BC Lake Stewardship and Monitoring Program

Kootenay Lake

2013-2015

A partnership between the BC Lake Stewardship Society and the Ministry of Environment

The Importance of Kootenay Lake & its Watershed

British Columbians want lakes to provide good water quality, aesthetics and recreational opportunities. When these features are not apparent in recreational lakes, questions arise. People begin to wonder if the water quality is getting worse, if the lake has been affected by land development, and what conditions will result from more development within the watershed.

The BC Lake Stewardship Society (BCLSS), in partnership with the Ministry of Environment (MoE), has designed a program, entitled *The BC Lake Stewardship and Monitoring Program* (BCLSMP), to help answer these questions. Through regular water sample collections, we can begin to understand a lake's current water quality, identify the preferred uses for a given lake, and monitor water quality changes resulting from land development within the lake's watershed. The level for a particular lake depends on study objectives as well as funding and human resources available. This report provides the 2013 to 2015 results of a Level 3 program for the West Arm of Kootenay Lake.

Through regular status reports, the BCLSMP can provide communities with monitoring results specific to their local lake and with educational material on lake protection issues in general. This useful information can help communities play a more active role in the protection of the lake resource. Finally, this program allows government to use its limited resources efficiently thanks to the help of area volunteers and the BC Lake Stewardship Society.

Kootenay Lake's monitoring program began in 2013 and was conducted by the Friends of Kootenay Lake volunteers (in partnership with the MoE). This report summarizes information derived from the program. The quality of the data is acceptable.

A **watershed** is defined as the entire area of land that moves the water it receives to a common waterbody. The term watershed is misused when describing only the land immediately around a waterbody or the waterbody itself. The true definition represents a much larger area than most people normally consider. The watershed area of Kootenay Lake is 7,771 km^2 (Bexson, 2017).

Watersheds are where much of the ongoing hydrological cycle takes place and play a crucial role in the purification of water. Although no "new" water is ever made, it is continuously recycled as it moves through watersheds and other hydrologic compartments. The quality of the water resource is largely determined by a watershed's capacity to buffer impacts and absorb pollution.

Every component of a watershed (vegetation, soil, wildlife, etc.) has an important function in maintaining good water quality and a healthy aquatic environment. It is a common misconception that detrimental land use practices will not impact water quality if they are kept away from the area immediately surrounding a water body. Poor land-use practices anywhere in a watershed can eventually impact the water quality of the downstream environment.

Human activities that impact water bodies range from small but widespread and numerous *non-point* sources throughout the watershed to large *point* sources of concentrated pollution (e.g. waste discharge outfalls, spills, etc.). Undisturbed watersheds have the ability to purify water and repair small amounts of damage from pollution and alterations. However, modifications to the landscape and increased levels of pollution impair this ability.

Kootenay Lake is a long, narrow lake located in the central Kootenay region between the Selkirk and Purcell mountain ranges and lies at an elevation of 530 m (Kootenay Lake Chamber of Commerce, 2017). It is one of the largest lakes in British Columbia with a surface area of 389 km^2 (Daley et. al, 1980). The lake is approximately 107 km long and has a maximum depth of 154 m and a mean depth of 94 m (Daley et. Al, 1980). The West Arm, where sampling took place, is approximately 30 km long (Friends of Kootenay Lake, 2013). Kootenay Lake has a number of primary inflows, including the Kootenay River at the south end and Duncan and Lardeau Rivers at the north end. The lake outflow is through the West Arm and joins the Columbia River at Castlegar.

Fish species reported in Kootenay Lake include: burbot, whitefish, bull trout, rainbow trout, kokanee, white sturgeon, dolly varden, brook trout, cutthroat trout, longnose dace, redside shiner, and yellow perch (Habitat Wizard, 2017). The lake has historically been stocked with white sturgeon, kokanee, rainbow trout, and cutthroat trout (Habitat Wizard, 2017). The main lake kokanee fishery has been closed since April 2015 due to low numbers,

however the West Arm fishery has been able to stay open with year to year restrictions.

In 1992, an experimental nutrient restoration program was implemented on Kootenay Lake to restore decreased productivity due to the Duncan Dam at the North Arm of the lake. In 2004, nutrient restoration started in the South Arm to compensate for impacts from the Libby Dam (Schindler et. al, 2007).

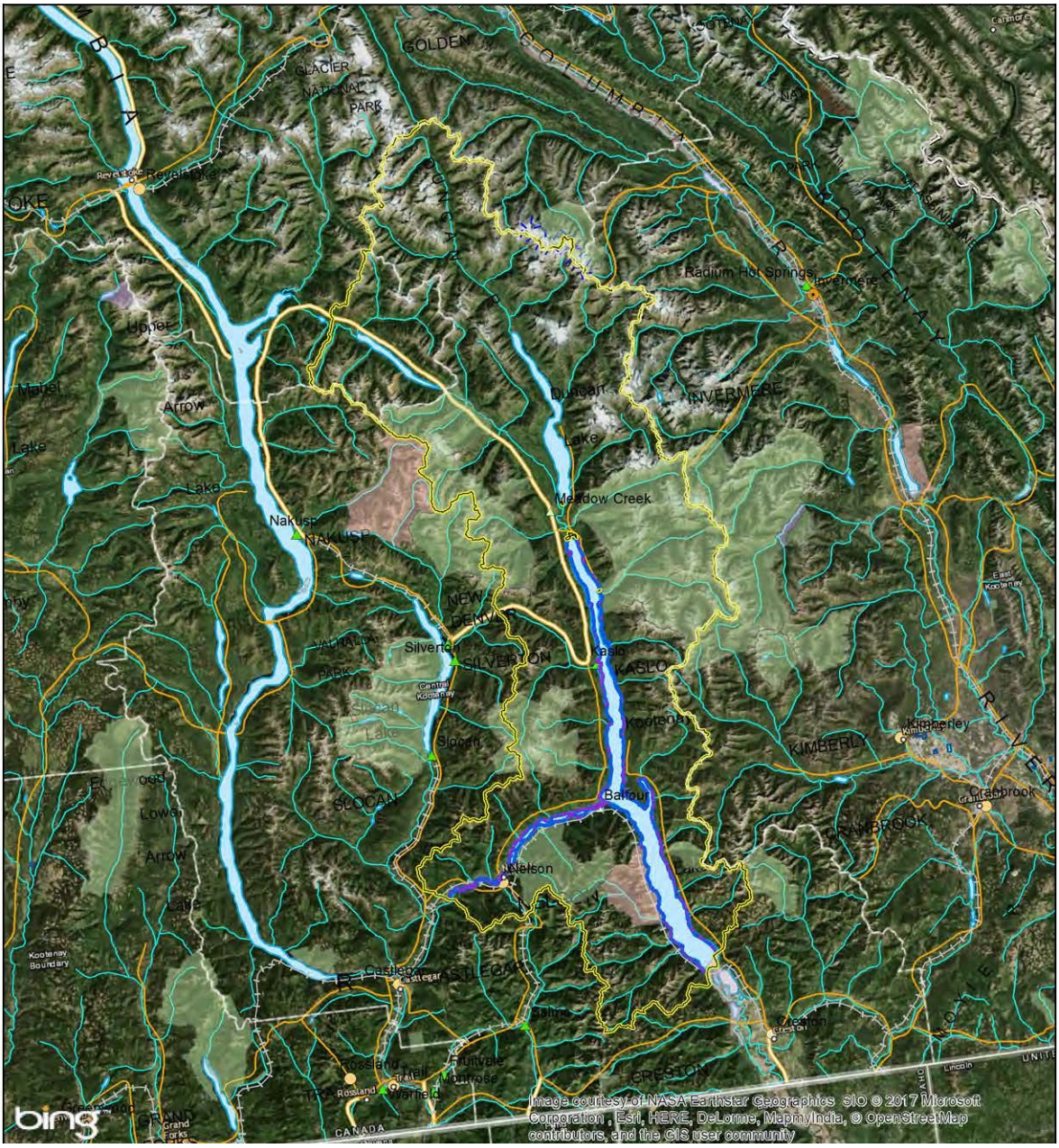
The flushing rate, a factor that affects water quality, is the rate of water replacement in a lake and depends on the amount of inflow and outflow of a lake. The higher the flushing rate, the faster excess nutrients can be removed from the system. The flushing rate for Kootenay Lake is 1.8 years (Daley et. al, 1980). The flushing rate for the West Arm is 3 to 4 days (Fraser, 2017).

Kootenay Lake Watershed and Land Use Map

WATERSHED CHARACTERISTICS

Watershed Area: 7771.5 km^2

Percent Land Use (approximate)	
Forested:	60%
Barren or sparsely vegetated	22%
Open range/grasslands	10%
Shrub land:	5%
Lake:	5%
Wetlands:	<1%
Parks:	21%
Lakeshore residential:	<1%



N

1:1,170,000

0 10 20 30 40 km

Watershed Boundary
Residential <= 1ha within 100m of Lakeshore
Grazing Leases

Imagery source: Bing

Provincial Parks
Ecological Reserves
Protected Areas
Recreation Areas
Conservancy Areas
Wildlife Management Areas

Non-Point Source Pollution and Kootenay Lake

Point source pollution originates from municipal or industrial effluent outfalls. Other pollution sources exist over broader areas and may be hard to isolate as distinct effluents. These are referred to as non-point sources of pollution (NPS). Shoreline modification, urban stormwater runoff, onsite septic systems, agriculture, and forestry are common contributors to NPS pollution. One of the most detrimental effects of NPS pollution is phosphorus loading to water bodies. The amount of total phosphorus (TP) in a lake can be greatly influenced by human activities. If local soils and vegetation do not retain this phosphorus, it will enter watercourses where it will become available for algal production.

Agriculture

Agriculture including grains, livestock, and mixed farming, can alter water flow and increase sediment and chemical/bacterial/parasitic input into water bodies. Potential sources of nutrients (nitrogen & phosphorus) include chemical fertilizers and improperly situated winter feeding areas.

Onsite Septic Systems and Grey Water

Onsite septic systems effectively treat human waste water and wash water (grey water) as long as they are properly located, designed, installed, and **maintained**. When these systems fail, they become significant sources of nutrients and pathogens. Poorly maintained pit privies, used for the disposal of human waste and grey water, can also be significant contributors.

Properly located and maintained septic tanks do not pose a threat to the environment, however, mismanaged or poorly located tanks can result in a health hazard and/or excessive nutrient loading to the lake.

Stormwater Runoff

Lawn and garden fertilizer, sediment eroded from modified shorelines or infill projects, oil and fuel leaks from vehicles, snowmobiles and boats, road salt, and litter can all be washed by rain and snowmelt from properties and streets into watercourses. Phosphorus and sediment are of greatest concern, providing nutrients and/or a rooting medium for aquatic plants and algae. Pavement prevents water infiltration to soils, collects hydrocarbon contaminants during dry weather and increases direct runoff of these contaminants to lakes during storm events.

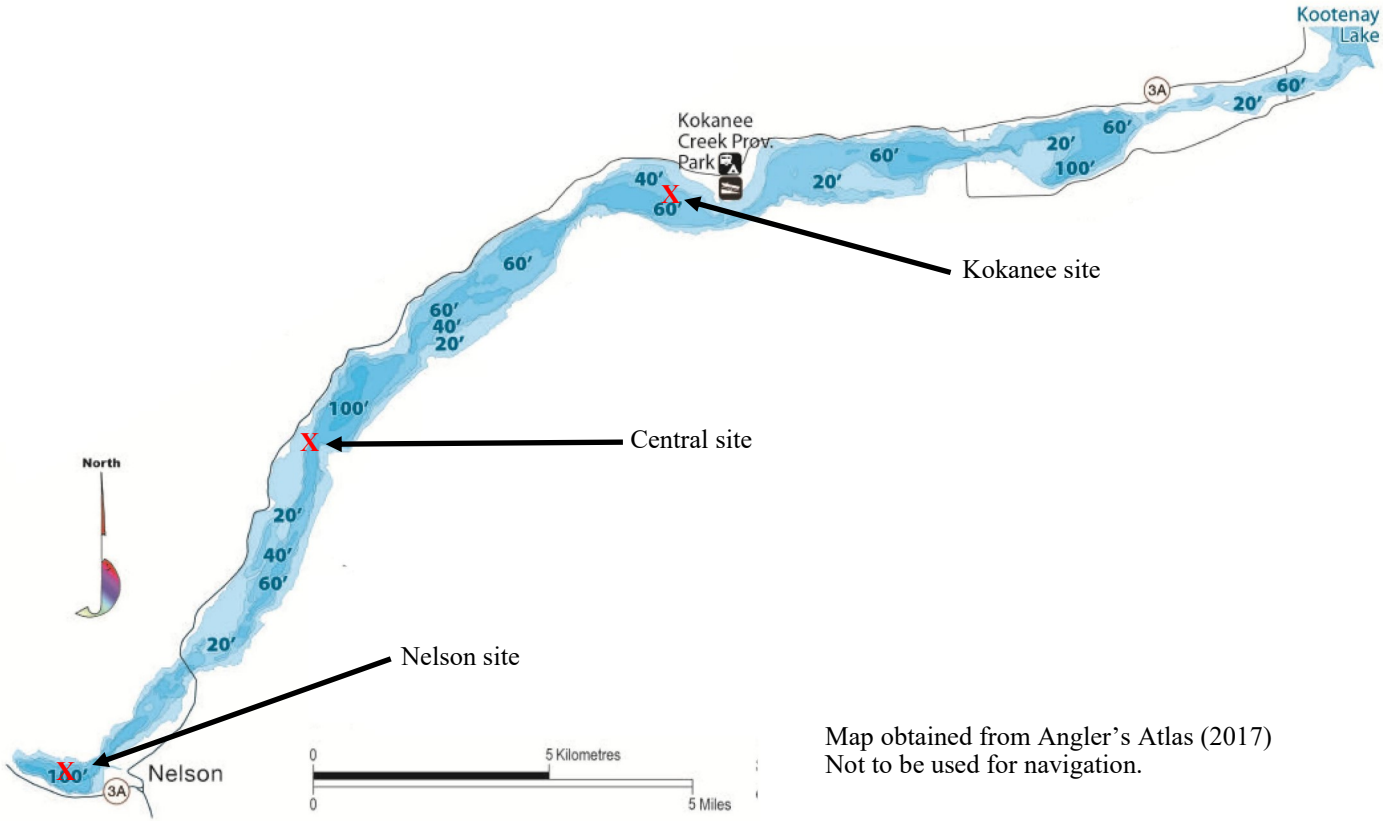
Forestry

Timber harvesting can include clear cutting, road building, and land disturbances, which alter water flow and potentially increase sediment and phosphorus inputs to water bodies.

Boating

Oil and fuel leaks are the main concerns of boat operation on small lakes. Other problems include the spread of aquatic plants and the dumping of litter. In shallow water operations, the churning up of bottom sediments and nutrients is a concern.

Kootenay Lake (West Arm) Bathymetric Map



Map obtained from Angler's Atlas (2017)
Not to be used for navigation.

Trophic Characteristics	2013			2014			2015		
	Kokanee	Central	Nelson	Kokanee	Central	Nelson	Kokanee	Central	Nelson
Max. Surface Temp (°C)	19.5	20.3	20.3	19.9	20.0	19.8	20.0	20.4	20.4
Min. Near-bottom Oxygen (mg/L)	7.8	8.0	7.7	8.1	7.2	7.4	8.6	8.6	7.9
Average Summer Surface TP (µg/L)	3.7	5.0	4.5	4.0	5.3	5.3	4.7	5.1	4.6
Avg. Chlorophyll α, or "Chl *a*" (µg/L)	2.0	2.0	2.2	2.5	2.9	2.7	3.0	2.8	2.9
Avg. Summer Secchi Depth (m)	6.7	6.4	5.5	6.5	6.6	5.9	6.0	5.7	5.6

What's Going on Inside Kootenay Lake?

Temperature

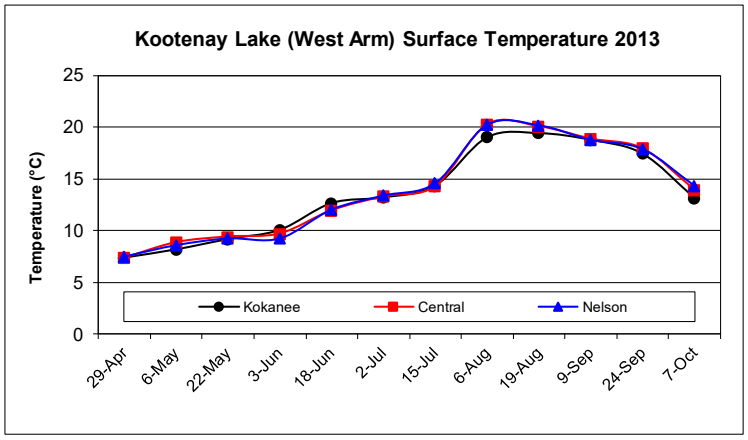
Lakes show a variety of annual temperature patterns based on their location and depth. Most interior lakes form layers (stratify), with the coldest summer water near the bottom. Because colder water is more dense, it resists mixing into the warmer, upper layer for much of the summer. In spring and fall, these lakes usually mix from top to bottom (overturn) as wind energy overcomes the reduced temperature and density differences between surface and bottom waters. In the winter, lakes re-stratify under ice with the most dense water (4°C) near the bottom. Kootenay Lake does not freeze over in the winter. The main lake would be considered monomictic while the West Arm is likely polymictic .

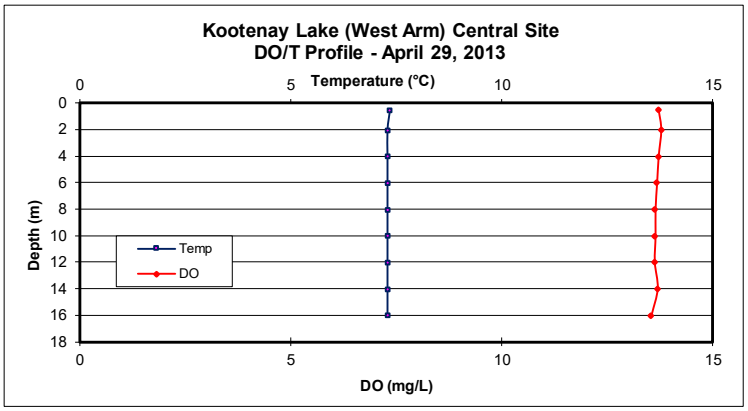
Lakes of only a few metres depth tend to mix throughout the summer or layer only temporarily, depending on wind conditions. In winter, the temperature pattern of these lakes is similar to that of deeper lakes.

Temperature stratification patterns are very important to lake water quality. They determine much of the seasonal oxygen, phosphorus and algal conditions. When abundant, algae can create problems for most lake users.

The review of ice-on and ice-off dates is important to the growing issue of climate change, particularly with how it is affecting B.C. lakes.

Temperature (T) was measured on the West Arm of Kootenay Lake at three sites (Kokanee, Central, and Nelson) from 2013 to 2015. Maximum surface temperature across sampling years ranged between 19.5ºC (Kokanee site, 2013) and 20.4ºC (Central and Nelson sites, 2015). The following graph summarizes the 2013 surface temperature data for all three sites on the West Arm of Kootenay Lake.





Dissolved oxygen and temperature readings at all three sites in April of 2013 show that the lake was mixed to at least 16m, the maximum depth measured. The previous graph shows the DO/T profile at the Central site during the spring of 2013 and indicates isothermy (same T) in the water column. Profiles for the Kokanee and Nelson sites on the same sampling date are similar. The West Arm of Kootenay Lake appears isothermal during the entire summer, indicating a well-mixed system. This may be due to water flow through and a short water residence time, resulting in the West Arm not stratifying (Nordin 2017, Pers. Comm.).

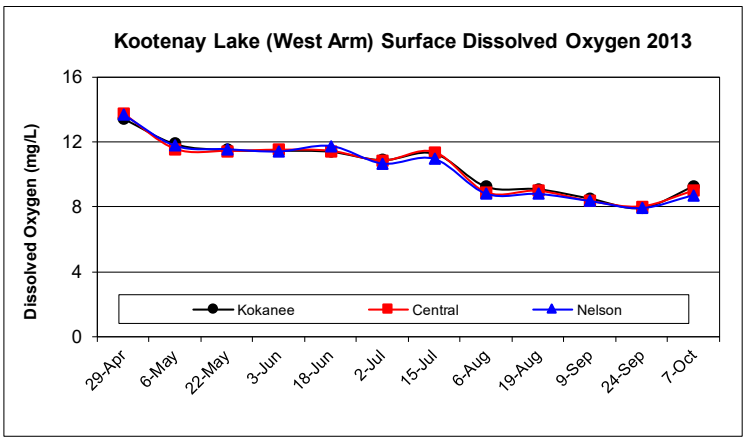
Dissolved Oxygen

Oxygen is essential to life in lakes. It enters lake water from the air by wind action and plant photosynthesis. Oxygen is consumed by respiration of animals and plants in summer, including the decomposition of dead organisms by bacteria. A great deal can be learned about the health of a lake by studying oxygen patterns and levels.

Lakes that are unproductive (oligotrophic) will have sufficient oxygen to support life at all depths through the year. But as lakes become more productive (eutrophic), and increasing quantities of plants and animals respire and decay, more oxygen consumption occurs, especially near the bottom where dead organisms accumulate.

In productive lakes, oxygen in the isolated bottom layer may deplete rapidly (often to anoxia), forcing fish to move into the upper layer (salmonids are stressed when oxygen levels fall below about 20% saturation) where temperatures may be too warm. Fish kills can occur when decomposing or respiring algae use up the oxygen. In the summer, this can happen on calm nights after an algal bloom, but most fish kills occur during late winter or at initial spring mixing because oxygen has been depleted under winter ice.

The graph below summarizes the 2013 surface dissolved oxygen (DO) data for the Kokanee, Central, and Nelson sites. Data indicate that DO is high (>8 mg/L) with the exception of the Kokanee and Nelson readings on Sep. 24 which were slightly below 8 mg/L at 7.93 mg/L and 7.91 mg/L, respectively. Data from 2014 and 2015 also show high oxygenation (>8 mg/L).



Trophic Status and Phosphorus

The term "trophic status" is used to describe a lake's level of productivity and depends on the amount of nutrients available for plant growth, including tiny floating algae called phytoplankton. Algae are important to the overall ecology of the lake because they are food for zooplankton, which in turn are food for other organisms, including fish. In most lakes, phosphorus is the nutrient in shortest supply and thus acts to limit the production of aquatic life. When in excess, phosphorus accelerates growth and may artificially age a lake. As mentioned earlier (page 3), ***total phosphorus (TP)*** in a lake can be greatly influenced by human activities.

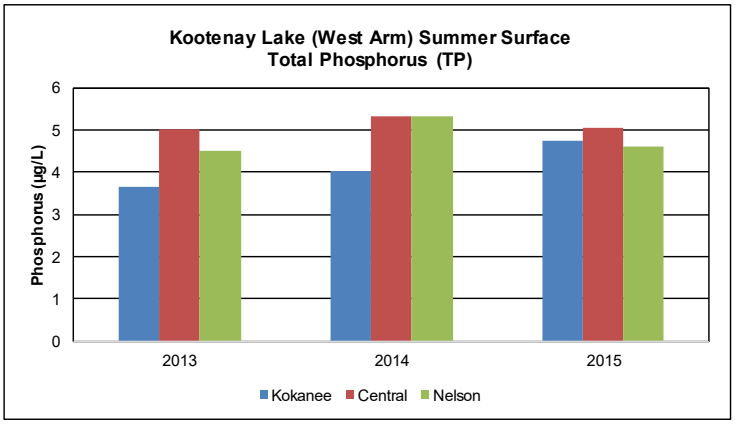
The trophic status of a lake can be determined by measuring productivity. The more productive a lake is the higher the algal growth and therefore the less clear the water becomes. Water clarity is measured using a ***Secchi disc***, a 20 cm diameter black and white disc used to indicate the depth of light penetration. Productivity is also determined by measuring nutrient levels and ***chlorophyll*** (the green photosynthetic pigment of algae). The concentration of chlorophyll *a* (chl *a*) in lake water is an indicator of the density of algae present in that same water and is directly related to the Secchi depth. Phosphorus concentrations measured during spring overturn can be used to predict summer algal productivity.

Lakes of low productivity are referred to as ***oligotrophic***, meaning they are typically clear water lakes with low nutrient levels (1-10 µg/L TP), sparse plant life (0-2 µg/L chl. *a*) and low fish production. Lakes of high productivity are ***eutrophic***. They have abundant plant life (>7 µg/L chl. *a*) including algae, because of higher nutrient levels (>30 µg/L TP). Lakes with an intermediate productivity are called ***mesotrophic*** (10-30 µg/L TP and 2-7 µg/L chl. *a*) and generally combine the qualities of oligotrophic and eutrophic lakes.

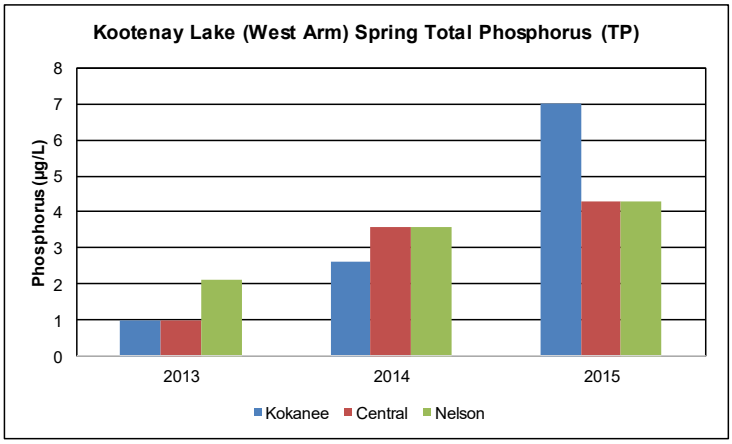
Lake sediments can themselves be a major source of ***ortho-phosphorus (OP)***, a form of ***total dissolved phosphorus (TDP)***. If deep-water oxygen becomes depleted (i.e. anoxic), a chemical shift occurs in bottom sediments. This shift causes sediment to release ortho-phosphorus to overlying waters. This *internal loading* of phosphorus can be natural but is often the result of external phosphorus addition. Lakes displaying internal loading have elevated algal levels and generally lack recreational appeal.

Kootenay Lake's summer surface TP values for all three sites across the sampling years are shown in the Trophic Characteristics table on page 3. Twelve samples were taken from the surface (0.5m) throughout the summer. Data from July 13, 2013 were excluded from the dataset as they appeared to be erroneous, likely due to a lab reporting error.

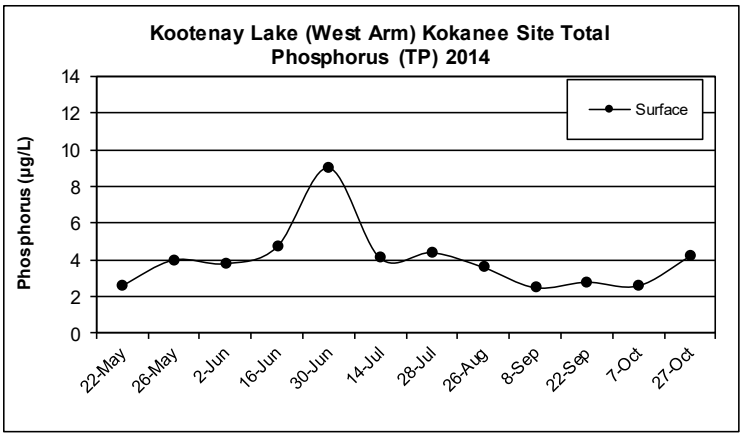
Kootenay Lake West Arm summer surface TP values for each site are shown in the following graph. The Kokanee site shows an increase over the years while the Central and Nelson sites show a slight increase in 2014 followed by a decrease in 2015. Average TP values fall within the oligotrophic range (1-10 µg/L TP).



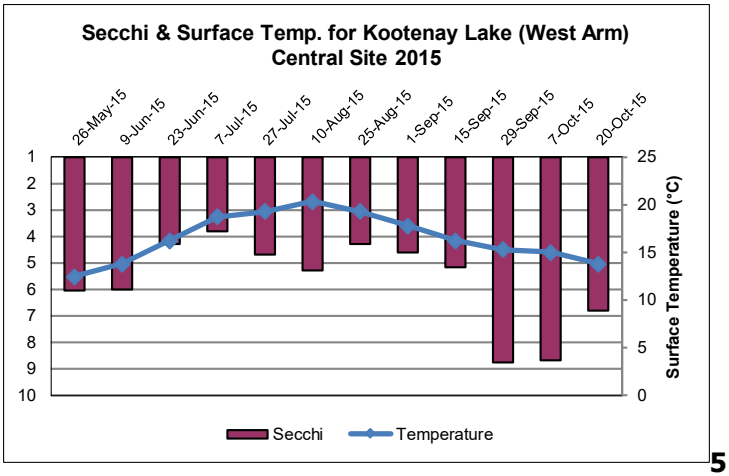
The following graph shows the spring TP data collected at all three sites on the first date of sampling (April 29, 2013, May 22, 2014, and May 26, 2015). The graph indicates that spring TP levels have increased over the years. The spring TP can be influenced by a number of factors such as when sampling was done or stream runoff, so it may not be a good indicator of trends.

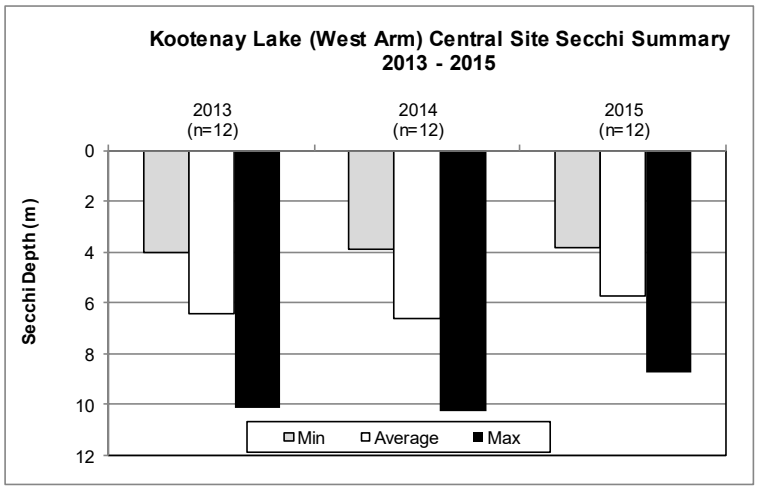


The graph below shows the surface TP at the Kokanee site in 2014. Summer values ranged from 2.5 µg/L (Sep. 8) to 9 µg/L (Jun. 30). There is an increase in TP in each sampling year during the May-June period. This is when there is the highest runoff and the highest water exchange rate is occurring. This seasonal increase is observed at all sites in each of the sampling years.



The following graph shows the summer Secchi and surface temperature readings taken at the Central site in 2015. Secchi depths ranged from 3.8 m (Jul. 7) to 8.8 m (Sep. 29). The 2015 data are representative of the other sampling years. Generally, as temperature increases, so do some species of algae. Due to the increase in algae, the water clarity can decrease and the Secchi depth decreases as well. However, this trend is not strongly indicated in the Secchi and temperature data collected from the West Arm of Kootenay Lake from 2013-15. Secchi is often a reflection of phytoplankton density but it would also be affected by runoff from streams coming into the West Arm. There may be a relationship of Secchi depth to hydrology and the amount of flow coming in from streams carrying inorganic (silt) particulate matter (Nordin 2017, Pers. Comm.).



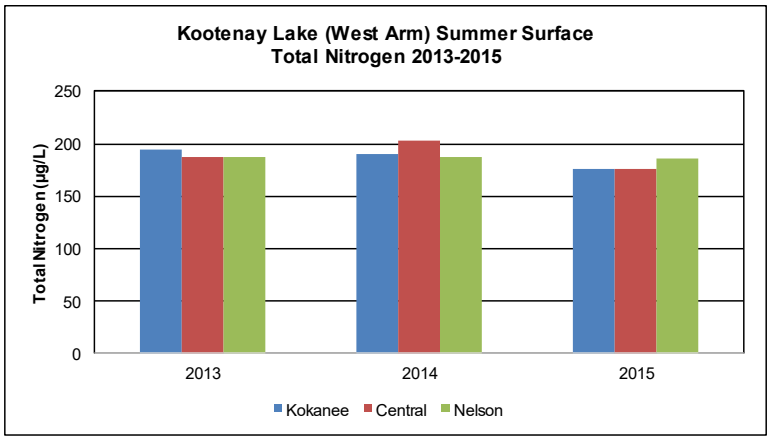


The graph above shows the minimum, average and maximum summer Secchi readings at the Central site from 2013-2015, as well as the number of readings in each year (n). Average summer Secchi depth between 2013 and 2015 ranged from 6.0 m to 6.7 m (Kokanee site), 5.7 m to 6.6 m (Central site) and 5.5 m to 5.9 m (Nelson site). The 2013-2015 data indicate that the clarity of Kootenay Lake remained relatively stable over the sampling years. Based on the average Secchi values, Kootenay Lake was exhibiting oligotrophic conditions (>6 m Secchi depth) for all years measured (Nordin, 1985).

Nitrogen

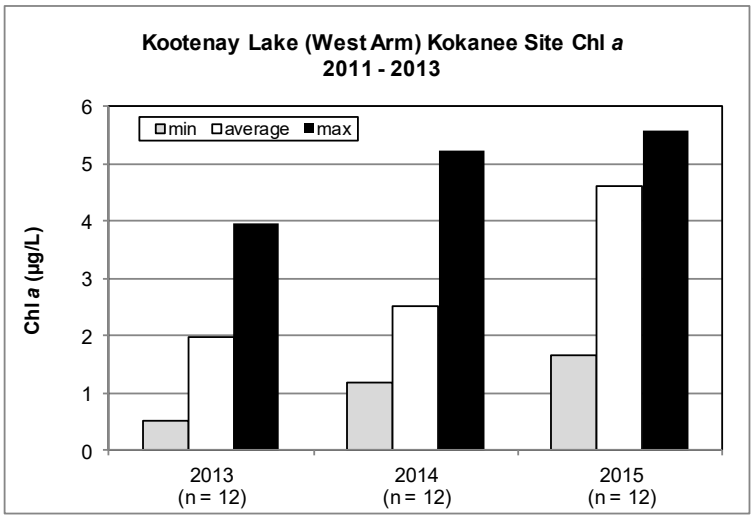
Nitrogen is the second most important nutrient involved in lake productivity. Nitrogen in water is present in several forms; organic compounds, ammonia, nitrite, nitrates or nitrogen gas. Generally, major sources of nitrogen compounds are municipal and industrial wastewater, onsite sewage systems, urban and agriculture runoff, atmospheric precipitation, groundwater and nitrogen fixation. In BC lakes, nitrogen is rarely the limiting nutrient for algal growth (see phosphorus section). In most lakes, the ratio of nitrogen to phosphorus is well over 15:1, meaning excess nitrogen is present. In lakes where the N:P is less than 5:1, nitrogen becomes limiting to algal growth and can have major impacts on the amount and species of algae present. The N:P for the West Arm of Kootenay Lake (using summer surface data from each site) was 53, 47 & 37 (Kokanee), 37, 38 & 35 (Central) and 41, 35 & 40 (Nelson) in 2013, 2014 & 2015 respectively. This indicates that this section of the lake is P-limited.

The following graph shows the average summer surface total nitrogen (TN) readings for Kootenay Lake from 2013-2015. Values range from 176 µg/L to 203 µg/L . These TN values put the West Arm of Kootenay Lake in the mesotrophic category (Nordin, 1985). As the graph shows, the concentrations have remained relatively stable over the years, slightly decreasing in 2015.



Average summer surface chlorophyll *a* in the West Arm of Kootenay Lake ranges from 1.96 µg/L (Central site, 2013) to 4.62 µg/L (Kokanee site, 2015). Average chl *a* data place Kootenay Lake in the mesotrophic category, with 2 slightly oligotrophic values in 2013 at the Kokanee and Central sites.

The graph below shows the chlorophyll *a* summary for the Kokanee site from 2013–2015. The graph shows a trend of slightly increasing average surface chl *a* over the years at the Kootenay site and this is also observed at the Central and Nelson sites.



Aquatic Plants

Aquatic plants are an essential part of a healthy lake. Factors that affect the type and amount of plants found in a lake include the level of nutrients (i.e. phosphorus), temperature, and introduction of invasive species.

Aquatic plants were surveyed in Kootenay Lake (Warrington, 1980) and include: *Potamogeton spp.* (*crispus, perfoliatus, illinoensis, friesii, robbinsii, zosteriformis, natans, gramineus, pusillus, pectinatus, praelongus, amplifolius and alpinus*), *Lemna minor, Callitriche spp. (anceps, hermaphroditica and heterophylla), Alisma plantago-aquatica, Equisetum spp. (palustre and fluviatile), Scirpus lacustris, Chara spp., Myriophyllum spp. (ussuriense and exalbescens), Ranunculus spp. (flabellaris, aquatilis, hyperboreus and flammula), Hippuris vulgaris, Scheuchzeria palustris, Rorippa nasturtium-aquaticum, Veronica spp. (americana and scutellata), Gratiola neglecta, Myosotis laxa, Utricularia vulgaris, Isoetes, Sagittaria, Polygonum amphibium, Eleocharis spp. (palustris and acicularis), Sparganium eurycarpum, Spirodela polyrhiza, Elodea spp. (canadensis and richard), Najas flexilis, Heteranthera dubia, Bidens beckii, Sium sauve, Typha latifolia, Ricciocarpus natans, Sparganium angustifolium, Ceratophyllum demersum, Vallisneria spiralis, Zannichellia palustris, Subularia aquatica, Limosella aquatica, Mimulus guttatus, and Tillaea aquatic.*

Aquatic plants play an important role in the lifecycles of aquatic insects, provide food and shelter from predators for young fish, and also provide food for waterfowl, beavers and muskrats.

Many aquatic plant species can spread between lakes via boaters potentially resulting in species introduction. Be sure to check for and remove all aquatic plant fragments from boats and trailers before entering or when leaving a lake.

Should Further Monitoring Be Done on Kootenay Lake?

Spring temperature and DO profiles for 2013-2015 indicate that the West Arm of Kootenay Lake was fully mixed. Based on average summer surface TP, the West Arm of Kootenay lake was exhibiting oligotrophic conditions from 2013-2015. Spring surface TP levels have increased over the years however they can be influenced by a number of factors such as when sampling was done or stream runoff, so this may not be a good indicator of trends. This section of the lake is P-limited and TN values are in the mesotrophic category. Average summer Secchi data indicate that the West Arm was oligotrophic, while average chl *a* indicate mesotrophic conditions, with two marginally oligotrophic readings at the Kokanee and Central sites in 2013. The clarity of the West Arm of Kootenay Lake remained relatively stable over the sampling period.

If volunteers are willing to continue monitoring, additional Secchi and surface temperature measurements will provide valuable long term records and help to identify early warning signs should there be a deterioration in water quality in the West Arm of Kootenay Lake. As variances can occur in different sections of a lake, it would be valuable to collect baseline data in the north-south section of the lake.

Tips to Keep Kootenay Lake Healthy

Yard Maintenance, Landscaping & Gardening

- Minimize the disturbance of shoreline areas by maintaining natural vegetation cover.
- Minimize high-maintenance grassed areas.
- Replant lakeside grassed areas with native vegetation.
- Do not import fine fill.
- Use paving stones instead of pavement.
- Stop or limit the use of fertilizers and pesticides.
- Do not use fertilizers in areas where the potential for water contamination is high, such as sandy soils, steep slopes, or compacted soils.
- Do not apply fertilizers or pesticides before or during rain due to the likelihood of runoff.
- Hand pull weeds rather than using herbicides.
- Use natural insecticides such as diatomaceous earth. Prune infested vegetation and use natural predators to keep pests in check. Pesticides can kill beneficial and desirable insects, such as lady bugs, as well as pests.
- Compost yard and kitchen waste and use it to boost your garden's health as an alternative to chemical fertilizers.

Onsite Sewage Systems

- Inspect your system yearly, and have the septic tank pumped every 2 to 5 years by a septic service company. Regular pumping is cheaper than having to rebuild a drainfield.
- Use phosphate-free soaps and detergents.
- Don't put toxic chemicals (paints, varnishes, thinners, waste oils, photographic solutions, or pesticides) down the drain because they can kill the bacteria at work in your onsite sewage system and can contaminate waterbodies.
- Conserve water: run the washing machine and dishwasher only when full and use only low-flow showerheads and toilets.
- Pick up after your pets as pet waste can lead to bacterial contamination of the lake water.

Auto Maintenance

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

Boating

- Do not throw trash overboard or use lakes or other waterbodies as toilets.
- Use biodegradable, phosphate-free cleaners instead of harmful chemicals.
- Conduct major maintenance chores on land.
- Use absorbent bilge pads to soak up minor leaks or spills.
- Check for and remove all aquatic plant fragments from boats and trailers before entering or leaving a lake. Eurasian milfoil is an aggressive invasive aquatic weed. Be sure to familiarize yourself with this plant and remove and discard any fragments.
- Do not use metal drums in dock construction. They rust, sink and become unwanted debris. Use polystyrene (completely contained and sealed in UV treated material) or washed plastic barrel floats. All floats should be labeled with the owner's name, phone number and confirmation that barrels have been properly emptied and washed.
- Recreational lake users are encouraged to take their waste and debris with them after using the lake during winter months.
- Leading by example is often the best method of improving practices - help educate fellow boaters.

Agriculture

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

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Bathymetric Map:
Angler's Atlas

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