Hutchinson
Environmental Sciences Ltd.

Lakeshore Capacity Assessment for Twin (Hammond), Fairy (Frere), Pike, and Bartle Lakes

Prepared for: J.L. Richards and Associates Limited
Job #: 210147

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Final Report

Signatures

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Executive Summary

Hutchinson Environmental Science Ltd. (HESL) was retained by J.L. Richards and Associates Limited (JLR) on behalf of the Township of Hudson to determine the shoreline development capacity of Upper and Lower Twin, Fairy, Bartle, and Pike Lakes (“Hudson Lakes”). The study is based on the Province of Ontario’s Lakeshore Capacity Assessment of nutrient status which can be used to set development thresholds. The study also includes water quality characterization, an assessment of recreational capacity, and a review of Best Management Practices (BMPs) and minimum development standards for shoreline development. The Township of Hudson Official Plan is currently being updated by JLR and the results and recommendations of this study will inform the policy updates to ensure that existing and future development minimizes impacts to the Hudson Lakes.

Fairy, Upper Twin, and Bartle Lakes have significant shoreline development, whereas the shoreline of Pike Lake is largely undeveloped, and there is no development on Lower Twin Lake. The lakeshore development capacity of all lakes was assessed based on phosphorus concentrations and recreational density. Based on Lakeshore Capacity Model (LCM) predictions of phosphorus concentrations, there is no development capacity on Bartle, Fairy, or Upper Twin Lakes. On Lower Twin Lake there is capacity for 16 permanent residences. On Pike Lake there is capacity for 22 permanent residences, in addition to development of the existing vacant lots.

Based on a definition of recreational carrying capacity that has previously been used in municipal planning (Township of Seguin 2015), there is remaining development capacity on Pike Lake (92 residences) and Lower Twin Lake (39 residences); Bartle, Fairy, and Upper Twin Lakes have already exceeded the recommended maximum density of 1 residence per 1.6 ha of offshore lake area. A final consideration relevant to development capacity is the long-term stability of the water quality of each lake. A significant increasing trend in total phosphorus (TP) concentration was detected in both Upper and Lower Twin Lakes.

Based on measured and modelled phosphorus concentrations and recreational density, new lot creation is not recommended along the shorelines of Bartle, Fairy, and Upper Twin Lakes (Table 7). All lines of evidence suggest that there is development capacity on Pike Lake; however, it should be noted that sediment resuspension from motorboat wakes could contribute to water quality issues in this very shallow lake. There is capacity for additional development and recreation on Lower Twin Lake; however, the increasing trend in phosphorus concentration is of some concern.

We recommend the following actions based on our understanding of water quality conditions in the Hudson Lakes, LCM predictions and current development practices:

1. Complete focused studies on Fairy Lake, Upper and Lower Twin Lakes to better determine the cause of elevated nutrients and cyanobacteria growth (Fairy Lake) and the increasing trend in phosphorus concentrations (Upper and Lower Twin Lakes).

2. Continue water quality monitoring through the MECP’s LPP. Spring (TP_{SO}) samples should be collected as soon as possible following ice off (i.e., in May). Consistency in the location and seasonal timing of sampling is important for establishing/augmenting a time series that is adequate for trend analysis.

3. Document existing sewage treatment systems and ensure that they meet the standards prescribed in the OBC. Replace any dysfunctional septic systems with systems that meet OBC requirements.

Consider implementing a septic system maintenance bylaw where septic tanks (that are apart of a tile field system) are pumped out once every five years.

4. Develop OP policies and enforcement mechanisms for shoreline development that mitigate impacts to adjacent waterbodies. Policies should include minimum development standards, including minimum lot size, lot frontage and setbacks, as well as BMPs such as shoreline buffers and proper sewage treatment system design and maintenance.
5. Encourage existing residents to establish/augment naturally vegetated shoreline buffers through public awareness, stewardship, and, if necessary, enforcement.
6. Prohibit new lot creation on Bartle, Fairy, and Upper Twin Lakes.
7. Allow additional development on Lower Twin and Pike Lakes, in accordance with the capacity models completed herein, but ensure that additional development proceeds in accordance with minimum development standards and BMPs that are developed and included in the updated Official Plans and are designed to minimize any negative impacts on water quality.
8. Examine TP trends in Upper and Lower Twin Lakes every year once LPP data are available and utilize the information to update development recommendations on Lower Twin Lake.
9. Ensure that any development on existing vacant lots of record is completed in accordance with minimum development standards and BMPs that are developed and included in the updated Official Plans and are designed to minimize any negative effects on water quality.
10. Update the LCMs every five years with current water quality and development data and incorporate any revised provincial guidance into model predictions of lakeshore capacity.

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Acronyms

BMPs – Best Management Practices

HESL – Hutchinson Environmental Sciences Ltd.

HLA – Hudson Lakes Association

JLR – J.L. Richards & Associates Limited

LCM – Lakeshore Capacity Model

MOE – Ministry of Environment

MPAC – Municipal Property Assessment Corporation

OP – Official Plan

OWIT – Ontario Watershed Information Tool

PWQO – Provincial Water Quality Objective

TP – Total Phosphorus

TP_{so} – Total Phosphorus measured at Spring Overturn

1. Introduction

Hutchinson Environmental Science Ltd. (HESL) was retained by J.L. Richards and Associates Limited (JLR) on behalf of the Township of Hudson to determine the shoreline development capacity of Upper and Lower Twin, Fairy, Bartle, and Pike Lakes ("Hudson Lakes").

The study is based on the Province of Ontario's Lakeshore Capacity Assessment of nutrient status which can be used to set development thresholds. The study also includes water quality characterization, an assessment of recreational capacity, and a review of Best Management Practices (BMPs) and minimum development standards for shoreline development. The Province of Ontario recommends the use of their Lakeshore Capacity Model (LCM) to determine the interim Provincial Water Quality Objective (PWQO) for phosphorus and the amount of shoreline development that can occur to maintain phosphorus levels below the PWQO of Background + 50% (Ministry of Environment (MOE), 2010). The LCM is a steady-state mass balance model that estimates hydrologic and phosphorus loading from natural (watershed runoff and atmospheric deposition) and human (septic systems and land disturbance) sources and links them, while considering lake dynamics, to predict total phosphorus (TP) concentrations in lakes.

This Lakeshore Capacity Assessment was completed to determine whether the Hudson Lakes are currently over thresholds for additional development and to quantify the number of lots that can be developed within any remaining capacity. Water quality data was collected to inform the Lakeshore Capacity Assessment, characterize water quality conditions in the lakes, and to help inform planning and policy development. The Township of Hudson OP is currently being updated by JLR and the results and recommendations of this study will inform OP updates to ensure that existing and future development minimizes impacts to the Hudson Lakes so that the lakes can continue to support recreational opportunities and aquatic biota in the future.

2. Site Description

The study lakes are located on the Hammond Lake Esker, in the Township of Hudson, in northern Ontario near the Quebec border, approximately 12 km west of Temiskaming Shores. Popular fishing lakes, they contain bass (*Micropterus spp.*), walleye (*Sander vitreus*), northern pike (*Esox lucius*), yellow perch (*Perca flavescens*), and brook trout (*Salvelinus fontinalis*), among other species. The surrounding landscape is predominantly forested, with a quarry and some cleared land between Fairy and Pike Lakes, and the Frog's Breath Golf Course between Upper Twin and Fairy Lakes.

Fairy Lake is small (surface area = 20 ha) but moderately deep (maximum depth (Zmax) = 14 m)[1]. This lake has a small catchment and no major surface water inputs via tributaries. The shoreline of Fairy Lake is largely developed, with the exception of approximately 300 m of the southern shore. Fairy Lake is connected to Upper Twin Lake by a culvert.

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[1] *Lake areas were determined based on satellite imagery using QGIS. Depths were determined during HESL's field survey.*

Upper Twin Lake is 111 ha in area and fairly deep (~24 m) with moderate shoreline development density. Lower Twin Lake (82 ha) is much shallower (~10 m) and has no documented[2] shoreline development. The Twin Lakes drain into Pike Lake via Pike Creek.

Pike Lake is very shallow (mean depth (Zavg) = 1.2 m; Zmax = 3.0 m) relative to its surface area of 199 ha. The shoreline is largely undeveloped, with the exception of the northeast shore, off of Pike Lake Road.

Bartle Lake is small (26 ha) but of moderate depth (Zmax = 12 m). Approximately half the shoreline is developed, with most residences on the upper part of the lake. Bartle Lake is hydrologically isolated from the other lakes until the confluence of its outflow and Pike Creek, approximately 1 km downstream of Pike Lake.

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[2] *According to the Municipal Property Assessment Corporation (MPAC) there is no shoreline development on Lower Twin Lake; however, satellite imagery shows a single building on the west side of the narrows (47.5035 -79.8780).*

Figure 1. Study lakes and HESL and Lake Partner Program (LPP) sampling locations.

3. Methodology

3.1 Background Review

An online survey was prepared using ArcGIS Survey123 in order to obtain information related to shoreline residency, septic systems, shoreline buffers, and other factors related to shoreline development and the mitigation of its effects on water quality. The survey was distributed to residents of the Hudson Lakes through the Hudson Lakes Association (HLA); 36 residents responded.

The historical water quality (Secchi depth and TP) data collected via the Ministry of Environmental Conservation and Parks' (MECP) Lake Partner Program (LPP) were summarized for each lake and analyzed for temporal trends using simple linear regression. Data from the various sites on each lake (Figure 1) were pooled for analysis.

3.2 Water Quality Field Survey

HESL sampled the Hudson Lakes on 24 August 2022. A single site was sampled on each lake; the deepest part of each lake was targeted based on available bathymetric mapping. Samples were collected from the water column (surface to Secchi depth) using a weighted bottle and from 1 m above the lakebed using a Kemmerer sampling device. The samples were analyzed by ALS Environmental for various standard water-quality parameters (nutrients, suspended solids, chlorophyll-a, bacteria, and dissolved organic carbon). Water temperature and dissolved oxygen were measured in the field using a YSI sonde; measurements were recorded at a 1-m interval from the surface to bottom of the water column.

3.3 Lakeshore Capacity Model Inputs

3.3.1 Lake Area and Watershed Information

Lake surface areas were determined by tracing imagery of the lakes using QGIS (v. 3.28.6-Firenze). Catchment areas and land cover types were determined using the MNRF's Ontario Watershed Information Tool (OWIT). Cleared areas evident in satellite imagery but not accounted for in the MNRF mapping were estimated by manual tracing. Similarly, the size of the golf course between Fairy and Upper Twin Lakes was manually determined based on satellite imagery as neither land cover dataset available through OWIT properly categorized this feature. For most of the catchments, the *Land Cover* and *Watershed Characteristics* tools of OWIT reported different wetland areas[3]; the average of the two values was used for each catchment. Due to the flat topography surrounding Bartle Lake and its lack of tributaries, its catchment could not be determined using OWIT. Based on the assumption that the majority of the catchment-based water loading is in the form of direct shoreline runoff and seepage (groundwater inflow), the catchment was estimated as the area within 100 m of the shoreline; this approximately corresponds to the area encircled by the shoreline roads for the developed part of the lake. The watershed information used as inputs for the LCM models are provided below (Table 1).

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[3] *The OWIT land cover data is sourced from the Provincial Land Cover 2000 dataset whereas the OWIT watershed characteristics data comes from the Ontario Basic Mapping program; the different wetland areas are due to different classifications of treed swamps (i.e., as wetland vs. forest).*

Table 1. Lake areas and catchment characteristics used as inputs to the Lakeshore Capacity Models.

Lake	Lake Area (ha)	Catchment Area (ha)	Golf Course (ha)	Wetlands (ha)	Cleared Land (ha)
Bartle	26	28	0	0	0
Fairy	20	168	12	0	2
Pike	199	837	0	28	66
Twin, Lower	82	514	0	52	0
Twin, Upper	111	481	8	14	18

3.3.2 Lot Counts

Shoreline development information (Table 2) was obtained from MPAC by JLR. The seasonal counts were apportioned between seasonal and extended seasonal based on the ratio of these occupancy types established via the resident survey conducted by JLR (i.e., approximately 2:1, based on responses from 35 residents).

Table 2. Lakeshore residency information used as inputs to the Lakeshore Capacity Models.

	Capita per residence for LCM*	Number of residences				
		Bartle	Fairy	Pike	Twin, Lower	Twin, Upper
Permanent	2.56	17	15	12	0	32
Extended Seasonal	1.27	3	5	1	0	28
Seasonal	0.69	6	11	2	0	58
Camp	0.37	0	1**	0	0	0
Total	–	26	32	15	0	118
Vacant Lots of Record	1.27	2	7	6	0	37

**as per Paterson et al. (2006). **The population of Camp Temiskaming was estimated as 30 people (campers + staff) based on inspection of photos available via the camp's website (https://www.camptemiskaming.com/gallery).*

3.3.3 Lake Phosphorus Concentrations

Average spring-overturn TP concentrations (TP_{SO}) were calculated based on all LPP TP data collected in May (Table 3); no samples were collected from any of the Hudson Lakes in April. The TP_{SO} data were used to assess the accuracy of LCM predictions for each lake.

Table 3. TP concentrations used as inputs to the Lakeshore Capacity Models.

Lake Name	TP_{SO} (μg/L)	Years of spring TP sampling	# samples
Bartle Lake	7.8	14	15
Fairy Lake	13.5	14	14
Pike Lake	11.7	5	10
Twin Lake, Lower	7.83	17	31
Twin Lake, Upper	7.51	17	23

3.3.4 Phosphorus and Water Loading

The phosphorus loading to each lake was calculated as the sum of natural and anthropogenic inputs, estimated using the standard LCM coefficients (Paterson et al. 2006). The TP loading to each lake comprised direct atmospheric deposition (16.7 mg/m^2/y), watershed runoff (5.5 mg/m^2/y; as recommended where wetlands < 3.5% and cleared lands < 15%), lot runoff (0.04 kg/lot/y), and shoreline septic system inputs (0.66 kg/capita/y; see Table 2 for assumed occupancies).

Water loading was calculated based on watershed area (exclusive of lake area) and the mean annual runoff estimate for each lake obtained from the MECP's provincial runoff database.

The model for Upper Twin Lake included upstream water and phosphorus loading from Fairy Lake. The model for Pike Lake included upstream water and phosphorus loading from Upper Twin and Lower Twin Lakes.

3.3.5 Soil Retention Coefficient

The soil retention coefficient was selected based on the geology of the study area and a scientific understanding of phosphorus attenuation. Decades of research has consistently shown that septic system phosphorus is immobilized in Precambrian Shield soils. Mechanistic evidence (Stumm and Morgan 1970; Jenkins et al. 1971; Isenbeck-Schroter et al. 1993) and direct observations (Willman et al. 1981; Zanini et al., 1998; Robertson et al. 1998; Robertson 2003) show strong adsorption of phosphate on charged soil surfaces and mineralization of phosphate with iron and aluminum. Mineralization reactions appear to be favoured in acidic and mineral-rich groundwater in Precambrian Shield settings (Robertson et al. 1998; Robertson 2003), such as those surrounding the Hudson Lakes, typically resulting in over 90% immobilization of septic-system phosphorus. The mineralization reactions appear to be permanent (Isenbeck-Schroter et al. 1993) and many studies conclude that most septic phosphorus is stable within 0.5–1 m of the tile drains in a septic field (Robertson et al. 1998; Robertson 2003; Robertson 2012). A recent review (Robertson et al. 2019) reported an average phosphorus attenuation of 97% between the septic tank and lake in non-calcareous soils.

The soils of the Hudson Lakes region are non-calcareous. According to the Ontario Soil Survey, the bedrock geology of the area is igneous and metamorphic rocks; the soil parent material is characterized as outwash (glaciofluvial deposition), with the soils developed on outwash materials that are "noncalcareous and [consisting] predominantly of sand" (Hoffman et al. *undated*). Based on mapping provided by the Ontario Geological Survey, the quaternary geology of the Hudson Lakes catchments comprises bedrock, glaciofluvial outwash deposits, and glaciofluvial ice-contact deposits (Figure 2). The bedrock is undifferentiated igneous and metamorphic rock, exposed at the surface or covered by a discontinuous, thin layer of drift (soil). The glaciofluvial outwash deposits are gravel and sand, including proglacial river and deltaic deposits. The glaciofluvial ice-contact deposits are gravel, sand, and minor till, including esker, kame, end moraine, ice-marginal delta, and subaqueous fan deposits.

In addition to catchment geology, LCM predictive accuracy was considered in determining the soil retention coefficient; preliminary model runs assuming no phosphorus retention by soil, as recommended by the MECP in the absence of site-specific soils data (MOE 2010), resulted in unacceptably low predictive accuracy of the models for all the Hudson Lakes (i.e., absolute error >> 20%).

The final models for all lakes included a soil phosphorus-retention coefficient of 80%. This value reflects good phosphorus retention based on the following soil characteristics:

a) The soil chemistry of the region. Geological mapping identifies soils as non-calcareous, meaning the soils have low total calcium and are acidic. Mapping identifies that mineral soils were glaciofluvial outwash, the parent material of which was derived from native bedrock (igneous and metamorphic rock) which has high concentrations of total iron and aluminum. The Lakeshore Capacity Assessment Handbook recommends soil with <1% calcium and >1% iron + aluminum to attenuate septic-related phosphorus in basins of at-capacity lakes; and,

b) Within glaciofluvial gravel and sand deposits, water percolation rates to achieve a 20 cm drop in water level, will be between 1 and 15 minutes (HESL 2019; 2022a; 2023a), as required by Ontario Regulation 244/09 for septic effluent treatment within septic leaching fields. Where glacio-fluvial ice-contact deposits occur, finer grains will be present (e.g., silt and clay) which may decrease 20 cm drop percolation rates beyond what is acceptable by Ontario Regulation 244/09 (HESL 2022b; 2022c; 2022d); where thin soil is present over bedrock, soil infiltration capacity will also be decreased. In both cases however, treatment of septic-related phosphorus will still occur within soil based on its favourable chemistry, even in the absence of septic leaching fields built to the requirements of the Ontario Building Code.

Based on the soil conditions and phosphorus geochemistry, the retention co-efficient is realistic and conservative, being much lower than the 97% attenuation reported by Robertson et al. (2019). Furthermore, the retention coefficient of 80% yielded very good model fit for the Hudson Lakes (avg. absolute error of 0.4 µg/L or 4%) indicating accurate application.

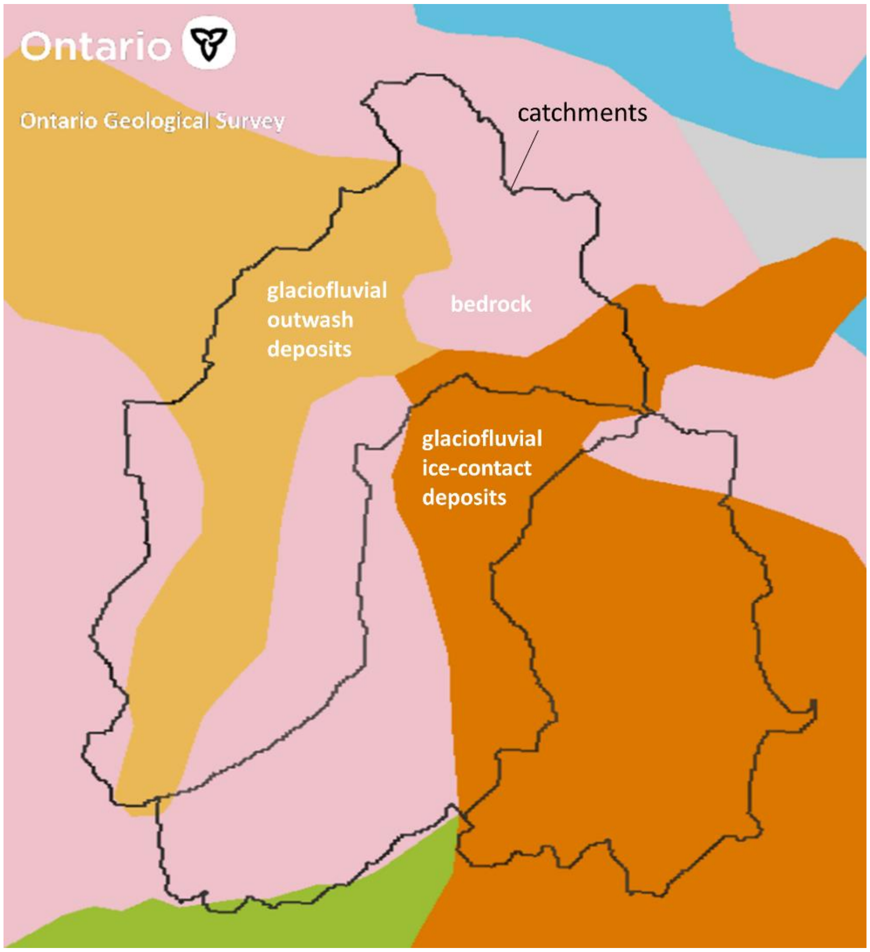


Figure 2. Quaternary geology of the Hudson Lakes area.

3.3.6 Phosphorus Sedimentation Rate

The lakes with anoxic hypolimnia (Bartle, Fairy, and Twin Lakes; see Figure 5) were modeled with a sedimentation coefficient (settling velocity) of 7.2 m/y, as per the LCM guidance. Pike Lake was assigned a settling velocity of 1.0 m/y due to its shallow depth and relatively large surface area; this type of lake morphometry is generally associated with a high degree of wind-driven sediment resuspension, consistent with a low annual net particle sedimentation rate.

3.4 Recreational Carrying Capacity

The offshore area of each lake, defined as the area >30 m from shore, was determined using QGIS. The recreational carrying capacity of each lake was then determined based on the offshore area and the criterion for maximum recreational density adopted by the Township of Seguin for lake management (i.e., 1 residential unit per 1.6 ha; Township of Seguin 2015). The existing recreational density for each lake was calculated based on offshore area and shoreline residency information (Table 2).

4. Results

4.1 Water Quality Conditions

The water quality of the Hudson Lakes is generally good but varies by lake and temporally within each lake. Historically, Pike Lake has generally had lower clarity (Secchi depth usually <2 m) and higher TP concentrations (usually >10 µg/L) than the other lakes (Figure 3), likely due to relatively high dissolved organic carbon (DOC) concentrations (Table 4) and the lake's shallow depth (max of ~3 m). Secchi depth (clarity) has been moderate in the other lakes (~3–5 m) and TP concentrations are usually low (<10 µg/L), indicative of oligotrophic conditions, with the occasional elevated concentration. For instance, the TP of Fairy Lake was 86 µg/L when assessed by HESL on 24 August 2022 (Table 4) but historically has consistently been below 20 µg/L (Figure 3). Ammonia, total suspended solids (TSS), and chlorophyll-*a* concentrations were also elevated in Fairly Lake in August 2022 (Table 4), suggesting that this lake can be highly productive at times, despite the relatively low TP concentrations recorded via LPP monitoring since 1991. Blue-green algal blooms have been observed previously in Fairy Lake (Timiskaming Health Unit 2023). Ammonia concentrations were relatively low in the other lakes, and *E. coli* bacteria and nitrate concentrations were very low in all lakes on 24 August 2022. TP concentrations of samples collected 1 m above the lakebed ("1 mob") were much higher than surface concentrations in Bartle Lake and Upper Twin Lake, possibly suggestive of a flux of phosphorus from the sediments (i.e., "internal phosphorus loading") in these lakes. TP was elevated 1 mob in Fairy Lake but somewhat lower than the highly elevated TP of the surface layer, likely reflecting entrainment of internally loaded phosphorus into the mixed layer of this lake.

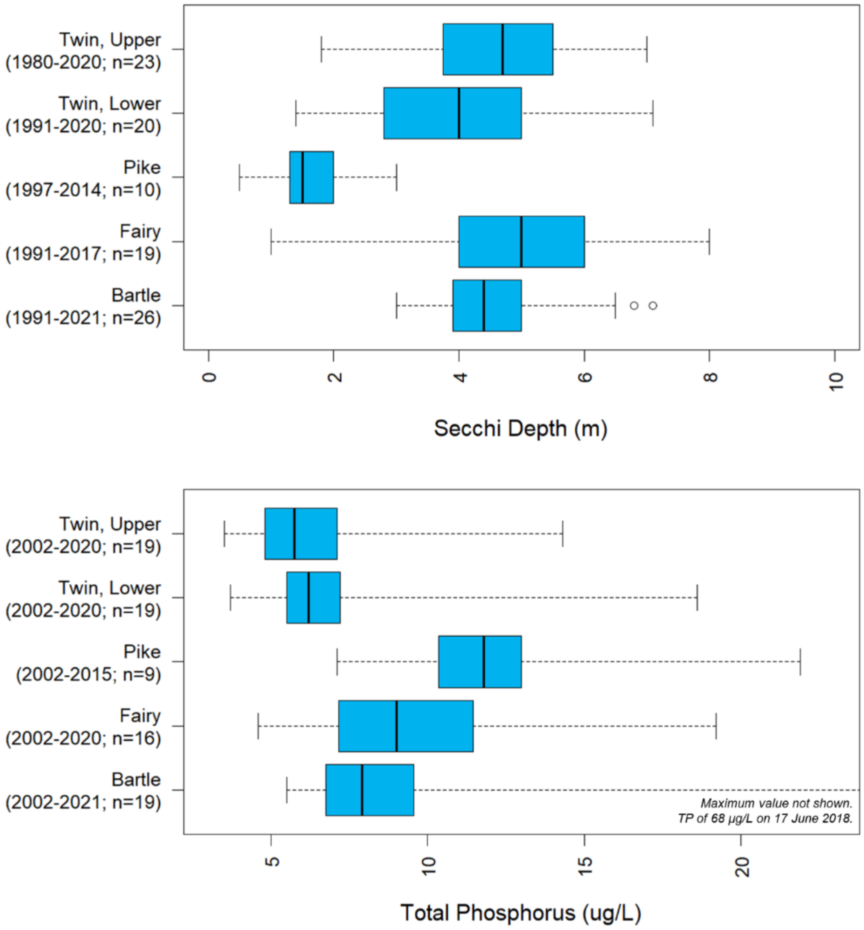
With the exception of shallow Pike Lake, the lakes were strongly stratified at the time of the HESL survey, with epilimnia (surface mixed layers) approximately 4–5 m deep and hypolimnia (bottom layers) depleted in oxygen; complete anoxia was observed directly above the lakebed in all lakes except for (unstratified) Pike Lake (Figure 5), consistent with the elevated TP concentrations observed 1 mob in Bartle, Fairy, and Upper Twin Lakes, and suggesting that internal loading may also occur at times in Lower Twin. The dissolved oxygen concentration was above 100% saturation in the metalimnion (middle layer) of Fairy Lake (data not shown), suggestive of a high rate of primary production, and consistent with the high nutrient and chlorophyll-a concentrations observed in this lake (Table 4).

Median spring (May) TP concentrations have been relatively stable in Bartle Lake, whereas TP has increased in Upper Twin Lake (+0.38 mg/L/y; $R^2 = 0.50$; $p < 0.01$) and Lower Twin Lake (+0.22 mg/L/y; $R^2 = 0.34$; $p = 0.01$); no statistically significant trends were detected for Pike or Fairy Lakes, but spring TP data availability for these lakes is limited (Figure 4). The trends (average annual rates of increase) correspond to total increases in TP of approximately 3 mg/L and 6 mg/L for Lower and Upper Twin, respectively, for a 15-year period; this represents relative increases between 2005 and 2020 of approximately 50% for Lower Twin and 90% for Upper Twin. While the increasing trends are noteworthy, the length of the available datasets are relatively modest and the increasing trend observed during this period does not necessarily entail future increases in the spring TP of these lakes (i.e., it is invalid to extrapolate beyond the available period of record).

Table 4. Water quality of the Hudson Lakes, as assessed by HESL on 24 August 2022.

	Bartle Lake	Fairy Lake	Pike Lake	Twin, Lower	Twin, Upper
Ammonia, Total (mg-N/L)	0.02	1.25	0.03	0.21	<0.005
*Ammonia, Un-ionized (µg-N/L)	0.2	91.9	2.6	6.7	<0.3
Chlorophyll-*a* (µg/L)	13.1	33.6	1.6	1.9	5.1
Dissolved Organic Carbon (mg/L)	4.5	4.4	9.2	9.5	4.7
Escherichia coli (CFU/100 mL)	0	0	0	2	0
Nitrate (mg-N/L)	<0.02	<0.02	<0.02	<0.02	<0.02
Phosphorus, Total (µg/L)	12.2	86.3	8.6	12.5	9.5
[1 mob]	[62.3]	[74.6]	[–]	[9.3]	[42.6]
Secchi Depth (m)	4.9	5.5	2.8	2.6	5.6
Suspended Solids, Total (mg/L)	<3	7	<3	<3	<3

**Un-ionized ammonia was calculated based on the average pH and temperature for the top 3 m of the water column.*



Maximum value not shown.
TP of 68 µg/L on 17 June 2018.

Figure 3. Secchi depths and TP concentrations determined via LPP monitoring.

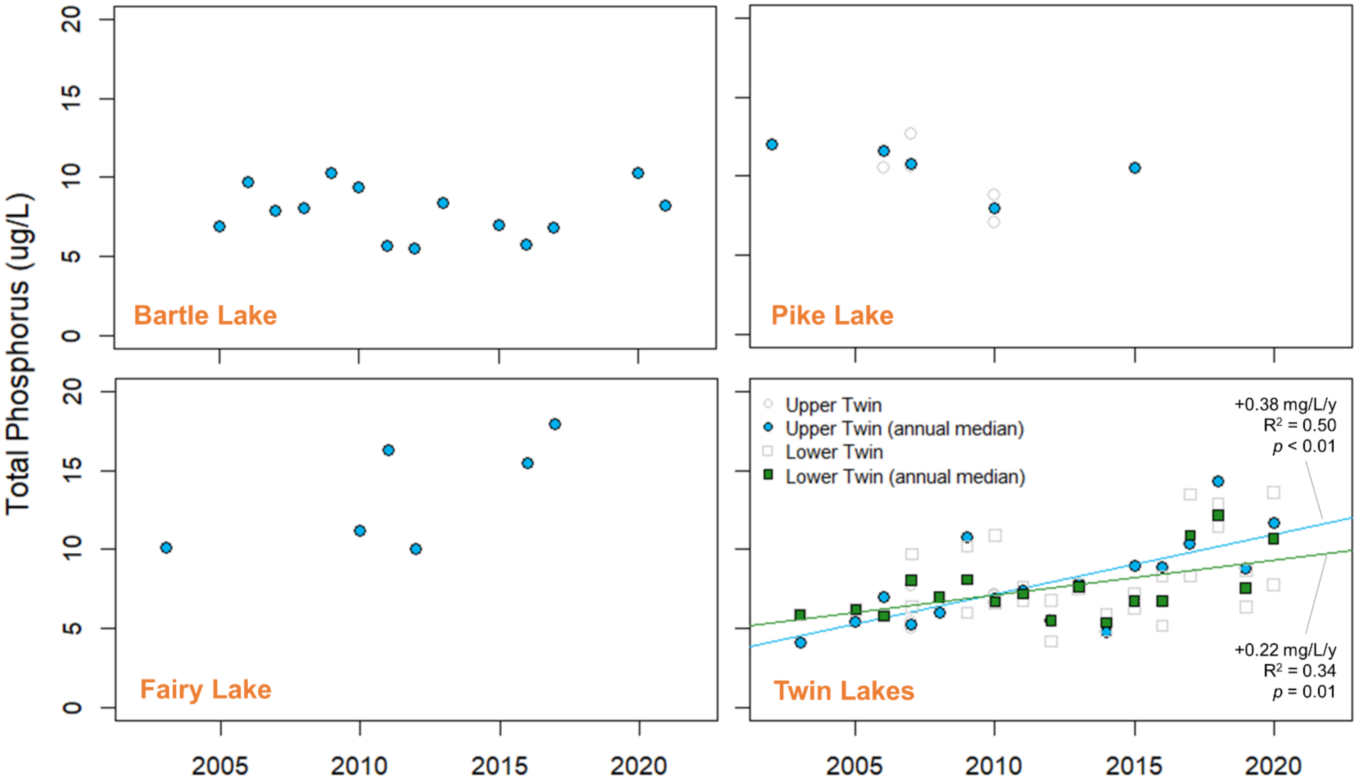


Figure 4. Time series of spring (May) TP concentrations in the Hudson Lakes based on LPP monitoring.

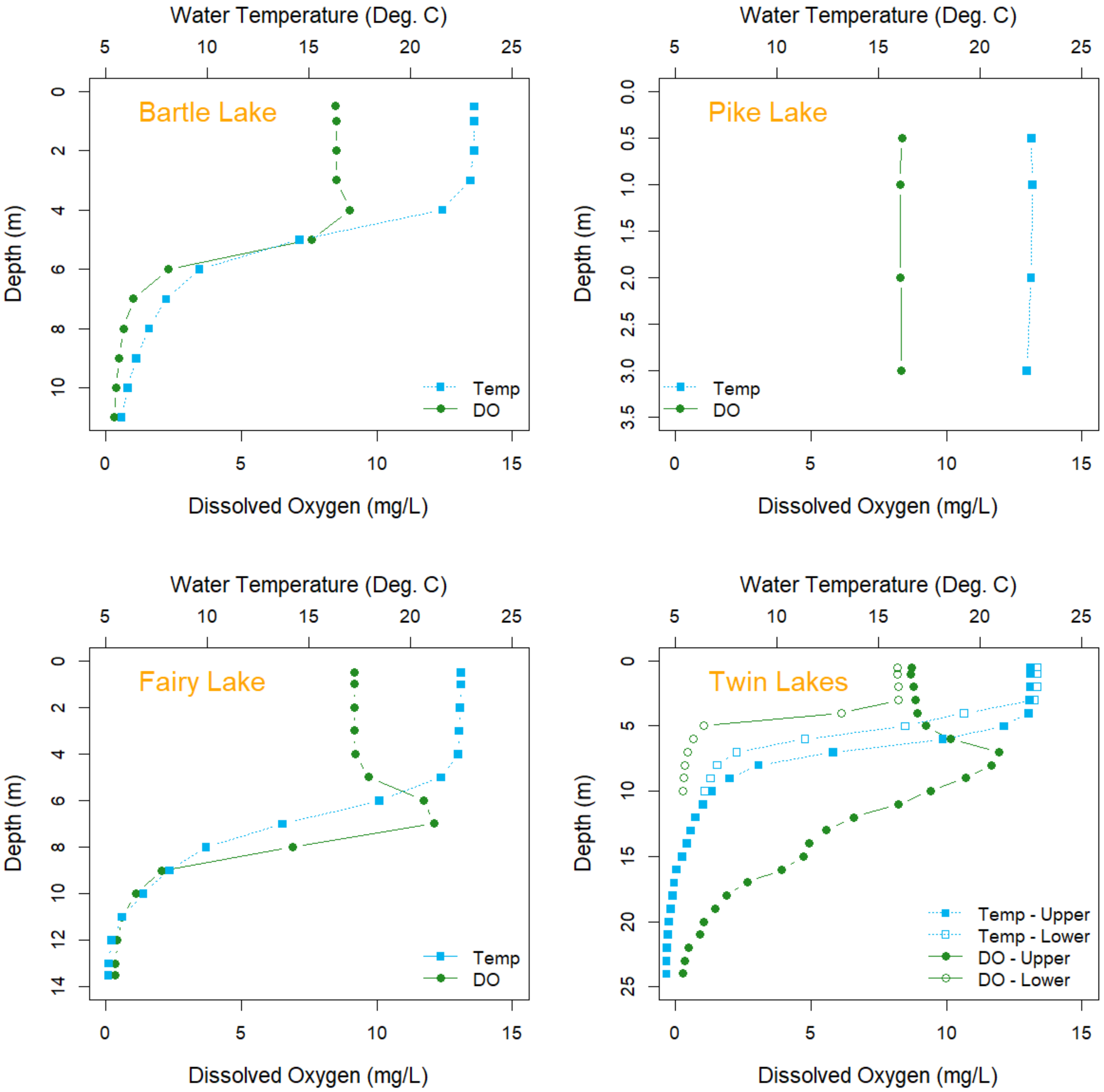


Figure 5. Vertical profiles of temperature and oxygen measured by HESL on 24 August 2022.

4.2 Lakeshore Development

4.2.1 Resident Survey

Of the 36 respondents to the online survey, 50% identified as permanent residents, 33% as summer-only residents, 14% said they occupied their residence "in summer and occasionally winter", and 3% (1 respondent) answered "regularly throughout the year". A single respondent reported having a composting toilet, with the majority (35/36) on septic systems. When asked to approximate the distance between the shoreline and the closest portion of their septic system[4], 58% said 30 m or greater, 11% said between 25–29 m, and 31% said between 15–24 m. When asked how recently septic systems had been "maintained/pumped", 64% said within the last 5 years, 11% said between 5–9 years, and 25% said it had been 10 years or longer[5]. Septic system age was reported to be largely between 10–29 years (69%), with 14% less than 10 years old, 8% aged 30 years or older, and 8% of unknown age[6]. When asked to characterize their waterfront, most chose "sandy beach" (83%) and/or "natural vegetation" (72%), with "wetland", "grass", and/or "hardened (concrete, wood retaining wall)" selected for only a few properties (6–8%); respondents were asked to select all types that applied (hence the percentages tallying to more than 100%). The distance between properties and the water was most commonly reported to be 10–20 m (44%), followed by 20–30 m (36%), then >30 m (14%), and lastly <10 m (6%). When asked what restrictions prevented the establishment of a vegetative buffer between their property and the water, the majority of those surveyed (61%) skipped the question, 30% indicated that no restriction(s) exist, and the remainder indicated either accessory buildings (6%) or a paved driveway (3%).

In summary, the survey indicates the following:

- half the respondents are year-round residents;
- almost all respondent properties are on a septic system;
- all respondent septic systems are located at least 15 m from shore;
- most respondent's septic systems are 10–29 years old and most have been pumped/serviced in the last 5 years;
- most respondent properties are 10–30 m from shore, with only two less than 10 m from shore;
- most respondent shorelines have been described as beach and/or natural vegetation;
- few respondents indicated any impediment to the establishment of a vegetative buffer zone.

It should be noted that the number of survey respondents (36) is only ~18% of the total number of lakeshore residents and that the data from those willing to participate in the voluntary survey may not be representative of all lakeshore residences.

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[4] *A distance of 20 m was assumed for the following responses: "the required amount according to Health Unit inspection plus some" and "more than the minimum".*

[5] *The response "scheduled for this summer" was assumed to represent a time of 10 years or greater.*

[6] *There were only 35 respondents for this question (1 skipped the question). Since one of the respondents provided answers for two septic systems, the total number of answers was 36.*

4.2.1 Shoreline Observations

Visual observations made by HESL from the lake (via boat) and air (via drone) are generally consistent with the information obtained through the online resident survey (Section 4.2.1). HESL noted several properties on each lake with minimal or absent vegetative buffer zones; one example from each lake is provided in Photographs 1–4.

Photographs 1–4. Examples of properties with inadequate shoreline vegetative buffer zones on each of the Hudson Lakes.

4.2.1 Modelled Development Capacity

Based on comparison of predicted future TP concentrations (TP_{Future}) with the lake-specific PWQOs of 150% of background concentrations, there is no development capacity on Bartle, Fairy, or Upper Twin Lakes, capacity for 22 additional permanent residences on Pike Lake, and capacity for 16 additional permanent residences on Lower Twin Lake (Table 5). This development capacity is in addition to development of existing vacant lots of record (assuming conversion to extended seasonal use). The LCM predictions of TP_{SO} were within 20% of the measured values for all lakes, which is an acceptable level of accuracy (MOE 2010). Additional considerations, beyond LCM predictions of TP and comparison to lake-specific TP PWQOs, are discussed in the following section.

Table 5. Observed and predicted phosphorus concentrations (µg/L) and associated development capacity of the Hudson Lakes.

Lake	Obs. TP_{SO}	Pred. TP_{SO}	Error (%)	PWQO (Bkgd. +50%)	Development Capacity* Permanent / Ext-Seas. / Seasonal
Bartle	7.78	7.56	-2.8	4.44	*over capacity*
Fairy	13.5	12.88	-4.6	8.59	*over capacity*
Pike	11.65	11.80	1.3	14.86	22 / 43 / 78
Twin, Lower	7.83	7.93	1.3	10.96	16 / 33 / 60
Twin, Upper	7.51	8.15	8.6	6.87	*over capacity*

**Refers to total development capacity, expressed as either permanent, extended seasonal, or seasonal dwellings (i.e., the total development capacity for each lake is not the sum of the values for the 3 residency types).*

4.3 Recreational Capacity

Pike Lake has recreational capacity for 92 residences. Lower Twin Lake has recreational capacity for 39 residences. Development on Fairy, Pike, and Upper Twin Lakes exceeds recreational carrying capacity (Table 6). This assessment was based on a definition of recreational carrying capacity (see Section 3.4) that has been used elsewhere in Ontario as part of municipal planning (Township of Seguin 2015).

Table 6. Recreational carrying capacity of the Hudson Lakes.

Lake	Lake Area (ha)		Residences (#)	Recreational Carrying Capacity (#)	Remaining Recreational Capacity (#)
	Total	>30-m offshore			
Bartle	25.7	18.0	26	11	*over capacity*
Fairy	19.8	15.1	32	9	*over capacity*
Pike	198.9	171.4	15	107	92
Twin, Lower	82.0	62.9	0	39	39
Twin, Upper	110.7	77.9	118	49	*over capacity*

5. Discussion

5.1 Water Quality Conditions

Bartle and Twin Lakes are oligotrophic, Fairy Lake is oligo-mesotrophic, and Pike Lake is mesotrophic, as categorized based on long-term monitoring of phosphorus concentrations. However, the phosphorus and chlorophyll concentrations observed in August 2022 suggest that there is likely significant seasonality in the water quality conditions of the Hudson Lakes, particularly in Fairy Lake, where phosphorus was markedly elevated relative to the long-term record, chlorophyll-a was quite high (indicative of eutrophic rather than oligo-mesotrophic conditions), and ammonia was well above the PWQO. Internal (sediment) loading is a common cause of seasonality in nutrient and phytoplankton concentrations.

Although still relatively low, spring phosphorus concentrations have been increasing in the Twin Lakes, which is cause for concern. Pike Lake spring phosphorus concentrations have historically been higher than those of the other lakes, despite its limited shoreline development; this is likely due to Pike Lake's higher DOC concentration and shallow depth, the latter attribute generally being associated with a high degree of sediment resuspension. *E. coli* concentrations were negligible in all lakes when assessed in August 2022, suggesting that there are no major issues with fecal contamination, and nitrate was below detection in all lakes, consistent with the lack of agricultural activity in the area.

Bartle, Fairy, and the Twin Lakes are dimictic, exhibiting vertical density stratification in the summer. In these lakes, the upper layer of the water column (epilimnion) is separated from the bottom layer (hypolimnion) by a thermal gradient (thermocline/metalimnion). In all the dimictic lakes, the hypolimnion was depleted of oxygen at the time of the August 2022 survey, which suggests that anoxia-driven internal phosphorus loading may occur in these lakes and is consistent with the elevated hypolimnetic ("off-bottom") phosphorus concentrations in Bartle and Upper Twin. The internally loaded phosphorus may have already been incorporated into the epilimnion in Fairy Lake at the time of sampling and could explain the lake's highly elevated epilimnetic phosphorus and chlorophyll concentrations, as noted above.

5.2 Lakeshore Capacity

Fairy, Upper Twin, and Bartle Lakes have significant shoreline development, whereas the shoreline of Pike Lake is largely undeveloped, and there is no development on Lower Twin Lake (according to MPAC). The lakeshore development capacity of all lakes was assessed based on phosphorus concentrations and recreational density.

Based on LCM predictions of phosphorus concentrations, there is no development capacity on Bartle, Fairy, or Upper Twin Lakes. On Lower Twin Lake there is capacity for 16 permanent (or 33 extended seasonal or 60 seasonal) residences. On Pike Lake there is capacity for 22 permanent (or 43 extended seasonal or 78 seasonal) residences, in addition to development of the existing vacant lots (assuming extended seasonal occupancy).

Based on a definition of recreational carrying capacity that has previously been used in municipal planning (Township of Seguin 2015), there is remaining development capacity on Pike Lake (92 residences) and

Lower Twin Lake (39 residences); Bartle, Fairy, and Upper Twin Lakes have already exceeded the recommended maximum density of 1 residence per 1.6 ha of offshore lake area.

A final consideration relevant to development capacity is the long-term stability of the water quality of each lake. A significant increasing trend in TP concentration was detected in both Upper and Lower Twin Lakes. Spring (May) TP data availability for Pike and Fairy Lakes was low, with the last May LPP sampling in 2015 and 2017, respectively; it is recommended that LPP sampling of all lakes be conducted, at a minimum, annually in May at a representative (central, deep) site.

Based on measured and modelled phosphorus concentrations and recreational density, new lot creation is not recommended along the shorelines of Bartle, Fairy, and Upper Twin Lakes (Table 7). All lines of evidence suggest that there is development capacity on Pike Lake; however, it should be noted that sediment resuspension from motorboat wakes could contribute to water quality issues in this very shallow lake. There is capacity for additional development and recreation on Lower Twin Lake; however, the increasing trend in phosphorus concentration is of some concern.

Table 7. Summary of lakeshore capacity assessments and spring TP trends for the Hudson Lakes.

Lake	**LCM**	**Recreational**	**Trend in TP_{SO}**	**Indication of Development Capacity**
Bartle	*over capacity*	*over capacity*	no trend	*No*
Fairy	*over capacity*	*over capacity*	no trend*	*No*
Pike	capacity	capacity	no trend*	Yes[1]
Twin, Lower	capacity	capacity	*increasing trend*	Yes[2]
Twin, Upper	*over capacity*	*over capacity*	*increasing trend*	*No*

**May TP data availability is considered low for the purpose of trend analysis.*

[1] *Increasing trend in phosphorus is of concern.*

[2] *The shallow nature of Pike Lake limits recreational opportunities.*

5.3 Mitigation Tools

For lakes with developed shorelines, the implementation of BMPs and certain minimum development standards can help to maintain or improve water quality.

5.3.1 Best Management Practices

Following lake management BMPs can be described as “no regrets” measures – following these guidelines related to shoreline buffers and sewage treatment (septic) systems helps to reduce external contaminant loading to waterbodies at relatively low cost and no risk of unintended consequences.

5.3.1.1 Shoreline Buffers

A shoreline buffer is an area along the shoreline of a developed lot that is naturally vegetated or re-vegetated. Shoreline buffers are a well-studied mitigation measure associated with waterfront development.

Buffers provide wildlife habitat, a visual screen, and filter sediment and other pollutants and absorb nutrients from runoff, thereby helping to mitigate impacts of stormwater (Zhang et al., 2010; Beacon Environmental, 2012). Vegetative buffers mitigate social density by screening the view of the shoreline from the lake and providing a buffer for view and noise between lots to help maintain a wilderness perspective. Shoreline vegetative buffers can also provide riparian protection and habitat for songbirds and wildlife. Zhang et al. (2010) found that buffer width can explain 35–60% of variance in removal efficacy for sediment, pesticides, nitrogen and phosphorus. Most studies demonstrate that buffers from 9–30 m provide more effective attenuation than smaller buffers and 30-m buffers provide effective water quality protective functions (Dillaha et al. 1985; Dillaha et al.1986; Dillaha 1989; Magette et al. 1986; Environmental Law Institute 2008; Wenger 1999).

The scientific literature demonstrates that a 30 m buffer generally provides a range of ecological services, and this buffer size is commonly recommended in the peer-reviewed literature focused on shoreline development, aligning with Provincial guidance (HESL 2021). While smaller buffers provide some benefits for water quality and aquatic habitat protection, larger buffers provide more ecological services, more completely. Buffers will likely become more important in protecting lake health as climate change effects on freshwater systems continue to intensify.

5.3.1.2 Sewage Treatment Systems

Sewage effluent from sewage treatment systems can negatively impact adjacent waterbodies through transmission of nutrients and bacteria. A quarter of the respondents to the JLR survey said it had been 10 years or longer since their septic systems had been pumped out/maintained. Septic system age was reported to be largely between 10–29 years (69%), with 14% less than 10 years old, 8% aged 30 years or older, and 8% of unknown age. Sewage treatment systems should be assessed, and dysfunctional systems should be brought up to OBC standards.

5.3.2 Minimum Development Standards

The minimum development standards utilized by 14 jurisdictions across North America, many of which are progressive in terms of lake management, are presented in Table 8 (HESL 2014). The most relevant minimum development standards related to shoreline development are building and septic setbacks, lot size and lot frontage. Increased building and septic setbacks maximize the ecological benefits associated with shoreline buffers discussed in Section 5.3.1.1, while increased lot sizes and frontages reduces the amount of built form and the related development pressure on lakes. Minimum development standards should be developed for the Hudson Lakes that are conservative and are protective of natural heritage features such as water quality.

Table 8. Minimum Development Standards of 14 Jurisdictions (HESL 2014).

Jurisdiction	Building Setback (m)	Septic Setback (m)	Lot Size (ha)	Lot Frontage (m)
Elliot Lake	20	–	0.4	45
Kenora - Black Sturgeon Lake	20	–	0.8	61 (122 for restricted development area)
Muskoka	20	30	–	60 (increased frontages to a maximum of 120 m may be required adjacent to narrow waterways)
Muskoka Lakes	20	30	–	60 (may be increased due to natural constraints)
Seguin	20[a]	–	1 (1.2 for island lots)	90 (120 for island lots)
Lake Simcoe Protection Plan	15 (Town of Innisfil)	–	–	–
Rideau Valley CA	30 – 90[b]	–	–	60 (Rideau Lakes)
Cariboo	7.6	35	–	46
Maine	23 – 76[c]	30	0.19	61
New Hampshire	–	23 – 38[d]	–	46
Minnesota	23 – 46[e]	–	0.19 – 0.74[e]	30 – 61[e]
Wisconsin	23	–	0.19	30

[a] May be increased to address water quality, wetland, fish habitat or other similar issues. [b] With greater setback dependant on biophysical site criteria [c] Depending on shoreland zone classification. [d] Depending on percolation rate of soil. [e] Depending on lake classification. Dashes indicate that the standard was not provided in the documentation reviewed; the Ontario Building Code requirement is 15 m.

6. Recommendations

We recommend the following actions based on our understanding of water quality conditions in the Hudson Lakes, LCM predictions and current development practices:

1. Complete focused studies on Fairy Lake, Upper and Lower Twin Lakes to better determine the cause of elevated nutrients and cyanobacteria growth (Fairy Lake) and the increasing trend in phosphorus concentrations (Upper and Lower Twin Lakes).

2. Continue water quality monitoring through the MECP's LPP. Spring (TP_{SO}) samples should be collected as soon as possible following ice off (i.e., in May). Consistency in the location and seasonal timing of sampling is important for establishing/augmenting a time series that is adequate for trend analysis.

3. Document existing sewage treatment systems and ensure that they meet the standards prescribed in the OBC. Replace any dysfunctional septic systems with systems that meet OBC requirements. Consider implementing a septic system maintenance bylaw where septic tanks (that are apart of a tile field system) are pumped out once every five years.

4. Develop OP policies and enforcement mechanisms for shoreline development that mitigate impacts to adjacent waterbodies. Policies should include minimum development standards, including minimum lot size, lot frontage and setbacks, as well as BMPs such as shoreline buffers and proper sewage treatment system design and maintenance.

5. Encourage existing residents to establish/augment naturally vegetated shoreline buffers through public awareness, stewardship, and, if necessary, enforcement.

6. Prohibit new lot creation on Bartle, Fairy, and Upper Twin Lakes.

7. Allow additional development on Lower Twin and Pike Lakes, in accordance with the capacity models completed herein, but ensure that additional development proceeds in accordance with minimum development standards and BMPs that are developed and included in the updated Official Plans and are designed to minimize any negative impacts on water quality.

8. Examine TP trends in Upper and Lower Twin Lakes every year once LPP data are available and utilize the information to update development recommendations on Lower Twin Lake.

9. Ensure that any development on existing vacant lots of record is completed in accordance with minimum development standards and BMPs that are developed and included in the updated Official Plans and are designed to minimize any negative effects on water quality.

10. Update the LCMs every five years with current water quality and development data and incorporate any revised provincial guidance into model predictions of lakeshore capacity.

7. References

Beacon Environmental, 2012: Ecological buffer guidelines review. Prepared for Credit Valley Conservation.

Dillaha, T.A. 1989: Water quality impacts of vegetative filter strips. ASAE Paper No. 89-2043.

Dillaha, T.A., Sherrard, J.H. and D. Lee. 1986: Long-term effectiveness and maintenance of vegetative filter strips. Virginia Water Resources Research Center, Bulletin 151.

Dillaha, T.A., Sherrard, J.H., Lee, D., Mostaghimi, S. and V.O. Shanholtz. 1985: Long-term effectiveness and sediment and Environmental Law Institute 2008

Environmental Law Institute. 2008: Planner's Guide to Wetland Buffers for Local Governments, ISBN 978-1-58576-137-1, ELI Project No.0627-01, 25 pp.

Hoffman, D.W., Wicklund, R.E., Richards, N.R. [undated] Soil Survey of New Liskeard-Englehart Area, Timiskaming District, Ontario. Report No. 21 of the Ontario Soil Survey. Experimental Farms Service, Canada Department of Agriculture and the Ontario Agricultural College.

Hutchinson Environmental Sciences Limited (HESL) 2014. Review and Analysis of Existing Approaches for Managing Shoreline Development on Inland Lakes. Prepared for Ontario Ministry of Environment.

Hutchinson Environmental Sciences Limited (HESL) 2021. Natural Shorelines and their Role in the Protection of Water Quality and Aquatic Habitat – State of the Science Report. Prepared for the County of Haliburton.

Hutchinson Environmental Sciences Limited (HESL) 2019. Procedure D-5-3, D-5-4, D-5-5 and Land Use Change Assessments, Munroe Lake Recreational Cottage Lots Draft Plan of Subdivision. March 12, 2019.

Hutchinson Environmental Sciences Limited (HESL) 2022a. Lakeshore Capacity Assessment for Bay Lake. March 25, 2022.

Hutchinson Environmental Sciences Limited (HESL) 2022b. 90 Swords Road, Lorimer Lake, Site-Specific Septic Assessment. June 23, 2022.

Hutchinson Environmental Sciences Limited (HESL) 2022c. 14 Viking Trail, Trout Lake, McDougall Township, Site-Specific Septic Suitability Assessment. July 7, 2022.

Hutchinson Environmental Sciences Limited (HESL) 2022d. 50 Lori Lea Trail, Lorimer Lake, Site-Specific Septic Assessment. September 9, 2022.

Hutchinson Environmental Sciences Limited (HESL) 2023. Charlotte Lake, County of Renfrew, Site-Specific Septic Suitability Assessment. June 20, 2023.

Isenbeck-Schroter, M., U. Doring, A. Moller, J. Schroter and G. Matthe. 1993. Experimental approach and simulation of the retention processes limiting orthophosphate transport in groundwater. J. Contam. Hydrol. 14: 143–161.

Jenkins, D., Ferguson, J.F., and A.B. Menar. 1971. Chemical processes for phosphate removal. Water Research 5: 369–389.

Magette, W. L, R. B. Brinsfield, R. E. Palmer and J. D. Wood. 1986. Vegetative filter strips for non-point pollution control: nutrient considerations. ASAE Paper No. 86-2024.

Ministry of Environment. 2010. Lakeshore Capacity Assessment Handbook – Protecting Water Quality in Inland Lakes on Ontario's Precambrian Shield. PIBS 7642e, Queen's Printer for Ontario.

Ontario Regulation 244/09: Sewage Systems. Under the Environmental Protection Act. June 23, 2009.

Paterson, A.M., Dillon, P.J., Hutchinson, N.J., Futter, M.N., Clark, B.J., Mills, R.B., Reid, R.A., and Scheider, W.A. 2009. A Review of the Components, Coefficients and Technical Assumptions of Ontario's Lakeshore Capacity Model. Lake and Reservoir Management, 22:1, 7-18.

Robertson, W.D., Schiff, S.L. and C.J. Ptacek. 1998. Review of phosphate mobility and persistence in 10 septic system plumes. Ground Water, 36: 1000–1010.

Robertson, W.D., 2003. Enhanced attenuation of septic system phosphate in noncalcareous sediments. Groundwater, 41: 48–56.

Robertson, W.D. 2012. Phosphorus Retention in a 20-Year-Old Septic System Filter Bed. Journal of Environmental Quality 41: 1437–1444.

Robertson, W.D., Van Stempvoort, D.R., and Schiff, S.L. 2019. Review of phosphorus attenuation in groundwater plumes from 24 septic systems. Science of the Total Environment, 692: 640–652.

Stumm and Morgan, 1970. Aquatic Chemistry – An Introduction Emphasizing Chemical Equilibria in Natural Waters. Wiley Interscience, New York, 583 pp.

Timiskaming Health Unit. 2023. Blue-Green Algae Bloom. timiskaminghu.com/351/blue-green-algae-bloom. Accessed September 7, 2023.

The Plantario Group Ltd. 1993. Zoning By-Law. Township of Hudson.

Township of Seguin. 2015. Township of Seguin Official Plan.

Wenger, S. 1999: A Review of the Scientific Literature on Riparian Buffer Width, Extent and Vegetation. Office of Public Service and Outreach, Institute of Ecology, University of Georgia.

Willman, B.P., G.W. Petersen and D.D. Frinton. 1981. Renovation of septic tank effluent in sand-clay mixtures. Journal of Environmental Quality 10: 439–444.

Zanini, K., Robertson, W.D., Ptacek, C.J., Schiff, S.L., and T. Mayer. 1998. Phosphorus Characterization in Sediments Impacted by Septic Effluent at Four Sites in Central Canada. Journal of Contaminant Hydrology, 33: 405–429.

Zhang, X., X. Liu, M. Zhang, M., R. A. Dahlgren and M. Eitzel. 2010: A review of vegetated buffers and a meta-analysis of their mitigation efficacy in reducing nonpoint source pollution. Journal of Environmental Quality, Vol. 39, pp. 76-84.

Zurawsky, M.A., W.D. Robertson, C.J. Ptacek and S.L. Schiff. 2004: Geochemical stability of phosphorus solids below septic system infiltration beds. J. Contaminant Hydrology 73: 129-143.

Appendix A. Lakeshore Capacity Model

Lakeshore Capacity Model

Bartle Lake

Anthropogenic Supply

Shoreline Development Type	Number	sage (capita years/yr)	
Permanent	17	2.56	
Extended Seasonal	3	1.27	
Seasonal	6	0.69	
Resort	0	1.18	
Trailer Parks	0	0.69	
Youth Camps	0	0.125	kg/capita/yr
Campgrounds/Tent trailers/RV parks	0	0.37	
Vacant Lots of Record	0	1.27	

Retention by soil (Rs) (0-1)	0.8	

Catchment

Upstream Lakes

Lake Area (Ao)	25.7	ha
Catchment Area (Ad)	28.0	ha
Wetland	0.0	%
Cleared	0.0	%

Hydrological Flow

Mean annual runoff	0.391	m/yr
Lake outflow discharge (Q)	209967	m3/yr
Areal water loading rate (qs)	0.82	m/yr
Inflow 1		m3/yr
Inflow 2		m3/yr
Inflow 3		m3/yr

Natural Loading

Atmospheric Load	4.29	kg/yr
Runoff Load	1.54	kg/yr

Upstream Loading

Background Upstream Load 1		kg/yr
Background Upstream Load 2		kg/yr
Background Upstream Load 3		kg/yr
Current Total Upstream Load 1		kg/yr
Current Total Upstream Load 2		kg/yr
Current Total Upstream Load 3		kg/yr
Future Upstream Load 1		kg/yr
Future Upstream Load 2		kg/yr
Future Upstream Load 3		kg/yr

Anthropogenic Loading

Current Anthropogenic Load	7.83	kg/yr
Future Anthropogenic Load	7.83	kg/yr

Areal Load Rate

Current Total Areal Loading Rate (L_T)	53.17	mg/m2/yr
Future Total Areal Loading Rate (L_{FT})	53.17	mg/m2/yr

Sedimentation

Is the lake anoxic?	y	
Settling velocity (v)	7.2	m/yr
In lake retention (Rp)	0.90	

Monitoring Data

Years of spring TP data	14	
Average Measured TPso	7.78	µg/L
Measured vs. Predicted TPso	-2.8	%
Is the model applicable?	y	
Over or under predicted?	under	

Modeling Results

TPlake	6.94	µg/L
TPout	6.63	µg/L
TPso	7.56	µg/L
TPfuture	6.94	µg/L

Phosphorus Thresholds

TPbk	2.96	µg/L
TPbk+40	4.15	µg/L
TPbk+50	4.44	µg/L
TPbk+60	4.74	µg/L

*if TPbk+40% < TPlake < TPbk+60% cell is orange

*if TPlake > TPbk+60% cell is red

No. of allowable residences to reach capacity:

# Permanent OR	at capacity
# Extended seasonal OR	at capacity
# Seasonal cottages OR	at capacity

Loads

Natural Load w/no developme	5.83	kg/yr
Background + 50% Load	8.75	kg/yr
Current Load	13.67	kg/yr
Future Load	13.67	kg/yr

Outflow Loads

Background Outflow Load	0.59	kg/yr
Current Outflow Load	1.39	kg/yr
Future Outflow Load	1.39	kg/yr

Lakeshore Capacity Model

Frere (Fairy) Lake

Anthropogenic Supply

Shoreline Development Type	Number	Usage (capita years/yr)	
Permanent	15	2.56	
Extended Seasonal	5	1.27	
Seasonal	11	0.69	
Resort	0	1.18	
Trailer Parks	0	0.69	
Youth Camps	30	0.125	kg/capita/yr
Campgrounds/Tent trailers/RV parks	0	0.37	
Vacant Lots of Record	7	1.27	
Retention by soil (Rs) (0-1)	0.8		

Catchment

Lake Area (Ao)	19.8	ha	
Catchment Area (Ad)	168.2	ha	156.7 (adj't for golf course)
Wetland	0.0	%	
Cleared	1.2	%	
Golf Course Area	11.5	ha	

Hydrological Flow

Mean annual runoff	0.400	m/yr
Lake outflow discharge (Q)	752000	m3/yr
Areal water loading rate (qs)	3.80	m/yr
Inflow 1		m3/yr
Inflow 2		m3/yr
Inflow 3		m3/yr

Natural Loading

Atmospheric Load	3.31	kg/yr	
Runoff Load	8.62	kg/yr	* adjusted for golf course

Upstream Loading

Background Upstream Load 1		kg/yr
Background Upstream Load 2		kg/yr
Background Upstream Load 3		kg/yr
Current Total Upstream Load 1		kg/yr
Current Total Upstream Load 2		kg/yr
Current Total Upstream Load 3		kg/yr
Future Upstream Load 1		kg/yr
Future Upstream Load 2		kg/yr
Future Upstream Load 3		kg/yr

Anthropogenic Loading

Current Anthropogenic Load	13.51	kg/yr	* includes golf course load
Future Anthropogenic Load	14.96	kg/yr	* includes golf course load

Areal Load Rate

Current Total Areal Loading Rate (L_T)	128.45	mg/m2/yr	* includes golf course load
Future Total Areal Loading Rate (L_{FT})	135.80	mg/m2/yr	* includes golf course load

Golf Course:	1.61	kg/yr

Sedimentation

Is the lake anoxic?	y	
Settling velocity (v)	7.2	m/yr
In lake retention (Rp)	0.65	

Monitoring Data

Years of spring TP data	14	
Average Measured TPso	13.50	µg/L
Measured vs. Predicted TPso	-4.6	%
Is the model applicable?	y	
Over or under predicted?	under	

Modeling Results

TPlake	12.22	µg/L
TPout	11.68	µg/L
TPso	12.88	µg/L
TPfuture	12.92	µg/L

Phosphorus Thresholds

TPbk	5.73	µg/L
TPbk+40	8.02	µg/L
TPbk+50	8.59	µg/L
TPbk+60	9.17	µg/L

*if TPbk+40% < TPlake < TPbk+60% cell is orange
*if TPlake > TPbk+60% cell is red

No. of allowable residences to reach capacity:

# Permanent OR	at capacity
# Extended seasonal OR	at capacity
# Seasonal cottages OR	at capacity

Loads

Natural Load w/no developmer	11.93	kg/yr
Background + 50% Load	17.89	kg/yr
Current Load	25.43	kg/yr
Future Load	26.89	kg/yr

Outflow Loads

Background Outflow Load	4.12	kg/yr
Current Outflow Load	8.78	kg/yr
Future Outflow Load	9.29	kg/yr

Lakeshore Capacity Model Pike Lake

Anthropogenic Supply

Shoreline Development Type	Number	Usage (capita years/yr)	
Permanent	12	2.56	
Extended Seasonal	1	1.27	
Seasonal	2	0.69	
Resort	0	1.18	
Trailer Parks	0	0.69	
Youth Camps	0	0.125	kg/capita/yr
Campgrounds/Tent trailers/RV parks	0	0.37	
Vacant Lots of Record	6	1.27	

Retention by soil (Rs) (0-1)	0.8

Catchment

Lake Area (Ao)	198.9	ha
Catchment Area (Ad)	851.3	ha
Wetland	3.3	%
Cleared	7.7	%

Hydrological Flow

Mean annual runoff	0.395	m/yr	
Lake outflow discharge (Q)	9673236	m3/yr	
Areal water loading rate (qs)	4.86	m/yr	
Inflow 1	2394312	m3/yr	Upper Twin
Inflow 2	3130634	m3/yr	Lower Twin
Inflow 3		m3/yr	

Natural Loading

Atmospheric Load	33.22	kg/yr
Runoff Load	46.82	kg/yr

Upstream Loading

Background Upstream Load 1	16.73	kg/yr	Lower Twin
Background Upstream Load 2	13.72	kg/yr	Upper Twin
Background Upstream Load 3		kg/yr	
Current Total Upstream Load 1	16.73	kg/yr	Lower Twin
Current Total Upstream Load 2	22.53	kg/yr	Upper Twin
Current Total Upstream Load 3		kg/yr	
Future Upstream Load 1	16.73	kg/yr	Lower Twin
Future Upstream Load 2	24.84	kg/yr	Upper Twin
Future Upstream Load 3		kg/yr	

Anthropogenic Loading

Current Anthropogenic Load	5.00	kg/yr
Future Anthropogenic Load	6.25	kg/yr

Areal Load Rate

Current Total Areal Loading Rate (L_T)	62.49	mg/m2/yr
Future Total Areal Loading Rate (L_{FT})	64.28	mg/m2/yr

Sedimentation

Is the lake anoxic?	n	
Settling velocity (v)	1.0	m/yr
In lake retention (Rp)	0.17	

Monitoring Data

Years of spring TP data	5	
Average Measured TPso	11.65	µg/L
Measured vs. Predicted TPso	1.3	%
Is the model applicable?	y	
Over or under predicted?	over	

Modeling Results

TPlake	11.15	µg/L
TPout	10.66	µg/L
TPso	11.80	µg/L
TPfuture	11.47	µg/L

Phosphorus Thresholds

TPbk	9.91	µg/L
TPbk+40	13.87	µg/L
TPbk+50	14.86	µg/L
TPbk+60	15.86	µg/L

*if TPbk+40% < TPlake < TPbk+60% cell is orange

*if TPlake > TPbk+60% cell is red

No. of allowable residences to reach capacity:

# Permanent OR	22
# Extended seasonal OR	43
# Seasonal cottages OR	78

Loads

Natural Load w/no developme	110.48	kg/yr
Background + 50% Load	165.72	kg/yr
Current Load	124.30	kg/yr
Future Load	127.85	kg/yr

Outflow Loads

Background Outflow Load	91.64	kg/yr
Current Outflow Load	103.10	kg/yr
Future Outflow Load	106.05	kg/yr

Lakeshore Capacity Model Upper Twin

Anthropogenic Supply

Shoreline Development Type	Number	Usage (capita years/yr)	
Permanent	32	2.56	
Extended Seasonal	28	1.27	
Seasonal	58	0.69	
Resort	0	1.18	
Trailer Parks	0	0.69	
Youth Camps	0	0.125	kg/capita/yr
Campgrounds/Tent trailers/RV parks	0	0.37	
Vacant Lots of Record	37	1.27	

Retention by soil (Rs) (0-1) 0.8

Catchment

Lake Area (Ao)	110.7	ha	
Catchment Area (Ad)	481.0	ha	473.3 (adj't for golf course)
Wetland	3.0	%	
Cleared	3.8	%	
Golf Course Area	7.66	ha	

Hydrological Flow

Mean annual runoff	0.402	m/yr	
Lake outflow discharge (Q)	3130634	m3/yr	
Areal water loading rate (qs)	2.83	m/yr	
Inflow 1	752000	m3/yr	Frere (Fairy) Lake
Inflow 2		m3/yr	
Inflow 3		m3/yr	

Natural Loading

Atmospheric Load	18.49	kg/yr	
Runoff Load	26.03	kg/yr	* adjusted for golf course

Upstream Loading

Background Upstream Load 1	4.12	kg/yr	Frere (Fairy) Lake
Background Upstream Load 2		kg/yr	
Background Upstream Load 3		kg/yr	
Current Total Upstream Load 1	8.78	kg/yr	Frere (Fairy) Lake
Current Total Upstream Load 2		kg/yr	
Current Total Upstream Load 3		kg/yr	
Future Upstream Load 1	9.29	kg/yr	Frere (Fairy) Lake
Future Upstream Load 2		kg/yr	
Future Upstream Load 3		kg/yr	

Anthropogenic Loading

Current Anthropogenic Load	26.58	kg/yr	* includes golf course load
Future Anthropogenic Load	34.27	kg/yr	* includes golf course load

Areal Load Rate

Current Total Areal Loading Rate (L_T)	72.16	mg/m2/yr	* includes golf course load
Future Total Areal Loading Rate (L_{FT})	79.56	mg/m2/yr	* includes golf course load

Golf Course: 1.07 kg/yr

Sedimentation

Is the lake anoxic?	y	
Settling velocity (v)	7.2	m/yr
In lake retention (Rp)	0.72	

Monitoring Data

Years of spring TP data	17	
Average Measured TPso	7.51	µg/L
Measured vs. Predicted TPso	8.6	%
Is the model applicable?	y	
Over or under predicted?	over	

Modeling Results

TPlake	7.53	µg/L
TPout	7.20	µg/L
TPso	8.15	µg/L
TPfuture	8.30	µg/L

Phosphorus Thresholds

TPbk	4.58	µg/L
TPbk+40	6.42	µg/L
TPbk+50	6.87	µg/L
TPbk+60	7.33	µg/L

*if TPbk+40% < TPlake < TPbk+60% cell is orange

*if TPlake > TPbk+60% cell is red

No. of allowable residences to reach capacity:

# Permanent OR	at capacity
# Extended seasonal OR	at capacity
# Seasonal cottages OR	at capacity

Loads

Natural Load w/no developmer	48.64	kg/yr
Background + 50% Load	72.96	kg/yr
Current Load	79.89	kg/yr
Future Load	88.07	kg/yr

Outflow Loads

Background Outflow Load	13.72	kg/yr
Current Outflow Load	22.53	kg/yr
Future Outflow Load	24.84	kg/yr

Lakeshore Capacity Model Upper Twin

Anthropogenic Supply

Shoreline Development Type	Number	Usage (capita years/yr)	
Permanent	32	2.56	
Extended Seasonal	28	1.27	
Seasonal	58	0.69	
Resort	0	1.18	
Trailer Parks	0	0.69	
Youth Camps	0	0.125	kg/capita/yr
Campgrounds/Tent trailers/RV parks	0	0.37	
Vacant Lots of Record	37	1.27	
Retention by soil (Rs) (0-1)	0.8		

Catchment

Lake Area (Ao)	110.7	ha	
Catchment Area (Ad)	481.0	ha	473.3 (adj't for golf course)
Wetland	3.0	%	
Cleared	3.8	%	
Golf Course Area	7.66	ha	

Hydrological Flow

Mean annual runoff	0.402	m/yr	
Lake outflow discharge (Q)	3130634	m3/yr	
Areal water loading rate (qs)	2.83	m/yr	
Inflow 1	752000	m3/yr	Frere (Fairy) Lake
Inflow 2		m3/yr	
Inflow 3		m3/yr	

Natural Loading

Atmospheric Load	18.49	kg/yr	
Runoff Load	26.03	kg/yr	* adjusted for golf course

Upstream Loading

Background Upstream Load 1	4.12	kg/yr	Frere (Fairy) Lake
Background Upstream Load 2		kg/yr	
Background Upstream Load 3		kg/yr	
Current Total Upstream Load 1	8.78	kg/yr	Frere (Fairy) Lake
Current Total Upstream Load 2		kg/yr	
Current Total Upstream Load 3		kg/yr	
Future Upstream Load 1	9.29	kg/yr	Frere (Fairy) Lake
Future Upstream Load 2		kg/yr	
Future Upstream Load 3		kg/yr	

Anthropogenic Loading

Current Anthropogenic Load	26.58	kg/yr	* includes golf course load
Future Anthropogenic Load	34.27	kg/yr	* includes golf course load

Areal Load Rate

Current Total Areal Loading Rate (L_T)	72.16	mg/m2/yr	* includes golf course load
Future Total Areal Loading Rate (L_{FT})	79.56	mg/m2/yr	* includes golf course load

Golf Course:	1.07	kg/yr

Sedimentation

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