Phosphorus in Soils Surrounding Marion County Lake

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Abstract

Marion County Lake has historically had a blue-green algae problem that has not been addressed due to lack of data about soil, water, and land use in the area. Phosphorus is often the limiting nutrient in water bodies causing eutrophication and leading to blue-green algae. This research sought to provide data about phosphorus in the soils surrounding the lake to help identify causes of the lake's water quality issues. Additionally, this research tried to identify relationships between different soil characteristics and phosphorus concentration. The first conclusion from the research was that approximately 1300 kg of phosphorus are present in the soils immediately surrounding the lake. Furthermore, measured soil properties did not match properties expected based upon soil maps of the area. A correlation was observed between flat slopes and high concentration of soil phosphorus. While it was expected that soil with high organic matter would have high retention of soil phosphorus, data from this research showed the opposite correlation. Distance from the lake's edge did not have a correlation with phosphorus content. Further research of erosion and water table levels surrounding the lake would be useful to support or disprove the conclusions made by this research.

Introduction

Phosphorus (P) contamination of surface waters can impair water quality, recreational uses, and aquatic habitats. Phosphorus introduction to surface waters occurs through many pathways, several of which stem from soils. Soils primarily contribute phosphorus to rivers, lakes, and streams via erosion of particulate-bound phosphorus. A secondary, and more minor mechanism is via sub-surface transport of soluble phosphorus in soil solution.

Some soils are more prone to phosphorus loss than others. Any combination of soil characteristics and environmental factors that discourages plant uptake or sorption of P increases the likelihood of phosphorus loss to downstream water bodies. Soil texture, slope, organic matter, hydraulic conductivity, precipitation, and cation exchange capacity are just a few factors that influence a soil's capacity to retain P (Domagalski and Johnson 2011). For example, a high water table causes prolonged anaerobic conditions leading to the reduction of iron hydroxides and oxides, which decreases the P sorption capacity. When high water table conditions occur, the soils contribute more P to the nearby surface water (Dupas et al. 2015). This is the main factor affecting P release, but it is exacerbated by drying and rewetting cycles (Gu et al. 2018). Low slope can also contribute to higher P leaching to surface waters (O'Toole, Chambers, and Bell 2018).

The "amount of phosphorus available to crops depends on the quantity of phosphorus in the soil solution and on the continued release of phosphorus from minerals to maintain the soil solution level of phosphate," which means the amount varies across different types of soil like sandy versus clayey soils (Diaz et al. 2011). The amount of P in each soil is no more than a fraction of a pound per acre, which means there is very little P available for plant uptake. Mineral P in Kansas soil is in calcium or magnesium complexes (Diaz et al. 2011).

P management is key to achieving the appropriate amount of P in agricultural use. Unfortunately, limitations or regulations of P levels in the soil are not well defined. Phosphorus limitations that exist in literature are mere suggestions and preferences. Several field studies have shown the dissolved phosphorus (DP) concentration of runoff is related to soil test P (r^2 of 0.58-0.98 mg kg^{-1}) of surface soil (0 to 5 cm). These relationships can identify critical levels which can support a DP concentration of runoff. In this regard, critical soil test P levels established by several states, ranging from 75 to 200 mg/kg, appear to be realistic (Sharpley, Daniel, Sims and Pote 1996).

Marion County Lake is prone to harmful algal blooms potentially caused by P inputs. Currently, there is not a plan in place to prevent harmful algal blooms from occurring. Due to a lack of information regarding the soils and organisms that surround the lake, management objectives cannot be set. This project seeks to answer numerous questions regarding P in the soils nearest Marion County Lake. With the information found in this report, the Marion County Lake Manager can decide to what extent the soils need to be managed and treated to minimize impacts on the use and quality of the lake.

This report specifically focuses on the following questions:

1. How do the soils observed around the lake compare to soil maps of the area?
2. How much phosphorus is in the soils surrounding Marion County Lake?
3. What relationships exist between soil characteristics and measured soil phosphorus concentrations?
4. Do the observed soil properties lend more to phosphorus losses to the lake, or phosphorus retention?

Site Description

Marion County Park and Lake is a 300-acre park located in Marion County, Kansas, Unites States. This county has a temperate continental climate with an average annual high temperature of 19 degrees Celsius and an average low temperature of 6.4 degrees Celsius (Kansas Mesonet 2019). The average overall temperature is 12.7 degrees Celsius. The park is located in the western Flint Hills region, approximately two miles southeast of the City of Marion. The lake itself is 153 acres and is fed by a 4000+ acre watershed that has variable land uses primarily consisting of agricultural land and residential areas. Average annual precipitation within Marion County is 81.5 centimeters. The park and lake were opened in 1940 as a product of the Civilian Conservation Corps. It is a popular recreation site and draws visitors from around the state for fishing, boating and other recreational activities. The lake is bordered by about 200 private residences.

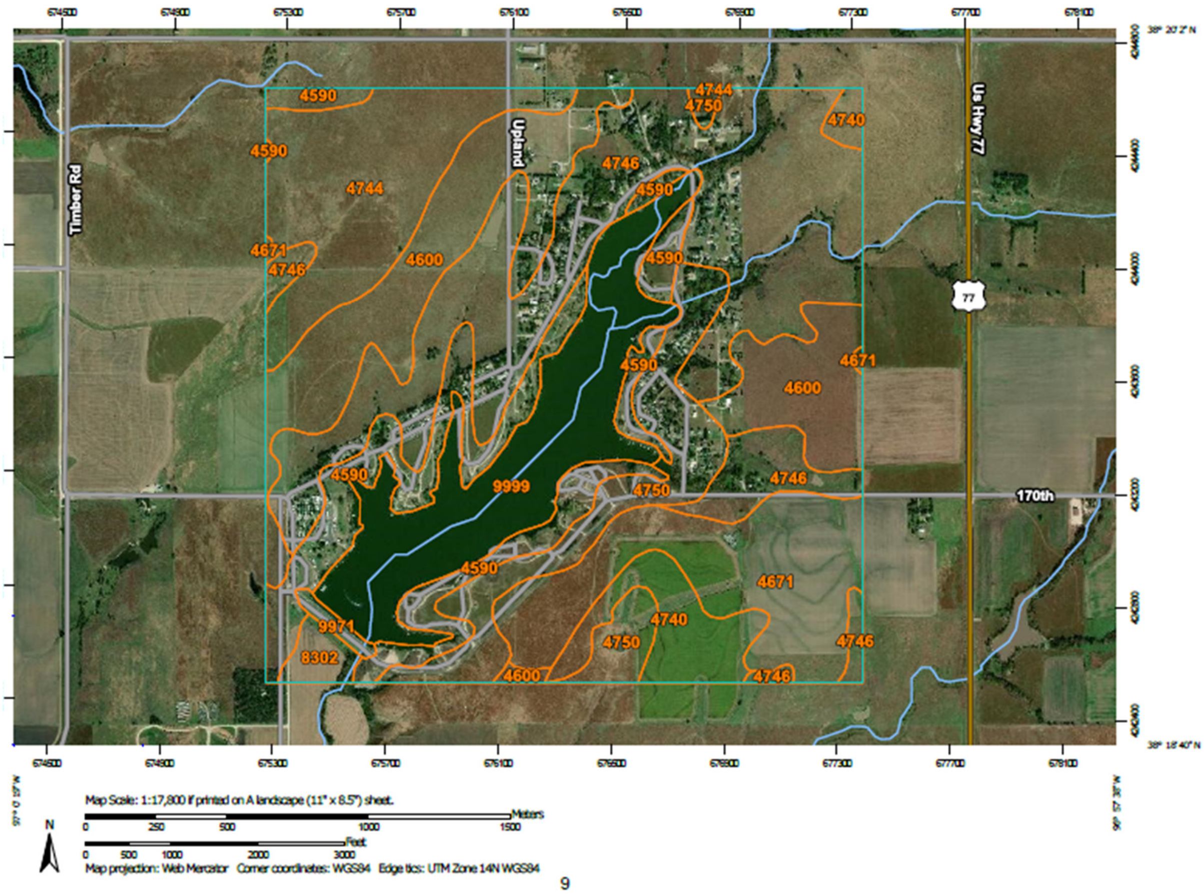

Figure 1. Mapped soils surrounding Marion County Lake (Web Soil Survey 2019).

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
4590	Clime-Sogn complex, 3 to 20 percent slopes	118.2	10.7%
4600	Dwight silt loam, 0 to 1 percent slopes	160.9	14.6%
4671	Irwin silty clay loam, 1 to 3 percent slopes	115.0	10.4%
4740	Labette silty clay loam, 1 to 3 percent slopes	45.7	4.1%
4744	Labette-Dwight complex, 0 to 3 percent slopes	113.3	10.3%
4746	Labette-Sogn silty clay loam, 0 to 8 percent slopes	300.0	27.2%
4750	Sogn silty clay loam, 0 to 10 percent slopes	93.3	8.5%
8302	Verdigris silt loam, 0 to 1 percent slopes, occasionally flooded	11.0	1.0%
9971	Arents, earthen dam	4.6	0.4%
9999	Water	141.4	12.8%
Totals for Area of Interest		1,103.3	100.0%

Figure 2. Map unit legend for Marion County Lake (Web Soil Survey 2019).

The primary soil unit in the area immediately surrounding the lake is the Clime-Sogn Complex (map unit 4590) with 3 to 20 percent slopes (Figures 1 and 2). The samples used in this study were all collected from areas mapped as soil unit 4590. The expected soil properties for this soil unit are displayed in Table 1 and are based on a combination of data from the Clime soil series type location and the Sogn soil series type location in Chase County and Geary County, KS respectively.

Table 1. Expected properties of the Clime-Sogn Complex (Web Soil Survey 2019).

Soil Unit	**CEC – meq/100 g soil**	**Organic Matter - %**	**Texture class**	**Clay %**	**Sand %**
4590: Clime-Sogn Complex	22.1	3.0	Silty Clay	40-60	40-60

A soil's K-factor describes its susceptibility to low energy water erosion. The K-factor is derived from a combination of the values for soil texture, organic matter, and saturated hydraulic conductivity, and can be as low as 0.02 or as high as 0.69. This factor is used as part of the Revised Universal Soil Loss Equation (RUSLE) in order to determine the amount of soil lost to erosion on an annual basis (Natural Resources Conservation Service 2019). The Clime-Sogn Complex has a K-factor of 0.24, which is a low to moderate value (Soil Survey Staff 2019). This K-factor is the lowest of all the adjacent soil units within the mapping area which range from 0.28-0.43.

Methods

The three main theories on how to choose sample locations are judgement, convenience, and probability sampling. Convenience sampling involves choosing only locations that are easily accessible to the researcher. For example, choosing sample locations following a road or path. This method is generally only used if there is no other choice. Marion County Lake has roads that touch the shore all the way around it, so there was no need to exclude hard to reach areas. Judgement sampling allows a researcher to choose locations that they believe to be significant or representative (Carter and Gregorich 2007). This is often used in a hybrid method with probability sampling to collect the most useful possible data. The hybrid usually includes increasing sample concentration along preferential flow paths such as sink holes (Stamper et al. 2014).

For this project, a hybrid of judgement and convenience patterns were used. Using a judgement sampling pattern, four sampling locations were selected along the shoreline based on suspicions they would yield diverse results. At each location, four samples were taken 12 yards apart, beginning at the lake shore. Samples labeled A1, B1, C1, and D1 were collected closest to the lake shore. Samples labeled A4, B4, C4, and D4 were collected furthest from the lake shore. The hypothesis was that phosphorus concentrations in the soil would change with distance from the lake's edge and vary between location due to differences in land use and proximity to residence and inflow tributaries.

Figure 3. Sampling transects A-D.

Samples were collected with a soil probe; the first sample was taken as close as possible to the shoreline, and then the other three samples were taken every 12 yards. The samples' profiles were described as observed in the probe, and then the contents were pushed straight into a labelled sample bag where the cores were broken up, as recommended by Kovar and Pierzynski (2009). The profile description forms are in Appendix A. For accurate chemical and physical interactions, 2 to 40 mm depth is recommended (Kovar and Pierzynski 2009) and that is the depth used in this project. Field notes were taken at each sample location at the time of sampling. Location, date, and author are necessary metadata for field notes (USDA 2017). Since the samples were all collected by the team together on one day, location and descriptions were the focus of the notes taken.

The soils were tested for phosphorus using the Mehlich method, as it is a flexible method appropriate for basic, clay soils (Kovar and Pierzynski 2009). The Kansas State University soils lab completed all quantitative analyses for the soil samples. In addition to phosphorus, also pH, organic matter, nitrate, potassium, ammonium, calcium, magnesium, sodium, CEC, texture, and percentages of sand, silt, and clay were determined.

Mean and variance are the two most important statistical features of soil data (Carter and Gregorich 2007). The mean is the geometric average value of the data. It is useful for understanding in general where the area sampled falls. Variance indicates the spread or variability of the data. This helps understand if the data is uniformly near the average or if there are places that do not come close to the average. To understand which factors are influencing variance in the data, ANOVA single factor variability tests were performed. A p-value was determined for the following variables: distance from shoreline, slope, organic matter, and cation exchange capacity. This p-value is the likelihood that the results are from the same population. This means that a low p-value indicates that the factor being tested is likely to be causing the differences in data. For this project, any p-value lower than 0.05 or 5% was considered significant.

Results

Results from the laboratory analysis are shown in Table 2.

Table 2. Soil sample test results. Analysis completed by the KSU Soil Testing Laboratory.

Sample ID	pH	Phosphorus - ppm	Na - ppm	CEC – meq/100 g soil	Organic Matter - %	Texture class	Clay %	Sand %
A1	7.8	5	9	24.1	5.5	Silt loam	20	24
A2	7.9	3	6	23.1	5.7	Silt loam	20	16
A3	7.7	4	10	21.9	6.1	Silt loam	22	16
A4	7.7	4	10	26.1	5.6	Loam	26	30
B1	7.5	50	244	30.5	8.2	Silty clay loam	28	18
B2	7.6	20	300	32.5	5.8	Silty clay loam	36	10
B3	7.6	30	150	29.1	6.1	Silty clay loam	32	20
B4	7.7	41	40	27.9	8.0	Silty clay loam	30	14
C1	7.4	4	11	27.2	8.3	Silty clay loam	36	14
C2	7.1	6	14	27.7	10.3	Silty clay loam	32	20
C3	6.4	4	11	25.1	9.0	Clay loam	36	22
C4	7.2	5	14	27.2	8.0	Silty clay loam	36	18
D1	7.5	4	14	27.5	8.1	Silty clay loam	38	10
D2	7.7	5	14	27.2	8.3	Silt loam	26	20
D3	7.8	4	14	27.0	8.7	Silt loam	24	12
D4	7.7	4	14	25.9	7.2	Silt loam	22	14

Each sample has a slightly basic pH, except for C3 (pH = 6.4). Transects A, C, and D are similar in terms of phosphorus and sodium concentrations, whereas transect B has significantly higher phosphorus and sodium concentrations. Transect B also has the highest CEC. Additionally, transect A has the lowest average CEC and organic matter. Transects C and D have the highest organic matter, followed by transect B and A, respectively. Of particular interest are the phosphorus test results, which are displayed in a graph in Figure 4 for comparison. The color scheme in Figure 4 is consistent for all graphs in this report.

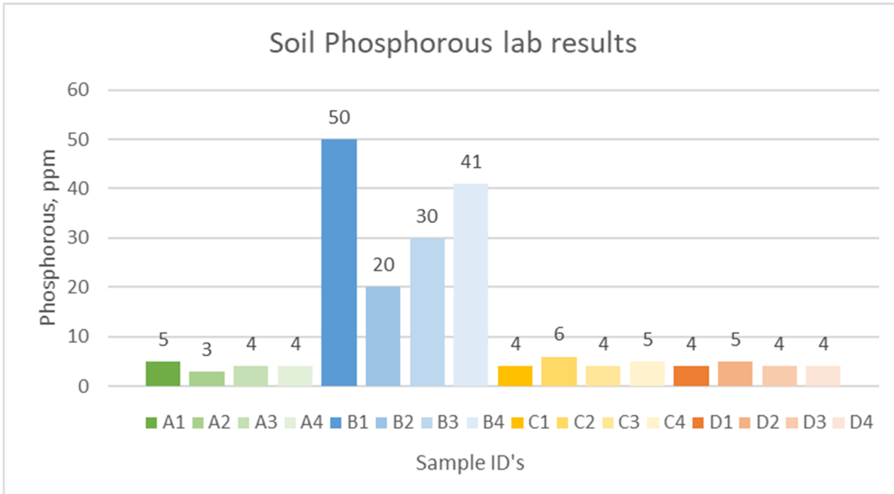

Figure 4. Soil phosphorus test results.

Half of the samples have a silty clay loam texture. Transect A has the coarsest texture, characterized by silt loam and loam. When plotted on the soil textural triangle, it is apparent that samples from the same transect display very similar textural properties (Figure 5).

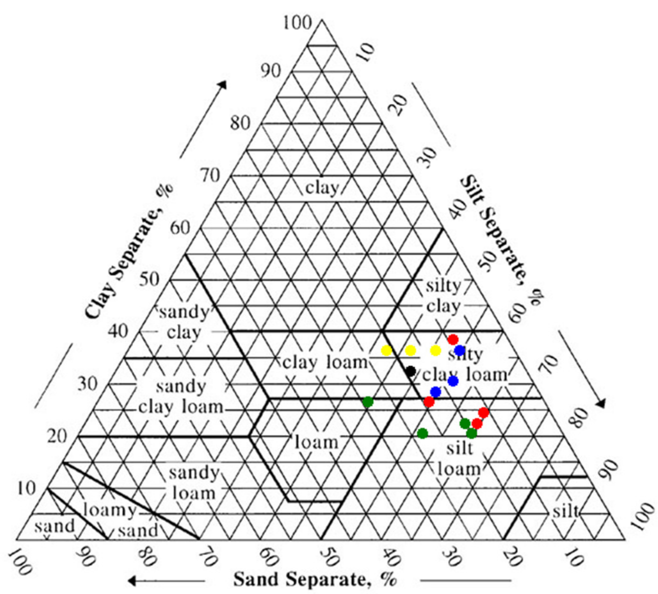

Figure 5. Soil texture triangle with plotted sample texture. Transects A, B, C, and D are represented by green, blue, yellow, and red respectively. B3 and C2 are represented by black, as they have the same texture.

Discussion

Expected vs. Observed Soil Properties

Expected soil properties are based on data for the Clime-Sogn Complex from Web Soil Survey (Table 1). The observed average CEC, organic matter, and texture differed from the expected values from Web Soil Survey for each transect, as shown in Table 3 below. Observed CEC values were between 5 and 25% higher than expected and organic matter values were between 90 to 200% higher than expected. Observed values for CEC align more with the following mapped soils further from the lake's shore: Irwin silty clay loam (1 to 3 percent slopes) to the southeast, Labette silty clay loam (1 to 3 percent slopes) to the northeast and southeast, Labette-Dwight complex (0 to 3 percent slopes) to the northwest, and the Labette-Sogn complex (0 to 8 percent slopes) to the east. Observed textures were coarser than expected values.

The expected pH for the Clime-Sogn complex matches closely with the measured pH for most samples. Fifteen of the sixteen samples measured within 0.4 of the expected pH of 7.5. The only exception is C3 with a pH of 6.4, hence the lower average pH for transect C (Table 3).

Table 3. The average values for CEC, pH, soil organic matter, and surface texture class for each transect are compared to the expected values from the soil map. The average texture class for each transect was determined by averaging each samples' clay, sand, and silt percentage.

	Average, Transect A	Average, Transect B	Average, Transect C	Average, Transect D	Expected Value
CEC, meq/100 g	23.8	30.0	26.8	26.9	22.1
pH	7.8	7.6	7.0	7.7	7.5
Organic matter, %	5.7	7.0	8.9	8.1	3
Surface texture class	Silt loam	Silty clay loam	Silty clay loam	Silty clay loam	Silty clay

Relationships between Soil Characteristics and Phosphorus

Prior literature shows there are significant correlations between soil organic matter, CEC, and texture (Ige, Akenremi, and Flaten 2007). Organic matter, CEC, and finer soil texture are associated with higher levels of phosphorus retention (Domagalski and Johnson 2011; Spargo 2013). Results obtained in this study are consistent with these prior findings. The sampled soils surrounding Marion County Lake have moderate to high organic matter content, moderately fine to fine textured soils, and therefore high CEC. Higher values for clay content and CEC correspond to higher phosphorus concentrations (Figures 7 and 8). However, there was no positive correlation between organic matter and phosphorus (Figure 6).

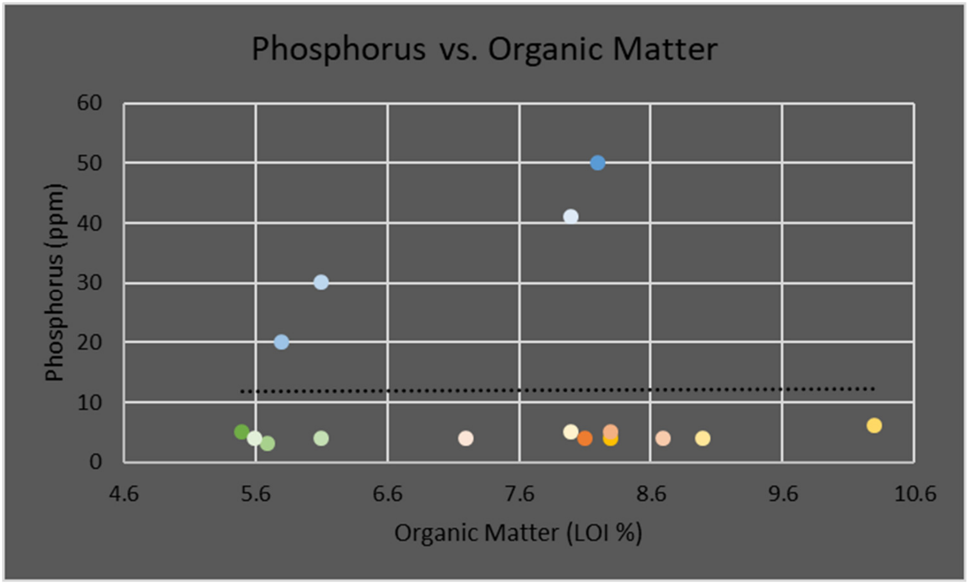

Figure 6. Phosphorus compared to organic matter of all 16 samples.

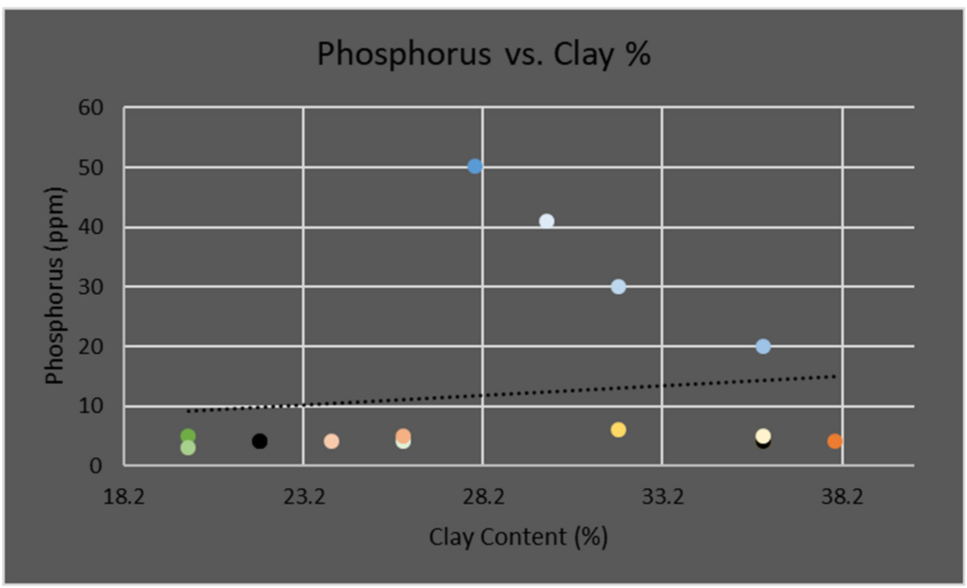

Figure 7. Phosphorus compared to clay content of all 16 samples.

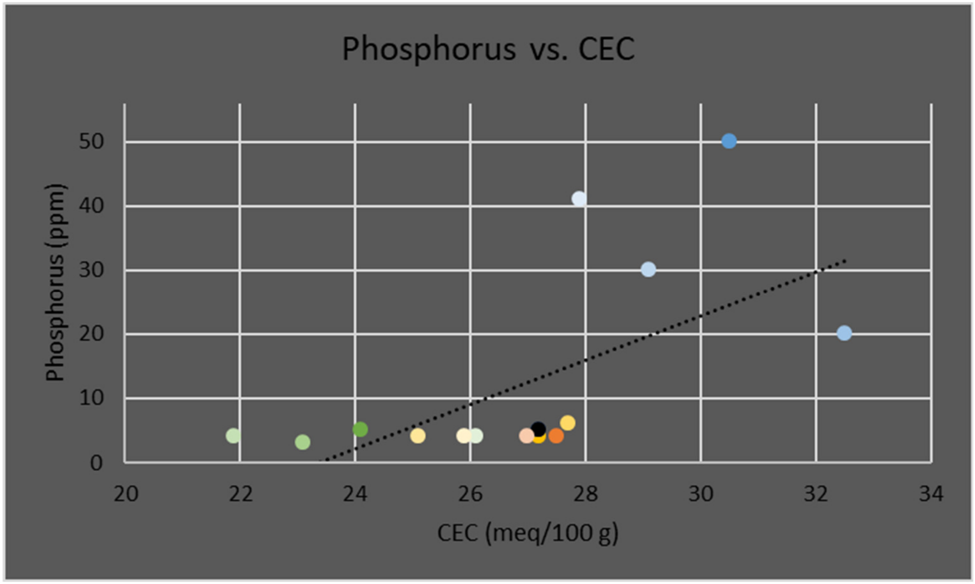

Figure 8. Phosphorus compared to CEC of all 16 samples.

To test the importance of various factors on phosphorus content, statistical analysis was performed including ANOVA tests and standard deviations. ANOVA tests were computed for five different scenarios (Appendix D) and their results are shown in Table 4. Low p-values mean that the factor makes a significant contribution to the data. All ANOVA tests had a very low p-value aside from the test comparing phosphorus measurements according to distance from the lake. This means that slope and organic matter both are significantly correlated to phosphorus content. Flatter transects had a higher average P-concentration than steep transects. An inverse correlation was seen in the data between organic matter and phosphorus; low organic matter corresponded to high phosphorus content. This was not the relationship expected based upon findings in literature. It is likely that other factors could contribute to this finding such as water table level, slope, and surrounding land use. ANOVA's were also computed analyzing organic matter and CEC amongst transects. Both ANOVA's had very low p-values, meaning that transect location was strongly correlated to both CEC and organic matter content.

Figure 9. Phosphorus ANOVA p-values.

Total Phosphorus Surrounding Marion County Lake

Using the phosphorus results and acreage of map unit 4590 around Marion County Lake, total phosphorus surrounding the lake can be estimated. The average phosphorus concentration amongst the 16 samples is 12 ppm. Assuming there are 2,000,000 lbs of soil in one-acre furrow slice, then there is an average of 12 kg phosphorus per acre in map unit 4590 (Landschoot 2016). Therefore, there is approximately 1300 kg of phosphorus in the soil immediately surrounding Marion County Lake. Calculations can be found in Appendix B.

Potential Phosphorus Losses to Marion County Lake

Without data regarding the slope, slope length, subsurface hydraulic gradients, and water table depth of the soils in the area, the true extent of phosphorus losses to Marion County Lake via soil erosion and subsurface transport remains uncertain. However, the K factor data from Web Soil Survey can be used to provide an estimate for loss of particulate-bound phosphorus. The K factor is an indication of tons of soil lost per acre annually by sheet and rill erosion. Soil mapping unit 4590 has a K-factor of 0.24. Using this information, the average mass of phosphorus lost annually per acre from map unit 4590 is 0.309 kg (see Appendix C for calculation). This means that less than 1% of the phosphorus stored in soils in map unit 4590 is loss via erosion annually.

Conclusion

Phosphorus levels in the soils surrounding Marion County Lake were approximately uniform, aside from transect B. Transect B was located next to the stream outflow into the lake and was also the closest to uphill residences compared to the other transects. The soil textures were similar for all samples, so it is inconclusive whether or not soil texture contributes to phosphorus retention at the site.

ANOVA tests showed that slope is a significant factor in phosphorus content; flatter slope contributes to higher P levels. Additionally, the ANOVA test showed an unexpected correlation between low organic matter and high phosphorus levels. The estimated total amount of phosphorus in the soil immediately surrounding the lake is 1300 kg. An estimated rate of 0.309 kg/ac/year of phosphorus is lost to the lake via erosion, which translates to 36.5 kg/year from a land area of 118.2 acres around the lake.

Future research should focus on the following areas: higher resolution soil phosphorus sampling, soil erosion rates, and water table depth monitoring. Higher resolution soil phosphorus sampling would give more insight as to why some areas, like transect B, have significantly higher phosphorus levels compared to other areas. More data would also allow for a more accurate average of the phosphorus load in soils surrounding Marion County Lake. Additionally, in-depth data collection regarding local land management practices, vegetation cover, slope percent, slope length, and water table depth would enable more precise calculations of soil erosion and groundwater movement, and thus more accurate estimations of particulate-bound and dissolved phosphorus losses. This would give park managers at Marion County Lake a better understanding of the risks that soils may pose to water quality.

Appendices

APPENDIX A: SOIL SAMPLE FIELD OBSERVATIONS

Transect	Point	Longitude	Latitude	Site Description	Elevation	Vegetation	Land Use	# of Horizons
A	1	-96.9864 W	38.3200 N	toe	408	N/a		1
A	2	-96.9864 W	38.3201 N	Backslope of hill	409	N/a		1
A	3	-96.9864 W	38.3201 N	Second shoulder of hill	410	N/a		1
A	4	-96.9865 W	38.3202 N	Farthest from lake; Shoulder of hill (~17% slope)	411	N/a		1
B	1	-96.9790 W	38.3289 N		406	N/a		1
B	2	-96.9791 W	38.3289 N		406	N/a		2
B	3	-96.9791 W	38.3290 N		406	N/a		1
B	4	-96.9792 W	38.3290 N	~2% slope; houses within ~100 feet near incoming stream	406	short grass, some trees, recreational park	Recreation	1
C	1	-96.9801 W	38.3243 N		407			1
C	2	-96.9800 W	38.3243 N		408			1
C	3	-96.9800 W	38.3243 N		409			1
C	4	-96.9799 W	38.3243 N	Houses, roads	410	short grass, trees (more than B)	Recreational park, picnic area	1
D	1	-96.9832 W	38.3196 N	Toe slope	407			2
D	2	-96.9832 W	38.3196 N	Foot slope	408			1
D	3	-96.9831 W	38.3196 N	Backslope	409			1
D	4	-96.9831 W	38.3196 N	Shoulder of hill; ~15% slope	410	Grass - medium to short	Disc Golf Course	2

Transect	Point	Horizon 1	Depth (cm) 1	Color 1	Texture 1	Redox C 1	Redox D 1	Effervescence 1	Other 1	Notes 1
A	1	A	7	10YR 2/2	Silt Loam	N/A	N/A	Violent	Carbonates masses, CAM	<Null>
A	2	A	7	10YR 3/2	Silt Loam	N/A	N/A	Violent	<Null>	<Null>
A	3	A	5	10YR 3/2	Silt Loam	N/A	N/A	Violent	<Null>	<Null>
A	4	A	5	10YR 2/2	Silt Loam	N/A	N/A	Violent	<Null>	DRAWING
B	1	A	3	10YR 2/2	Silt Loam	N/A	N/A	Violent	CAM = 15%; FGR = 10%	<Null>
B	2	A	4	10YR 2/2	Silt Loam	N/A	N/A	Strong	CAM = 15%; FGR = 10%	<Null>
B	3	A	12	10YR 2/2	Silt Loam	F3m	Strong	CAM	<Null>	<Null>
B	4	A	8	10YR 2/2	Silt Loam	N/A	N/A	Violent	~20% Clay (more clay)	Sticky; DRAWING
C	1	A	8	10R 2/1	Silt Loam	N/A	N/A	Violent	<Null>	<Null>
C	2	A	3	10R 2/1	Silt Loam	N/A	N/A	Slight	~14% Clay	<Null>
C	3	A	8	10YR 2/1	Silt Loam	N/A	N/A	Slight	<Null>	Goose poop
C	4	A	6	10R 2/1	Silt Loam	N/A	N/A	Nothing	<Null>	Coarser; 13 - 17% Clay overall samples; *Raining throughout*
D	1	A	4	10YR 2/2	Silt Loam	N/A	N/A	Slight	~15% Clay	<Null>
D	2	A	3	10YR 2/2	Silt Loam	N/A	N/A	Violent	~20% Clay	<Null>
D	3	A	5	10YR 2/2	Silt Loam	N/A	N/A	Violent	CAM	<Null>
D	4	A	3	10 YR 2/2	Silt Loam	N/A	N/A	Violent	<Null>	<Null>

Transect	Point	Horizon 2	Depth (cm) 2	Color 2	Texture 2	Redox C 2	Redox D 2	Effervescence 2	Other 2	Notes 2
A	1	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
A	2	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
A	3	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
A	4	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
B	1	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
B	2	Bw	11	10YR 2/2	Silt Loam	F3m	Strong(less)	CAM	N 31% Clay	<Null>
B	3	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
B	4	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
C	1	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
C	2	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
C	3	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
C	4	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
D	1	Bw	12	10R 2/2	Silt Loam	N/A	N/A	Slight	~22% Clay	DRAWING
D	2	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
D	3	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>	<Null>
D	4	Bw	9	10YR 2/2	Silt Loam	N/A	N/A	Violent	~16% Clay	<Null>

APPENDIX B: CALCULATION OF PHOSPHORUS SURROUNDING MARION COUNTY LAKE

Assuming phosphorus at A1 is representative of the whole map unit, there is 531.9 kg phosphorus surrounding Marion County Lake:

(5 mg phosphorus / 1 kg soil) x (0.45 kg soil / 1 lb soil) x (2,000,000 lb soil / 1 afs) x (1 kg phosphorus / 1,000,000 mg phosphorus) x 118.2 ac of map unit 4590 = 531.9 kg phosphorus

This calculation was repeated for each sample. The results in the table below were averaged to obtain a mean value of 1300 kg for total phosphorus in map unit 4590.

Sample	A1	A2	A3	A4	B1	B2	B3	B4	C1	C2	C3	C4	D1	D2	D3	D4
Phosphorus	531.9	319.14	425.52	425.52	5319	2127.6	3191.4	4361.58	425.52	638.28	425.52	531.9	425.52	531.9	425.52	425.52

APPENDIX C: PHOSPHORUS LOSS FROM SOIL VIA EROSION TO MARION COUNTY LAKE

The average phosphorus concentration in soil mapping unit 4590 is 12 ppm. Using this average and the K factor (0.24), average phosphorus loss per acre and total phosphorus loss via sheet and rill erosion of soil can be determined:

(0.24 tons of soil loss / acre per year) x (2,000 lb soil / 1 ton soil) x (0.454 kg soil / 1 lb soil) x (12 mg phosphorus / 1 kg soil) x (1 kg phosphorus / 1,000,000 mg phosphorus) x 118.2 ac = 0.309 kg phosphorus lost annually

APPENDIX D: ANOVA COMPUTATIONS

Description	Transect	Sample # 1 (closest to lake)	2	3	4 (farthest from lake)	Std. Dev.
Phosphorus, ppm (comparing sample #s against eachother)	A	5	3	4	4	0.71
	B	50	20	30	41	11.30
	C	4	6	4	5	0.83
	D	4	5	4	4	0.43
	Sum	63	34	42	54	
	Average	15.75	8.5	10.5	13.5	
	Variance	522	60	169	336	
	Std. Dev.	19.78	6.73	11.26	15.88	
	p-value	0.927				
Phosphorus (comparing steep vs. flat slope transects)	Steep transects	P, ppm	P, ppm	Flat transects		
	A1	5	50	B1		
	A2	3	20	B2		
	A3	4	30	B3		
	A4	4	41	B4		
	D1	4	4	C1		
	D2	5	6	C2		
	D3	4	4	C3		
	D4	4	5	C4		
	Sum	33	160			
	Average	4.125	20			
	Variance	0.41	339.14			
	Std. Dev.	0.60	17.23			
	p-value	0.029				
Phosphorus (comparing high OM transects vs. low OM transects)	High OM transects	P, ppm	P, ppm	Low OM transects		
	C1	4	5	A1		
	C2	6	3	A2		
	C3	4	4	A3		
	C4	5	4	A4		
	D1	4	50	B1		
	D2	5	20	B2		
	D3	4	30	B3		
	D4	4	41	B4		
	Sum	36	157			
	Average	4.50	19.63			
	Variance	0.57	352.27			
	Std. Dev.	0.71	17.56			
	p-value	0.039				

		Transect				
Description	Sample #	A	B	C	D	Std. Dev.
Organic Matter, % (comparing data within transects)	1	5.5	8.2	8.3	8.1	1.17
	2	5.7	5.8	10.3	8.3	1.91
	3	6.1	6.1	9	8.7	1.38
	4	5.6	8	8	7.2	0.98
	Sum	22.9	28.1	35.6	32.3	
	Average	5.725	7.025	8.9	8.075	
	Variance	0.069167	1.5625	1.046667	0.4025	
	Std. Dev.	0.23	1.08	0.89	0.55	
	p-value	0.002				

		Transect				
Description	Sample #	A	B	C	D	Std. Dev.
CEC, meq/100 g (comparing data within transects)	1	24.1	30.5	27.2	27.5	2.27
	2	23.1	32.5	27.7	27.2	3.33
	3	21.9	29.1	25.1	27	2.65
	4	26.1	27.9	27.2	25.9	0.82
	Sum	95.2	120	107.2	107.6	
	Average	23.8	30	26.8	26.9	
	Variance	3.16	3.91	1.34	0.49	
	Std. Dev.	1.54	1.71	1.00	0.60	
	p-value	0.001				

References

Carter, M. R., and E. G. Gregorich. *Soil Sampling and Methods of Analysis*. 2nd ed. Taylor & Francis Group, LLC, 2007.

"Chapter 7.--Soil Survey Data Collection, Management, and Dissemination." In *Soil Survey Manual*. United State Department of Agriculture, 2017.

Diaz, D. A., D. B. Mengel, and K. L. Martin. 2011. Phosphorus Facts: Soil, Plants, and Fertilizer. *Kansas State University Department of Agronomy*. https://www.agronomy.k-state.edu/services/soiltesting/documents/fertilizer_recommendations_and_references/PhosphorusFacts.pdf (last accessed October 2019).

Domagalski, J. L., and H. M. Johnson. 2011. Subsurface transport of orthophosphate in five agricultural watersheds, USA. *Journal of Hydrology* 409 (1):157–171.

Dupas, R., G. Gruau, S. Gu, G. Humbert, A. Jaffrézic, and C. Gascuel-Odoux. 2015. Groundwater control of biogeochemical processes causing phosphorus release from riparian wetlands. *Water Research* 84:307–314. http://www.sciencedirect.com/science/article/pii/S0043135415301500 (last accessed 3 October 2019).

Gu, S., G. Gruau, R. Dupas, C. Rumpel, A. Crème, O. Fovet, C. Gascuel-Odoux, L. Jeanneau, G. Humbert, and P. Petitjean. 2017. Release of dissolved phosphorus from riparian wetlands: Evidence for complex interactions among hydroclimate variability, topography and soil properties. *Science of the Total Environment* 598:421–431.

Gu, S., G. Gruau, F. Malique, R. Dupas, P. Petitjean, and C. Gascuel-Odoux. 2018. Drying/rewetting cycles stimulate release of colloidal-bound phosphorus in riparian soils. *Geoderma* 321:32–41. http://www.sciencedirect.com/science/article/pii/S001670611731176X (last accessed 3 October 2019).

Ige, D. V., O. O. Akinremi, and D. N. Flaten. 2007. Direct and Indirect Effects of Soil Properties on Phosphorus Retention Capacity. *Soil Science Society of America Journal; Madison* 71 (1):95–100. http://search.proquest.com/docview/216054716/abstract/FD125280AA2043FFPQ/1 (last accessed 9 December 2019).

Kovar, John, and Gary Pierzynski. "Methods of Phosphorus Analysis for Soils, Sediments, Residuals, and Waters." SERA-IEG 17, June 2009.

Landschoot, P. 2016. What is an "Acre Furrow Slice" of Soil? *Penn State Extension*. https://extension.psu.edu/what-is-an-acre-furrow-slice-of-soil (last accessed 9 December 2019).

Natural Resources Conservation Service, United States Department of Agriculture. 2019. Field Office Technical Guide. Revised by Ecological Sciences Division. https://efotg.sc.egov.usda.gov/#/details (last accessed 14 December 2019).

O'Toole, P., J. M. Chambers, and R. W. Bell. 2018. Understanding the characteristics of riparian zones in low relief, sandy catchments that affect their nutrient removal potential. *Agriculture, Ecosystems & Environment* 258:182–196. http://www.sciencedirect.com/science/article/pii/S0167880918300872 (last accessed 22 September 2019).

Sharpley, A., T. C. Daniel, J. T. Sims, and D. H. Pote. 1996. Determining environmentally sound soil phosphorus levels. *U.S. Department of Agriculture*. https://pubag.nal.usda.gov/pubag/downloadPDF.xhtml?id=20713&content=PDF (last accessed September 2019).

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. *Web Soil Survey*. https://websoilsurvey.sc.egov.usda.gov/ (last accessed 9 December 2019).

Spargo, J. 2013. Interpreting Your Soil Test Results. https://ag.umass.edu/sites/ag.umass.edu/files/fact-sheets/pdf/spttl_2_interpreting_your_soil_test_results_0.pdf (last accessed 9 December 2019).

Stamper, D.J., C.T. Agouridis, D.R. Edwards, and M.A. Purschwitz. "Effect of Soil Sampling Density and Landscape Features on Soil Test Phosphorus." *Applied Engineering in Agriculture* 30, no. 5 (2014): 773–81.