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2021 Branch & Derby Intercounty Drain Water Quality Report

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Prepared For:

Paw Paw Lake Special Assessment Advisory Committee

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Summary:

This document is intended to concisely summarize recent Branch & Derby Intercounty Drain water quality monitoring efforts. The complete database of water quality results and supporting documents is maintained by Spicer Group.

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* Table of contents only - please find the complete Low Impact Development Manual for Michigan on SEMCOG's website.

BACKGROUND

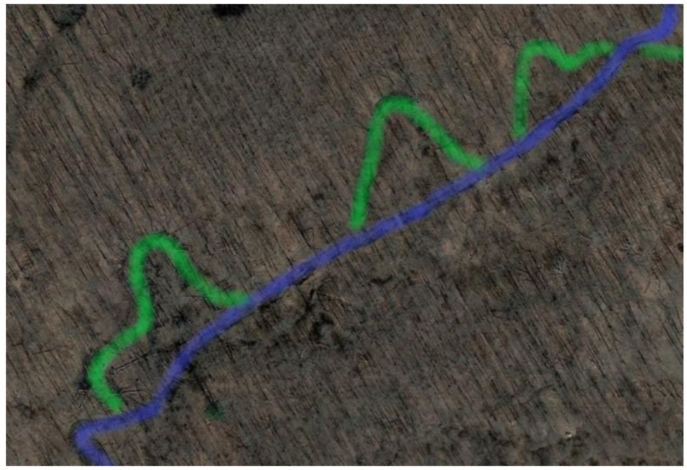

Figure 1 - Straightened portion of the Branch & Derby Drain between the downstream-most Paw Paw Lake Road crossing and Hagar Shore Road crossing. The green channel shows the former route of the drain, and the blue channel shows the current, straightened route of the drain. Source: Google Earth.

The Branch & Derby Intercounty Drain is located within Berrien and Van Buren Counties in southwest Michigan. It is approximately six miles in length, and flows through a multitude of landscapes, including wooded wetlands, forests, farmland, and pasture areas. Historically, the drain has been straightened with the intention of expediting drainage and conveyance. The drain is the largest tributary to ~ 900-acre Paw Paw Lake. The lake is a popular place for recreation, including boating, fishing, and swimming. Concern was raised about the drain contaminating the lake with nutrients and suspended solids, leading to algae blooms and undesirable lake conditions. Therefore, a water quality monitoring program was implemented on the drain to better understand the extent of the nutrient and sediment load conveyed by the drain. This report outlines the water quality results from the monitoring program.

Figure 2 - Outlet of the Branch & Derby Drain to Paw Paw Lake. Note the color difference between Paw Paw Lake and the Branch & Derby Drain. The dark brown color is sediment, suspended and dissolved solids, and tannins conveyed through the drain. Photo taken on June 28, 2021. Photo Credit: Cody Krieger

Sample Site Locations

The water quality monitoring program on the Branch & Derby Drain began in 2017. Three Teledyne ISCO autosamplers were purchased and installed on the drain in key monitoring locations. Since 2017, monitoring locations have moved slightly in order to fill data gaps and obtain more information about different reaches of the drain. Sample site A1 has remained consistent since 2017. A1 is located near the outlet of the drain, immediately upstream of the Paw Paw Lake Road crossing. Sample site names for each year remained consistent (A1, A2, and A3), however, location was not consistent. This could lead to much confusion when reviewing water quality data. To mitigate confusion, each unique sample site location was given its own unique name. In total there were six unique sample sites along the drain. Site A1 is the downstream-most sample site, and A6 is the upstream-most sample site. Sample site location and names are described in the table and shown in the map below.

Sample Site Name		Alternative Name (Year Name was Used)	Years Monitored	Location Description	Coordinates
Downstream-most	***A1***	A1 (2017 – 2021)	2017 – 2021	Near drain's outlet to Paw Paw Lake. Site is located just upstream of Paw Paw Lake Road Crossing.	42.218518°, -86.265510°
↑	***A2***	A2 (2021)	2021	Downstream from confluence of Branch & Derby Drain and McConnel and Olcott Drains, downstream from Hagar Shore Road drain crossing.	42.229174°, -86.261344°
	A3	A3 (2020 – 2021)	2020 – 2021	Upstream from confluence of Branch & Derby Drain and McConnel and Olcott Drains, upstream from Hagar Shore Road drain crossing.	42.229487°, -86.260945°
	A4	A2 (2020)	2020	Green Drain outlet to Branch & Derby Drain	42.229464°, -86.252854°
	A5	A2 (2017 – 2019)	2017 – 2019	Downstream of M-140 in-line detention basin, upstream of Branch & Derby confluence with the Green Drain.	42.229699°, -86.252725°
Upstream-most site	***A6***	A3 (2017 – 2019)	2017 – 2019	Upstream of M in-line detention basin.	42.229683°, -86.251327°

Table 1 - Branch & Derby Drain water quality monitoring sample sites 2017 - 2021.

Branch & Derby Drain Water Quality Monitoring Sample Sites 2017 – 2021

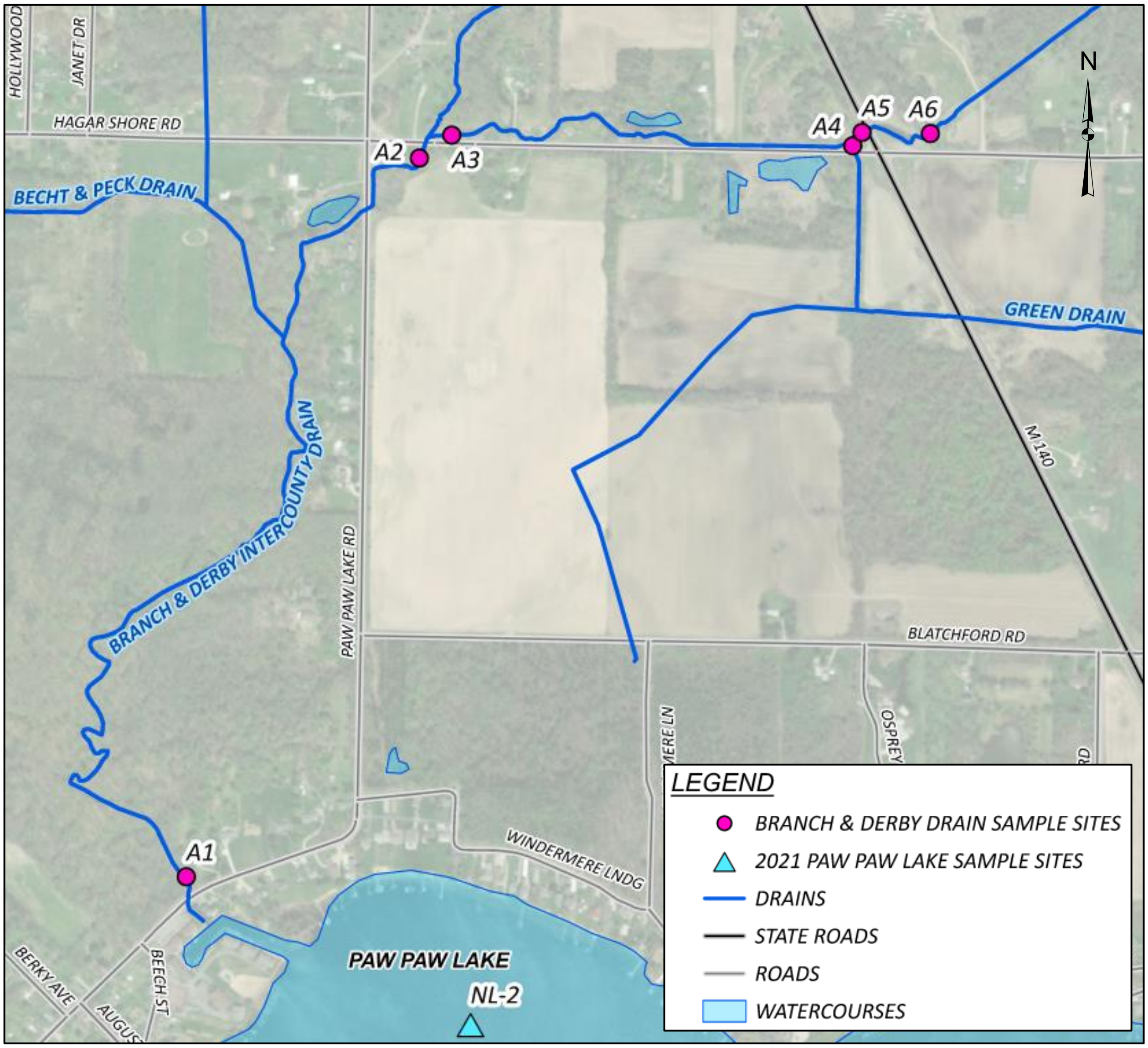

Figure 3 - Branch & Derby Drain water quality monitoring sample sites. Note - not all sites were monitored every year 2017 - 2021. Samples were collected with Teledyne ISCO autosamplers during rain events with significant runoff.

Since samples were collected with autosamplers, it was important that each site selected had a level area where samplers could be installed upright and anchored to a tree, permanent fence, or other sturdy anchor point. Anchoring was necessary, as some storm events can lead to flows strong and deep enough to carry away equipment.

AUTOSAMPLER AND SAMPLE EVENT PROGRAMMING

Autosamplers were utilized to collect water samples from the Branch & Derby Drain during rain events. The model of autosampler utilized was Teledyne ISCO's 6700 model. Attached to the 6700 model was a Teledyne ISCO 730 bubbler unit. The bubbler unit measures water level by pushing out a standardized volume of air into the waterbody it is installed in. Depending on the water pressure that the bubbler must push through to release the bubble into the water, water level is calculated. The bubbler communicates with the 6700 autosampler's computer. The autosampler can be programmed to start grabbing samples from the drain depending on a change in water level, time, or a variety of other parameters. The photos below show the various components of the autosamplers utilized to collect water samples on the Branch & Derby Drain.

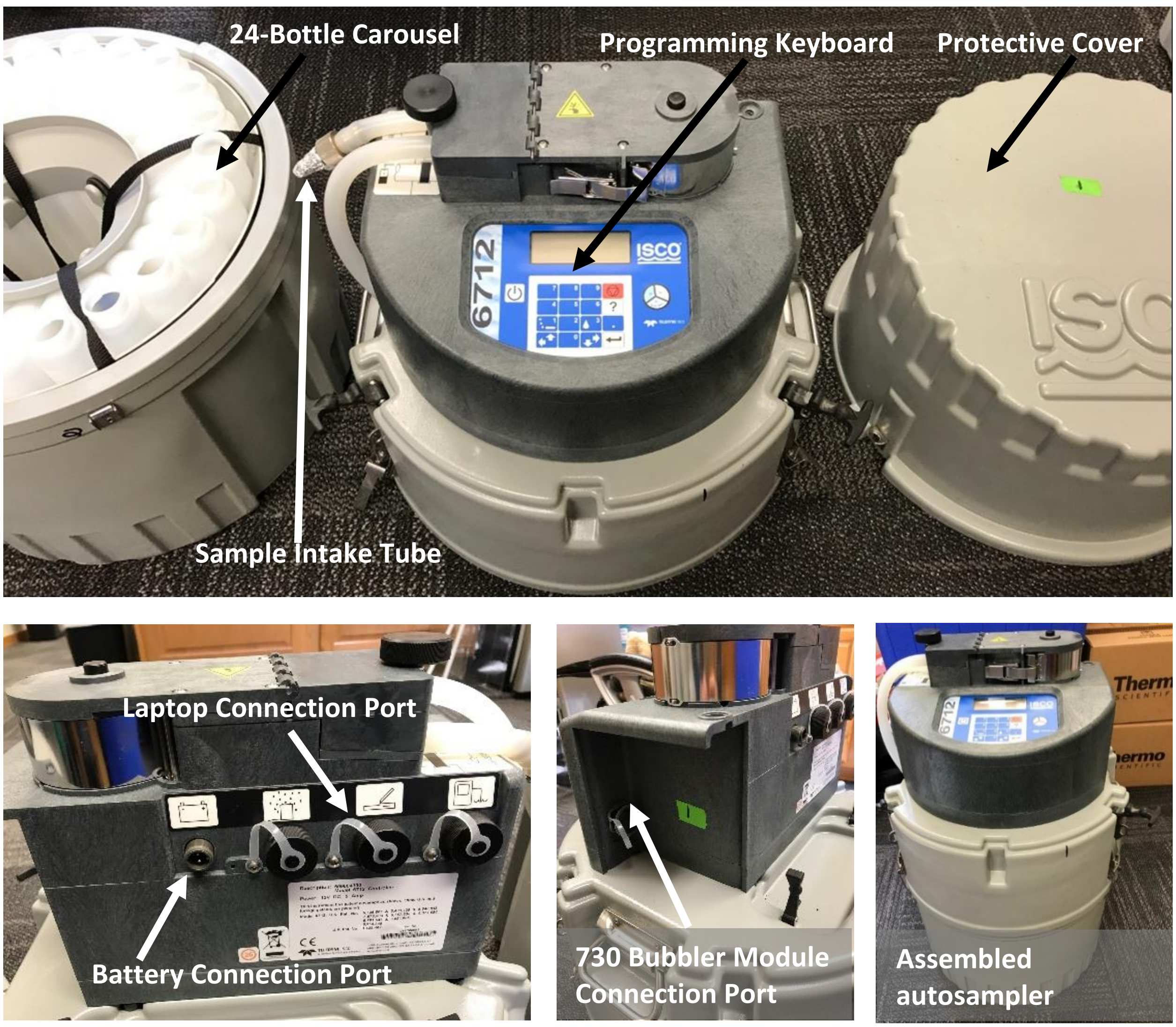

Figure 4 - Teledyne ISCO 6700 series autosampler Diagram.

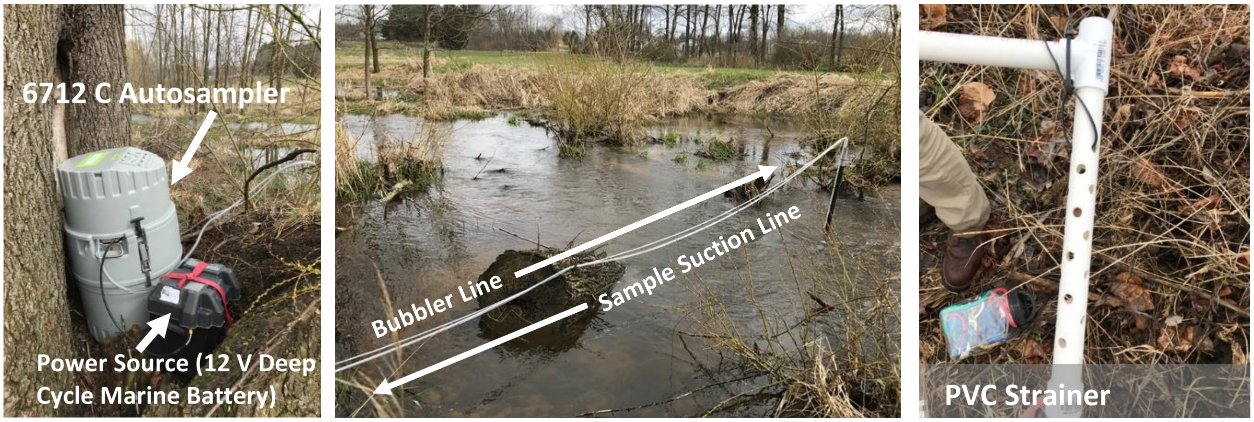

Figure 5 - Field installation of an autosampler on the Branch & Derby Drain (sample site A6). The autosampler is placed on an elevated, flat area, is connected to a power source (12 V deep cycle marine battery), suction line, and bubbler line. The suction and bubbler lines are installed in the drain's centerline and are encapsulated within the PVC strainer. The strainer ensures that when samples are collected through the suction line, nothing large like leaves, crayfish, etc. get stuck in the tubing. Similarly, the strainer protects the bubbler line from damage and a clogged line.

In the Branch & Derby Drain, autosamplers were programmed to start sampling once the water level measured in the drain began to rise due to runoff from a rain event. When the water level increased by three inches, the autosampler started pulling 400 mL water samples every 20 minutes until each of the 24 bottles in the base of the autosampler were filled. When the sampler completed the sample event, field personnel went to each sampler, downloaded the data, and reviewed sample collection time compared to the curve in water level. The samples collected on the positive slope of the curve were composited. This sample was determined to be "beginning of the storm" samples. Samples collected on the negative slope of the curve were composited and determined to be "end of the storm" samples.

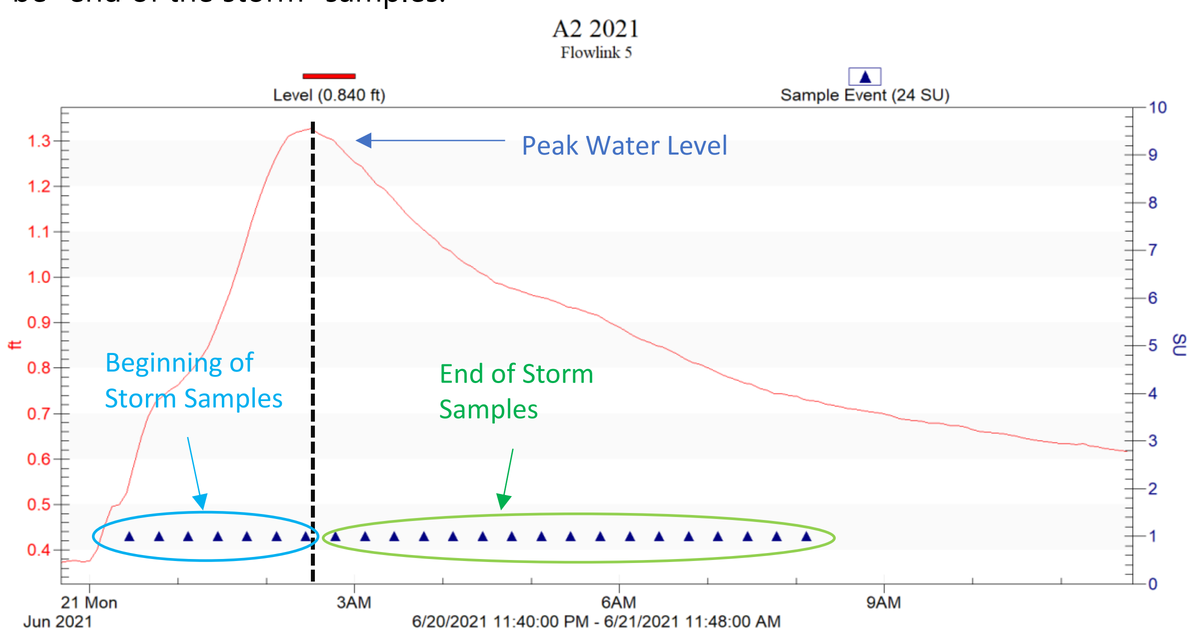

Figure 6 - June 21 - 22, 2021 sample event at sample site A2. The red line denotes water level (ft) in the drain at site A2, and the blue triangles denote when a sample was collected by the autosampler. The first seven samples were composited for the "beginning of storm" sample and the last 17 samples were composited as the "end of storm" sample.

Water Quality Parameters Measured

Parameters monitored in the Branch & Derby Drain were consistent with what was monitored in Paw Paw Lake in 2021 and in years previous. Keeping parameters consistent helps to eliminate variables when comparing the lake and drain's water quality. Parameters monitored on the drain include:

- Total phosphorus (TP)
- Orthophosphate, also referred to as soluble reactive phosphorus (SRP)
- Nitrate
- Ammonia
- Total suspended solids (TSS)
- Water Level
- Rainfall

Chemical parameters TP, SRP, nitrate, ammonia, and TSS were analyzed by a NELAP certified laboratory. Standard methods utilized to analyze and measure the concentration of each parameter are listed in the table below:

Parameter	***Standard Method***
Total Phosphorus (TP)	EPA 0365.3
Orthophosphate (SRP)	EPA 0300.0
Nitrate	EPA 0300.0
Ammonia	SM 4500-NH3 G-2011
Total suspended solids (TSS)	SM 10200 H

Table 2 - Standard methods utilized by laboratories to analyze water samples.

Water level was measured by the Teledyne ISCO autosampler and the connected 730 bubbler unit. Level data was collected every 5 minutes, 24 hours a day, 7 days a week. Field checks of level were performed during sample collection and autosampler maintenance.

Rainfall data came from the Southwest Michigan Regional Airport (KBEH) weather station located in Benton Harbor, Michigan. The weather station is located approximately 10 miles to the south and west of Paw Paw Lake.

SAMPLING RESULTS

TOTAL PHOSPHORUS

Phosphorus is an element that is a major component in all lifeforms. Every living thing, from a human being to green algae has phosphorus in it. In fact, after calcium, phosphorus is the second most abundant mineral in the human body. Phosphorus can also be found in inorganic forms like in rocks. Total phosphorus is the measurement of all types of phosphorus (both organic and inorganic) within the water.

The main concern with phosphorus regarding inland lakes and streams is that too much phosphorus can lead to excess algal and aquatic plant growth. Excess algal growth can lead to reduced dissolved oxygen, cloudy water, unpleasant odors, discolored water, and many more undesirable water quality issues. Excess aquatic plant growth can be an issue for motorboats, as it can become tangled in propellers.

Phosphorus is a key factor for plant and algal growth because it is the limiting nutrient for their growth. A limiting nutrient is defined as a component that limits the amount of the product that can be formed or its rate of formation, because it is present in small quantities. Too much phosphorus in a lake or other water body year after year can lead to hastened aging of a lake, or "eutrophication."

Figure 7 - Autosampler suction and bubbler lines installed on the Branch & Derby Drain, sample site A2, May 2021.

Reducing total phosphorus in the water column is one of the goals noted in Paw Paw Lake's Lake Improvement Plan, as historically TP concentrations have been elevated compared to other Michigan inland lakes. One of the ways phosphorus can be reduced in Paw Paw Lake is by reducing the amount of phosphorus flowing into the lake from tributaries. Since the Branch & Derby Drain is the largest tributary to Paw Paw Lake, it is a priority to mitigate phosphorus flowing from the drain to the lake. Total phosphorus concentrations measured in the Branch & Derby Drain were compared to total phosphorus concentrations measured in Paw Paw Lake. Data is shown in the figure below.

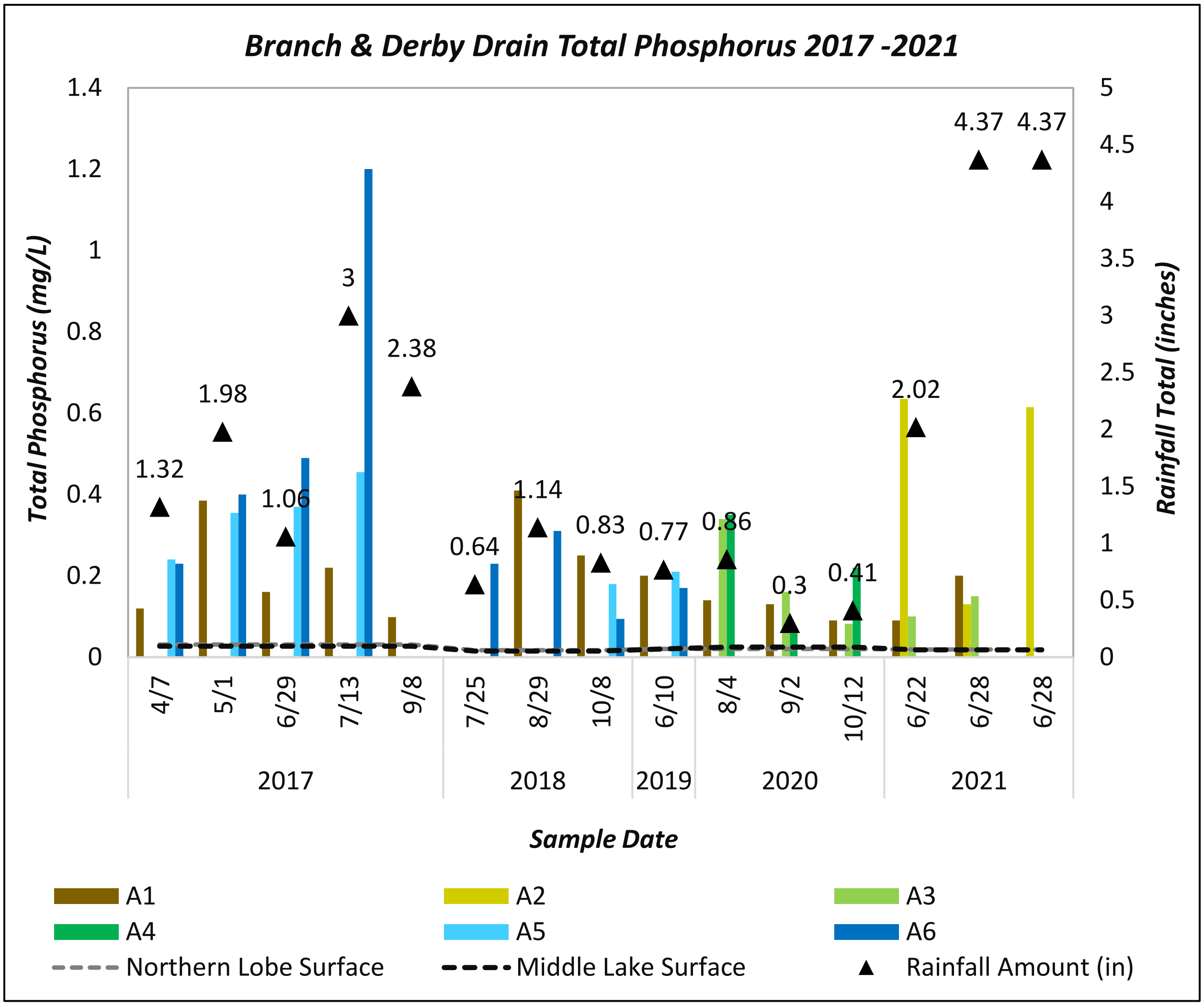

Figure 8 - Total phosphorus measured during rain events on the Branch & Derby Drain 2017 - 2021. If "beginning of storm" and "end of storm" samples were collected for a given sample site during a sample event, the beginning and end of storm phosphorus values were averaged in order to calculate the average concentration for the storm, also called the Event Mean Concentration. Average concentrations are reported in the figure above.

Branch & Derby Drain total phosphorus concentrations continue to be much higher than Paw Paw Lake total phosphorus concentrations. On average, Branch & Derby Drain TP concentrations can be anywhere between 3 – 34 times higher than Paw Paw Lake TP concentrations. The data collected show that more rainfall during an event does not correlate with higher TP concentrations. However, the greater the rainfall, typically the greater the loading of phosphorus due to a larger volume of water flowing through the drain. Since the drain has much higher concentrations of TP compared to the lake, measures should be taken to reduce TP within the drain's water. Measures include responsible land management within the Branch & Derby Drain's watershed, removal of sediment from the drain, reconnection to the drain's original floodplain, detention basins, incorporation of native plant species in the design of basins and other best management practices.

Soluble Reactive Phosphorus

Orthophosphate, also known as soluble reactive phosphorus (SRP), is a main constituent in fertilizers used for agriculture and residential purposes. SRP is a form of phosphorus that is readily available for plants, algae, and other organisms to uptake and use. SRP can be introduced into a lake or stream via stormwater runoff, animal waste, and plant and animal decomposition. SRP is included in the measurement of total phosphorus, since it is a form of phosphorus, therefore SRP concentrations should never be higher than TP concentrations. SRP concentrations measured in the Branch & Derby Drain are shown in the graph below. Values are compared to SRP concentrations measured in Paw Paw Lake for each respective year.

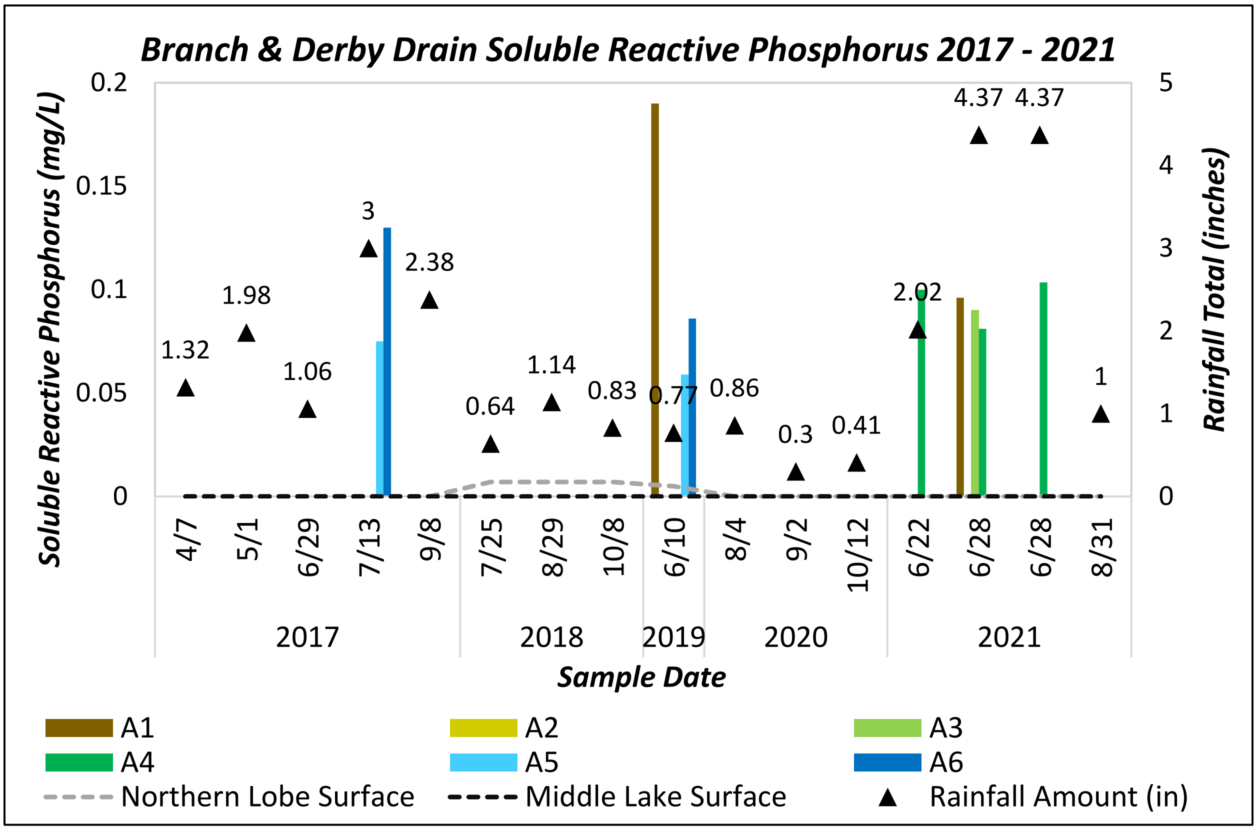

Figure 4 - Soluble reactive phosphorus measured in the Branch & Derby Drain 2017 - 2021. SRP levels are compared to Paw Paw Lake SRP concentrations measured over time as well as rainfall totals for each rain event sampled.

Like total phosphorus, soluble reactive phosphorus was much higher in the Branch & Derby Drain compared to Paw Paw Lake when it was detected. Most (67%) samples collected and analyzed for SRP did not have high enough concentrations of SRP to be reported. SRP tends not to be as high in the later summer and early fall months based on the current dataset. Having low SRP concentrations within the Branch & Derby Drain is desirable for Paw Paw Lake, as SRP is readily available for uptake by algae and other small organisms that can lead to undesirable lake conditions if their populations are too high.

Nitrate

Nitrate is a form of nitrogen that is naturally found in aquatic and terrestrial ecosystems. However, nitrate may be introduced into the environment at unnatural levels by sewage, fertilizers, and manure used as fertilizer. Nitrate may also become incorporated into an aquatic ecosystem by atmospheric deposition. According to USGS "more than 3 million tons of nitrogen are deposited in the United States each year from the atmosphere, derived either naturally from chemical reactions or from the combustion of fossil fuels, such as coal and gasoline." (Source: https://www.usgs.gov/special-topic/water-science-school/science/nitrogen-and-water?qt-science_center_objects=0#qt-science_center_objects)

When at excessive levels, nitrate leads to eutrophication of a water body, much like phosphorus. The presence of nutrients like nitrogen and phosphorus can lead to excessive algae growth, which can deplete dissolved oxygen in the water and severely harm water quality. At it's most severe, this process can even lead to anoxic "dead zones," such as those found in the Gulf of Mexico and Lake Erie. Dead zones refer to areas that are completely depleted of oxygen that cannot support the majority of aquatic life.

Figure 60 - Western Lake Erie basin algae bloom, 2014. Source: NASA

Additionally, excess nitrate in the environment can become toxic for both humans and wildlife. Levels above 10 mg/L are unsafe for human consumption, according to the U.S. Environmental Protection Agency. Excess nitrate in the body can lead to what is called methemoglobinemia or "blue baby syndrome." This condition reduces red blood cells' ability to carry oxygen throughout the body. Cattle may also develop methemoglobinemia if they drink water that has too high of nitrate levels. At 30 mg/L, nitrate can inhibit growth, impair the immune system, and cause stress in exposed aquatic species.

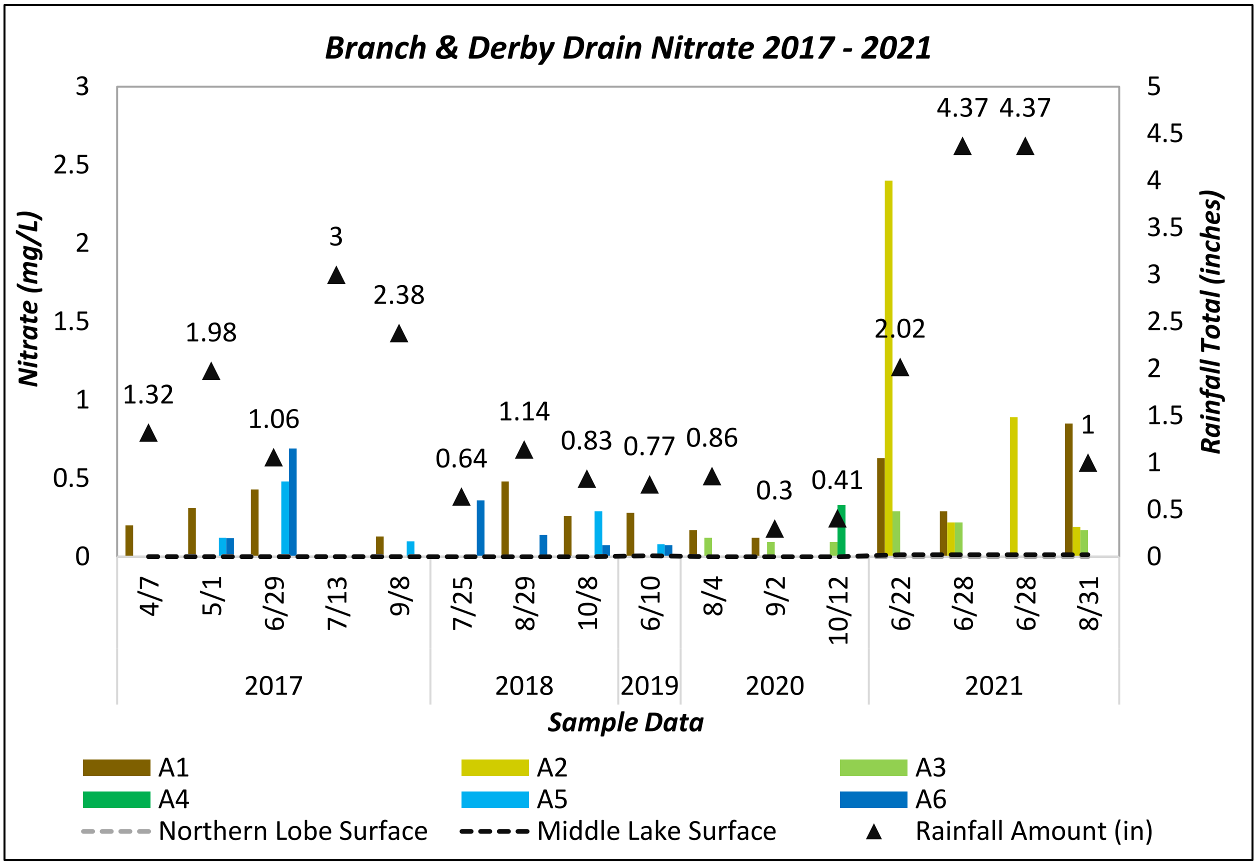

Figure 11 - Nitrate concentrations measured in Branch & Derby Drain, compared to nitrate measured in Paw Paw Lake.

Again, nitrate, like total phosphorus and soluble reactive phosphorus, is higher in the drain than it is in the lake. There is not a strong correlation between increased rain events and increased nitrate concentration. Similarly, there does not appear to be a seasonal trend where nitrate concentrations are higher in certain months compared to others. Sample sites directly downstream from the in-line detention basin tend to have lower concentrations nitrate than samples collected before the basin. As the drain flows closer to the lake, nitrate concentrations tend to increase again and are at their highest at the downstream-most sample site.

The highest measured concentration of nitrate was at A2 on 6/22/2021 during a week of wet weather at 2.4 mg/L. The sample collected at A3 just upstream from A2 was significantly lower in concentration. Between these two sample sites, two drains flow into the Branch & Derby. The first being the McConnell and Olcott Drain, and the second being a roadside ditch that flows on the southside of Hagar Shore Road. Typically this ditch is dry, but it was flowing during that particular rain event due to the substantial amount of rain that fell. It's likely that the increase in ammonia was coming from either or both of these tributary drains. Nitrate did decrease as the drain neared the lake, so it may have been diluted by other tributaries or been sorbed by wetlands or other nitrate sinks along the way.

AMMONIA

Ammonia is another form of nitrogen that exists naturally in an aquatic environment. Natural sources include the decomposition of organic material and vegetation, gas exchange with the atmosphere, forest fires, animal and human waste, and the nitrogen fixation process. Just like nitrate, SRP, and TP, ammonia levels can become too high in the environment due to human influence. Unnatural sources of ammonia include commercial fertilizer, industrial applications, and wastewater treatment plant effluent.

Unlike other forms of nitrogen, which have indirect effects on aquatic life due to the over enrichment of water, ammonia causes direct toxic effects on aquatic life. When ammonia is present in water at high enough levels, it is difficult for aquatic organisms to sufficiently excrete the toxicant, leading to toxic buildup in internal tissues and blood, and potentially death. Environmental factors, such as pH and temperature, can affect ammonia toxicity to aquatic animals. (Source: https://www.epa.gov/wqc/aquatic-life-criteria-ammonia#:~:text=When%20ammonia%20is%20present%20in,ammonia%20toxicity%20to%20aquatic%20animals.)

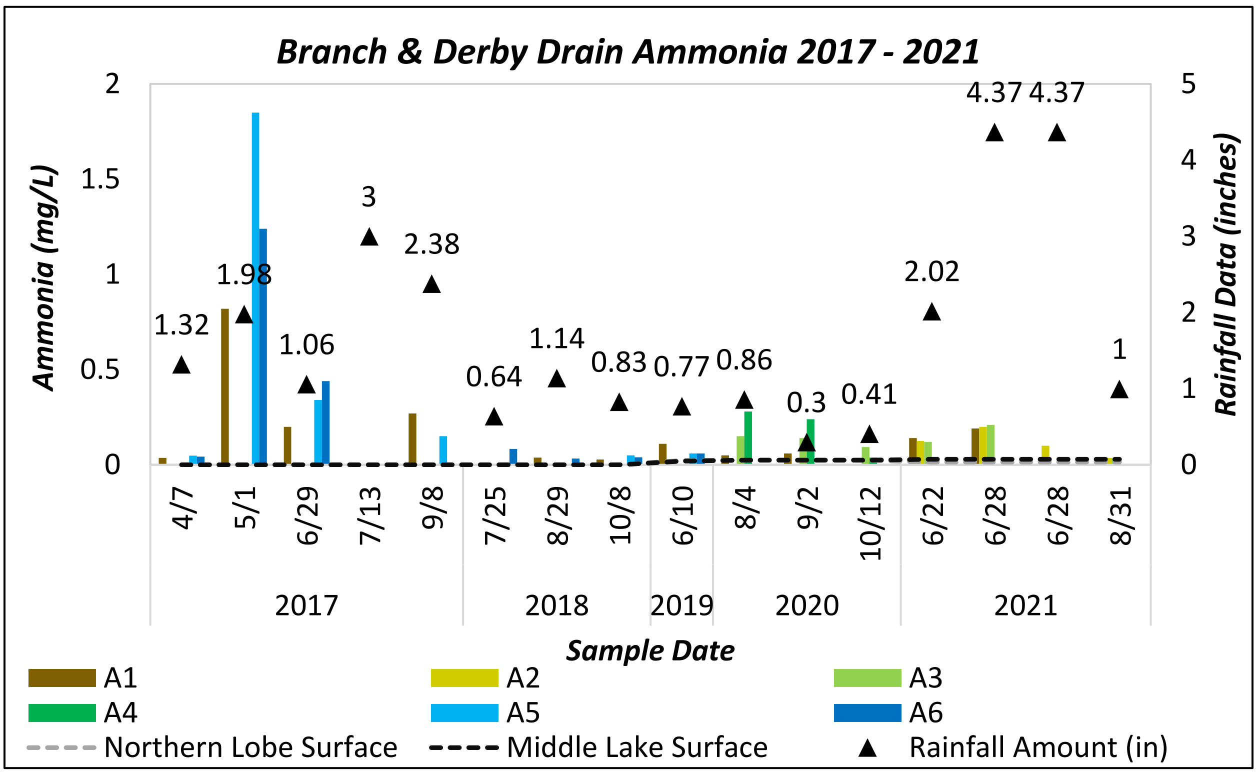

Figure 12 - Ammonia concentration measured in the Branch & Derby Drain during wet weather events over time. Data is compared to measured Paw Paw Lake ammonia concentrations over time.

Like all nutrients monitored in the Branch & Derby Drain, ammonia concentrations are much higher in the drain compared to Paw Paw Lake. Paw Paw Lake has had a concentration of ammonia ranging from "U" (which means a concentration near or at zero) to 0.029 mg/L in the last 5 years of monitoring. By comparison, the drain has had concentrations of ammonia measured anywhere between 0.022 – 2.1 mg/L.

Again, no correlation between rainfall totals and ammonia concentration exists. Ammonia concentrations tended to be highest in the 2017 monitoring season and has not been as high since then. This may be due to the time of year that samples were collected in 2017, as it factored in the early part of the growing season in May, where other monitoring seasons did not. During some events, ammonia concentrations decreased the further downstream samples were collected, and other events the exact opposite was true; trends were inconsistent. Effort should be made to help reduce ammonia concentrations in the drain. This can be accomplished by responsible land management within the Branch & Derby Drain's watershed, removal of sediment from the drain, reconnection to the drain's original floodplain, detention basins, incorporation of native plant species in the design of basins and other best management practices.

Total Suspended Solids

Total suspended solids are small particles that consist of organic material, clay, and other particulate matter suspended in the water and are measured in milligrams per liter (mg/L). Oftentimes, TSS carries other types of contaminants including nutrients, metals, and hydrocarbons (which is more common in urban areas). While TSS occurs naturally in some waterways, an excessive increase in TSS can lead to a decrease in visibility and an increase in other undesired contaminants previously mentioned, in addition to smothering fish eggs and other aquatic wildlife. Therefore, low concentrations of TSS are desired.

Figure 13 - Total suspended solids flowing into Paw Paw Lake from the Branch & Derby Drain. Image taken on June 28, 2021. Source: Cody Krieger

The State of Michigan has a “narrative standard” for TSS; meaning, the water should not have unnatural physical characteristics (MDEQ Rule 50, Part 4 of Act 451). Typically, water with TSS concentrations at >20 mg/L is clear, 40 – 80 mg/L is cloudy, and >150 mg/L appears dirty. Of all the samples collected in the Branch & Derby Drain, 51% of them were considered “clear,” 31% of samples were considered “cloudy,” and 18% of them were “dirty.” Results are shown in the graph below, along with rainfall totals for each event, Paw Paw Lake TSS concentrations on average, and State of Michigan guidance standards.

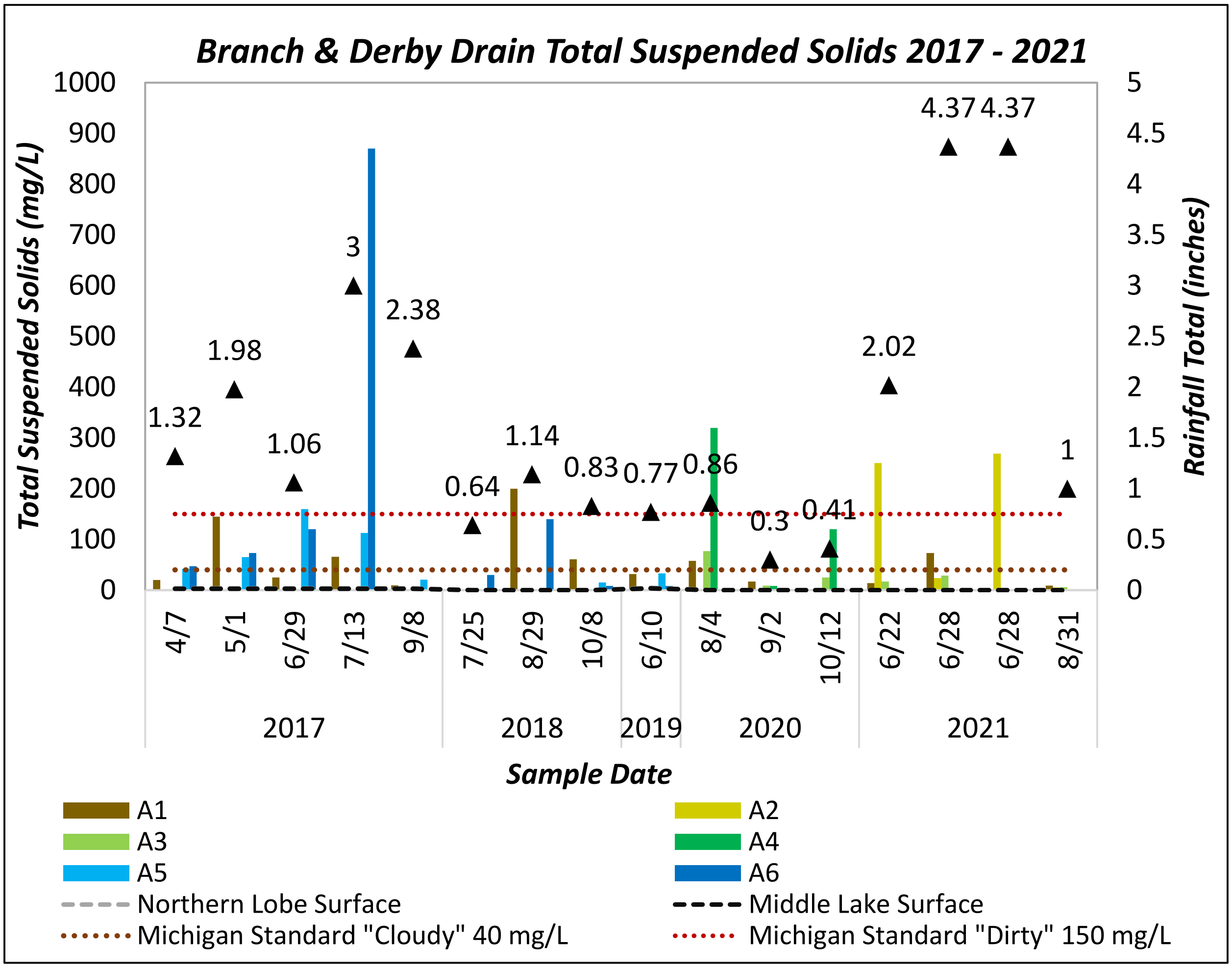

Figure 14 - Total suspended solids measured in the Branch & Derby Drain over time. Values are compared to the State of Michigan's narrative standard for TSS and values measured in Paw Paw Lake.

Following the same pattern as nutrients monitored, TSS did not have a strong positive or negative correlation with total rainfall. The highest concentration of TSS measured was on 7/13/2017 at site A6, with a concentration of 870 mg/L. A6 is the only sample site upstream of the M-140 detention basin. Effectively, the detention basin dropped sediment between A6 and the next sample site A5, which is located just downstream of the M-140 crossing and basin. The aerial images shown below (obtained from Google Earth) demonstrate how much sediment has been deposited in the basin over time since its construction.

Figure 15 - Aerial view of the M-140 basin on the Branch & Derby Drain. Note the sediment deposition in 2019 and 2021 images.

Nutrients tend to adhere to or be associated with TSS. Meaning, if more water quality management structures like an in-line basin are included within the drain's watershed water quality improvement will take place within the drain, which will ultimately have a positive impact on the water quality of Paw Paw Lake.

RECOMMENDATIONS

Based off the water quality results, the following actions are recommended for water quality improvement within the Branch & Derby Drain:

1. *Responsible land management within the watershed*
   Responsible land management includes maintaining a vegetative buffer between the drain and land that has been impacted by humans (i.e. farm field, lawns, parking

lot, road, etc.), maintaining forests and not cutting down all the trees, minimizing the amount of impervious areas (roads, parking lots, homes, buildings) within the watershed, applying fertilizer conservatively or not at all, planting native species of plants, or picking up after your pet. For more guidance on responsible land management to help protect water, soil, and forest quality, refer to Michigan Forestry Best Management Practices for Soil and Water Quality, written by the Michigan Department of Natural Resources and EGLE. For more guidance on protecting inland lakes and their watersheds, please refer to Protecting Michigan's Inland Lakes: A Guide for Local Governments and Protecting Michigan's Inland Lakes: A Toolkit for Local Governments Part I, both written by EGLE, and supported by the Van Buren Conservation District, Michigan State University Extension, Southwest Michigan Planning Commission, Michigan Lakes and Streams Association, and Michigan Natural Shoreline Partnership.

Figure 16 - View of Paw Paw Lake and its watershed after a rainstorm. Photo taken on June 26, 2021. Source: Cody Krieger

2. *Install best management practices such as detention basins or manmade wetlands*
   Best Management Practices, or BMPs, refers to an acceptable practice that could be implemented to protect water quality. A BMP can either be a physical thing built in the field or it can be a practice, such as public education or checking for leaks in a chemical tank. There are some physical BMPs implemented in the field on the Branch & Derby Drain, the most notable being the in-line detention basin. However, there are also erosion prevention measures that have been installed along various reaches of the drain. While individually some BMPs may seem too

small to make an impact on water quality, collectively they make a big difference. BMPs are scalable and can be large or small depending on budget, personnel, staff to get the work completed, and other factors. A useful guide for BMPs and low impact development is Southeast Michigan Council of Governments' Low Impact Development Manual for Michigan.

3. *Clean the sediment out of existing BMPs and the drain's channel*
   Maintenance of existing BMPs and the drain's channel is imperative for the systems to function properly and most efficiently. As sediment builds up in a BMP or a drain, less space is available for additional sediment and nutrients to drop out of suspension in the system. Meaning that the sediment and nutrients pass through the system. Conveyance of water through the system can also be compromised, and in extreme cases can lead to flooding upstream of the clogged area. By removing sediment, nutrients and sediment are taken out of the watershed and cannot be pushed farther downstream to Paw Paw Lake.

Figure 17 - Confluence of Branch & Derby Drain and Green Drain near Hagar Shore Road. Photo taken on April 29, 2020. Source: Spicer Group.

4. *Reconnect the drain to its floodplain*
   Historically, many natural stream channels have been straightened and disconnected from the meandering original channel and associated floodplain. Floodplains are important for many reasons, including the reduction of flood risk,

as it provides more space for the river or stream to flow as the water rises, it helps filter out sediment and nutrients, as it slows down the flow of water and allows for settling out of solids, allows for aquifers to recharge, and improves wildlife habitat. The Branch & Derby Drain has also been straightened, however reconnection to the original channel and floodplain is feasible in some locations. By doing so the benefits of a connected floodplain, as previously mentioned, will be realized.

Figure 18 - Lower Branch & Derby Drain near outlet to Paw Paw Lake. Note that the drain is not connected to the floodplain at this location. Photo taken on April 29, 2020. Source: Spicer Group.

CONCLUSIONS

For each parameter monitored in the Branch & Derby Drain – total suspended solids, total phosphorus, soluble reactive phosphorus, nitrate, and ammonia, the following trends remained consistent:

- The Branch & Derby Drain had much higher concentrations of each parameter compared to Paw Paw Lake for each sampling event.

- There was not a strong correlation between total rainfall for the event and an increase or decrease in parameter concentration. This means that other variables, such as time of the year, intensity of runoff/flow, groundwater influence, and how the land is being used within the watershed during a monitoring event (i.e. farming, lawn work, fertilizing lawn, road construction, etc.) are likely to have a more correlated impact on water quality within the drain.

- Responsible land management within the watershed, installing best management practices such as detention basins or manmade wetlands, cleaning the sediment out of existing BMPs and the drain’s channel, and reconnecting the drain to its floodplain will all help in improving water quality within the drain and Paw Paw Lake.