Manchester Urban Ponds Restoration Program

YEAR 1 REPORT

April 2001

Art Grindle, Program Coordinator

Acknowledgements

Many people have been involved with the UPRP and are responsible for its success to date. Without the dedication of the Manchester Conservation Commission to its purpose of conserving the remaining natural resources of Manchester, the UPRP might not exist today. Its members are: Jane Beaulieu (Chair), Todd Connors, Jennifer Drociak, Joanne McLaughlin, Michael Poisson, and Eric Skoglund. These individuals have been instrumental in determining the program's direction and goals.

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Executive Summary

The urban environment presents numerous hazards to the health of nearby freshwater ecosystems. Pavement and buildings form a barrier against runoff infiltration. As a result, the rain water picks up accumulated pollutants as it quickly runs off these areas and flushes them into receiving water bodies. These pollutants may include bacteria, heavy metals, oil, and phosphorus among other things.

Manchester's ponds are no exception to this phenomenon. Crystal Lake, Dorrs Pond, Maxwell Pond, McQuesten Pond, Nutts Pond, Pine Island Pond, and Stevens Pond have all been impacted by human activities to some extent. Some ponds are much more polluted than others due to their surrounding circumstances. As part of the Supplemental Environmental Projects program (SEPP) developed by the US EPA, the State of New Hampshire, and the City of Manchester, the Urban Ponds Restoration Program is assessing the condition of these ponds and will be recommending and carrying out restoration projects to improve pond ecological integrity.

Crystal Lake – Crystal Lake is used for public swimming, fishing, boating and features numerous lakeside homes and cabins. In general, water quality in Crystal Lake appears to have improved since sampling was conducted in the early 1980's. The creation of a pond preservation society at Crystal Lake, which has worked to improve the health of the lake, may be at least partially responsible for the reduction of phosphorus and algae concentrations there.

Dorrs Pond – Dorrs Pond is used for fishing, passive recreation such as hiking and biking, and education. Historically, it has been used for ice harvesting, swimming, and industry. The water quality of Dorrs Pond appears not to have changed significantly since sampling was conducted in the early 1980's. Although urban development has progressed in the Dorrs Pond watershed over the last twenty years, the overall water quality does not reflect any drastically negative changes. The water quality of this pond seems to have been poor for at least the last twenty years.

Maxwell Pond – Maxwell Pond is used for fishing, hiking and education. In years past, it was the location of an ice harvesting operation, and popular as a swimming hole in the summer. Similar to Dorrs Pond, the water quality of Maxwell Pond has not significantly changed since sampling was conducted in the early 1980's. The water quality parameters reflect that of a fairly typical New Hampshire lake. Though phosphorus and conductivity levels are slightly high for New Hampshire, Maxwell Pond is one of Manchester's cleaner urban ponds.

McQuesten Pond – McQuesten Pond is used for birdwatching and wetlands education. At two feet deep, it is barely able the be classified as a pond at all. The McQuesten wetland area is very rich in life, featuring more than twenty bird species. The water quality of McQuesten Pond reflects the biological productivity that is inherent in an urban wetland. The area is abused by illegal dumping and encroached upon by large areas of pavement. It is also being overtaken by exotic plant species.

Nutts Pond – Nutts Pond is used for light fishing and its surrounding lands used for walking and biking. Historically, Nutts Pond was a popular summer destination for swimming and other water activities. The water quality of the pond has been poor for at least the last thirty years, since municipal sewage was discovered discharging into the pond in the late 1960's. Phosphorus levels have fallen and clarity has improved over the last twenty years, however. Nutts Pond is now the recipient of a large amount of untreated urban runoff causing nutrient and chemical loading.

Pine Island Pond – Pine Island Pond is used for boating, fishing, and occasional swimming. In the past, the pond was the site of a popular amusement park which included a swimming area. The water quality of Pine Island Pond seems to have declined since sampling was conducted in the early 1980's.

Phosphorus and chlorophyll *a* concentrations are currently twice as high as a typical New Hampshire lake. Pine Island Pond's one saving grace may be its high flushing rate; a function of its status as an impounded brook.

Stevens Pond – Stevens Pond is used for open-water and ice fishing and supports a valuable wetland ecosystem. The water quality of Stevens Pond reflects the fact that a major Interstate highway looms above it. Nutrient levels are much higher than ideal, but seem to have decreased since sampling was conducted here in the early 1980's. Along with Nutts Pond, Stevens Pond seems to have the most severe nutrient loading problem.

After more chemical and biological data is collected during 2001, prioritization of possible pond restoration projects will begin. Meanwhile, as further investigation progresses, smaller scale projects will be undertaken to rectify easily remedied problems such as erosion washouts or small untreated drain outfalls.

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Introduction

The Manchester Urban Ponds Restoration Program (UPRP) has been established to assess the health of seven of Manchester's urban ponds (Crystal Lake, Dorrs Pond, Maxwell Pond, McQuesten Pond, Nutts Pond, Pine Island Pond, Stevens Pond) and then take steps to restore these ponds, to the greatest extent possible, to a cleaner, healthier condition. Historic uses of these ponds include swimming, fishing and boating, but recently these activities, for the most part, have become impossible due to the poor water quality of the ponds. One of the stated objectives of the Restoration Program is to restore the ponds to their historic uses within five years of the Program's inception.

The UPRP is part of a greater environmental effort underway in Manchester. As part of a solution to address Manchester's combined sewer overflows, six Supplemental Environmental Projects were conceived, including the Urban Ponds Restoration project. The Supplemental Environmental Projects are outlined in Appendix A. The UPRP is overseen by the Manchester Conservation Commission. The five other projects are: Environmental Education Curriculum Development, Children's Environmental Health Risk Reduction, Stormwater Management, Streambank Stabilization, and Wetlands/Land Preservation. These projects will increase awareness and improve environmental conditions in the city.

An objective of the first year of the UPRP was to gather baseline data regarding the current water quality conditions, and identify threats to the future health of these ponds. This objective was met. The study was overseen by the Manchester Conservation Commission and conducted by the staff of the Manchester Urban Ponds Restoration Program, with the help of community volunteers, and with funding from the City of Manchester. The majority of the fieldwork was conducted from April through October of 2000. The current water quality is described herein, and possible recommendations for the reduction of pollution inputs are discussed.

This report is organized in such a way to allow for ease of reproduction of individual pond sections. The aspects covered here (shoreline surveys, water quality, recommendations), are discussed for each pond studied. Comparisons between various data years whenever available, and between different ponds are also included where appropriate. Manchester's seven urban ponds are each quite different from one another, and each face unique challenges posed by our urban landscape.

One of the goals of the program's first year was to assess and summarize the situation at each pond and recommend possible actions to improve these situations. To recommend specific solutions to pond issues at this point is certainly possible, but the formulation of a "long term pond plan" is still a bit premature. After a full assessment has been satisfactorily made, "long term pond plans" can be developed. Specific solutions to some pond issues include erosion control measures, urban runoff treatment measures, and proper trash disposal among other things.

Shoreline Surveys

Shoreline surveys were conducted at all seven ponds during the spring and summer of 2000. The purpose was to collect information about existing or potential problem areas on pond shorelines. Problem areas targeted included, but were not limited to, eroded banks, trash or other debris, invasive plant species, or inadequate buffers. The areas identified were numerous, and in many cases extreme. Some need immediate attention, while others can be considered a lower priority.

The locations of these areas were mapped using GPS equipment and also manually recorded on maps. Where possible, the surveys were conducted from the shoreline. In cases where the shoreline was inaccessible, the survey was conducted by boat.

This information will be used to plan pond restoration activities in the most beneficial, efficient and logical manner possible. From these shoreline surveys, a list has been compiled of the most pressing pond problem areas. The list is based on the information gathered during the 2000 shoreline surveys and other sources of anecdotal and historical information. It will be updated as required – whether problem areas are remedied and removed, or other problem areas are identified. Possible remedies to some of the identified problems are presented in the "Recommendations" sections of this report. It is anticipated that these shoreline surveys will be complimented by shoreline vegetation percentage surveys and submerged and emergent vegetation inventories in the 2001 field season.

Water Quality

The Manchester UPRP conducted water sampling at Manchester's seven urban ponds during the spring, summer, and autumn of 2000. The New Hampshire Volunteer Lake Assessment Program (VLAP) sampling procedure, coordinated by the New Hampshire Department of Environmental Services, was used as a template for these sampling field sessions. VLAP has also created summary reports for each pond. The detailed procedure for collecting water samples is included in Appendix B. All water sample analyses (except Total Phosphorus) were performed at the NH DES Limnology Center in Concord, NH, by NH DES personnel *. TP was analyzed by NH DES Laboratory Services. The raw water quality data is included in Appendix C. The data are represented in graphs in Appendix D.

Sampling was accomplished with the help of these dedicated volunteers: Ken Cardin, Nicole Clegg, Blanche Grondin, Jennifer Drociak, David Erickson, Natalie Landry, Scott Shepard, and Steve Smith. Many thanks to these volunteers for their efforts. Due to occasional equipment difficulties, and conflicting schedules, the data are not as complete as they might have been. Presented here, are the raw data collected up to this point, with some interpretation. Given the different circumstances at each pond, the numbers representing the various parameters may not reflect that pond's water quality condition relative to any other of the ponds studied.

Water quality monitoring parameters included temperature, dissolved oxygen, pH, acid neutralizing capacity, conductivity, total phosphorus, chlorophyll *a* abundance, Secchi disk transparency, and turbidity. A brief explanation of each parameter follows. Table 1 presents a comparison of measured parameters in Manchester ponds to a "typical" NH lake.

* 311 separate analyses were performed by the NH DES Limnology Center, free of charge, which would have totaled **$2,654**.

Turbidity – 89 @ $10.00 each =	$890
Conductivity – 89 @ $6.00 each =	$534
pH – 89 @ $6.00 each =	$534
Chlorophyll *a* – 21 @ $20.00 each =	$420
ANC – 23 @ $12.00 each =	$276

Table 1
Comparison of "Typical" New Hampshire Lake Values[1]
to Manchester Pond Values[2]
2000 Sampling Season

Parameter	# of Lakes/Stns.	"Typical" NH Lake*		Dorrs Pond		Maxwell Pond		Nutts Pond		Pine Island Pond		Stevens Pond		Crystal Lake	
		Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median	Mean	Median
pH	780	6.5	6.6	7.08	7.08	6.54	6.55	6.77	6.79	6.97	7.07	7.11	7.15	6.99	6.94
Alkalinity (mg/L)	781	6.6	4.9	6.2	---	6.8	6.9	13.9	14.1	17.1	19.5	34.2	34.8	18.1	18.8
Total phosphorus (mg/L)	772	---	.012	.045	---	.014	.014	.015	.013	.024	.024	.019	.019	.011	.011
Conductivity (uMhos/cm)	768	59.4	40.0	408	---	121.8	127.3	488	454	287.1	308	769	765.5	418.7	418.0
Secchi disk (M)	663	3.7	3.2	1.1	1.0	---	---	3.2	3.3	1.9	1.9	2.6	2.6	4.3	4.5
Chlorophyll *a* (mg/m^3)	776	7.16	4.58	30.84	30.84	1.55	1.07	27.42	21.12	8.04	8.58	8.68	4.08	3.39	2.72

1) "Typical" values are summer epilimnetic values.

2) Manchester Pond Values are epilimnetic median and mean values.

* Estabrook, R. 2001. Interdepartmental Memo. NH DES. Water Division.

Temperature and Dissolved Oxygen

The dissolved oxygen concentration of a water body is directly related to temperature. At colder temperatures, water holds more oxygen than at warmer temperatures. Thus, summer dissolved oxygen concentrations are typically lower than those in cooler months. Dissolved oxygen levels are key to the health of a pond ecosystem. Aquatic organisms cannot survive in extremely low oxygen environments.

A dissolved oxygen (DO) and temperature profile is determined by measuring DO and temperature at each meter of depth from the water's surface to the pond bottom. Deeper ponds experience pronounced thermal stratification, while in shallower ponds stratification is more subtle, if present at all. Due to biological processes that consume oxygen at the pond bottom, some ponds incur a dissolved oxygen deficit in the hypolimnion (bottom layer).

Pond stratification occurs when different temperatures exist at the top, middle, and bottom layers of the water column. Generally, the deeper a body of water, the more pronounced the stratification may become. This is mainly influenced by the amount of solar energy that reaches each water layer. As the sun becomes lower in the sky in the fall, thermal stratification lessens and usually disappears completely by winter.

"Typically, the deeper the reading, the lower the percent saturation of oxygen. Colder waters are able to hold more dissolved oxygen than warmer waters, and generally, the deeper the water, the colder the temperature. As a result, a reading of 9 mg/L of oxygen at the surface will yield a higher percent saturation than a reading of 9 mg/L at 25 meters, because of the difference in water temperature." (NH Dept. of Env. Services, 1999).

pH

The lower the pH of water, the more acidic the water. The higher the pH of water, the more alkaline the water. Pond pH is crucial to the well being of pond dwelling organisms. A pH of less than 5.5 (acidic) has detrimental effects on fish growth and reproduction. A pH between 6.5 and 7.0 is considered ideal for freshwater ecosystems. The median pH for New Hampshire lakes is 6.7. (NH Dept. of Env. Services, 1999). The median pH for Manchester's ponds is 6.95.

Acid Neutralizing Capacity

Acid Neutralizing Capacity (ANC) describes the ability of water to buffer against acidic inputs, like acid rain. This is also known as a lake's alkalinity. The higher a water body's ANC, the better it's ability to buffer acidic inputs. Lakes with low ANC, typical of New Hampshire, are especially vulnerable to the effects of acid precipitation.

A desirable ANC for any lake is greater than 20 mg/L of CaCO. The average ANC for New Hampshire lakes is 6.5 mg/L. (NH Dept. of Env. Services, 1999.) The average ANC for Manchester's ponds is 17.8 mg/L.

Conductivity

Conductivity, also known as specific conductance, is a measure of the ability of water to conduct an electric current. This is determined by the number of ionic particles present in the water. High conductivity values may be indicative of non-point source pollution, but at the same time, may be affected even more dramatically by natural geologic features of the watershed.

Conductivity values for New Hampshire lakes that are greater than 100 uMhos are most likely indicative of anthropogenic sources of excess ions in the water, since the average conductivity for New Hampshire lakes is 56.8 uMhos. Anthropogenic sources include urban runoff (metals, sodium), and agricultural runoff (sediment, phosphorus). (NH Dept. of Env. Services, 1999.) The average conductivity for Manchester's ponds (epilimnion or upper layer) is 414.9 uMhos.

Phosphorus

Phosphorus is the nutrient that generally, or often limits algal production in lakes and ponds. Without excess phosphorus in the system, algal production is hindered and nuisance algal blooms do not occur. As phosphorus amounts increase, so do algae concentrations.

Phosphorus exists as a natural element, but becomes a problem when inputs from such sources as septic systems, erosion, animal wastes, and fertilizer load the water body with excess amounts. The median phosphorus concentration in the epilimnion of New Hampshire lakes is .011 mg/L. (NH Dept. of Env. Services, 1999.) The median phosphorus concentration for Manchester's ponds (epilimnion) is .022 mg/L.

Chlorophyll *a*

The concentration of chlorophyll *a* is an indicator of algal abundance. Because of the presence of chlorophyll *a* pigment in algae, the relative concentration of chlorophyll *a* in the water gives an indication of the concentration of algae. As the algae population increases, so does the chlorophyll *a* concentration.

Chlorophyll *a* concentrations greater than 10.0 mg/m^3 usually indicate an algal bloom. The mean chlorophyll *a* value for New Hampshire lakes is 7.47 mg/m^3. (NH Dept. of Env. Services, 1999.) The mean chlorophyll *a* concentration for Manchester's ponds is 12.89 mg/m^3.

Secchi Disk Transparency

Secchi disk sighting measures the depth that one can see into the water. To measure Secchi disk transparency, a black and white patterned disk is lowered into the water, and the depth at which it is no longer visible is recorded. This is indicative of actual water clarity, which is affected by the amount of algae and particulate matter (turbidity) in the water column. Secchi disk readings are somewhat subjective, but generally correlate with chlorophyll *a* concentrations and turbidity levels.

The mean transparency for New Hampshire lakes is 3.7 meters. (NH Dept. of Env. Services, 1999.) The mean transparency for Manchester's ponds is 2.6 meters.

Turbidity

Turbidity is a measure of suspended matter in the water. The more material (clay, silt, algae) suspended in the water, the higher the turbidity. These materials cause light to be scattered and absorbed, instead of transmitted in straight lines, leading to decreased water clarity. High turbidity readings are often found in water adjacent to construction sites, or waters otherwise polluted. (NH Dept. of Env. Services, 1999.)

The median turbidity for New Hampshire lakes is 1.0 NTU. (NH Dept. of Env. Services, 1999.) The median turbidity for Manchester's ponds is 1.55 NTU.

Manchester's Ponds

A description of findings for each of Manchester's ponds follows. Water quality measurements for Crystal Lake and Dorrs Pond are summarized in Tables 2 and 3.

Crystal Lake

History

Crystal Lake, once known as Skenker's Pond (Potter, 1856) and later as Mosquito Pond, occupies approximately 19 acres in Manchester's south end. It is accessible by Bodwell Road where a city park provides a swimming beach and picnicking facilities. Camps and houses surround most of the pond, except for the southwestern end where wetlands prevail.

A brief probe into the history of this water body tells us that it has a history of recreational use, over the last century. Before the early twentieth century, not much is recorded about the pond's history. In 1919, the City of Manchester created a municipal bathing area on 19 acres at the pond's north end. This consisted of a bath house and picnic grounds near the beach (Connor, et. al., 1985). This area was used for city-sponsored swim meets in the 1920's for Manchester children (Manchester Park, Common and Playground Comm., 1929). Due to the area's popularity, "the accommodations at Crystal Lake (were) entirely inadequate, and the bathhouse (needed to) be enlarged." (Manchester Park, Common and Playground Comm., 1928). A new bathhouse with modern improvements for an estimated 1,500 bathers was constructed and the beach was extended in 1942 by the Works Progress Administration (The Leader, 1942). In 1987, the fieldstone-constructed bathhouse underwent a renovation sponsored by the City Parks and Recreation Department (Union Leader, 1987) and still stands at the site today.

A local story tells of a man known as "the hermit of Mosquito Pond" who lived self-sufficiently near Crystal Lake. Charles Lambert came to Manchester in the 1840's and after a number of heartbreaks retreated to the woods to live a life of quiet solitude. He purchase approximately 40 acres near Crystal Lake and built his own hut using logs and old lumber that remained on the property from prior uses. He grew most of his own food and traded with local apothecaries with his home-grown herbs. Over the years his hermit lifestyle made him into a kind of local celebrity, and he became the object of many a curiosity seeker. In spite of his choice of a reclusive life, hundreds of people would visit him in the summer months (Perreault, 1984).

Mr. Lambert lived at his hermit homestead for over 60 years, spending the last two years of his life with the Sisters of Mercy at the House of St. John for aged men. Mr. Lambert passed away in 1914 and his body now lies in St. Joseph's Cemetery marked by a plain white tombstone, inscribed "The Hermit" (Perreault, 1984).

Today, Crystal Lake remains a very popular swimming spot – sometimes too popular. Recent work by the Crystal Lake Preservation Association and the N.H. Department of Environmental Services on water quality improvement projects has helped to ensure that Crystal Lake will remain swimmable and fishable for many years to come.

Shoreline Survey

The Crystal Lake shoreline survey was conducted on May 2, 2000 by Art Grindle and Joanne McLaughlin (Manchester Conservation Commission) from the shoreline.

Shoreline survey findings:

- Sediment buildup at storm drain outfall adjacent to City beach
- Sediment delta at storm drain outfall adjacent to Melody Pines
- Erosion at privately owned beaches
- Litter in bathhouse area and on public beach
- Invasive species present (*phragmites*), chemical treatment ongoing by Crystal Lake Preservation Association

Water Quality

The total phosphorus concentration (TP) measured in the epilimnion of Crystal Lake ranged from 0.013 to 0.009 mg/L, with a mean of 0.011 mg/L. This average is lower than that recorded in 1981-1982 by the NH Department of Environmental Services (DES). The mean TP published in the 1985 DES report was 0.016 mg/L, 0.005 mg/L. higher than the 2000 mean. The highest TP value recorded in the hypolimnion in 2000 was .038 mg/L., and the average was .025 mg/L. This is an average reduction of .017 mg/L since 1981-1982.

Conductivity in the epilimnion ranged from 416 to 422 uMhos/cm, with an average of 418.7 uMhos/cm. This is an increase of 113.7 uMhos/cm over the 1981-1982 DES average. The average hypolimnion conductivity also increased since '81-'82, from 315 to 417 uMhos/cm.

Composite values for chlorophyll *a* for the upper 3 meters ranged from 1.23 to 6.21 mg/m^3, with a median of 2.72 mg/m^3. This is a reduction of 19.45 mg/m^3 since '81-'82, when the median measured 22.17 mg/m^3. Secchi disk transparency ranged from 3.6 to 4.8 meters, with a median of 4.5. This is an increase in transparency of 1.5 meters since '81-'82 when the median value was 3.0 meters. This indicates a direct relationship between chlorophyll *a* content and water transparency.

The pH of Crystal Lake ranged from 6.92 to 7.11, with a median of 6.94. This is slightly lower than pH readings in '81-'82, when the median was 7.2. This difference may be attributed to the fact that pH rises in the presence of higher algal concentrations. Acid Neutralizing Capacity (ANC) ranged from 16.7 to 18.9 mg/L of CaCO with an average of 18.1 mg/L of CaCO. This is slightly lower than the '81-'82 DES average of 19.8 mg/L of CaCO.

Turbidity in Crystal Lake was relatively low ranging from 0.41 to 0.59 with an average of 0.49 (NTU).

Table 2[1]
Comparison of Crystal Lake – 1981*, 1985, 1997+ & 2000**

Parameter	7/14/1981	1985 Median	6/30/1997	2000 Mean	2000 Median
pH	7.3	7.4	7.1	6.99	6.94
Alkalinity (mg/L)	21.9	20.8	16.1	18.1	18.8
Total phosphorus (mg/L)	.043	0.02	.019	.011	.011
Conductivity (uMhos/cm)	317	316	342	418.7	418.0
Secchi disk (m)	2.0	3.0	4.5	4.3	4.5
Chlorophyll a (mg/m3)		22.17		3.39	2.72

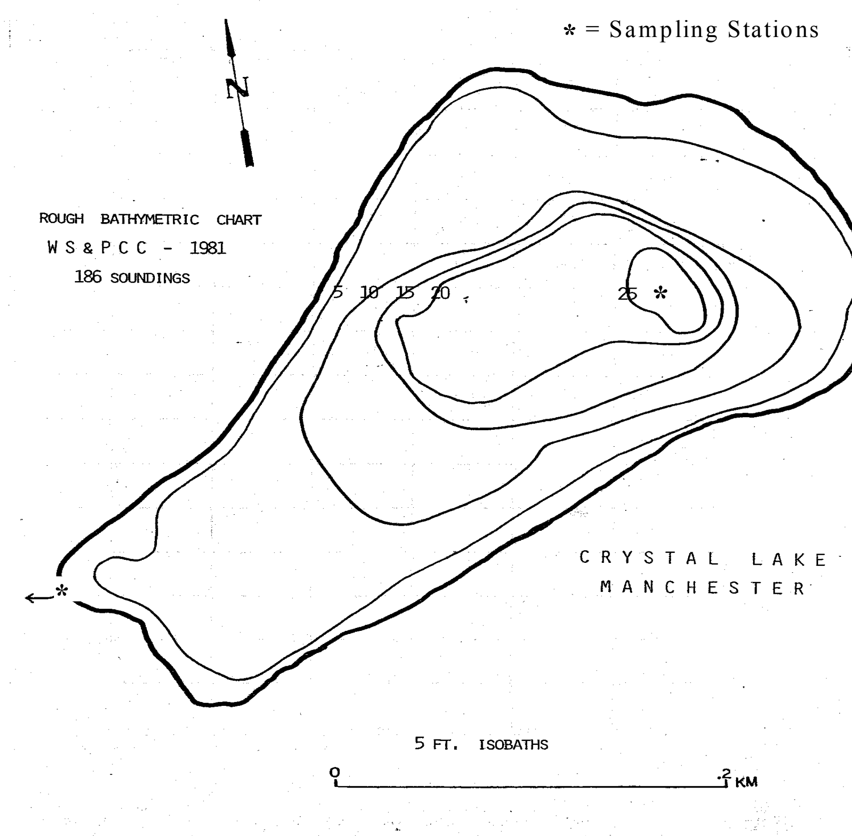
1) All values are epilimnetic values, except chlorophyll *a* which is a composite.

* NH Dept. of Environmental Services. 1981. Trophic Classification of NH Lakes and Ponds.

** Estabrook, R., et al. 1985. Urban Lakes Diagnostic/Feasibility Study. Staff Report No. 140. New Hampshire Water Supply and Pollution Control Commission.

+ NH Dept. of Environmental Services. 1998. Lake Trophic Data.

Figure 2 – Crystal Lake Sampling Stations



Recommendations

Specific solutions to pond issues include erosion control measures, urban runoff treatment measures, and proper trash disposable among other things. Specific recommendations for Crystal Lake are as follows:

1) Remediation of two storm drain outfalls that directly input to Crystal Lake. These will require engineered solutions such as settling basins and possibly the installation of a runoff treatment device such as the StormTreat system. Also required will be the revegetation of the area where the sediment is originating. Revegetation of the source of the sediment to one of the outfalls is unlikely since the source is Corning Road, a well-used city road.

2) Education of property owners along the lake's shoreline in the wise maintenance of beaches, since erosion in these areas is ongoing.

3) Treatment of invasive aquatic plant species (*phragmites*). Chemical treatment has been applied in the recent past with some success. This treatment should and will be continued.

4) Increased maintenance of the bathhouse and general beach area. This area is routinely cleaned up by the Crystal Lake Preservation Association as well as the Parks & Recreation Department. These activities should and will continue.

5) Maintenance of the StormTreat system installed at the lake's north end in 1999. Ensuring that the system is operating at 100% effectiveness should be a priority.

The largest issues facing Crystal Lake are its high volume of recreational use and pond-side development.

Dorrs Pond

History

The history of Dorrs Pond dates back to the days of Manchester's early settlers. It has played host to many activities over the decades, both utilitarian, and recreational. Many of these activities have taken their toll on the pond's ecosystem. Though a thriving, natural freshwater ecosystem exists there today, it is an artificial pond first created to serve the people of Manchester (or Derryfield at the time).

In 1736, Archibald Stark moved to what is now Manchester from Londonderry and settled on the Thaxter grant near Amoskeag Falls. After his death in 1758, his property was divided among his four sons, one of which was John Stark - the future Revoluntionary War hero (Rowell, 1904). The parcel of land that John inherited encompassed the area of Ray Brook and what is now Dorrs Pond. It was on Ray Brook that John Stark ran a sawmill for many years, presumably put there by his father.

Various historical accounts say that Stark was working at the Ray Brook mill when he heard of the fight at Lexington in April of 1775 (Willey, 1896). General Stark immediately left to fight the British and went on to become one of the leading figures of the Revolutionary War. The sawmill was apparently abandoned during the years of the War, and the remains of the dam at the sawmill site could be seen during low water until at least the late 1890's. Stark also owned a mill at Amoskeag Falls and it has been reported that this was the mill where he was working when he left for the War (Moore, ca. 1940's). The true accounts of that historic day will most likely never be known for sure.

Sometime in the mid-1800's, George Horace Dorr, a successful realtor and auctioneer, bought this North Manchester property. In 1862 Ray Brook was dammed, creating an artificial impoundment which was to become Dorrs Pond. Beginning in 1863, ice was harvested here in the winter for sale to the people of Manchester. At the time there existed a 100-foot by 60-foot ice house on the property, and the business supported 22 workers (Seney, 1998). It is also reported that when circuses came to Manchester during this period, elephants where taken to Dorrs Pond to wash and cool down (Seney, 1998).

Early in the twentieth century, the property had come to belong to the Amoskeag Manufacturing Company. Amoskeag removed the dam and drained the pond, ironically due to its biological richness and what the company called "nuisance" sport fishing for the state-stocked German carp (Weigler, 1983). In 1923, Amoskeag deeded the property to the city for conversion into a summer swimming area. The dam was reconstructed to raise the water level, bath houses were built, and sand was hauled in to create a beach. After these developments, recreational use of the pond increased to such a point that the Beech Street trolley was extended to transport the hundreds of beach-goers to the pond.

After 1936 however, use of Dorrs Pond as a swimming hole dropped off drastically. The Livingston Park pool was completed in that year, and it became the destination of choice for swimmers on hot summer days (Weigler, 1983). In the following decades, focus shifted from the natural areas of the park to new areas designed for more specific uses, such as athletic fields and playgrounds. In the 1970's, the pond-side nature trails were groomed and mulched by the Manchester Garden Club and the city Parks and Recreation Department but no pond or trail management plan has ever been created.

Today the pond and its surrounding woods provide a pocket of natural beauty in Manchester's urban environment. It still attracts many nature lovers, but plenty of trouble-makers as well. The secluded nature of the park seems to be a double-edged sword. It provides escape for those seeking relief from asphalt and concrete, but also presents opportunities for less wholesome activities. As restoration efforts move forward, historic uses may once again be the rule instead of the exception at Dorrs Pond.

Shoreline Survey

The Dorrs Pond shoreline survey was conducted on May 2, 2000 by Art Grindle and Joanne McLaughlin from the shoreline.

Shoreline survey findings:

- Sediment input from upstream Lessard's Brook
- Tributaries on east side apparently impacted by road runoff
- Tributaries on west side impacted by trail traffic
- Litter all around pond, especially in "picnic" areas
- Trails degraded
- Dam in need of debris clean up (periodically)

Another issue of note is that Goldfish Pond appears to be heavily polluted, possibly by highway runoff, and lies upstream of Dorrs Pond.

Water Quality

Hypolimnion dissolved oxygen readings varied greatly from month to month at Dorrs Pond. This may be due to the shallow area in which readings were taken. The August 28th high temperature reading at 2 meters of 30.7 degrees Celsius cannot be explained, and thus remains suspect. It may be a result of warm inputs, or destratification, but neither hypothesis seems very likely based on ambient air temperatures at the time and water temperatures measured later in the season.

The total phosphorus concentration (TP) measured in the epilimnion of Dorrs Pond varied from .034 to .055 mg/L, with a mean of .045 mg/L. When the pond was stratified, TP in the lower level or hypolimnion was measured as 0.088 mg/L. Two of the pond's main inlets are significant sources of phosphorus input, with Lessard's Brook averaging .171 mg/L and Inlet 2 East averaging .039 mg/L. The '81-'82 DES study found a median of .042 mg/L TP. Eighteen years apparently have not significantly changed phosphorus inputs to Dorrs Pond. These inlets drain highly urbanized areas. See Table 1 for a comparison between 1985 values and 2000 values.

Conductivity in the epilimnion ranged from 389 to 427 uMhos/cm, with a mean of 408 uMhos/cm. When the pond was stratified, the hypolimnion conductivity measured 432 uMhos/cm. As expected, the inlets also were highly conductive, averaging 707 and 414 uMhos/cm each. These are very high conductivity levels, most likely caused by the large amount of urban runoff that this location receives. Conductivity levels in '81-'82 were significantly lower, by 119 uMhos/cm. The DES study found an average epilimnion conductivity of 289 uMhos/cm.

Composite values for chlorophyll *a* for the upper 1.5 meters ranged from 15.86 to 45.81 mg/m^3, with a median of 30.84 mg/m^3. This was lower than the '81-'82 DES findings, where the median was 38.84 mg/m^3. These readings indicate a highly productive water body. Composite samples are derived from combining water samples from each meter of the water column from the midpoint of the metalimnion (middle layer) to the surface.

Secchi disk transparency ranged from 0.8 to 1.5 meters, with a median of 1.0 meters. The minimum transparency was recorded in June. Water clarity and chlorophyll *a* concentrations seem to be vaguely related since water clarity is low and chlorophyll *a* concentrations are high. The '81-'82 DES Secchi disk transparency readings were slightly deeper, with a median of 1.6 meters.

The pH of Dorrs Pond ranged from 6.92 to 7.26, with a median of 7.08. pH values in June and August are higher, reflecting the fact that pH rises during algal blooms. pH values in the 1985 DES study where not significantly different than those taken in 2000. The '81-'82 median was 7.0. Alkalinity, or Acid Neutralizing Capacity (ANC) ranged from 13.3 to 19.0 mg of CaCO/L, with an average of 16.2 mg/L in 2000. The '81-'82 DES alkalinity median value was 15.4 mg/L of CaCO.

Turbidity of epilimnion samples ranged from 3.3 to 4.2 (NTU), with an average of 3.75 (NTU). This was the highest turbidity recorded in any Manchester pond. High turbidity is most likely caused in this case, by a large volume of urban runoff to this location. Turbidity measurements were not taken at Dorrs Pond during the '81-'82 DES Diagnostic/Feasibility Study.

The overall water quality of Dorrs Pond has not significantly changed over the last eighteen years, though it is slightly more degraded now, even with the continuing development in the watershed. The approximately 134 acres of city-owned forested woodland which surrounds the pond has prevented pondside development, thus providing the pond a reprieve from receiving any more direct urban runoff than it historically has.

Table 3[1]

Comparison of Dorrs Pond – 1981*, 1985, 1997[+] & 2000**

Parameter	7/14/1981	1985 Median	7/17/1997	2000 Mean	2000 Median
pH	6.8	7.0	7.1	7.08	7.08
Alkalinity (mg/L)	13.9	15.4	22.2	16.2	---
Total phosphorus (mg/L)	.060	.042	.031	.045	---
Conductivity (uMhos/cm)	201	258	469	408	---
Secchi disk (m)	1.3	1.6	1.3	1.1	1.0
Chlorophyll a (mg/m3)		38.84		30.84	---

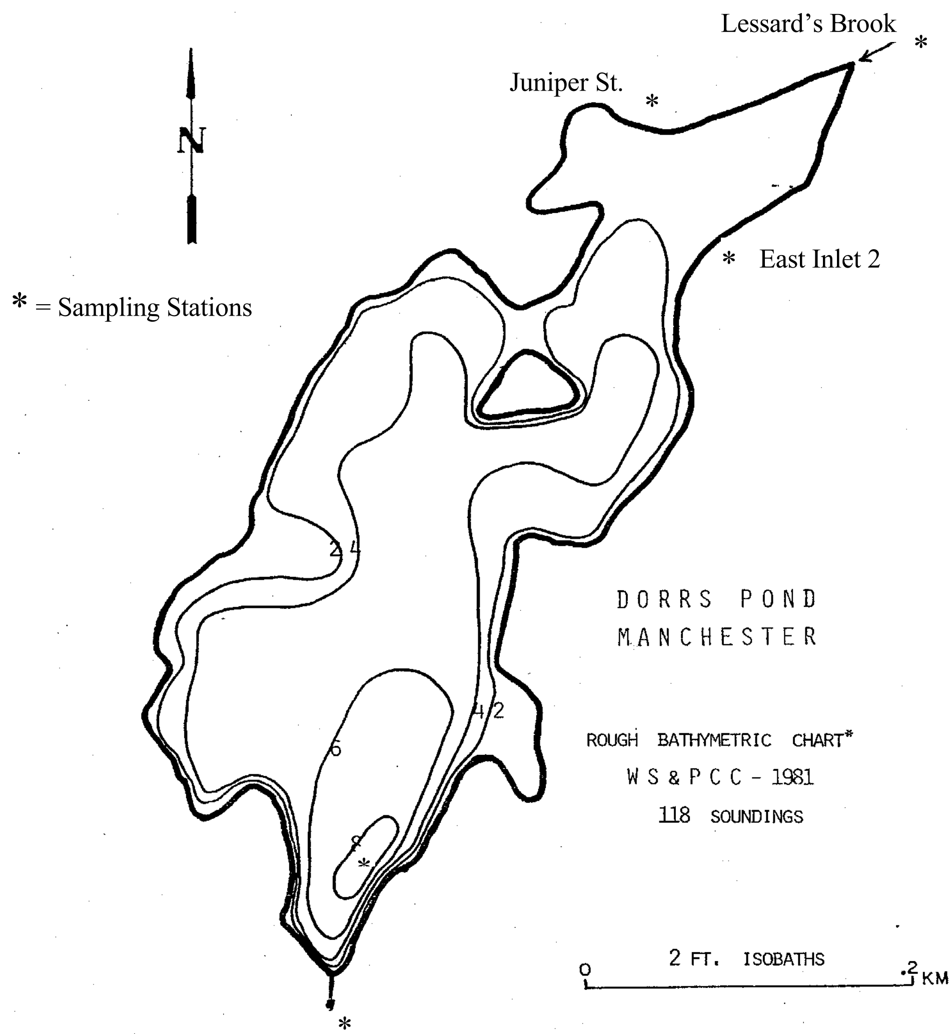
1) All values are epilimnetic, except chlorophyll *a* which is a composite.

* NH Dept. of Environmental Services. 1981. Trophic Classification of NH Lakes and Ponds.

** Estabrook, R., et.al. 1985. Urban Lakes Diagnostic/Feasibility Study. Staff Report No. 140. New Hampshire Water Supply and Pollution Control Commission.

[+] NH Dept. Of Environmental Services. 1998. Lake Trophic Data.

Figure 3 – Dorrs Pond Sampling Stations



Recommendations

Specific solutions to pond issues include erosion control measures, urban runoff treatment measures, and proper trash disposal among other things. Specific recommendations for Dorrs Pond are as follows:

1) Reduce sediment and nutrient load from main inlet (Lessard's Brook). A large amount of the nutrient load originates at Northside Plaza. Plans are already underway to treat the runoff from this area by means of a Downstream Defender.

2) Discuss with the Hooksett Conservation Commission the clean up Goldfish Pond, given its large amount of highway runoff. Goldfish Pond drains into Dorrs Pond.

3) Remediate road and industrial runoff impacting tributaries on Dorrs Pond east side. This may require engineering treatment measures in the tributaries before the flow reaches the pond, such as settling basins.

4) Eliminate disturbance of tributaries on the pond's west side caused by trail use. Installation of bike and wheelchair-friendly bridges is recommended at these intermittent stream crossings.

5) Place secure trash receptacles in areas where litter is a problem. To date, there have been trash receptacles only in areas where they are easily accessible by Parks & Rec. or Highway Department staff. The Dorrs Pond Preservation Society has organized litter clean ups in the past, but more diligence is required on the part of the City.

6) Repair and maintain trail network to reduce erosion, especially where the trail runs close to the pond's edge. This work is already ongoing, by Eagle Scouts and the Dorrs Pond Environmental Initiative – a group of concerned area citizens.

The largest issue facing Dorrs Pond is untreated urban runoff and the buildup of sediment in the pond as a whole, but specifically at its north end. Dredging of sediments may be recommended (as mentioned in the DES 1985 Diagnostic and Feasibility Study).

Maxwell Pond

History

Maxwell Pond, located on Front Street, is a small water body that, like other Manchester ponds has a long history involving many uses. Both recreational and occupational uses abounded here in decades past. Recorded accounts of Maxwell Pond's history are few and difficult to locate, but anecdotal information and memories are numerous and valuable.

Maxwell Pond was created by the installation of a dam on Black Brook in 1900. In 1954, a NH Fish and Game Department survey noted that the pond contained only warm water fish species, such as: chain pickerel, horned pout and sunfish, but was a marginal salmonid water body. There are reports, however, of fishermen catching trout here and especially upstream in Black Brook where conditions most likely would have been ideal for a trout fishery.

Maxwell Pond was reportedly named for A.H. Maxwell, who owned the Manchester Coal & Ice Company at the time ice was harvested there. Ice harvesting took place in the 1930's and 1940's, when Maxwell Pond was the best source in Manchester for pure ice. The company, located upstream, would keep the ice cold with haybales and sell it year round (Drociak, 2000).

Until the late 1950's, Maxwell Pond was a popular spot with neighborhood people for swimming, picnicking, and fishing in the summer, and skating, bonfires and hockey games in the winter. It was even considered for a secondary municipal water source for the City of Manchester, but the idea was apparently abandoned sometime in the 1960's. In the late 1950's and early 1960's Maxwell Pond began to change when a cement company located upstream began impacting Black Brook by washing sediment into the streambed.

> "For several years following, the pond became rich with algae blooms. It was then dredged yearly so that the community could resume swimming and fishing. When the dredging ceased, …this oasis became unfishable and unswimmable. The flow of sediments downstream quickly brought with it the rise of many aquatic vascular plants. Apartment complexes were also built nearby bringing the extra pressures of increased human impact." (Drociak, 2000)

Today, the pond which had a maximum depth of 8 feet in 1954, now has a maximum depth of just 4 feet. Clearly the land uses upstream have had an impact on Maxwell Pond. A few people still fish there, but with limited success. Neighborhood children use the steep hillside adjacent to the pond for sledding in the winter, but historic uses of Maxwell Pond are greatly diminished. The Maxwell Pond shoreline is much the same as it was a century ago, but characteristics of the pond itself have changed immensely. The obstacles facing the pond are relatively few, so restoration of the pond's historic uses is certainly possible in the near future.

Shoreline Survey

The Maxwell Pond shoreline survey was conducted on June 28, 2000 by Art Grindle and Joanne McLaughlin from the shoreline.

Shoreline survey findings:
- Erosion area on north side of pond near trail
- Large washed out storm drain outfall and parking lot runoff on north side
- Unvegetated banks near mouth of Black Brook on northwest side
- Litter and other debris in and around brook and pond
- Sedimentation of entire pond from upstream sources
- Invasive plant species prevalent

- Untreated storm drain outfall on Black Brook, north side

Water Quality

Dissolved oxygen levels were relatively high in relation to other Manchester ponds due to the stream-like characteristics of Maxwell Pond. The lowest dissolved oxygen saturation recorded at Maxwell Pond was 62.0% at the pond's deepest point.

Due to the fact that the deepest spot in Maxwell Pond is 1.1 meters, there was no thermal stratification, so only "surface grab" samples were necessary for in-pond sampling. Total phosphorus concentrations ranged from 0.009 to 0.02 mg/L, with an average of 0.014 mg/L. According to data from NH DES Trophic Classification of NH Lakes and Ponds, 1981, TP concentration was 0.018 mg/L. Due to the high turnover of pond volume and shallowness here, inlet samples are especially important. TP concentrations in the inlet samples (Black Brook) never rose above 0.018 mg/L and averaged 0.015 mg/L.

Conductivity of Maxwell Pond ranged from 98.76 to 133.90 uMhos/cm, with an average of 121.80 uMhos/cm. NH DES 1981 data shows conductivity at 56.0 uMhos/cm. Inlet samples ranged from 97.66 to 131.5 uMhos/cm and averaged 120.04 uMhos/cm in 2000.

In-pond chlorophyll *a* concentrations were very low, ranging from 1.07 to 2.51 mg/m^3, and averaging 1.55 mg/m^3. These low readings are most likely due to the pond's high flushing rate.

As the bottom could clearly be seen at 1.1 meters, Secchi disk transparency was >1.1 meters and could not be measured more accurately due to lack of depth.

The pH of Maxwell Pond ranged from 6.39 to 6.69, averaging 6.54. This is slightly low for NH freshwater ecosystems, but still within the range for supporting aquatic life. pH readings by NH DES in 1981 were similar at 6.4.

ANC was also consistently lower than other Manchester ponds, ranging from 4.5 to 8.7 mg of CaCO/L, with an average of 6.8 mg/L. In 1981, NH DES found ANC to be 6.4 mg/L. Maxwell is therefore less able to buffer acidic inputs, which may help explain the low pH readings.

Turbidity in Maxwell Pond ranged from 1.15 to 2.90 (NTU) and averaged 2.03 (NTU). NH DES 1981 turbidity readings were a bit higher at 4.3 (NTU).

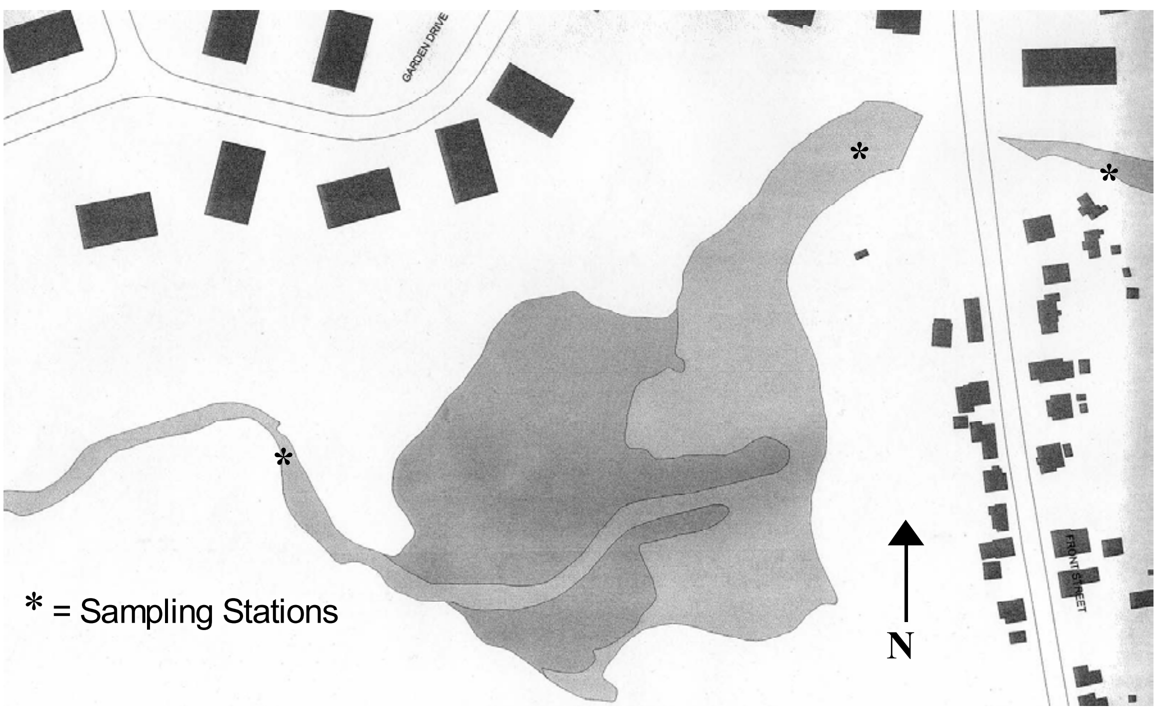
Table 4[1]
Comparison of Maxwell Pond – 1981* and Maxwell Pond – 2000

Parameter	1981	2000 Mean	2000 Median
pH	6.4	6.54	6.55
Alkalinity (mg/L)	7.0	6.8	6.9
Total phosphorus (mg/L)	.018	.014	.014
Conductivity (uMhos/cm)	56.0	121.8	127.3
Secchi disk (m)	>1.2	>1.1	

1) All values are epilimnetic.

* NH Dept. of Environmental Services. 1981. Trophic Classification of NH Lakes and Ponds.

Figure 4 – Maxwell Pond Sampling Stations



Recommendations

Specific solutions to pond issues include erosion control measures, urban runoff treatment measures, and proper trash disposal among other things. Specific recommendations for Maxwell Pond are as follows:

1) Revegetate eroded areas of pond bank on the north side of the pond. Several areas have been stripped of

vegetation due to a high volume of foot traffic. These areas need to be restored to reduce erosion that is now occurring.

2) Remediate storm drain outfall from adjacent apartment complex to reduce flow velocity and reduce nutrient load by possibly installing a series of detention basins, in cooperation with the property owner.

3) Identify sources of sediment upstream on Black Brook and take steps to eliminate those sources.

4) Place secure trash receptacles in Blodgett Park – there are none presently in this area at all.

The largest issue facing Maxwell Pond is sedimentation from upstream sources.

It is also recommended that the NH Fish and Game Department consider the possibility of the installation of a fish passage system over the dam that currently impounds Maxwell Pond. Black Brook appears to be ideal cold water fish (such as trout and salmon) habitat. With future sedimentation reduction in Black Brook, fish stocking may become a viable option. The possibility also exists for dam removal, thus restoring Black Brook to its natural condition and providing unhindered anadromous fish passage in the future.

McQuesten Pond

History

McQuesten Pond is a relative little known pond on Manchester's West Side. It is a unique pond in that its deepest spot is only about 18 inches. This area supports a rich and diverse wetland ecosystem that is particularly special because of its proximity to urban surroundings. It exists precariously, buffered by horribly inadequate wooded areas, and impacted by urban runoff.

Very little can be found regarding the history of McQuesten Pond, or Mallard Pond, which it is sometimes called. This may be due in part to the ponds status as private property, divided up among several land owners. The pond itself is, to some extent, an artificial impoundment. There is a stone weir in the upper portion of the pond, and an earthen dam extending nearly across the pond in the lower portion. These two structures create three pond "sections". No records can be located regarding how or when these structures came to be. From 1991 through 1995, West High School science classes used the pond as an outdoor classroom to explore and learn about its wetland ecosystem, under the direction of Ron Miller. The students involved conducted, among other things, a species inventory including wetland plants, upland plants, birds, amphibians, reptiles, fish, mammals, and aquatic invertebrates.

McQuesten Pond has fallen victim over the years to neglect and abuse, like so many other wetland areas across the country. With cooperation of the land owners who own the pond itself, restoring this pond to a more natural state can be accomplished through education and dispelling the idea that wetlands are "wastelands".

Shoreline Survey

The McQuesten Pond shoreline survey was conducted on May 2, 2000, by Art Grindle and Joanne McLaughlin from the shoreline.

Shoreline survey findings:

- Invasive species prevalent (Japanese knotweed, purple loosestrife, *Phragmites*)
- Litter and debris in and around pond on 2nd Street side (illegal dumping)
- Paved parking areas within 10 feet of pond on 2nd Street side
- Heating oil tank in tributary, as well as other debris
- Large buildup of organic debris in pond
- Tributary pollutant inputs suspected
- Dumpster and cooking grease storage within 10 feet of pond with no treatment

Water Quality

Inlet and outlet samples were taken at McQuesten Pond, without any in-pond samples. McQuesten Pond is less than 18 inches deep in any spot so in-pond sampling was not appropriate in this case. The flushing rate of the ponded area of the McQuesten wetland complex is high, so the inlet and outlet samples are believed to be adequately representative of the larger water body.

Total phosphorus concentrations in the inlet ranged from 0.013 to 0.024 mg/L, averaging 0.020 mg/L. Outlet TP concentrations were higher ranging from 0.059 to 0.109 and averaging 0.088 mg/L. The differences between inlet and outlet concentrations may be attributed to phosphorus inputs from the commercial business strip directly adjacent to the east side McQuesten Pond on Second Street, or to internal phosphorus loading.

Inlet conductivity levels ranged from 501 to 641 uMhos/cm with an average of 585 uMhos/cm. Outlet conductivity levels ranged from 372 to 553 uMhos/cm with an average of 480 uMhos/cm. This may indicate that some settling is occurring in the pond itself.

McQuesten inlet and outlets had an average pH of 6.95 with very little difference between the two sampling locations.

Inlet turbidity ranged from 1.82 to 5.0 (NTU) and averaged 3.74 (NTU). Outlet turbidity ranged a bit higher from 2.6 to 7.2 (NTU) and averaged 5.43 (NTU).

McQuesten Pond is in essence, little more than a flooded wetland. It is highly biologically productive partly because of its shallow depth. Therefore, it is realistically inappropriate to compare this water body to other typical New Hampshire lakes and ponds.

Figure 5 – McQuesten Pond Sampling Stations

Recommendations

Specific solutions to pond issues include erosion control measures, urban runoff treatment measures, and proper trash disposable among other things. Specific recommendations for McQuesten Pond are as follows:

1) Clean up east side of pond and remove debris. Large amounts of refuse have been dumped in the area abutting the Second Street commercial zone. It is recommended that some type of fence or other barricade be installed in this area to prevent future dumping.

2) Treatment of invasive plant species. A substantial stand of Japanese Knotweed (*Polygonum* sp.) exists in the same general area where dumping has become a problem. It may be possible to cut these plants and chemically treat the stumps to prevent regrowth. Simultaneously planting competitive native shrubs in this area may also help eradicate the invasive species present.

3) Treat parking lot runoff from Second Street businesses. There are existing paved parking areas within ten feet of the water's edge in at least one area. It is recommended that the property owners/management be educated about the impacts that untreated parking lot runoff has on water bodies, and possibly work with them to move the edge of pavement further from the water's edge. Certain activities on these parking areas, such as cooking grease storage and winter salt/sand use, are contributing to the nutrient load reaching McQuesten Pond. It is recommended that some kind of working partnership be created between the City and the businesses in this area to remediate the problems that these large paved areas present.

The largest issue facing McQuesten Pond is runoff and debris dumping from adjacent urbanized areas.

In June of 2000, For Manchester received a $4,000 grant from Wal-Mart/Sam's Club for a habitat enhancement project at McQuesten Pond. Plans are currently ongoing to improve the buffer area between the Second Street commercial area and the pond. The project is being carried out by the Manchester UPRP.

Nutts Pond

History

Nutts Pond has played an important part in Manchester history since the city's earliest days. It has been the location of summer fun and winter commerce over the years but today serves only as a testament to what urban encroachment does to an aquatic ecosystem. This pond is one of Manchester's few natural ponds to have never been dammed. The remains of a weir are located in the outlet, Tannery Brook, but the pond's physical characteristics are relatively unchanged from its original state.

Since colonial times Nutts Pond has been known by more than one name. In the mid-1800's, it was known as Fort Pond, but "in ancient time(s) was known as Swager's Pond" (Potter, 1856). It came to be known as Nutts Pond shortly thereafter, named for a popular local circus midget, Commodore Nutt. At that time, the Nutt family farm was situated near the pond.

The pond has been put to many uses over the years. Archeological evidence discovered in 1976 substantiates historical records of the existence of a fort on the north shore of the pond (Slown, 1987). In 1746, Archibald Stark, seeing a necessity for a safe haven for colonists from Native American attacks, built a wooden garrison at this site (Manchester Leader, 1929).

> "Captain Goffe, in whose honor Goffe's Falls was named, offered his home as a place of refuge in Indian attacks but these attacks grew so numerous and so vicious that the home was not safe. It was at that time in 1746 that Stark fort was built and the well was dug under the direction of Lieut. Archibald Stark." (The Manchester Leader, 1929).

The well still exists at the site today although it has long since been filled in. The Manchester Coal and Ice Company, which owned the lot in 1928, deeded the well and a 15' by 30' lot surrounding it, to the Molly Stark Chapter of the Daughters of the American Revolution (DAR) on December 24, 1928. The DAR erected a fence around the area and placed a boulder at the site with a bronze marker reading " Built by Archibald Stark, father of General John Stark, 1746. Erected by Molly Stark Chapter, D.A.R. – 1929." The site was dedicated in a Flag Day ceremony on June 14, 1929 (The Manchester Leader, 1929).

The Manchester Coal & Ice Company harvested ice at Nutts Pond until at least the 1920's, but preceeding them were at least two other ice companies. Ice harvesting at Nutts Pond probably began about 1860 by A.L. Walker, followed by Dickey & Young, and then L.B. Bodwell & Company (The Mirror, 1899). Nutts Pond ice was described by The Mirror in 1899, as pure, sweet and clear.

> "Nutt's Pond ice…is the purest, cleanest and best of ice. There isn't a dwelling house, or a house of any sort, near the pond shore except the Waumbeck, the office structure and cottage belonging to the ice dealers. From January to January every precaution is taken to prevent any contamination of the pond's water." "Few people are aware that even the water of Nutt's Pond is especially good water and yet such is the fact. Hence it follows that Nutt's Pond ice, considering the utter absence of harmful influences, is better ice than ordinarily good ice. The early settlers found a colony of Indians around Nutt's Pond, Potter's History of Manchester tells us, and the first white men patronized a famous well close to the pond shore. The well is still there, together with remains of the Indian forts. The old well was supplied by some of the springs which help to make Nutt's Pond." (The Mirror, 1899).

By 1938, Nutts Pond had become a popular swimming and recreation area. A 1938 NH Fish and Game Department survey indicates that the pond was routinely treated with chlorine due to the high volume of bathers, thus preventing any fisheries management plan on the part of the Fish and Game Department. In 1951, the area now known as Precourt Park, on the pond's north side, was sold to the city by the Manchester Coal & Ice Company. It was named Precourt Park in honor of Anthony Precourt, who was then the

Superintendent of the Parks and Recreation Department (Slown, 1987). Incidentally, Albert J. Precourt had been treasurer of the Manchester Coal & Ice Company in past years.

During the 1950's and 1960's, Nutts Pond gained popularity as a swimming area and as result the Parks and Recreation Department installed a large scale chlorination system to treat high bacteria levels (Slown, 1987). However, water testing after chlorination revealed that high bacteria levels still prevailed and the pond was closed to public swimming in July, 1968. It was later ascertained that the bacterial pollution was the result of a combined sewer outfall that emptied into the pond at a point near the swimming area. Though new sewer systems were installed in the area to accommodate large scale commercial and multi-family housing developments, the pollution of Nutts Pond became an increasingly serious problem during the 1960's and 1970's (Slown, 1987.) Sewerage was no longer the problem, however, commercial and industrial development of much of the Nutts Pond watershed forced the pond to become a depository for untreated stormwater runoff, causing a significant chemical and organic pollution load.

After three water quality studies, the last of which was conducted in 1975, Bernard M. Reen, Manchester Public Works Director, declared Nutts Pond permanently closed to public swimming due to pollution from runoff. He called it "part of the price we pay for progress." (Slown, 1987). In the mid 1980's, certain city officials argued for the filling and eventual development of Nutts Pond. These ideas were never pursued, presumably because of the pond's value as a flood water storage facility.

Various groups have held pond clean ups in recent years in attempts to address the substantial amount of litter and other solid waste around and in the pond. The amount of waste removed is usually replaced in full in a short time, however. There is still interest in Nutts Pond as a natural resource though. Weekday lunch-time visitors frequent the pond to watch wildlife or just enjoy a few quiet moments by the pond, and weekend visitors enjoy fishing and exploring the existing trials beside the pond. If appreciation can be built, and awareness raised, Nutts Pond can once again become the natural treasure for which it has the potential.

Shoreline Survey

The Nutts Pond shoreline survey was conducted on May 2, 2000, by Art Grindle and Joanne McLaughlin from the shoreline.

Shoreline survey findings:

- Sediment deltas at storm drain outfalls (3) on north and south ends of pond
- Significant erosion at edge of parking area in several spots
- Large amounts of litter and debris in and around pond
- Areas near Tannery Brook outlet & inlet degraded and littered
- Large amounts of solid waste on west side of pond near railroad bed
- Several eroded areas along west edge of pond
- Entire trail along west side of pond degraded and heavily littered
- Tannery Brook inlet significant source of nutrient input (heavy sedimentation)
- Untreated runoff from PSNH property channeled toward pond

Water Quality

Nutts Pond, being over 9 meters deep, was stratified before sampling began in April of 2000. Each sampling session found a clearly defined epilimnion, metalimnion, and hypolimnion. Dissolved oxygen was almost nonexistent in the lowest depths of Nutts Pond, regularly measuring as low as 1.0% DO saturation. These kinds of anoxic conditions preclude most aquatic life in these areas.

The hypolimnion held the highest concentrations of phosphorus ranging from 0.017 to 0.270 mg/L and averaging 0.099 mg/L. These are by far the highest TP concentrations of any Manchester pond. This is likely due to runoff from surrounding commercial and recreational areas. Epilimnion TP values ranged from 0.010 to 0.023 mg/L and averaged 0.017 mg/L.

Conductivity levels also were very high, especially in the hypolimnion, where readings ranged from 1559 to 1940 uMhos/cm, and averaged 1769 uMhos/cm. This was found to be related to metals contamination when samples were analyzed for various metals concentrations. The most significant metals found were iron (58.3 mg/L) and sodium (319.0 mg/L) in the hypolimnion. Epilimnion conductivity ranged from 392 to 695 uMhos/cm, and averaged 485 uMhos/cm.

Composite chlorophyll *a* concentrations for the upper metalimnion and epilimnion ranged from 2.54 to 62.76 mg/m^3 and averaged 24.83 mg/m^3. This is a high concentration considering the "typical" value for a NH lake is 3.9 mg/m^3.

Secchi disk transparency and chlorophyll *a* content appeared to be independent of each other. Transparency ranged from 2.0 to 4.3 meters, and averaged 3.1 meters. This is relatively high transparency considering the thick chlorophyll *a* concentrations.

Nutts Pond pH values ranged from 6.70 to 6.84 and averaged 6.77. This is within the range considered ideal for freshwater ecosystems.

The ANC values ranged from 13.2 to 14.6 mg of CaCO/L and averaged 13.9 mg/L.

Turbidity was high in Nutts Pond, especially in the hypolimnion where values ranged from 1.03 to 64.0 (NTU) and averaged 39.8 (NTU). Epilimnion turbidity values were low, averaging 0.93 (NTU). The high turbidity in the hypolimnion may be due to metals contamination.

Table 5[1]

Comparison of Nutts Pond – 1981*, 1995 & 2000**

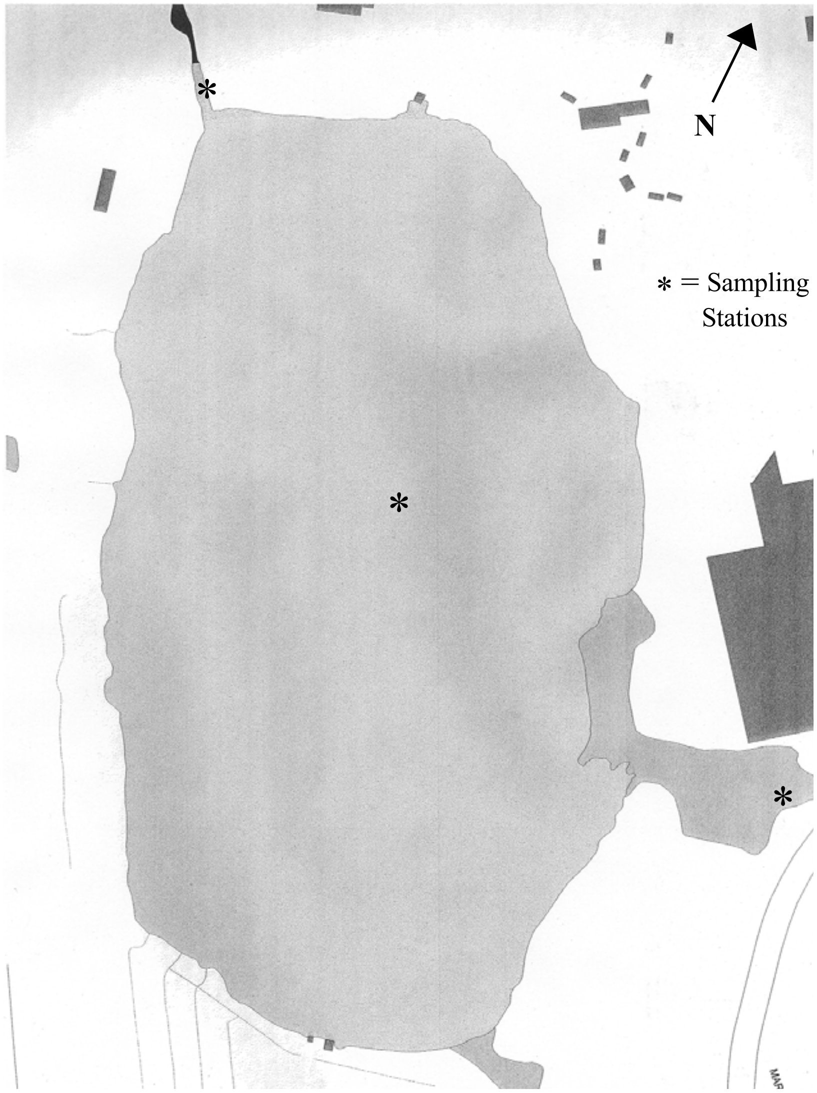
Parameter	1981	1995	2000 Mean	2000 Median
pH	7.1	8.9	6.77	6.79
Alkalinity (mg/L)	12.0	15.8	13.9	14.1
Total phosphorus (mg/L)	.025	.025	.015	.013
Conductivity (uMhos/cm)	194	567	488	454
Secchi disk (m)	2.5	2.5	3.2	3.3

1) All values are epilimnetic.

* NH Dept. of Environmental Services. 1981. Trophic Classification of NH Lakes and Ponds.

** NH Dept. of Environmental Services. 1996. Lake Trophic Data.

Figure 6 – Nutts Pond Sampling Stations



Recommendations

Specific solutions to pond issues include erosion control measures, urban runoff treatment measures, and proper trash disposal among other things. Specific recommendations for Nutts Pond are as follows:

1) Remediation of three storm drain outfalls that input directly to Nutts Pond. These will require engineered solutions such as moving the outfall, installing settling basins, swales, or mechanical treatment devices. Two of the outfalls are at the pond's south end and are fed by street drainage from March Avenue. The other outfall is at the pond's north end and is fed by street drainage from South Willow Street, Driving Park Road, and Leclerc Circle.

2) Reconstruct and revegetate several eroded areas on the north end of the pond. The most severely eroded area is caused by the draining of the paved parking area toward the pond. The parking area may need to be regraded to effectively remedy this situation.

3) Clean up debris and other refuse all around (and in) the pond, especially at the Precourt Park parking area. The trash receptacles that exist there now routinely overflow with trash from neighboring restaurants. More receptacles are needed, as well as more frequent trash collection at this site. Regularly scheduled community clean ups are recommended. A neighborhood public awareness campaign would also help.

4) Landscape and revegetate area on the west side of the pond near Tannery Brook. This is a degraded gravel area worn by foot traffic and ATV's. The area is wooded and could be a pleasant pond-side park with some landscaping and policing. There is an historic wellhead at this site that should be listed on an historic register (either state or national). This would add to the value of this particular area as an urban pond-side park. It is recommended that the historic site become registered and the area be redeveloped as parkland.

5) Clean up debris on west side of the pond near the railroad bed. This area has been abused as a dumping ground for construction and other debris.

6) Create trail network on west side of the pond where there is now an existing gravel road. There are several eroded areas along the pond's west edge that are used as fishing perches by neighborhood children. There are usually broken bottles, beer cans, graffiti, and other trash present in this area. By improving the trails and encouraging more passive public use, this area can become valuable open space. It is also recommended that the City secure an easement along the pond's south edge that Public Service of New Hampshire currently owns. With this, a pond circuit trail could be created for public use.

7) Investigate suspicions that bottom sediments are contaminated with metals, PCB's and other chemicals and take steps to remedy the situation. Depending on what is discovered, dredging may be recommended. Water samples taken near the pond bottom have been found to contain very high levels of iron, sodium and chloride.

8) Reduce sedimentation occurring at Tannery Brook inlet. Where Tannery Brook flows under March Avenue near Home Depot, there is a large sedimentation problem. The now culverted Tannery Brook needs to be accurately mapped to determine where the sediment comes from and how best to address it. Working closely with the Storm Water Control portion of the SEPP is recommended.

9) Treat sheet runoff from the PSNH property, suspected of containing PCB's or other chemicals. Creation of a pond-side buffer on the south end of the pond is recommended, as well as targeted water sampling to detect any contaminants.

The largest issue facing Nutts Pond is untreated urban runoff from heavily used paved areas.

NH DES, in cooperation with the Manchester UPRP, is planning a Diagnostic/Feasibility Study on Nutts Pond in 2001-2002. This will be an in-depth analysis of the water quality and watershed of Nutts Pond.

Pine Island Pond

History

Among Manchester's urban ponds, Pine Island Pond may be historically, the most famous due to its hosting of a popular amusement park. Like so many other Manchester ponds, Pine Island Pond is an artificial impoundment created by a dam at its outlet. This has created a natural jewel in Manchester's quickly growing South end. Several homes and cottages occupy the pond's northwestern shore, and it is bordered on its eastern side by a city road and Manchester Airport.

Over the years, Pine Island Pond has been heavily used for recreational as well as educational purposes. In 1902, Manchester Traction, Light & Power Company opened Pine Island Park – an amusement park with rides, games, a roller rink and dance hall. A swimming area was also featured at the pond. In its heyday, the park would attract fun-seeking patrons from as far away as Boston. Easy access to the park was provided by a trolley car line owned by Manchester Traction, Light & Power. Through its duration, the park endured hurricanes and fires, but was ultimately unable to keep up with progress (Clayton, 1993). After struggling for decades, the park closed in 1962.

In recent times Pine Island Pond has been the subject of some contention. It was completely drained at one point to the dismay of neighborhood residents and another time was proposed for filling and development. The current Pine Island Park, a playground and passive recreation area, was once the site of 4-H educational center until it was lost to a fire. The park now consists of interpretive nature trials that meander along part of the shoreline, created as an Eagle Scout project. A new playground was also recently constructed at the site.

Pond side residents have always been concerned when it comes to the future of Pine Island Pond. It is widely agreed among long-time Pine Island Pond neighbors that the pond seems to be filling in with sediment rather quickly. It is still a fairly popular and productive fishing spot, but as the pond continues to become shallower, this situation is sure to change. Historic uses of the pond have not been altered greatly over the years, however, pond-front property owners are reluctant to swim there these days. Urban runoff has yet to make an irreversible difference at Pine Island Pond, although the effects are certainly becoming apparent.

Shoreline Survey

The Pine Island Pond shoreline survey was conducted on May 16, 2000, by Art Grindle and David Erickson by boat.

Shoreline survey findings:

- Sedimentation at mouth of Cohas Brook
- Large outfall from airport on south end of pond
- Untreated road runoff from 3 storm drain outfalls on north end of pond
- 2 culverts of unknown origin near insurance company
- Culvert of unknown origin on east side of pond

Water Quality

In 2000, Pine Island Pond had been stratified since before sampling began there in May. Under stratified conditions, dissolved oxygen levels in the hypolimnion routinely dipped below 5.0% saturation. Once stratification was no longer apparent in October, dissolved oxygen readings leveled off throughout the water column.

Pine Island Pond total phosphorus readings were relatively uniform throughout the water column, with the epilimnion averaging .024 mg/L, metalimnion averaging .025 mg/L and hypolimnion averaging .028 mg/L. No values in any pond layer were more than 0.009 mg/L from their respective mean (maximum deviation < 0.009 mg/L).

Conductivity values were also relatively uniform throughout the water column. The epilimnion averaged 287.1 uMhos/cm. The metalimnion averaged 263.8 uMhos/cm. The hypolimnion averaged 304.5 uMhos/cm. These values are quite high, possibly due to inputs from Cohas Brook or the airport. These inputs are scheduled to be more thoroughly sampled next year (2001).

Composite chlorophyll *a* concentrations for the upper metalimnion and epilimnion ranged from 3.08 to 12.45 mg/m^3 with an average of 8.04 mg/m^3.

Secchi disk transparency appeared to be reduced by higher chlorophyll *a* content. As chlorophyll *a* increased, Secchi disk transparency decreased. Transparency ranged from 1.3 to 2.4 meters and averaged 1.9 meters at a total depth of 4.0 meters.

Pine Island Pond pH values ranged from 6.55 to 7.21 and averaged 6.97 – higher than ideal.

ANC values ranged from 6.6 to 22.8, peaking in August, and averaging 17.1 mg of CaCO/L. These readings indicate that Pine Island Pond has substantial buffering capacity.

Turbidity ranged from 1.38 to 4.20 (NTU) in the hypolimnion and averaged 2.79 (NTU). Epilimnion turbidity ranged from 0.95 to 2.30 (NTU) and metalimnion turbidity ranged from 1.07 to 1.55 (NTU). The peak turbidity was recorded once stratification was no longer apparent, possibly indicating that the pond layers had mixed, or "turned over".

Table 6[1]
Comparison of Pine Island Pond – 1980*, 1997, & 2000**

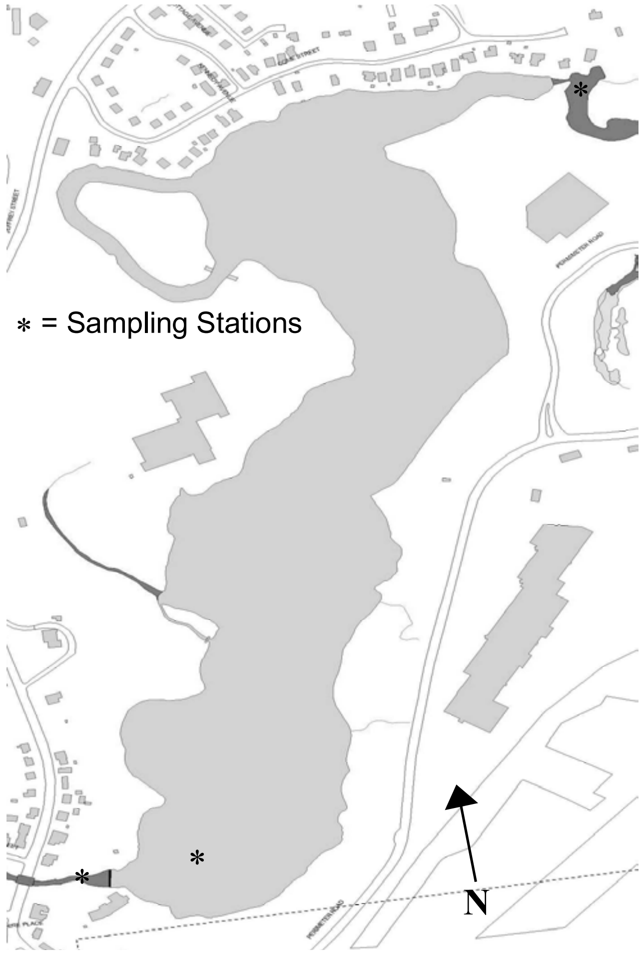
Parameter	8/5/1980	7/24/1997	2000 Mean	2000 Median
pH	7.1	7.2	6.97	7.07
Alkalinity (mg/L)	15.2	20.6	17.1	19.5
Total phosphorus (mg/L)	.015	.018	.024	.024
Conductivity (uMhos/cm)	142.8	290.4	287.1	308
Secchi disk (m)	2.0	1.4	1.9	1.9

1) All values are epilimnetic.

* NH Dept. of Environmental Services. 1980. Trophic Classification of NH Lakes and Ponds.

** NH Dept. of Environmental Services. 1998. Lake Trophic Data.

Figure 7 - Pine Island Pond Sampling Stations



Recommendations

Specific solutions to pond issues include erosion control measures, urban runoff treatment measures, and proper trash disposal among other things. Specific recommendations for Pine Island Pond are as follows:

1) Reduce sedimentation coming from Cohas Brook. Surveying the length of Cohas Brook from Pine Island Pond, upstream to at least Harvey Road, is recommended to identify any sediment of other pollution sources. Current surveys are incomplete. This will most likely be done by a NH DES intern during the 2001 field season.

2) Remediate three storm drain outfalls at the pond's north end. These may require engineered solutions, or retrofitting the storm drains with filtration systems. These outfalls are fed by direct street runoff.

3) Investigate and possibly remedy three small culverts of unknown origin. There are two culverts on the west side of the pond and one culvert on the east side, which have sources that are unknown at this point. It is recommended that the sources of these culverts be determined and if necessary, they be removed or otherwise rectified.

4) Work with the Smart Associates of Concord, NH to determine the nature of a large outfall at the south end of the pond, which appears to come from the airport, or Perimeter Road.

The largest issue facing Pine Island Pond is sedimentation from upstream sources.

The NH Fish and Game Department has expressed willingness in the past to install a fish passage system at the dam at Pine Island Pond's south end. It is recommended that this possibility be pursued by the UPRP to restore an historic anadromous fish run to the Great Cohas drainage.

Stevens Pond

History

Stevens Pond has been a popular recreation spot with Manchester kids for generations. The pond is still heavily used by area residents for fishing and skating. This natural pond covers approximately 16 acres with a large wetland area on the northwest side of the pond. This provides excellent habitat for wetland species such as red-winged blackbirds and great blue herons.

According to N.H. Fish and Game Department records, Stevens Pond was experimentally reclaimed for smallmouth bass in 1952. This involved the application of emulsified rotenone (a fish toxin) to the pond surface, in hopes of killing all fish in the pond. Although a complete kill was not achieved due to the presence of a floating bog along part of the shoreline preventing adequate spraying, over 9,000 smallmouth bass fingerlings and 45,000 smallmouth bass fry were stocked over the course of 1952 and 1953 (NH Fish & Game, 1960). Despite this effort, the dominant fish species in the pond remained brown bullheads and common suckers, as was discovered through fish sampling in 1958. Two species of crayfish were also stocked at Stevens Pond in 1953. After six years, one of the crayfish species had establish itself and maintained a substantial population (NH Fish & Game, 1960). The pond was described as "highly productive", with "good populations of desirable game fish" which were in "excellent condition" (NH Fish & Game, 1960).

In 1964, Interstate 93 was completed through Manchester. The south bound lanes were built directly over the northeastern edge of Stevens Pond. Since that time, water quality in Stevens Pond has deteriorated. "Analyses from 1981 to 1997 show…a 100% increase in conductivity levels, a 220% increase in sodium levels, and a 182 % increase in chloride levels." (Couture, 2000). Clearly, Interstate 93 runoff has had an effect on the pond over the years.

Stevens Pond's value as a natural resource has always been noted, as demonstrated in a letter from Arthur E. Newell, Supervisor of Fisheries Management and Research for the N.H. Department of Fish & Game, to James Hall of Manchester dated 11/23/1960. Mr. Newell states: "…biologists in the Fish and Game Department are interested in preserving certain strategically located ponds, such as Stevens Pond, in their original state." Unfortunately, Stevens Pond has not been preserved, but abused over the years. Nevertheless, it persists as a focal point for birdwatchers, fishermen, and ice skaters of Manchester's East Side.

Shoreline Survey

The Stevens Pond shoreline survey was conducted on May 23, 2000 by Art Grindle and Scott Shepard by boat.

Shoreline survey findings:

- I-93 storm water runs off directly into pond
- Eroded areas (spotty) along Bridge Street side of pond
- Excessive vegetation in south end of pond
- Area adjacent to Bridge Street heavily littered
- Inlet collects highway runoff
- Excessive exotic species growth (*Phragmites*, purple loosestrife)

Water Quality

Pronounced stratification was observed at Stevens Pond beginning in June. Dissolved oxygen saturation was already down to 0.10 mg/L at 5 meters of depth (or 1.0% saturation) by the end of June. This continued even once stratification became less pronounced in late September (0.20 mg/L DO at 5 meters, or 2.0% saturation).

Total phosphorus levels in the hypolimnion ranged from .011 to .094 with and average of .042 mg/L. High TP levels in the hypolimnion may indicate internal loading. Epilimnion TP levels ranged from .008 to .029 with an average of .019.

Conductivity levels remained relatively constant throughout the season and throughout the water column. Epilimnion conductivity ranged from 742 to 803 and averaged 769.0 uMhos/cm. Metalimnion conductivity ranged from 743 to 799 and averaged 771.0 uMhos/cm. Hypolimnion conductivity ranged from 760 to 872 and averaged 792.3 uMhos/cm. These are very high readings, most likely caused by highway runoff from I-93.

Composite chlorophyll *a* concentrations for the upper metalimnion and epilimnion ranged from 3.44 to 23.11 and averaged 8.68 mg/m^3.

Secchi disk readings ranged from 2.1 to 2.9 and averaged 2.6 meters. Transparency did not appear to be directly affected by chlorophyll *a* content.

Stevens Pond turbidity values were highest in the hypolimnion. This may be caused by high levels of sodium and chloride in the bottom sediments from highway runoff. Turbidity ranged from 0.95 to 34.0 with an average of 9.80 (NTU). Epilimnion and metalimnion turbidity values averaged 2.36 and 2.34 respectively.

Table 7[1]
Comparison of Stevens Pond – 1981*, 1997, & 2000**

			2000	
Parameter	7/29/1981	7/23/1997	Mean	Median
pH	7.2	7.7	7.11	7.15
Alkalinity (mg/L)	33.0	31.8	34.2	34.8
Total phosphorus (mg/L)	.028	.028	.019	.019
Conductivity (uMhos/cm)	301	696	769	765.5
Secchi disk (m)	2.0	1.3	2.6	2.6

1) All values are epilimnetic.

* NH Dept. of Environmental Services. 1981. Trophic Classification of NH Lakes and Ponds.

** NH Dept. of Environmental Services. 1998. Lake Trophic Data.

Fish Survey

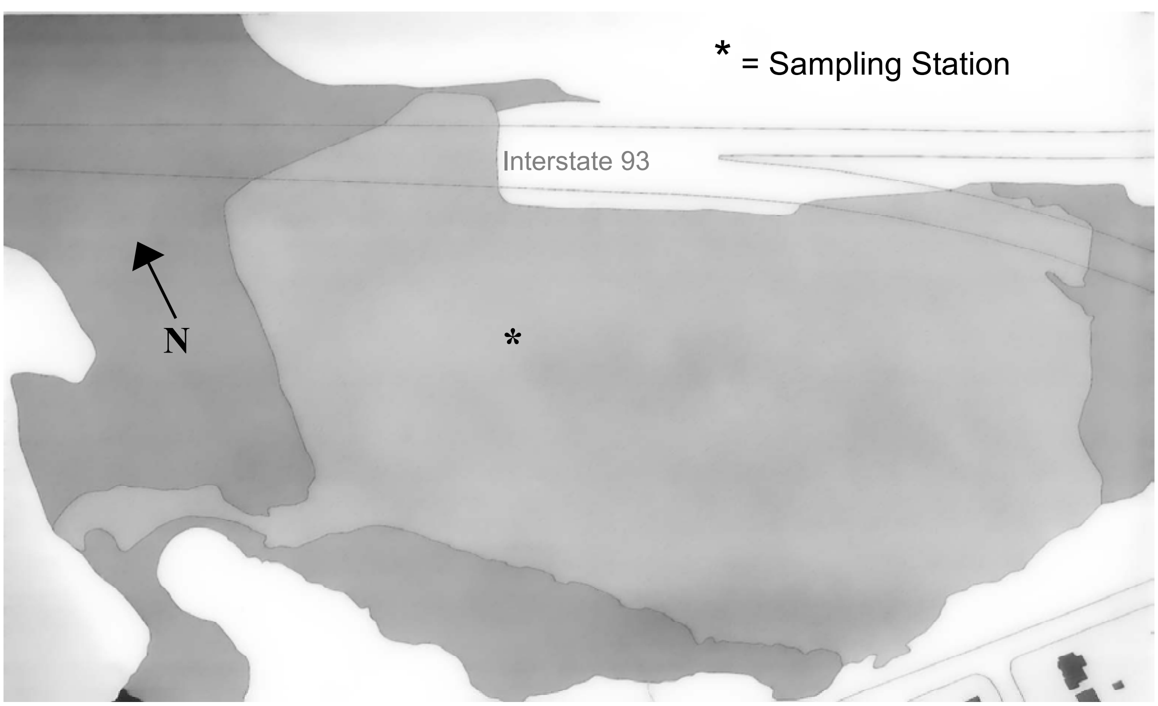
A fish survey was conducted at Stevens Pond on July 11, 2000 with the help of New Hampshire Fish & Game, the US Fish & Wildlife Service and NH DES. Over a period of approximately 34 minutes of actual fishing time, 93 fish were collected. They were weighed and measured and returned to the pond. The results of the survey are included in Table 8. Five yellow perch and five largemouth bass were kept for fish tissue analysis. The results of the analysis were not ready for inclusion at the time of this report. Raw data is included in Appendix D.

Table 8
Average fish length, weight and catch rate for species sampled at Stevens Pond, July 11, 2000*

Species	Average Lt.(mm)	Average Wt.(gm)	Fish/Hour
Largemouth bass	243	244	43
Bluegill	110	41	67
E. Chain pickerel	287	138	7
Common sunfish	130	55	20
Common white sucker	400	714	2
Yellow perch	237	179	14

* NH Fish and Game Department, 2000.

Figure 8 – Stevens Pond Sampling Stations



Recommendations

Specific solutions to pond issues include erosion control measures, urban runoff treatment measures, and proper trash disposal among other things. Specific recommendations for Stevens Pond are as follows:

1) Retrofit I-93 bridge to divert stormwater runoff. Stormwater runs directly into Stevens Pond from the I-93 bridge. An engineered solution by NH DOT will be necessary to divert runoff. It is recommended that the City work with the NH DES and NH DOT to implement some kind of stormwater diversion and treatment system.

2) Revegetate areas experiencing erosion due to heavy foot traffic on the side of the pond abutting Bridge Street. Creation and maintenance of a trail network in this area is recommended to enhance proper public use and remedy erosion issues common to heavily used shorelines. This particular area is also heavily littered, due to public use and abuse and its proximity to Bridge Street, which seems to accumulate refuse. Installation and maintenance of trash receptacles is recommended in this area.

3) Treat invasive species near boat launch. A thick stand of *Phragmites* exists near the boat launch, as well as in other areas around the pond. Chemical treatment may be recommended to control further growth. Replanting of competitive native species may also be effective.

The largest issue facing Stevens Pond is the untreated runoff it collects from I-93.

General Recommendations

Based on the various data collected in 2000, many recommendations can be made for future investigations. First of all, it is recommended that more varied kinds of data be collected to more accurately represent what the true ecological conditions of these ponds are. For example, very little biological data, such as fish, vegetation, and macroinvertebrate data, has been collected up to this point. There is an obvious need for this type of basic information. The water quality data that has been collected is crucial – but the way in which the water quality affects the pond biota is arguably more important than the raw numbers. Assumptions can be made regarding the state of the pond ecosystems based on the known water quality. These assumptions, however, are only truly valuable if used to form hypotheses of the actual biological conditions pending closer examination, further study, and better data.

As part of the UPRP work plan for 2001, complete fish surveys, submerged aquatic vegetation surveys, macroinvertebrate sampling, tributary streambank/habitat surveys, pond sediment depth mapping, and percent vegetated pond edge surveys will be completed. At the same time, more detailed water quality monitoring will be taking place with foci on various parameters at each pond, where deemed appropriate. These foci will be determined based on information that was collected in 2000. For example, more frequent metals analysis of Stevens and Nutts Pond samples, more detailed storm event sampling at pond inlets, and analysis for PCB's in sediments at Nutts Pond are examples of possible foci for the next season's sampling.

Some recommendations for broad, city-wide activities to further the cause of pond restoration can also be made from what was learned in the first year of baseline monitoring. Storm drain and catch basin maintenance is a key component in keeping ponds pollution free in an urban environment. Sedimentation of receiving water bodies can potentially be greatly reduced by proper catch basin maintenance. More frequent cleaning of specific catch basins that directly influence surface water bodies by the City Highway Department is recommended.

Many of the lands that surround Manchester’s urban ponds are publicly owned. Livingston Park and Precourt Park are a couple of examples. Trash receptacles at these areas fill up quickly due to the high volume of lunchtime visitors. The receptacles overflow with trash once they are full and much of this material ends up in the nearby pond. More frequent trash pick-up at these areas by the City Highway Department is recommended to reduce the amount of litter blown into the ponds.

References Cited

"Bathhouse Work Stalled" Manchester Union Leader. June 12, 1987.

Clayton, J. 1993. In the City. Peter E. Randall Publ., Portsmouth, NH. 166 pp.

Couture, S. Jan. 6, 2000. Letter to NH Dept. of Transportation, Attn: Charles Hood. NH Dept. of Environmental Services, Biology Section. Concord, NH.

"D.A.R. Dedicates Spot Where Stark Fort Stood". The Manchester Leader. June 15, 1929.

Drociak, J. "Memories of Maxwell Pond". Pond Possibilities. Vol.1, Issue 2.

Estabrook, R.H., J.N. Connor, R.B. Henderson, R.E. Towne, K.D. Warren. 1985. Urban Lakes Diagnostic/Feasibility Study, Staff Report No. 140. New Hampshire Water Supply and Pollution Control Commission. Concord, NH.

"Greater Crystal Lake Fast Taking Shape" The Leader. Feb. 27, 1942. Manchester, NH.

Manchester Park, Common, and Playground Commission. 1928. 5th Annual Report of Manchester Park, Common and Playground Commission. Manchester, NH.

Manchester Park, Common, and Playground Commission. 1929. 7th Annual Report of Manchester Park, Common and Playground Commission. Manchester, NH.

Moore, H.P. ca. 1940. A Life of General John Stark of New Hampshire.

New Hampshire Fish and Game Department. 1960. Job Completion Report, Project F-8-R-4, Job #2. Concord, NH.

New Hampshire Volunteer Lake Assessment Program. 1999. Annual Report for Crystal Lake Manchester. NH DES, Water Division, Biology Bureau, Concord, NH.

Perreault, R.B. "Mosquito Pond, or Life in the Woods" The Manchester Journal. July 4, 1984.

Potter, C.E. 1856. The History of Manchester. Manchester, NH. 763pp.

"Pure, Sweet and Clear". The Mirror. April 22, 1899.

Rowell, R. 1904. Gen. John Stark's Home Farm. John B. Clarke Co.

Seney, M.A. "Ray Brook dammed in 1862 to create city's Dorrs Pond". The Union Leader. Dec. 4, 1998..

Slown, J.R. ca. 1987. Nutt's Pond: A Case Study With Commentary.

Weigler, B. "Benign Neglect of an Urban Forest". The Manchester Journal. Aug. 14, 1983.

Willey. 1896. Willey's Book of Nutfield.