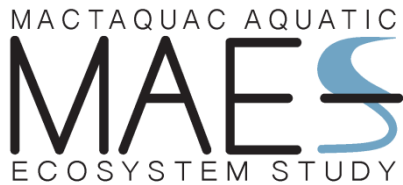


**Mactaquac Aquatic Ecosystem Study
Report Series 2019-073**



**METHODS PAPER:
Sampling Physical Limnology in the
Mactaquac Headpond**

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DISCLAIMER

Intended use and technical limitations of the report, “Sampling Physical Limnology in the Mactaquac Headpond”. This interim report describes the methodologies being developed to sample the physical limnology of the Mactaquac Headpond. CRI does not assume liability for any use of the included information and data outside the stated scope.

1. Introduction

The Mactaquac Aquatic Ecosystem Study (MAES) is a whole-river ecosystem study on the Saint John River (SJR). Annual and seasonal limnological surveys of the Mactaquac headpond (reservoir) were undertaken between 2014 and 2018 (excluding 2017) to establish a spatiotemporal understanding of the reservoir's physicochemical properties (*MAES Project 1B.1.6*). This report outlines the methods employed to assess the physical limnological characteristics of the reservoir over the study period.

2. Methods

Study Design

The limnological survey consists of fixed site vertical profiles (standard approach of Wetzel 2001). Vertical profiles were established for thirteen sites in the reservoir (Figure 1). Sites are located from immediately above the Mactaquac Generating Station (MGS) to the lotic environment upstream of the town of Nackawic. A site consisted of left, right, and center sampling points along cross-reservoir transects (Table 1) with the exception of three sites (HP2, HP8, and HP9) which are stand-alone single sampling points. At each sampling location the center site was determined as the center of the river channel. River left and river right (looking downstream) sampling locations at a site were defined as half way between the center channel point and the left or right shoreline.

Annual Site Selection

In 2014, vertical profiles were recorded at nine sites: HP1, HP4, HP5, HP6, HP7, HP8, HP10, HP11, HP12, and HP13. These sites were selected to represent the majority of flow conditions in the headpond. Each site consisted of three sample points (left, right, and center: see above), with the exception of HP8 where a single, central sampling point was established. At each sample point one vertical profile was recorded.

In 2015, profiles were recorded at eight sites, seven of which were taken from 2014 (HP1, HP4, HP7, HP8, HP11, HP12, HP13) and one of which was newly established (HP3). Profiles were collected at each point along all transects, except for HP8 and HP13 where only the central (deepest) points were sampled. During the fall of 2015, profiles were also collected at the center sampling points of HP1, HP4, and HP10 (which was not sampled in August).

In 2016, vertical profiles were recorded on a monthly basis (June-August, October) at four sites, each consisting of a single sampling point near the center of the transect. Two sites (HP4, HP5) had previously been surveyed while two (HP2, HP9) were newly selected in 2016.

In 2018, all sites, HP1-13, were sampled monthly (July-October) at the center sampling point as in 2016. However, where deeper sites were found along the original transect those points were also profiled and referred to as left (L), or right (R) of the center point (e.g., HP11L). Monthly sampling in 2018 typically occurred in the third week of the month, unless delayed due to weather.

Equipment

Across all years, profiles were collected using a YSI 6600 V2 sonde equipped with temperature, pressure, pH, dissolved oxygen (DO), and turbidity sensors. Between 2014 and August 2018 the sonde was fitted with either a YSI 6562 polarographic DO sensor or a YSI 6150 ROX optical DO sensor. Beginning in September 2018 the optical sensor was installed exclusively.

Dissolved oxygen sensors were calibrated using percent air saturation and operated with DO charge between 25-75 (polarographic sensor) or DO gain between 0.85-1.15 (optical sensor; YSI 2010). Sensor calibration for pH (three-point) was conducted in the laboratory prior to sampling, and sensor calibration for pressure (barometric pressure) was performed at each site. Site depth was estimated using a portable depth sounder (Speedtech Instruments), except for 2015 when a Lowrance HDS7 unit (Navico, Inc.) was used. After an equilibration period just below the surface for 1-2 minutes, the sonde was lowered to depth at a rate of 1 meter per minute. The sonde recorded sensor readings every 20s resulting in a resolution of three readings per meter. The sampling procedure was developed to limit the influence of flow and weather condition on sonde decent (e.g., not a straight vertical profile but extending downriver on a tangent). For example, crews prioritized collecting data on “good” weather days and assessed profile data on site to ensure site depth was consistent with previous visits. Weights could not be attached to the sonde cable to control the vertical descent and some horizontal movement is expected. Data scrubbing for erroneous values (surface and bottom) are described below.

Prior to profiling in August of 2018, the YSI 6562 DO sensor installed in the sonde began to fail its calibration (*i.e.*, produce out-of-range values after stabilizing). Rather than accept the out-of-range calibration, the calibration was aborted. Engaging DO charge (Dochrg) under Sonde Menu>Report revealed that the probe sensor’s DO charge was below the specified range (50 ± 50 mV; YSI 2010). In accordance with maintenance instructions (YSI 2012) and per the recommendations of external water quality monitoring standard operating procedures (NMED 2018; WVDEP 2018) the probe’s potassium chloride electrolyte solution and Teflon membrane were replaced. Profiles with unacceptable DO charge values were discarded (Caldwell 2012) and following maintenance of the DO probe as described above, sampling point locations with erroneous data were re-sampled.

Data Management

In 2018, standardized data management procedures were developed to facilitate rapid data assessment. At each site, vertical profiles were exported from the sonde onto the accompanying YSI 650 MDS handheld unit and dissolved oxygen data were reviewed for sudden/sharp discontinuities in the chemocline. If irregularities were noted, a new profile was taken. Individual profiles were uploaded from the handheld unit to a PC using EcoWatch Lite v. 1.0.5.15. In all years of sampling, profile data were trimmed from either surface or sediment layer to remove unrealistic values (e.g., entries with negative depth and single-digit specific conductance values, entries with extremely high turbidity values indicative of the sonde contacting the sediment).

In both 2014 and 2016, data profiles revealed small negative turbidity values (e.g., -0.1). These values are not necessarily erroneous and may reflect the fact that turbidity insitu was less than the calibration solution (YSI, 2016). However, the values may be erroneous if calibration was completed incorrectly (YSI, 2016). In 2015 and 2018, turbidity values are not negative and for

most profiles are extremely small values (<2 NTU), suggesting that outside of certain sites or periods of high flow (e.g. spring) turbidity is low. This suggests that the negative values observed in 2014 and 2016 are more likely related to low turbidity insitu than to improper unit calibration.

3. Data Collection Summary

In 2014, vertical profiles were completed from August 26th to 29th. In 2015, profiles were completed from August 12th to 18th. Sites HP1, HP4, and HP 10 were also profiled during the fall of 2015 to assess the extent of depth and dissolved oxygen variation in the headpond between stratified and non-stratified periods. Fall 2015 sampling was completed on October 21 (HP1), November 4 (HP4), and November 6 (HP10).

The reservoir sites sampled in 2014 were originally named HPxx, where HP is indicative of headpond and xx is a two-digit multiplier of ten (*e.g.*, HP10, HP20, HP30), or were named after a representative characteristic of the river reach (*i.e.*, LONGS, LOTIC). The sampling site added in 2015 (HP35) was named such because it is in between HP30 and HP40. It should be noted that HP13 is located primarily in the loctic habitat immediately upstream of the major influence of the headpond (Figure 1).

Among years when HP5 was sampled (2014, 2016, 2018) a large variation in the depth profile (Table 2) exists. This is largely explained by the steep slope of the river bottom around HP5 (Figure 2). Additionally, as noted in the subscript to Table 2, the sampling location of HP5 in 2015 was located ~450 m upstream of the 2014 designation of HP5. Additionally, in 2018, only the right channel location (the deepest point) of HP5 was sampled. Among year differences in dissolved oxygen and temperature at HP5 must be interpreted with caution due to the possible influence of depth on the profile.

During 2016, monthly sampling was conducted between June 2-11, July 19-25, August 4-5, and October 19-20 at all sites. In 2018, monthly vertical profiles were completed between July 18-20, August 20-29, September 20-24, and October 29-31.

In 2016, profiling was expanded to consider monthly and seasonal variation. The increase in temporal sampling effort resulted in reduced spatial sampling effort: that is, fewer sites were sampled more frequently. The sites chosen for sampling in 2016 were paired with plankton collection and sampling to facilitate a concurrent study of the reservoir's plankton community (Nguyen, et al. 2017). To accommodate both sampling programs, new sites were developed at HP2 and HP9. Accordingly, the four sites studied in 2016 were HP2, HP4, HP5, and HP9. However, in the original documentation of the 2016 sampling, the sites were given the existing site names of HP1, HP2, HP3, and HP4 respectively. Due to the conflicting and confusing use of site names, all sites were reassigned "new" site names in 2018 as shown in Table 1. The new site assignments are arranged such that HP1 is considered the downstream-most site and HP13 is considered the upstream-most site. The corresponding new and old site names for each of HP1-13 are included in Tables 1 and 2. With the exception of Tables 1 and 2 here, sites are described in this report and associated analytical reports (Dolson-Edge et al., 2018) by their standardized 2018 designations.

The dissolved oxygen values measured during June 2016 with the polarographic probe featured large discontinuities, negative values, and wide variation. These erratic data were associated with voltage spikes (>16.0 volts) at HP2 which can be indicative of probe malfunction (Caldwell 2012). All four profiles conducted during June 2016 were flagged as potentially erroneous (Small

et al., 2010) as the DO probe likely experienced catastrophic failure during deployment. The June 2016 profiles are therefore not recommended for use in subsequent analyses.

Profiles recorded on September 17th 2018 at four sites (HP11L, HP11C, HP12L, and HP13) with the optical probe were found to contain a discontinuity in their dissolved oxygen data at a consistent depth of ~17 m. A fifth site (HP12C) that was also profiled on September 17th 2018 (total depth: 9.9m) lacked DO discontinuities. While the exact cause of this probe's failure is undetermined, it likely suffered from partial unsealing of the wiper shaft o-ring (quad seal) due to the length of its service life (D. Hryn, pers. comm.). When evaluating dissolved oxygen profiles from 2018 it is recommended that profiles from September at HP11L, HP11C, HP12L, and HP13 be interpreted with caution.

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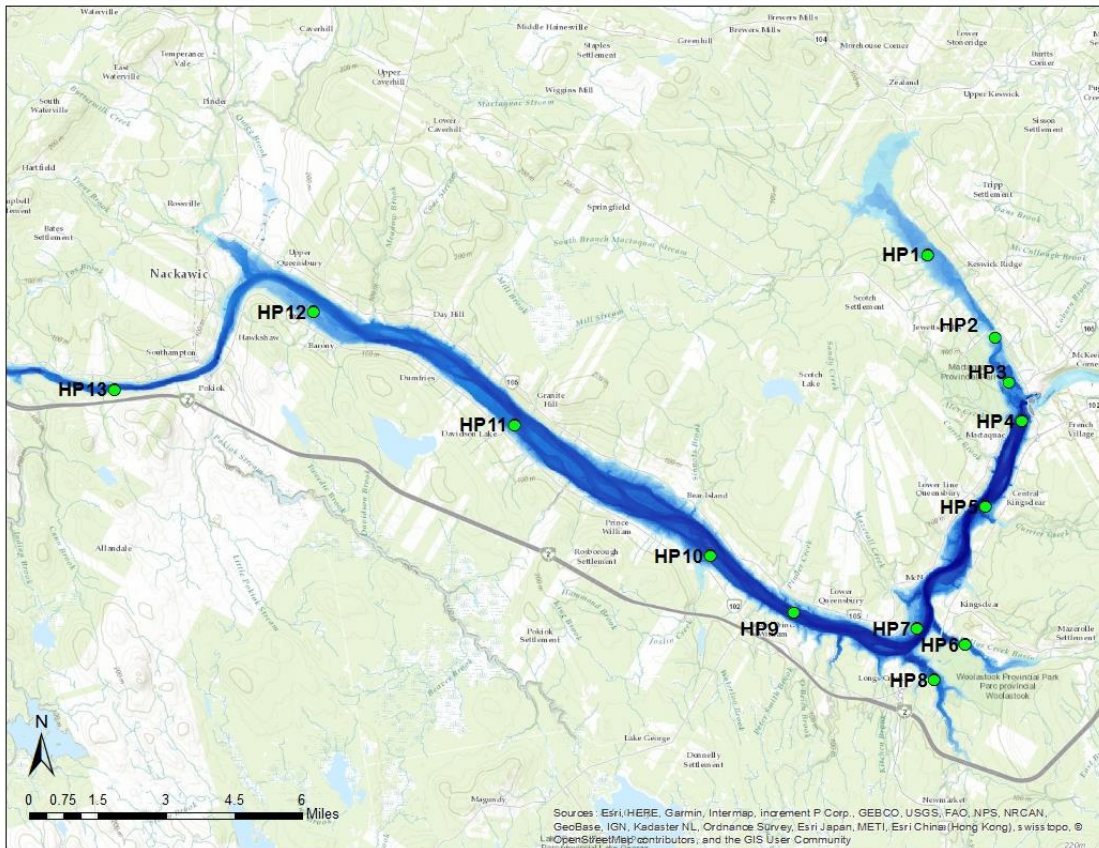


Figure 1. MAES Physical limnology sampling sites, 2014-2018.

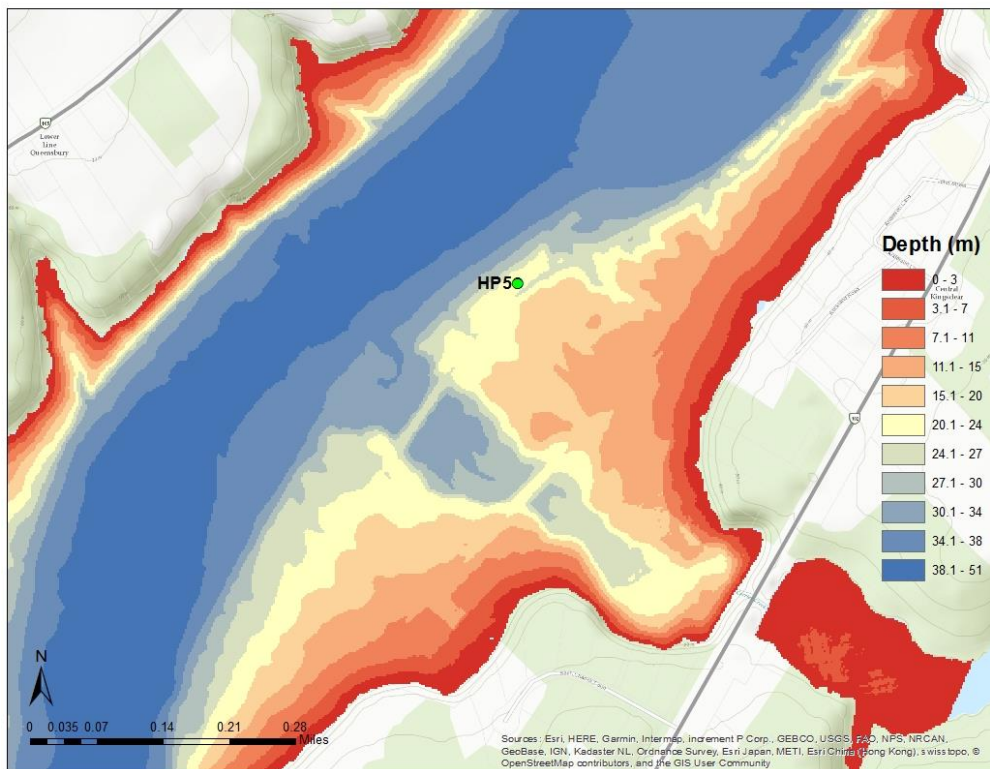


Figure 2. Bathymetric depth profile around sampling site HP5.

Table 1. MAES physical limnology sampling sites, 2014-2018ⁱ. U/S indicates upstream; D/S indicates downstream. Old site names in italics indicate sites profiled as part of a related 2016 plankton community study.

Site Description	Site Name(s)		Transect Point	Coordinates		Years sampled			
	New	Old		Latitude	Longitude	2014	2015	2016	2018
Mactaquac Arm	HP1	HP30	Center	N46.00012	W66.91730	x	x	-	x
			Left	N46.00160	W66.91524	x	x	-	-
			Right	N45.99953	W66.91852	x	x	-	-
Mactaquac Public Beach	HP2	<i>HP1</i>	Center	N45.97403	W66.88643	-	-	x	x
Mactaquac Park	HP3	HP35	Center	N45.95951	W66.87997	-	x	-	x
			Left	N45.96067	W66.87749	-	x	-	-
			Right	N45.95911	W66.88314	-	x	-	-
Mactaquac Dam	HP4	HP40	Center	N45.94717	W66.87388	x	x	x	x
			Left	N45.94762	W66.87388	x	x ⁱⁱ	-	-
		<i>HP2</i>	Right	N45.94644	W66.87108	x	x	-	-
U/S Mactaquac Dam	HP5	HP50	Center	N45.91996	W66.89040	x	-	x	-
			Left	N45.91889	W66.88790	x	-	-	-
		<i>HP3</i>	Right	N45.92163	W66.89330	x	-	-	x
Kelly's Creek	HP6	HP20	Center	N45.87588	W66.89920	x	-	-	x
			Left	N45.87516	W66.89950	x	-	-	-
			Right	N45.87644	W66.89860	x	-	-	-
U/S Kelly's Creek	HP7	HP60	Center	N45.88094	W66.92110	x	x	-	-
			Left	N45.88185	W66.92466	x	x	-	-
			Right	N45.87978	W66.91790	x	x	-	x
Long's Creek	HP8	LONGS	Center	N45.86466	W66.91315	x	x	-	x
Kings Landing	HP9	<i>HP4</i>	Center	N45.88589	W66.97754	-	-	x	x
U/S Long's Creek	HP10	HP70	Center	N45.90372	W67.01540	x	x	-	x
			Left	N45.90701	W67.01270	x	-	-	-
			Right	N45.90101	W67.01660	x	-	-	-
D/S Nackawic	HP11	HP10	Center	N45.94509	W67.10531	x	x	-	x
			Left	N45.94793	W67.10217	x	x	-	x ⁱⁱⁱ
			Right	N45.94331	W67.10758	x	x	-	-

Site Description	Site Name(s)		Transect Point	Coordinates		Years sampled			
	New	Old		Latitude	Longitude	2014	2015	2016	2018
Nackawic		HP80	Center	N45.98052	W67.19748	x	x	-	x
			Left	N45.98351	W67.19669	x	x	-	x ⁱⁱⁱ
			Right	N45.97913	W67.19975	x	x	-	-
U/S Nackawic (Lotic)	HP13	LOTIC	Center	N45.95523	W67.28825	x	x	-	x
			Left	N45.95695	W67.28806	x	-	-	-
			Right	N45.97913	W67.19975	x	-	-	-

ⁱ Limnological profiling was not conducted in 2017.

ⁱⁱ The left transect point at HP4 was also sampled at N45.94891 W66.87474 during 2015.

ⁱⁱⁱ The left transect points at HP11 and HP12 were surveyed during August-October 2018 but not during July.

Table 2. Depth variation at MAES physical limnology sampling sites, 2014-2018ⁱ. Site depths reported here were obtained from the YSI probe. Old site names in italics indicate sites profiled as part of a related 2016 plankton community study.

Site Name(s)		Transect Point	Coordinates		Depth (m)										
New	Old		Latitude	Longitude	2014	2015		2016				2018			
					Aug	Aug	Oct/Nov	Jun	Jul	Aug	Oct	Jul	Aug	Sep	Oct
HP1	HP30	Center	N46.00012	W66.91730	14.2	13.8	13.7	-	-	-	-	12.6	12.9	12.9	13.9
		Left	N46.00160	W66.91524	14.3	13.8	-	-	-	-	-	-	-	-	-
		Right	N45.99953	W66.91852	13.3	13.8	-	-	-	-	-	-	-	-	-
HP2	<i>HP1</i>	Center	N45.97403	W66.88643	-	-	-	19.8	19.9	20	19.6	19.6	19.3	18.5	19.1
HP3	HP35	Center	N45.95951	W66.87997	-	26.7	-	-	-	-	-	25.3	26.9	25.5	26.8
		Left	N45.96067	W66.87749	-	21.7	-	-	-	-	-	-	-	-	-
		Right	N45.95911	W66.88314	-	15.9	-	-	-	-	-	-	-	-	-
HP4	HP40 <i>HP2</i>	Center	N45.94717	W66.87388	35.8	37.5	32.8	37.9	38	39	37.7	34.8	37.2	35.8	37
		Left	N45.94762	W66.87388	26	36.7	-	-	-	-	-	-	-	-	-
		Right	N45.94644	W66.87108	12.9	17	-	-	-	-	-	-	-	-	-
HP5	HP50 <i>HP3</i>	Center[ii]	N45.91996	W66.89040	27.3	-	-	36.2	36	36	35.1	-	-	-	-
		Left	N45.91889	W66.88790	12.1	-	-	-	-	-	-	-	-	-	-
		Right	N45.92163	W66.89330	37.7	-	-	-	-	-	-	42.7	38.2	40.5	36.3
HP6	HP20	Center	N45.87588	W66.89920	24.8	-	-	-	-	-	-	23.4	22.6	-	23.8
		Left	N45.87516	W66.89950	13.2	-	-	-	-	-	-	-	-	-	-
		Right	N45.87644	W66.89860	18.6	-	-	-	-	-	-	-	-	-	-
HP7	HP60	Center	N45.88094	W66.92110	22.6	21.4	-	-	-	-	-	-	-	-	-
		Left	N45.88185	W66.92466	11.8	10.9	-	-	-	-	-	-	-	-	-
		Right	N45.87978	W66.91790	39.2	37.6	-	-	-	-	-	38.6	37.5	37.4	38.1
HP8	LONGS	Center	N45.86466	W66.91315	26.7	21.9	-	-	-	-	-	19.9	24.6	25	2.6
HP9	<i>HP4</i>	Center	N45.88589	W66.97754	-	-	-	35.3	35.8	36	34.8	35	33.9	34.3	34.4
HP10	HP70	Center	N45.90372	W67.01540	28.4	-	29.1	-	-	-	-	28.8	27.9	27.9	28.9
		Left	N45.90701	W67.01270	33.8	-	-	-	-	-	-	-	-	-	-
		Right	N45.90101	W67.01660	9.9	-	-	-	-	-	-	-	-	-	-
HP11	HP10	Center	N45.94509	W67.10531	22.5	22.1	-	-	-	-	-	21.9	21.9	21.2	21.7
		Left	N45.94793	W67.10217	29.3	29.3	-	-	-	-	-	-	29.2	28.2	-
		Right	N45.94331	W67.10758	14.5	12.5	-	-	-	-	-	-	-	-	-
HP12	HP80	Center	N45.98052	W67.19748	10.8	10.4	-	-	-	-	-	10.6	10.8	9.7	9.4
		Left	N45.98351	W67.19669	21.7	23	-	-	-	-	-	-	22.6	21.5	-
		Right	N45.97913	W67.19975	13.1	12.5	-	-	-	-	-	-	-	-	-
HP13	LOTIC	Center	N45.95523	W67.28825	27	21.4	-	-	-	-	-	17.7	22.1	20.1	18.7
		Left	N45.95695	W67.28806	20.6	-	-	-	-	-	-	-	-	-	-
		Right	N45.97913	W67.19975	25.3	-	-	-	-	-	-	-	-	-	-

[i] Limnological sampling was not conducted in 2017.

[ii] The 2016 profile at HP5 (center) was collected at N45.91681 W66.894141 which is ~450m upstream of the 2014 profile at HP5 (center).