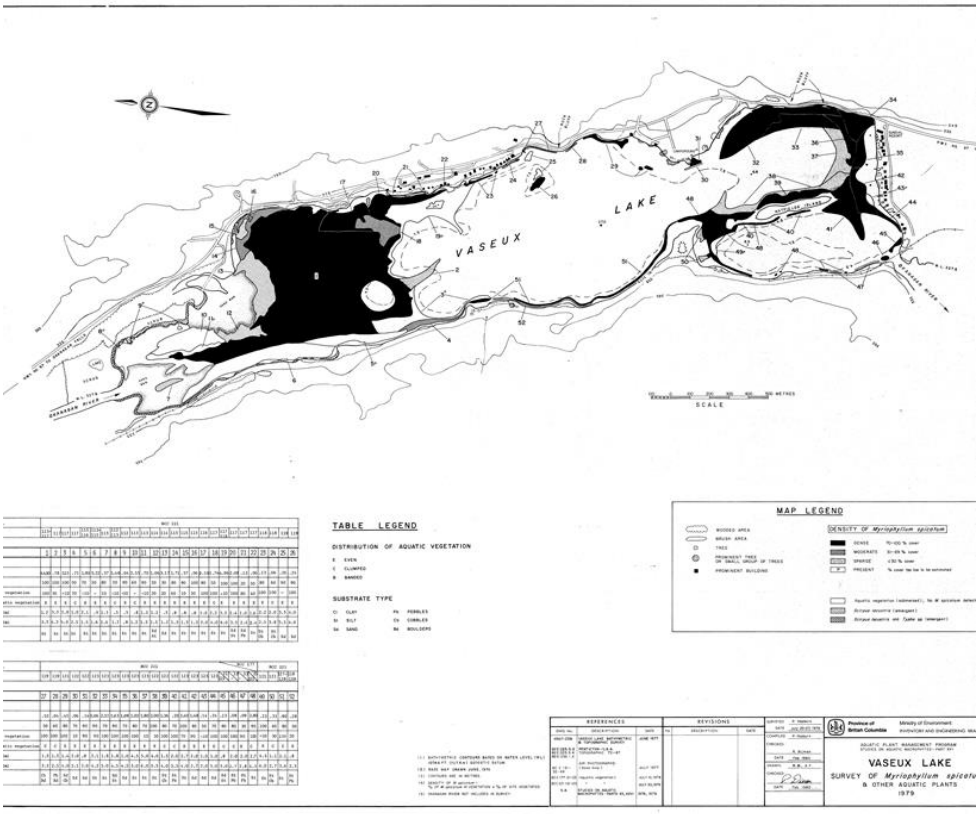


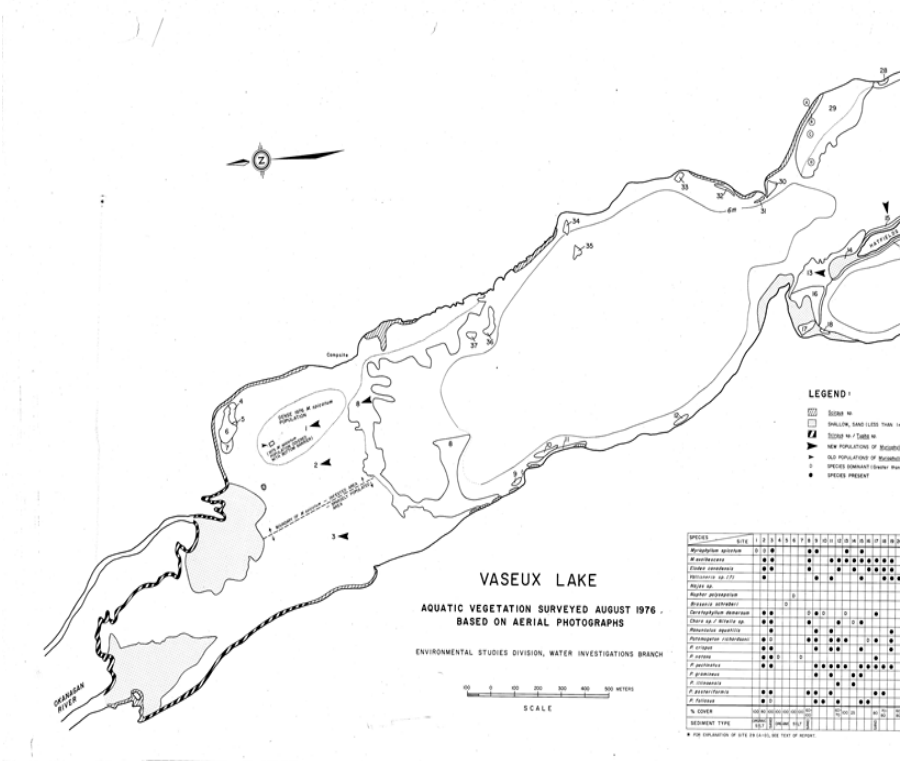
The nuisance production of invasive milfoil and filamentous green algae cause numerous problems including: accelerating lake infilling with organic sediment, slowing water movement in summer, reducing available fishery habitat (water in weedbeds too hot) and increasing the nutrient budget, thus creating a negative cascade.

Although the gradual infilling of productive lakes is a natural part of the lake aging process, a warming climate and increasing development in the Okanagan can unduly accelerate this process. We have designed a monitoring program to identify water quality, sedimentation and plant growth trends, identify the causes of the increased nuisance growths and provide options

for lake enhancement. The enhancement goals include reducing or reversing the excessive milfoil/algae growth and sedimentation rates in Vaseux Lake.

Figure 2: Examples of Historic Aquatic Plant mapping from 1970's





2.0 METHODOLOGY

2.1 Environmental Protection

Methods required by Vaseux Lake's environmental sensitivity include extensive use of rowing (observing boat motor ban for Bird Sanctuary) and not disturbing nesting, or migratory resting areas, as well as not creating navigation or entanglement hazards with sample gear.

We voluntarily decontaminate all boats and gear before using them at every lake, and will both ensure that our gear is clean of aquatic invasive species before and after field work at Vaseux Lake.

2.2 Utilizing Existing Reports and Information

As part of preparing this proposal, LAC has conducted an exhaustive review of information sources to allow focus on information gaps, and avoid redundant sampling. Many reports are available on the Vaseux watershed and these provide important background data and information to this study, streamlining the effort and sampling costs. For example, the Okanagan Basin Agreement (1973) conducted exhaustive studies on nutrient loading and concluded that the nutrient loading to Vaseux Lake was primarily from upstream sources and from septic fields, and not from agriculture or forestry. This information is dated, but still holds true, and allows us to focus our efforts in developing a nutrient budget for the lake. More examples are provided in the Literature Cited for this proposal.

The RFP encouraged review of the Swan Lake study (WWAL 2016) and it focussed on measuring the influences of surrounding land use on water quality in Swan Lake, particularly, any influence from sewerage disposal systems. The WWAL concept of initial reconnaissance sampling with a focused program moving forward was a good approach. The reliance on chloride as a conservative ion that can be used to broadly assess anthropogenic influence is also appropriate and widely employed in limnology. There were some shortcomings in the Swan Lake study that we propose to rectify, principally, we will collect sufficient water chemistry samples with QA/QC samples to support statistical analyses, trend analyses, and spatial analyses.

The RFP program for Vaseux Lake incorporates more elements than the Swan Lake RFP did, including evaluation of siltation rates, mapping of milfoil growth/expansion and filamentous green algae populations. Thus, we propose to sample sedimentation quantity and quality, and map aquatic plant density in addition to water sampling. Our proposed methods are detailed in the following sections 3 through 7.

2.3 Data Needs from RDOS

The Consulting Team will seek clarification from RDOS on which of the ~65 residences on the Vaseux foreshore are seasonal or year-round, and those known to be on septic (sewer not expected). If any, stormwater outfalls, and pending development permit information will be requested.

2.4 Utilizing Existing Water Quality Data

Larratt Aquatic already performs the required monitoring of water quality on Vaseux Lake as a condition of the BC MoE Permit to Operate for the Okanagan Falls Wastewater Treatment Plant. It involves monthly sample collection and in-field monitoring from ice-off through November (ice-on) at the sample site located near the deepest area of Vaseux Lake (Figure 3). The water quality parameters already collected for the WWTP Permit are provided in Table 2.4-1. This monthly data can be used to monitor lake dynamics without additional work under the Vaseux Lake

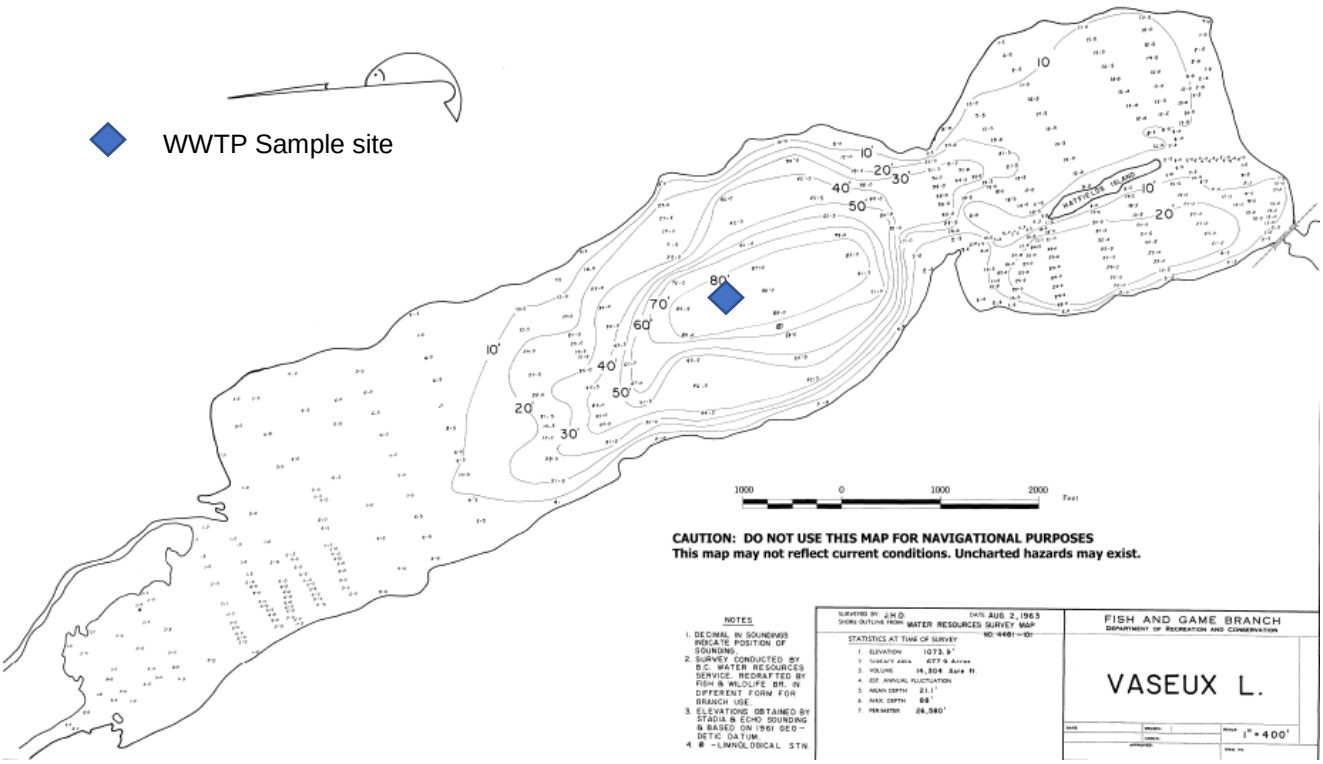
Assessment. For statistical rigor, sampling in the Vaseux Lake Assessment will coincide with the Permit sampling. This can also save analytic costs. For example, hardness from the Permit study can be used to calculate metal toxicity in this study. In some cases, Larratt Aquatic could perform sampling for both projects on the same field trip(s) for added cost efficiency. Additionally, BC MoE (Penticton) has an extensive database of Okanagan Basin water quality that can be used to determine loading from upstream lakes.

Table 1: Water quality parameters collected monthly for the WWTP project

Analysis	Detection Limit
Chlorophyll-a	0.1 ug/L
Phosphorus, Total (persulfate)	0.002 mg/L
Phosphorus, Dissolved (persulphate)	0.002 mg/L
Phosphorus, dissolved reactive	0.005 mg/L
Nitrogen, Total (TKN+NO2+NO3)	0.05 mg/L
Nitrogen, Organic (TKN-NH3)	0.05 mg/L
Nitrogen, Inorganic (NO2, NO3, NH3)	
Chloride	0.1 mg/L
Sulphate	1.0 mg/L
Total Metals + Hardness	Various

Each WWTP field trip generates 2 sets of water quality samples (1,5,10 m composite (above thermocline) and 20,22,24 m composite (below thermocline). It is vital that both water layers be sampled separately and as composites to obtain high quality data.

Figure 3: Bathymetry of Vaseux Lake, showing existing sample site



2.5 Proposed Study Overview

RDOS wants solutions to the interrelated Vaseux Lake issues with eurasian milfoil, filamentous algae, nutrient loading and sedimentation. We have included sufficient water, groundwater, sediment and aquatic plant sampling to support thorough statistical analyses. Without this, a case for causation cannot be made. We will bring these results to bear on identifying feasible management techniques and developing a Vaseux Lake management plan as part of the final report.

The next two bullet sections outline the proposed work, described fully in sections below.

PHASE 1

- initial reconnaissance sampling of Vaseux Lake perimeter water quality to identify point-source loading (60+ sites), using multi-meter
- installation of drive point piezometers to measure shallow groundwater solution chemistry (6 piezos)
- multi-meter profiles to measure horizontal extent of anaerobic zone under summer stratification and winter ice cover
- installation of thermistor line (TidBit Temp/light loggers) in deepest area (5 depth loggers) and within/outside aquatic plant beds (6 loggers)
- 1st water quality sampling in late Sept 2017 (20 composite samples)
- triplicate sediment core sampling (8), install sediment gauges (6), sediment traps (6)
- weed mapping in GIS of entire lake, filamentous algae mapping, sampling and identification
- survey for upstream sediment sources (bank instability, creek failures)
- Vaseux perimeter land use inventory, and land use ground truthing
- 2nd through-ice water quality sampling and profiles (winter sampling safety precautions)
- calculate water balance
- conduct climatic, geologic review
- conduct detailed hydrogeologic assessment using well logs, samples, piezometer samples
- build Vaseux Lake database
- GIS map production of a) sample sites b) point-sources c) aquatic plant beds
- initial data analysis
- Phase 1 interim report

PHASE 2

- 3rd water quality sampling (ice-off) and multimeter profiles
- 4th water quality sampling (freshet) and multimeter profiles
- 5th water quality sampling (summer) and multimeter profiles
- complete updating of database
- determine chloride loading, nutrient loading
- calculate nutrient/Cl/metal budgets for Vaseux Lake
- measure sediment traps, gauges, submit samples
- complete all statistical data analyses
- identify solutions for Vaseux milfoil, algae, nutrient, sediment issues
- submit draft final report with recommendations, Vaseux Lake Remediation Plan, summary report for RDOS review
- submit final report, mapping, database in January 2019

3.0 PROPOSED STUDY COMPONENTS – PHASE 1

3.1 Water Quality Sampling – Phase 1

3.1.1 Initial reconnaissance sampling

A Hannah multi-meter with GPS will be used at 50 – 60 perimeter sites to identify areas of interest for more intensive sampling, such as sample sites for piezometers (shallow groundwater), point-source loading sites and lake sample sites. Anticipated sample sites are presented in Figure 3.1-1. The multi-meter parameters include: pH, temperature, dissolved oxygen, conductivity and total dissolved solids. This information will be added to the Vaseux database to be created for RDOS The profiles will help define water layering.

We will also use the multimeter to collect up to 5 depth profiles in September. This will define water layering and the lateral extent of the anaerobic zone. The seasonal behavior of the water layers will be determined from the WWTP Permit sampling at no cost to this study. We located one August thermal survey from 1967 that showed a thermocline at 8.3 m with oxygen depletion to 3 mg/L below the thermocline. We can compare 2015-2017 summer profiles to this one.

Temperature/Light Loggers: Thermal layering will be confirmed by the addition of anchored line of 5 temperature/light loggers at the deepest point in the lake. Additional logger pairs (6) will be anchored inside and outside dense aquatic weedbeds to detect elevated water temperatures. In many of our studies of shallow lakes, the temperature in these weedbeds are warmer than outside the weedbeds and can exceed fish tolerances during hot summer days.

3.1.2 Main sampling program

Using the reconnaissance sampling, ~ 20 sites will be selected for water quality sampling in late September 2017. These will include those sites with the highest apparent impacts, and areas of greatest vulnerability (e.g., stormwater discharge, vicinity of septic disposal, weedbeds). Background samples should be collected from Park areas of Vaseux Lake that are undeveloped and these compared to samples collected from the two residential areas. To keep costs down, the used of composited samples each consisting of 3-5 subsamples will be utilized. This will quantify the harm invasive milfoil can do to fishery habitat.

The following planned sample site scheme is depicted in Figure 4:

- **3 Inflow/Outflow samples** Okanagan River 100m upstream and 100 m, 500 m downstream of WWTP discharge samples are already collected by RDOS staff, and this monthly data will be valuable in the Vaseux Lk Assessment. We will collect 2 inflowing creeks at mouth (both have agriculture in their immediate watersheds) (2) and Vaseux Lake outflow (1). *These samples are vital for calculating nutrient and metal/chloride mass balances***.** We anticipate that the creek samples can be dropped in future work if their loading rates are low
- **5 Shallow groundwater** Five drive point piezometers would be installed and the elevation of the top of each measured by Trimble to the nearest cm; (2) in both residential foreshore areas and (1) to act as a control in the undeveloped park area. *These will detect impacts from long-term septic disposal on shallow groundwater solutions and facilitate calculation of nutrient budgets for the lake.*
- **1 Well** There are several wells along the perimeter of Vaseux Lake and more located in adjacent uplands. There may be access to a well for sampling. *Piteau can use well log data to determine hydraulic gradients and K values for the hydrogeologic assessment.*
- **2 Residential area - littoral samples** (1) one composite of 5 subsamples in the east residential development and (1) one composite of 5 subsamples in the south residential

development. *These may detect diluted impacts from long-term septic disposal or landscape fertilizing and help define the relative impact of the residential developments*

- **1 Park area - littoral samples** (1) one composite of 5 subsamples from the west undeveloped shore to act as a foreshore control sample. *In any BACI statistical design, control samples are essential to discerning changes to the system*
- **2 Main lake volume – pelagic samples** (1) one depth integrated composite sample collected from 4-6 m deep mid-lake area, and utilizing the upper (epilimnion) composite sample collected for the WWTP Permit study. *These samples can act as a control for littoral samples and for aquatic plant bed samples.*
- **4 Aquatic plant beds -** (3) composited samples from northern dense beds and (1) sample from southern dense beds. *Rooted aquatic plants obtain most of their nutrients from the sediment and nutrients imported with sedimentation stimulate their growth. Plants with diffuse leaves such as milfoil can actually pump nutrients from the sediments into the water column, where they stimulate filamentous algae growth. We can detect this with composite samples drawn from the upper 2 meters of the water column in dense plant beds.*
- **2 not-yet identified point source locations** These sites may arise from the initial sampling, such as highway stormwater ditch discharges. *Point-source discharges can be concentrated and can be one of the easiest water quality issues to rectify.*
- **3 QA/QC** For Phase 1, two duplicates and one blank sample will be submitted as per BC MoE study guidelines.
  Total = 20

Between Phase 1 and 2, we would conduct 5 sampling field trips (late summer overturn 2017, through-ice 2017/18, ice-off 2018, freshet 2018, and summer 2018) at the Vaseux sites to allow sufficient data for statistical analyses.

Figure 4: Proposed Sample Sites for Vaseux Lake Assessment, Phase 1 and Phase 2

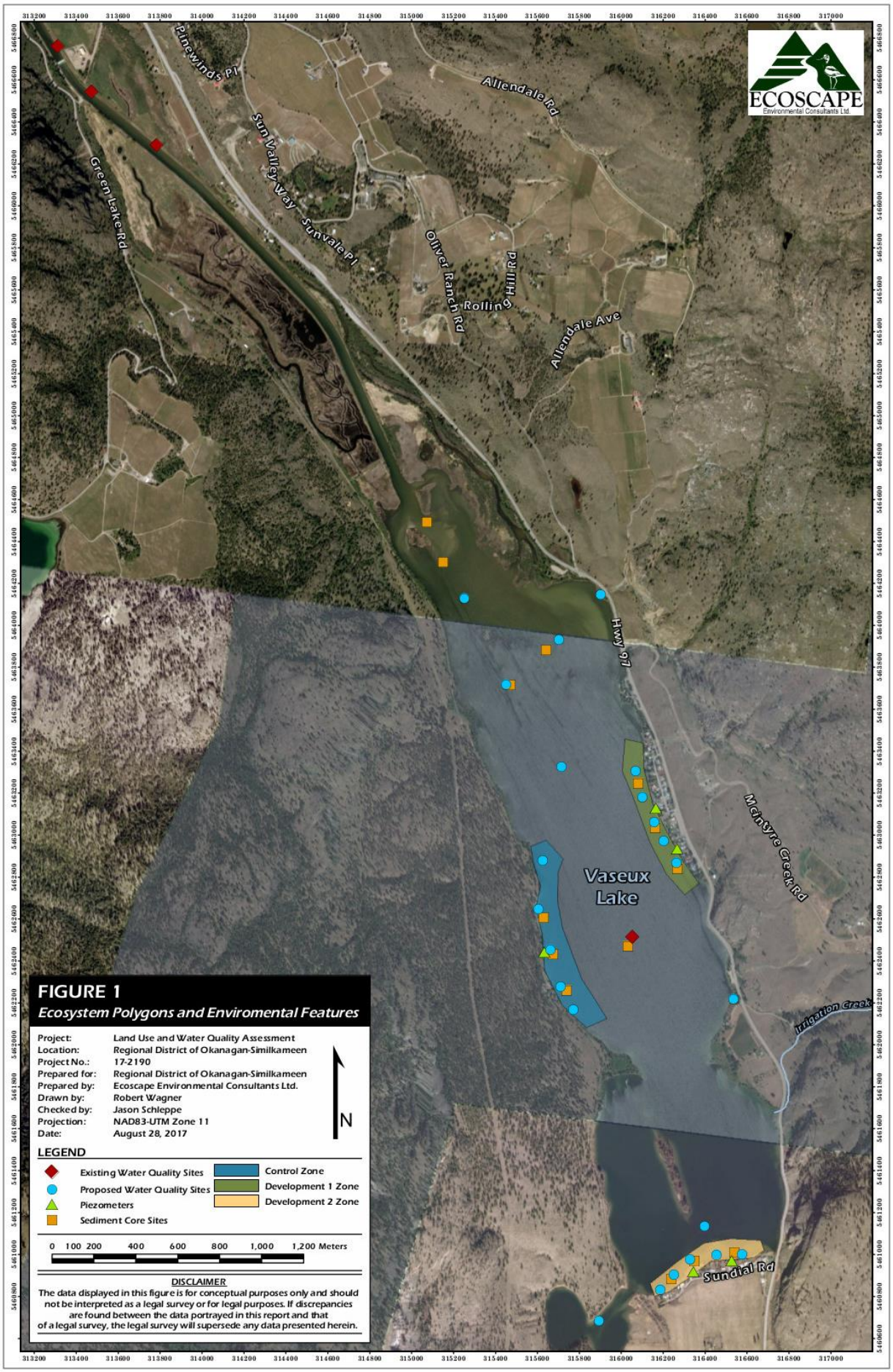


Table 2 provides parameters selected for analysis, and the rationale for each. They include those that are critical to aquatic plant growth and to lake function. While other parameters would be of interest such as pesticides, chemical inhibitors and endocrine disruptors, these analyses are very expensive and do not address the core questions posed by the RFP. They are best reserved for a BC MoE sampling program that targets point-source contaminants.

Table 2: Selected water quality parameters for Vaseux Lake Assessment 2017-2018

	Water Parameter	Rationale
Lab Analyses	Nutrients N's P's K Sulphate	Nutrients in water bodies can stimulate nuisance algae growth, ultimately altering habitat values for fish and waterfowl
	Metals scan + Hg	Metals (Fe, Ca, Mg etc.) help control the flux of nutrients in a lake water column and heavy metals that may accumulate in aquatic food chains (mercury (Hg), cadmium (Cd), arsenic (As), chromium (Cr), thallium (Tl), and lead (Pb)
	Ions Cl	Chloride serves as a useful indicator of anthropogenic influence/ impacts due to its conservative properties
	Bacteria – *E. coli*	*E. coli* indicate recent fecal contamination and the possible presence of pathogens and measurable E. coli are often found in septic discharge
Multi-meter	pH	pH determines metal mobility, nutrient state, carbonate precipitation
	Temperature	Water temperature defines water layers and will also be monitored using light/temp loggers)
	Dissolved oxygen (DO)	Defines balance point between photosynthetic producers and decomposition consumers; DO controls the rate of internal sediment decomposition and metal/nutrient fluxes
	Conductivity /TDS	Measures amount of dissolved constituents

All water samples will be composites either temporally (creek or culvert flow), spatially (depth composites in lake above or below thermocline) or laterally (batch samples from shoreline areas). To match the WWTP Permit work, deep water column composites will include a 1,5,10 m composite (above thermocline) and a 20,22,24 m composite (below thermocline), as needed. It is vital that both water layers be sampled separately and as composites to obtain high quality data.

QA/QC Quality assurance/Quality control sampling is necessary as laid out by B.C. guidelines and prompt re-analyses of inexplicable outlier samples will also be undertaken**.** QA/QC for this study will match the existing Permit program that meets Provincial standards. In brief, sampling provided by LAC will include the collection of quality assurance samples as described in Table 3, and QC procedures outlined below.

Table 3: Vaseux Lake Water Quality Assurance (QA)

Depth/Composite	Collection Device	Replicates	Containers	Handling
1,5,10m composite and 20,22,24m composite	Van Dorn water sampler	1 per every 10 samples (+DI field blank)	9-120ml plastic	no preservative; keep cool in dark on ice delivered to Caro same day

NOTE: QA replicate samples will be labeled with unique identifiers known to LAC and RDOS but not to the lab.

Delivery of samples to the lab on the same day as collection avoids sample preservation and increases analytic accuracy.

Regular database updates (QC) As data comes in, it will be added to the database and subjected to a screening tool that identifies values that exceed one or more guidelines. These data will be flagged and if they are outliers, a query/request for re-analysis will be sent to the lab. This prevents the inclusion of erroneous outlier data.

Meter Calibration and Sampler Cleaning (QC)
All meters will be calibrated every day prior to use, and re-calibrated if needed at each site. The pH probe, and stand-alone pH meter will be calibrated the day prior to going into the field (needs pH standard solutions, etc., best done in a lab setting). The Van Dorn samplers will be cleaned prior to use on each sampling trip with sampler cleaner and rinsed thoroughly.

Data Security (QC)
The Hanna HI 9828 multi-meter automatically stores data tagged to location but key data will also be transcribed in a field book during profiling as a paper back-up. Field notes and all data will be compiled in Excel and reported to RDOS in the interim and final reports.

Invitation to Attend (QC)
On any sample day convenient to RDOS, a staff member may wish to attend the Vaseux sampling to verify procedures and to gain insight into field procedures.

3.2 Sediment Sampling and Monitoring – Phase 1

Assessing the quantity and quality of sediment deposited in a lake allows effective basin management. Sediment quality is important because it can act as a sink for nutrients and metals, and conversely it can act as a source of constituents to the overlying water column. Once in the food chain, sediment-derived constituents may pose an even greater concern due to bioaccumulation (e.g., methyl-mercury). Sediment core samples can provide historical sediment deposition as well as magnitudes and trends in nutrients, metals etc. derived from the lake's basin that are associated with sediment.

Every lake accumulates sediment from external materials deposited from inflows and from incomplete decay of aquatic growth within the lake itself. The extent of anaerobic conditions is also relevant because anaerobic conditions reduce decomposition rates by orders of magnitude, thus increasing the rate of sediment accumulation as a lake ages. Further aquatic plant beds produce large quantities of labile organic material and reduce water velocities, both of which can increase sediment accumulation rates. We will determine the relative contributions of internal and external sediment sources by:

- Collecting 7 batched sediment core samples for surficial 0 – 10 cm (recent) They will be collected as follows:
  - (1) inflow area of recent deposition *to determine the nutrient, metal organic content of imported sediments*
  - (1) deepest site in lake *to evaluate sediment focusing*
  - (2) dense aquatic plant beds (2 – 4 m depth) *to determine the effect of plant bed organic accumulations on sediment chemistry*
  - (2) shallow substrates adjacent to the 2 residential areas *to determine the effect of shoreline disturbance on sediment chemistry*

- (1) shallow substrates adjacent to undeveloped park area, outside of dense beds *to establish control values for Vaseux Lake to compare to plant bed and shoreline disturbance values*

- and (1) sediment core samples from deep 20 cm (historic, prior to European influence). These sediment samples can be compared to similar work conducted on other Okanagan mainstem lakes **TOTAL = 8**

The sediment cores will be fractioned by sediment depth and at least 3 cores will be collected and batched per sample to help overcome the inherent variability of sediment chemistry. The sediment quality parameters and their rationales are presented in Table 4.

Table 4 Selected sediment parameters for Vaseux Lake Assessment 2017-2018

Sediment Parameter	Rationale
Volatile solids / dry weight	Allows calculation of percentage of organic (decaying plants, algae, etc.) and inorganic (sand, silt, clay) in lake sediments
Nutrients T-N P's	Nutrients in sediments are the primary source of nutrients for nuisance aquatic plant growth
Metals scan (K S Fe Na Pb Ca Cu etc.)	Iron (also Ca Mg etc) determine nutrient mobility from the sediment to the water column

- Installing sediment traps
  - (4) in the N inflow end where deposition is expected to be the most serious and
  - (2) in the S end shallows to act as a control

  The sediment traps will be installed in 2017 and retrieved in 1 year to determine annual sediment accumulation. These rates can be compared to other Okanagan Lakes LAC studies.

- Installing (4) sediment gauges in the N inflow end where deposition is expected to be the most serious; and (1) in a southern shallow site within a dense aquatic plant bed, and (1) in a southern shallow site outside a dense aquatic plant bed to act as a control. These will be read on at least 4 field trips.

- Identifying the rate of summer and winter expansion of the anaerobic zone and its horizontal extents using the thermistor data and multimeter transects. This mapping will be accomplished using a technique LAC developed for low-elevation reservoirs.

3.3 Aquatic Plant Mapping

Excessive aquatic plant growth is not only unpleasant, it can cause serious problems for lake ecology. These growths can slow water travel through Vaseux, pump nutrients out of the sediments and into the water column, provide habitat for filamentous algae and reduce fishery potential in the areas covered by dense milfoil beds. Most aquatic plants acquire their nutrients from the substrates but water column nutrients are also important because they supply phytoplankton. In the short term, these algae suspended in the water column can shade and inhibit the growth of aquatic plants, especially during an algae bloom. Thus, lower phytoplankton populations can increase aquatic weedbed growth. However, in the long term, phytoplankton trap and retain inflowing nutrients, contributing to lake aging. We plan to determine these effects using the phytoplankton analyses performed under the WWTP Permit sampling.

Aquatic plant bed mapping will be completed for Vaseux Lake for all taxa. Each mapped bed will be given a percentage of invasive milfoil, as well as the other plants. The mapping will be based on drone imagery, satellite imagery, and "ground-truthing" with a grid of GPS'd locations, according to the methods used by OBWB. This mapping will be compared to historic maps for expansion of plant beds and species shifts. Specifically, we will be determining the expansion of invasive *Myriophyllum spicatum*.

3.4 Nuisance Algae Sampling

Filamentous green algae growth is stimulated by nutrients in the water column, and can be exacerbated by nutrients released by milfoil leaves. Dense mats of these algae can clog pumps, block weirs and cause extreme diurnal swings in DO that are harmful to fish and fish food organisms (benthic invertebrates).

Their populations will be mapped using drone images, and photographed. We will also collect algae samples and identify the filamentous species because this is relevant for control. For example, branched filamentous green algae can be mechanically removed while unbranched species cannot. Algae identification and control is a specialty of Larratt Aquatic.

3.5 Land Use Inventory and Survey

Mapping available from RDOS will be utilized to inventory the land use in the vicinity of Vaseux Lake. Briefly, there are 2 residential subdivisions, and a highway in the riparian area, and small forage and vineyards within the lake watershed. These agricultural areas may influence two small creeks that report to Vaseux Lake. Fortunately, much of the watershed is undeveloped park).

3.6 Sediment Sources

Upstream sediment sources and channel stability issues will be identified using GIS and drone imagery. Okanagan River is channelized and receives stormwater. Bank failures (if any) and stormwater can both supply fine sediments to Vaseux Lake. Flows reporting to Okanagan River are likely the main contributors of sediment.

The consulting team has experience identifying sediment sources such as skid road drainage and watershed slope failures. There are several small creeks emptying into Vaseux Lake and they can transport contaminants or sediments to the lake, as evidenced by alluvial fans. These are likely to be small sources that may not require sampling after 2017.

4.0 DATA ASSESSMENT, MODELLING AND REPORTING – PHASE 1

4.1 Hydrogeologic Assessment

The hydrogeologic assessment will use existing groundwater information together will piezometer results from this study and well logs. Information on the lithology beneath Vaseux Lake is available from the OBWB Supply and Demand Study (2009) and will allow estimation of groundwater contributions and hydraulic conductivity (rate of water movement in the aquifer) when combined with the results from piezometer samples of water quality and local well samples.

Piteau will do a desktop hydrogeological assessment for the area which will include the development of a water balance that accounts for groundwater recharge and discharge areas, plus the gains and losses attributed to septic fields, evapotranspiration and irrigation return flow. The assessment will include maps and cross sections depicting the spatial distribution of water quality, direction of groundwater flow and the nature of interaction between groundwater and surface water in the lake. Water level and quality data will be collected by other members of the

Team. These will also allow estimates of groundwater/subsurface drainage contaminant loading rates to Vaseux Lake.

For the purposes of this study it is assumed that only the top 4 meters of the upper, unconfined aquifer is interacting with Vaseux Lake. The Okanagan glacial aquifers have a typical hydraulic gradient of 0.1 with an estimated hydraulic conductivity of $1x10^{-5}$ m/s (OBWB 2009 and Smerdon 2009). The amount of aquifer interacting with Vaseux Lake (or any of the Okanagan mainstem lakes) and a typical groundwater discharge into Vaseux Lake can only be estimated, however, and loading rates are based on these estimates. These groundwater loading estimates for ions, metals and nutrients can be verified by comparing their predictions to actual water chemistry within Vaseux Lake.

4.2 Climatic and Geologic Review

Existing climatic and geologic information will be reviewed and summarized as part of Phase 1 to facilitate the hydrogeologic and water balance assessments.

4.3 Water Balance Model

Many estimates needed for calculation of the Vaseux Lake water balance already exist, allowing this proposed study to focus on the remaining items (Table 5). For example, the estimated water loss to evaporation is already calculated specifically for Vaseux (Schertzer and Taylor 2009).

Table 5: Available Water Balance Parameters for Vaseux Lake

Parameter (units)	**Value**	
Surface area (m^2)		2,752,000
Volume (m^3)		17,600,000
Mean depth (m)		6.4
Mean annual outflow (m^3)		529,200,000
Max depth (m)		28
Normal water elevation (m asl)		327.05
Highest target elevation (m asl)		327.6
Residence Time (yr.)		0.03 (11 days)*
Water Balance Fluxes (m^3/year)		
Inputs	Okanagan River inflow	
	Inflowing creeks	
	Precipitation on lake surface	
	Groundwater inflow	
	Total Inputs	
Outputs	Avg outflow to Osoyoos Lake ref[1]	529.2×10^6
	Evaporation (m^3/yr) ref[2]	1.01×10^6
	Water Licenses	
	Discharge to groundwater (S end)	
	Total Outputs	

References: ref[1] OBA 1973 ref[2] Schertzer and Taylor 2009

*theoretical; actual retention time below summer thermocline will be longer, while residence time in the surface layer may be shorter than 11 days; residence time in weedbed will be longer than in the open water

4.4 Initial data analysis

Using the database LAC will construct for Vaseux Lake, data analysis scripts will be prepared and tested with the 2017 data. The database will be constructed in Excel with a design that facilitates analysis and graphing with the statistical package, "R". The validity of and possible causes for outlier results will be considered. Most importantly, this initial analysis will provide direction to Phase 2 sampling.

Sampling in one year provides a baseline while additional years of sampling are required to detect trends. In all, we would collect 4 samples from Vaseux sites to allow statistical analyses. Together with existing water quality data, trend analysis will be undertaken. Data will be graphically presented whenever possible for ease of understanding. An example of a box plot of trend analysis is provided in Figure 5.

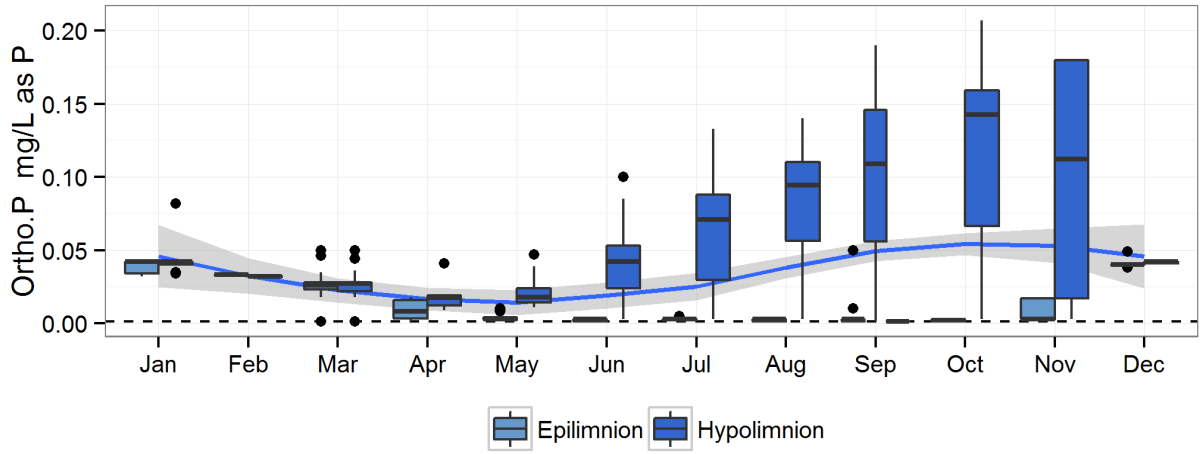


Figure 5: Monthly concentration of orthophosphate in an Okanagan lake epilimnion and hypolimnion, 1970-2015

4.5 Phase 1 Interim Reporting

An interim report of Phase 1 results will be prepared in the early months of 2018 (Table 7.0-1). This will serve as a template for the main report and again, it will help guide Phase 2 work. A draft of this report would be reviewed with RDOS.

5.0 PROPOSAL STUDY COMPONENTS - PHASE 2

Phase 2 involves using the Phase 1 monitoring program for the continued gathering and analysis of data from ice-off freshet and summer phases in 2018. Prior to the commencement of Phase 2, we would meet with RDOS to finalize the work plan and to discuss any proposed optional items. Any revisions to the Phase 2 workplan would reflect the results from Phase 1.

5.1 Sampling

The monitoring program mounted in 2017 will continue in 2018, as will other data gathering. The same sampling programs and methodologies described in detail for Phase 1 will be used for Phase 2.

- 3rd water quality sampling (ice-off) and multimeter profiles,
- 4th water quality sampling (freshet) and multimeter profiles
- 5th water quality sampling (summer) and multimeter profiles

This will be combined with the data gathered under the WWTP Permit sampling that commences at ice-off and continues monthly through to ice-on in November.

Sediment core samples are not needed in 2018 because sediments accrue slowly. Sampling every 5 years is adequate for sediment chemistry. The sediment gauges would be read on each trip to determine seasonal accrual. The sediment traps installed in September 2017 would be retrieved in September 2018 and their contents analysed for dry weight (organic and sand/silt/clay fractions) and volatile solids (organic fraction). This allows an estimate of annual sediment accrual from internal and external sources.

5.2 Complete Database

All data from the 2018 Vaseux Lake Assessment data collection and the WWPT Permit data collection will be entered into the database using "R" statistical package formatting and scripts. R Scripts allow for the generation of high quality statistical graphs. Separate folders will be created for numeric data from profile data, water chemistry, sediment chemistry, sediment accrual and aquatic plant data.

A data screening tool will be developed that flags any data that exceeds a guideline as that data is entered into the database. This will involve comparing analytical results to aquatic life, drinking water and watering BC MoE guidelines as well as Contaminated Sites Regulations (CSR) on a site by site basis to identify point source issues.

6.0 DATA ANALYSIS AND MODELLING – PHASE 1 AND 2 COMBINED

6.1 Statistical Analysis

A thorough statistical data analysis on project data and comparison to BC MoE historic data will be conducted. A first step will involve calculating descriptive statistics (average, mean, standard deviation, median) and generating box plots (e.g. Figure 5). Using these results as a guide, the following detailed analyses will be performed:

BACI Impact Assessment The data collection proposed here will support a Before–After Control-Impact (BACI) design. The BACI design and associated statistical test is based on repeated sampling of parameters over time in paired control and impact areas, and it requires that the sampling design produces enough samples to provide adequate statistical power and meet analysis requirements. This approach to impact assessment allows us to see differences between pairs of sites control (undeveloped) and impacted (shoreline residential) and control (light native aquatic vegetation) and impacted (milfoil bed), and using historic versus study results for before/after analysis.

Trend analyses The Vaseux data base will be analyzed for trends in water chemistry and aquatic plant growth. If long-term sampling that includes tracking plant growth and sedimentation rates is chosen by RDOS, then searches for trend can be expanded to these parameters.

Regression Models

Potential future trend analyses would be done using Mann-Kendall non-parametric linear trend analysis. Water chemistry data is rarely normally distributed and use of parametric analysis such as Least-Squares Regression would require manipulation of the data to force normalcy. A non-parametric trend test (such as Mann-Kendall) allows for direct trend analysis of water chemistry data.

Results below detection limits Non-detect data occurs when the sample result is below the Lab reportable detection limit. When this occurs in water or sediment chemistry required for analysis, the "<" value will be replaced with ½ of the detection limit and that value flagged as calculated. This is the standard procedure employed by BC MoE in their analyses to reduce bias.

6.2 Chloride Loading, Nutrient Loading

Mean annual chloride and nutrient loading will be based on groundwater discharge and water quality samples collected in this study, and compared to other Okanagan samples, including those from Swan Lake (WWAL, 2016).

We will develop the loading model for each parameter (Cl, N, P, key metals) as tables similar to Table 6.

Table 6: Typical Chloride Loading from Land Use to shallow groundwater and Inflows

	Land Use	Okanagan Cl loading rate*	Area adjacent to Vaseux	Cl loading estimate and %
Land use Cl loading reporting to groundwater	Roads/Hwy 97	27-37 kg / 2lane/km		
	Residences on septic	440 mg/L, 6.8 kg/yr	65	
	Natural Cl loading in local groundwater			
	Undeveloped slopes /wetland areas	0 kg/yr		No net loading expected
Cl loading from inflows and loss from discharge	Inflow from Okanagan R.			
	Inflow from Vaseux Cks			
	Discharge to Osoyoos Lk			
Cl losses	Cl loss to ion exchange in soil solutions*[1]			
	Cl loading balance			

***** corrected from: NaCl (60.1%), CaCl (63.9%) and MgCl (74.5%) loading rates to Cl only

*[1] numerous authors

6.3 Nutrient Budget Calculations

After nutrient loading rates have been determined, nutrient budgets for Vaseux Lake can be calculated. These will allow us to rank the nutrient contributions (internal loading vs external loading - inflow loading, point-source land-use loading shoreline residences, for example). The nutrient budget will also include internal loading of nutrients recycling from the substrates in anaerobic zones and from milfoil beds releasing nutrients to the water column using targeted water sampling and the available bathymetry of Vaseux Lake. For this, we will use the bathymetric approach LAC developed that involves calculating the nutrients concentrations in individual water layer volumes (Appendix 3).

6.4 Investigating Vaseux Lake Remediation

LAC has designed and successfully implemented many reservoir/lake management techniques over the past 35 years. Relevant examples are provided in Table 7. Some of these could address the Vaseux Lake concerns of interrelated excessive algae and milfoil growth, nutrient and sediment inflows.

Table 7: Lake Restoration and Management Techniques

Problem addressed:	Lake Improvement Technique	Examples of LAC Experience
Algae, Nutrients Sediment	aeration both stratification-retaining and destratification systems to improve water quality and reduce anaerobic sediment accumulation	Rose Valley Reservoir, Logan Lake Heustis Pit Lake
Algae	algae control with nutrient management and ionized copper	Rose Valley Reservoir, McKinley Reservoir, Garnett Valley Reservoir
Milfoil	lofted fabric barrier, limestone cap barrier	Logan Lake, Okanagan Lake, McKinley Reservoir
Milfoil, Sediment	reservoir re-contouring, mechanical removal	McKinley Reservoir, Kalamalka Lake
Nutrients, Sediment	strategic water wasting	McKinley Reservoir, Rose Valley Reservoir,
Nutrients, Milfoil	sediment capping with limestone to prevent nuisance aquatic plant growth	Okanagan Lake at Pritchard Arm
Sediment	increasing channel stability upstream of lake addressing point-sources of sediment	Greystokes watershed, Lambly watershed,
Milfoil	rototilling for plant mass removal, root disruption (OBWB)	Kalamalka Lake, Okanagan Lake
Sediment	alternate treatment of stormwater in constructed wetlands designed for periodic sediment removal	Kelowna, West Kelowna stormwater management
Nutrients, metals	nutrient and metal attenuation in designed wetlands with subsurface drainage through anaerobic media	Highmont tailings pond HVC, Bethlehem tailings pond HVC
Nutrients sediment	riparian stabilization helps prevent contaminants, nutrients, sediment from reaching the lake	Logan Lake constructed inflow wetlands, Highmont tailings pond HVC.

The selection recommended from these and other options will be based on research and the sampling program proposed for Vaseux Lake. We would incorporate insights from RDOS and BC MoE on the feasibility of these given such parameters as waterfowl values, access to power, and recreation values. These recommendations would then be built into a Vaseux Lake Management Plan.

7.0 FINAL REPORT

A concise report, complete with the Vaseux database and detailed GIS mapping to meet all BC MoE / RDOS requirements will be completed in January 2019, well ahead of the OBWB Grant Program requirement of March 31, 2019. It will be presented in draft for consultative review by the RDOS in late 2018.

Report Layout The final report layout will build on the interim Phase 1 report layout. It will contain detailed methodology, including a description of the sampling performed; methods, statistical methods (spatial, trend, BACI, regression, etc.) results and analyses; and recommendations. A 3-4 page Summary Report will also be prepared for general audiences and it will be presented in the report as the Executive Summary Section. We developed this report style for complex mine reclamation reports and it has been well received.

Analyses Presentation The analyses will be presented to clearly convey how Vaseux Lake compares to aquatic life, drinking water and watering BC MoE guidelines as well as Contaminated Sites Regulations (CSR). This report will clearly identify point-source water quality challenges arising from land use in the immediate vicinity of Vaseux Lake, and from upstream sources. Similarly, GIS milfoil mapping from 2017 will be compared to historic mapping, and sediment chemistry will be compared to Okanagan mainstem lake values.

Recommendations The recommendations will be built into a Vaseux Lake Management Plan focused on mitigating excessive aquatic plant growth, and reduce internal and external nutrient loading, and lessen sediment build-up in Vaseux Lake. The Plan will be developed in consultation with RDOS and BC MoE. For example, aeration could reduce organic sediment accumulation but would require a compressor and airline into the lake – this type of lake modification is best undertaken with regional support. Other actions such as addressing point-source nutrient loading can be dealt with using collaboration with land owners.

Finally, the LAC consulting team is offering to prepare a Power Point presentation of the study findings and to present it at RDOS' request, as a public service.

8.0 OPTIONAL PROGRAM ELEMENTS

The following two options are offered for consideration by RDOS. Option 1 can be added to Phase 1 where it will enhance the Land-Use and weedbed surveys or added to Phase 2. The long-term sampling proposed in Option 2 would follow Phase 1 and 2.

8.1 Option 1: Foreshore Inventory Mapping (FIM)

FIM Rationale/Value-Added Foreshore Inventory and Mapping (FIM) is a mapping protocol, developed in the Okanagan, and used throughout BC and now in Alberta, to map lake shorelines and determine cumulative effects that have resulted from densification, urbanization, and growth along lake shorelines. The FIM process gathers data on broad land use, shore morphology, lakebed substrates, riparian condition, and describes shoreline modifications such as docks, retaining walls, and groynes. This information can be used to assess the cumulative effects from land use upon environmental benchmarks such as water quality, nuisance aquatic plant growth, and sedimentation rates.

Currently, many lake management projects in the province of BC follow a three-step process described below.

1. Foreshore Inventory and Mapping (FIM) is a protocol that is used to collect baseline information regarding the current condition of a shoreline. The FIM uses a mapping based (GIS) approach to describe shorelines. These inventories provide information on shore types, substrates, land use, and habitat modifications. This new information has been combined where possible, with other mapping information such as previous fisheries inventories, recent orthophotos, and other information.

2. An Aquatic Habitat Index (AHI) is generated using the FIM data to determine the relative habitat value of the shoreline. The Aquatic Habitat Index uses many different factors such as biophysical criteria (e.g., shore type, substrate information) fisheries information (e.g., juvenile rearing suitability, migration and staging areas), shoreline vegetation conditions (e.g., width and type of riparian area), terrestrial ecosystem information (Sensitive Ecosystem Inventory), and modifications (e.g., docks, retaining walls) to estimate the relative habitat value of a shoreline segment. This assessment was the first known to the author to incorporate areas identified to be important terrestrial habitats. The Habitat Index classifies this information in a 5-Class system from Very High to Very Low and describes the relative value of the different shorelines areas to one another.

3. Shoreline Management Guidelines are prepared as part of FIM to identify the Shoreline Vulnerability or sensitivity to changes in land use or habitat modification. Shoreline Vulnerability Zones are based upon the Aquatic Habitat Index described above. The Shoreline Vulnerability Zone uses a risk-based approach to shoreline management, assessing the potential risks of different activities (e.g., construction of docks, groynes, marinas) in the different shore segments. The Shore Line Management Guidelines document is intended to provide background information to stakeholders, proponents, and governmental agencies when land use changes or activities are proposed that could alter the shoreline thereby affecting fish or wildlife habitat.

For the Vaseux Lake Assessment, we are proposing to develop Step 1 for Vaseux Lake, and use this to relate water quality aspects to land development. This protocol will inform shoreline management planning to address how riparian land use change and densification may affect the shoreline and the lake.

8.2 Option 2: Long-term annual sampling proposal

Sampling in one year provides a baseline while additional years of data are required to detect trends. The very best water quality programs in the Okanagan employ financially sustainable annual sampling in preference to expensive one-year studies. Of necessity, the annual sustainable studies collect only those parameters critical to answering the concerns for that water body. A tentative budget for this option for Vaseux Lake is provided in Section 11. This estimate would be revised using the data analyses developed in this Project.

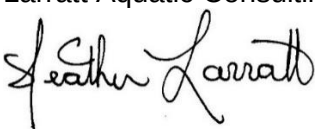
LAC proposes to conduct the long-term sampling on the same field trip as the Permit sampling trip to minimize RDOS expenditures. Data gained from the long-term sampling option would be added to the proposed Vaseux Lake database, analyzed and an update to the Vaseux Lake Assessment Report prepared annually.

9.0 FINAL SUMMATION

This proposal meets all the requirements laid out in the Vaseux Lake Assessment RFP and it also offers:

- construction of a comprehensive Vaseux Lake database, with a data screening tool
- extensive use of composite sampling to improve data accuracy (labor intensive, lower lab costs)
- comparison of 2017/18 milfoil mapping in GIS with historic mapping
- determination of aquatic plant impacts on lake chemistry and on fish habitat value
- filamentous green algae monitoring and identification
- use of sediment traps, sediment gauges and sediment coring
- review of all stimuli of excessive aquatic plant growth (not just water column nutrients)
- use of temp/light loggers to continuously monitor Vaseux water layer behavior
- Vaseux Lake nutrient budget calculations and metal budgets important to lake function
- development of a Vaseux Lake Management Plan, as part of this study

Larratt Aquatic Consulting Ltd.



Heather Larratt
Honors B.Sc., R.P. Bio

10.0 PROJECT SCHEDULE FOR VASEUX LAKE ASSESSMENT PHASE 1 AND 2

Vaseux Phase 1 **2017/2018**	Sep-17 24/25	Sep-17 26/27	Oct-17 4/5	Oct-17 12/13	Nov-17 1/2	Dec-17	Jan-18	Feb-18
Field Work								
kick-off meeting (at RDOS discretion)								
initial reconnaissance sampling, install drive points, sediment traps								
use transects to measure horizontal extent of anaerobic zone								
1st wq sampling to coincide with WWTP Permit sampling								
Sediment coring, sampling, install sediment gauges, algae sampling								
weed mapping, land use ground truthing								
survey for upstream sediment sources (bank instability, creek failures)								
2nd wq sampling through-ice (winter sampling safety precautions)								
Vaseux perimeter land use inventory								
Water Balance								
Climatic, Geologic, Hydrogeologic Review								
Data Management								
build Vaseux Lake database								
hydrogeological assessment								
GIS mapping of weedbeds, sample sites, etc.								
Interim Reporting								
initial data analysis								
report writing								
	LAC		Piteau		Ecoscape		RDOS	

Vaseux Phase 2 **2018/2019**	Mar-18 ice-off	May-18	Jun-18	Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19
Field Work									
Phase 1 review and Phase 2 scoping meeting									
3rd wq sampling (ice-off)to coincide with WWTP Permit sampling									
4th wq sampling (freshet) to coincide with WWTP Permit sampling									
5th wq sampling (summer) to coincide with WWTP Permit sampling									
Data Management									
complete updating of database									
determine chloride loading, nutrient loading									
calculate nutrient budgets for Vaseux Lake									
measure sediment traps, gauges									
Final Reporting									
complete statistical data analysis									
identify solutions for Vaseux milfoil, algae, nutrient sediment issues									
draft final report with recommendations for RDOS review									
final report, mapping, database									

11.0 LAB ANALYSES AND COST TABLES FOR VASEUX LAKE ASSESSMENT PHASE 1 AND 2

	Water Quality Sampling	multi-meter profiles (pH, Diss.O2, temp, conductivity)	nutrient, Cl samples (ammonia, nitrate, phosphate, sulphate)	metals scan	Total coliforms E. coli	
Phase 1	initial sampling	60 shallow 10 deep				
	1st late summer	20 shallow 1 deep	20	10	10	
	2nd thru ice	1 deep	2	2		
	TOTAL		22	12	10	
	PRICE/sample		42.00	65.00	25.00	
	COST		$924.00	$780.00	$250.00	$1,954.00
Phase 2	3rd ice-off	1 deep	16			
	4th freshet	1 deep	16	8	8	
	5th summer	1 deep	16	8	8	
	TOTAL		48	16	16	
	PRICE/sample		42.00	65.00	25.00	
	COST		$2,016.00	$1,040.00	$400.00	$3,456.00

	Samples	AFDW/DW	metals scan	coliforms	
Phase 1	late summer	8	8	2	
	TOTAL	8	8	2	
	PRICE/sample	19.00	65.00	25.00	
	COST	$152.00	$520.00	$50.00	$722.00
Phase 2	freshet	8	8	2	
	summer	8	8	2	
	sed. trap samples	6			
	TOTAL	22	16	4	
	PRICE/sample	19.00	65.00	25.00	
	COST	$418.00	$1,040.00	$100.00	$1,558.00

LARRATT AQUATIC

Vaseux Lake - Land Use and Water Quality Assessment Phase 1

PROFESSIONAL FEES

Company and Role		Ecoscape			Larratt Aquatic			Piteau	Subtotals	Totals
		Jason Schleppe, M.Sc., R.P.Bio	Rob Wagner B.Sc	Field Biologist	Heather Larratt, B.Sc., R.P.Bio	Jamie Self, R.P.Bio	LAC Field Tech	Remi Allard P.Eng M.Eng		
		Senior Fisheries Biologist	GIS Specialist	Field Biologist	Senior Aquatic Specialist	Aquatic Specialist	Field Tech	Senior Hydrogeologist		
Task \ Hourly Rate		$ 105	$ 90	$ 85	$ 105	$ 85	$ 50	$ 175		
	Project Management				8				$ 840	
Aquatic Vegetation Mapping, Sediment Accrual Mapping	Aquatic vegetation mapping using OBWB methods and GIS	10		10		10			$ 2,750	
	GIS map production		12						$ 1,080	
	Water balance determination	2		5	2			3	$ 1,370	
	ground truthing land use inventory	3							$ 315	$ 6,355
Phase 1 Water quality, sediment, and algae sampling; Data management; Interim report	survey upstream sediment sources, drone, GIS					7	7		$ 945	
	Initial multi-meter sampling, install drive points, sed traps					16	16		$ 2,160	
	Deploying thermistor lines, anaerobic extent					8	8		$ 1,080	
	Water quality, algae, plant, sediment, QA/QC sampling					10	10		$ 1,350	
	through ice winter sampling					6	6		$ 810	
	Database development, initial analysis					12			$ 1,020	
	hydrogeologic analysis							10	$ 1,750	
	interim report	4			10	15		3	$ 3,183	
										$ 12,298
									Total Fees	$ 18,653
Total Hours		19	12	15	20	84	47	16	150	
Total Fees		$ 1,995	$ 1,080	$ 1,275	$ 2,100	$ 7,140	$ 2,350	$ 2,713	$ 18,653	

YEAR 1 DISBURSEMENTS

Program	Task	Item		No. Units	Unit type	Unit Rate			Totals	Subtotal
Ecoscape disbursements	travel	Mileage		300	km	$ 0.60			$ 180	
	GIS	Trimple GEO XM 7 GPS Unit		2	day	50.00			$ 100	
	mapping	Boat and Motor		2	day	100.00			$ 200	
Lab analyses costs (Caro Labs, Kelowna)	water focussed	Nitrate, ammonia, phosphate, sulphate, chloride		20		42.00			$ 840	
	water intensive	complete metals scan		10		65.00			$ 650	
	bacteriological	total coliforms and E. coli		10		25.00			$ 250	
	sediment	nutrient, metals scan, AFDW/DW		8		89.00			$ 712	
LAC disbursements	travel	Mileage		2		140.00			$ 280	
	equipment	(boat, motor, drone, field meters, piezometers,		2		440.00			$ 880	
									Disbursements	4,092.00

Professional Fees	$ 18,653
Total Disbursements	$ 4,092
Total Cost (GST not included)	$ 22,745
Total Cost (GST included)	$ 23,882

Vaseux Lake - Land Use and Water Quality Assessment Phase 2

PROFESSIONAL FEES

Company and Role		Ecoscape			Larratt Aquatic			Piteau	Subtotals	Totals
		Jason Schleppe, M.Sc., R.P.Bio	Rob Wagner B.Sc		Heather Larratt, B.Sc., R.P.Bio	Jamie Self, R.P.Bio	LAC Field Tech	Remi Allard P.Eng M.Eng		
		Senior	GIS Specialist		Senior Aquatic	Aquatic	Field Tech	Senoir		
~~Hourly Rate~~		$ 105	$ 90		$ 105	$ 85	$ 50	$ 175		
	Project Management				5				$ 525	
Phase 2 Water quality, sediment, and algae sampling	Ice off water quality, piezo sampling					7	7		$ 945	
	freshet water quality, piezo sampling					7	7		$ 945	
	summer water quality, piezo sampling					7	7		$ 945	
	Retrieving sediment traps, thermistor lines					3	3		$ 405	$ 3,765
	Updates to mapping		5						$ 450	
	Database completion					10			$ 850	
	Statistical data analysis and graphing	5			2	18			$ 2,265	
	Development of recommendations for Vaseux Lk remediation				10				$ 1,050	
	Final reporting	4			15	20		3	$ 4,220	
										$ 8,835
									Total Fees	**$ 12,600**
Total Hours		**9**	**5**		**32**	**72**	**24**	**3**	**118**	
Total Fees		**$ 945**	**$ 450**		**$ 3,360**	**$ 6,120**	**$ 1,200**	**$ 525**	**$ 12,600**	

Phase 2

Program	Task	Item	No. Units	Unit type	Unit Rate	Totals	Subtotal
Lab analyses costs	water focussed	Nitrate, ammonia, phosphate, sulphate, chloride	48		42.00	$ 2,016	
	water intensive	complete metals scan	16		56.00	$ 896	
	bacteriological	total coliforms and E. coli	16		25.00	$ 400	
	sediment	nutrient, metals scan, AFDW/DW	6		89.00	$ 534	
LAC disbursements	travel		4		140.00	$ 560	
	equipment	equipment (boat, motor, meters, samplers)	4		100.00	$ 400	
Disbursements							4,806.00

Professional Fees	**$ 12,600**
Total Disbursements	**$ 4,806**
Total Cost (GST not included)	**$ 17,406**
Total Cost (GST included)	$ 18,276

Option 1: Vaseux Lake Foreshore Inventory Mapping (FIM)

PROFESSIONAL FEES

Company and Role			Ecoscape					Subtotals	Totals
			Jason Schleppe, M.Sc., R.P.Bio		Field Biologist	Rob Wagner B.Sc. GIS			
			Senior		Field Biologist	GIS Analyst			
~~Hourly Rate~~			$ 105		$ 75	$ 90			
Foreshore Inventory and Mapping		Project Management	1					$ 105	
		Foreshore Inventory and Mapping Field	16		16			$ 2,880	
		FIM Data Processing			8	8		$ 1,320	
		FIM GIS Mapping				10		$ 900	
		FIM reporting			15			$ 1,125	
		Data Analysis for FIM				4		$ 360	
									$ 6,690
								Total Fees	**$ 6,690**
Total Hours			**17**		**39**	**22**	**0**	**78**	
Total Fees			**$ 1,785**		**$ 2,925**	**$ 1,980**	**$ -**	**$ 6,690**	

FIM DISBURSEMENTS

Program	Task	Item	No. Units	Unit type	Unit Rate	Totals	Subtotal
Disbursements		Mileage	300	km	$ 0.60	$ 180	
		Trimble GEO XM 7 GPS Unit	2.0	day	50.00	$ 100	
		Boat and Motor	2.0	day	100.00	$ 200	
Disbursements							480.00

Professional Fees	**$ 6,690**
Total Disbursements	**$ 480**
Total Cost (GST not included)	**$ 7,170**
Total Cost (GST included)	$ 7,529

Option 2 Vaseux Lake Long-term monitoring

PROFESSIONAL FEES

Company and Role		Larratt Aquatic			Ecoscape		Subtotals	Totals
		Heather Larratt, B.Sc., R.P.Bio	Jamie Self, R.P.Bio	LAC Field Tech	Field Biologist	Rob Wagner B.Sc. GIS		
		Senior Aquatic Specialist	Aquatic Specialist	Field Tech	Field Biologist	GIS Analyst		
~~Hourly Rate~~		$ 105	$ 80	$ 50	$ 75	$ 90		
Sampling, mapping and reporting	Project Management						$ -	
	Review of BC MoE upstream data (yearly)		5				$ 400	
	Collection of point-source samples, piezos (yearly)		14	14			$ 1,820	
	Assessment of remediation measures (yearly)	8	6				$ 1,320	
	Collection of sediment traps, gauges, thermistors (yearly)		3	3			$ 390	
	Aqautic Plant/filamentous algae mapping (every 2 years)				8	10	$ 1,500	
	Collection of sediment core samples (every 5 years)		8	8			$ 1,040	
	Annual update reporting		10	10			$ 1,300	$ 7,770
							Total Fees	**$ 7,770**
Total Hours		8	46	35	8	10	107	
Total Fees		$ 840	$ 3,680	$ 1,750	$ 600	$ 900	$ 7,770	

Long-Term Sampling Disbursements

Program	Task	Item	No. Units	Unit type	Unit Rate	Totals	Subtotal
Lab analyses costs	nutrients	Nitrate, ammonia, phosphate	10	lab analysis	42.00	$ 420	
	metals	complete metals scan	5	lab analysis	56.00	$ 280	
	bacteriological	total coliforms and E. coli	5	lab analysis	25.00	$ 125	
	sediment	nutrient, metals scan, AFDW/DW	2	lab analysis	89.00	$ 178	
Disbursements	mileage	truck	150	km	$ 0.60	$ 90	
		Trimble GEO XM 7 GPS Unit	1	day	50.00	$ 50	
		Boat and Motor	1	day	100.00	$ 100	
Disbursements							1,243.00

Professional Fees	**$ 7,770**
Total Disbursements	**$ 1,243**
Total Cost (GST not included)	**$ 9,013**
Total Cost (GST included)	$ 9,464

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BC MOE. 2015. Ambient Water Quality Guidelines for Cadmium – Technical Report. 114pp.
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Key Okanagan References

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Nasmith, Hugh, 1967. Lake Glacial History and Surficial Deposits of the Okanagan Valley, British Columbia. Accessed at:
http://a100.gov.bc.ca/appsdata/acat/documents/r15765/Glacial_History_Okanagan_1229638479345_3b14c7d11bc41141a63e69fdd84aa684c1f8536fbf3c4a39a4f7248e0349c8fd.pdf

Okanagan Basin Agreement 1973. Canada-British Columbia Okanagan Basin Agreement, The Final Report November 28, 1973.

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Schertzer, W.M. and B. Taylor. 2009. Assessment of the Capability to Compute Evaporation from Okanagan Lake, Other Mainstem lakes and Basin Lakes and Reservoirs using the Existing Database. Report to the Okanagan Water Supply and Demand Study on Lake Evaporation. Environment Canada. January 2009.

Self, J. and H. Larratt, 2016. Long-term water quality trends, nutrient budgets, and cyanobacteria blooms as they affect the Kokanee fishery of Wood Lake. Prepared for British Columbia Ministry of Environment and Ministry of Forests, Lands and Natural Resource Operations, Penticton BC

Western Water Associates Ltd., January 2016. Swan Lake – Land Use and Water Quality Assessment. Prepared for Regional District of North Okanagan RDNO.

EcoCat Reports for Vaseux Lake

Report: Okanagan Basin Historic Aquatic Plant Mapping 1976 to 1982
http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=39988

Report: Okanagan Watershed Descriptions For: Chute Creek, Eneas Creek, Equesis Creek, Kelowna (Mill) Creek, Lambly Creek, Mission Creek, Naramata Creek, Naswhito Creek, Okanagan lake, Peachland Creek, Penticton Creek, Powers Creek, Robinson Creek, Shingle Creek, Similkameen River, Trepanier Creek, Trout Creek, Vaseux Creek, Vernon Creek,
http://a100.gov.bc.ca/pub/acat/public/viewReport.do?reportId=32362

APPENDIX 1: TEAM RESUMES

Appendix 1 contains the brief resumes for the consulting team including:

- H. Larratt, Aquatic Biologist 1st Hons B.Sc. R.P. Bio.
- Jamie Self, Aquatic Biologist H. B.Sc. R.P. Bio.
- Jason Schleppe M.Sc. R.P. Bio.
- Remi Allard, M. Eng., P. Eng. Principal Hydrogeologist, Piteau Associates
- Rob Wagner B.Sc.GIS Specialist
- Mike Schutten M.A.Sc.

Detailed resumes for the consulting team are available upon request, as is general company information at the following websites:

Larratt Aquatic lakebiology.ca
Ecoscape ecoscapeltd.com
Piteau www.piteau.com.

LARRATT AQUATIC

Heather Larratt: 1st Hon. B.Sc.
Principal Biologist R.P. Bio.

Education

1978 First Class Honors B.Sc. in Environmental Biology, U of Calgary

Certifications

1978 NASDS certified SCUBA diver
1980 Industrial First Aid "B" ticket (numerous other first aid courses since)
2010 Swift Water Rescue certification, 2013 re-certification
2012 WorkSafe St Johns Standard First Aid + CPR 2012

Professional Affiliations and Professional Volunteer Positions

College of Applied Biology, member
B.C. Water Supply Association, member
B.C. Lake Stewardship Society, member
B.C.W.W.A., member
RDCO Environmental Advisory Commission (EAC) volunteer 2003 – 2011
ORCAP advisor on aggregate mining in residential areas 2007 - 2012
Volunteer tutor for grade 11, 12 chemistry, biology for adults returning to upgrade high school 1998 – present

Professional Experience

Heather Larratt has 38 years of experience in source to tap water quality and reservoir management. In 1985, she also became involved in the reclamation of mine tailings ponds as wetlands and pit lakes as bioreactors using microflora.

Areas of Expertise

- Identification and treatment of algae problems in water supplies
- Guidance on reservoir management to protect water quality
- Design criteria for new impoundments to minimize microfloral problems.
- Innovations provided to clients include the use of powdered limestone as a sediment cap, strategic aeration/wasting, in-situ generation of copper ions and lowering THM's through reducing algae concentrations.
- Riparian and pit lake reclamation planning and implementation.
- Innovations in mine reclamation include developing a resilient passive sulphate reducing bacteria (SRB) treatment for metal removal, identifying the link between low B vitamin concentrations and low algae production in pit lakes, and developing a rapid method for planting aquatic macrophytes in tailings.

Awards

Professional Canadian Mineral Analysts, Best Paper 1995
Major's Environmental Award for Best Professional Volunteer Organization (EAC) 2001
BC Water Supply Association MSC Award for Outstanding Contribution to the Water Supply Industry 2014

Larratt Aquatic Consulting Ltd. 2605 Campbell Rd. West Kelowna B.C. V1Z 1T1
Phone: 250.769.5444 Email: heather@larratt.net

LARRATT AQUATIC

Jamie Self:
Aquatic Biologist

Education

2008-2011 U Waterloo – Biology/Ecology
2004-2007 U Waterloo – Urban Planning

Certifications

2011 Boat Operator's Certification
2016 WorkSafe Occupational First Aid Level 1
R.P. Bio.

Professional Experience

Jamie Self worked in co-op positions for the Province of Ontario as well as two Ontario municipalities during his Urban Planning studies and worked full-time from May – September 2011 for Larratt Aquatic. He joined LAC full time in May 2012.

Areas of Expertise

- Data management
- Electronic interfaces with sampling meters and loggers
- Photography
- Phytoplankton identification
- GIS

Examples of Recent Projects

- Managed field work program for reservoirs, watersheds and mines, 2011 to present
- Conducted field sampling for 28 lake and watershed monitoring projects throughout BC
- Performed algae identification and reporting for samples from a variety of reservoirs and lakes
- Drafted annual reports for water purveyors and mines, including sections on limnology, water quality and microflora
- Data management for 29 projects, spanning 2011 to present
- Developed several data screening tools to alert clients of data inconsistencies and guideline exceedances
- Developed statistical tools using "R"
- Managed drone and underwater camera imagery




OUR TEAM

Jason Schleppe, M.Sc., R.P.Bio

Senior Natural Resource Biologist - Director

Mr. Schleppe has thirteen (13) years of environmental experience and is a Principal Consultant with Ecoscape. Jason has published numerous technical and peer reviewed reports and has worked on most of the large watersheds in the southern interior of British Columbia. His range of projects spans numerous sectors of the marketplace (e.g., Government, Crown Corporations, and Private Industry) and includes a range of practices including fisheries research, environmental land use planning, environmental impact assessment, and watershed management .

Mr. Schleppe is a leader in the province in the development of Foreshore Inventory and Mapping (FIM), a methodology that is being used to guide land use planning and development related activities along shoreline areas. As part of these comprehensive environmental shoreline planning processes, he has been actively involved in community and outreach initiatives that have included local First Nations partners. Also, Jason has been part of the evolution of Source Water Protection Planning in the Okanagan, working with the community, and local and provincial agencies to ensure adequate source water protection. The District of Lake Country's Oyama and Vernon watersheds are being used as examples, highlighting his ability to bring together community and governmental objectives directed at conservation of key community assets. Mr. Schleppe has been involved on numerous water infrastructure projects, including bridges, water intakes, dams, stream restoration, and forestry operations.

The following is a brief list of projects that highlight his diversity of experience.

Glenmore Ellison Improvement District Water Intake
Mr. Schleppe provided environmental services associated with construction of the Glenmore Ellison Improvement District on Okanagan Lake. This project overlapped with critical shore spawning kokanee and Ecoscape was responsible for mitigation and compensation planning to ensure that critical fisheries resources were not impacted. This project involved extensive liaison with regulatory agencies as part of the Canadian Environmental Assessment Act approval process for the required Fisheries Act authorizations. The attention to detail in the planning stages allowed us to facilitate the necessary permits and regulatory approvals in a timely fashion.
Ecoscape subsequently provided Environmental Monitoring and Reporting Services through to the project's completion to satisfy the regulatory approvals.

Source Water Protection Planning
Mr. Schleppe has worked on two source water protection plans within the Okanagan. His works on these projects has included development of a source water protection planning tool for water purveyors. The planning tool includes development of a Vulnerability Index, which will be used as a flagging tool to identify areas of concern as they relate to water quality. This Vulnerability Index will be used by local and provincial agencies during application review processes to identify whether proponents have adequately addressed source water protection.

Turtle Reservoir Expansion, South East Kelowna Irrigation District
Mr. Schleppe conducted fish, wildlife and habitat surveys for ecosystems occurring within and adjacent proposed inundation areas of Turtle Lake as part of ongoing applications to expand the reservoir. These assessments involved identifying and quantifying important trout spawning areas, moose wintering grounds, and amphibian habitats along the shoreline of the lakes to determine potential environmental effects of reservoir expansion. Subsequently measures were developed to ensure that temporal and long term ecological effects of reservoir development and expansion would be appropriately mitigated.

EDUCATION

Water Quality Technology (Completed 7 of 8 semesters of 2 year program) at Okanagan University College

M.Sc Biology
University of Lethbridge, Lethbridge, AB

B.Sc. Biology
Okanagan University College, Kelowna BC

SUMMARY OF RECENT EXPERIENCE

2006 –Consulting Biologist.
Ecoscape Environmental Consultants

2003-2006, Consulting Biologist. EBA Engineering Consultants Ltd.

2003, Solid Waste Management Technician, Regional District of North Okanagan

AFFILIATIONS

Chair, Environmental Advisory Committee, Regional District Central Okanagan

Member, British Columbia College of Applied Biology

Member, British Columbia Association of Professional Biologists

CERTIFICATIONS AND TRAINING

Small Vessel Operator Proficiency (SVOP)

Electroshocker Crew Supervisor

First Aid Level 1 with Travel Endorsement

Certified for Riparian Areas Regulation Assessments

Certified Danger Tree Assessor for Urban and Recreational Areas

Environmental Monitoring for Construction Projects Training

102-450 Neave Ct., Kelowna, British Columbia, Canada V1V 2M2
Phone: 250-491-7337 / Fax: 250-491-77722

www.ecoscapeltd.com



OUR TEAM

Mike Schutten, M.A.Sc.

Contaminant Hydrogeologist

Mike Schutten is an Environmental Scientist with Ecoscape. With over five (5) years of experience, he has been heavily involved with contaminated site investigations, remediation and hydrogeological assessments. More specifically, Mike has experience with Phase I, II and III Environmental Site Assessments (ESAs), Brownfield redevelopment, Landfill monitoring, in-situ chemical oxidation via injection, and remediation system monitoring. Additionally, he has experience in aquifer and well yield testing, lake bathymetry, GIS, environmental impact assessments, land development permitting, sediment and erosion control, and surveying.

Mike is a well-versed Environmental Scientist with skills in hydrogeological assessments, groundwater and surface water monitoring and sampling (including low-flow sampling), monitoring well installations, environmental drilling and soil sampling, soil vapour sampling, landfill gas monitoring, lake profiling, environmental monitoring, in-situ chemical oxidation (via injection), and remediation system monitoring. Mike has experience in research design and dissemination in the field of hydrogeology, and has a thorough understanding of groundwater flow regimes in both fractured and porous media.

The following is a list of projects that highlight Mike's experience:

Mount Polley Tailings Breach Comprehensive Environmental Impact Assessment (CEIA), Likely, BC
Mike contributed to the water quality portion of a CEIA being done in response to a tailings pond breach at the Mt. Polley mine near Likely, BC. He acted as the on-site project coordinator, and worked to develop and maintain a water monitoring and sampling program that intended to delineate and predict the movement of a plume of sediment released from a tailings pond into Quesnel Lake. Throughout this project, Mike was actively involved in training and mentoring First Nations youth in field sampling and data collection techniques.

Phase III Contaminated Site Remediation for Shell Canada, Midhurst, Ontario.
Mike worked as junior project manager, designing and maintaining a biostimulation injection program intended to provide oxygen (via oxidation) to naturally occurring subsurface bacteria. Providing oxygen allowed these bacterial colonies to break down BTEX and petroleum hydrocarbons released into the subsurface by a historical retail fuel outlet.

Wellington County Landfill Monitoring, Ontario
Mike acted as a field coordinator for environmental assessments being conducted at multiple landfill sites, which included groundwater and surface water monitoring and sampling, landfill gas monitoring, acquisition of work permits, data and trend analysis, annual reporting, and liaising between the client and various government organizations.

EDUCATION

M.A.Sc. Contaminant Hydrogeology
McMaster University, Hamilton, ON
Thesis: The Influence of Hydrodynamic Forces on the Transport and Retention of Colloids in Single, Saturated, Dolomitic Limestone Fractures.

B.Sc. (Hons.) Earth and Environmental Science
McMaster University, Hamilton, ON

Minor in Geographic Information Studies (GIS)
McMaster University, Hamilton, ON

SUMMARY OF EXPERIENCE

2015—Current , Ecoscape Environmental Consultants

2012 – 2014 , Environmental Scientist. SNC-Lavalin Environment & Water (SNC-Lavalin Inc.).

2009-2012, Research Assistant. Department of Civil Engineering, McMaster University.

TRAINING AND CERTIFICATES

Small Vessel Operator Proficiency (SVOP)

Marine Emergency Duty (MEDA3)

First Aid Standard C + CPR

Swiftwater Rescue Technician

Electrofishing Crew Leader

Bear Awareness

Site Supervisor Training

WHMIS

102-450 Neave Ct., Kelowna, British Columbia, Canada V1V 2M2
Phone: 250-491-7337 / Fax: 250-491-77722

www.ecoscapeltd.com



OUR TEAM

Robert Wagner, B.Sc.

GIS Specialist/Land Surveyor/Survey Grade GPS

Mr. Wagner is a GIS Analyst / Environmental Scientist with Ecoscape. He has over 14 years of experience completing large assignments including the preparation of reports, maps, field inventories, GIS models and analysis associated with terrestrial and aquatic habitats, watershed assessments, and topographic/bathymetric modeling. Mr. Wagner specializes in data management, utilizing GPS for data field collection and GIS for processing and analysis. He is highly skilled in GIS applications and has extensive experience with Sensitive Habitat Inventory and Mapping, watershed assessments, and Terrestrial Ecosystem Mapping inventories.

Mr. Wagner's multi-disciplinary background allows him to contribute to all projects, by performing air photo interpretation, environmental monitoring, ecosystem mapping, land surveying, preparation of environmental construction management plans (e.g., erosion and sediment control), AutoCAD, GIS, and a variety of other tasks, as needed. As the primary GIS analyst and mapping specialist, Mr. Wagner has the experience necessary to more than adequately manage and analyze the range of data collected for the various types of Ecoscape projects.

Ecosystem Inventory Mapping/Trail Mapping
Mr. Wagner completed trail delineation (airphoto interpretation) and classification, topographic modeling, slope analysis, ecosystem mapping, and all phases of data management for a biophysical inventory and environmental impact assessment of Knox Mountain Park.

Source Water Protection Plans / Watershed Assessments
Mr. Wagner completed mapping deliverables, topographic modeling, slope analysis, risk analysis, and all phases of data management for 3 comprehensive source water protection plans for Hydraulic Creek, Oyama Creek, and Vernon Creek watersheds.

Arrow Lakes Reservoir Tributary Fish Migration Access Assessment and Monitoring Program (BC Hydro)
Mr. Wagner has completed topographic field surveys of Arrow Lake tributaries for the purpose of developing detailed 3D models for the determination of fish passage issues. Mapping deliverables will include a multi-year comparison of annually generated topographic models incorporating field data and real-time reservoir elevations. Mr. Wagner is solely responsible for the management of all data and mapping deliverables.

Sensitive Habitat Inventory and Mapping, River Inventory and Mapping, Foreshore Inventory and Mapping, Wetland Inventory and Mapping
Mr. Wagner is responsible for all data management and mapping deliverables for the diverse array of inventories listed above. In the past year, Ecoscape has completed approximately 10 of these large scale comprehensive inventories, of which Mr. Wagner has played an integral role.

EDUCATION

B.Sc., Environmental Science
Royal Roads University, Victoria, BC

Post-Graduate Diploma,
Georgian College of Applied Arts & Technology, Barrie, ON

Diploma,
Georgian College of Applied Arts & Technology, Barrie, ON

SUMMARY OF EXPERIENCE

2006 – present, Environmental Scientist / GIS Specialist. Ecoscape Environmental Consultants Ltd.

2004 – 2006, Environmental Scientist / GIS Specialist. EBA Engineering Consultants Ltd

2001 – 2004, Professional
Contractor, Environmental Technologist. Various companies.

PUBLICATIONS

"The Development of Detention Options for the Douglas Creek Watershed" (Royal Roads University and Friends of Mount Douglas Park Society), August 2003

"Independent Study on Ethanol Awareness" (Georgian College of Applied Arts and Technology), August 2000

"Technical Report on the Dissociation of Hexavalent Chromium" (Georgian College of Applied Arts and Technology), August 1999.

TRAINING AND CERTIFICATES

Swiftwater Flood Rescue Technician II – August 2010

2008 Basic Safety for Small Non-pleasure Vessels (Med A3)

Emergency First Aid – Industry with Alberta Endorsement and Level A CPR

Spinal Immobilization Endorsement

Electrofishing Crew Leader

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REMI J.P. ALLARD, M.Eng./P.Eng.

Principal Hydrogeologist

EDUCATION

M. Eng. (civil), University of Manitoba, 1993

B. Sc., Geological Engineering, University of Manitoba, 1984.

QUALIFICATIONS AND EXPERIENCE

Mr. Allard has over 30 years' of experience as an engineer/hydrogeologist. He has been a consultant in the Interior of BC since 1998, having completed all types of hydrogeological assessments including groundwater potential evaluation, new source development, aquifer and well protection planning, monitoring and rehabilitation. He has substantial experience in the design and permitting of effluent disposal systems. He excels at all types of spatial and temporal analysis of groundwater and surface water quality data.

Mr. Allard has several years of experience in Africa, South America, as well as on remote projects in the northern regions of Canada. He has worked throughout Canada and overseas on oil & gas and mining projects. He has also conducted hydrology and hydrogeology baseline studies, as well as managed multi-discipline teams on Environmental Assessment projects for the Mining plus Oil & Gas industries.

Remi is the Past President of the BC Groundwater Association, past technical director with the Canadian Groundwater Association and a former director with GeoExchange BC. He sits on several technical advisory committees including the Okanagan Basin Water Board Water Stewardship Council. He has presented papers at the NGWA Groundwater Summit (USA), the first and second National Conferences on Geo-exchange Business Policy in Canada (2006 & 2007), the Canadian National Water Well Conference (2004, 2008, 2014), as well as the regular presentations at annual conferences for the BC Groundwater Association, BC Water and Waste Association and Water Supply Association of BC.

Mr. Allard has on several occasions participated as an expert in public hearings, stakeholder reviews and environmental permitting, most notably the Ekati Diamond Project in northern Canada. He has also acted as a technical expert on several legal claims involving hillside drainage and flowing artesian boreholes.

CAREER HISTORY

Present:	Piteau Associates Engineering Ltd., Principal Hydrogeologist, Kelowna Office Manager
2011/2012:	Western Water Associates - Hydrogeologist, Founding & Managing Partner
2009/2011:	Sustainable Subsurface Solutions (Kelowna) Owner/ Principal Hydrogeologist
2001/2009:	Golder Associates Ltd. (Kelowna) Associate, Groundwater Group Leader
1998/2001:	EBA Engineering Consultants (Kelowna)
1995/1998:	Rescan Environmental and Compañía Rescan Peru (Vancouver and Lima)
1992/1995:	Wardrop Engineering International (Winnipeg and various countries in Africa)
1988/1990:	Associated Engineering Services Ltd (Vancouver and Ethiopia)
1986/1988:	AMEC (Prince George, BC)

MEMBERSHIPS

- Association of Professional Engineers and Geoscientists of British Columbia
- British Columbia Groundwater Association (Past President)
- Canadian Groundwater Association (Past Technical Director)
- British Columbia Water and Waste Association
- Water Supply Association of British Columbia
- National Groundwater Association (USA)