Exploration Green Water Quality Baseline Study

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ABBREVIATIONS

°C - Degrees Celsius

µS/cm - Micro Siemens per Centimeter

mg/L - Milligrams per Liter

mL – Milliliter

mpn/100mL - Most Probable Number per 100 Milliliters

EPA – Environmental Protection Agency

NELAP – National Environmental Laboratory Accreditation Program

TCEQ – Texas Commission on Environmental Quality

TCWP – Texas Community Watershed Partners

TSS – Total Suspended Solids

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INTRODUCTION

Beginning in 2015, the community organizations involved in the Exploration Green project, including Texas Community Watershed Partners (TCWP), undertook the ambitious plan of turning a 178-acre Clear Lake golf course into a series of stormwater detention ponds. With the primary goal of providing up to 500 million gallons of storage in stormwater, the project aims to restore wetland habitat with native vegetation and act as a natural form of stormwater treatment [1][2]. Exploration Green's detention ponds are surrounded by urban residential and heavily commuted roadways dotted with commercial and office buildings. Feeding into Horsepen Bayou, Exploration Green is potentially a significant drainage source into the Armand Bayou subwatershed. These qualities make Exploration Green an excellent candidate for testing the effectiveness of stormwater wetlands on water quality and urban runoff, yet a baseline study for this project does not yet exist for comparative data analysis. This research aims to fulfill that need and provide a basis for future decision-making and analysis as it pertains to water quality within constructed detention ponds such as the ones present at Exploration Green.

METHODOLOGY

Three outflow locations of three different construction phases were chosen to compare constructed wetlands with varied amounts of the desired vegetation. Water quality testing began in April of 2023 and continued weekly through February of 2024. Using a combination of handheld and composite lab sampling, data parameters were maximized under the specified budget. Parameters included ammonium nitrogen levels, dissolved oxygen, specific conductivity, water temperature, pH, flow level, and rainfall amount. Handheld sampling equipment was calibrated immediately before weekly arrival on site and represented water quality at midday and afternoon. Automatic biweekly composite samples were distributed into plastic containers, on ice, with the proper preservation solutions. These samples were handed off to a courier to be tested for ammonia nitrogen level, E. coli counts, total phosphorus, and total suspended solids at a NELAP accredited lab. The table below details the specific equipment and methodology.

Location	Outflow Volume	Outflow Concentration
Exploration Green Nature Park Phase 1 (Site 1)	Measured with ISCO 6712 automated sampler triggered to collect a biweekly composite sample in a 9L bottle. Flow volume recorded from the ISCO 730 bubble flow meter. Rainfall amount measured from the ISCO 674 tipping bucket rain gauge. A pasture stick was used as a flow reference.	Direct laboratory measurements of composite samples analyzed biweekly. A YSI ProQuatro handheld multiparameter meter measures additional parameters onsite weekly with a YSI Professional Plus being used as needed.

Exploration Green Nature Park Phase 3 (Site 3)	Measured with ISCO 6712 automated sampler triggered to collect a biweekly composite sample in a 9L bottle. Flow volume recorded from the ISCO 730 bubble flow meter. Rainfall amount measured from the ISCO 674 tipping bucket rain gauge. A pasture stick was used as a flow reference.	Direct laboratory measurements of composite samples analyzed biweekly. A YSI ProQuatro handheld multiparameter meter measures additional parameters onsite weekly with a YSI Professional Plus being used as needed.
Exploration Green Nature Park Phase 4 (Site 4)	Measured with ISCO 6712 automated sampler triggered to collect a biweekly composite sample in a 9L bottle. Flow volume recorded from the ISCO 730 bubble flow meter. Rainfall amount measured from the ISCO 674 tipping bucket rain gauge. A pasture stick was used as a flow reference.	Direct laboratory measurements of composite samples analyzed biweekly. A YSI ProQuatro handheld multiparameter meter measures additional parameters onsite weekly with a YSI Professional Plus being used as needed.

Each lab sampling event was timed so that the courier handling the samples would reach the lab in the appropriate hold time. The storage methods and hold time of each lab parameter is listed in the table below.

Parameter	**Matrix**	**Sample Type**	**Container**	**Preservation**	**Sample Volume**	**Hold Time**
E. coli	water	composite	Sterile, plastic	Sodium Thiosulfate <60 C	125mL	24 hours*
TSS	water	composite	Plastic	<60C	1000mL	7 days
Total Phosphorus	water	composite	Plastic	Nitric acid <60 C	250mL	28 days
Ammonia as Nitrogen	water	composite	Plastic	Sulfuric acid <60 C	500mL	28 days

KEY FINDINGS

BASE FINDINGS

The range of each parameter was analyzed and recorded. Instead of mean, median values were selected as being representative of the dataset. This was done to more accurately reflect the typical water quality present, independent of specific events and outliers.

Specific conductance measured with an overall range of 172.2 to 648 µS/cm. In terms of specific sites, Site 1 had a range of 222.9 to 721 µS/cm, Site 3 a range of 172.2 to 608 µS/cm, and Site 4 a range of 276.3 to 648 µS/cm. Median values of 501.5, 287.65, and 448.05 µS/cm were present for Site 1, 3, and 4 respectively.

E. coli measured with an overall range of 10 to 13,000 mpn/100mL. In terms of specific sites, Site 1 had a range of 86 to 13,000 mpn/100mL, Site 3 a range of 10 to 5,790 mpn/100mL, and Site 4 a range of 47 to 13,000 mpn/100mL. Median values of 394, 110, and 427.5 mpn/100mL were present for Site 1, 3, and 4 respectively.

Total phosphorus measured with an overall range of 0.0600 to 0.688 mg/L. In terms of specific sites, Site 1 had a range of 0.0665 to 0.688 mg/L, Site 3 a range of 0.0600 to 0.496 mg/L, and Site 4 a range of 0.0600 to 0.269 mg/L. Median values of 0.2995, 0.163, and 0.0624 mg/L were present for Site 1, 3, and 4 respectively.

Total suspended solids measured with an overall range of 1 to 77.5 mg/L. In terms of specific sites, Site 1 had a range of 7.6 to 77.5 mg/L, Site 3 a range of 1 to 67.1 mg/L, and Site 4 a range of 13.7 to 68.2 mg/L. Median values of 19, 4.35, and 34.5 mg/L were present for Site 1, 3, and 4 respectively.

Dissolved oxygen measured with an overall range of 1.57 to 10.19 mg/L. In terms of specific sites, Site 1 had a range of 1.85 to 10.09 mg/L, Site 3 a range of 1.57 to 8.38 mg/L, and Site 4 a range of 2.8 to 10.19 mg/L. Median values of 5, 4.71, and 5.04 mg/L were present for Site 1, 3, and 4 respectively.

The water temperature measured with an overall range of 10.7 to 40.3°C. In terms of specific sites, Site 1 had a range of 10.7 to 35.6°C, Site 3 a range of 11.5 to 40.3°C, and Site 4 a range of 11.6 to 39.8°C. Median values of 27.05, 26, and 27.6°C were present for Site 1, 3, and 4 respectively.

pH measured with an overall range of 6.34 to 9.36. In terms of specific sites, Site 1 had a range of 6.34 to 9.15, Site 3 a range of 6.68 to 9.36, and Site 4 a range of 6.45 to 8.81. Median values of 7.755, 7.1, and 7.625 were present for Site 1, 3, and 4 respectively.

Nitrogen of ammonia had an overall range of 0.1 to 3 mg/L. In terms of specific sites, Site 1 had a range of 0.1 to 0.9 mg/L, Site 3 a range of 0.1 to 3 mg/L, and Site 4 a range of 0.1 to 1.4 mg/L. A median value of 0.1 mg/L was present for all sites.

Nitrogen of ammonium measured with an overall range of 0.44 to 4.67 mg/L. In terms of specific sites, Site 1 had a range of 0.91 to 4.67 mg/L, Site 3 a range of 0.44 to 2.76 mg/L, and Site 4 a range of 0.6 and 3.84 mg/L. Median values of 1.76, 1.16, and 2.93 mg/L were present for Site 1, 3, and 4 respectively.

Flow Level had an overall range of 0 to 2.234 feet. In terms of specific sites, Site 1 had a range of 0 to 2.85, Site 3 a range of blank to blank, and Site 4 a range of blank to blank. Median values of 1.017, 0.321, and 0.42 were present for Site 1, 3, and 4 respectively.

Total rainfall over the sampling period was calculated to be 49.22 inches. The rain gauge measuring the data rarely displayed a 30-minute rainfall event above 1.0 inches. In terms of specific sites, Sites 1 and 4 tended to collect the most amount of rain while Site 3 collected the least. The average amount of rainfall every 30 minutes ranged from 0 to 0.003 inches.

LOCAL COMPARISON

To find a comparative baseline, data from two different sampling sites were referenced along Horsepen Bayou in as close proximity to Exploration Green as possible. One near bay area boulevard and the other near Middlebrook. Sampling sites further downstream were not used due to increases in salinity level and the vicinity to other types of outflow or runoff sources. Upstream, the water body is thinned into residential drainage and did not have any available water quality data in the TCEQ Texas Clean Rivers database referenced [3]. The data selected indicated water quality snapshots within the time frame of June 21st to June 22nd of 2023. Regular long-term sampling data from the comparative sources was not available. Methodology differed slightly; the selected sources having been measured at different depths in the water source. Only some of the tested parameters were able to be compared using this method. For example, most local sampling efforts test for Enterococci instead of E. coli. This is most likely because Enterococci can be used for a wider variety of water sources [4]. Secchi disks and narrative descriptions also seem to be the preferred method of determining the turbidity of water in the area rather than testing for total suspended solids.

For specific conductance, Exploration Green was measured to have nearly less than half to as much as half of the level of conductance reported in Horsepen Bayou. Site 1, 3, and 4 measured with values of 532, 225, and 463 µS/cm respectively. The site at bay area boulevard measured with values ranging from 896 to 2670 µS/cm while the site at Middlebrook measured with values ranging from 1290 to 5610 µS/cm.

For pH, Exploration Green was measured to have values similar to Horsepen Bayou, presenting as slightly more acidic than downstream. Site 1, 3, and 4 measured with values of 7.65, 7.2, and 7.69 respectively. The site at bay area boulevard measured with values ranging from 7.4 to 7.9 while the site at Middlebrook measured with values ranging from 7.7 to 8.5.

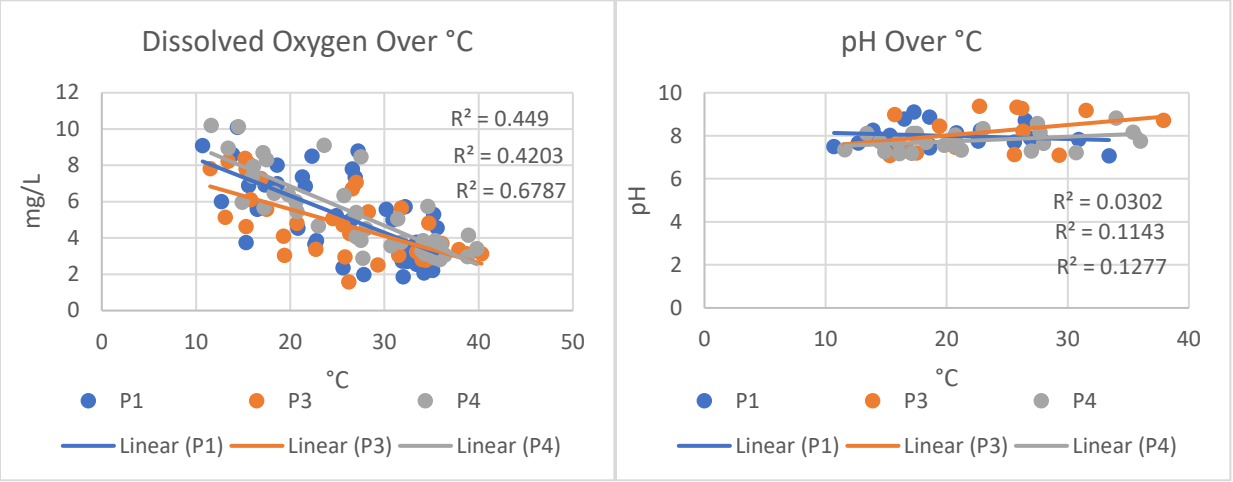
For total phosphorus, Exploration Green was tested to have values less than half of what was present in Horsepen Bayou. Site 1, 3, and 4 measured with values of 0.183 mg/L and less than 0.0600 mg/L respectively. The site at bay area boulevard was tested to have a value of 0.6 mg/L while the site at Middlebrook tested to have a value of 0.855 mg/L.

For nitrogen content of ammonia, Exploration Green was tested to have values similar to Horsepen Bayou. Sites 1, 3, and 4 were measured to have values of 0.2 mg/L and less than 0.1 mg/L respectively while the Middlebrook site measured to have 0.242 mg/L. The site at Bay Area Boulevard did not test for this parameter.

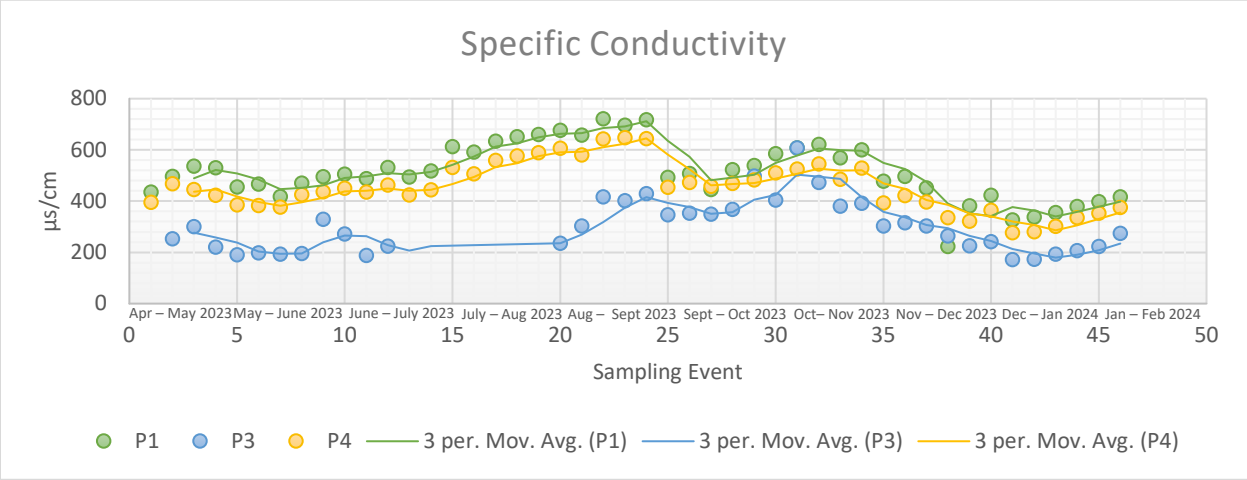
For dissolved oxygen, Exploration Green was measured to have slightly lower values than Horsepen Bayou. Sites 1, 3, and 4 were measured to have values of 2.98, 3.23, and 3.60 mg/L respectively. The site at Bay Area Boulevard was measured to have a gradient of 0.3 to 5.3 mg/L while the site at Middlebrook had a gradient of 0.2 to 7.5 mg/L.

TRENDS

There were several observable trends that occurred both between the different phases and between different seasonal conditions. In warmer months, the pH increased in the frequency of values over 9.0, while the colder months increased the frequency of values below 7.0. When graphically compared to temperature, there existed little correlation between the two parameters, having a maximum R value rounded to 0.37. The change in dissolved oxygen accompanied the change in temperature closely with an R value rounded to 0.66.



There existed a clear difference in specific conductance between the different outflow sites throughout the testing period. Site 1 consistently displayed the highest values followed by Site 4 and Site 3, with Site 1 and 4 displaying trend lines of highly similar shape to one another.



After data correction, nitrogen of ammonium displayed a similar trend of Site 1 with the highest values followed by Site 4 and Site 3.

Figure before correction

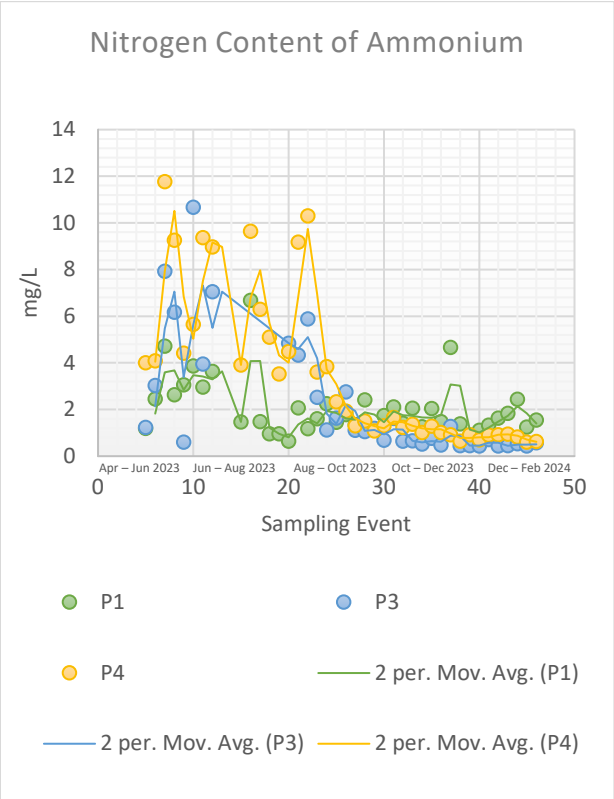
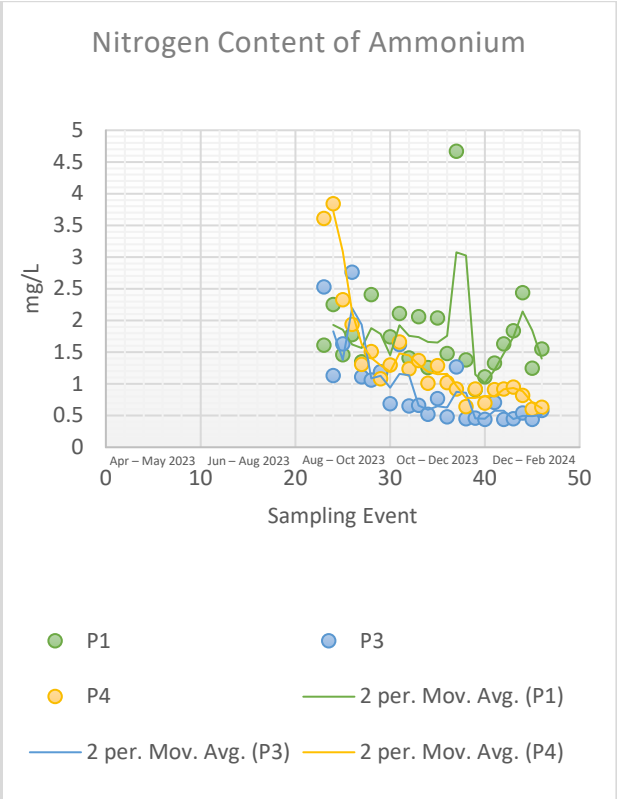
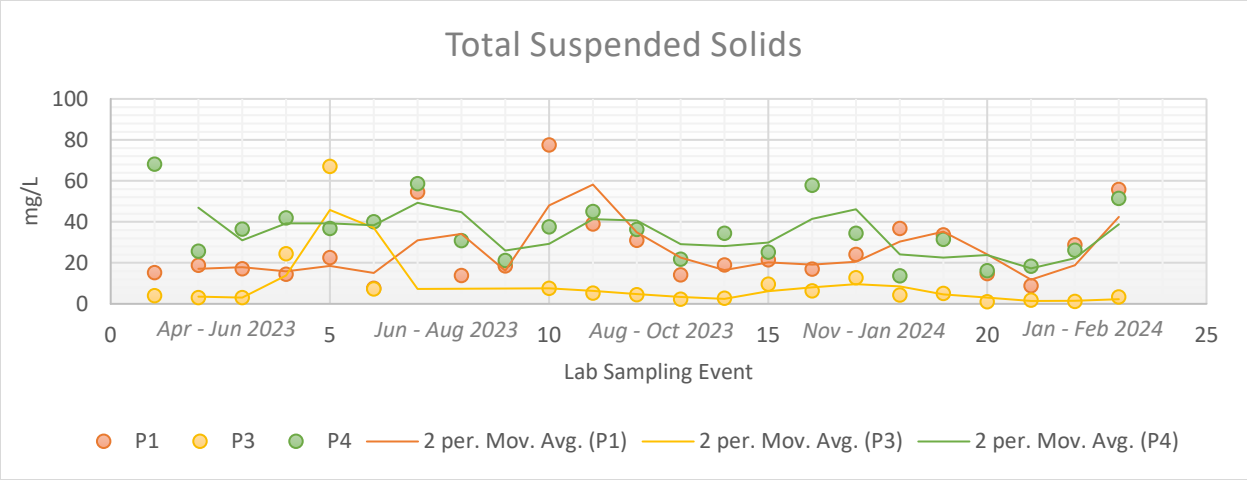


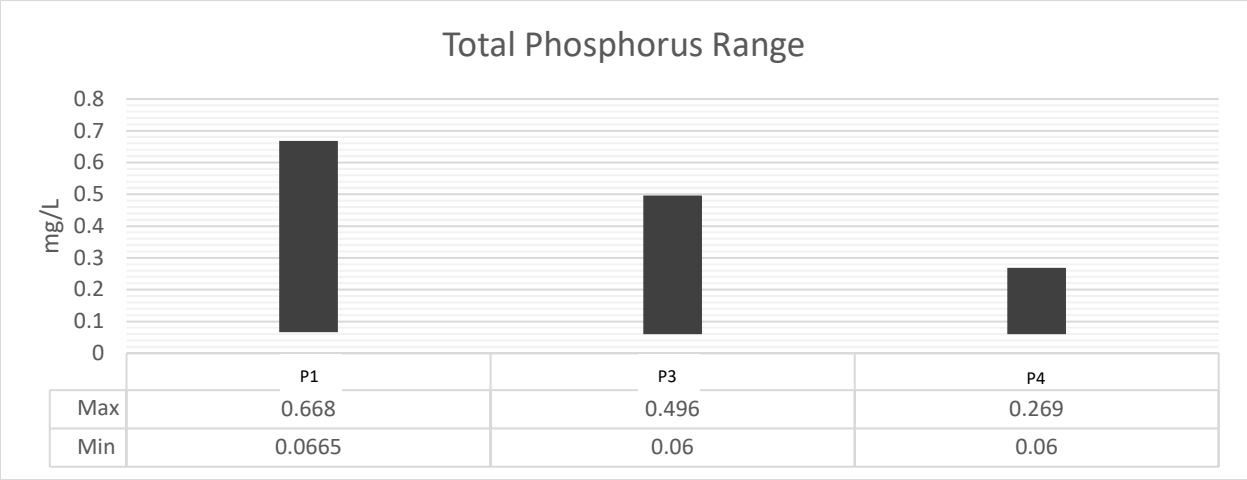
Figure After correction



The clear difference in median values between the different sites in terms of total suspended solids displays a general difference in turbidity levels between the different detention ponds. Site 4 contained the most amount of total suspended solids more often while Site 3 contained the least amount of total suspended solids the most often. The difference is slightly visible when displayed graphically.



Total phosphorus also appeared to have distinct differences in average water quality between the different phases, having clear differences in maximum values. When ordered from highest to lowest in both median and maximum values, Site 1 ranks as having the highest phosphorus levels while Site 4 had the lowest values.



	P1	P3	P4
Max	0.668	0.496	0.269
Min	0.0665	0.06	0.06

Conclusion

Exploration Green's subcategory for aquatic life based off TCEQ standards appears to fall under the intermediate category for most of the year, varying in oxygen levels from minimal to exceptional [5]. This is reflected in the observed fish life that reside in the detention ponds, only containing abundance of low-oxygen tolerant species.

The geometric mean of each site's E. coli levels was calculated to be 542.97, 166.45, and 353.9 mpn/100mL for Site 1, 3, and 4 respectively. This places Site 3 in the second category for primary contact recreation and Site 1 and 4 in the first category of secondary contact recreation [6]. However, single spikes in E. coli levels routinely measured above the levels recommended for secondary contact recreation. One spike in two sites simultaneously measured over 10,000 units above the level for noncontact recreation.

Most other parameters were within expected levels for stormwater, going outside of expected ranges on rare occasions. Nitrogen of ammonia experienced a prolonged spike in values shortly before the end of this study after nearly an entire year of Site 4 having not experienced a single spike in levels.

Overall, Exploration Green shows promise in its ability to act as a filtration method, displaying improved comparative levels with parameters such as specific conductance and total phosphorus. However, more research is needed to concretely confirm the method's effect on water quality. There also still exists parameters that the detention ponds could improve upon, such as stabilizing E. coli and dissolved oxygen levels.

The areas in which this study could improve include better equipment and maintenance, the use of parameters that allow for better comparison to local sampling efforts, and the ability to sample from different levels within the water body. More extensive state water quality standards are recommended to more easily deduce whether certain parameters are outside of expected levels.

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