Hatch Pond Study 2014: In Lake Conditions, Processes and Possible Management Options

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Introduction

Hatch Pond is in South Kent, Connecticut, slightly east of Route 7 and north of the South Kent School (Figure 1). The pond currently covers about 70 acres in an elongate, northwest-southeast alignment. It is bordered on the east by a railroad and South Kent Road, while the western shoreline is largely steep, forested terrain. Womenshenuk Brook flows from Leonard Pond from the north and exits Hatch Pond from the south. Additional land, including part of the South Kent School and the Bulls Bridge Golf Club, is drained by smaller tributaries, with a total watershed area of slightly more than 3 square miles.

Land use is varied, including forest, wetland, agriculture and residential area as well as the school and golf club (Figure 2). Slopes are steep in much of the watershed. A large emergent wetland has formed over time at the inlet of the pond, covering about 20 acres south of South Kent Road that was probably open water at some time in the distant past. There is a dam at the south end of Hatch Pond that raised the water level several feet at some point in the past, but it is apparent that the pond has experienced substantial infilling over many decades.

Reports by NEAR, the most recent in 2012, document excessive nutrient loading and related biological problems over the last decade, driven largely by inputs from the Arno Farm, a dairy operation at the north end of the lake. Concentrations of nitrogen (N) and phosphorus (P) were very high in water discharged from the dairy farm, while concentrations upstream were more moderate or even low. Inputs from the unnamed tributary the drains the South Kent School, part of the golf course, and some additional lands have also been elevated at times, but the load from the dairy farm stands out as far greater than all other sources. The CT DEP had assessed Hatch Pond in 1990 (CTDEP 1991) and considered it to be moderately fertile. Water quality deterioration over a 15 year period was apparent.

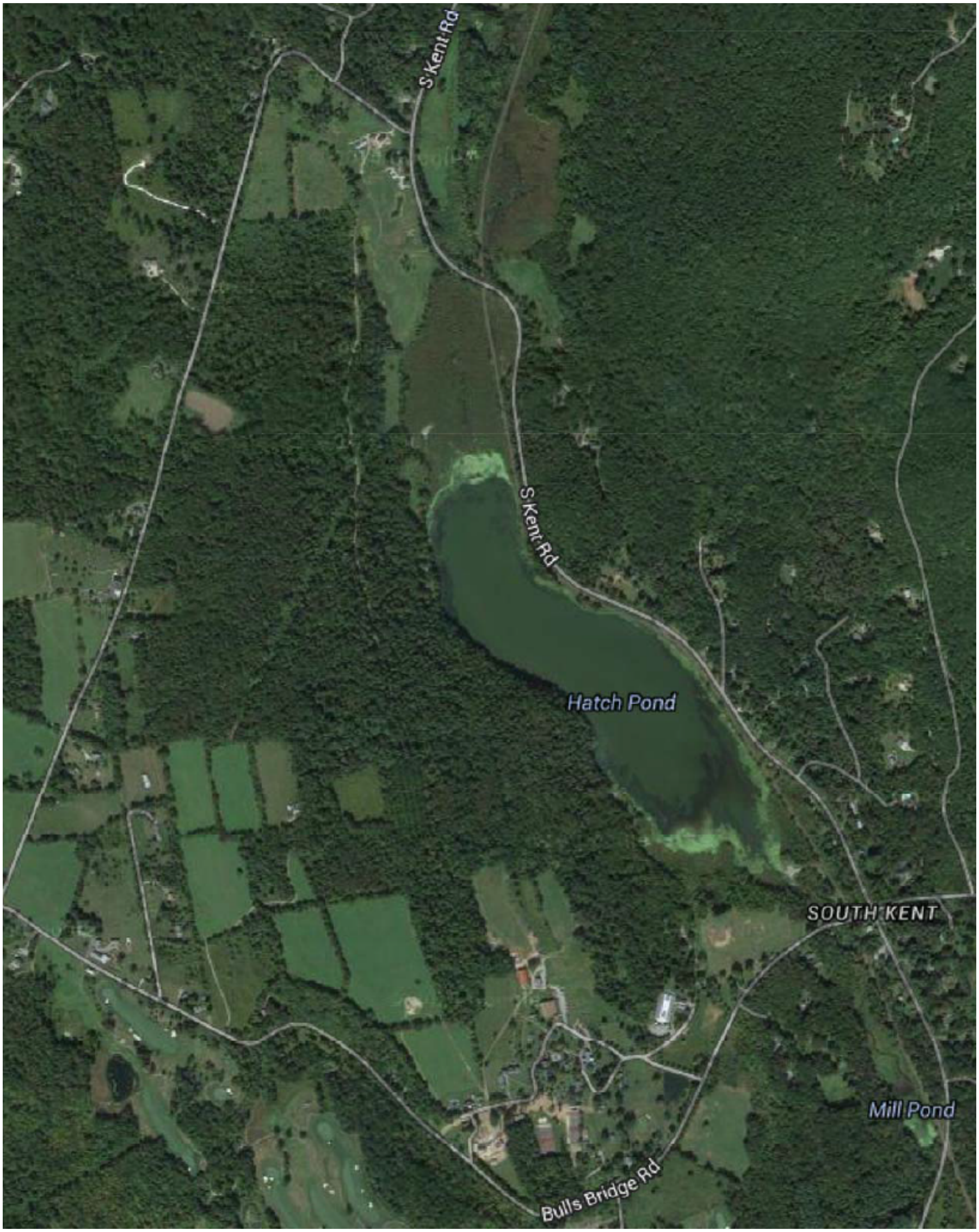
Most striking is the apparent change in the depth of Hatch Pond. Mean and maximum depths were reported in 1959 as 11.5 ft (3.5 m) and 26.2 ft (7.9 m), respectively (State Board of Fisheries and Game 1959). More recent measurements (NEAR 2012) indicated a maximum depth of less than 15 ft (4.5 m). Watershed inputs during large storms, manure from the dairy farm, and internally generated and retained organic matter are all possible sources of the sediment. It is also possible that the measurements made about 60 years ago were made with weights on graduated lines that went considerably into the soft sediment before stopping, thereby overestimating water depth. The high level of internal organic production and the establishment of emergent wetland at the north end of the pond point to substantial infilling even if water depths were overestimated, but little change in water depth was noted between 2004 and 2010 (NEAR 2012).

Hatch Pond experiences both rooted plant nuisance growths and algae blooms dominated by cyanobacteria. Clarity was low through 2006 and there was enough of a thermal difference over the relatively shallow depth to allow moderately stable water layers to develop. Oxygen was lost near the bottom, and the anoxic zone extended upward to depths as shallow as 5 ft (1.5 m). Hatch Pond has long been popular for fishing and rowing, but became virtually unusable during the summer through the combination of rooted plant and algae growths.

South Kent School purchased the Arno Dairy Farm in 2010 and terminated dairy farming; the improvement in water quality in the pond was quickly evident (NEAR 2012). Conditions remained impaired, but decreased loading was documented and water quality increased slightly. Unfortunately,

Figure 1. Map of Hatch Pond area.

Figure 2. Aerial view of Hatch Pond and its immediate area.



the increased clarity allowed plants, most notably the invasive species Eurasian water milfoil (*Myriophyllum spicatum*) to extend into deeper water.

This study was undertaken to assess water quality changes 4 years after conversion of the dairy farm to a sustainable farming operation as part of the South Kent School curriculum. The loss of inputs from the dairy farm is perceived to have substantially lowered nutrient loading, but the importance of other watershed sources and internal recycling from sediment reserves has not been adequately characterized. Evaluation of possible management actions to address water quality issues require greater understanding of existing conditions and nutrient loading than was available prior to this study. A Section 319 grant from the CT DEEP supported this effort. Fuss & O'Neill evaluated watershed conditions and processes, while WRS and NEAR provided inlake assessments. This report covers the inlake portion of the scope of work and resultant watershed projections.

Study Elements

Temperature and oxygen profiles were collected on 9 dates between late April and mid-September, with an emphasis on the spring period, when oxygen demand can be most accurately measured. Additional water quality variables were assessed on 5 dates between April and September of 2014. Phytoplankton and zooplankton were assessed with water quality. Sediment quantity and quality were evaluated in June and July of 2014. Water depths were obtained with sediment probing, allowing a new bathymetric map to be generated. All sampling and analyses were conducted in accordance with an approved Quality Assurance Project Plan (QAPP). The approved QAPP is a separate document but is incorporated into this report by reference and fully explains the methods and approach.

Nutrient loading from internal sources was assessed by multiple approaches to bracket possible loads. Nutrient loading from all sources was estimated as a total based on empirical models that apply inlake concentrations and physical features to generate the loads required to achieve the observed inlake concentration.

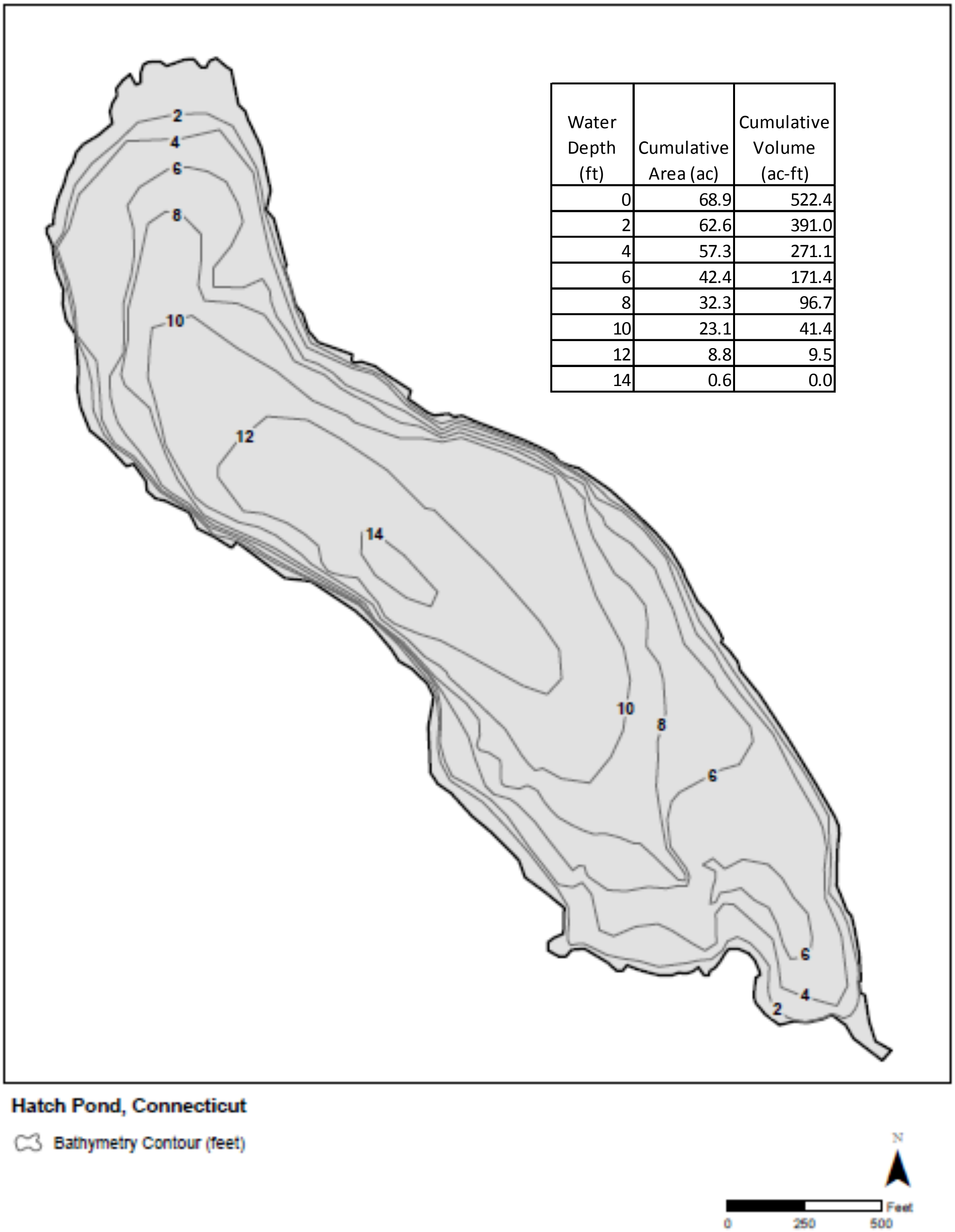
Management options were evaluated in light of current conditions and trends over time.

Physical Pond Features

Current bathymetry of Hatch Pond (Figure 3) indicates a mean depth of 7.6 ft (2.3 m) and a maximum depth of no more than 15 ft (4.5 m). Pond area was measured as 68.9 ac (27.8 ha), within the range of past estimates; changing water level will affect area estimation. Pond volume was calculated as 522.4 acre-feet (645 million m^3). This is similar to conditions observed since 2004 but is dramatically different than the depth contours reported in 1959.

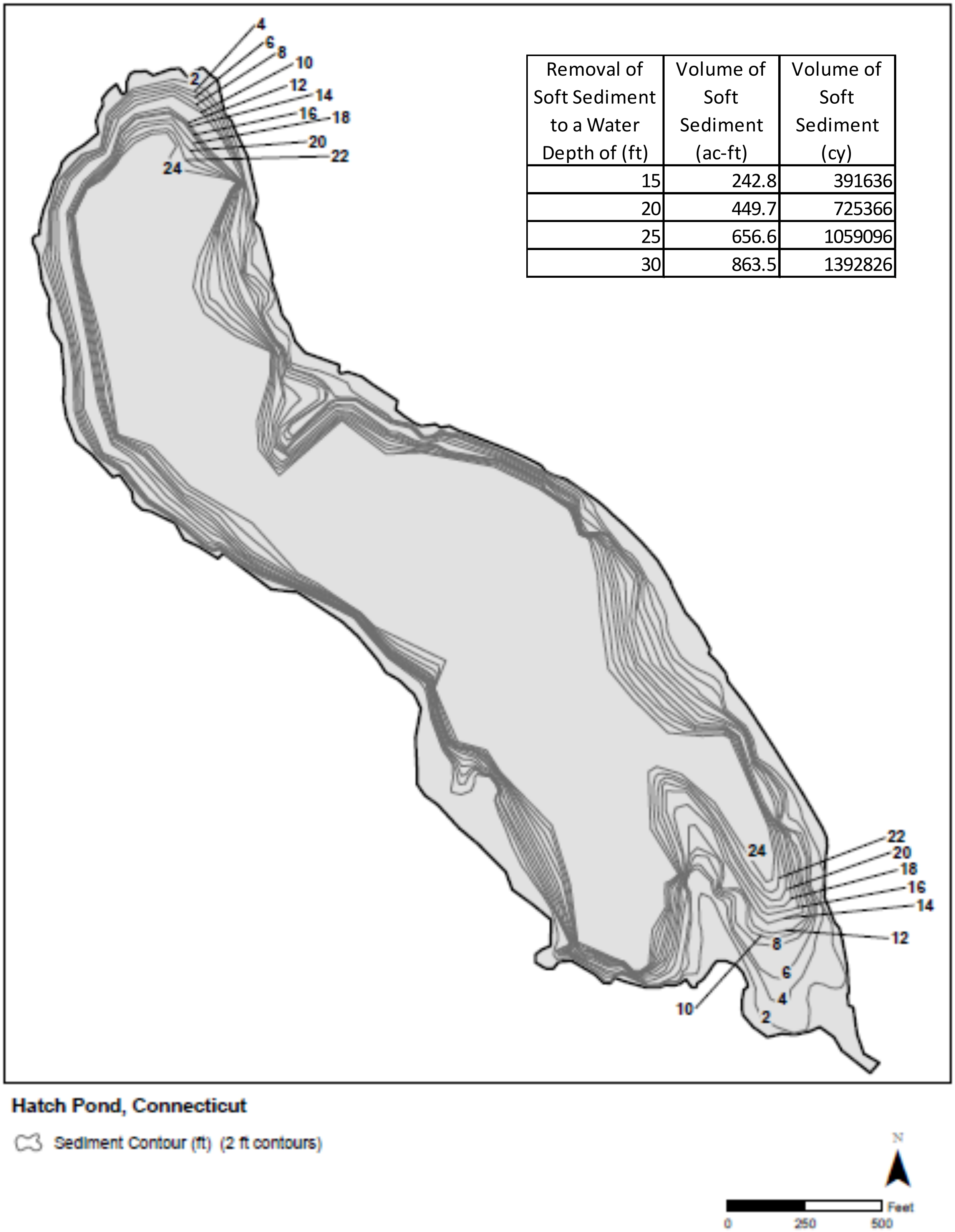
Sediment probing revealed very deep soft sediment deposits (Figure 4). A 40 foot probe did not reach a hard substrate in most central areas, where water depths ranged from 10 to 14 ft. Assuming removal of sediment (dredging) as a management option to achieve water depths of 15 to 30 ft, the associated quantities of sediment range from 392,000 cy to 1,393,000 cy. These are very large quantities of soft sediment for a relatively small water body. The steep slopes observed in the upland topography apparently extended into the pond historically, and sediment has accumulated in the submerged "valley", greatly reducing the original depth, which exceeded 40 ft (12.1 m) in some areas.

Figure 3. Hatch Pond bathymetry as of 2014.



Water Depth (ft)	Cumulative Area (ac)	Cumulative Volume (ac-ft)
0	68.9	522.4
2	62.6	391.0
4	57.3	271.1
6	42.4	171.4
8	32.3	96.7
10	23.1	41.4
12	8.8	9.5
14	0.6	0.0

Figure 4. Hatch Pond soft sediment distribution as of 2014.



Removal of Soft Sediment to a Water Depth of (ft)	Volume of Soft Sediment (ac-ft)	Volume of Soft Sediment (cy)
15	242.8	391636
20	449.7	725366
25	656.6	1059096
30	863.5	1392826

This portion of the overall study did not assess watershed conditions or even inlet conditions, so flow data were not generated. To estimate detention time, a water yield for northeastern watersheds of 1.7 cubic feet per second (cfs) per square mile of watershed (Higgins and Colonel 1972) was applied. With a current watershed area estimate of 2009 acres, this suggests an average flow of 5.3 cfs. Low summer flows may be as low as 0.2 to 0.3 cfs/square mile, suggesting low flows on the order of 0.6 to 1.0 cfs.

Based on the estimated flow through Hatch Pond, the volume of the pond would be replaced 7.4 times per year, indicating a detention time of 49 days on average. During summer low flows the water in the pond may not be replaced even once; summer inflow may be only 40% of the pond volume.

Chemical Pond Features

Water Quality

Temperature and oxygen profiles were collected on nine dates in 2014 (Table 1). Water clarity was assessed with a Secchi disk on each date as well. Conditions were nearly uniform from top to bottom on April 29 and May 7 (Figures 5 and 6), but exhibited development of stratification on May 13 (Figure 7). Mixing by wind or inflow created uniform conditions again on May 20 (Figure 8). From May 27 through September 18, temperature varied from top to bottom, with colder water on the bottom, but the thermal gradient was never strong and resistance to mixing was not large (Figures 9-13). Despite limited stratification, oxygen depression developed near the bottom by May 27 (Figure 9) was similar or slightly less on June 16 (Figure 10), and intensified through July (Figure 11). Oxygen depression was observed at depths >5 ft and oxygen was lower than desirable for aquatic life at depths >7 ft by August 1. Complete oxygen depletion did not occur, but values <1 mg/L occurred at depths >9 ft. These conditions persisted through August (Figure 12), but mixing in September lead to improved but not uniform conditions by September 18 (Figure 13).

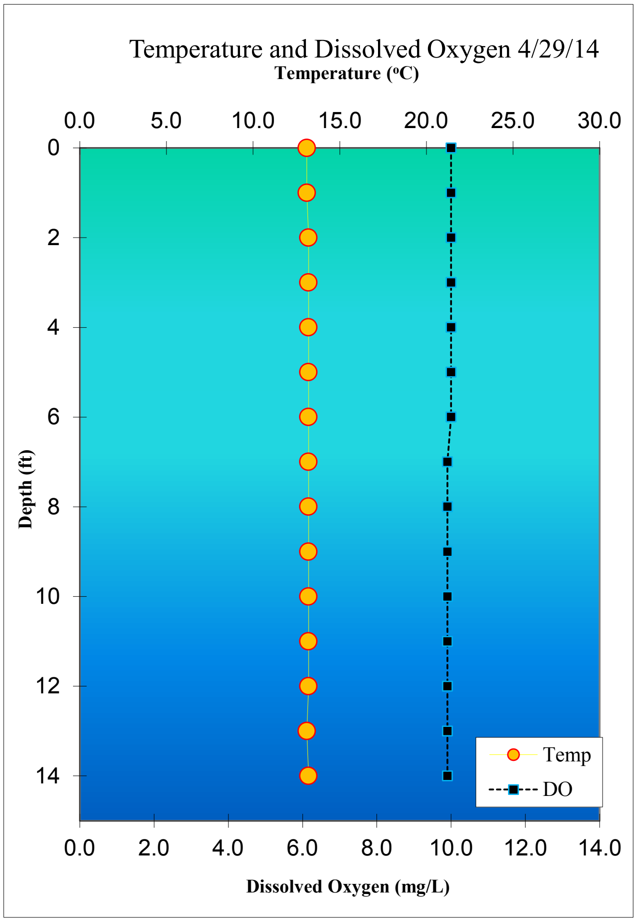
Summer of 2014 was fairly mild, with few large storms or wind events. With dense aquatic plant growths and limited summer inflow, vertical mixing in Hatch Pond was limited. Without any true thermal stratification, the pond still managed to lose oxygen from the bottom through decomposition at a rate too rapid for atmospheric re-aeration to counter, and low oxygen conditions were encountered for about two months. This promotes release of phosphorus and other undesirable compounds from bottom sediments, although it is actually the reduction-oxidation (redox) potential that governs that release. As oxygen declines, so does redox potential, with lower redox promoting chemical reactions that liberate phosphorus, iron, manganese, sulfur and other contaminants. Although oxygen cannot decline below 0 mg/L, redox potential continues to decrease and becomes negative, indicating the strength of those chemical interactions. Redox potential was not measured in this study, but may vary over time even after oxygen has reached 0 mg/L.

Water clarity (Table 1) was in excess of 10 ft (3.0 m) through May, but declined in June to 7 ft (2.1 m) and was between 4.3 and 5.3 ft (1.3-1.6 m) for the summer. Most of the loss of clarity was due to algae in the water, but some resuspension of inorganic or non-living organic matter occurs as well and reduces clarity. The relatively higher clarity in spring allows rooted plants to grow, while lower clarity during summer limits additional growths. Past studies have suggested depths of plant colonization between 7 and 9 ft; areas <9ft deep had dense plant growth in 2014, with some growth to depths of 11 ft.

Table 1. Water clarity, temperature, oxygen and thermal resistance to mixing for Hatch Pond in 2014.

Water Clarity									
Date	4/29/2014	5/6/2014	5/13/2014	5/20/2014	5/27/2014	6/16/2014	8/1/2014	8/27/2014	9/18/2014
Secchi (m)	3.0	3.8	3.9	3.7	3.0	2.1	1.3	1.6	1.4
Water temperature (C)									
Date/Depth (ft)	4/29/2014	5/6/2014	5/13/2014	5/20/2014	5/27/2014	6/16/2014	8/1/2014	8/27/2014	9/18/2014
0	13.1	15.2	18.9	18.3	23.4	23.3	26.6	25.8	19.5
1	13.1	15.2	18.8	18.3	23.2	23.1	26.5	25.6	19.5
2	13.2	15.1	18.8	18.3	22.5	22.8	25.5	24.7	19.1
3	13.2	15.0	18.7	18.3	21.5	22.4	25.5	24.6	18.9
4	13.2	14.9	18.6	18.3	21.1	21.9	25.2	24.0	18.8
5	13.2	14.5	18.5	18.3	20.6	21.9	24.9	23.7	18.8
6	13.2	14.3	18.4	18.3	20.3	21.7	24.8	23.1	18.8
7	13.2	14.3	18.3	18.3	19.9	21.6	24.6	22.7	18.7
8	13.2	14.2	17.1	18.2	19.5	21.6	24.3	22.6	18.7
9	13.2	14.2	16.6	18.2	19.2	21.4	24.0	22.4	18.7
10	13.2	14.1	16.2	18.2	18.9	21.3	23.8	22.0	18.7
11	13.2	14.1	15.6	18.2	18.6	21.2	23.8	21.7	18.6
12	13.2	14.1	15.2	18.2	18.2	21.0	22.4	21.5	18.3
13	13.1	14.1	15.0	18.2	17.9	20.5	22.0	21.2	18.1
14	13.2	14.1	14.8	18.1	17.6	19.5	21.6	20.9	17.9
15		14.1	14.5		17.3	19.0	20.9		17.9
Dissolved Oxygen (mg/L)									
Date/Depth (ft)	4/29/2014	5/6/2014	5/13/2014	5/20/2014	5/27/2014	6/16/2014	8/1/2014	8/27/2014	9/18/2014
0	10.0	9.8	9.6	8.6	9.9	9.0	9.5	10.7	8.4
1	10.0	9.8	9.6	8.7	9.9	9.0	9.7	11.0	8.4
2	10.0	9.8	9.7	8.7	10.0	9.0	9.7	11.4	8.5
3	10.0	9.8	9.7	8.7	10.6	9.0	9.7	11.4	8.5
4	10.0	9.9	9.7	8.7	10.8	9.0	9.5	11.7	8.5
5	10.0	9.9	9.8	8.7	12.0	8.8	8.2	11.5	8.3
6	10.0	9.9	9.8	8.7	11.9	8.4	6.4	8.6	8.3
7	9.9	9.9	9.8	8.7	11.8	8.4	3.3	4.0	8.3
8	9.9	9.9	8.7	8.7	10.6	8.1	1.1	2.1	8.2
9	9.9	9.9	8.6	8.7	9.8	7.7	0.3	0.8	8.0
10	9.9	9.9	8.5	8.7	6.8	7.1	0.2	0.4	7.9
11	9.9	9.9	7.2	8.7	4.9	6.5	0.1	0.3	6.6
12	9.9	9.8	6.1	8.7	2.1	4.5	0.1	0.3	2.4
13	9.9	9.7	5.5	8.7	1.6	1.8	0.1	0.2	2.6
14	9.9	9.6	4.7	8.6	1.0	0.4	0.1	0.2	0.5
15		9.2	3.7		0.5	0.2	0.1		0.3
Percent saturation of DO									
Date/Depth (ft)	4/29/2014	5/6/2014	5/13/2014	5/20/2014	5/27/2014	6/16/2014	8/1/2014	8/27/2014	9/18/2014
0	95	98	103	91	116	106	118	131	91
1	95	98	103	92	116	105	121	135	91
2	95	97	104	92	115	105	118	137	92
3	95	97	104	92	120	104	118	137	91
4	95	98	104	92	121	103	115	139	91
5	95	97	105	92	134	100	99	136	89
6	95	97	104	92	132	96	77	100	89
7	94	97	104	92	130	95	40	46	89
8	94	96	90	92	115	92	13	24	88
9	94	96	88	92	106	87	4	9	86
10	94	96	86	92	73	80	2	5	85
11	94	96	72	92	52	73	1	3	71
12	94	95	61	92	22	50	1	3	26
13	94	94	55	92	17	20	1	2	28
14	94	93	46	91	10	4	1	2	5
15		89	36		5	2	1		3
RTRM									
Date/Depth (ft)	4/29/2014	5/6/2014	5/13/2014	5/20/2014	5/27/2014	6/16/2014	8/1/2014	8/27/2014	9/18/2014
0									
1	0	0	2	0	6	6	3	6	0
2	-2	2	0	0	20	9	33	29	10
3	0	2	2	0	28	11	0	3	5
4	0	2	2	0	11	14	10	19	2
5	0	7	2	0	13	0	10	9	0
6	0	4	2	0	8	5	3	18	0
7	0	0	2	0	10	3	6	12	2
8	0	2	27	2	10	0	9	3	0
9	0	0	11	0	7	5	9	6	0
10	0	2	8	0	7	3	6	11	0
11	0	0	12	0	7	3	0	8	2
12	0	0	8	0	9	5	41	5	7
13	2	0	4	0	7	13	11	8	5
14	-2	0	4	2	7	25	11	8	5
15		0	5		7	12	19		0
Total RTRM	-2	20	92	5	158	116	172	145	38

Figure 5. Hatch Pond temperature, oxygen and resistance to mixing profiles: 4/29/14



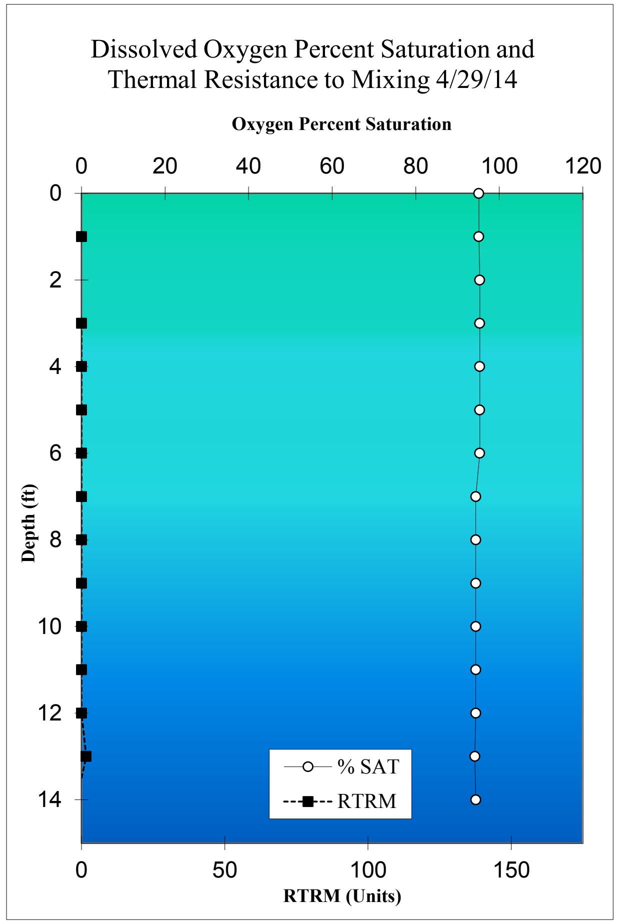
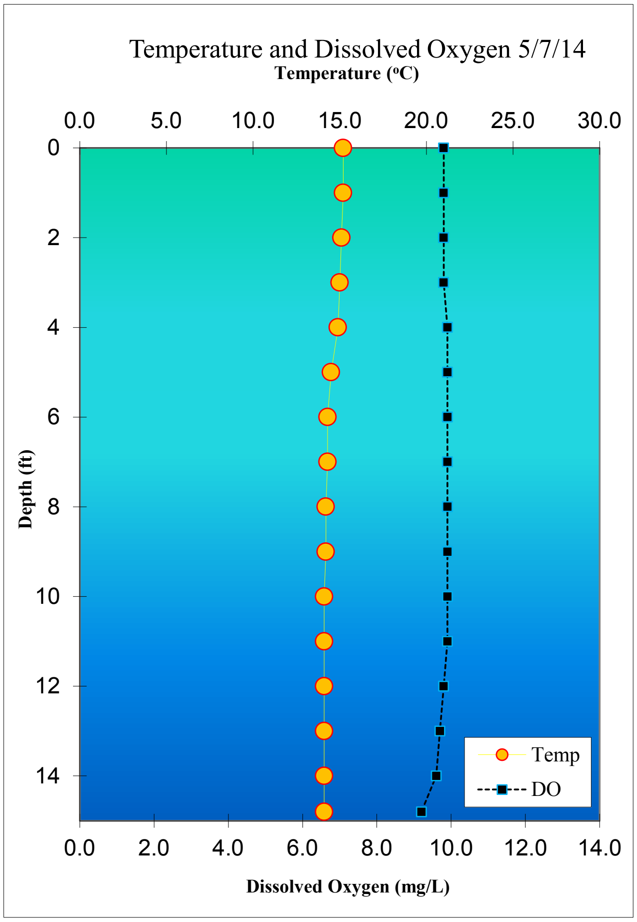


Figure 6. Hatch Pond temperature, oxygen and resistance to mixing profiles: 5/7/14



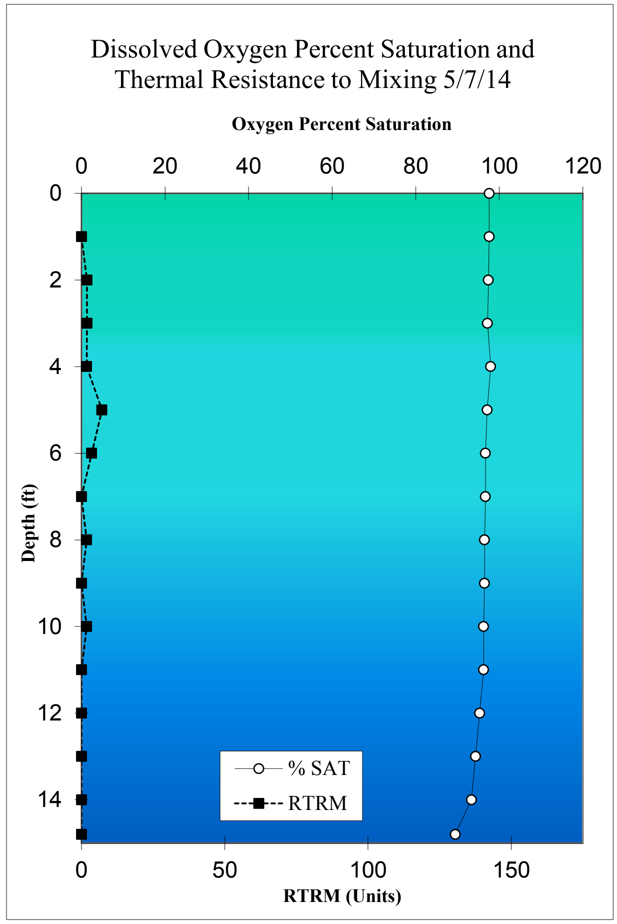
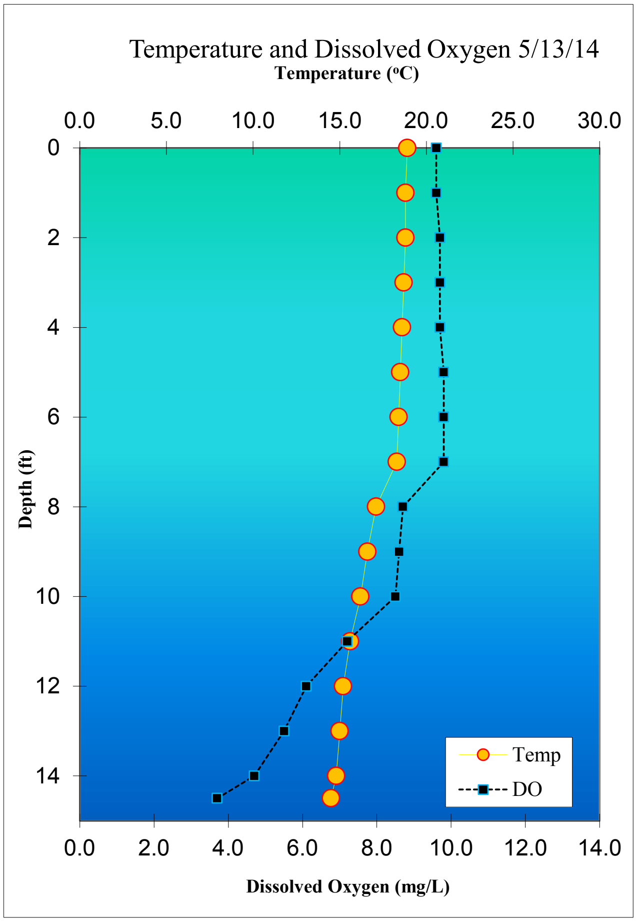


Figure 7. Hatch Pond temperature, oxygen and resistance to mixing profiles: 5/13/14



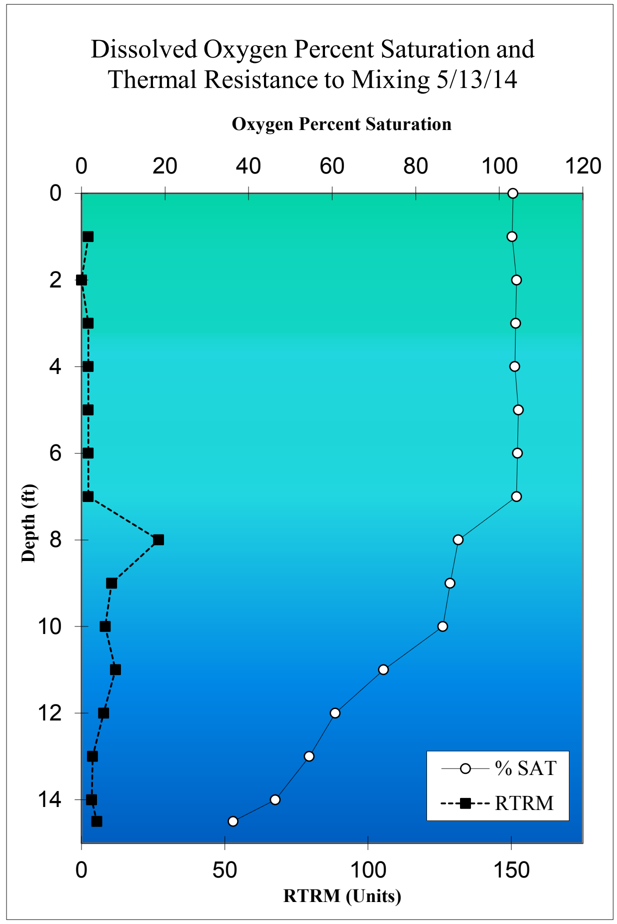
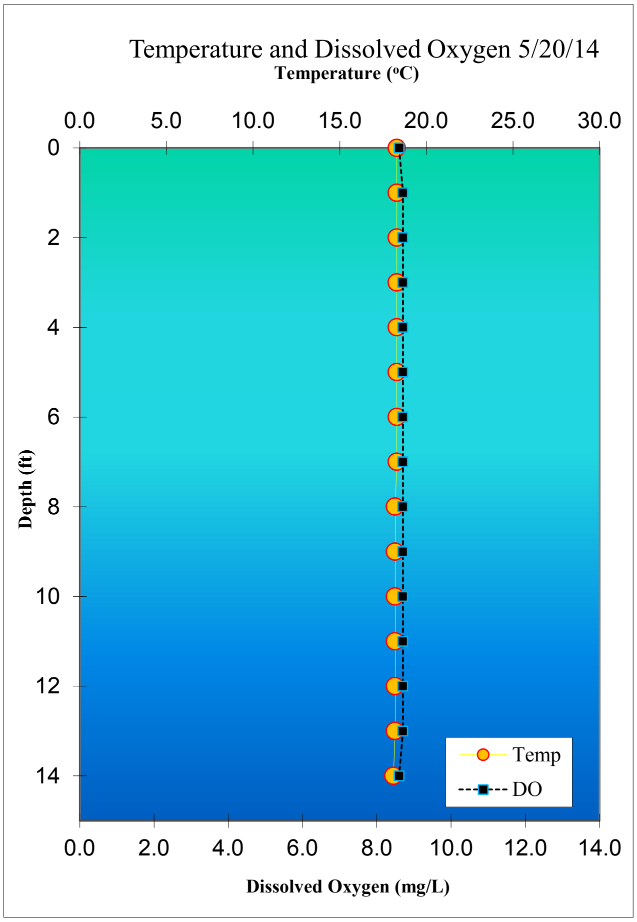


Figure 8. Hatch Pond temperature, oxygen and resistance to mixing profiles: 5/20/14



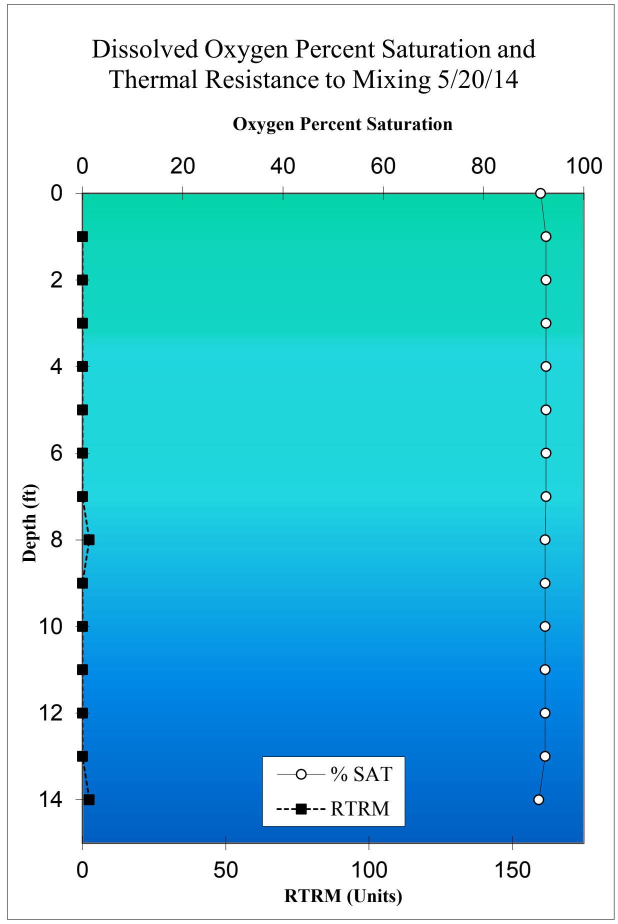
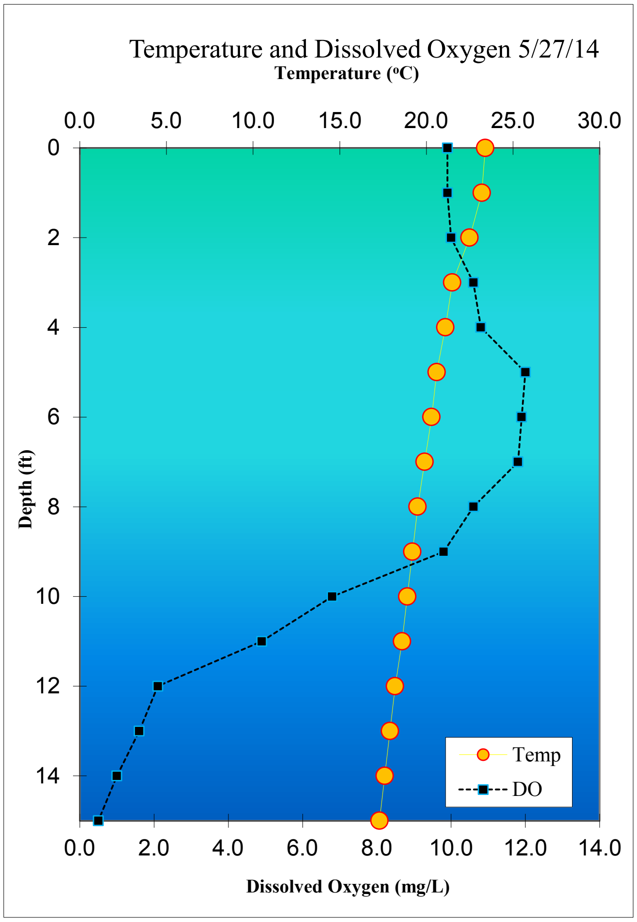


Figure 9. Hatch Pond temperature, oxygen and resistance to mixing profiles: 5/27/14



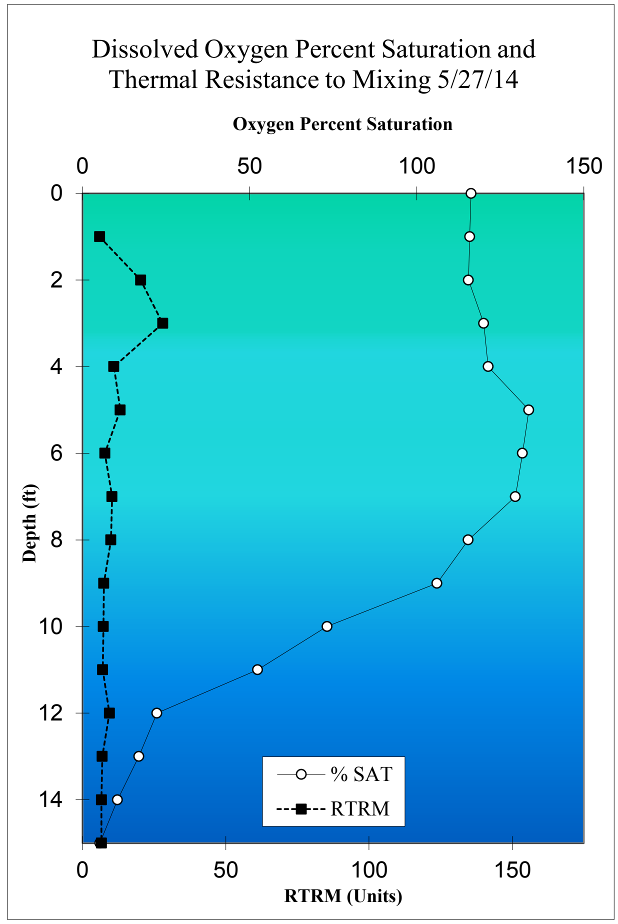


Figure 10. Hatch Pond temperature, oxygen and resistance to mixing profiles: 6/16/14

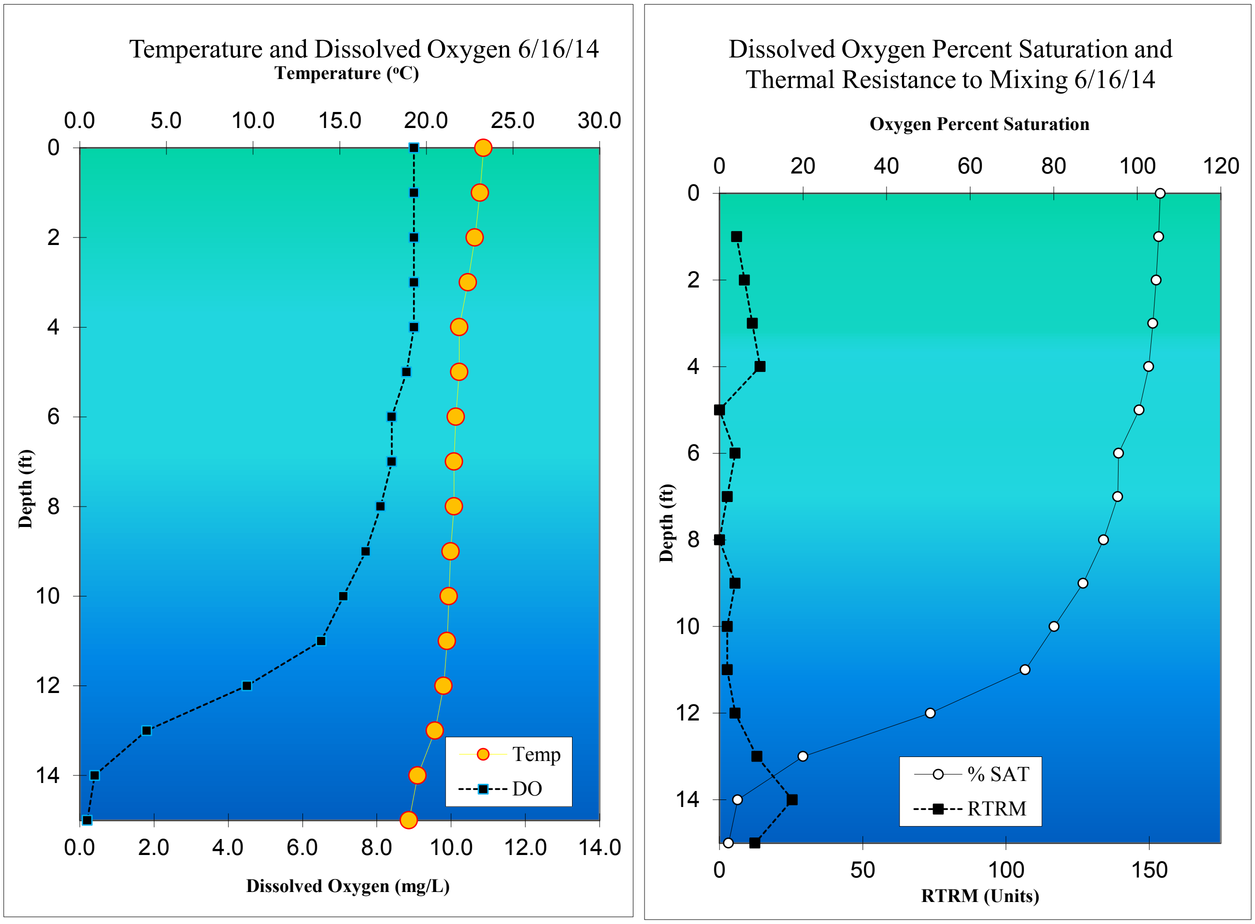
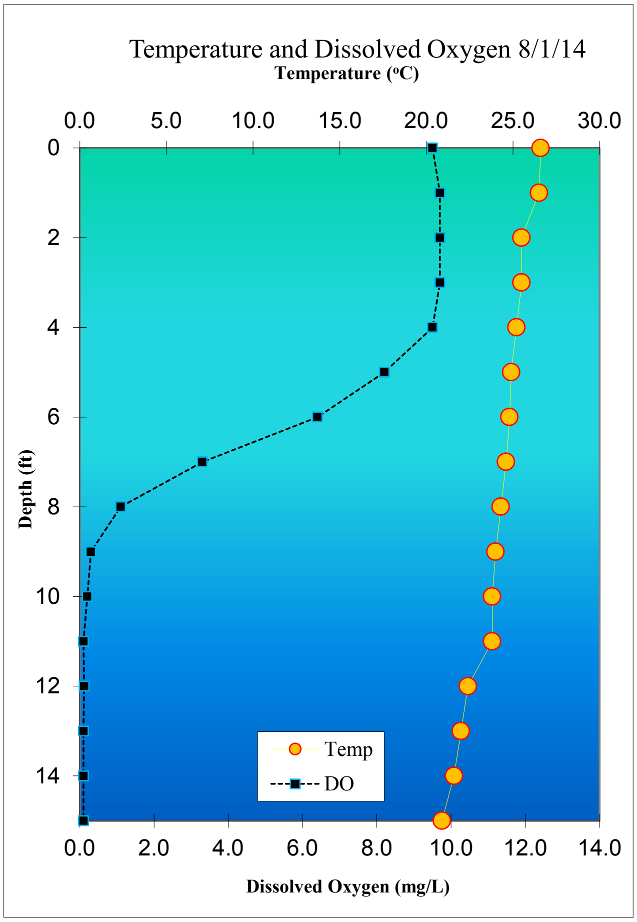


Figure 11. Hatch Pond temperature, oxygen and resistance to mixing profiles: 8/1/14



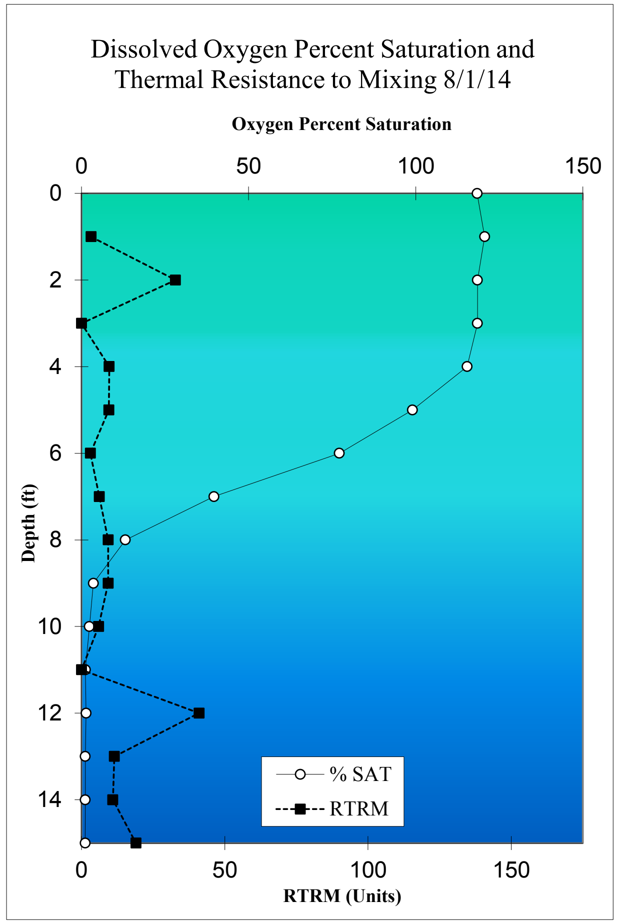
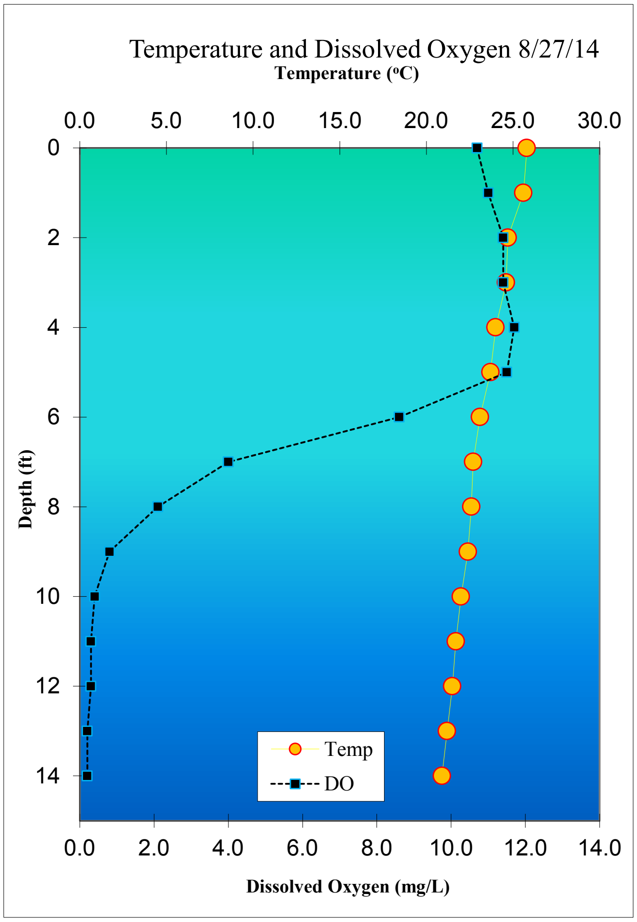


Figure 12. Hatch Pond temperature, oxygen and resistance to mixing profiles: 8/27/14



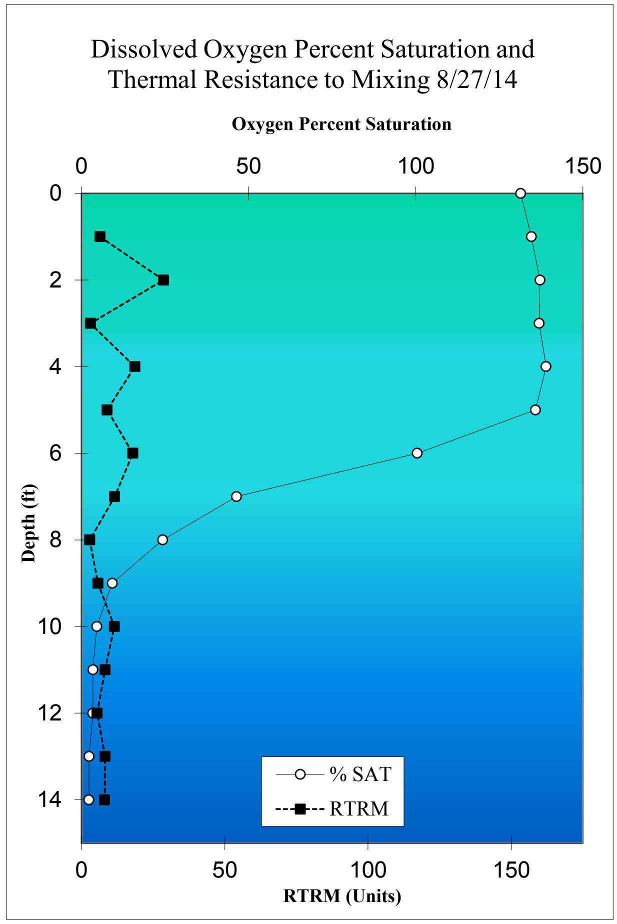
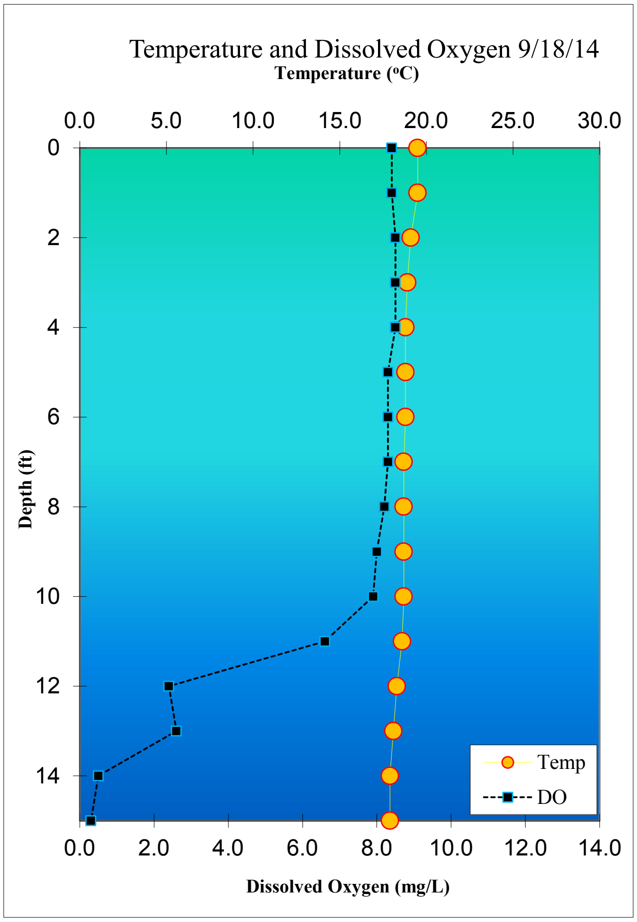
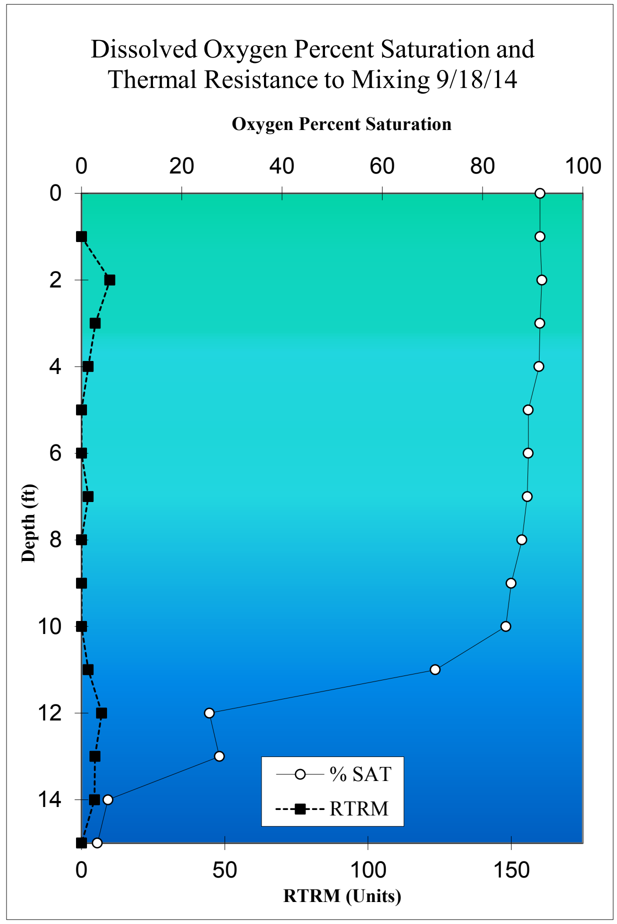


Figure 13. Hatch Pond temperature, oxygen and resistance to mixing profiles: 9/18/14





Nutrient chemistry in 2014 (Table 2) indicates moderate levels of total nitrogen with no strong surface to bottom gradient at any time. Ammonium nitrogen was low to moderate except at the bottom during the period of low oxygen, when it increased to almost 0.9 mg/L by late August. This accumulation is related to both release from sediment and lack of conversion of settling organic particulate nitrogen beyond ammonium to nitrite and nitrate due to oxygen shortage. Nitrate was scarce everywhere all the time; this is not unusual in freshwater aquatic habitats, but does favor cyanobacteria that can utilize dissolved nitrogen gas.

Total phosphorus levels were moderate to high, increasing through the summer and showing an increase from surface to bottom during the period of low oxygen in deeper waters. The summer increase at a time of lower inflow and vertical gradient is indicative of internal release from sediments, although the change is not extreme in 2014. Dissolved P exhibits some increase from spring into summer, but is fairly static through the summer; dissolved P is a subset of total P and is often utilized rapidly when available, so lower and fluctuating values are expected for this water quality variable.

The pH was between 7.2 and 8.4, typical for ponds in this region, and was higher at the surface than at the bottom as a consequence of more photosynthesis near the top (removes CO_2 and increases pH) and more decomposition at the bottom (releases acids that depress pH).