BIG FOOT CREEK WATERSHED STUDY PHASE 1

GENEVA LAKE, WALWORTH COUNTY, WI

2020

BY: GENEVA LAKE ENVIRONMENTAL AGENCY

Big Foot Creek's outlet to Geneva Lake with Big Foot Beach State Park to the north (top).

This project was supported by an Environmental Education Foundation grant, a Wisconsin Department of Natural Resources Small Scale Lake planning grant, # SPL400019, and the Geneva Lake communities, the Villages of Williams Bay, and Fontana-on-Geneva Lake, the Towns of Linn and Walworth and the City of Lake Geneva.

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INTRODUCTION

Big Foot Creek Watershed is located on the eastern end of Geneva Lake, Walworth County, WI with lands in the City of Lake Geneva, the Town of Linn, and the Town of Bloomfield (Appendix A). The watershed is 1358.17 acres in size with mixed land use and hydrological soil types (Appendix B). It is drained by Big Foot Creek, a small creek that flows westward and empties into Geneva Lake just south of the entrance to Big Foot Beach State Park). For years it has been the source of a reddish discharge to Geneva Lake in the general area of the State Park's swim area. Past monitoring has shown it to have other significant water quality issues. Land use in the watershed is varied, with rural, open land representing over 78% of the watershed's land use. The open rural portion of the watershed is comprised of mostly wetlands that have been tiled, drained, filled, farmed, mined, and burned. From the 1950's thru the 1970's a dump/land fill was operated in the south-central portion of the watershed. A small portion of the northern area of the watershed drains residential and commercial areas of the City of Lake Geneva via storm sewers.

During the summer of 2019, a Wisconsin Department of Natural Resource Small Scale Lake Planning Grant was used to monitor Big Foot Creek to document water quality. The purpose the Big Foot Creek Watershed Study Phase I was to document the creek's water quality and its loading to Geneva Lake. Information from Phase I will be used in Phase II to develop a more in-depth study of the watershed for the development of management practices to improve the creek's water quality and reduce the pollution loading to Geneva Lake.

WATERSHED LAND USE AND SOILS

Most of the Big Foot Creek watershed is relatively flat. Much of the wetland is around 867 ft above the North American Vertical Datum per 1988 (NAVD88) while the higher lands to the north and south are around 75 ft higher. For reference Geneva Lake's designated elevation is 864 ft NAVD88. A few hills are dispersed around the wetland but are not higher than 70 ft above the wetland.

Major land use within the Big Foot Creek Watershed is agriculture, 898.5 ac.(64.9%), open, wetland, woody 323.8 ac. (23.3%), residential, 129.2 ac. (9.3%) and commercial 33.4 ac.(2.4%) A significant portion of the watershed is not covered with impervious surfaces.

Of more significant is the hydrologic soil types found within the watershed. Hydrological soil types are divided into four groups: Group A soils with high infiltration rates, deep, well drained sands, and gravel, Group B soils

with moderate infiltration rates, moderately deep, to deep, and moderately well to well drained soils, Group C soils with a low infiltration and with a layer that impedes downward movement of water and, Group D soils with high runoff potential, low infiltration rates and high-water table.

The Big Foot Creek watershed has a complex mix of soils with three of the hydrologic soil types present (Appendix B). The majority (79%) of the soils within the watershed are of the soil Group B, with moderately well drained soils. Group D soils with high runoff potential make up about 20% of the watershed with soil Group A comprising the remainder of the watershed.

WATER QUALITY HISTORY.

Big Foot Creek's water quality first raised concern in 1976-1977 when Geneva Lake's first Water Quality Management Plan was prepared. Studies of the tributaries to Geneva Lake conducted as a part of that study, identified Big Foot Creek as the second most degraded of the nine major perennial streams flowing into Geneva Lake [(1)]. It led the major perennials in terms of ammonia nitrogen, total and dissolved phosphorus, and total nitrogen concentrations.

In 1992 a Wisconsin Lake Planning grant was awarded to conduct hydrologic and pollution loading to Geneva Lake. Using the Agricultural Nonpoint Pollution Model (AGNPS), three of Geneva Lake's major sub-watersheds, including the Big Foot Creek sub-watershed, were studied. The AGNPS modeling found that for a one-year storm event (a storm likely to occurred once a year) Big Foot Creek watershed was a significant source of phosphorus to Geneva Lake [(2)].

Additional studies in 1993, [(3)] [(4)] [(5)] found that Big Foot Creek not only had these same nutrient issues, but identified other water quality concerns, such as low oxygen conditions, high COD, excessive solids, turbidity, and iron. In 1996 a Wisconsin Department of Natural Management Lake Planning Grant was used to conduct an in-depth diagnostic-feasibility study on Geneva Lake. This study resulted in a second edition of the Lake Management Plan for Geneva Lake [(6)] and the Hydrology and Water Quality of Geneva Lake, Walworth County report [(7)]. This study found that tributaries to Geneva Lake were the largest source of phosphorus[(7)].

Samples collected on November 8, 1997 and July 19, 2000, both at base flow conditions, found Big Foot Creek to have the highest total phosphorus concentrations, and was either the highest or second highest source of phosphorus loading to Geneva Lake at the time of sampling[(7)]. Samples collected during high flow conditions on May 13, 1998, also found Big Foot Creek to be a major contributor of phosphorus to Geneva Lake [(7)].

It has been suggested that the red appearance of the water, low oxygen, high total phosphorus, and ammonia values may be related. As the groundwater becomes exposed to the atmosphere, with the help of oxygen,

dissolved iron in the groundwater goes from soluble to insoluble form and forms a red flocculant of iron within the water. This process uses oxygen in the surface waters reducing dissolved oxygen resulting in the reduction of nitrogen. The low oxygen values also result in the release to the surface waters of inorganic phosphorus that is tied up in the sediment. This results in a red flocculent of insoluble iron, high inorganic phosphorus, high ammonia nitrogen and low dissolved oxygen. More studies are needed to confirm these relationships as the magnitude of what is happening in the creek may be driven by more than these processes alone.

METHODS:

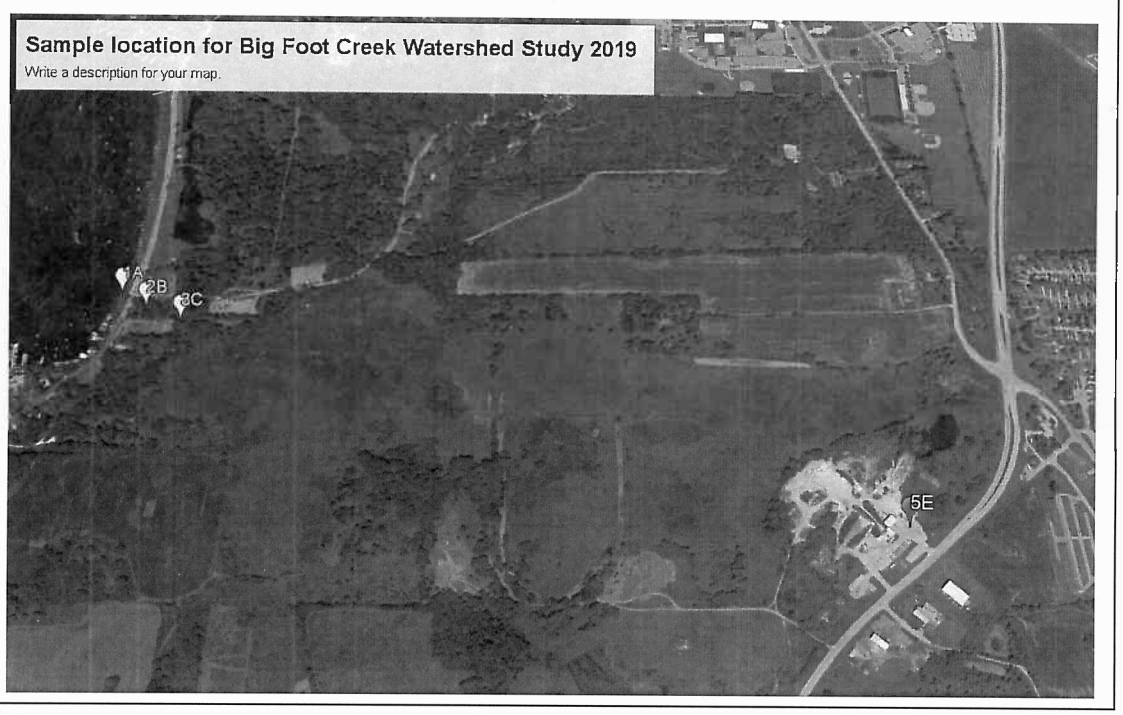
With the help of a grant from the Environmental Education Foundation of the Geneva Lake area, students from Badger High School were hired to assist with the field and lab work for this study. These students were trained in collection and sample handling protocol, and the use of meters for analysis of several water quality parameters. Their involvement in this study offered them the opportunity to learn and apply real world lab and field techniques. It also gave them an opportunity to take some ownership in the effort to improve the quality of the watershed in which their school is located.

The original intent of the study, was to monitor four creek sites at different locations to track the degraded water quality. A defined upstream channel near the parking lot area of the State Park could not be found, so only three stream sites were monitored. Most of the water movement through this area is overland flow.

The three sample sites included in this study were: the discharge site of Big Foot Creek to Geneva Lake where three culverts discharge to Geneva Lake (Site # 1A-10051986); a stream sample site located in Big Foot Beach State Park, east of the culverts under South Lake Shore Drive, just north of the entrance to Big Foot Beach State Park (site 2B- 10051989); a stream site located on the eastern portion of tax parcel IL 1200003A where the stream flow through a single culvert under a gravel access road (3C-10051986). A background groundwater site (well) at the Otto Jacobs plant (site # 5E-#10051988) was sampled at each sampling (Figure 1, Appendix B)

Samples were collected once a month between May and October for six sample dates. The May samples were not sent to the Wisconsin State Lab of Hygiene for analysis, leaving only five sample dates for analysis of total dissolved solids, iron, total phosphorus, ammonia, and chemical oxygen demand.

Figure 1. Sampling location for Big Foot Creek Watshed Study, Geneva Lake, WI 2019



For each sampling, several bottles of sample were collected. One bottle was for pH, conductivity, turbidity, total dissolved solids (TDS) and alkalinity. A separate dissolved oxygen bottle was used to collect samples for dissolved oxygen analysis. These analyses were performed by the field crew following collection.

Three other bottles per site were also collected for each sampling. These samples were shipped to the Wisconsin State Lab of Hygiene (WSLH) for analysis. One bottle was preserved with sulfuric acid and was use for nutrient analysis. One bottle was preserved with nitric acid and was analyzed for iron. A third unpreserved bottle was used for total suspended solids and chemical oxygen demand.

An Orion model 230A pH meter with an Orion 9107BN probe was used for pH measurements. The meter was calibrated with 7.0 and 10.0 standards for each sampling. Conductivity and total dissolved solids were measured with a Hach model 44660 conductivity/TDS meter. A blank and standard of 0.7065 mS/ were used for each sampling to check meter accuracy. Turbidity was measured in NTUs using a LaMotte 2020we Turbidimeter that was zeroed with deionized water and standardized with a 1 NTU and a 10 NTU standards for each sampling. Alkalinity was measured using a Hach low level test kit. Dissolved oxygen was measured using the Winkler titration method.

The WSLH samples were collected processed and shipped per WSLH guidelines. The WI State Lab of Hygiene uses EPA approved methods for their inhouse analysis. (Appendix C).

After the water samples were collected at sites 1A-10051985, 2B-10051989 and 3C-10051986, a cross-sectional profile of the stream channel was measured to determine area. Flows at site B and C were measured in culverts. Flow at site A were measured at a section of the stream that had relatively unimpeded flow and was straight. Total width and depth were recorded for determination of area. Flows were measured using a Global Water Flow Probe FP111. Discharge (Q in cfs, cubic feet per second) was calculated by multiplying stream area (squared feet) by flow (feet per second).

RESULTS AND DISCUSSION:

Background Sample: It is believed that groundwater is a significant source of water to the Big Foot Creek. The background well sample (E5-11051988, OJ well) was a groundwater sample collected from a well located at the Otto Jacobs plant in the eastern portion of the watershed. It is unknow what depth the well was drawing water from, but it is believed to be relatively shallow. The background well sample showed good water quality for the parameters tested (Table 1). None of the background well samples had measurable total dissolved solids or chemical oxygen demand. Only one background well sample had measurable phosphorus of 0.0081 mg/l. Only three of the six background well samples had detectable levels of ammonia (NH_3) and they averaged 0.095 mg/l, below the groundwater preventative action level (PAL) of 0.92 mg/l. (Wisconsin Administrative Code NR 140.1, table 1.) Two background well samples had detectable iron levels that averaged 0.146. mg/l. The PAL for groundwater iron is 0.15mg/l (Wisconsin Administrative Code NR 140.1, table 2).

Table 1. Average results of parameters tested at the background site E-5,100051988, O.J. Well

Average Results of Parameters tested at site E5, 10051988, OJ Well.		
parameters	average	N
pH	7.6	6
Turbidity (NTU)	0.72	6
Conductivity mS/cm	0.588	6
Total Dissolved Solids (g/l)	0.255	6
Dissolved Oxygen (mg/l)	4.92	6
Total Dissolved Solids (mg/l)	ND	6
Iron (mg/l)	0.146	2
Total Phosphorus (mg/l)	0.0081	1
Ammonia (mg/l)	0.095	3
Chemcial Oxygen Demand (mg/l)	ND	6
N = number of detectable results	ND = not detected	
Source: WSLH, GLEA		

Big Foot Creek Samples: The sampling results of Big Foot Creek during the 2019 summer confirmed earlier reports of water quality problems (Table 2). Although water quality showed some variability in concentrations and stream discharge between sites, they responded to environmental conditions much the same. When concentration showed an increase on a specific sampling date, all sites showed increases. When water clarity and concentrations showed an improvement at one site, all sties showed similar improvements.

Table 2. Average concentrations of selected parameters at three location on Big Foot Creek, Geneva Lake, WI, 2019.

Average concentration of selected pollutants at the three locations on Big Foot Creek, Geneva Lake, Walworth CO. Summer 2019.				
	units	1A-10051985	2B-0051989	3C-10051986
field temp	°C	17.7	17.1	17.5
pH		7.58	7.67	7.61
turbidity	NTU	32.9	35.2	35.6
conductivity	mS/cm	0.628	0.635	0.623
Total Dissolved Solids	g/l	0.306	0.318	0.262
Dissoved oxygen	mg/l	3.90	4.08	3.11
Alkalinity	mg/l	267.5	261.7	269.4
Total suspended sollids	mg/l	21.5	29.8	26.6
Iron	mg/l	13.0	13.8	13.5
Total Phosphorus	mg/l	0.818	0.859	0.853
Ammonia	mg/l	0.228	0.224	0.221
Chemical oxygen demand.	mg/l	50.0	50.4	36.8
discharge	CFS	4.08	1.44	3.24
10051985 1A - Creek discharge to lake.			Source: GLEA, WSLH	
10051989 2B - East of Highway				
10051986 3C - South side of Laz culvert.				

A comparison of the average concentration of selected water quality parameters at the discharge site to the lake with values from the background groundwater well sample (5E 10051988) and Geneva Lake, showed the Big Foot Creek's water quality as measured by these selected parameters was significantly worse than the lake and the groundwater. Groundwater values were closer to the lake than to the stream (Table 3). Total phosphorus and ammonia were significantly higher in Big Foot Creek than in both the background groundwater well sample and Geneva Lake.

Table 3. Comparison of selected water quality parameters from background groundwater site, Big Foot Creek site and spring turnover values on Geneva Lake, WI.

Comparison of selected water quality parameters from groundwater background values to Big Foot Creek, and spring turnover values for Geneva Lake, WI.			
Parameter	Groundwater site 5E Average of 5 samples	Big Foot Creek site 1A Average of 5 samples	Geneva Lake 4/28/2020
pH	7.6	7.58	8.54
Turbidity (NTU)	0.72	32.6	0.452
Conductivity (mS/cm)	0.588	0.628	0.558
Iron (mg/l)	0.146	13	ND
Total Phosphorus (mg/l)	0.0081	0.818	0.0097
Ammonia (mg/l)	0.095	0.228	ND
Source: GLEA and WI SLH	ND = not detected		

The average total phosphorus from the five sample dates and the three sites was 0.843 mg/l. The five sample averages for each site showed a difference of only 0.041 mg/l from the site with the highest five sample average to the site with the lowest five sample average (Table 4).

The highest concentration of total phosphorus for all sample dates and sites was recorded as 1.90 mg/l from site 3C-10051986 east of the highway, on August 20, 2019 (table 4). All three sites experienced their highest total phosphorus concentration on August 20, 2019 when the stream was at or near baseflow. All three sites experienced their lowest discharge on August 20. The concentration of in-stream phosphorus by the low stream stage may have resulted in the higher phosphorus values.

Table 4. Total phosphorus concentrations at three sites on five dates from Big Foot Creek, Geneva Lake, WI, 2019.

Total Phosphorus Concentrations (mg/l) at three sites on five sample dates, Big Foot Creek, Geneva Lake WI 2019.						
	14-Jun	23-Jul	23-Aug	10-Sep	15-Oct	stdv
1A-10051985	0.260	1.48	1.82	0.430	0.0975	0.6962
2B-10051989	0.253	1.56	1.90	0.430	0.122	0.7307
3C-10051986	0.261	1.64	1.84	0.46	0.0931	0.7315
Source: GLEA, WSLH						

The lowest concentration of total phosphorus at all sites occurred on October 15 with a value of 0.0931 mg/l at site 3C-10051986, the most upstream site of the three stream sites. The lowest concentration of total phosphorus for all three sites occurred on October 15. The relationship between discharge and TP concentration is not consistent between sites and dates.

Creek values showed degradation in almost all major parameters at all sample sites and on all sample dates. Dissolved oxygen concentrations and percent saturation found at all three stream sites on all sample dates were lower than the dissolved oxygen and percent saturation values found in the well sample. Groundwater typically has low dissolved oxygen levels due to respiration and decomposition driven by soil organisms. Little oxygen is produced due to low light conditions. Oxygen demand in the creek, as measured by chemical oxygen demand (COD), indicates that something, living or chemical, is using dissolved oxygen in the creek at a rate higher than it is replaced. The concentrations of total phosphorus and ammonia were relative to dissolved oxygen. Samples with low dissolved oxygen, had higher total phosphorus and ammonia.

Although there is some variability in the values due to the weather and creek stage, Big Foot Creek's water quality as measured at the discharge point to the lake, regularly had total phosphorus, ammonia, chemical oxygen demand and dissolved oxygen values of concern (Table 5).

Table 5. Water Quality of Big Foot Creek, Geneva Lake WI, at the Creek's discharge to Geneva Lake, WI.

Water quality of the Big Foot Creek, Geneva Lake mixing zone at selected site during the summer of 2019.							
Parameters	units	5/14/19	6/14/19	7/23/19	8/20/19	9/10/19	10/15/19
Field Temp.	0C	14	24	22	20	20	6
pH	units	7.87	7.44	7.39	7.42	7.52	7.82
Turbidity	NTU	5.29	11.5	69.9	50.8	14.1	5.53
conductivity	mS/cm	0.59	0.65	0.72	0.69	0.53	0.59
total dissolved solids	g/l	0.30	0.32	0.54	0.35	0.23	0.28
dissolved oxygen	mg/l	5.78	4.02	0.76	1.93	3.3	7.58
total suspended solids	mg/l	NT	12.3	21.0	55.0	16.3	2.75
iron	mg/l	NT	5.04	26.1	25.9	6.48	1.52
total phosphorus	mg/l	NT	0.260	1.48	1.82	0.430	0.0975
ammonia	mg/l	NT	0.0930	0.473	0.439	0.0900	0.0462
chemcial oxygen demand	mg/l	NT	42.0	66.2	70.8	50.6	20.0
NT = not tested.							
Source: Geneva Lake Environmental Agency, WI State Lab. of Hygiene.							

The total phosphorus surface water standard per NR 102.06 (3) (b) is 0.075 mg/l. Although the surface water standard applies to "average minimum 7-day low streamflow which occurs once in 10 years", it can be used as a guide. All samples collected on all five sample dates over five months during this study exceeded 0.075 mg/l.

Big Foot Creek not only has issues with dissolved pollutants, but it has a history of a serious objectionable discharge of "red" or "orange" colored water. Initially it was suspected that the coloration was caused by iron floc from the dissolution of iron in the groundwater as it contacts the atmospheric oxygen. Dissolved organic acids or other dissolved compounds may also play a role in the color. A history of dumps, landfill, tiling and draining in this watershed, especially in the wetland, may be reason to suspect a groundwater/surface water interaction for causing some of the creek's water quality degradation.

Total Phosphorus Loading: The role of phosphorus in lake degradation is best understood when a stream's phosphorus loading to a lake is defined. Geneva Lake is a phosphorus limited lake, meaning that phosphorus is the limiting nutrient for more plant growth and water quality problems. Total phosphorus loading is calculated by multiplying the total phosphorus concentration (mg/l) by the stream discharge (cubic feet per second). With a few conversions it is expressed in lb./day.

Big Foot Creek stream discharges were different at each of the three sites on all sampling dates. The creek's discharge site to the lake (1A) had the highest discharge for all sampling dates, however site 3C had the highest of all sites on October 15 (Table 6). The highest discharge during the study from Big Foot Creek to the lake was on September 10, when the stream discharge to Geneva Lake was calculated to be 12.1 cubic feet per second (CFS) following an intense rain event within 12 hrs.

Total phosphorus concentrations and total phosphorus loading in Big Foot Creek varied during the 2019 summer (Table 6). The highest phosphorus loading from Big Foot Creek to Geneva Lake during this study was 29.1 lbs./day on September 10. It occurred with the highest discharge of 12.1 cubic feet per second (cfs). Total phosphorus concentration at that time was the median phosphorus concentration value of 0.43 mg/l. The September 10th sampling took place within 12 hours after a major storm event of 1.90 inches over two hours. This caused a dilution of the in-stream phosphorus concentrations while increasing stream discharge.
The lowest phosphorus loading to Geneva Lake was measured on October 15th, when the creek's discharge was the median value of 3.05 cfs. and the phosphorus concentration was the lowest at 0.0975 mg/l.

Samples collected from Big Foot Creek in 1997, 1998, and 2000 by the USGS suggested that total phosphorus loading from Big Foot Creek was more seasonal than discharge or concentration related[7]. The 2019 data indicates that there may be a relationship between flow, concentration and loading with discharge causing the biggest impact to the overall loading. There was no readily observable relationship with any of the other dates. Something within the watershed is driving these values beyond weather. More data is needed to make those correlations.

Table 6. Total phosphorus loading to Geneva Lake, WI from Big Foot Creek, Geneva Lake, WI.

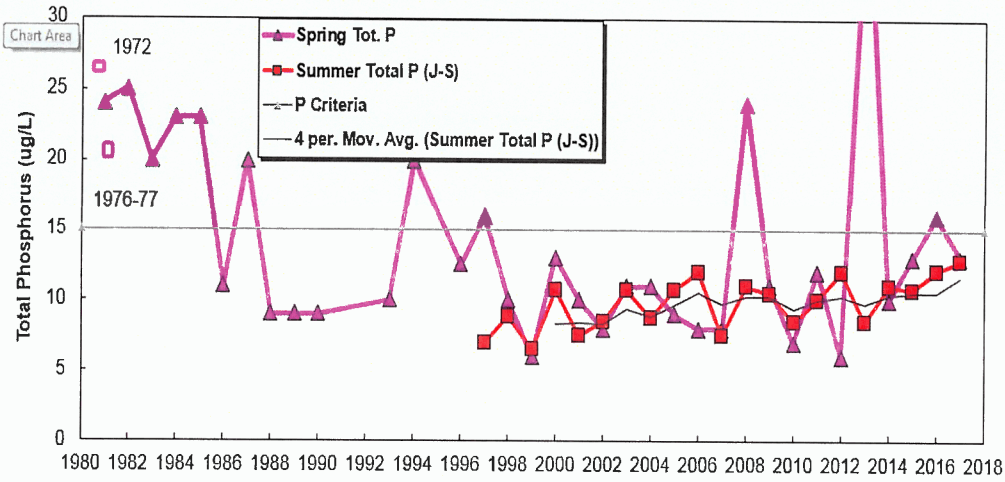
Total phosphorus loading to Geneva Lake, WI from Big Foot Creek on selected dates in 2019.			
date	Discharge cfs	Concentration mg/l	Loading lb/day
6/14/2019	3.16	0.26	4.58
7/23/2019	2.69	1.48	22.2
8/20/2019	1.7	1.82	17.3
9/10/2019	12.05	0.43	29.1
10/15/2019	3.052	0.0975	1.66
Source: GLEA, WI SLH Funding from a WI DNR Small Scale Lake Planning Grant			

It should be noted that base flow and high flow concentrations, discharge and loading from this study do not match up with similar calculation conducted by the USGS in 1997, 1998 and 2000. The USGS discharge and concentrations were much lower than recorded in this study[7]. As expected, this resulted in much lower loading recorded in the USGS study verses what was found in this study.

Although no biological data was collected, the low oxygen conditions in the stream are a serious problem, limiting or prohibiting any healthy fauna. From a nutrient loading perspective, the phosphorus delivered to the lake from this creek is significant. Geneva Lake is a phosphorus limited lake. It presently meets its recommended phosphorus standard of 15 ug/l.(figure 2). If heavy phosphorus loading continues, it will exceed the Geneva Lake phosphorus standard and ultimately lead to significant lake water quality degradation.

The colored flocculent is a serious aesthetic issue, especially when it is being discharged into the lake just south of the Big Foot State Park swim area. If the colored flocculent is from unknown dissolved solids rather than just iron, it may present a health issue.

Figure 2. Total phosphorus, and recommended total phosphorus standard for Geneva Lake, WI. Source: Dale Robertson, U.S. Geological Survey, Personal Communication Jan. 23, 2018.



In the early spring of 2020, the GLEA hired Applied Ecological Services to conduct a Phase II study on the Big Foot Creek Watershed. The primary goal of Phase II is to report on the chemical, physical, and biological processes driving the water quality impairments, their severity and to provide recommendations of best management practices to address these issues. That report is scheduled to be completed with report preparation in early 2021.

Acknowledgments:

We would like to thank the Wisconsin Department of Natural Resources and the Environmental Education Foundation for their financial assistance with this project. Thanks to Badger High School for their financial support in hiring Badger students to assist with sampling and lab work which offered a hands-on leaning opportunity for students; Yeager Borchert, Katie Porubcan, Maddie Krien, Emily Sheen, Katie Spende and teachers Taylor Hennlich and Corinne Grossmeier. We would also like to thank the property owners and managers that allowed us access to our sampling sites; State of Wisconsin Big foot Beach State Park, Otto Jacobs Company, and Mike Trainer and Mike Lazzaroni of the Boat House. Thanks to the Geneva Lake Environmental Agency's staff and board for their support.

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(3) Wisconsin Department of Natural Resources, Colin Beveridge, Unpublished, Memorandum on Water Quality Analysis , Buttons, Bay/Big Foot Creek, August 25, 1993
(4) Geneva Lake Environmental Agency, A Preliminary Investigation of the Big Foot Creek's Degraded Water Quality, August 1993.
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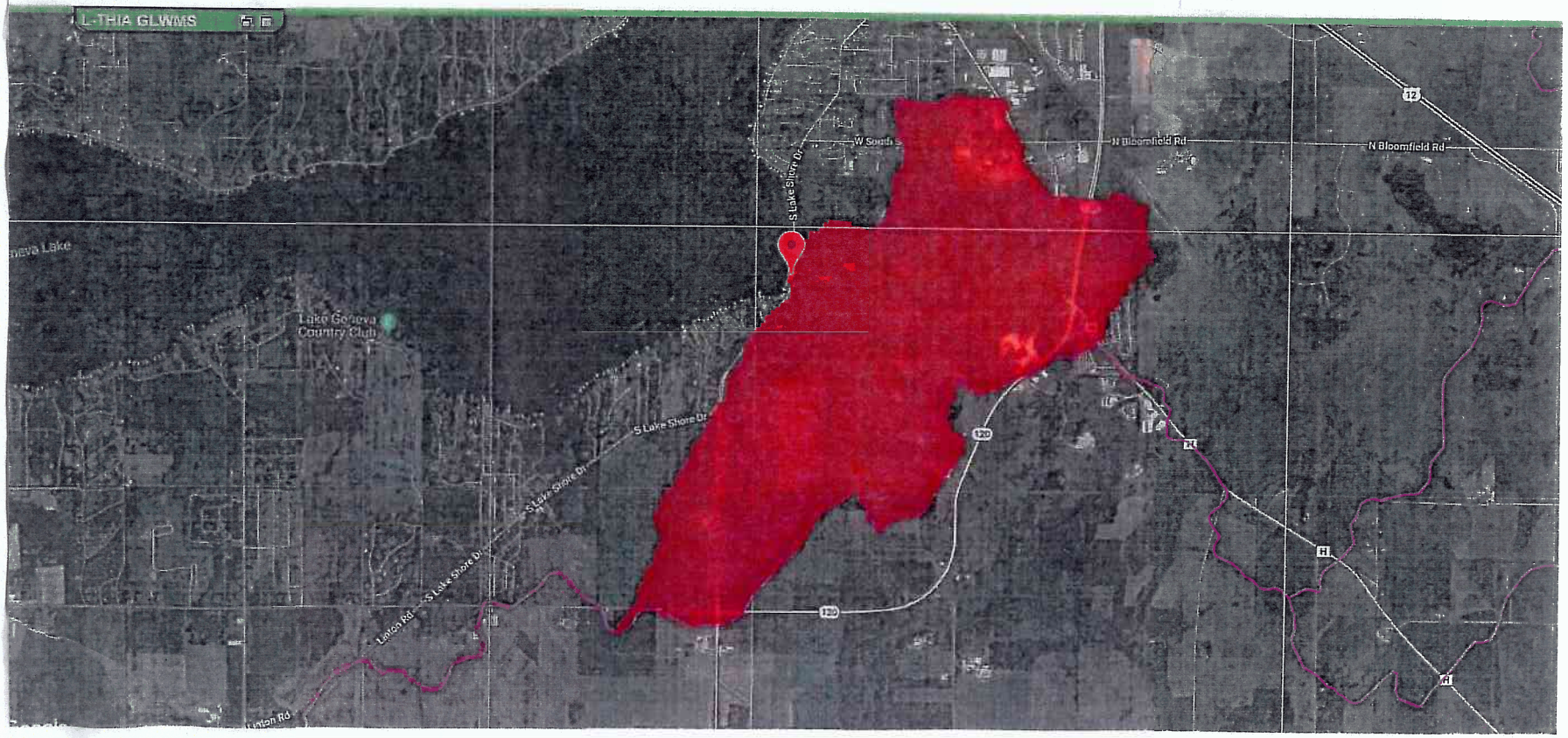
(6) SEWRPC, Community Assistance Planning Report No. 60, (2nd edition) A lake Management Plan for Geneva Lake, Walworth County Wi. May 2008.
(7) Robertson, D.M., Goddard, G. L., Mergener E. A., Rose, J.R., Garrison, P.J., 2002, U. S. Geological Survey, Water-Resource Investigation Report 02-4039, Hydrology and Water Quality of Geneva Lake, Walworth County, WI 30p.

Big Foot Creek's Watershed, Geneva Lake, Walworth County, WI

Apparent outlet point coordinate (In GCS_WGS_1984): Lat = 42.56631872751941, Lng = -88.43723943581528

north



APPENDIX B

Land Use and Hydrologic Soil Groups of Big Foot Creek Watershed.

Land Use and Hydrological Soil group. Big Foot Creek Wateshed, Geneva Lake WI			
Land use	Soil group	acres	%
Cropland generalized agriculture	D	223.51	16.5
Deciduous Forest	D	25.13	1.9
Pasture/Hay	D	10.01	0.7
Grassland; Herbaceous	D	3.34	0.2
Open Water	D	2.89	0.2
Woody Wetlands (swamp)	D	2.45	0.2
Open Space/Park	D	2.22	0.2
High-density Residential (townhomes to 1/4 ac lots)	D	1.33	0.1
Barren Land	D	1.33	0.1
Cropland generalized agriculture	B	523.96	38.6
Pasture/Hay	B	139.89	10.3
Deciduous Forest	B	139.66	10.3
Low-Density Residential (general 1/3 - 2 ac lots)	B	90.74	6.7
Open Space/Park	B	85.84	6.3
High-density Residential (townhomes to 1/4 ac lots)	B	33.36	2.5
Woody Wetlands (swamp)	B	12.45	0.9
Open Water	B	12.45	0.9
Barren Land	B	10.9	0.8
Grassland; Herbaceous	B	10.01	0.7
Shrub; Scrub	B	6.89	0.5
Commercial/Industrial/Transportation	B	6.67	0.5
High-density Residential (townhomes to 1/4 ac lots)	A	3.78	0.3
Barren Land	A	3.34	0.2
Open Space/Park	A	1.56	0.1
Deciduous Forest	A	1.33	0.1
Open Water	A	0.89	0.1
Cropland generalized agriculture	A	0.89	0.1
Shrub; Scrub	A	0.44	0.0
Grassland; Herbaceous	A	0.44	0.0
Woody Wetlands (swamp)	A	0.22	0.0
Pasture/Hay	A	0.22	0.0
Total		1358.17	100.0
Source: L-THIA (Long-Term Hydrologic Impact Assessment) .			
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APPENDIX C Sampling station numbers and locations.

Sampling Location for Big Foot Creek Watesrhed Study, 2019. Geneva Lake, WI			
Station	ID #	name	location
1A	10051985	lake/creek mix. Outlet to lake	42° 33' 58.57" N 88° 26' 13.44" W
2B	10051989	East of lakefront Rd.	42° 33' 57.89" N 88° 26'10.76" W
3C	10051986	Culvert-Laz South Branch	42° 33' 57.10" N 88° 26' 7.14" W
4E	10051988	OJ well background	42° 33' 41.76" N 880 25' 1.80" W
Source: GLEA			

APPENDIX D.

Wisconsin State Lab methods for laboratory analysis:

Total Suspended Solids:	SM 2540D
Iron:	EPA 200.7
Phosphorus:	EPA 365.1
Ammonia	EPA 350.1
COD high level	ASTM D1252-06B
Nitrate + Nitrite -N	EPA 353.2
Total Kjeldahl-N	EPA 351.2

APPENDIX E Weather Conditions at time of sampling

5/14/2019:	Sunny, calm, 18 C., Start time 1600 hr., no precip in last 48 hrs., 1.55" previous 7 days.
6/14/2019:	Partly cloudy, 50% sun, wind S. start time 1010 hr., no precip in last 24 hrs., 0.65" in last 48 hrs., 0.65" previous 7 days.
7/23/2019:	Mostly clear, 90% sun, 29 C., NW wind 5 mph, start time 1000 hr., no precip. in last 48 hrs., 0.25" in last 72 hrs.,
	2.81 " previous 7 days.
8/20/2019:	Rain at beginning, turning partly cloudy, air 22 C, 0.24" of rain previous 3 hrs., start time 15:23, 0.65 " in previous 7 days.
9/10/2019:	Cloudy, 10% sun, 30 C., humid, intenst event of 1.90" from 0400 hr to 0600 hrs. on day of sampling.
	Sample start time 1300 hr., 1.99 " of rain previous 7 days.
10/15/2019:	Partly cloudy, 75% clouds, calm, air 11 C., start time 0950 hr., no precip in last 48 hrs., 0.65" in previous 7 days.

APPENDIX F

Water Quality Data from all four sites on all six sampling dates.

Site 1A 10051985

Creek/Lake mixing zone.	1A,10051985						
Parameter	units	5/14/19	6/14/19	7/23/19	8/20/19	9/10/19	10/15/19
field temp	°C	14	24	22	20	20	6
pH		7.87	7.44	7.39	7.42	7.52	7.82
turbidity	NTU	5.29	11.5	69.9	90.8	14.1	5.53
conductivity	mS/cm	0.589	0.680	0.730	0.690	0.530	0.590
Total Dissolved Solids	g/l	0.295	0.34	0.359	0.357	0.23	0.28
Dissolved oxygen	mg/l	5.8	4	0.8	1.7	3.3	7.6
D.O. % Saturation	%	56.3	47.9	8.7	21.8	36.4	60.8
Alkalinity	mg/l	231.2	204	258.4	380.8	251.6	251.6
Total suspended solids	mg/l	NT	12.3	21.0	55.0	16.3	2.75
Iron	mg/l	NT	5.04	26.1	25.9	6.48	1.52
Total Phosphorus	mg/l	NT	0.260	1.48	1.82	0.43	0.0975
Ammonia	mg/l	NT	0.0930	0.473	0.439	0.0879	0.0462
Chemical oxygen demand.	mg/l	NT	42.0	66.2	70.8	50.6	20.2
discharge	CFS	1.82	3.16	2.69	1.7	12.05	3.05
NT= not tested		ND = not detected					

Site 2B 10051989

East of Highway		2B, 10051989					
Parameter	units	5/14/19	6/14/19	7/23/19	8/20/19	9/10/19	10/15/19
field temp	°C	14	24	21	NR	20	6.5
pH		8.21	7.43	7.42	7.41	7.59	7.85
turbidity	NTU	3.71	12	76.4	93.2	13.3	5.51
conductivity	mS/cm	0.638	0.680	0.710	0.760	0.540	0.570
Total Dissolved Solids	g/l	0.319	0.34	0.357	0.357	0.27	0.28
Dissolved oxygen	mg/l	6.4	4.2	0.5	1.7	3.4	6.2
D.O. % Saturation	%	56.2	47.9	8.7	21.8	36.4	60.8
Alkalinity	mg/l	224	204	285.6	388.8	244.8	265.20
Total suspended sollids	mg/l	NT	12.5	46.0	65.0	18.0	3.00
Iron	mg/l	NT	4.74	29.9	26.2	6.45	1.46
Total Phosphorus	mg/l	NT	0.261	1.64	1.84	0.462	0.0931
Ammonia	mg/l	NT	0.0831	0.473	0.423	0.0874	0.0484
Chemical oxygen demand.	mg/l	NT	39.8	69.8	69.9	49.0	20.6
discharge	CFS	1.19	1.35	1.539	0.591	2.68	1.297
NT= not tested		ND = not detected					

Site 3C, 10051986

Culvert behind the Boat House			Site 3C, 10051986				
Parameter	units	5/14/19	6/14/19	7/23/19	8/20/19	9/10/19	10/15/19
field temp	°C	14	24	21	20	20	6
pH		7.84	7.45	7.43	7.54	7.66	7.76
turbidity	NTU	6.3	12.7	76	100.4	13.1	6.44
conductivity	mS/cm	0.638	0.650	0.692	0.675	0.510	0.540
Total Dissolved Solids	g/l	0.318	0.33	0.347	0.35	0.26	0.27
Dissoved oxygen	mg/l	4.67	3.4	0.1	0.48	3.7	6.3
D.O. % Saturation	%	45.4	40.1	1.23	5.29	40.8	50.9
Alkalinity	mg/l	272	197.2	278.8	374	244.8	249.8
Total suspended sollids	mg/l	NT	16.8	32.0	61.0	18.7	4.25
Iron	mg/l	NT	4.98	28.5	26.9	5.59	1.46
Total Phosphorus	mg/l	NT	0.253	1.56	1.90	0.429	0.122
Ammonia	mg/l	NT	0.083	0.463	0.416	0.0878	0.0528
Chemical oxygen demand.	mg/l	NT	42.8	71.2	75.4	49.8	18.2
discharge	CFS	0.98	1.2	3.43	1.55	7.97	4.37
NT= not tested		ND = not detected					

APPENDIX F (cont.)

Site 5E, 10051988

Groundwater per well at O. Jacobs. (background). 5E 10051985

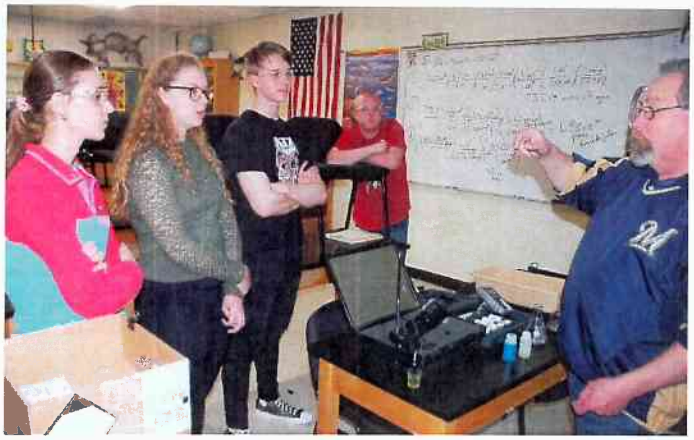
Parameter	units	5/14/19	6/14/19	7/23/19	8/20/19	9/10/19	10/15/19
field temp	^{0}C	NR	23	15	19	13	6
pH		7.63	7.41	7.69	7.44	7.69	7.74
turbidity	NTU	2.04	0.57	0.72	0.24	0.21	0.51
conductivity	mS/cm	0.610	0.540	0.602	0.581	0.610	0.57
Total Dissolved Solids	g/l	0.315	0.27	0.302	0.302	0.31	0.28
Dissoved oxygen	mg/l	5.28	4.9	4.02	3.2	5.5	6.84
D.O. % Saturation	%	NR	56.9	39.9	34.6	52.2	54.8
Alkalinity	mg/l	231.2	197.2	333.2	387.6	326.4	265.2
Total suspended sollids	mg/l	NT	ND	ND	ND	ND	ND
Iron	mg/l	NT	0.187	ND	ND	0.104	ND
Total Phosphorus	mg/l	NT	ND	ND	ND	ND	0.00809
Ammonia	mg/l	NT	0.0948	0.0937	ND	0.987	ND
Chemical oxygen demand.	mg/l	NT	ND	ND	ND	ND	ND
discharge	CFS						

NT= not tested ND = not detected

APPENDIX G

Big Foot Creek Watershed Study, 2019. Training of Badger Students for field and lab work. Student assistance available due to a grant from the Environmental Education Foundation. GLEA/twp

Learning how to operate equipment.



Learning concept and operating proceedure.

Running tests.

APPENDIX G (cont.)

Big Foot Creek Watershed Study, 2019. Badger Students collecting samples in the field. Students assistance available due to a grant from the Environmental Education Foundation. GLEA/twp

Students conducting stream measurements for area, flow and discharge, May 2019., Site 1A-10051985, Stream discharge to Geneva Lake

Students conducting stream measurements for area, flow and discharge, June 2019, Site 1A-10051985, Stream discharge to Geneva Lake.

Students conducting stream measurements for area, flow and discharge, June 2019, Site 2B-10051986, east of road.

APPENDIX H

Pictures of sampling site 1A-10051985, Big Foot Creek discharge to Geneva Lake.

Sept. 3, 2019

Sept. 10, 2019

Sept 10, 2019

Sept. 13, 2019

Sept. 13, 2019

Oct. 15, 2019

APPENDIX H (cont.)

Pictures of sample site 2B-10051989 Big Foot Creek, East of road.

10/15/19

5/17/19

7/15/19

7/15/19

APPENDIX H (cont.)

Pictures of sample site 3C-10051986, Big Foot Creek, Laz culvert.

5/3/19

9/10/19

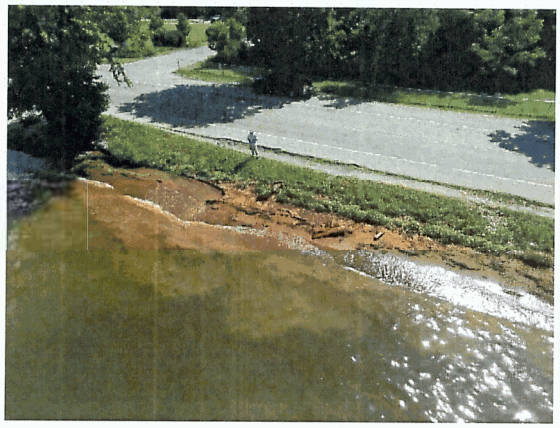
10/15/19

10/15/19

APPENDIX I

Misc. Pictures of Big Foot Creek, Geneva Lake and Big Foot Creek Wetland.

7/15/19, stream outlet to Geneva Lake.



4/17/19. Wetland, looking east.

4/17/19, State Park and wetland looking north.

4/17/19, Wetland, looking south.

4/17/19, Wetland looking west toward Geneva Lake.

4/17/19, Wetland looking west, towards Geneva Lake.