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Memorandum

Date: **November 24, 2014**

To: **Dominique O'Brien, Manager of Community Services, Seguin Township**

From: **Tammy Karst-Riddoch, Kris Hadley**

Re: **J100033 – 2013 Water Quality Monitoring Summary**

In 2014, Seguin Township completed the seventh year of sampling for its Water Quality Monitoring Program. This program collects total phosphorus (TP) concentration data and other pertinent lake information (e.g., Secchi depth, dissolved oxygen concentration, lake depth, dissolved organic carbon, etc.) in support of the water quality model developed by AECOM (2009) to predict phosphorus concentrations in Township lakes. Continued monitoring will also allow the Township to identify potential problems in lake water quality as they emerge.

The 2014 monitoring was conducted by summer students employed by Seguin Township. HESL staff provided sampling instructions, a half day training session and ongoing technical guidance, and assisted coordination with the laboratory at Dorset Environmental Science Centre (DESC). In May, water samples were collected from 46 lakes for analysis of spring overturn TP concentration and in August, 38 of those lakes were revisited to measure dissolved oxygen and temperature profiles, Secchi depth and lake depth.

The major findings from the 2014 monitoring period are summarized below and recommendations are provided for future sampling.

1. Spring Total Phosphorus Sampling

Duplicate water samples from 46 lakes were analyzed for spring TP concentrations. We evaluated the analytical precision of the data (i.e., how well sample duplicates agreed). Contamination of samples can occur during sample collection or as a result of zooplankton biomass, which can produce elevated TP concentrations and 'bad splits' between field duplicates. Even with careful sampling, bad splits are common and occur for approximately 10% of sample submissions to DESC (pers. comm., Bev Clark). For the 2014 data, we flagged all sample pairs that differed by more than a) 40% from the minimum of the two values, and b) 4 μg/L, and removed the higher of the two values, assuming contamination, which is the approach currently used by the District Municipality of Muskoka. There was 1 bad split identified in the 2014 samples, representing 2% of the samples (Table 1). This percentage of bad splits represents good sampling practices as it is below the average for samples submitted to DESC. We recommend continued vigilance in following sampling protocol when collecting water samples to minimize the potential for sample contamination. We note that samples flagged as outliers due to contamination should be reassessed by comparison with data from additional years of sampling as the monitoring program progresses.

Table 1. Bad Splits Between Duplicate Samples Collected by the Seguin Township Monitoring Program (ST) and the Lake Partner Program (LPP)

Year	# of Bad Splits (>40% and >4 µg/L difference between sample pairs)	Total # of Samples	% Bad Splits
2008 (ST)	3	25	12
2009 (ST)	7	37	19
2010 (ST)	6	36	17
2011 (ST)	11	47	23
2012 (ST)	4	50	8
2013 (ST)	1	53	2
2014 (ST)	1	48	2
LPP (02-10)	16	233	7

Outliers between years of data were identified using the Dixon's Q and Grubbs' outlier tests at a significance level of $\alpha = 0.05$. In total, 8 values were identified as outliers based on both tests and were removed from the dataset (Table 2). We note that these values should be reassessed as outliers each year as additional data are collected. For example, with the addition of the 2014 data, the sample from McDonald Lake (2009), which was previously identified as an outlier, is now included in the dataset.

Table 2. Outlier TP Values (2002-2014)

Lake	Year	Outlier TP (µg/L)	Mean 2002-2014 TP (µg/L) **(outlier excluded)**
Cosh Lake	2008	21.0	7.22
Gilbank	2006	13.93	8.43
Joselin (Burnt) Lake	2002	10.6	5.04
Lane	2013	10	4.96
Little Whitefish Lake	2006	10.1	4.53
McNutt Lake	2008	16.5	8.69
Salmon Lake	2002	13.2	5.92
Sucker Lake	2008	8.36	5.20

Table 3 summarizes the 2014 total phosphorus concentration results and mean concentrations of data collected in previous years by both the Seguin Township monitoring program (2008-2014) and the Lake Partner Program (2002-2011). Combined, these two monitoring programs provide spring overturn total phosphorus data for 74 of the 128 lakes in Seguin Township that have a surface area of at least 10 ha. The LPP data for 2013-2014 have not yet been posted, but these data should be reviewed and included in future revisions to the phosphorus model if applicable.

The MOECC recommends a minimum of two years of spring overturn TP data to be 95% confident of being within 20% of the mean annual concentration of a lake. For Seguin Township lakes, 73 lakes now have at least two years of monitoring data, with 71 of these having three or more years., 56 lakes in 2012, 47 lakes in 2011, 39 lakes in 2010, and only 28 lakes in 2009. These data will provide more reliable estimates of long term, steady-state total phosphorus concentration of the lakes for calibration and validation of the model, thereby providing more robust and confident assessment of shoreline development capacity.

Table 3. Mean Spring Total Phosphorus (TP) Concentrations in Seguin Township Lakes (n=74)

Lake	# of Years Sampled (02-09)	Mean TP (02-09) (µg/L)	TP 2014 (µg/L)	# of Years Sampled (02-14)	Mean TP (02-14) (µg/L)
Armishaw Lake	1	6.50		3	5.23
Baby Lake	2	6.38	6.80	6	6.15
Back Lake	1	5.50		3	7.07
Black Water Lake	4	11.75		7	10.74
Blue Lake	3	4.93	3.00	6	4.24
Brennan Lake	0		9.40	3	10.22
Capton Lake	1	6.95	8.10	3	7.20
Clear Lake	6	3.12	4.40	11	3.43
Cosh Lake	0		5.80	4	6.87
Diamond Lake	1	13.84	9.20	5	9.97
Draper Lake	1	7.60	5.70	4	7.11
Dyson Lake	3	5.39		6	4.66
Fair Lake	1	8.25	5.70	3	7.32
Faris Lake	1	3.90	2.90	3	3.67
First Lake	1	7.10	6.30	4	6.44
Flaxman Lake	1	4.50	5.10	3	4.50
Forget Lake	1	7.06		4	5.63
Gilbank Lake	3	9.75	6.90	6	8.18
Haines Lake	1	4.90	7.80	4	7.89
Horseshoe Lake	8	7.23	6.67	13	7.31
Isabella Lake	8	9.38	10.40	13	9.75
Joselin (Burnt) Lake	7	5.08		9	5.04
Kight Lake	1	11.10		3	10.59
Kingshott Lake	0		8.30	4	10.46
Lane Lake	1	5.10	4.20	3	4.71
Lieback Lake	1	6.40		3	5.45
Linger Long (Napken) Lake	1	11.07		4	9.44
Little Lake Joe	0			3	4.48
Little Otter Lake	0		7.40	2	5.30
Little Seguin/Duck Lake	4	8.60	10.10	9	9.15

Lake	# of Years Sampled (02-09)	Mean TP (02-09) (µg/L)	TP 2014 (µg/L)	# of Years Sampled (02-14)	Mean TP (02-14) (µg/L)
Little Whitefish Lake	3	4.63	4.20	7	4.48
Long Lake	2	9.67		3	8.51
Long Lake 1	1	4.82		2	4.32
Lower Fry Lake	0		11.60	5	13.44
Manitouwaba Lake	8	6.26	4.20	10	5.99
Maple Lake	5	12.56	11.80	10	11.17
Martin Lake	4	7.20		6	7.02
McDonald Lake	1	10.80	8.10	3	8.68
McGowan Lake	7	4.46	6.20	10	5.24
McKechine Lake	1	3.40	3.70	4	3.89
McLean Lake	1	8.40	6.80	4	7.29
McNutt Lake	4	8.97	8.30	7	8.63
Mirror Lake	1	5.00		3	6.99
Murdock Lake	1	13.45	10.60	3	11.98
Mutton Lake	0		9.80	4	10.50
Neville Lake	1	9.80		3	10.41
Oastler Lake	5	6.36		8	6.52
Otter Lake	8	6.41	5.30	13	6.06
Pender Lake	0		5.80	3	5.19
Portage Lake	1	7.77	6.80	6	6.06
Rankin Lake	8	8.57		11	8.32
Roberts Lake	3	7.25		5	6.87
Salmon Lake	7	6.05		9	5.92
Scime Lake	0			1	9.06
Scott Lake	1	7.09	6.60	5	7.27
Second Lake	1	13.75	8.90	4	10.34
Star Lake	8	9.46	10.70	13	9.69
Storm Lake	1	5.65		3	5.87
Sucker Lake	0		6.10	5	5.38
Sugar Lake	7	7.39	5.40	12	6.78
Ten Mile Lake	0			3	9.33
Third Lake	1	12.10	12.50	4	9.85
Three-Legged Lake	6	5.88		8	5.42
Tiffin Lake/Silver	1	6.14	6.50	5	6.54
Trout Lake	1	5.40		4	5.11
Tub Lake	1	7.85	7.40	3	7.10
Tucker Lake	1	9.15	9.80	5	8.34
Turtle Lake	5	8.56	7.40	10	7.96
Upper Fry Lake	6	14.03	15.30	11	15.33
Virtue Lake	2	10.38		5	8.66
Whitefish Lake	1	3.40		4	5.07
Windfall Lake	1	7.65		3	7.32
Yarrow Lake	0		9.80	3	9.17

Simple linear regression was used to determine whether TP concentrations were changing significantly over time (2002-2014) in any of the lakes. Only lakes with at least 5 years of data were analyzed. No lakes displayed a significant positive trend in TP over time ($p<0.05$).

2. August Field Sampling

Many of the lakes in Seguin Township are shallow, with the potential to have internal phosphorus loading due to resuspension of phosphorus in the water column with wind mixing and/or have relatively high concentrations of dissolved organic carbon (tea-stained lakes), which were suspected as contributing to error in the 2009 model predictions. In addition, some lakes may be prone to anoxia (lack of oxygen) in the hypolimnion, which can also result in internal phosphorus loading and error in the model predictions. To identify these potential problems, dissolved oxygen and temperature profiles, lake depth, Secchi depth and water colour (qualitative) were monitored at 36 study lakes in August. These field data are summarized in Table 4.

Of the 36 lakes monitored in August 2014, 13 were shallow and mixed to the bottom (Table 4). These lakes should be evaluated for potential internal phosphorus loading due to wind mixing and resuspension of phosphorus into the water column in future revisions to the model.

Table 4. Summary of August 2014 Field Sampling Results

Lake Name	Depth (m)	Surface Water Temperature (˚C)	Dissolved Oxygen (1-m off bottom) (mg/L)[1]	Potentially Anoxic Hypolimnion?[2]	Shallow Mixed Water Column?[3]	Secchi Depth (m)	Water Colour
Brennan Lake	2.9	22.6	1.86		Yes	2.7	Brown
Cosh Lake	4.3	21.5	0.16 (3 m)		Yes	2.4	Red/orange
Diamond Lake	4.8	20	0.04		Yes	2.1	Yellow/brown
Draper Lake	4.4	23.3	3.63 (3 m)		Yes	3.6	Yellow/cloudy
Duck Lake	17	20.1	0.06	No		2.3	Orange/Red
Faris Lake	18	22.2	0.02	Yes		6	Yellow
First Lake	2.5	22.8	8.40 (1 m)		Yes	2.5	Muddy-Yellow
Gilbank Lake	18	22	0.3	No		2.9	Yellow
Horseshoe I	12	19.9	0.03	No		3.7	Clear/Yellow
Horseshoe II	31	19.9	0.07 (20 m)	Yes (below 20 m)		3.5	Clear/Yellow
Horseshoe III	18	20	0.04	No		3.9	Clear/Yellow
Isabella Lake	15	19.9	0.11	No*		2.4	Red
Kingshott Lake	3.9	21.7	2.49 (2 m)		Yes	2	Orange/red
Lane Lake	6.5	21.5	1.32 (5 m)		Weak Stratification	5	Yellow
Little Otter	5.3	21.5	0.05		Yes	3	Yellow
Little Whitefish Lake	7	21.9	0.08		Yes	4.5	Green

Lake Name	Depth (m)	Surface Water Temperature (˚C)	Dissolved Oxygen (1-m off bottom) (mg/L)[1]	Potentially Anoxic Hypolimnion?[2]	Shallow Mixed Water Column?[3]	Secchi Depth (m)	Water Colour
Long Lake	5.6	21.2	0.27 (4 m)		Yes	5.6	Yellow
Manitouwaba Lake	5.5	23.7	0.04 (4 m)		Weak Stratification	3.1	Clear/Light brown
Maple Lake	13	19.7	0.04	No		2.9	Yellow
McDonald Lake	2.5	24.5	6.6 (1 m)		Yes	2.5	Yellow
McGown Lake	12	20.8	0.04	No		6.5	Clear/Blue
McKechine Lake	6.5	23.6	0.8 (5 m)		Yes	4.1	Clear/Yellow
McLean Lake	12	22.8	0.06	No		2.5	Yellow/brown
McNutt Lake	11	21.8	0.04	No		3	Brown
Otter Lake	30	20.9	6.58 (23 m)	No (to 23 m)		4	Yellow
Pender Lake	6.4	22.3	0.22 (5 m)		Weak Stratification	4.2	Yellow
Portage Lake	18	20.7	0.15		Weak Stratification	3.5	Orange
Second Lake	3.3	20.1	7.06		Yes	3.1	Yellow/Orange
Silver Lake	12	20.8	0.09	No		3.3	Brown
Star Lake	24	19.6	0.05	No		3.1	Red/brown
Sucker Lake	18	20.8	0.06 (16 m)	No		3.1	Yellow/Green
Sugar Lake	16	20.4	0.09	No		2.5	Orange
Ten Mile Lake	8.8	24.2	0.03 (6 m)	Yes*		2.5	Brown
Third Lake	9.2	20.1	0.02	Yes		3.9	Red/brown
Tub Lake	2.6	23.4	0.11 (1 m)		Yes	1.7	Red/brown
Tucker Lake	5.3	22.7	0.05		Weak Stratification	2.8	Red
Turtle Lake	13	21	0.04	No		3	Yellow
Upper Fry Lake	11	22.5	0.07 (7 m)		Weak Stratification	1.4	Red/brown

[1]depth in brackets is provided where DO was measured at a depth greater than 1-m off bottom; [2]mean hypolimnetic dissolved oxygen concentration <0.1 mg/L; [3]Weak Stratification refers to lakes that have a thermocline (>1°C change/1 m depth) that extends to the lake bottom.

*dissolved oxygen profile is suspect.

The water of 33 lakes was noted as being tea-stained, “yellow”, “orange” or ‘brown’ with relatively shallow Secchi depths indicating that they likely have high DOC concentrations (Table 4). These lakes should be identified in revisions to the model to explain possible error in the model predictions associated with organically-bound phosphorus.

Several of the lakes displayed low oxygen concentrations (<0.1 mg/L) within 1 m of the lake bottom, but only 4 of the lakes (Faris, Horseshoe II, Ten Mile and Third lakes) were considered to potentially develop anoxic (no oxygen) hypolimnia as mean dissolved oxygen concentrations in the bottom waters of these lakes was <0.1 mg/L in 2014. Dissolved oxygen concentration in the hypolimnion of lakes can continue to decline until fall overturn and so anoxia and internal phosphorus loading potentially occurs in these lakes. Potential internal phosphorus loading in these lakes should be considered in future revisions of the model.

3. Summary and Recommendations

- A total of 74 of 128 lakes (58%) in Seguin Township have measured spring total phosphorus concentration data, of these 71 lakes have a minimum of 3 years of data as of the end of the 2014 sampling season.
- August monitoring of dissolved oxygen, temperature, lake depth and Secchi depth has been completed for 68 lakes. These data have been useful to flag shallow lakes, high DOC lakes and lakes that potentially undergo anoxia for refinement of the model that is scheduled for 2014.
- We recommend that the monitoring program continue, as developed, with review and refinement if necessary pending results of the model update. The list of monitoring lakes ('A' Lakes) is provided in Table 5.
- If additional resources are available, we recommend monitoring lakes with no existing data and we will work with the Township to identify suitable lakes. Additional lakes that could be monitored are included in Table 6 ('B' Lakes).
- Due to the complex lake shape and bathymetry of Horseshoe Lake, we recommend that spring total phosphorus sampling should be conducted at 3 locations in the lake as was done in 2013 and 2014 to support multi-basin modeling of the lake.
- A large percentage of the Seguin Township monitoring lakes potentially have high dissolved organic carbon concentrations that could result in error in model predictions. If additional time or funding is available, we recommend that a subset of lakes be sampled for dissolved organic carbon. HESL will work with Seguin Township to select the most appropriate lakes for additional sampling if this is possible.
- There may be additional phosphorus data from LPP which could be used for the update of the model. These data should be reviewed for quality and included in the long term monitoring data set as appropriate.

Table 5. Seguin Township Lake Monitoring List

'A' Lakes	
Even Years (2016, 2018…)	**Odd Years (2015, 2017…)**
Baby Lake	Armishaw Lake
Blue Lake	Back Lake
Brennan Lake	Black Water Lake
Capton Lake	Clear Lake
Cosh Lake	Dyson Lake
Diamond Lake	First Lake
Draper Lake	Forget Lake
Fair Lake	Horseshoe Lake
Faris Lake	Isabella Lake
Flaxman Lake	Joselin (Burnt) Lake
Gilbank Lake	Kight Lake
Haines Lake	Lieback Lake
Kingshott Lake	Linger Long (Napken) Lake
Lane Lake	Little Lake Joe
Little Otter Lake	Little Seguin/Duck Lake
Little Whitefish Lake	Martin Lake
Long Lake	Mirror Lake
Long Lake 1	Neville Lake
Lower Fry Lake	Oastler Lake
Manitouwaba Lake	Otter Lake
Maple Lake	Portage Lake
McDonald Lake	Rankin Lake
McGowan Lake	Roberts Lake
McKechine Lake	Salmon Lake
McLean Lake	Star Lake
McNutt Lake	Storm Lake
Murdock Lake	Sucker Lake
Mutton Lake	Sugar Lake
Pender Lake	Three-Legged Lake
Scime Lake	Trout Lake
Scott Lake	Tucker Lake
Second Lake	Turtle Lake
Ten Mile Lake	Virtue Lake
Third Lake	Whitefish Lake
Tiffin Lake/Silver	Windfall Lake
Tub Lake	
Upper Fry Lake	
Yarrow Lake	

Table 6. Seguin Township Monitoring Program Lakes ('A' Lakes) and Additional Lakes ('B' Lakes)

2009 Model Lake No.	Lake Name	Watershed Code	Upstream Lakes	'A' Lakes	'B' Lakes
87	5	S3	0		x
26	1	GB (end)	0		x
95	10/Good Lake	S6	0		x
27	2	GB (end)	28		x
1	3	B (end)	7		x
100	4	LJ	0		x
88	6/Vinett Lake	S3	92		x
89	7	S3	0		x
126	8	OT	0		x
127	9	OT	0		x
54	Aikman Lake	MC	56		x
101	Anselmi Lake	LJ (end)	0		x
102	Armishaw Lake	LJ (end)	0	x	
61	Baby Lake	S1	0	x	
49	Back Lake	H	0	x	
28	Bennett Lake	GB	0		x
97	Black Water Lake	S8	0	x	
2	Blue Lake	B	0	x	
15	Brennan Lake	BS	25	x	
103	Brush Lake	LJ (end)	0		x
104	Burr Lake	LJ	113		x
50	Capton Lake	H	0	x	
62	Carruthers Lake	S1	0		x
105	Carter Lake	LJ (end)	0		x
29	Catfish Lake	GB (end)	0		x
63	Clear Lake	S1	61	x	
30	Clear Lake 1	GB (end)	0		x
106	Clubbe Lake	LJ (end)	0		x
51	Cochrane Lake	H	0		x
64	Cosh Lake	S1	0	x	
65	Dainty Lake	S1	0		x
44	Dell Lake	H	0		x
66	Diamond Lake	S1	0	x	

2009 Model Lake No.	Lake Name	Watershed Code	Upstream Lakes	'A' Lakes	'B' Lakes
107	Dick Lake	LJ (end)	0		x
108	Draper Lake	LJ (end)	0	x	
109	Dyson Lake	LJ (end)	0	x	
110	Fair Lake	LJ (end)	0	x	
67	Faris Lake	S1	0	x	
16	First Lake	BS	18	x	
17	Flaxman Lake	BS	22	x	
31	Forget Lake	GB (end)	0	x	
90	Fume Lake	S3	87,88,91		x
111	Gerow Lake	LJ (end)	0		x
68	Gilbank Lake	S1	72b,83	x	
42	Haines Lake	H (end)	47,48	x	
112	Hamer Lake	LJ	0		x
32	Heaslip Lake	GB (end)	0		x
33	Hines Lake	GB (end)	40		x
45	Home Lake	H	43		x
55	Hooton Lake	MC	0		x
84	Horn Lake	S2	0		x
18	Horseshoe Lake (includes Virtue Lake)	BS	17,19	x	
113	Hurst Lake	LJ	0		x
60	Isabella Lake	S (end)	70,85,90,93,94,95, 96,97,98	x	
91	Jelso Lake	S3	0		x
34	Joselin (Burnt) Lake	GB (end)	37	x	
52	Kight Lake	H	0	x	
35	Kingshott Lake	GB	0	x	
114	Krapek Lake	LJ to Portage	0		x
43	Lane Lake	H	0	x	
69	Lieback Lake	S1	0	x	
3	Linger Long Lake/Napken	B	0	x	
19	Lioness Lake	BS	15		x
56	Lipscombe Lake	MC	58		x
98	Little Manitouwaga Lake	S9	99		x

2009 Model Lake No.	Lake Name	Watershed Code	Upstream Lakes	'A' Lakes	'B' Lakes
70	Little Seguin/Duck Lake	S1	66,73	x	
71	Little Whitefish	S1	63	x	
53	Long Lake	H	0	x	
72	Long Lake 1	S1	0	x	
115	Loucks Lake	LJ (end)	0		x
4	Lovell Lake	B	0		x
85	Lower Fry Lake	S2	86	x	
99	Manitouwaba Lake	S9	0	x	
73	Maple Lake	S1	74,78,81	x	
74	Martin Lake	S1	62,65,67,75,76,77	x	
116	McCan Lake	LJ (end)	0		x
75	McCauley Lake	S1	0		x
57	McCoy Lake	MC (end)	54,59		x
5	McDonald Lake	B	3,6	x	
36	McGowan Lake	GB	0	x	
46	McGruther Lake	H	0		x
37	McKechine Lake	GB	0	x	
76	McLean Lake	S1	0	x	
47	McNutt Lake	H	49,50,51,52,53	x	
117	McTaggart Lake	LJ	112,121,124		x
118	Mirror Lake	LJ (end)	0	x	
77	Mohan Lake	S1	69		x
119	Motley Lake	LJ	104		x
6	Murdock Lake	B	0	x	
78	Mutton Lake	S1	80	x	
48	Neville Lake	H	44,45,46	x	
38	Oak Lake	GB (end)	0		x
7	Oastler Lake	B	4,5,8	x	
39	One Island Lake	GB (end)	0		x
8	Otter Lake	B	2,9,10,11,12,13,14	x	
40	Payne Lake	GB	0		x
20	Pender Lake	BS	0	x	
120	Pickering Lake	LJ (end)	0		x
79	Ponsford Lake	S1	0		x

2009 Model Lake No.	Lake Name	Watershed Code	Upstream Lakes	'A' Lakes	'B' Lakes
128	Portage Lake	LJ (end)	0	x	
9	Rankin Lake	B	0	x	
41	Richmond Lake	GB (end)	36		x
121	Roberts Lake	LJ	0	x	
10	Salmon Lake	B	0	x	
96	Santa Lake	S7	0		x
11	Scime Lake	B	0	x	
12	Scott Lake	B	0	x	
21	Second Lake	BS	16,24	x	
13	Sovereign Lake	B	0		x
22	Spectacle Lake	BS	0		x
80	Star Lake	S1	79,82	x	
94	Storm Lake	S5	0	x	
122	Sucker Lake	LJ (end)	125	x	
81	Sugar Lake	S1	0	x	
58	Tarver Lake	MC	0		x
92	Ten Mile Lake	S3	89	x	
23	Third Lake	BS (end)	21	x	
59	Three-Legged Lake	MC	55	x	
123	Tiffin/Silver Lake	LJ (end)	117	x	
72.5	Trout Lake	S1	72	x	
93	Tub Lake	S4	0	x	
124	Tucker Lake	LJ	0	x	
82	Turtle	S1	68	x	
86	Upper Fry Lake	S2	84	x	
125	Watson Lake	LJ	119		x
83	Whitefish Lake	S1	71,64	x	
24	Windfall Lake	BS	0	x	
14	Wright Lake	B	0		x
25	Yarrow Lake	BS	20	x	

TKR, KH