Lakes of the Carvel Pitted Delta

-Stony Plain Region-

Summer Field Program - 2021

Classification: Protected A

Table of Contents

Report Prepared May 2022

A drone image of PL1, 2020. Photo provided by M. Myshak.

Introduction

There are several dozen small kettle lakes located on the post-glacial landscape of Parkland County known as the Carvel Pitted Delta. These unique lakes and their watersheds primarily drain into the Sturgeon River sub-watershed; some portions drain directly south towards the North Saskatchewan River. There are approximately 25 named lakes and 70 unnamed lakes in this area. The geographic extent of the Carvel Pitted Delta is described in the 2016 Mayatan Lake Watershed Management Plan.[1] These small lakes and their associated landscapes are considered to have unique ecological value by local and provincial governments, as well as by conservation agencies. They provide ecosystem services and habitat to support fish, wildlife, and waterfowl populations. They also provide extensive opportunities for nature pursuits and outdoor recreation.

Biologist and volunteer Pauline Molnar taking a fishing break at Lake (PL1) in 2021. Photo by David Trew.

The small watersheds of these lakes continue to change, mostly as a result of human development. The lakes are now surrounded by varying proportions of forested, agricultural and recreational land, and by rural residential developments. Some lake watersheds have been extensively impacted by human activities, while some on private lands remain relatively undisturbed. The Carvel Pitted Delta and its "hummocky" landscapes also play a significant role in regional groundwater recharge, as described in "*Summary of groundwater conditions in the Sturgeon River Basin"* (2019). [2]

Although five of the named lakes have been sampled in recent years by the Alberta Lake Management Society (ALMS), there is a general lack of current water quality data for the majority of these lakes. Hydrologic data are also limited; eight named lakes are monitored for summer water levels and water balances have only been prepared for

[1] Logan, M., D. O. Trew and D. Mussel. Mayatan Lake Watershed Management Plan. North Saskatchewan Watershed Alliance, Edmonton, AB. 97 pp.

[2] Oiffer, A. 2019. Summary of groundwater conditions in the Sturgeon River Basin. Prepared for the North Saskatchewan Watershed Alliance, Edmonton, AB. 39 pp.

Classification: Protected A

three (S. Figliuzzi, P. Eng.).[3,4,5] There is limited current information related to aquatic ecosystem health and sportfish capability of the unnamed lakes, although several of the named lakes do have managed sport fisheries.

During the summer of 2021, ALMS and the Mayatan Lake Management Association (MLMA) successfully delivered an expanded, community-based water quality survey program for 44 of these small lakes. Twenty-one named lakes and 23 unnamed lakes were sampled, many for the first time. Unnamed lakes were assigned an identification code recorded as PL# (PL = Parkland Lake; see regional map Figure 1). The primary goal of the project was to develop an updated and improved regional overview of lake water quality, with the intent of stimulating community interest and more detailed lake evaluations. The survey was a collaborative effort supported by several partners, including ALMS, MLMA, the Land Stewardship Centre of Canada (LSCC), the North Saskatchewan Watershed Alliance (NSWA), the Stony Plain Fish and Game Association (SPFGA), and the Dept. of Earth Sciences, University of Alberta. Twenty-seven private landowners were also engaged in the project and graciously provided lake access. Many additional photographs from this project can be found at www.alms.ca/carvel-pitted-delta.

Biologist and volunteer David Trew measuring water clarity of a lake in the Carvel Pitted Delta region using a Secchi disk. Photo by Bradley Peter, 2020.

[3] Logan, M., B. Milholland, D.O. Trew and S. Figliuzzi. 2012. Mayatan Lake State of the Watershed Report. North Saskatchewan Watershed Alliance, Edmonton, AB. 88pp.
[4] Regier, J. and D.O. Trew. 2016. Jackfish Lake State of Watershed Report. 2016. North Saskatchewan Watershed Alliance, Edmonton, AB. 181 pp.
[5] Gordy, M., J. Regier, B. Muldoon and D.O. Trew. 2018. Hubbles Lake State of the Watershed Report. North Saskatchewan Watershed Alliance, Edmonton, AB. 159 pp.

Classification: Protected A

Historical Context

Some of these small lakes were first sampled in the late 1940s and early 1950s by Dr. R. B. Miller, Dept of Zoology, University of Alberta and were described in GOA publications entitled "*Preliminary Biological Surveys of Alberta Watersheds*".[6] The emphasis of these lake surveys was to evaluate sportfish capability. Some water quality and biological data were gathered, lake depths were measured manually, and fish species were determined.

During the 1950s and 1960s coarse-scale testing on some of these lakes was conducted by the Alberta Geological Survey as part of efforts to characterize province-wide surface water chemistry. The Alberta Fish and Wildlife Division conducted further evaluations of sportfish capability (under the Canada Land Inventory) and initiated trout stocking programs during the 1960s-70s.

Detailed water quality sampling was initiated on certain lakes by Alberta Environment between the 1970s and 1990s, providing preliminary nutrient and phytoplankton data. During this same period, many lakes were investigated as part of graduate student research programs at the University of Alberta. Data for several of these lakes were first published by Prepas and Trew (1983) in their paper "*Evaluation of the Phosphorus-Chlorophyll Relationship for Lakes off the Precambrian Shield in Western Canada*".[7]

A floating platform at Gerhart's Lake. Photo by David Trew, 2021.

During the 2000s, further testing was conducted on certain named lakes by ALMS, providing summer data on major ion chemistry, temperature/dissolved oxygen, nutrients, and general trophic conditions. The conditions of three lakes have been investigated more extensively as part of watershed planning work conducted by the NSWA (2012-18). These lakes included Mayatan Lake, Jackfish Lake and Hubbles Lake.

In 2020, a preliminary project to assess and update lake water quality information in the Carvel Pitted Delta was conducted by ALMS, the University of Alberta, and the MLMA. During that project, twelve lake basins were sampled to assess mid-summer water quality. The preliminary work conducted during summer 2020 has been summarized by Trew (2020)[8] and Von Gunten et al. (2021).[9] During winter 2021, eighteen basins were sampled by MLMA to assess late winter dissolved oxygen conditions and other water quality parameters under the ALMS' Winter LakeKeepers program.[8]

[6] Miller, R.B. and W.H MacDonald. 1949. Preliminary Biological Surveys of Alberta Watersheds (1947-49). Department of Lands and Forests, Government of the Province of Alberta, Edmonton AB. 139 pp.

[7] Prepas and Trew. (1983). Evaluation of the Phosphorus-Chlorophyll Relationship for Lakes off the Precambrian Shield in Western Canada. Journal of the Fisheries Research Board of Canada. Vol 40, Number 1, pp 27-35.

[8] https://www.mayatanlake.ca/files/DTrewpres.pdf. Accessed April 2022.

[9] Von Gunten,K., D.O. Trew, B. Smerdon, D. Alessi. 2021. Controls on natural phosphorus in small lakes in central Alberta, Canada. Submitted to the Canadian Water Resources Journal.

[8] Sinn, C., B. Peter. 2021. Winter LakeKeepers Report 2020-2021. Alberta Lake Management Society, Edmonton, AB. https://alms.ca/wp-content/uploads/2021/12/WLK_2020-2021_Final_20211202.pdf

Classification: Protected A

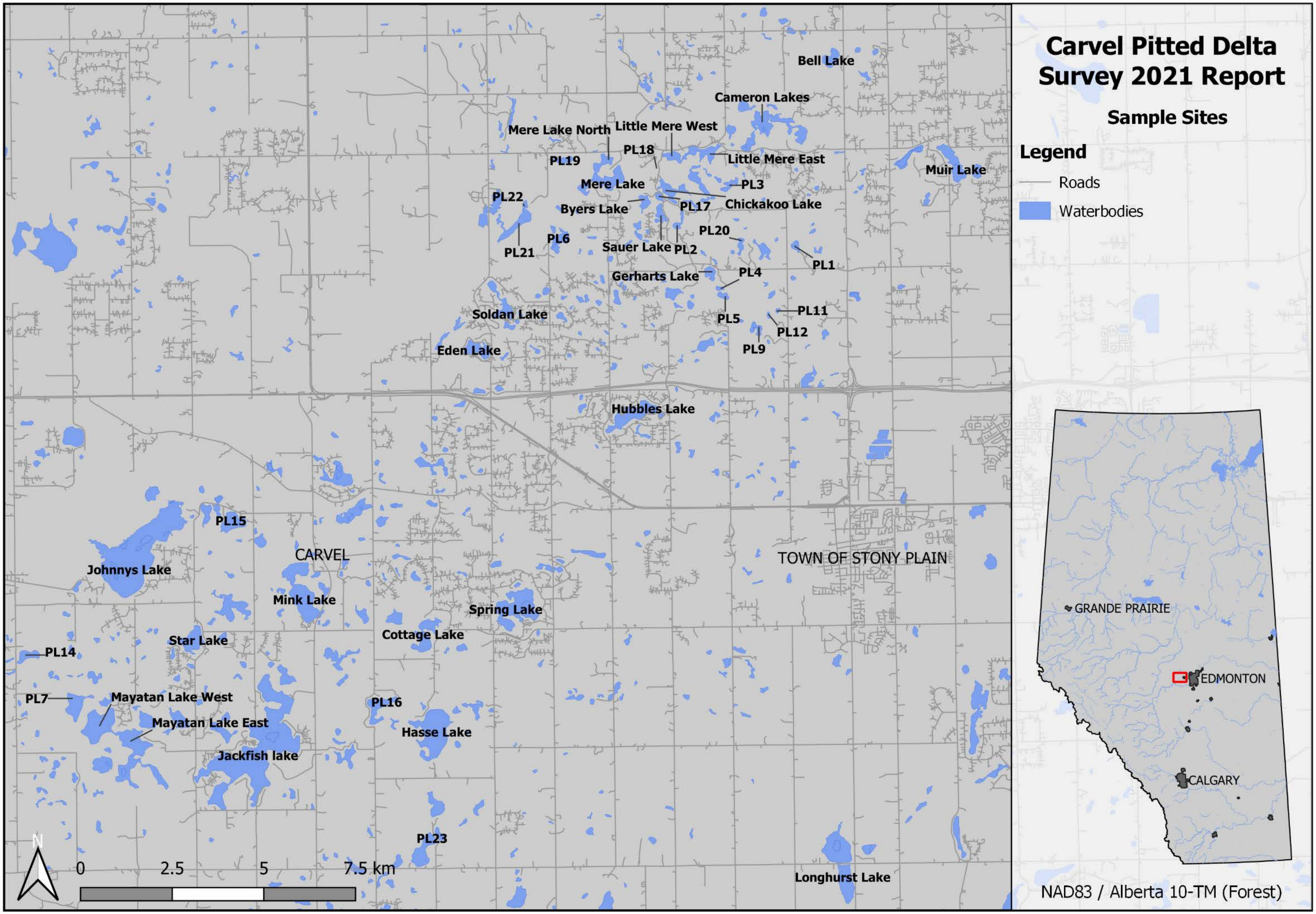

Figure 1. A regional map of 44 lakes sampled in the Carvel Pitted Delta Region in the summer of 2021. Unnamed lakes have been assigned an arbitrary code indicated by PL#.

Methods

Each lake was sampled once between August 11th and October 5th, 2021. Given the finite resources available, the sampling design was intended to capture lakes during the period of relatively high water temperatures. Under such conditions, it was anticipated that the deeper lakes would be thermally stratified and display low surface nutrient and algal concentrations, whereas shallow lakes would likely be well mixed and display higher nutrient and algal concentrations.

Boats and vehicles were supplied by MLMA volunteers. Samples were collected at the deepest location of each lake, as identified from the relatively few bathymetric maps available, or as estimated by a cursory survey of depths using a weighted measuring tape. At one lake (PL18), samples were collected from the shore as boat access was not possible. Water column measurements (profiles) and discrete bottom samples were not collected from this site. Various techniques were used to collect water quality data, including:

- Water Clarity: measured using a Secchi disk.
- Temperature, Dissolved Oxygen, Conductivity profiles: measured using a YSI ProSolo probe. Readings were generally collected at 0.1 m, 0.5 m, 1.0 m, and then every meter until lake bottom.
- Routine Water Chemistry and Nutrients: samples were collected from 0.5 m depth using a horizontal Van Dorn discrete sampler.
- Bottom Total Phosphorus: a discrete sample was collected from 1 m above the lake bottom using the Van Dorn device.
- Samples for water chemistry and nutrients were sent to Bureau Veritas in Edmonton for analysis. Samples collected for chlorophyll-*a* were sent to Innotech Alberta in Vegreville for analysis.

The raw lake data collected during this project have been uploaded to the Gordon Foundation's DataStream, which provides open access and long-term storage. Data can be viewed and downloaded from: https://lakewinnipegdatastream.ca.

This report provides a new, regional overview and synopsis for 44 lakes, but does not provide a detailed assessment for individual waterbodies. Fact sheets for individual lakes may be produced during the upcoming 2022/23 phase of this work.

MLMA President and volunteer Walt Neilson measuring water clarity with a Secchi disc at lake PL14 in 2021. Photo by David Trew.

Classification: Protected A

Physical Characteristics

All the lakes of the Carvel Pitted Delta sampled in this project were comparatively small, with surface areas ranging from 0.30 hectares (PL18) to 281.0 hectares (Jackfish Lake) (Figure 2). The median size of all sampled lakes was 19.0 hectares. Despite their small sizes, many of the lakes are relatively deep. Depths were recorded at each sample location and ranged from 1.0 m to 21.5 m (Figure 3). Again, these maximum depth values should be considered as approximations, as formal bathymetric surveys have not been conducted on the majority of these lakes.

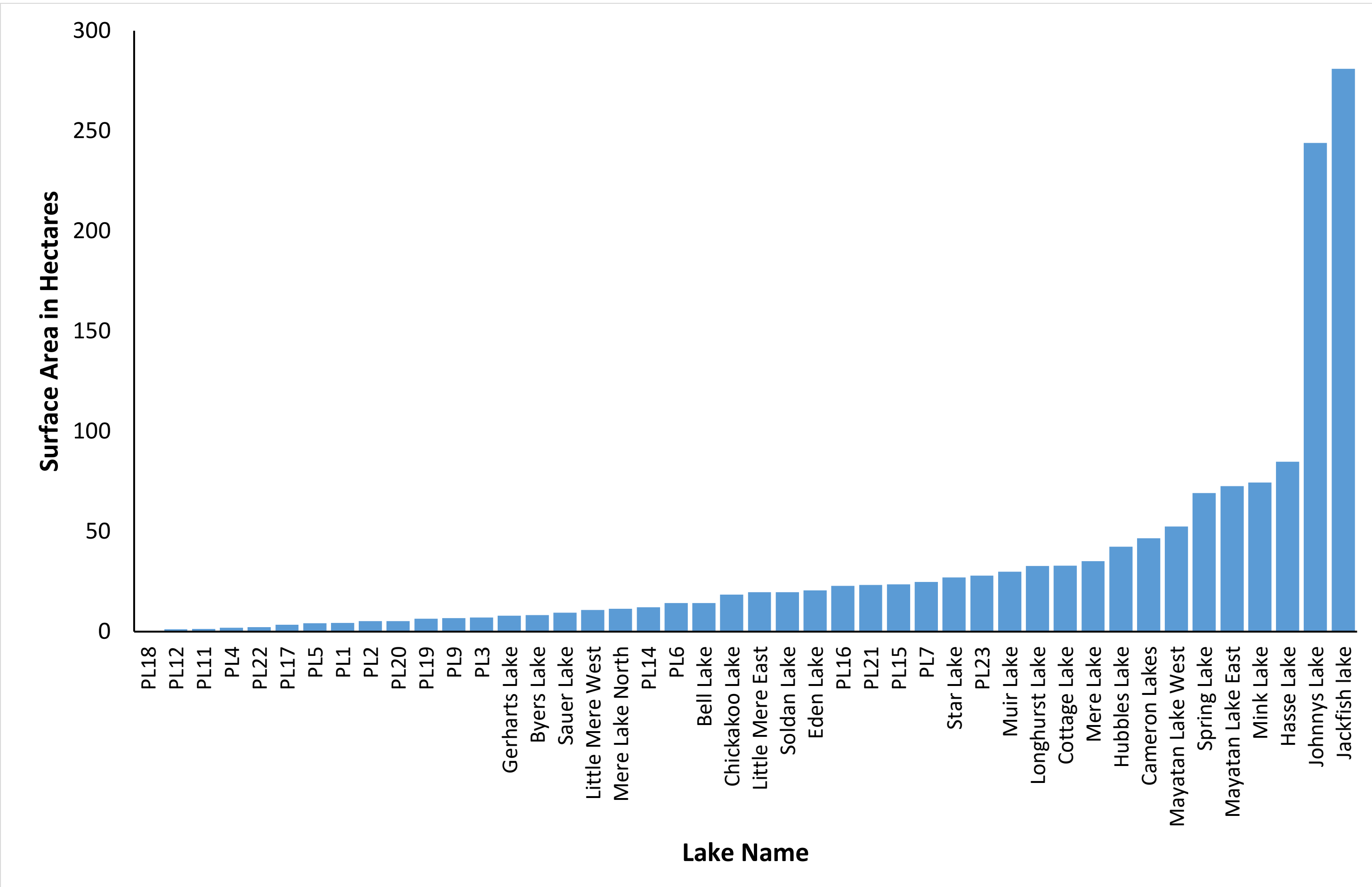

Figure 2. Lake surface area (hectares) calculated using ArcGIS (provided by NSWA 2021).

Classification: Protected A

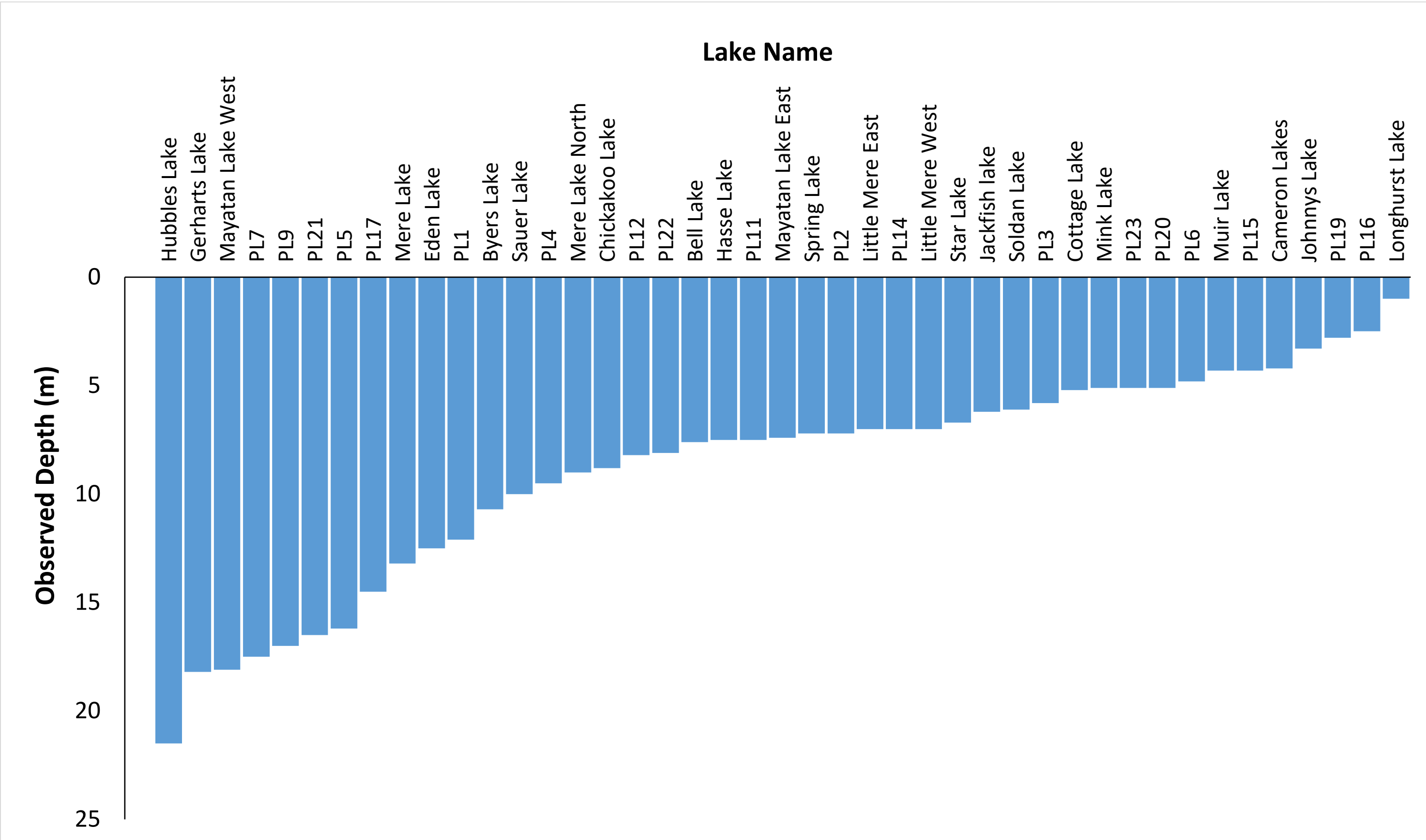

Figure 3. Observed maximum depths recorded at each sampling site using a measuring tape and weight. PL18 has not been included.

A view of lake PL1. Photo by David Trew, 2020.

Temperature

As sampling occurred between mid-August and early October, a range of surface water temperatures was observed (Figure 4). The shallow lakes generally displayed warmer and more uniform vertical conditions. A pattern of strong thermal stratification was observed in deeper lakes. During thermal stratification, a warm surface layer of water becomes distinct from a cooler bottom layer of water due to the formation of a thermal density gradient. In these lakes, the thermocline was often established between 5 – 8 m. Thermal stratification has important implications for fisheries habitat and nutrient cycling. In general, shallow lakes often mix from the top to the bottom during the summer months, while deeper lakes may not. As lakes in Alberta cool during autumn, vertical mixing becomes more common. Lake surface area, lake shape, and surrounding landscape can also influence the degree to which a lake will stratify or mix.

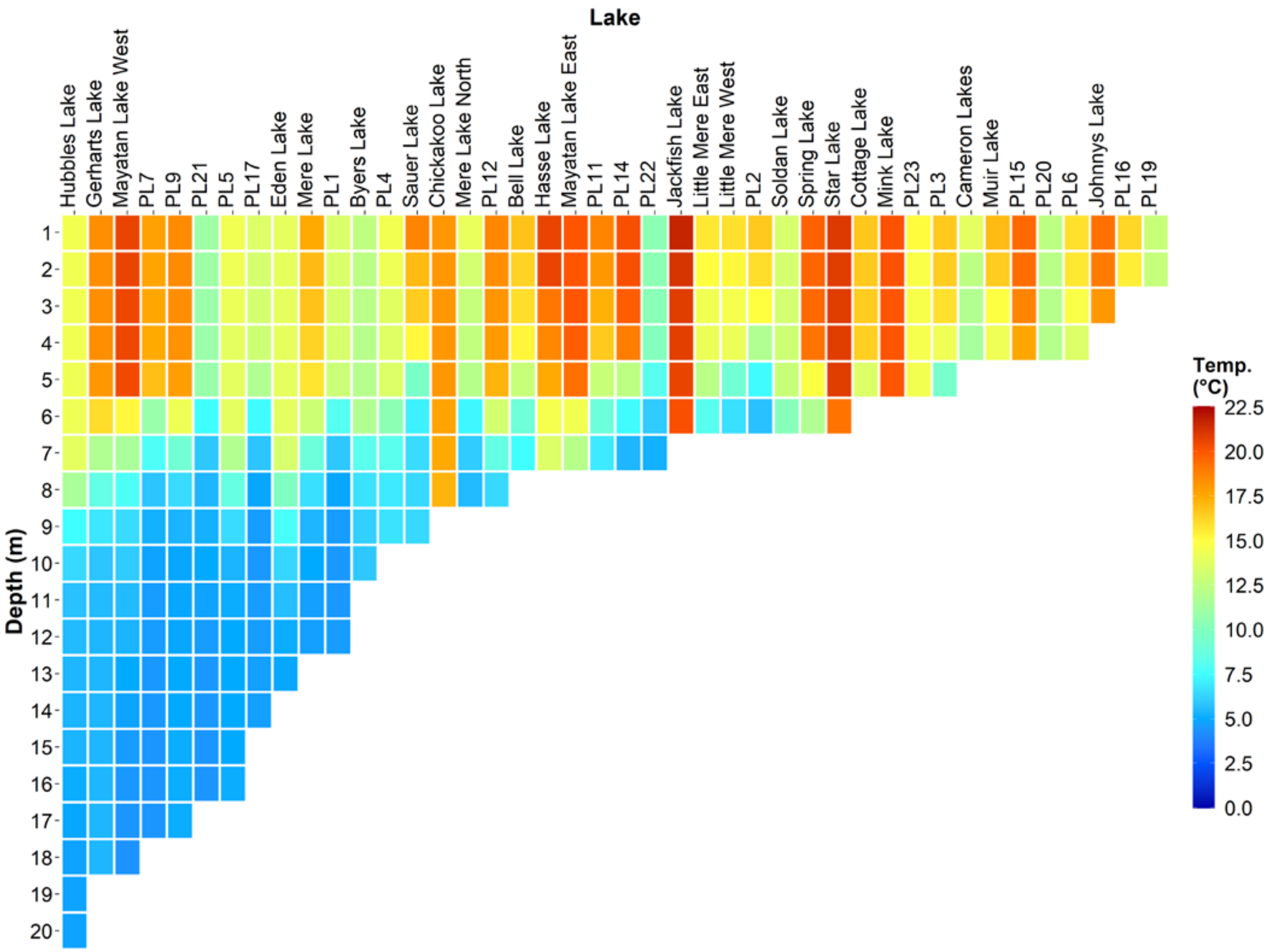

Figure 4. Temperature (°C) profiles for 42 lakes sampled between August 11th and October 5th, 2021. Coloured boxes reflect the temperature measured at that specific depth measurement. Note that while 0.1 m and 0.5 m readings are available for each lake, this figure begins at 1 m depth for visual purposes. Longhurst Lake and PL18 have not been included in this figure.

Classification: Protected A

Dissolved Oxygen

Dissolved oxygen can vary greatly both among lakes and within individual lakes due to factors such as water column mixing, temperature, and biological activity (Figure 5). Dissolved oxygen concentrations in the deeper lakes were strongly influenced by thermal stratification. Very low oxygen or anoxic conditions were regularly observed below the thermocline.

Low oxygen conditions were occasionally observed throughout the water column in some of the shallow lakes sampled. In lakes with high phytoplankton concentrations (e.g., Cameron Lakes, Little Mere East, Chickakoo, Cottage Lake), the decomposition of organic matter in the bottom sediments combined with diurnal photosynthetic/respiration patterns and full lake mixing likely contributed to low oxygen conditions in surface waters.

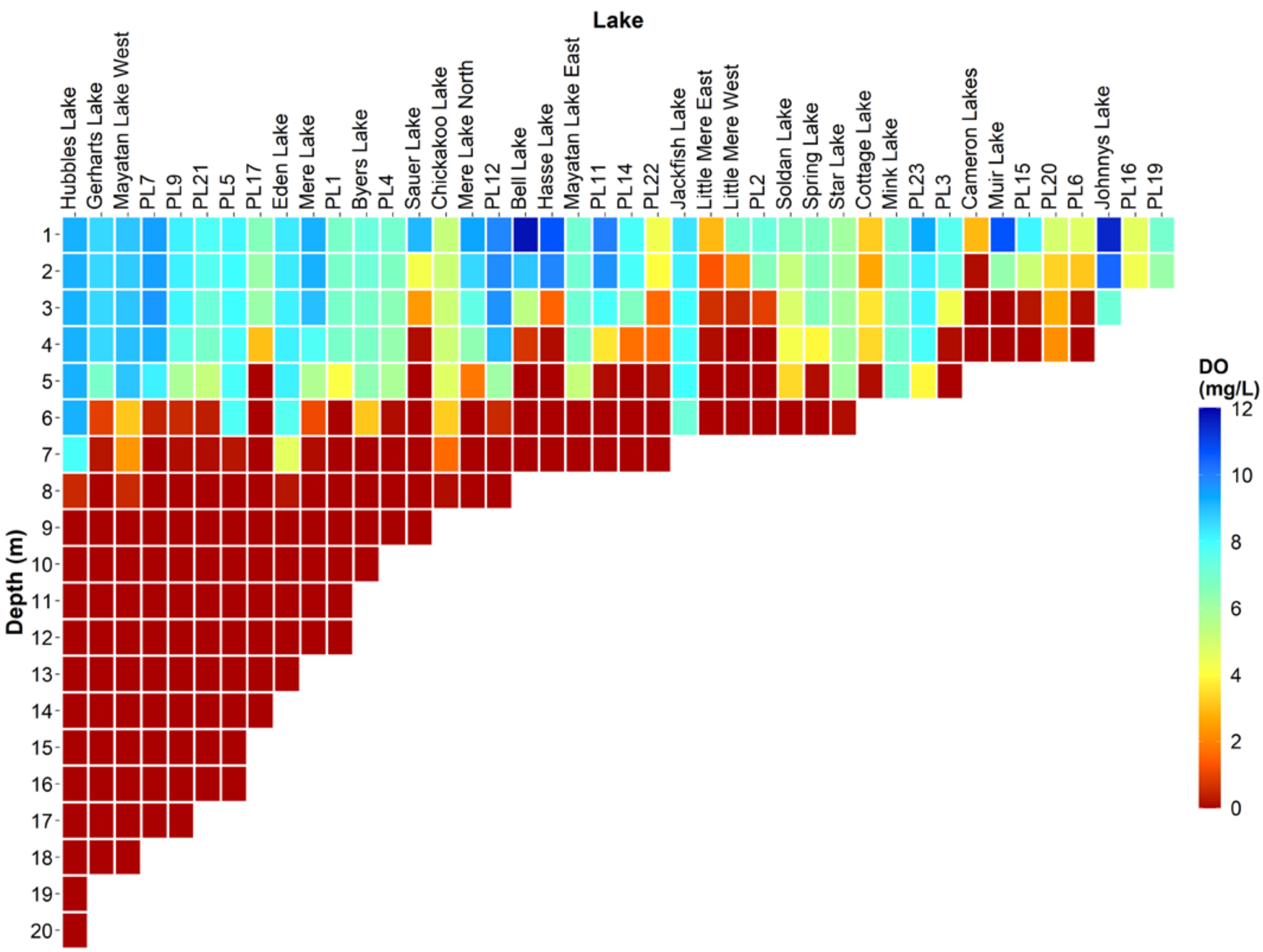

Figure 5. Dissolved oxygen (mg/L) profiles for 42 lakes sampled between August 11th and October 5th, 2021. Coloured boxes reflect the dissolved oxygen concentration measured at that specific depth measurement. Note that while 0.1 m and 0.5 m readings are available for each lake, this figure begins at 1 m depth for visual purposes. Longhurst Lake and PL18 have not been included in this figure.

Classification: Protected A

Total Phosphorus

Phosphorus represents one of the most important nutrients controlling the growth of phytoplankton in lakes. Surface samples of total phosphorus displayed a wide range of concentrations in the lakes of the Carvel Pitted Delta region (Figure 6). Concentrations of total phosphorus ranged from 5.2 µg/L at PL5 to 780 µg/L at Cameron Lakes. These concentrations span the full range of trophic states from oligotrophic (low nutrients) to mesotrophic (moderate nutrients), eutrophic (nutrient-rich), and hypereutrophic (very nutrient-rich). Based on surface total phosphorus samples, eight lakes were tentatively classified as oligotrophic, fourteen lakes as mesotrophic, fifteen lakes as eutrophic, and seven lakes as hypereutrophic. When visualized on the regional map, some interesting grouping of lake types can be observed (Figure 7). A small cluster of mesotrophic lakes exists in the southwestern portion of the region, and a small cluster of oligotrophic lakes can be observed in the northeastern portion of the region. The diversity of lake types in such a small region warrants further investigation to assess potential human impacts. The natural influences of groundwater on lake chemistry and lake flushing rates may also be important for understanding the diversity of these lakes.

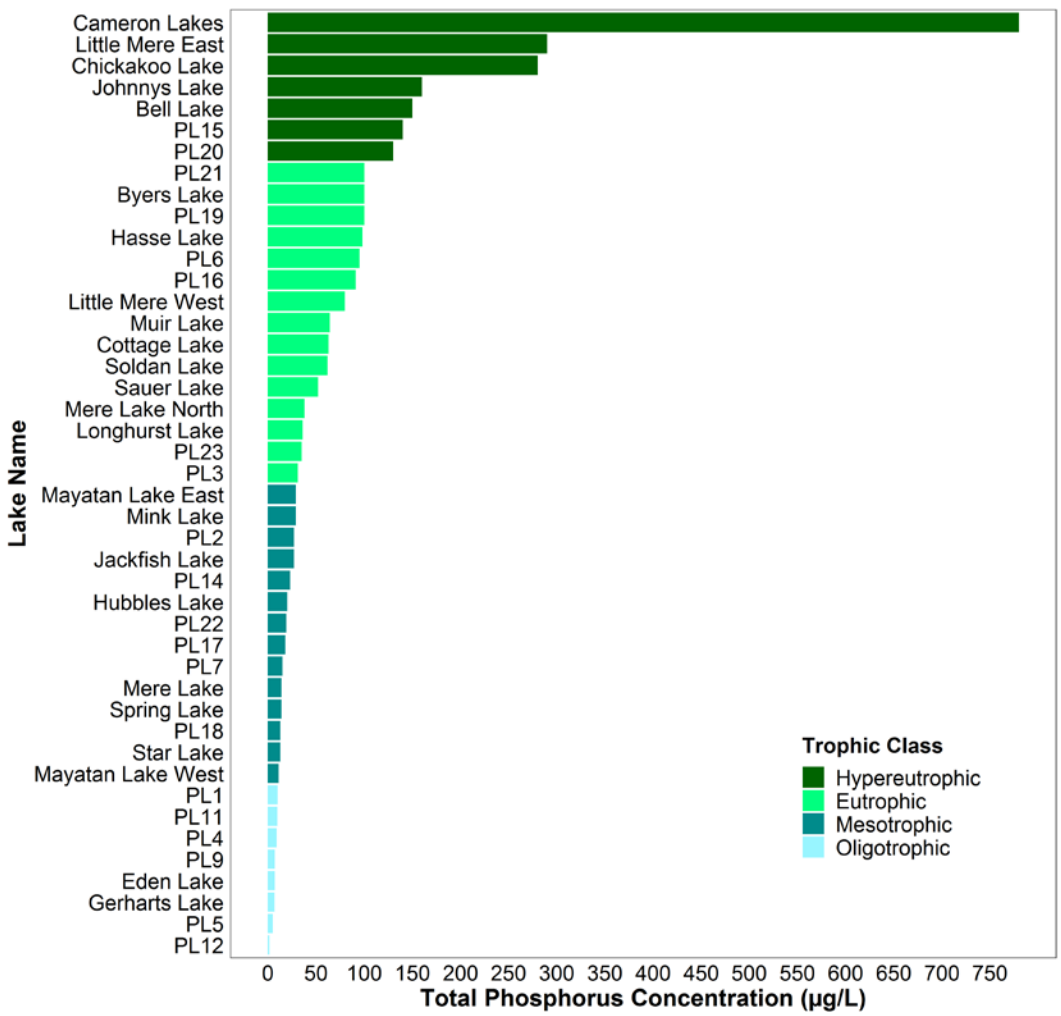

Figure 6. Total phosphorus concentrations for all 44 lakes sampled between August 11th and October 5th, 2021. Samples were collected at 0.5 m depth. Trophic categories have been divided into oligotrophic (<10 µg/L), mesotrophic (10-30 µg/L), eutrophic (30-100 µg/L), and hypereutrophic (>100 µg/L).

Classification: Protected A

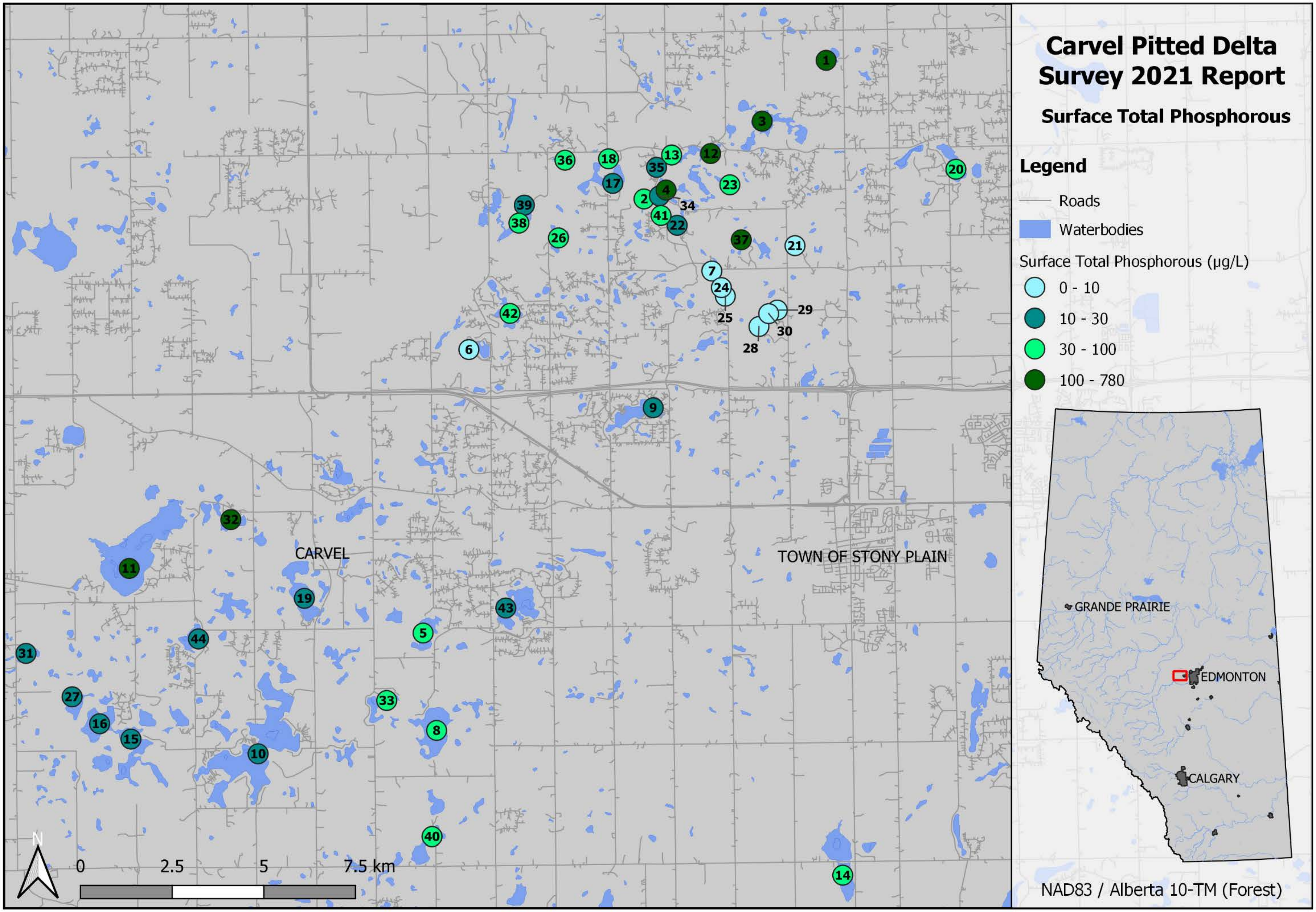

Figure 7. Total phosphorus values sorted into trophic categories for each lake sampled in the Carvel Pitted Delta region. Different colours represent different trophic categories, from oligotrophic (0-10 µg/L), to mesotrophic (10-30 µg/L), to eutrophic (30-100 µg/L), to hypereutrophic (>100 µg/L). The maximum observed phosphorus value was 780 µg/L. See Appendix Table 1 for the lake label description.

Samples collected from 1 m above the bottom of each lake revealed that bottom concentrations of total phosphorus tended to be much higher than surface concentrations (Figure 8). This is particularly evident in deep lakes with thermal stratification, such as PL1, Mayatan Lake West, and PL9, as phosphorus release from the anoxic sediments can become trapped in bottom waters. Bottom phosphorus is more likely to become available for phytoplankton growth at the surface in shallower lakes that mix periodically due to wind activity, or in deeper lakes during autumn cooling.

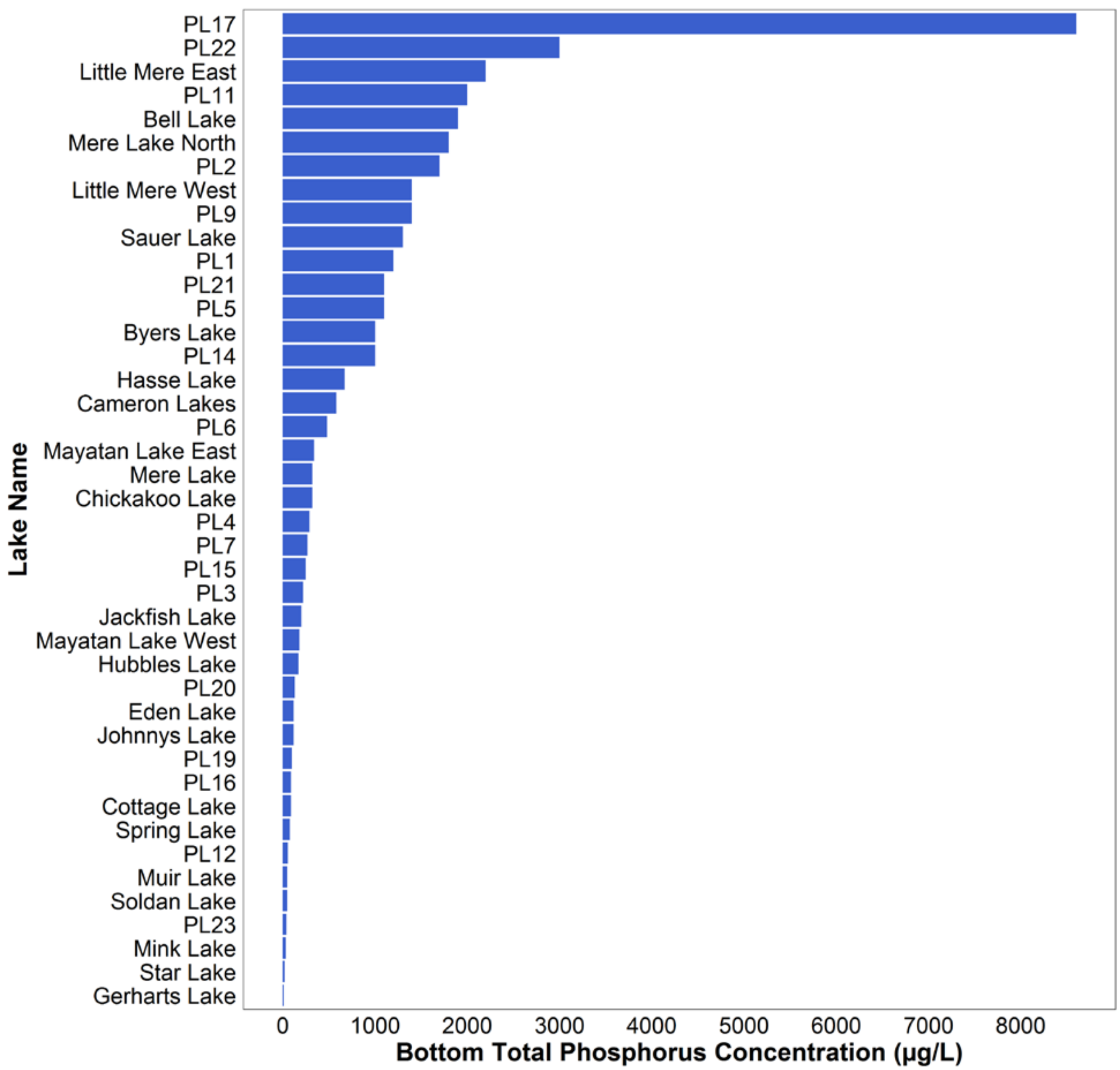

Figure 8. Bottom total phosphorus concentrations from 42 lakes sampled between August 11th and October 5th, 2021. Samples were collected 1 m above the bottom of the lake. Longhurst Lake and PL18 are not included in this figure.

Classification: Protected A

Chlorophyll-a

Chlorophyll-*a* is a photosynthetic pigment and is used as an indicator of the amount of phytoplankton (algae and cyanobacteria) in a lake. In general, lakes with low phosphorus concentrations tend to display low concentrations of chlorophyll-*a,* as phosphorus is the primary nutrient limiting the growth of phytoplankton. The lakes of the Carvel Pitted Delta spanned the full range of trophic states based on their chlorophyll-*a* concentrations (Figure 9). Eight lakes were tentatively classified as oligotrophic, ten lakes as mesotrophic, twelve lakes as eutrophic, and fourteen lakes as hypereutrophic. When visualized on the regional map, a small cluster of oligotrophic lakes can again be observed in the northeastern region of the Carvel Pitted Delta (Figure 10). Overall, chlorophyll-*a* concentrations ranged from 1.6 µg/L at PL12 to 310 µg/L at Johnny's Lake.

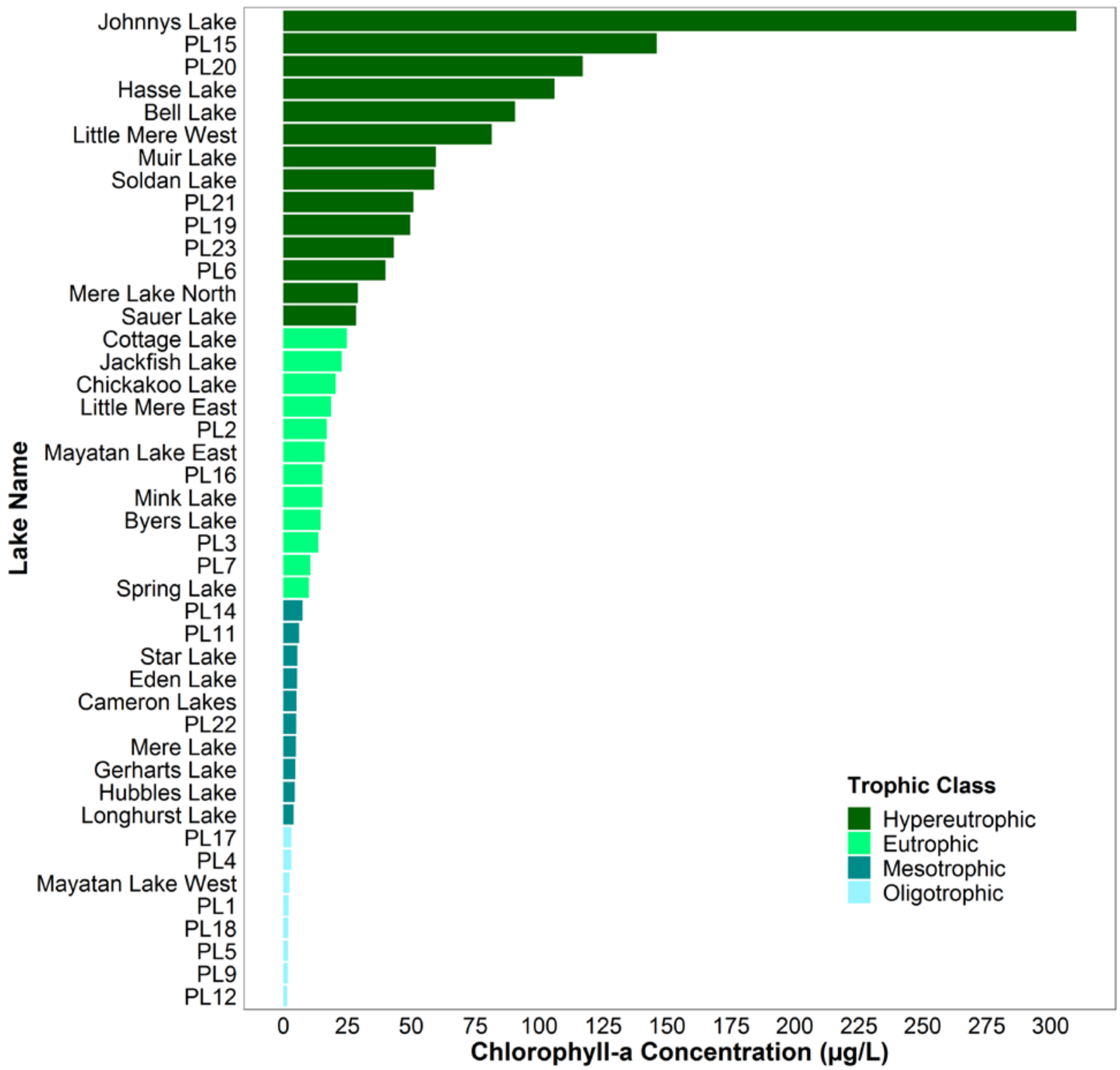

Figure 9. Chlorophyll-*a* concentrations for all 44 lakes sampled between August 11th and October 5th, 2021. Samples were collected at 0.5 m depth. Trophic categories have been divided into oligotrophic (<3.5 µg/L), mesotrophic (3.5-9 µg/L), eutrophic (9-25 µg/L), and hypereutrophic (>25 µg/L).

Classification: Protected A

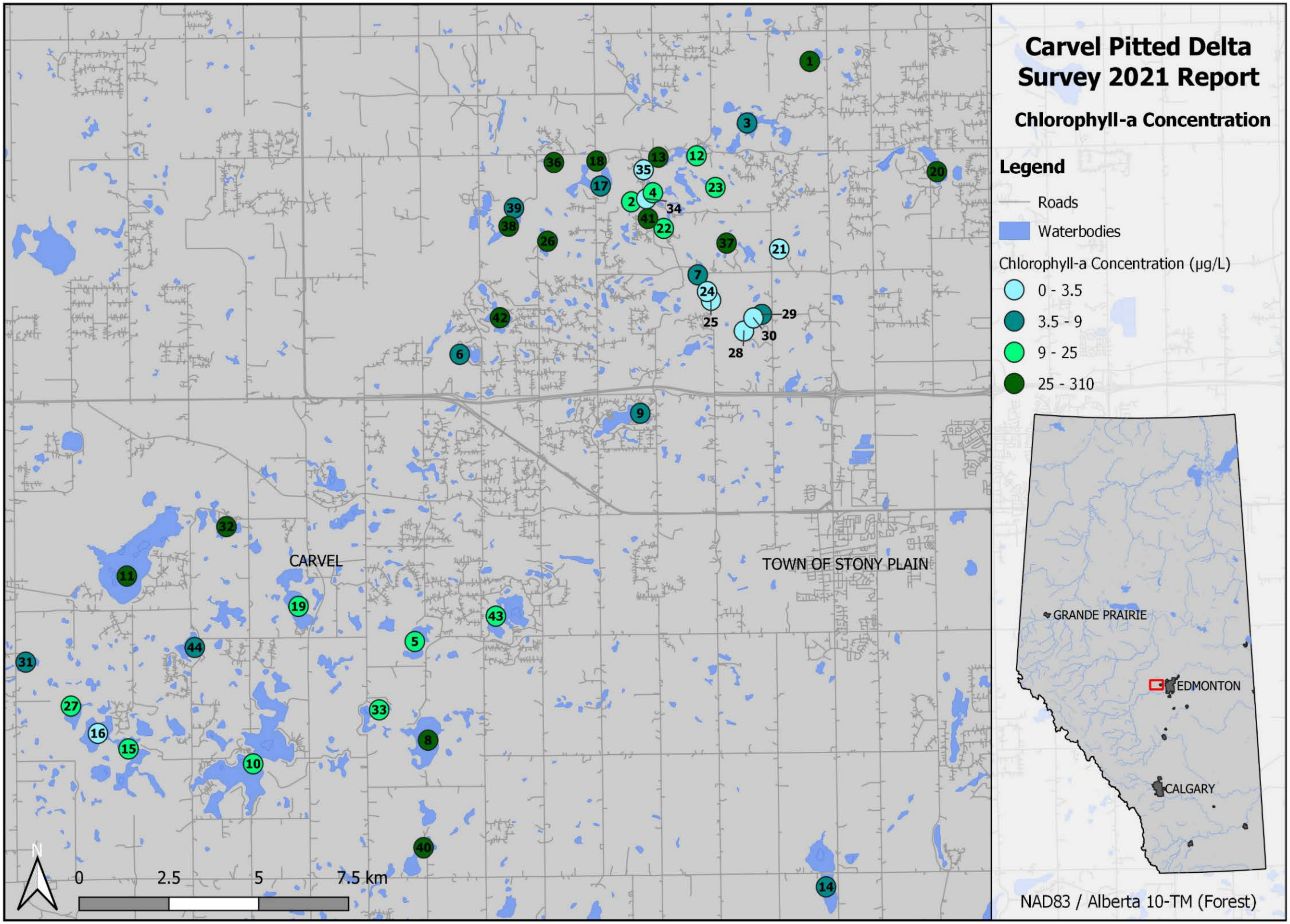

Figure 10. Chlorophyll-a concentrations (µg/L) sorted into trophic categories for each lake sampled in the Carvel Pitted Delta. Different colours represent different trophic categories, from oligotrophic (0-3.5 µg/L), to mesotrophic (3.5-9 µg/L), to eutrophic (9 -25 µg/L), to hypereutrophic (>25 µg/L). The maximum observed chlorophyll-a value was 310 µg/L. See Appendix Table 1 for the lake label description.

Euphotic Depth

Water clarity measured with a Secchi disc was recorded for each lake and subsequently used to estimate euphotic zone thickness (calculated as 2 x Secchi depth) (Figure 11). The euphotic zone is considered the primary photosynthetic zone in lakes and is conventionally defined as the depth to which 1% of surface penetrating light remains. The colour of the water, the amount of suspended solids and the amount of phytoplankton in the water can greatly influence water clarity. In the sampled lakes, euphotic zone depths ranged from 0.8 m at Johnny's Lake to 12.5 m at PL9. The minimum measurement of 0.8 m (at Johnny's Lake) coincided with the highest observed chlorophyll-a concentration (310 µg/L), indicating that a phytoplankton bloom significantly impacted water clarity on the sampling date. In three instances, euphotic depth was equal to the lake bottom (Longhurst Lake, PL16, and PL12). These transparent conditions may allow for the growth of submerged aquatic plants across the lake bottom.

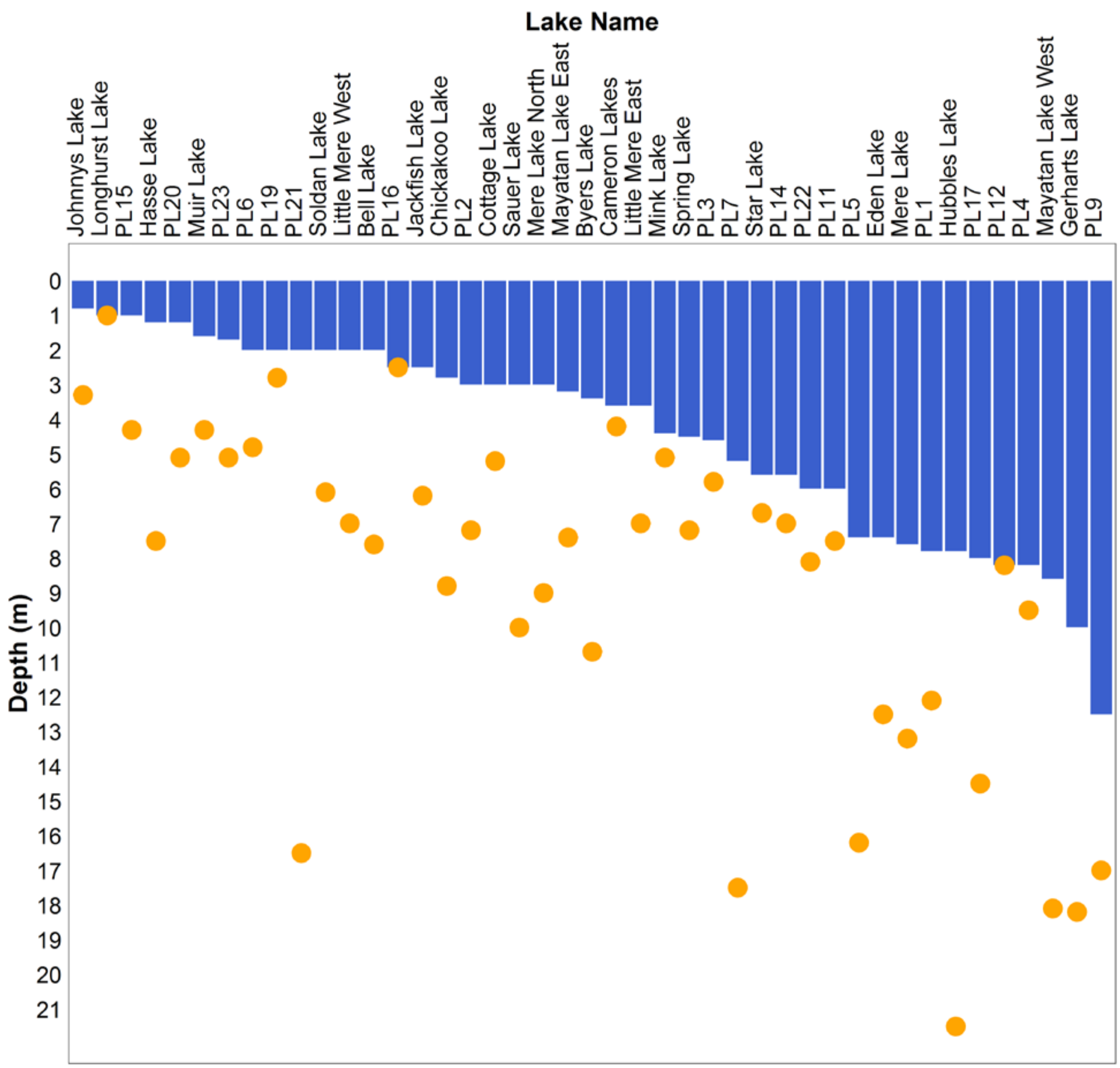

Figure 11. Lake profile depths (yellow points) and euphotic depths (bars) in meters, calculated by doubling Secchi disk depths, for 43 lakes sampled between August 11th and October 5th, 2021. Where the Secchi disk depth was equal to the lake depth, the euphotic depth was calculated simply as the lake depth (Longhurst Lake, PL16, PL12). Secchi depth was not available for PL18.

Major Ions

Groundwater, local geology, and human activity can all impact the concentrations of the major cations and anions in lake water. When comparing major ions across the sampled lakes, sulphate (SO_4^{2-}) displayed the highest variation in concentrations, ranging from 1.2 µg/L at Byers Lake to 1200 µg/L at Mink Lake (Figure 12). The majority of lakes displayed carbonate (CO_3^{2-}) concentrations that fell below the laboratory detection limit (DL= 1 mg/L). For graphing purposes, these lakes were assigned a value representing 50% of the DL, or 0.5 mg/L. The lakes of the Carvel Pitted Delta region display a very wide range of ionic concentrations and proportions, indicative of unique and differing water types.

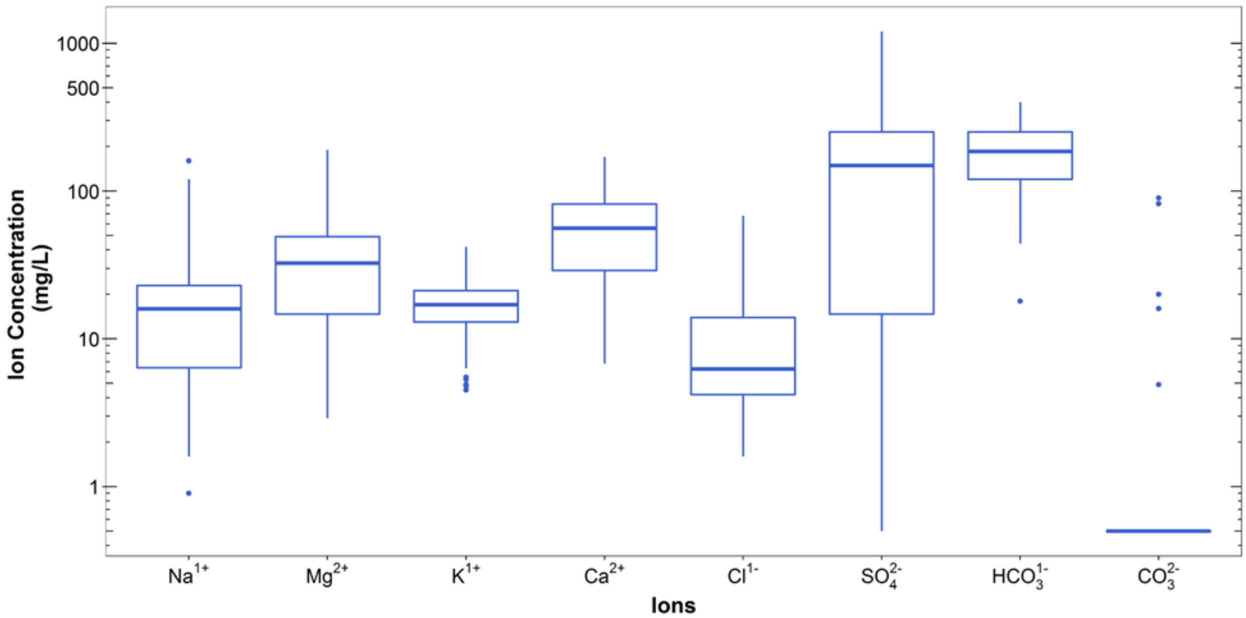

Figure 12. The distribution of major ions concentrations (mg/L) represented as box plots measured from samples collected at 0.5 m depth at 44 lakes between August 11th and October 5th, 2021. Note that the y-axis represents a logarithmic scale of ionic concentrations.

A view of lake PL2. Photo by David Trew.

Classification: Protected A

Conductivity

Specific conductivity is a measure of the capacity of water to conduct an electrical current and is used as a general indicator of the dissolved salt content of lake water. Lakes with higher concentrations of ions tend to have higher conductivities than lakes with low concentrations of ions. Conductivity was measured using two methods: in discrete water samples collected from 0.5 m and returned to the analytical lab, and as *in situ* vertical profiles using the YSI probe. Conductivity values measured in the lab ranged from 91 µS/cm at PL3 to 2200 µS/cm at Mink Lake (Figure 13, Figure 14). When visualized on the regional map, a wide spatial distribution of conductivity values is apparent, with some local clustering of lakes also evident (Figure 14).

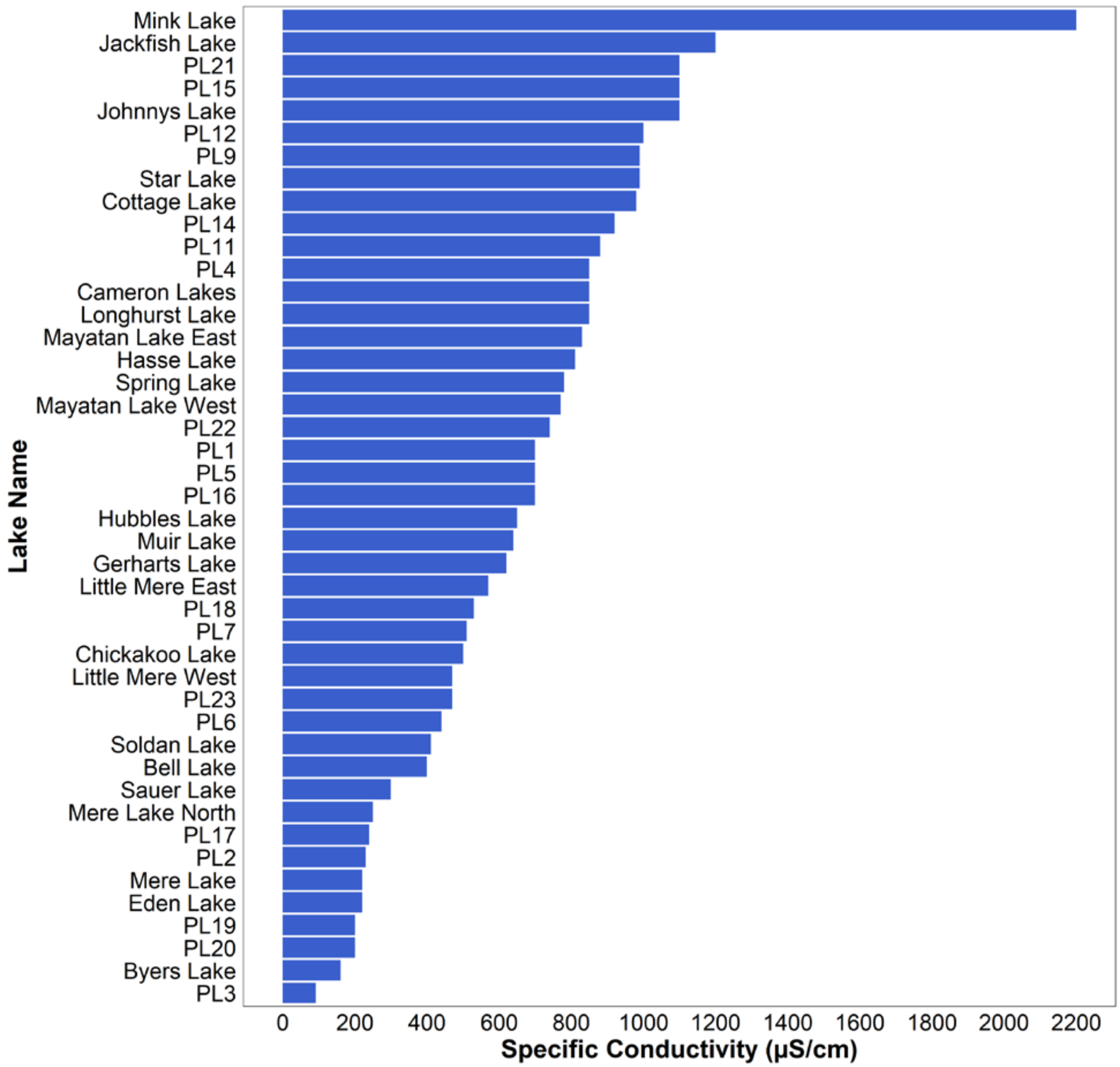

Figure 13. Specific conductance (µS/cm) measured from discrete samples collected at 0.5 m depth at 44 lakes between August 11th and October 5th, 2021.

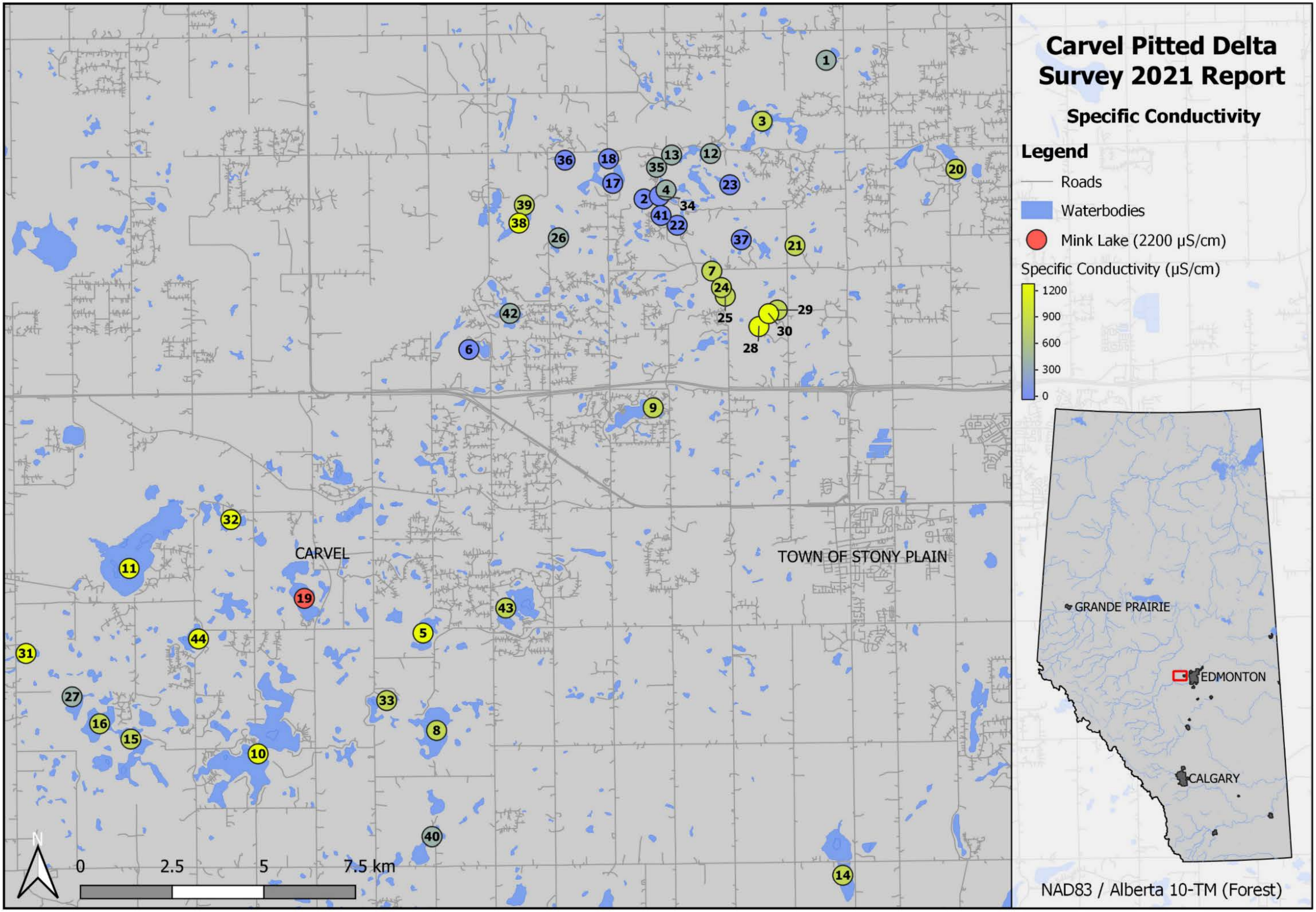

Figure 14. Conductivity values for 44 lakes in the Carvel Pitted Delta region. Conductivity values range from 91 µS/cm at PL3 to 2200 µS/cm at Mink Lake. See Appendix Table 1 for the lake label description.

C

Based on vertical profile measurements of conductivity, the lakes displayed a wide range of conditions. Conductivity values remained fairly consistent from the surface to the bottom in shallow lakes (Figure 15). However, deeper lakes with thermal stratification demonstrated much higher conductivity values below the thermocline compared to surface observations, as can be observed in Gerharts Lake, PL9, PL5, PL14 or PL11.

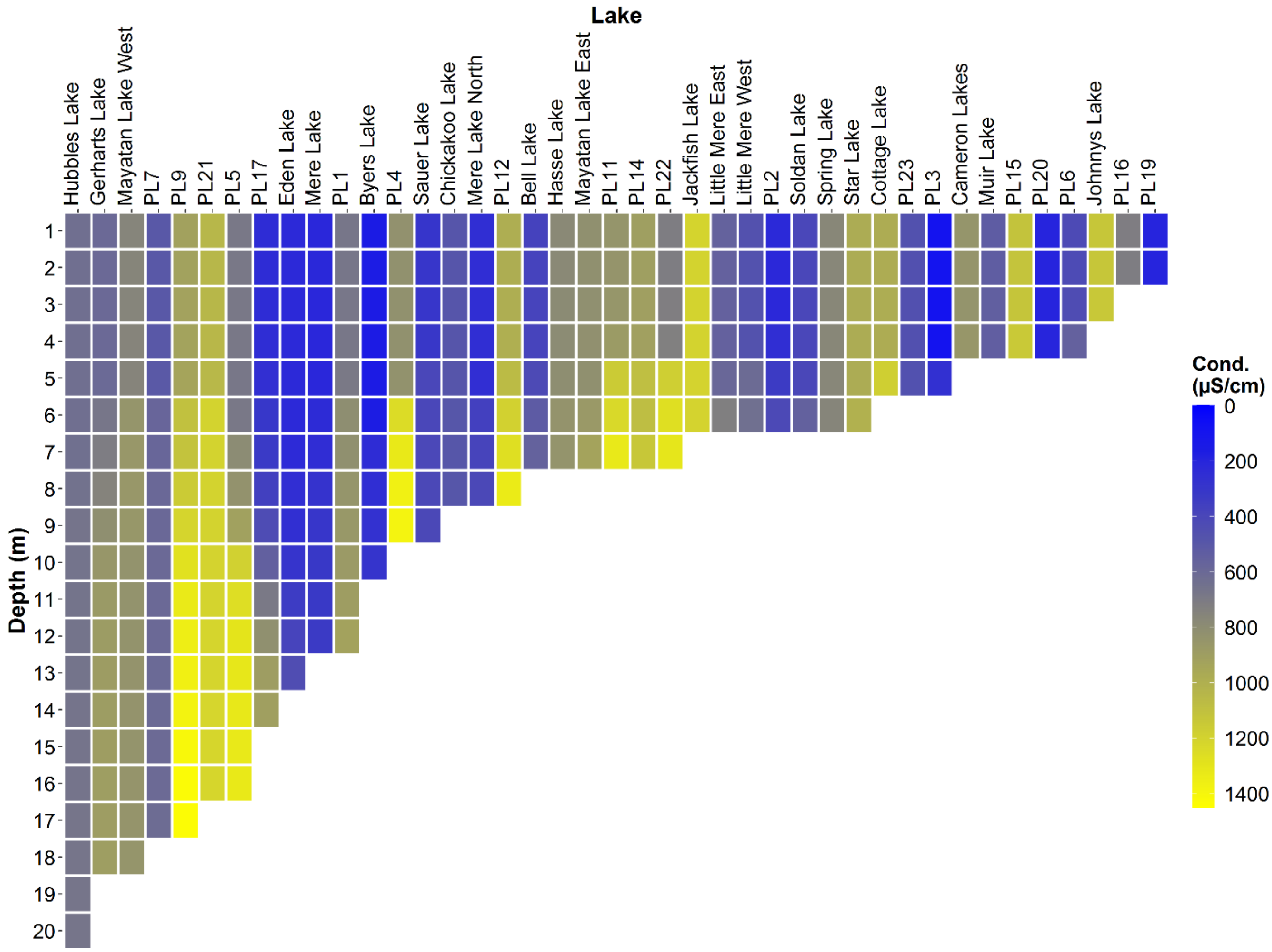

Figure 15. Conductivity (µS/cm) profiles for 41 lakes sampled between August 11th and October 5th, 2021. Coloured boxes reflect the conductivity measurements at each specific depth measurement. Note that while 0.1 m and 0.5 m readings are available for each lake, this figure begins at 1 m depth for visual purposes. Mink Lake has been excluded from this figure due its high conductivity values. Longhurst Lake and PL18 have not been included in this figure.

Summary

The Stony Plain/Carvel Pitted Delta region contains many beautiful small lakes which span an unusually wide range of physical attributes, chemistries, and trophic conditions. The region includes deep lakes with low productivities and clear waters, as well as shallow lakes with high nutrient levels and significant blooms of phytoplankton. The results of this preliminary survey clearly suggest that a multitude of natural and human factors are influencing lake water quality over relatively short distances. From a hydrologic perspective this region constitutes a unique lake assemblage and is positioned within a diverse hydrogeological setting.

The funding partners conducted this water quality survey to initiate the development of an improved information base to support future land and water management decisions, and to encourage local conservation and stewardship activities. New funding has been acquired for 2022 and will support an additional round of lake water quality surveys in this region. Aquatic invasive species concerns are being evaluated in lakes elsewhere in Alberta, but this topic has not been addressed systematically in lakes of the Carvel Pitted Delta. Future work will incorporate aquatic invasive species sampling within this region. The lack of lake bathymetric data (area, depth, volume) for most of these lakes precludes hydrologic assessments, again challenging water management and related discussions. Preliminary bathymetric data will be gathered for several lakes in 2022. Preliminary riparian zone assessments, land cover data and watershed delineations are available for a limited number of the named lakes; this information will be further evaluated in 2022/23. Finally, public awareness of individual lake conditions is constrained by the lack of published educational materials. A long-term goal of the project will be to initiate the development of succinct information packages for individual lakes.

Alec Macdonald (left) and Dr. Konstantin Von Gunten (right) collecting samples from lake PL2. Photo by David Trew.

Classification: Protected A

Acknowledgements

The MLMA undertook initial project development, funding development and community outreach for this project. The Land Stewardship Centre (LSCC), the North Saskatchewan Watershed Alliance (NSWA), the Stony Plain Fish and Game Association (SPFGA), and the Alberta Lake Management Society (ALMS) provided funding for this project. David Trew, Walt Neilson, and Pauline Molnar conducted the field work and provided in-kind support for the study.

ALMS provided advice and guidance for the design of the survey, provided field equipment, facilitated laboratory analysis logistics, and undertook data management. Dr. Konstantin Von Gunten, Dr. Brian Smeardon and Dr. Dan Alessi, Dept. of Earth Sciences, University of Alberta, provide advice during the initial design of this 2021 survey and were actively involved in preliminary studies conducted in 2020. Preliminary riparian assessments, lake and watershed areas, and land cover data were provided by Mary Ellen Shain and Brad Tyssen of the NSWA. The cooperation of 27 individual landowners who enabled access to many of these lakes is gratefully acknowledged. Jamie Kalla supported data entry and figure and map production.

This report was prepared by Bradley Peter (ALMS), Caleb Sinn (ALMS), David Trew (MLMA), and Walt Neilson (MLMA).

The cattails at Lake PL3. Photo by David Trew, 2021.

Mayatan Lake Management Association

Land Stewardship Centre

Stony Plain Fish & Game Association & Wabamun Gun Club

NSWA NORTH SASKATCHEWAN WATERSHED ALLIANCE

ALMS

UNIVERSITY OF ALBERTA

Classification: Protected A

Appendix

Classification: Protected A

Appendix Table 1. Labels assigned to each lake used to identify lakes on map figures.

Name	Label	Name	Label
Bell Lake	1	PL3	23
Byers Lake	2	PL4	24
Cameron Lakes	3	PL5	25
Chickakoo Lake	4	PL6	26
Cottage Lake	5	PL7	27
Eden Lake	6	PL9	28
Gerharts Lake	7	PL11	29
Hasse Lake	8	PL12	30
Hubbles Lake	9	PL14	31
Jackfish lake	10	PL15	32
Johnnys Lake	11	PL16	33
Little Mere East	12	PL17	34
Little Mere West	13	PL18	35
Longhurst Lake	14	PL19	36
Mayatan Lake East	15	PL20	37
Mayatan Lake West	16	PL21	38
Mere Lake	17	PL22	39
Mere Lake North	18	PL23	40
Mink Lake	19	Sauer Lake	41
Muir Lake	20	Soldan Lake	42
PL1	21	Spring Lake	43
PL2	22	Star Lake	44

Appendix Table 2. Sample date, Secchi depth, water quality parameters, lake surface area, and maximum observed depth for 44 lakes sampled in the Carvel Pitted Delta region.

Variable	Bell Lake	Byers Lake	Cameron Lakes	Chickakoo Lake	Cottage Lake	Eden Lake	Gerharts Lake	Hasse Lake	Hubbles Lake
Sample Date	9/10/2021	10/4/2021	9/27/2021	8/27/2021	8/24/2021	9/21/2021	8/31/2021	8/16/2021	9/28/2021
Secchi Depth (m)	1	1.7	1.8	1.4	1.5	3.7	5	0.6	3.9
Total Alkalinity (mg/L)	130	71	250	120	110	93	220	130	140
HCO_3^- (mg/L)	160	87	330	150	130	110	260	160	180
Ca^{2+} (mg/L)	31	16	130	57	110	20	75	51	60
CO_3^{2-} (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cl^- (mg/L)	32	2.3	6.3	6.2	6.2	10	5.6	5.8	5.8
Chl-*a* (µg/L)	90.6	14.6	5.1	20.5	24.8	5.4	4.6	106	4.4
Cond. (µS/cm)	400	160	850	500	980	220	620	810	650
Hardness (mg/L)	120	66	440	230	470	78	340	330	320
NO_3+NO_2 (µg/L)	<4.2	<4.2	6.1	14	<4.2	<4.2	<4.2	87	<4.2
TKN (mg/L)	3.6	1.4	4.8	2.2	2.8	0.66	0.57	2.5	0.92
Mg^{2+} (mg/L)	11	6.4	25	22	50	6.5	38	48	41
NH_3-N (µg/L)	3.3	<3	6.1	9.8	<3	3.5	<3	87	<3
DOC (mg/L)	25	15	35	19	22	7.5	9.6	17	8.9
K^- (mg/L)	37	14	14	17	22	15	4.8	21	12
Na^+ (mg/L)	14	1.7	6.4	5.3	15	5.3	19	22	24
SO_4^{2-} (mg/L)	13	1.2	200	120	410	<1	110	290	190
TDP (µg/L)	86	12	820	240	20	<3	<3	25	4.8
Bottom TP (µg/L)	1900	1000	580	320	87	120	11	670	170
TP (µg/L)	150	100	780	280	63	6.9	6.6	98	20
TDS (mg/L)	220	85	560	310	670	110	400	520	420
pH	8.2	7.26	8.01	7.4	7.08	7.86	8.08	8.19	8.22
Surface Area (ha)	14.3	8.3	46.6	18.5	33	20.5	8	84.8	42.4
Maximum Observed Depth (m)	7.6	10.7	4.2	8.8	5.2	12.5	18.2	7.5	21.5

Appendix Table 2 continued. Sample date, Secchi depth, water quality parameters, lake surface area, and maximum observed depth for 44 lakes sampled in the Carvel Pitted Delta region.

Variable	Jackfish Lake	Johnnys Lake	Little Mere East	Little Mere West	Longhurst Lake	Mayatan Lake East	Mayatan Lake West	Mere Lake	Mere Lake North
Sample Date	8/13/2021	8/19/2021	9/5/2021	9/5/2021	9/8/2021	8/12/2021	8/12/2021	9/7/2021	9/24/2021
Secchi Depth (m)	1.25	0.4	1.8	1	>1	1.6	4.3	3.8	1.5
Total Alkalinity (mg/L)	140	320	210	170	230	150	200	97	100
HCO_3^- (mg/L)	170	220	250	210	100	190	210	120	120
Ca^{2+} (mg/L)	110	33	65	55	10	40	33	20	27
CO_3^{2-} (mg/L)	<1	82	<1	<1	90	<1	20	<1	<1
Cl^- (mg/L)	7.5	33	23	20	68	3.6	3	5	7.1
Chl-*a* (µg/L)	22.8	310	18.6	81.4	4.1	16.2	2.5	4.9	29.1
Cond. (µS/cm)	1200	1100	570	470	850	830	770	220	250
Hardness (mg/L)	560	210	250	230	170	380	370	90	110
NO_3+NO_2 (µg/L)	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2	<4.2
TKN (mg/L)	1.5	3.4	2.9	3	4.4	1.7	1.3	1.3	1.6
Mg^{2+} (mg/L)	69	31	22	23	34	69	70	9.5	11
NH_3-N (µg/L)	3.6	<3	<3	3.7	<3	<3	<3	<3	3.9
DOC (mg/L)	13	55	24	22	53	19	18	13	15
K^- (mg/L)	25	19	18	20	28	30	27	15	17
Na^+ (mg/L)	30	160	12	13	120	20	23	3.2	4.2
SO_4^{2-} (mg/L)	530	230	58	45	94	300	240	3.6	12
TDP (µg/L)	10	35	220	44	23	8.2	5.1	5.4	13
Bottom TP (µg/L)	200	120	2200	1400	NA	340	180	320	1800
TP (µg/L)	27	160	290	80	36	29	11	14	38
TDS (mg/L)	850	730	330	280	500	560	510	110	140
pH	7.67	9.05	7.6	7.52	9.64	7.74	8.82	7.34	7.72
Surface Area (ha)	281	244.1	19.7	10.8	32.8	72.7	52.5	35.2	11.5
Maximum Observed Depth (m)	6.2	3.3	7	7	1	7.4	18.1	13.2	9

Appendix Table 2 continued. Sample date, Secchi depth, water quality parameters, lake surface area, and maximum observed depth for 44 lakes sampled in the Carvel Pitted Delta region.

Variable	Mink Lake	Muir Lake	PL1	PL2	PL3	PL4	PL5	PL6	PL7
Sample Date	8/11/2021	9/10/2021	9/20/2021	9/13/2021	9/13/2021	9/20/2021	9/20/2021	9/13/2021	8/25/2021
Secchi Depth (m)	2.2	0.8	3.9	1.5	2.3	4.1	3.7	1	2.6
Total Alkalinity (mg/L)	180	170	230	55	36	290	210	120	230
HCO_3^- (mg/L)	220	200	280	67	44	350	260	150	250
Ca^{2+} (mg/L)	170	58	75	16	6.8	110	72	52	29
CO_3^{2-} (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1	16
Cl^- (mg/L)	18	24	4.2	33	1.6	4.3	4.2	3.6	1.6
Chl-*a* (µg/L)	15.2	59.7	2.1	16.9	13.7	3	1.8	39.9	10.6
Cond. (µS/cm)	2200	640	700	230	91	850	700	440	510
Hardness (mg/L)	1200	230	330	65	29	470	350	220	250
NO_3+NO_2 (µg/L)	65	<4.2	37	<4.2	12	13	16	27?	<4.2
TKN (mg/L)	1.7	1.9	1.3	1.8	1.7	1.1	0.61	2.2	1.4
Mg^{2+} (mg/L)	190	22	34	5.8	2.9	46	41	21	43
NH_3-N (µg/L)	65	<3	32	3.1	12	8.2	12	24	3.9
DOC (mg/L)	17	20	16	19	16	9.1	9.5	22	12
K^- (mg/L)	42	18	6.3	14	15	4.9	4.5	16	19
Na^+ (mg/L)	57	18	26	13	0.9	18	17	5.1	15
SO_4^{2-} (mg/L)	1200	79	130	<1	<1	180	170	93	54
TDP (µg/L)	8.2	12	5.4	12	14	4.2	<3	28	9.6
Bottom TP (µg/L)	34	49	1200	1700	220	290	1100	480	270
TP (µg/L)	29	64	10	27	31	9.3	5.2	95	15
TDS (mg/L)	1800	330	440	120	49	570	450	270	300
pH	8.1	8.47	8.08	7.63	7.38	8.05	8.11	7.99	8.7
Surface Area (ha)	74.4	29.9	4.3	5.2	7.1	2	4.2	14.2	24.9
Maximum Observed Depth (m)	5.1	4.3	12.1	7.2	5.8	9.5	16.2	4.8	17.5

Appendix Table 2 continued. Sample date, Secchi depth, water quality parameters, lake surface area, and maximum observed depth for 44 lakes sampled in the Carvel Pitted Delta region.

Variable	PL9	PL11	PL12	PL14	PL15	PL16	PL17	PL18	PL19
Sample Date	8/30/2021	8/30/2021	8/30/2021	8/19/2021	8/20/2021	8/24/2021	9/24/2021	9/24/2021	9/28/2021
Secchi Depth (m)	6.25	3	5.5	2.8	0.5	>2.5	4	NA	1
Total Alkalinity (mg/L)	310	290	330	200	180	120	93	15	69
HCO_3^- (mg/L)	380	360	400	240	220	150	110	18	84
Ca^{2+} (mg/L)	110	100	140	66	87	80	27	73	16
CO_3^{2-} (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1	<1
Cl^- (mg/L)	1.6	3.1	1.8	14	13	5.6	6.3	5.1	14
Chl-*a* (µg/L)	1.7	6.1	1.6	7.5	146	15.2	3	2	49.6
Cond. (µS/cm)	990	880	1000	920	1100	700	240	530	200
Hardness (mg/L)	530	460	570	400	420	320	110	240	61
NO_3+NO_2 (µg/L)	12	<4.2	<4.2	<4.2	4.6	15	6.2	39	49
TKN (mg/L)	0.56	0.95	0.53	1.9	3.7	3.6	1.5	0.87	2.3
Mg^{2+} (mg/L)	61	49	54	56	50	29	10	14	5.3
NH_3-N (µg/L)	12	<3	<3	<3	<3	15	6.2	16	33
DOC (mg/L)	6.6	11	8.6	19	28	25	16	7.4	19
K^- (mg/L)	5.5	5.5	5.3	20	34	23	13	17	19
Na^+ (mg/L)	18	24	17	23	40	6.4	4.5	3	7.4
SO_4^{2-} (mg/L)	280	210	280	280	360	250	15	220	<1
TDP (µg/L)	<3	5.8	<3	10	34	54	8.8	5.2	36
Bottom TP (µg/L)	1400	2000	53	1000	250	89	8600	NA	100
TP (µg/L)	7	9.8	<3	23	140	91	18	13	100
TDS (mg/L)	690	600	710	580	710	490	130	340	100
pH	8.2	8.26	8.01	8.21	8.25	7.36	7.7	6.85	7.54
Surface Area (ha)	6.8	1.3	1.1	12.1	23.7	22.9	3.4	0.3	6.5
Maximum Observed Depth (m)	17	7.5	8.2	7	4.3	2.5	14.5	NA	2.8

Appendix Table 2 continued. Sample date, Secchi depth, water quality parameters, lake surface area, and maximum observed depth for 44 lakes sampled in the Carvel Pitted Delta region.

Variable	PL20	PL21	PL22	PL23	Sauer Lake	Soldan Lake	Spring Lake	Star Lake
Sample Date	10/1/2021	10/5/2021	10/5/2021	9/3/2021	8/27/2021	9/21/2021	8/13/2021	8/11/2021
Secchi Depth (m)	0.6	1	3	0.85	1.5	1	2.25	2.8
Total Alkalinity (mg/L)	74	320	250	210	110	180	140	100
HCO_3^- (mg/L)	91	390	300	260	130	210	170	120
Ca^{2+} (mg/L)	16	110	76	50	29	52	41	95
CO_3^{2-} (mg/L)	<1	<1	<1	<1	<1	<1	<1	<1
Cl^- (mg/L)	6.4	39	3.1	16	8.6	11	13	5.1
Chl-*a* (µg/L)	117	50.8	5	43.2	28.5	58.9	10	5.5
Cond. (µS/cm)	200	1100	740	470	300	410	780	990
Hardness (mg/L)	61	440	350	220	130	210	310	490
NO_3+NO_2 (µg/L)	9.5	31	6.6	<4.2	<4.2	17	<4.2	45
TKN (mg/L)	2.6	2.5	2.4	1.7	2.4	2	1.7	1.5
Mg^{2+} (mg/L)	4.9	39	40	23	15	20	51	61
NH_3-N (µg/L)	9.5	27	6.6	4.1	<3	13	<3	45
DOC (mg/L)	20	34	19	15	19	15	15	18
K^- (mg/L)	19	9.6	7.6	14	16	22	13	28
Na^+ (mg/L)	1.6	66	17	15	7.1	7.4	29	22
SO_4^{2-} (mg/L)	7.7	230	170	8.3	30	14	260	440
TDP (µg/L)	44	50	17	8.1	22	8	6.6	4.7
Bottom TP (µg/L)	130	1100	3000	42	1300	48	77	19
TP (µg/L)	130	100	19	35	52	62	14	13
TDS (mg/L)	100	700	500	270	170	230	500	720
pH	7.22	8.29	8.05	8.21	7.6	7.93	7.48	7.08
Surface Area (ha)	5.2	23.3	2.3	28	9.4	19.7	69.2	27
Maximum Observed Depth (m)	5.1	16.5	8.1	5.1	10	6.1	7.2	6.7