

# **Chestermere Lake, Alberta sediment collection results**

*Technical Report Prepared for:*

**The Town of Chestermere**

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## Introduction

### *Project Background*

Since its creation in 1903, Chestermere Lake, Alberta has served as a storage basin and settling pond within the Western Irrigation District's (WID) Headworks Canal. Water is drawn from a Bow River diversion weir downstream of the Calgary Zoo. The Canal system provides irrigation water for agriculture and drinking water for four downstream communities. In 1963, the City of Calgary signed an agreement with the WID to drain three stormwater outfalls into the Canal. Now, there are 34 stormwater outfalls contributing to the WID Canal, with the ability to overwhelm the Canal system with volumes of water in larger storm events. Dissolved in the Canal water are various urban and industrial contaminants as well as suspended particulate matter. The heavier suspended matter settles and is stored within Chestermere Lake as water passes through the reservoir. Sediment storage, along with the storage and accumulation of sediment bound contaminants, is a continual process.

Due to Chestermere Lake's variable water quality, the Town of Chestermere commissioned a state of the knowledge report in the fall of 2000 to summarize all past literature on the ecology of the lake. The report<sup>1</sup> was completed by Aquality Environmental Consulting Ltd. on April 30, 2001 and presented to Town Council. The recommendations from this document identified knowledge gaps regarding sediment depth and sediment quality. Poor sediment quality was linked to some of the water quality problems seen in Chestermere Lake. Sediments collected from upstream at the Bow River, Nose Creek and several storm sewer outfalls contain a wide array of contaminants, including industrial organochlorines (DEHP), heavy metals such as aluminum, cadmium, chromium, copper, iron, mercury and zinc, and the nutrient phosphorus<sup>2</sup>. The *Aquality* report and others have recommended that Chestermere Lake sediments should be collected and analyzed for possible heavy metal contamination by the metals listed above.

Sediment sampling was undertaken by Aquality Environmental Consulting Ltd. in March 2001. The purpose of this sampling was to fill the knowledge gaps outlined in the *Aquality* report. Specifically, we needed to quantify sediment accumulation across the lake and collect cores for a

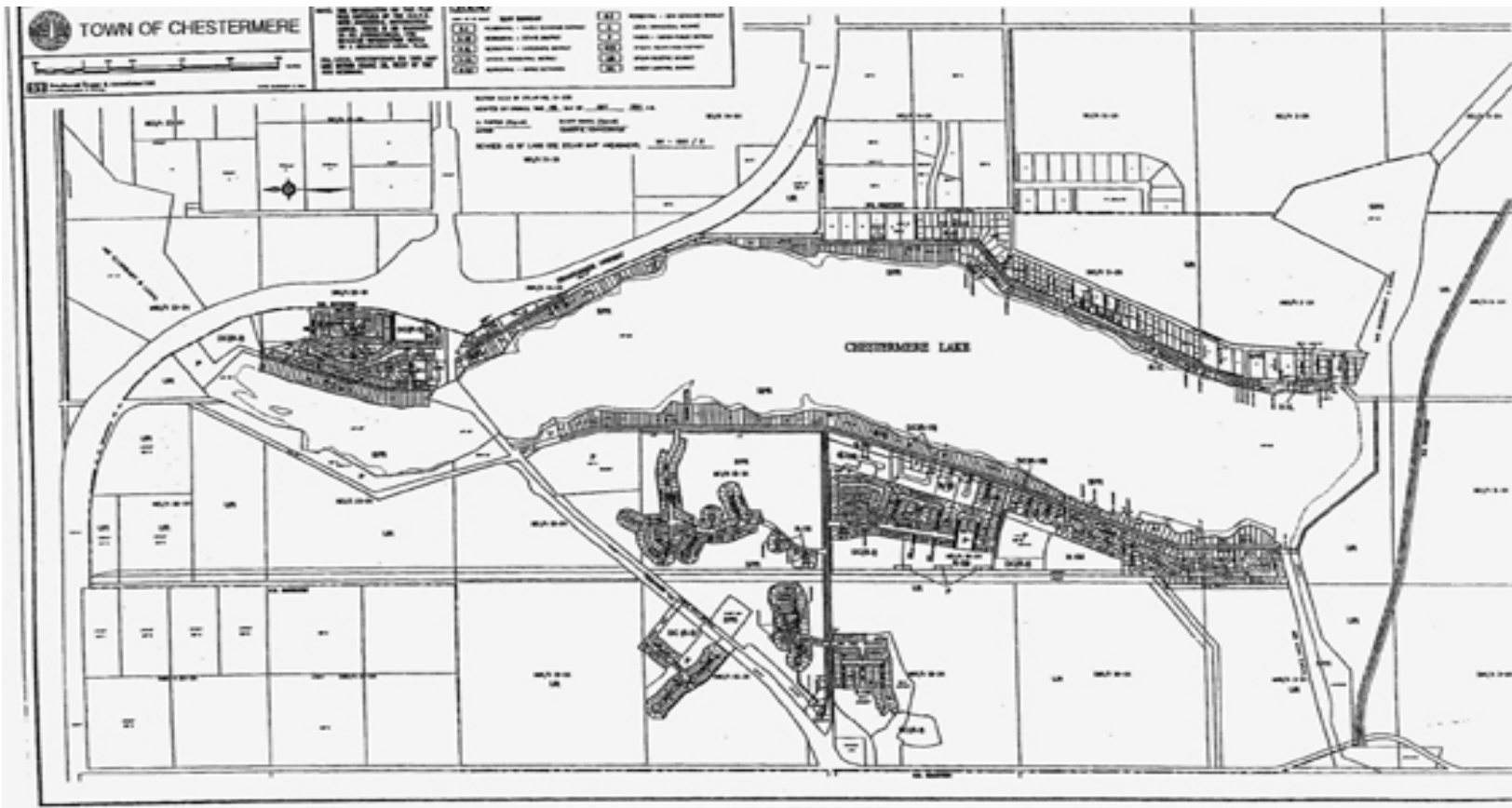
variety of physical and chemical analyses. The following technical report summarizes the results of sediment depth and quality sampling.

### ***Site Description***

Chestermere Lake is a 261 ha offstream storage reservoir, 7 km east of the city of Calgary, Alberta (Tp 24 R28 W4) in Municipal District # 44 (Figure 1). The lake has an elongate oval shape (5.12 km long by 0.77 km wide)<sup>3</sup> with a drainage basin area of 5 km<sup>2</sup> and lies in the Foothills Fescue Prairie Ecoregion<sup>4</sup>. This arid region of southern Alberta is characterized by hot summers, cold winters and temperatures modified by Chinook winds. Annual precipitation in the area is 432 mm and evapotranspiration exceeds precipitation by 34 mm/year<sup>5</sup>. The geology underlying Chestermere Lake is a bedrock of sandstone, shale and coal, with a surficial layer of till left from the melting of the Pleistocene ice sheets<sup>6</sup>. Soils of the area are thin Orthic Black Chernozemics. Lake sediments consist of bottom mud and organic sand and silt underlain by sand and silt with thicknesses ranging from 0.5m to 1.5m<sup>7</sup>. The lakeshores slope steeply to a historical maximum depth of 7 m<sup>8</sup>. The 12.3 km shoreline around the lake has been fully developed with over 400 lots, and over 3330 people live within the basin<sup>9</sup>.

This reservoir was created in 1903 by the Canadian Pacific Railroad as part of the Western Headworks Canal system linking water from the Bow River to ranchers as far as 90 kms away. Downstream from the reservoir, the towns of Gleichen, Rockyford, Standard and Strathmore draw their drinking water supply from the canal. Since 1963, stormwater from the city of Calgary has been added to the Headworks, but a moratorium on further inputs was imposed in 1983<sup>10</sup>. Other historic details of the canal development and town settlement can be found in Thompson<sup>11</sup> and Peake<sup>12</sup>. The canal system is managed today by the Western Irrigation District (WID), which maintains the constant water levels on Chestermere Lake during the summer months. The lake receives approximately  $179 \times 10^6$  m<sup>3</sup> water/day; resulting in a retention time of about 11 days, with lower retention times during high-flow periods<sup>13</sup>.

Approximately 55% of the influent water exits the reservoir from Canal A in the southeast corner nearest the inflow, while the rest spills from Canal B in the north end<sup>14</sup> (Figure 1). From October to April the lake is drawn down to a depth of 1.5m and the canals are closed to any water flow to prevent ice damage to the headgates and private docks. Water quality details can be found in White<sup>15</sup>.



**Figure 1: The 261 hectare WID reservoir at Chestermere Lake, Alberta, 7 km east of the city of Calgary. The lake has a drainage basin of 5 km<sup>2</sup>, with an elongate oval shape 5.12 km long by 0.77 km wide. The 12.3 km long shoreline is heavily developed with over 400 lots and 3330 permanent residents. Planning diagram used with permission from the Town of Chestermere and Southwell Trapp & Associates Ltd.**

## Methods

### *Field collection*

Sampling was conducted on March 2 and 3, 2001. Sediment cores were collected by hand with a 2m long acrylic core tube (diameter = 5 cm) along two transects with sites spaced 1000 m apart (Figure 2). Twelve sites were sampled and collections made after first drilling several holes through the ice. At each site, two full sediment cores (down to the mineral soil) and a third sample of the surface sediments (0.5 cm thick) were collected. Care was taken to ensure that the sampling procedure created minimal disturbance at the sediment-water interface.

Collected samples were quickly extruded from the corer, emptied into pre-labelled freezer bags, double-bagged and frozen in coolers containing dry ice. One of the full core sets were divided into thirds before bagging and freezing. The coring tubes were rinsed in lake water before resampling. All samples were brought back to the University of Calgary or the University of Alberta and kept frozen at -20 °C until analysis. Sediments analyzed for heavy metals were shipped to Maxxam Analytics Inc. for analysis.

### *Sediment deposition*

From the sediment core depth field information, a two-dimensional model of sediment accumulation was calculated for Chestermere Lake. Depths were plotted on a map of the lake, and a sediment bathymetry was calculated using a point interpolation method.

### *Sediment metal analysis*

Within one month of sampling, two frozen sediment samples (one a surface sample (101 D-01) and one a sample of the 22-28cm depth (103 D-03)) were analyzed for a suite of 33 heavy metals by the method of Inductively Coupled Plasma (ICP) at Maxxam Analytics Inc. Calgary. The following metals were analyzed: Silver (Ag), Aluminum (Al), Arsenic (As), Boron (B), Barium (Ba), Beryllium (Be), Calcium (Ca), Cadmium (Cd), Cobalt (Co), Chromium (Cr), Copper (Cu), Iron (Fe), Potassium (K), Lithium (Li), Magnesium (Mg), Manganese (Mn), Molybdenum (Mo), Sodium (Na), Nickel (Ni), Phosphorus (P), Lead (Pb), Sulfur (S), Antimony (Sb), Selenium (Se), Silicon (Si), Tin (Sn), Strontium (Sr), Titanium (Ti), Thallium (Tl), Uranium (U), Vanadium (V), Zinc (Zn), Zirconium (Zr). Unfortunately, Mercury (Hg) analysis is unreliable under ICP analysis and was not included in the present study. Background information on these heavy metals appears in the following two tables. Natural and industrial sources of selected elements identified in the ICP scan appear in Table 1. The potential human health impacts of the metals identified in the ICP scan are identified and discussed in Table 2.

## Chestermere Lake Sediment Sampling Sites

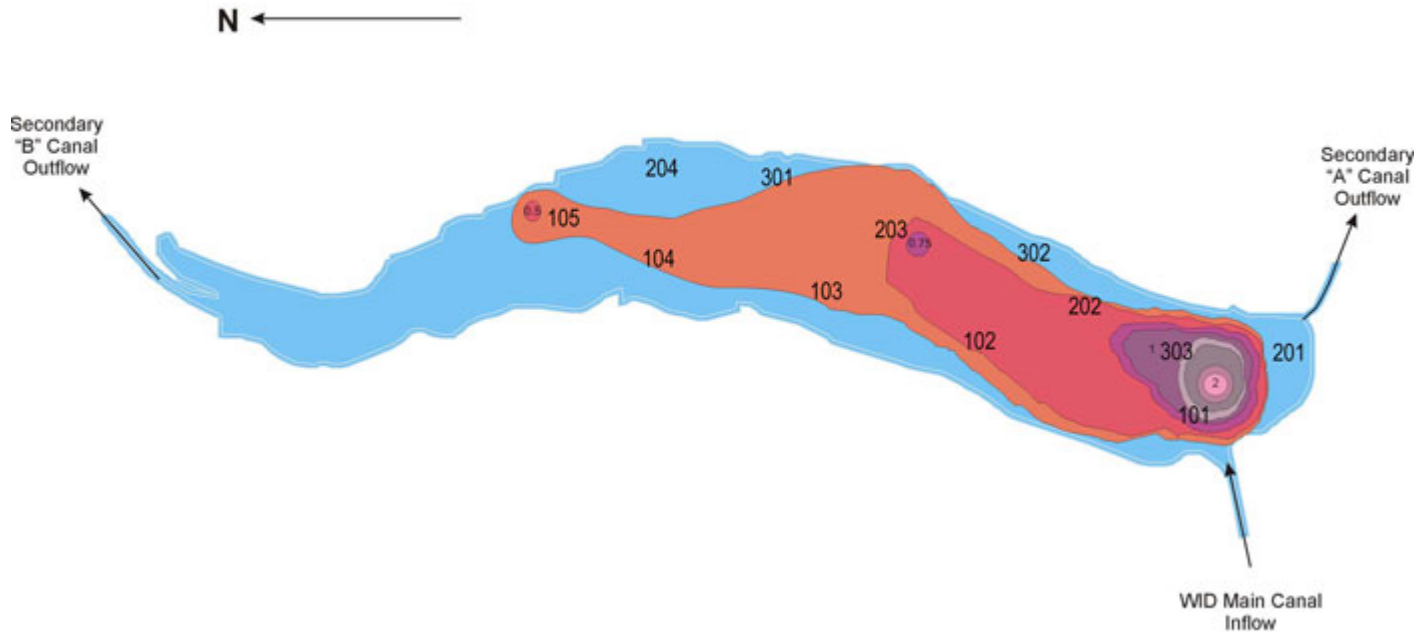


Figure 2: Chestermere Lake sediment sampling sites. Sediment collections made on March 2 and 3, 2001 by *AQUALITY* Environmental Consulting Ltd.

**Table 1:** Natural and industrial sources of elements identified in ICP scan.

Element	Natural Sources	Industrial Sources
Sb	Small amounts found in the earth's crust.*	Extensively used in industry, incl. in lead storage batteries, sheets & pipes, ammunition, pewter, infrared detectors, end retardants, & fireworks.*
Li		Used in the manufacture of storage batteries & metal alloys. Used in heat transferring agents, reducing agents, and as medication.* <sup>κ</sup>
Be	Chemical component of certain kinds of rocks, coal & oil, soil, & volcanic dust. <sup>♦</sup>	Used in nuclear weapons & reactors, missile parts, satellite & x-ray parts, navigational systems, mirrors, heat shields, rocket propellants, & fuel containers.*
B	Widely occurrent in nature; present in air, water, & soil. <sup>♦</sup>	Used in glass production, fire retardants, cosmetics, photographic material, pesticides, wood preservatives, fillers, insulating materials, & conductive agents. <sup>♦♦</sup>
Al	Aluminum is the most abundant metal and the third most abundant element, after oxygen and silicon, in the earth's crust. It is widely distributed and constitutes approximately 8 percent of the earth's surface layer. <sup>♦</sup>	Used in fillers, insulating materials, reprographic agents, textiles, & conductive & reducing agents, incl. consumer products, bldg. materials, & furnishings. <sup>♦</sup>
Mg	Primary component of mineral soil; comprises 2% of the earth's crust. <sup>γ</sup>	Used in making structural parts, diecast auto parts, missiles, precision instruments, optical mirrors, flash bulbs & flares, pyrotechnics, & batteries. <sup>κ</sup>
Si	Primary component of mineral soil; comprises 28% of the earth's crust. <sup>γ</sup>	
P		
As	Widely distributed in earth's crust, esp. in minerals and ores containing copper or lead.*	By-product of Cu and Pb smelting. Used in wood preservatives, agricultural products, glass, & nonferrous alloys.*
Se	Widely but unevenly distributed in the earth's crust; commonly found in sedimentary rock formations.*	Used in photochemicals, anti-dandruff shampoos, pigments in plastics, paints, enamels, inks, & rubber, red & black glass, fungicides, insecticides, & oxidizing agents. <sup>♦♦</sup>
Zn	Zinc is one of the most common elements in the earth's crust, found in the air, soil, & water and present in all foods. <sup>♦</sup>	Used in batteries, alloys, cosmetics, incl. sunblocks, deodorants, & diaper rash ointments, fillers, paint manufacture, polystyrene manufacture, SBR latex production, conductive & reducing agents, & pesticides. <sup>♦♦</sup>
Cu	Occurs naturally throughout the environment: in rock, soil, water, sediment, air, plants, & animals. <sup>♦</sup>	Heavily used in industry, incl. in circuit board manufacture, fillers, odor agents, conductive & reducing agents, industrial machinery, paper production, metallurgy, dyes, textiles, glass, ceramics, & pesticides. <sup>♦</sup>
Ni	Found in the earth's crust in the form of various nickel minerals, & present in all facets of the environment, incl. plants, animals, & soil.*	By-product of fuel oil & coal combustion, mining & refining operations, municipal waste incineration, & steel & nickel alloy production. Used in steel & alloys, batteries, magnets, ceramics, circuit board manufacture, fillers, odor agents, reprographic agents, textiles, conductive agents, & reducing agents. <sup>♦♦</sup>
Co	Soil & dust, seawater, volcanic eruptions, forest fires, most rocks, surface &	By-product of coal & oil burning, & other industrial processes. Present in car, truck, & aircraft exhaust, &

<sup>κ</sup> New Jersey Department of Health & Senior Services website ([www.state.nj.us/health/eoh/rtkweb](http://www.state.nj.us/health/eoh/rtkweb)).

<sup>♦</sup> Environmental Defense Scorecard website ([www.scorecard.org](http://www.scorecard.org)).

<sup>γ</sup> Brady, 1990. *The Nature and Property of Soils*. Macmillan Publishing Co., New York.

<sup>\*</sup> National Safety Council Chemical Backgrounder website ([www.crossroads.nsc.org](http://www.crossroads.nsc.org)).

	underground waters, plants, & animals.*	sewage sludge from cities. Used in paints, consumer products, buildings, & furnishings.*•
Fe		Used in fillers, paints, reprographic agents, & reducing agents.
Mn	Abundant in the earth's crust; found in many types of rocks.*	Used in steel production, matches, batteries, fireworks, fertilizers, animal feed, porcelain, & fungicides.*
Cr	Cr III occurs naturally in the environment and is found in rocks, animals, plants, soil, & in volcanic dust & gases (Cr 0 & VI produced by industry).♦	Used in nuclear & high temp. research, refractories, drilling muds, metal-finishing, textiles, fungicides, wood preservatives, odor agents, leather treatment, industrial water treatment, photo-mechanical processing, dyes & pigments, catalytic manufacture, & in the production of chromic acid & specialty chemicals.*•
V	A natural element in the earth; found in fuel oils, coal, rocks, & soil alike.♦	By-product of fuel-oil combustion. Used in manufacture of steel, rubber, plastics, ceramics, & certain other chemicals.♦
Ti		Used as a structural material in aircraft jet engines & in making electrodes, lamp filaments, & surgical instruments.κ
Sc		
Ca	Primary component of mineral soil; comprises 4% of the earth's crust.γ	
K	Primary component of mineral soil; comprises 3% of the earth's crust.γ	Used in heat transferring agents & reducing agents.♦
Sr		Used in fireworks, red signal flares, tracer bullets, & tin & lead alloys. Also used as a source of electric power.κ
Mo		Used in electroplating, iron & steel production, missile & aircraft parts, & in oxidizing agents.*κ
Ag	One of the basic elements that make up our planet; rare, but naturally occurring in the environment.♦	Used in fillers, lubricants & additives, odor agents, photochemicals, textiles, conductive agents, & pesticides.♦
Cd	Present in the earth's crust; all soils and rocks, including coal and mineral fertilizers, contain some cadmium.♦	By-product from treatment of Cu, Pb, & Fe ores. Used in metal plating, batteries, pigments, plastic stabilizers, pesticides, alloys, and chemical reagents.*
Pb	Found in small amounts in the earth's crust & in all parts of the environment.♦	By-product from burning fossil fuels, mining, and manufacturing. Used in batteries, ammunition, metals, circuit board manufacture, fillers, heat transferring agents, lubricants, additives, paints, printed circuit board manufacture, & conductive agents.♦♦
Hg	Naturally occurring in the environment.*	Used in common consumer products, incl. toys, calculators, cameras, & radios, heat transferring agents, pigments, refining, lubrication oils, antiseptics, batteries, some lamps, laboratory chemicals, & conductive agents.♦
Ba	Found in ore deposits. Sometimes present in drinking water & food.♦	Widely used in industry: for drilling muds, ceramics, paints, glass, rubber, tiles, bricks, insect & rat poisons, & additives for oils & fuels.♦
Na	Primary component of mineral soil; comprises 3% of the earth's crust.γ	

♦ Agency for Toxic Substances and Disease Registry website ([www.atsdr.cdc.gov](http://www.atsdr.cdc.gov)).

**Table 2:** Health impacts of selected toxic elements. Several elements are included that are considered non-toxic because exposure is low or the reference dose is high. Abbreviations are: **R** = recognized, **S** = suspected toxicant to body system. Reference doses are for ingestion of the elemental form and are estimates of the daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects over a lifetime. Carcinogen risk expresses how much added cancer risk is associated with lifetime exposure to a unit dose of a chemical (presented as the additional cancer risk associated with an average daily dose of one milligram of a chemical per kilogram of bodyweight). The elements Ca, Mg, Na, K, and Si are not included because these elements are not generally considered toxic. Phosphorus, though toxic in elemental form, was not included because aquatic forms are not toxic.

Element	Reference Dose (mg/kg-d)	Carcinogen Risk	Neurological	Circulatory	Respiratory	Endocrine	Gastro-intestinal	Other
<b>Ag</b>	0.005							(S) skin
<b>Al</b>	0.1		S (link to Alzheimer's)	S	S			
<b>As</b>	0.0003	R (1.5)	S	S	S	S	S	(S) reproductive
<b>B</b>	0.09		S	S	S			
<b>Ba</b>	0.07		S		S			(S) developmental
<b>Be</b>	0.002	R (4.3)		impaired kidney function	S	S	S	(S) skin
<b>Cd</b>	0.0005	R (inhalation only)	S	impaired kidney function	(R) emphysema	S		(R) reproductive & developmental, bone softening, Itai Itai disease
<b>Co</b>	no data	R (inhalation)	S	S	S	S	S	(S) skin
<b>Cr</b>	0.005	S		S	S		S	(S) skin
<b>Cu</b>	0.037			S	S		S	(S) development & reproductive
<b>Fe</b>	no data		S	S	S		S	
<b>Hg</b>	0.0003		lysis of brain cells, memory loss, fatigue, behavior change, irritability, death	impaired kidney function, blood toxin	impaired function	S	Vomiting, diarrhea	(R) development
<b>Li</b>	no data		S	S				
<b>Mn</b>	0.14		S		S		S	(S) reproductive

<b>Mo</b>	0.005		S					
<b>Ni</b>	0.02	R (no data)	S	S	S	S		(S) reproductive & skin
<b>Pb</b>	0.0000785	R (0.0085)	Reduced brain function, damage to nervous system, loss of coordination	Reduced haem synthesis & kidney function	S	S	S	(R) reproductive & developmental (S) skin
<b>Sb</b>	0.0004		S	S	S		S	(S) reproductive
<b>Sc</b>	no data							
<b>Se</b>	0.005		S	S	S		S	(S) reproductive & skin
<b>Sr</b>	0.6	R <sup>1</sup>						
<b>Ti</b>	no data				S			
<b>V</b>	0.007				S		S	
<b>Zn</b>	0.3				S		S	(S) reproductive & developmental

<sup>1</sup>As noted in a recent Calgary publication, Sr-90 is a recognized carcinogen. The ICP does not differentiate between Sr (not a recognized carcinogen) and Sr-90. The risk of cancer from Sr-90 is small. It has an ingestion risk value of 0.0000000000409. Which means if all 6 billion people on the planet ingested 1 mg of strontium-90 per kg of their body wt for their entire lives, one person of the 6 billion would have a 25% increased risk of cancer.

## Results

### *Sediment deposition*

Our calculations showed three distinct zones of sediment accumulation in Chestermere Lake (Figure 3). As expected, the zone of greatest sediment accumulation is at the mouth of the inflow canal. Further calculations of sediment depth and area yielded a quantification of sediment volumes stored in the reservoir. These volumes are presented in Table 3. Our estimates suggest that the reservoir has accumulated more than 780 400 m<sup>3</sup> of sediment since its creation in 1903. This has resulted in a loss of depth of over 2 meters in some areas of the lake (an accumulation rate of 20 mm/year, assuming even input rates over the past 98 years). The inflow sites had significantly higher average sediment thickness (191 cm) and therefore, higher sedimentation rates, than the rest of the lake. However, it is more likely that the majority of sediment loadings have occurred in more recent times, such as the past twenty years.

The sediment pile at the inflow canal mouth is gradually being pushed across the lake by both wave action and new accumulations of sediment. Sediment will continue to be redistributed around the lake, filling the deepest areas first, in a process called sediment focusing<sup>16</sup>. More information on sediment focusing and the distribution kinetics of sediments can be found in Blais and Kalfi<sup>17</sup>.

**Table 3:** Area, depth and volume of distinct sediment deposition zones within Chestermere Lake.

Area (ha)	% Total Area	Sediment Depth (m)	Sediment Volume (m <sup>3</sup> )
2	1	2.00	20 000
83	32	0.50	154 000
261	100	0.25	626 400
<b>Total</b>			<b>780 400</b>

### *Sediment Quality*

The results of the ICP heavy metal analysis appears in Table 4. None of the 33 heavy metals analyzed showed concentrations that exceeded the CCME Canadian Sediment Quality Guidelines for the Protection of Aquatic Life<sup>18</sup>. However, Arsenic (As) and Cadmium (Cd) were very close to the limit and should be monitored at other sites throughout the lake. Arsenic concentrations were higher at deeper sediment levels, while cadmium concentrations were elevated both at the surface and at deeper sediment levels.

### Chestermere Lake Sediment Contour Plot

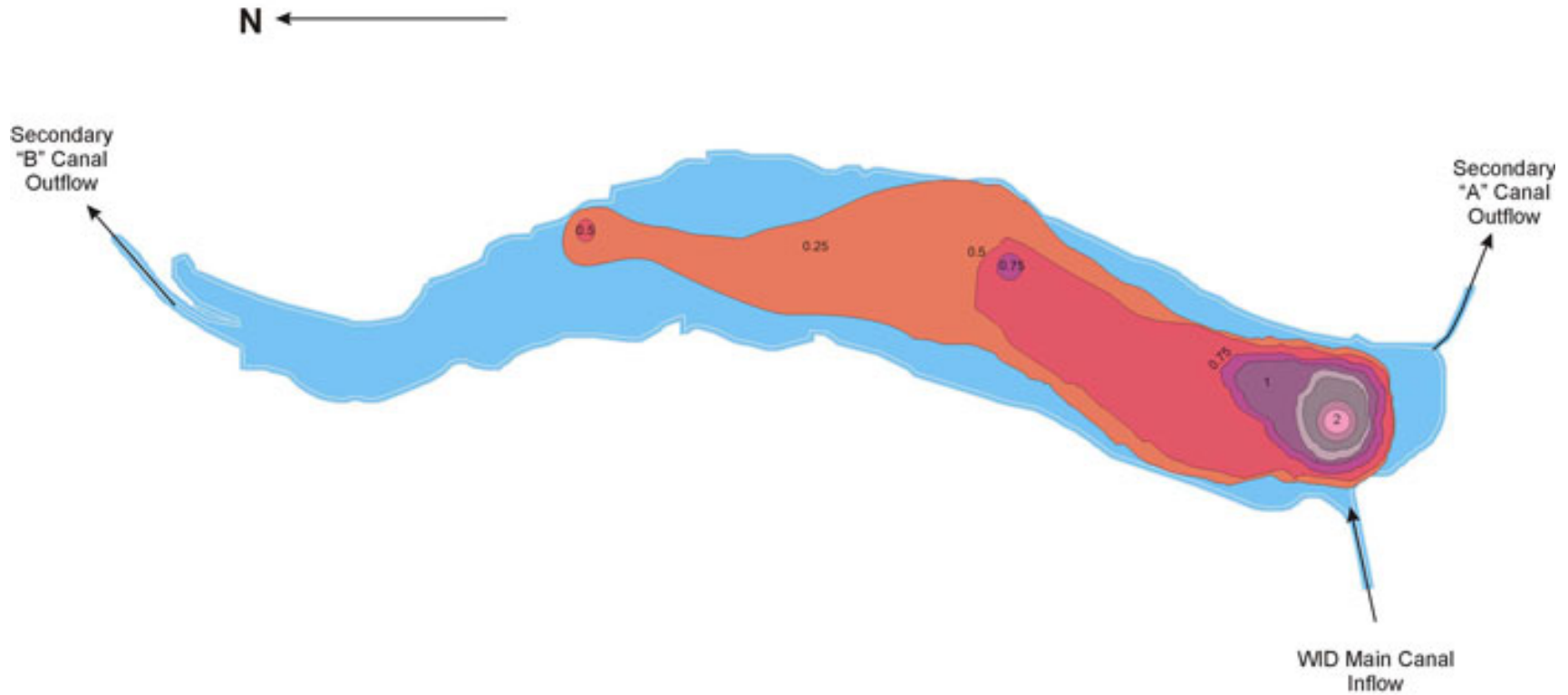


Figure 3: Chestermere Lake sediment contour plot. Contour intervals are 0.25 m. Sediment accumulations of up to 2 m are shown near the WID inflow Canal. Contour data are based on sediment coring data collected by Aquality Environmental Consulting Ltd. On March 2 and 3, 2001.

**Table 4:** Sediment concentrations in Chestermere Lake compared to remote sites in Alberta. Bold elements are near the CCME Canadian Sediment Quality Guidelines for the Protection of Aquatic Life<sup>19</sup>. Guidelines in parentheses are from other sources (i.e. Alberta Surface Water Quality Guidelines). All analyses performed by Induced Coupled Plasma (ICP) scan.

Element	Chestermere Sample 101D-01 (µg/g)	Chestermere Sample 103D-03 (µg/g)	CCME Guideline (µg/g)	Remote Alberta Lakes Sediment* (µg/g) n = 50
Ag	0.172	0.207	(20)	<0.2
Al	8380.839	12482.222		6110.00
<b>As</b>	<b>3.452</b>	<b>5.335</b>	5.9 (10)	2.86
B	0.705	0.720	(2)	No data
Ba	7.717	250.245	(500)	242.86
Be	0.261	0.473	(4)	≤0.5
Ca	80489.24	7081.260		6510.00
<b>Cd</b>	<b>0.440</b>	<b>0.574</b>	0.6 (1)	<1
Co	5.974	8.702	(20)	6.60
Cr	15.849	15.423	37.3 (50)	13.98
Cu	14.770	19.443	35.7 (63)	12.36
Fe	13359.55	17763.162		2223.00
Hg			0.17 (0.2)	0.0775
K	1008.19	2322.413		950.00
Li	9.169	12.302		No data
Mg	7634.03	3492.622		3490.00
Mn	274.24	391.870		283.26
Mo	0.411	0.386	(4)	most < 2 one case = 30
Na	151.02	175.831		140.00
Ni	18.67	17.043	(40)	16.70
P	375.89	496.288		713.81
Pb	25.30	10.742	35 (50)	8.07
S	2008.08	630.112		No data
Sb	0.08	0.102	(20)	<5
Sc				1.88
Se	0.86	0.540	(2)	No data
Si	50.20	22.384		No data
Sn	0.70	0.426		No data
Sr	162.22	41.467		31.80
Ti	10.33	23.224		100.00
Tl	0.09	0.138		No data
U	0.61	0.738		No data
V	19.37	24.784	(100)	27.37
Zn	62.23	66.012	123 (120)	71.67
Zr	4.10	18.063		No data

\*Remote Alberta Lake sediment data from 50 northern Alberta lakes with no anthropogenic disturbances within their catchments. Unpublished data from McEachern<sup>20</sup>.

## Discussion

### *Sediment deposition*

Our estimates suggest that the reservoir has accumulated more than 780 400 m<sup>3</sup> of sediment. This has resulted in a loss of depth of over 2 meters in the inflow areas of the lake with an accumulation rate of 20 mm/year. The sediment accumulation rate for a natural lake is approximately 1-2 mm/year. This accumulation may impair the reservoir's ability to accept sediment and will lead to increased siltation downstream throughout the WID canal infrastructure. Siltation may degrade fish habitat within the lake. These and other water quality problems in the reservoir and canal system have been identified in past reports by engineers and other scientists. Aside from decreasing the functionality of the lake as a settling pond, there are potential human health risks associated with the accumulation of sediment-bound contaminants such as heavy metals.

Sediment accumulation is a continual physical process that could degrade water quality and further impair aquatic habitat until corrected. As well, there are no immediate plans to improve the quality or lessen the quantity of water entering the lake. All indications are that continued growth of the City of Calgary will bring increasing volumes of stormwater and increased loads of sediment and bound contaminants. Because the lake has a finite capacity for sediment storage, we have proposed a three-phased approach for sediment removal and disposal (see Chestermere Lake Sediment Removal Proposal<sup>21</sup>).

The lake has historically provided good treatment of inflowing water, as pollutants are diluted, degraded, biotransformed, biologically incorporated and/or settled. However, as more sediment settles and redistributes, more fish habitat is lost within the lake as it is covered by silt. As much as 50% of the lake has been affected by accelerated siltation. As well, water clarity is impacted, with plumes of turbid water noticeable for several days around the inflow following rainfall events.

Chestermere Lake needs some form of restorative action such as dredging to remove the excessive accumulations of historic sediment, and to create capacity for future sediment depositions. Previous initiatives to remove sediment have been hampered by cost concerns and a lack of appropriate techniques to adequately deal with the problem. However, advancements in sediment removal technology will now allow sediment removal with minimum disturbances and within economic realities.

### ***Sediment quality***

None of the 33 heavy metals sampled had concentrations that exceeded the CCME Canadian Sediment Quality Guidelines for the Protection of Aquatic Life. However, Arsenic and Cadmium have concentrations very near these guideline limits. Both of these metals are likely entering Chestermere Lake from the City of Calgary's industrial sector stormwater runoff.

Arsenic, used in wood preservatives, agricultural products and glass has seen reduced production since the 1980s. Lowered production is likely why concentrations of arsenic are lower in surface (more recent) sediments. Arsenic has a strong affinity for aquatic particles such as iron oxides and manganese oxides and quickly becomes associated with sediments. Once deposited, aquatic organisms are exposed to arsenic and its adverse impacts vary based on its organic and inorganic forms. Arsenic can cause decreased benthic invertebrate abundance, increased mortality and behavioural changes.<sup>22</sup>

Cadmium is used in metal plating, batteries, plastic stabilizers, pigments, pesticides and chemical reagents. Once in the aquatic environment, it quickly associates with particulate matter including organic matter, iron hydroxides, manganese hydroxides, carbonates and sulphides.<sup>23,24</sup> Once in the sediments, cadmium is available to the aquatic organisms and can decrease benthic invertebrate abundance, and increase mortality.<sup>25</sup>

Constituents in sediment buried deeper than 10 cm are assumed to be buried and unavailable to biota. Aside from specific perturbations such as dredging, most heavy metals will stay buried in the system. However, an exception to this rule is mercury, which is mobile in sediments. Mercury can move from deeper sediments to the surface, where it is available for biological uptake. Because the ICP method for mercury analysis yields highly variable results, other methods are used when analyzing this heavy metal. Future samplings at Chestermere Lake should focus on the heavy metal content of surficial sediments and there should be a collection program specifically for mercury.

### **Conclusions**

Chestermere lake is slowly infilling with sediment and will continue to do so and may degrade water quality and fish habitat until action is taken to remove this material. Dredging undertakings should focus on removing the accumulations at the WID canal mouth area. While heavy metal concentrations in the sediments are generally below CCME Guideline limits for the Protection of Aquatic Life, arsenic and cadmium are both very close to these limits at sediment depths of 0-28

cm. Heavy metals may already be having an impact on the aquatic biota of Chestermere Lake. Mercury, which is another heavy metal of concern in reservoirs receiving stormwater was not analyzed in the present study, and should be considered in future research studies.

### **Acknowledgements**

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## Endnotes

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## Appendix A

### What is mercury?

Mercury (chemically abbreviated as Hg) is a heavy metal that typically forms an ion with a two positive (2+) charge. The charge is significant because it determines how Hg binds to other substances and is thus transported through the ecosystem. Mercury exists in several forms but usually is bound to sulfur in mineral soils.

Mercury exists in several forms in the natural environment.

**Total mercury** is a measure of all mercury in a sample including forms bound to soil, soluble forms, and forms bound to organic matter.

**Methyl mercury** is the form considered most important to biota. It occurs as monomethyl ( $\text{CH}_3\text{Hg}^+$ ) or dimethyl ( $(\text{CH}_3)_2\text{Hg}$ ) mercury and is a byproduct of bacterial decomposition of organic matter. Methyl mercury is a fraction of total mercury and its concentration in the environment depends on the concentration of organic material and methylating bacteria in the environment.

### Where is mercury found?

Mercury exists naturally in soils, typically bound to sulfur groups and is not considered to be very soluble. It is believed that 50% or more of problem mercury has been deposited in organic soils from recent coal combustion.

### Mercury solubility:

In order to be a problem there has to be an exposure to mercury. The solubility of mercury is therefore important.

Under oxygen poor (anaerobic) conditions, mercury solubility is so low that Hg (II) aq is virtually undetectable. Groundwater is usually anaerobic and therefore mercury in mineral soils poses little threat.

Under oxygenated conditions mercury enters several soluble complexes the most important being  $\text{Hg}(\text{OH})_2$ .

The exception is in organic soils where anaerobic conditions promote bacterial use of sulfur and thus the formation of methyl mercury.

Methyl mercury accumulates in living organisms because the methyl group allows it to pass through cell membranes. This is the primary pathway for mercury bioaccumulation up the food chain. Some researchers have shown that there is a correlation between total mercury and mercury accumulation in fish with the underlying assumption that there is a correlation between total mercury and methyl mercury concentrations. This agrees with what is known about mercury but requires consideration of local bacteria and organic matter contents of soil.

### Why is mercury toxic?

Mercury has an affinity to bind with sulfur. This attraction is what makes mercury toxic to living organisms. Mercury binds to the sulfur groups of amino acids and enzymes and renders them inactive and interferes with other cellular functions. In Japan's Minimata Bay, 798 people died or suffered permanent neurological damage due to industrial dumping of mercury.