Swanton Reservoir

Inland Lake Water Quality Report

Division of Surface Water
Inland Lakes Program
January 2019

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Introduction: Inland Lakes Monitoring

EPA has implemented a sampling strategy that focuses on evaluating chemical conditions near the surface and physical conditions in the water column of inland lakes. Physical profile measurements are summarized either for the entire water column or the epilimnion depending on the existence of thermal stratification. The sampling target consists of an even distribution of 10 sampling events divided over a two-year period and collected during the recreation season of May 1 through October 31.

Key parameters analyzed in lakes include chlorophyll-*a*, ammonia, D.O., pH, total dissolved solids along with various metals for multiple beneficial use assessments. Other parameters used to evaluate lakes include secchi depth, total phosphorus and total nitrogen. Details of the sampling protocol used at the time of this sampling are outlined in the ***2016 Inland lakes sampling Procedures Manual***. Sampling objectives for inland lake surveys are defined in Ohio EPA's Inland Lakes Sampling QAPP, and the rules relative to inland lakes beneficial uses are described in the 2010 and successive Water Quality Monitoring Integrated Reports.

Study Lake: Swanton Reservoir

This lake report will describe the physical characteristics of Swanton Reservoir and the watershed that it draws from. It will then discuss the physical, chemical and biological aspects that existed during the 2017 sampling effort. These sampling results are then applied to relevant beneficial uses, and a trend assessment is provided comparing 2017 results to data collected from Swanton Reservoir during 2006. Finally, lake management implications are discussed for potential water quality improvement strategies.

Figure 1. Location of Swanton Reservoir in Fulton County, northwestern Ohio.

Swanton Reservoir is a 25-acre upground reservoir that was built in 1937 as a Public Drinking Water Supply (PDWS) source water for the village of Swanton, and also serves as a source of recreation. Located in eastern Fulton County, Swanton Reservoir is open to public fishing and boating and a small launch ramp is provided. All watercraft are restricted to either hand powered or electric motors. Fish management activities include fall stocking of rainbow trout. This is considered a "put and take" fishery, not capable of sustaining a viable year-round population. A survey done by Ohio DNR in 2005 indicated that the lake contains a largely stunted population of panfish (i.e. bluegill, green sunfish). Swimming is not allowed at any time.

Key Attributes

Source water for the reservoir is obtained from Swan Creek via pumps located at River Mile 30.85. There is also a ground water well nearby for back-up during periods of drought. The reservoir storage capacity is about 100 million gallons, serving approximately 3,700 people residing in the village of Swanton. Pumping of water from the nearly 82 square mile drinking water protection area is conducted when stream water quality is best and is suspended during runoff events. The lake does provide some preliminary treatment through initial settling of suspended materials and biological assimilation of nutrients.

Table 1. Swanton Reservoir Lake Key Attributes.

Lake Type:	Dam/Permanent Impoundment[1]
Ecoregion:	Huron-Erie Lake Plains (HELP)
Surface Area:	25 acres[1]
Residents Served:	3,690
Drinking Water Protection Area:	16.4 mi^2
Storage Capacity:	100 million gallons [1]
Maximum Depth:	4.7 meters (15.4 feet)[2]
[1] *Ohio EPA 2009* [2] *Ohio EPA 2017 study data*	

The L1 sampling location is centered at GPS location 41.56943˚ N latitude -83.87529˚ W longitude near river mile (RM) 30.25 of Swan Creek (see Figure 2). The "L1" naming convention indicates a primary sampling location that is deemed representative of the whole lake and is the location used to determine attainment status of applicable beneficial uses. Other locations (e.g. L2, L3 etc.) may be determined necessary to support attainment decisions on larger lakes and reservoirs.

Figure 2. Aerial imagery of Swanton Reservoir with location of L1 shown. Sources: OSIP Imagery, Copyright: ©2014 Esri

Watershed Overview

The drainage area of Swan Creek is 204 square miles. Its headwaters rise in Henry, Fulton and western Lucas counties. Over 200 miles of creeks and ditches drain this watershed. Swan Creek itself is about 40 miles long.[1] The gradient is like that of the Maumee River with a drop of 2.1 feet per mile. The major streams that feed Swan Creek are Ai Creek, Blue Creek, and Blystone Ditch. Primary land use within the Swan Creek watershed is comprised of 71 percent cultivated crop, 14 percent deciduous forest, 5 percent pasture/hay, 4.9 percent open space development and 1.8 low intensity development.

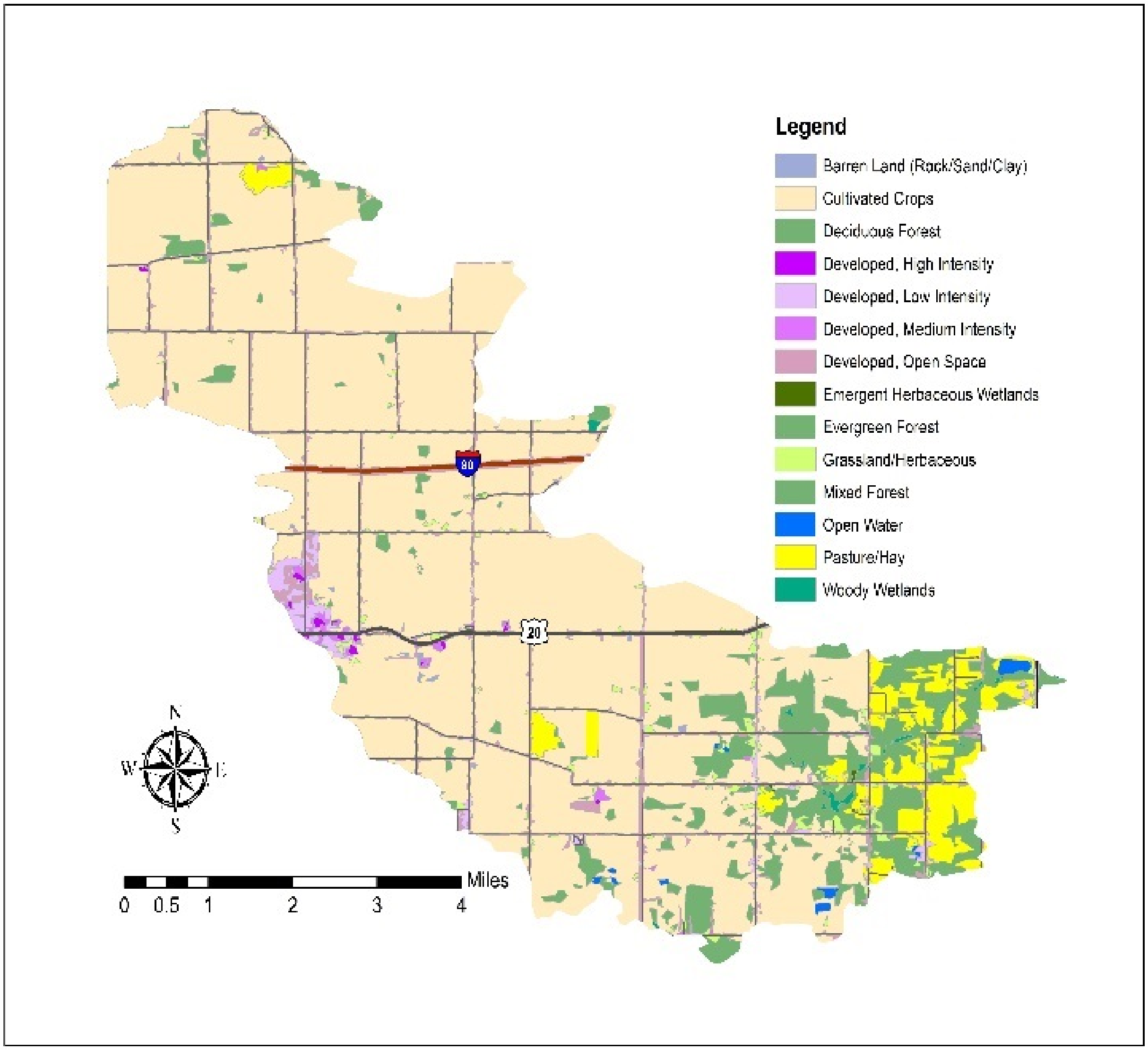

Figure 3. Figure 3. Land cover in the Swan Creek watershe. Sources: NLCD 2011 (Homer et.al.)

The watershed is located entirely in the Huron-Erie Lake Plains (HELP) ecoregion, and more specifically the Oak Openings. The HELP ecoregion is a broad, fertile, nearly flat plain that takes its name from being formed by retreating glacial lakes. US EPA describes this ecoregion as "fine, poorly drained, water-worked glacial till and lacustrine sediment; also, coarser end moraine and beach ridge deposits." Several areas of the HELP Ecoregion have special ecological importance, such as the Oak Openings region, which helps to buffer the Swan Creek watershed.

When the Great Black Swamp was drained in the late 1800s, settlers in northwest Ohio discovered very fertile soils under the deciduous swamp forests. Today most of the area has been cleared and artificially drained for agricultural crop production. Stream habitat and water quality have been degraded by channelization and agricultural drainage activities. The soils of the project area are level to gently sloping and are very poorly to somewhat poorly drained. Lucas County soils formed in clayey and loamy lake-laid sediment and water-reworked glacial till on broad flats of an old glacial lake.[2]

[1] *Swan Creek Watershed Plan of Action, Maumee RAP/TMACOG, April 2001.*

[2] *Soil Survey of Lucas County, USDA Soil Conservation Service, June 1980.*

Results Discussion

Water Column Chemistry

A physical profile of the water column was evaluated during each sampling event at the L1 sampling location at Swanton Reservoir. Readings were recorded at the surface (which is defined as a 0.5 meter depth), at 0.5 meter intervals thereafter, and a final measurement at 0.5 meters above the bottom of the lake.

Physical conditions changed throughout the sampling season in this relatively shallow lake. The stratification that did occur was somewhat abbreviated due to the shallow nature of the lake. Thermal stratification often occurs in deeper lakes during the warm summer months, consisting of an upper mixed zone (epilimnion), a slightly denser middle zone (metalimnion), and a lower zone (hypolimnion) where mixing is impeded by a density barrier caused by lower water temperatures near the bottom of a lake. A sharp decrease in temperature and dissolved oxygen is often noted where the hypolimnion forms. However, in the case of Swanton Reservoir, water temperature and dissolved oxygen decreased steadily through the water column, with a slightly sharper drop-off near the bottom of the lake, indicating the presence of a small, abbreviated hypolimnion (Figure 4). The hypolimnion of productive lakes can become depleted of oxygen (hypoxic) if consumption by decomposing organic matter exceeds reaeration by atmospheric diffusion and photosynthesis. Dissolved oxygen levels in the metalimnion and epilimnion can swing significantly over a 24-hour period under such conditions.

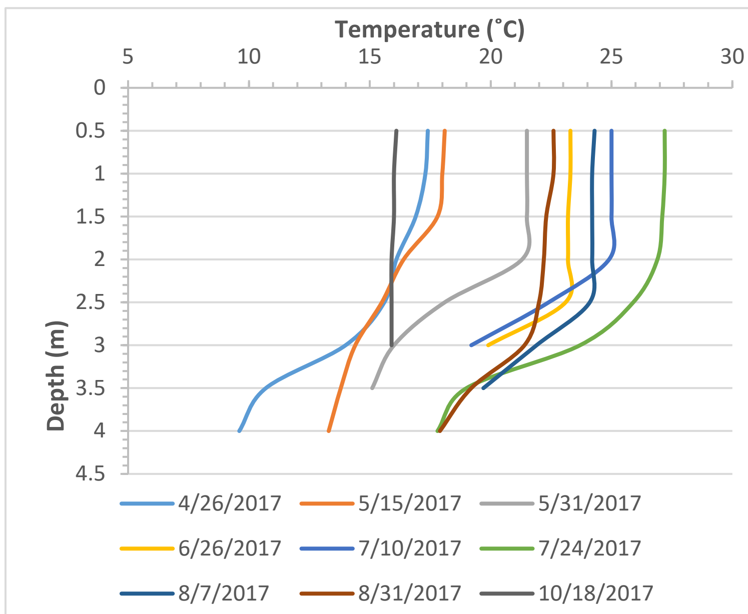

Figure 4. Temperature profiles record during 2017

Fish access to habitat, cool water and benthic prey can be limited if any part of the water column becomes hypoxic. An oxygen deficit, defined for the purposes of this report as a concentration of 4 mg/L or less, was documented during all sampling the events, except for one measurement in late April, at L1. The zone of oxygen deficit extended from the bottom of the lake to between a 2.5- and 3.0-meter depth (which was about 1.0 meters from the bottom). Under these conditions, organically bound phosphate in lake sediments decomposes and is converted to orthophosphate (the biologically available form of phosphate), that can then be released to the water column for uptake. Because orthophosphate is a reactive form of phosphorus, its concentration is often a good indication of the amount of phosphorus that is readily available for plant and algae growth.

Swanton Reservoir transparency at L1 averaged 1.35 meters over the sampling period (median 1.24 m). Low Secchi readings in Swanton Reservoir were likely caused by algal growth and suspended solids in this shallow, productive lake environment. Profile data indicated dissolved oxygen trending downward as summer progressed, likely resulting from lack of inflow and increasing water temperatures. Dissolved oxygen levels in the epilimnion did fall during October below the EWH inland lakes minimum criterion of 4.0 mg/l, although bottom DO concentrations and average DO concentrations through the entire water column were consistently lower during most of the summer (Table 2). The dissolved oxygen criterion of 4.0 mg/l applies in the epilimnion of stratified lakes, and throughout the water column in unstratified lakes. Swanton Reservoir experienced stratification during all but the last two smaling events when the lake likely experienced fall turnover.

Table 2. Dissolved oxygen concentration in Swanton Reservoir during 2017.

Dissolved Oxygen Concentrations, Swanton Reservoir L1 2017			
Parameter (mg/L)	D.O. (mg/L) - Surface	D.O. (mg/L) - Bottom	Mean D.O. (mg/L) – Whole Water Column
Aquatic Life Criterion	**≥4.0**[1]		
04/26/2017	11.02	10.65	11.67
05/15/2017	11.03	4.84	9.14
05/31/2017	12.17	0.5	6.73
06/26/2017	8.33	3.51	7.39
07/10/2017	9.61	0.73	6.75
07/24/2017	10.68	0.7	5.88
08/07/2017	8.88	0.39	6.16
08/31/2017	8.78	0.08	5.13
10/18/2017	3.18	2.77	2.92

[1] The dissolved oxygen criteria apply in the epilimnion of stratified lakes and throughout the water column in unstratified lakes.

Metals, nutrient and other physical parameters such as dissolved oxygen, pH, turbidity, and alkalinity were collected and analyzed from the surface at L1. The results were compared to the statewide EWH criteria and LH targets. No exceedances were recorded during this sampling effort.

The amount of phosphorus in a lake is important because it is commonly the growth limiting nutrient. Sources of phosphorus to a lake can be external (i.e. tributary loading or precipitation) and internal (i.e. biota, sediment or groundwater). Only a small portion of organic phosphorus is available for biological uptake, but in dissolved ionic form (orthophosphate) it passes easily through membranes and is readily available. Decomposition of dead plants and animals releases inorganic phosphorus into the water column.

Phosphorus bound to particulate matter in the sediment can also be released to the water column under anoxic conditions if the bond is redox sensitive (i.e. iron or calcium).

Nutrient parameters were analyzed to help understand trophic dynamics in the Swanton Reservoir. Internal loading of phosphorus was determined to be a potential factor in this system. Total phosphorus concentration at the surface based on the 10 sampling events averaged 36.0 µg/l while bottom mean concentration was 148.8 µg/l.

The release of nutrients, especially phosphorus, can stimulate the growth of algal blooms. This process may be exacerbated during autumn when thermal stratification degrades, and the lake experiences the complete mixing associated with fall turnover. Total nitrogen (TN) is the sum of total Kjeldahl nitrogen (TKN) and nitrate/nitrite and can be an important factor in systems that are nitrogen limited. TN values were reflective eutrophic to hyper-eutrophic (Figure 5).

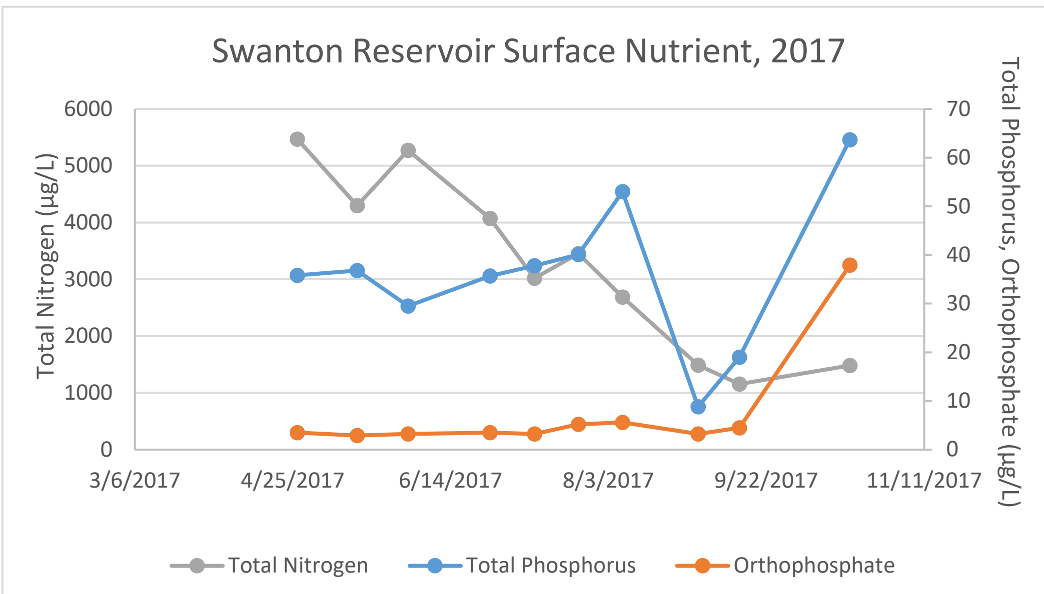

Figure 5. Swanton Reservoir surface nutrient data, 2017

Sediment Chemistry

A sediment grab sample was collected using a Petite Ponar dredge during October 2017 at L1 and was analyzed for metals, nutrients, s-VOCs (PAHs), PCBs and pesticides (organo-chlorine insecticides) (Figure 6) (Table 3).

Sediment data were evaluated using *Ohio Sediment Reference Values (SRVs)* (Ohio EPA, 2008) along with guidelines established in *Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems* (MacDonald, Ingersoll, & Berger, 2000). Ohio EPA SRVs represent ecoregion background conditions for metals based on data collected at Ohio reference sites. These values were developed for lotic (flowing) water bodies and are based on Ohio ecoregions. Sediment concentrations for lentic (non-flowing) surface water bodies can be screened using these values. MacDonald guidelines define two levels of ecotoxic effects. A threshold effect concentration (TEC) is a level of sediment chemical quality

Figure 6. Use of a Petite Ponar dredge for lake sediment sample collection.

below which harmful effects are unlikely to be observed and can be considered comparable to background conditions. A probable effect concentration (PEC) indicates a level above which harmful effects are likely to be observed. These guidelines include both metals and organic parameters.

Finally, guidelines established by the Ontario Ministry of the Environment (Persuad, Jaagumagi, & Hayton, 1993) were used to evaluate sediment sample results for total organic carbon (TOC) and total phosphorus (TP). These guidelines include the lowest effect level (LEL) and the severe effect level (SEL). The LEL is a level of sediment concentration that can be tolerated by a majority of benthic organisms. The SEL is a concentration considered harmful to most benthic organisms.

Organic compounds were undetected in the sediment sample collected at L1, and, thus, are not reported in Table 3. Concentrations of metals were below the Ohio SRVs for the Huron-Erie Lake Plains ecoregion. Copper, iron, and manganese exceeded the LEL, but were still below the SEL. Nickel and zinc exceeded both the TEC and LEL, but were also still below the PEC and SEL. Thus, the sediment sample collected at L1 did not contain metals in concentrations exceeding the paired, more protective reference value (the PEC or the SEL) (Table 3).

Table 3. Chemical parameters measured above screening levels in samples collected by Ohio EPA from bottom sediments in Swanton Reservoir, September 2017.

Parameter	L1 Concentration
TOC (%)	**4.0**
Arsenic (mg/kg)	**6.31**
Cadmium (mg/kg)	0.563
Chromium (mg/kg)	8.43
Copper (mg/kg)	**1780.0**
Lead (mg/kg)	13.6
Nickel (mg/kg)	**19.3**
Selenium (mg/kg)	ND
Zinc (mg/kg)	49.2
Mercury (mg/kg)	ND
T-Phosphorus (mg/kg)	**707.0**

ND - not detected at or above the method reporting limit.
Contamination levels were determined for parameters using Ohio Sediment Reference Values (SRVs), consensus-based sediment quality guidelines (MacDonald, et.al. 2000) and guidelines from the Ontario Ministry of the Environment (Persuad et. al. 1993). Bold numbers indicate values above the Lowest Effect Level (LEL).

Sediment nutrient concentrations were slightly elevated at L1. The sample result of 1.7 percent for TOC exceeded the LEL of one percent. Additionally, the sediment sample result of 707 mg/kg TP exceeded the LEL of 600 mg/kg. This indicates a baseline concentration of phosphorus is present in the lake's sediment, further reinforcing that internal loading of phosphorus may be occurring and contributing to algal bloom growth.

Phytoplankton Results

The phytoplankton community in Swanton Reservoir was characterized based on water samples collected using an integrated tube sampler deployed to either a maximum of two meters (m) or twice the Secchi depth if less than one meter. Samples were collected at L1 during three of the five sampling events (May, July and September). Samples were preserved with Lugol's solution and submitted to a contract lab for analysis. The phytoplankton present in a representative aliquot were identified to at least genus level (usually species), and cell densities (cells/L) and bio-volumes ($\mu m^3/L$) were estimated. Phytoplankton communities exhibit a seasonal succession when factors like water temperature, nutrients, transparency and photoperiod favor certain types. Grazing by larval fish and zooplankton also affects community composition. Temperate lakes in Ohio are usually dominated by diatoms in the spring until micronutrients like silica are depleted, then by blue green algae (cyanobacteria) in the fall, when an ability to control buoyancy and fix nitrogen from the atmosphere gives certain types a competitive edge.

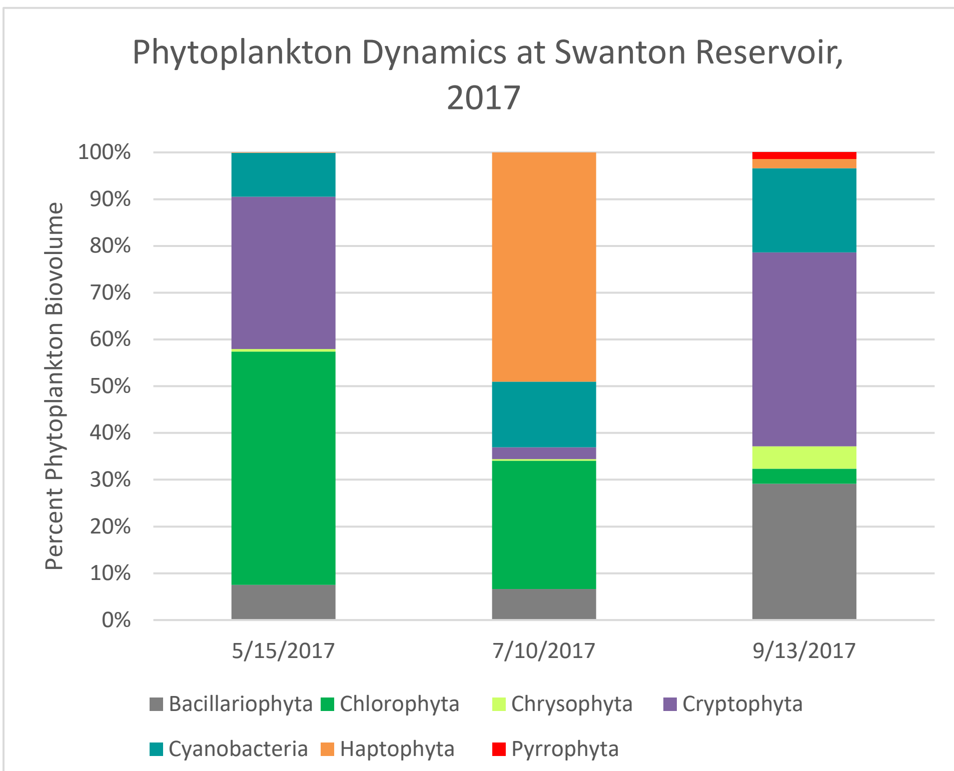

Figure 7. Phytoplankton dynamics at Swanton Reservoir during 2017.

The population exhibited during the study period at L1 contained six to seven different classes of algae represented in all samples. Cyanobacteria represented 9 to 18 percent of the total biovolume of phytoplankton across the study period. When breaking down the results by sampling event, the total biovolume of cyanobacteria increased throughout the summer into fall. In May cyanobacteria accounted for

9.35 percent of the total biomass, Chlorophyta was the dominate class accounting for nearly 50 percent of the biovolume. In September, cyanobacteria accounted for 18.02 percent of the total biovolume of phytoplankton, but the sample was dominated by cryptophyta, a type of common freshwater algae.

A community dominated by cyanobacteria is of concern when toxin-producing phytoplankton are present. Discussion of cyanotoxin sampling results is contained below in the Recreation Use Assessment section. Genera of phytoplankton that can produce cyanotoxins identified within the samples collected at Swanton Reservoir included *Aphanizomenon*, *Planktonlyngbya*, and *Pseudanabaena* (D'Anglada, 2016). Seasonal phytoplankton succession in reservoirs can be quite complicated and highly variable. This variability can even exist longitudinally, with completely different communities dominating the upper, middle and lower sections of larger reservoirs (Wetzel, 2001). However, the existence of toxin producing cyanobacteria along with a major shift toward cyanobacteria dominance are symptomatic of a eutrophic (nutrient enriched) system. A breakdown of the seasonal phytoplankton composition is presented in Figure 7.

Beneficial Use Assessment

Public Drinking Water Use Assessment

Public drinking water use attainment status will be determined and reported in the 2018 Integrated Report. Ohio EPA is in the process of preparing the report, which fulfills the State's reporting obligations under Section 305(b) (33 U.S.C. 1315) and Section 303(d) (33 U.S.C. 1313) of the Federal Clean Water Act.

Like all public lakes in Ohio (except Piedmont Reservoir), Swanton Reservoir is designated a public water supply (PWS) in the Ohio WQS. The reservoir is also currently used as a Public Drinking Water Supply (PDWS) source water for the Village of Swanton serving approximately 3,690 residents. In Ohio, PDWS source water quality is assessed by comparing water quality data within an assessment unit (AU) to established numeric criteria for the core indicators: nitrate; pesticides and other contaminants; algae/cyanotoxins; and Cryptosporidium (Ohio EPA D. , 2018). A PDWS is deemed impaired for its use if there are two or more excursions of nitrate above 10.0 mg/L within a 5-year period. The AU is placed on a watch list if there is one nitrate value that exceeds 8 mg/L.

Swanton Reservoir was sampled 10 times during 2017 for nitrates. Results for nitrate were well below 8 mg/L for all ten sampling events at Swanton Reservoir in 2017. The atrazine (pesticide) indicator is based on a maximum contaminant level (MCL) of 3.0 µg/L (developed under the Safe Drinking Water Act). Results for atrazine were below the MCL for all ten sampling events at Swanton Reservoir during the 2017 sampling seasons.

Expanded organics sampling was also conducted during October of 2017 to screen for organic constituents in sediments. All organic parameters were below their associated detection limit.

An AU is considered impaired for the Drinking Water Use if a source water has two or more excursions above state drinking water thresholds for cyanotoxins within a 5-year period. It is placed on a watch list if there is a cyanotoxin concentration that is greater than or equal to 50% of the state drinking water thresholds. Cyanotoxin samples (microcystin, saxitoxin and cylindrospermopsin) were collected and analyzed 10 times at L1 during the assessment period at Sawnton Reservoir. All cyanotoxin results were below detection. The AU including Swanton Reservoir (Swan Creek – 04100009 07 02) is currently listed unknown due to insufficient data and watch list for nitrates due to historical data. There is now sufficient data to make PDWS beneficial use impairment determinations for this assessment unit. At this time the assessment unit would be considered in full attainment of the PDWS beneficial use but would remain on a watch list for nitrates.

Recreation Use Assessment

Ohio conducts a monitoring and notification program of selected public and semi-private beaches to test the water quality and notify the public whenever bacteria and algal toxin levels present a potential health risk to those engaged in water activities. In support of this monitoring program, only algal toxin concentrations were examined to determine suitability for recreation use, due to the lack of a bathing beach at Swanton Reservoir.

Standards for algal toxin concentrations are currently being developed, but the State of Ohio has established thresholds for recreational advisories. For public beaches, a recreational public health advisory is posted when a possible harmful algal bloom (HAB) is visually confirmed and/or when cyanotoxin levels are equal to or exceed recreational public health advisory thresholds, whether or not a HAB is still present. An elevated recreational public health advisory (no contact) is posted when cyanotoxin levels are equal to or exceed the elevated recreational public health advisory thresholds (State of Ohio, 2016).

Swanton Reservoir is considered a recreation lake, samples were collected and analyzed for microcystin, saxitoxin and cylindrospermopsin during 10 events at L1 during 2017. The results for all toxin samples were below the current advisory thresholds for recreation water for all three toxins, thus recreation use is supported based upon these sampling events. Anatoxin was not analyzed during this survey (Table 5).

Table 4. Summary of data used to determine the recommended advisory thresholds for cyanotoxins in recreational waters.

Numeric Thresholds for Cyanotoxins in Recreational Water[2]			
Parameter (µg/L)	Microcystins	Cylindrospermopsin	Saxitoxin
Proposed Criterion (Advisory)	**6**	**5**	**0.8**
Proposed Criterion (No Contact)	**20**	**20**	**3**
04/26/17	<0.3	<0.05	<0.02
05/15/17	<0.3	<0.05	<0.02
05/31/17	<0.3	<0.05	<0.02
06/26/17	<0.3	<0.05	<0.02
07/10/17	<0.3	<0.05	<0.02
07/24/17	<0.3	<0.05	<0.02
08/07/17	<0.3	<0.05	<0.02
08/31/17	<0.3	<0.05	<0.02
09/13/17	<0.3	<0.05	<0.02
10/18/17	<0.3	<0.05	<0.02
% Over Threshold	**0**	**0**	**0**
Narrative	**support**	**support**	**support**

Human Health - Fish Consumption

Ohio has been sampling streams and lakes annually for sport fish contamination since 1993. Fish are analyzed for contaminants that bioaccumulate in fish and that could pose a threat to human health if consumed in excessive amounts. Contaminants analyzed in Ohio sport fish include mercury, PCBs, DDT, mirex, hexachlorobenzene, lead, selenium and several other metals and pesticides. Other contaminants are sometimes analyzed if indicated by site-specific current or historic sources. Since no recent data has been collected at Swanton Reservoir, no consumption advisories have been issued beyond the statewide advisory for mercury. Statewide fish consumption advisories can be found at: ***epa.ohio.gov/dsw/fishadvisory/index.aspx***.

Aquatic Life Use Assessment

The current aquatic life use (ALU) designation for all inland lakes in Ohio is exceptional warmwater habitat (EWH) except for upground reservoirs which are designated warmwater habitat (WWH). In order to evaluate the ALU in Swanton Reservoir, ammonia, dissolved oxygen, pH, total dissolved solids and various metals were analyzed. Statewide water quality criteria for these parameters are summarized in Table 35-1 of the Ohio water quality standards. Other important parameters for assessing lake condition in Swanton Reservoir included nutrient parameters (e.g. total phosphorus, total nitrogen) and biological response variables (e.g. chlorophyll-a).

Where criteria do not exist, a common approach to assessing relative lake condition is to compare lake water quality sampling data to a regional and lake-type derived percentiles (e.g. 25th) of existing lake data. The lower 25th percentile generally represents minimally impacted conditions protective of aquatic life (i.e. fish) in Lakes. For Ohio EPA, inland lake ALU benchmarks were calculated for total nitrogen (T-N), total phosphorus (T-P) and chlorophyll-a (Chl. a) based on the lower 25th percentile of lake median data and for secchi depth based on the upper 75th percentile of lake median data. Data used to determine benchmarks were collected by Ohio EPA from Ohio inland lakes between 1989 and 2006.

Table 5. Summary of important lake data collected in Memorial Reservoir during 2016/17.

	Lake Aquatic Life Use Benchmarks				WWH WQS		
Parameter	Chl. *a* (µg/L)	Secchi (m)	T-N (µg/L)	T-P (µg/L)	D.O. (mg/L)	pH (SU)	NH3-N (mg/l)
Benchmarks	**≤6.0**	**≥2.6**	**≤1225**	**≤18**	**≥5.0**	**6.5>pH<9.0**	
04/26/17	*8.68*	1.18	5470	35.8	11.36	8.45	0.053
05/15/17	7.68	2.2	4296	36.8	10.62	8.21	0.064
05/31/17	13.7	0.63	5270	29.5	11.12	8.46	<0.05
06/26/17	7.29	0.66	4070	35.7	8.16	8.38	<0.05
07/10/17	16	1.0	3021	37.8	8.91	8.53	<0.05
07/24/17	15.9	1.5	3450	40.1	10.05	8.73	<0.05
08/07/17	15.9	1.9	2689	53	8.47	8.31	<0.05
08/31/17	13.6	1.3	1488	8.8	6.39	8.35	0.088
09/13/17	31.5	0.95	1155	19	11.44	8.49	0.062
10/18/17	3.88	2.2	1483	63.7	2.92	7.76	0.631
Median	13.65	1.24	3235.5	36.3			
% Exceeded					**10%**	**0%**	**0%**

*Highlighted values indicate exceedances of ALU benchmarks or statewide chemical WWH-WQS criteria.

Chlorophyll-a, total phosphorus, total nitrogen and Secchi depth are evaluated by first calculating a median value from the two-year dataset. This value is then compared to the ALU targets identified in table 3. Dissolved oxygen, pH and ammonia were evaluated in a manner similar to base aquatic life parameters. Average D.O. and median pH values were calculated from profile readings taken in the epilimnion since the lake does stratify.

Swanton Reservoir revealed signs of enrichment in the source water since the two response variables, Chlorophyll a and Secchi exceeded their targets, and the two causal nutrient parameters, total nitrogen and total phosphorus were well above their respective benchmarks. Due to its hybrid nature, Swanton Reservoir is prone to external sources of nutrients that can be attributed to Swan Creek, an agricultural impacted stream that is the source water for the reservoir.

Trend Assessment

Ohio EPA conducted a detailed assessment of chemical, physical and biological conditions of Swan Creek and selected tributaries during the summer of 2006 to determine if streams and rivers within the watershed were attaining water quality goals. The survey revealed that out of 33 sites accessed in the Swan Creek watershed only four (15%) fully met their designed WWH aquatic life uses. E. coli results where elevated exceeding the recreation standard at all sampling stations. An assessment of the Swanton Reservoir was also conducted in this time frame. Swanton Reservoir was determined to be eutrophic with a final TSI score 64.5. The technical support document (TSD) titled *Biological and Water Quality Study of Swan Creek and Selected Tributaries 2006* is posted at: ***epa.ohio.gov/portals/35/documents/SwanCreekTSD2006.pdf***.

The 2017 Swanton Reservoir Carlson TSI values were calculated in the same manner using formulas from Reckhow and Chapra (Reckhow & Chapra, 1983) as follows:

Secchi disk TSI = 60 - 14.41 ln (*SD meters*)

Chlorophyll-*a* TSI = 9.81 ln (*Chl-a ug/l*) + 30.6

Total phosphorus TSI = 14.42 ln (*TP ug/l*) + 4.15

The linear regressions for Carlson's TSI were calculated using data collected from thousands of lakes in and outside the U.S. The TSI represents absolute values that can be applied to most lakes to characterize their trophic status and general condition. A TSI value was calculated for each of the three variables collected from Swanton Reservoir in 2017 (Table 7). Per Carlson's (1977) recommendation, average summer (July, August, September) chlorophyll-*a* and spring (April, May, June) total phosphorus TSI values were used to determine the final TSI value. Transparency based (Secchi depth) TSI values were calculated but Carlson warns against using transparency as a variable in waters with high non-algal turbidity, namely, sediment and silt (Carlson, 1980). Such is the case with many lakes and more specifically, reservoirs in Ohio. However, Swanton Reservoir did not exhibit high non-algal turbidity attributes. Trophic State Index ranges based on Carlson's classification system are as follows:

Oligotrophic (lacking nutrients):	Less than 38 TSI
Mesotrophic (midrange nutrient availability):	38-47 TSI
Eutrophic (nutrient enriched):	48-66 TSI
Hypereutrophic (over Enriched):	>66 TSI

Since Ohio does not have a very robust baseline of lake data, the use of TSI as a general tool for trend assessment is appropriate. Based on data collected in 2017, the final TSI for Swanton Reservoir was calculated to be 57, which is slightly lower than the 2006 TSI value of 64.5. In both instances, the TSI value is reflective of the elevated TP concentrations observed in Swanton Reservoir. Although there appears to be a slight improvement in water quality based on trophic state analysis, both studies indicate the lake is productive and maintains a eutrophic status. Although nutrient availability in sediment and biomass is not considered, the TSI value shows there are enough nutrients (TP) present in the water column to cause this lake to be considered nutrient enriched, since the TSI-TP values are all above the eutrophic/nutrient-enriched threshold of 48.

Table 6. Trophic state classification, TSI data and trends in trophic state for Swanton Reservoir data from 2017.

Site	Date	Chl. *a* (µg/L)	TSI Chl-*a*	SD (m) Raw Data	TSI SD	TP (µg/L)	TSI TP	Final TSI	Trophic Classification
Swanton Reservoir L-1	04/26/17	8.68	**52**	1.18	**58**	35.8	**56**	**57**	Eutrophic
Swanton Reservoir L-1	05/15/17	7.68	**51**	2.2	**49**	36.8	**56**		
Swanton Reservoir L-1	05/31/17	13.7	**56**	0.63	**67**	29.5	**53**		
Swanton Reservoir L-1	06/26/17	7.29	**50**	0.66	**66**	35.7	**56**		
Swanton Reservoir L-1	07/10/17	16	**58**	1.0	**60**	37.8	**57**		
Swanton Reservoir L-1	07/24/17	15.9	**58**	1.5	**54**	40.1	**57**		
Swanton Reservoir L-1	08/07/17	15.9	**58**	1.9	**51**	53	**61**		
Swanton Reservoir L-1	08/31/17	13.6	**56**	1.3	**56**	8.8	**36**		
Swanton Reservoir L-1	09/13/17	31.5	**64**	0.95	**61**	19	**47**		
Swanton Reservoir L-1	10/18/17	3.88	**44**	2.2	**49**	63.7	**64**		

Conclusions

Upground Reservoirs are a reliable way for communities to store surface water prior to its treatment for drinking. Since they are off stream, they have an advantage over traditional impoundments because the quality of inlet water pumped can be somewhat controlled. This is especially true if the source water has seasonally high nitrate levels. These reservoirs are also designed with enough storage capacity to withstand periods of drought. Many upground reservoirs have boat ramps and are stocked with sportfish. While this provides an important source of recreation, all lake management decisions should be made based on drinking water as the primary use.

Swanton Reservoir has been in service for over 80 years, which is enough time for nutrients to accumulate in the system. This is reflected in the watch list status for nutrient concentrations and non-support status for chlorophyll a.

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