2019 Sand Lake NE Wash Data Collection and Loading Calculations – LEAPS 4/18/2020

Introduction

Sand Lake is a 318 acre drainage lake in northwestern Barron County. There are several perennial and intermittent streams/drainage gullies that contribute water, sediment, and nutrients to the lake. In 2016, one of the largest gullies, known locally as the NW Wash was repaired with funds provided by a WDNR lake protection grant. The NW Wash was a relatively short, but very steep and ragged gully that became a huge negative impact after a 2010 rain event that dumped more than 8" of rain over a very short period of time. The resulting runoff and gully erosion filled in a 0.12-acre area of the lake that was previously more than two feet deep in a single day (Figure 1).

Figure 1: Sand Lake - Bottom of the NW Wash after a 2010 significant rain event (LEAPS)

On the other side of the lake, is another wash, locally known as the NE Wash. While not in as bad a shape as the NW Wash was in before it was repaired, the NE Wash has been contributing significant amounts of sediment for decades. Recent observations seem to support that it might be getting worse (Figure 2). The NE Wash is a 1.7 mile long intermittent stream that drops at least 100-ft from the top (28^{th} Ave) to the bottom where it exits into the lake (Figure 3). The 1.7 miles of the NE Wash is fed by a watershed that covers more than 2,423 acres (Figure 4). Every drop of water that falls on this area moves toward Sand Lake. Along the way, some water is soaked into the ground; some is captured in small ponds and other depressions in the landscape, and more evaporates or is used up by the flora and fauna in the region. However, when enough rain water or snowmelt occurs that it fills all the ponds and depressions and can no longer be infiltrated into the ground, it moves through the entire system to Sand Lake carrying with it sediment and nutrients. The extent to which this happens varies every year.

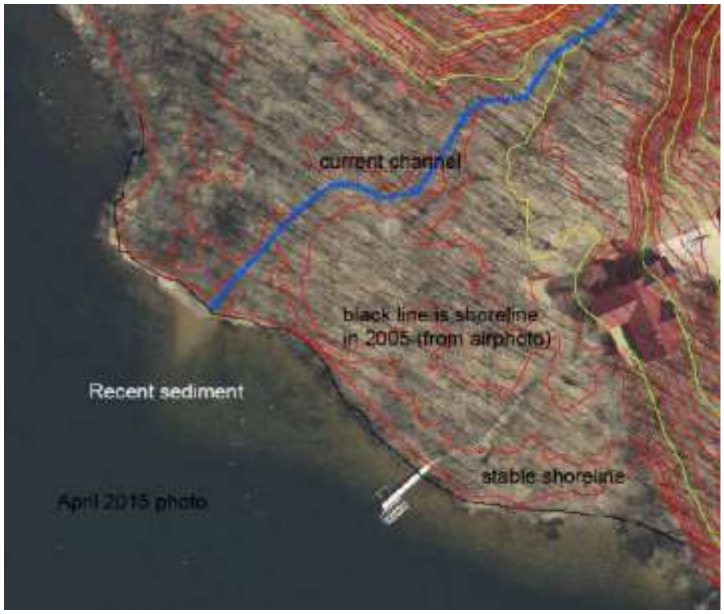

Figure 2: 2015 evidence of new sediment in the lake from the NE Wash

Figure 3: Sand Lake, Barron County NE Wash (lime green line)

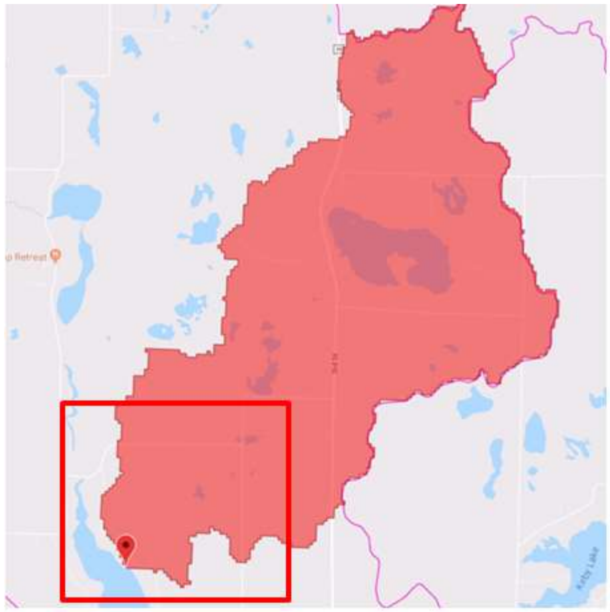

Figure 4: Sand Lake, Barron County NE Wash watershed. Red square represents the area in Figure 3 (LEAPS)

In 2018, the Sand Lake Management District implemented a two year project (2018 and 2019) to better quantify the amount of water, sediment, and nutrients that were contributed to the lake from the NE Wash.

Project Specifics

The NE Wash project included collection of flow data and water samples measuring total suspended solids (TSS) and total phosphorus (TP) in an attempt to quantify water flow and loading of these two parameters. TSS is easy to see as it ends up looking like sand and other debris deposited in the lake at the outlet of the wash to the lake. These deposits reduce the depth of the lake and smother gravel or rocky bottoms that may serve as spawning areas for walleye and other fish species. The shallower water also warms up faster impacting the overall temperature of the lake.

TP is not easy to see as it is a nutrient dissolved in the water or attached to sediment particles that accelerates the growth of aquatic plants and algae in the lake. The sediment washed into the lake provides the shallower and more organic substrate needed for aquatic plant to grow. Aquatic plants die and drop to the bottom of the lake during the season creating more organic material that supports future plant growth. As TP levels in the lake increase, so does the amount of algae suspended in the lake water and attached to hard surfaces and plants in the water (called filamentous algae).

Lake volunteers near the NE Wash were tasked with the responsibility of alerting the Lake District and their consultant when there was water moving through the wash. Lake District volunteers and the consultant also watched weather reports to identify storm events that might cause runoff through the system. Not all storm events caused water to move all the way through the system. If the wash was dry, it required a great deal more rainfall and snowmelt to cause water to get to the lake. If the wash was already close to running, it only required a small amount of rain to push it into the running stage.

Another part of this project included the installation of pressure transducers at four different points along the NE Wash from the culvert under 28th Ave to where the wash empties into the lake. Pressure transducers continuously record the pressure caused by water flowing over them when placed in the bottom of a stream channel. If there is no water flowing over them, then it is expected that the pressure would be the same as the air pressure around it. With water flow the pressure is different than the air pressure around it. Pressure readings can be correlated with field collected flow and stage data to determine a rating curve. From that curve, a continuous estimate of actual flow can be made.

Ecological Integrity Services (EIS) owned and operated by Steve Schieffer was contracted with to provide transducer installation, data readout, and data analysis. His data coupled with flow data and water samples collected by volunteers was used to establish water discharge and loading values for TSS and TP. Four transducers were placed in the NE Wash, both in 2018 and 2019. A fifth transducer was installed to record air pressure in the area. Pressure transducers were installed at the Culvert under 28th Ave, Between Big Pond and Bormans Pond, just below Bormans Outlet, and at the Bottom of the wash approximately 300 yards upstream of the lake (Figure 5).

Figure 5: NE Wash transducer locations and the Two Ponds

Precipitation

SLMD volunteers collected rainfall data during the 2-yr NE Wash project. Precipitation records were kept by a volunteer in 2018. The year 2018 was a wet year, but few significant events occurred which caused the wash to run. Rainfall was recorded from May 27, 2018 through mid-October 2018. The only time that water was witnessed flowing from the wash to the lake was on Sept 21, 2018 after a 5.5” single day rain event. However, the water entering the lake from the bottom of the NE Wash only lasted a day or less. No flow measurement was recorded and no water sample was collected.

But what a difference a year makes. The year 2019 was a wet year that provided a great deal of data. Water moved through the system making its way into Sand Lake for a period of 72-84 days between late March and mid-June. Although not quantified, water again made it to the lake during some timeframe in the fall of 2019 as well. Precipitation was monitored at one site near Granite Lake just to the east of Sand Lake. A volunteer recorded rainfall data with the Community Collaborative Rain Hail and Snow (CoCoRaHS) program. Nearly 8” of rain was documented at this site from March 15, 2019 to June 10, 2019. Figure 6 reflects how rainfall recorded at this site measures up to normal rainfall in WI. Rainfall in April and May was well above what is a 30-yr average. Couple this with snowmelt that began and ended in the last two weeks of March and there was a lot of water movement.

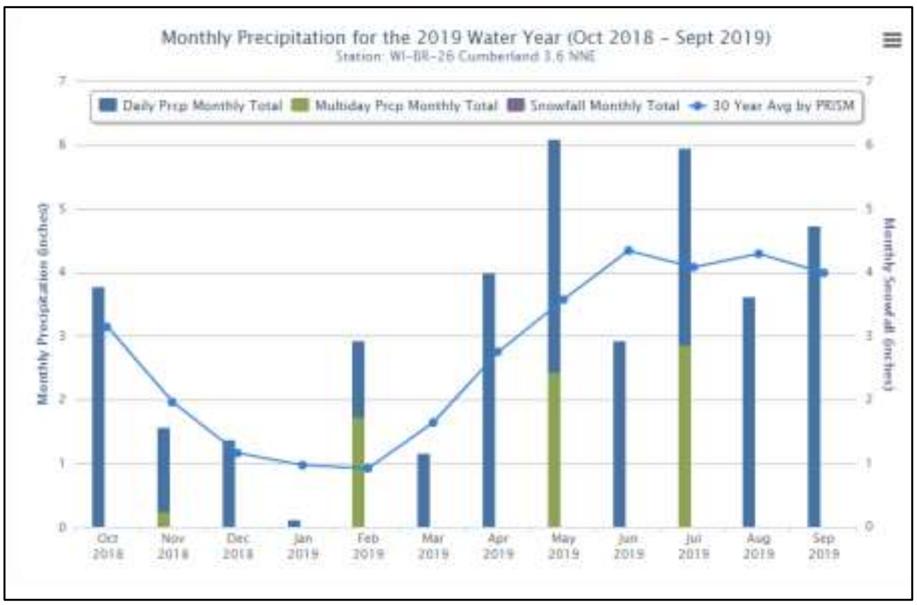

Figure 6: Rainfall data near the north end of Granite Lake, Barron County (CoCoRaHS - last accessed 4/19/20)

Flow Data

Based on pressure transducer data, flow from the Culvert under the road at the top of the NE Wash started on or about March 18, 2019 and ended about June 10, 2019 for a total of 84 days (Figure 7). Flow did not drop to “zero” until June 10. Actual flow was recorded in the field only once on May 30, 2019. The average flow over the entire 84 day time frame is estimated at 2.1-cuft/sec. No water samples were collected and no other flow readings were recorded.

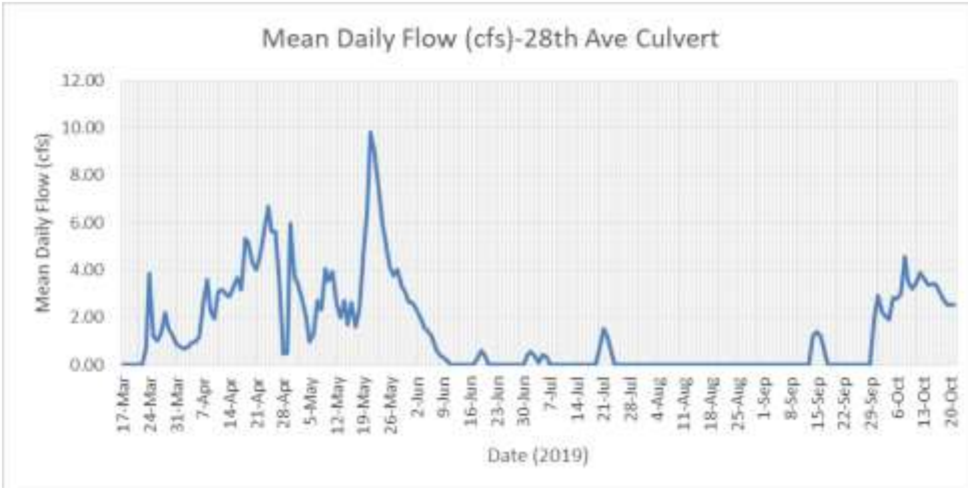

Figure 7: 2019 Seasonal mean daily flow - Culvert at 28th Ave (EIS, 2019)

Based on pressure transducer data, flow between the Big Pond and Bormans Pond was first recorded on or about March 22, 2019 and ended about June 8, 2019 for a total of 78 days of flow (Figure 8). Flow dropped to “zero” at least five times during that time frame, but then started up again. Actual flow was recorded in the field on April 18 and on May 30. The average flow over the entire 78 day time frame is estimated at 2.14-cuft/sec. No water samples were collected and no other flow readings were recorded.

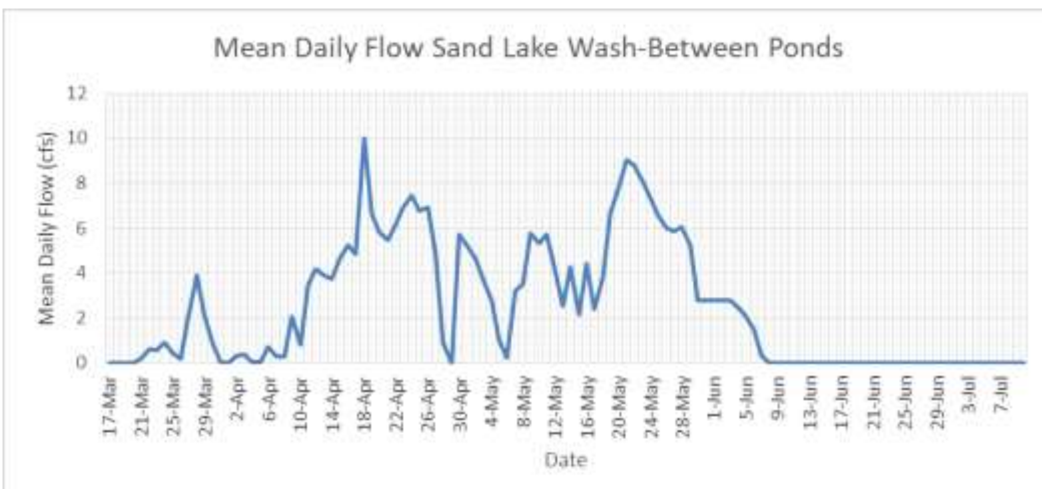

Figure 8: 2019 Seasonal mean daily flow - Between Ponds (EIS, 2019)

Based on pressure transducer data, flow from Bormans Pond began on or about March 23, 2019 and ended about June 3, 2019 for a total of 72 days (Figure 9). Flow dropped to “zero” at least seven times during that time frame. Actual flow was recorded in the field on four separate dates (4/18, 5/15, 5/19, and 5/30). The average flow over the entire 72 day time frame is estimated at 2.63-cuft/sec. TSS and TP water samples were collected four times (4/15, 5/15, 5/19, and 5/30). No other flow readings or water samples were recorded.

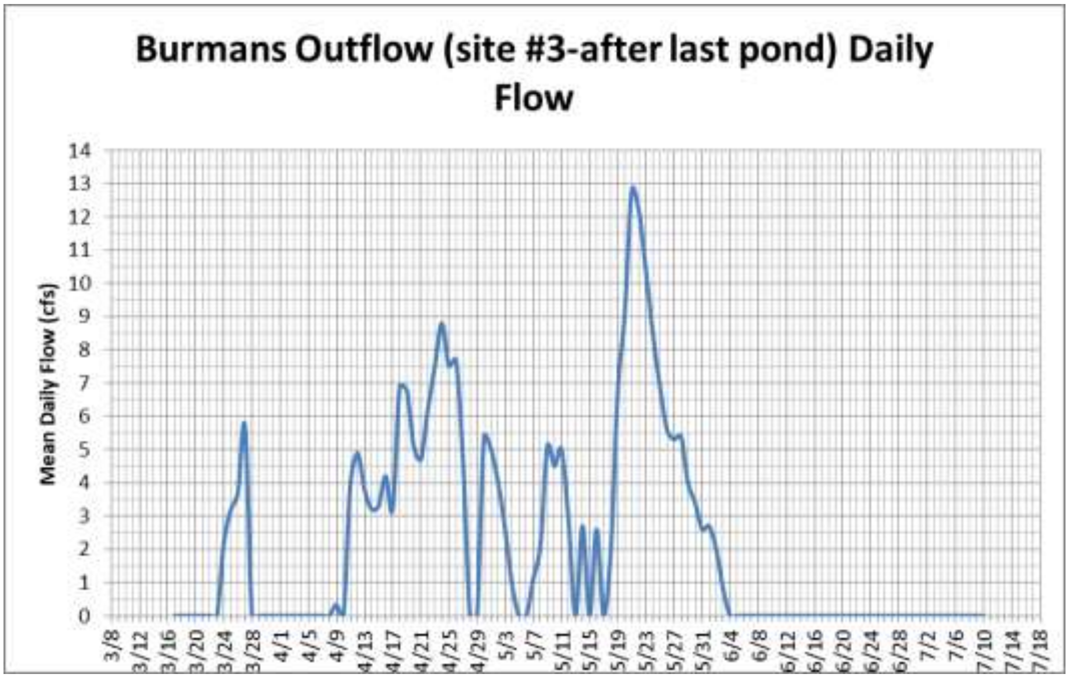

Figure 9: 2019 Seasonal mean daily flow - Bormans Outlet (EIS, 2019)

Based on pressure transducer data, flow from the outlet of the NE Wash to the lake started on or about March 27, 2019 and ended on or about June 10, 2019 for a total of 75 days of flow (Figure 10). Flow dropped to "zero" at least five times during that time frame, but then started up again. Actual flow was recorded in the field on five separate dates (4/15, 4/18, 5/15, 5/19, and 5/30). The average flow over the entire 75 day time frame is estimated at 2.5-cuft/sec. TSS and TP water samples were collected four times (4/15, 5/15, 5/19, and 5/30). No other flow readings or water samples were recorded.

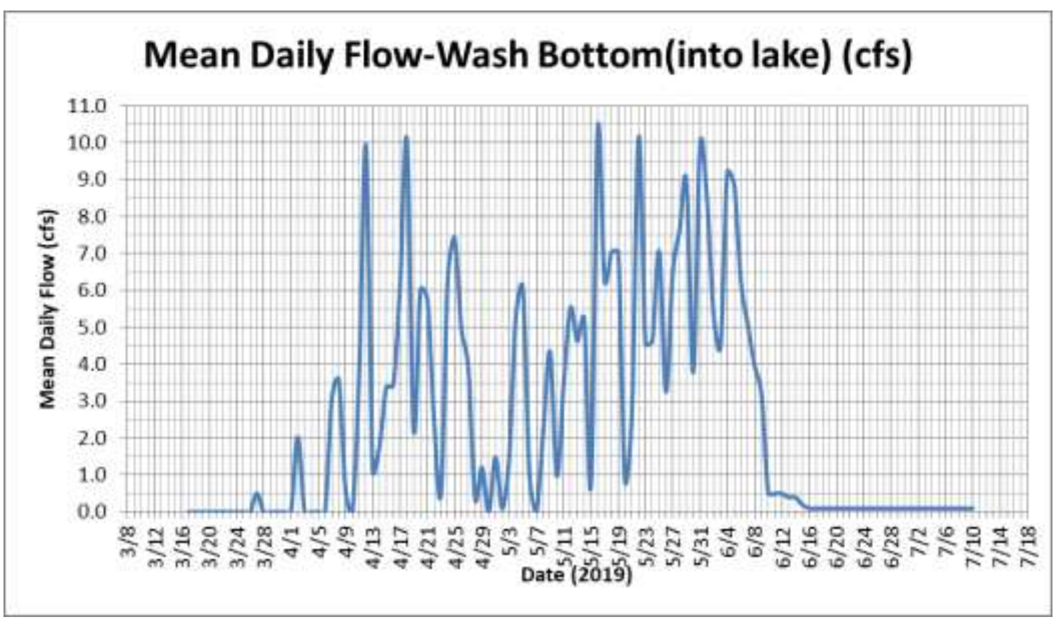

Figure 10: 2019 Seasonal mean daily flow, Outlet to Sand Lake (EIS, 2019)

Total suspended solids (TSS) and total phosphorous (TP) loading calculations are based on the mean seasonal flow and the mean of lab results for water samples collected. Water samples were only collected from the site at Bormans Outlet and at the Outlet to the Lake site at the bottom of the NE Wash. Data collected is reflected in Table 1.

Table 1: 2019 Data collection in the NE Wash

Site	Date	Time	Flow Volume(feet^3/s) - Field Measures	Estimated Seasonal Flow (cuft/sec) - Transducers	Dates	TSS(mg/l)	TP (mg/l)
Culvert by Road-TOP	5/30/2019	9:15	3.42	2.1	3/18-6/10	no data	
Between ponds	4/18/2019	11:30	10.17	2.14	3/22-6/8	no data	
Between ponds	5/30/2019	9:30	2.14				
Borman's outlet	4/14/2019	8:45	NA	2.63	3/23-6/3	3.25	0.108
Borman's outlet	4/18/2019	11:45	8.07			no data	
Borman's outlet	5/15/2019	12:15	0.30			0	0.0566
Borman's outlet	5/19/2019	12:42	8.67			3.2	0.0844
Borman's outlet	5/30/2019	9:40	4.08			0	0.0567
Wash Bottom	4/14/2019	8:45	1.52	2.04	3/27-6/10	5	0.098
Wash Bottom	4/18/2019	12:15	10.08			no data	
Wash Bottom	5/15/2019	12:00	0.71			0	0.0391
Wash Bottom	5/19/2019	12:50	7.04			59.7	0.155
Wash Bottom	5/30/2019	10:15	3.78			4.2	0.0597

2019 Seasonal Flow	cuft	liters	gallons	# of Days	gallons/day
Culvert	15240960.00	431575216.13	114010087.99	84.00	1357262.95
Between Ponds	14421888.00	408381718.12	107883015.24	78.00	1383115.58
Bormans Outlet	16360704.00	463282783.03	122386339.36	72.00	1699810.27
Outlet to Lake	13219200.00	374325442.56	98886300.81	75.00	1318484.01

Water Movement through the NE Wash

Data from the transducers was converted into an Excel spreadsheet that shows when flow at each of the sites was documented between March 17, 2019 and June 20, 2019 (Table 2).

Table 2: 2019 Dates of flow from transducers

	17-Mar	18-Mar	19-Mar	20-Mar	21-Mar	22-Mar	23-Mar	24-Mar	25-Mar	26-Mar	27-Mar	28-Mar	29-Mar	30-Mar	31-Mar
Culvert															
Between Ponds															
Bormans Outlet															
Outlet to Lake															

	1-Apr	2-Apr	3-Apr	4-Apr	5-Apr	6-Apr	7-Apr	8-Apr	9-Apr	10-Apr	11-Apr	12-Apr	13-Apr	14-Apr	15-Apr
Culvert															
Between Ponds						16									
Bormans Outlet											19				
Outlet to Lake											15				

- no flow
- flow recorded
- first day of nearly continuous flow
- last day of nearly continuous flow

	16-Apr	17-Apr	18-Apr	19-Apr	20-Apr	21-Apr	22-Apr	23-Apr	24-Apr	25-Apr	26-Apr	27-Apr	28-Apr	29-Apr	30-Apr
Culvert															
Between Ponds															
Bormans Outlet															
Outlet to Lake															

	1-May	2-May	3-May	4-May	5-May	6-May	7-May	8-May	9-May	10-May	11-May	12-May	13-May	14-May	15-May
Culvert															
Between Ponds															
Bormans Outlet															
Outlet to Lake															

	16-May	17-May	18-May	19-May	20-May	21-May	22-May	23-May	24-May	25-May	26-May	27-May	28-May	29-May	30-May	31-May
Culvert																
Between Ponds																
Bormans Outlet																
Outlet to Lake																

	1-Jun	2-Jun	3-Jun	4-Jun	5-Jun	6-Jun	7-Jun	8-Jun	9-Jun	10-Jun	11-Jun	12-Jun	13-Jun	14-Jun	15-Jun	16-Jun	17-Jun	18-Jun	19-Jun	20-Jun
Culvert																				
Between Ponds																				
Bormans Outlet																				
Outlet to Lake																				

Based on transducer data from 2019, on the fifth day after flow was recorded in the Culvert on top, flow was recorded between the Big Pond and Bormans Pond, suggesting it took four days to fill the Big Pond in 2019. The Big Pond covers approximately 3.2 acres when full enough to flow out into the channel that leads to Bormans Pond (Figure 11). The average flow from the culvert to the Big Pond was estimated at 2.1-cuft/sec. Based on transducer results from the culvert site, once flow started around March 18th, it maintained consistent flow with no “zero” readings. If the assumption is made that the water flowing from the culvert to the Big Pond started at “zero” on day one, and was at the mean level by day four, then the average flow over that four day period would have been 1.05-cuft/sec. This equates to 8.33-acft of water in four days to fill the Big Pond. If the big pond is 3.2 acres, its average depth would then be 2.6-ft when full.

Figure 11: Big Pond - First retention basin, approx. 3.2 acres (LEAPS, 2020)

Based on transducer data from 2019, on the third day after flow was recorded in the channel between the Big Pond and Bormans Pond, flow was recorded coming out of Bormans Pond, suggesting it took two days to fill Bormans Pond in 2019. Bormans Pond covers approximately 0.70 acres when full enough to flow out into the NE Wash that leads down the hill to Sand Lake (Figure 12). The average flow between the Big Pond and Bormans Pond was estimated at 2.14-cuft/sec. Based on transducer results every site except the Culvert, it took about 18 days for consistent flow to be reached and maintained at each site. If the assumption is made that the water flowing from the Big Pond to Bormans Pond started at “zero” on day one, and was at the mean level by day eighteen, then at day two it would have been at 0.24-cuft/sec. This equates to 0.95-acft of water in two days to fill Bormans Pond. If Bormans Pond is 0.70 acres, its average depth would then be 1.36-ft when full.

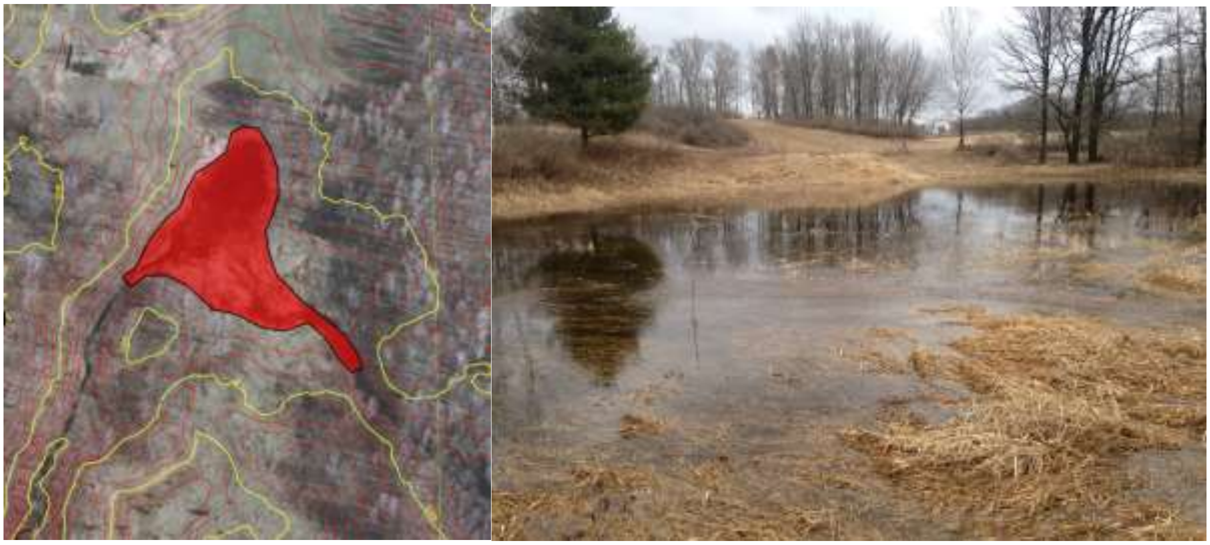

Figure 12: Bormans Pond - Second retention area, approx. 0.70 acres (LEAPS, 2020)

Water flow from the Culvert lasted a week longer in June then did flow from the Big Pond or Bormans Pond. Flow out of Bormans Pond into the steep part of the NE Wash ravine stopped 12 days before water exiting the bottom of the NE Wash stopped. Related to this is the fact that the pressure transducer placed at the bottom of the NE Wash recorded data for an extended period when even though there was water at the site, none of it was reaching the lake. The bottom of the NE Wash is reminiscent of an alluvial fan of sediment that is frequently seen in mountainous regions (Figure 13). This alluvial plain consists of mostly sand and quickly infiltrates water coming down the ravine, at least until it gets saturated or runoff exceeds the capacity of the area to infiltrate the water. Sand and sediment in this area has likely been building up for centuries, at least since the last glacier went through and carved out the Sand Lake basin. Larger and more frequent rain storms may be exacerbating the issue.

Figure 13: Mountainous alluvial plain (left); Sand Lake NE Wash alluvial plain (right) (Barron County, 2018)

Total Suspended Solids (TSS) and Total Phosphorus (TP) Loading Calculations

Table 3 reflects the calculations for water discharge and nutrient/sediment loading. TSS and TP samples were only collected at two of the four sites – Bormans Outlet at the top of the steep ravine leading heading to the lake and at the Outlet to the Lake on the bottom of the steep ravine leading to the lake. Based on the data collected 122,386,340 gallons of water left Bormans Outlet and entered the main portion of the NE Wash over a 72 day period. Over that time period, 1,645-lbs (just shy of a ton) of sediment and other suspended solids, and 78-lbs of phosphorus were carried by that water into the top of the NE Wash.

Table 3: Water discharge and TSS/TP loading calculations (LEAPS, 2020)

2019 Seasonal Flow	cuft	liters	gallons	# of Days	gallons/day
Culvert	15240960.00	431575216.13	114010087.99	84.00	1357262.95
Between Ponds	14421888.00	408381718.12	107883015.24	78.00	1383115.58
Bormans Outlet	16360704.00	463282783.03	122386339.36	72.00	1699810.27
Outlet to Lake	13219200.00	374325442.56	98886300.81	75.00	1318484.01
2019 Seasonal Loading	Mean TSS (mg/L)	Total Seasonal Load (kg)	Total Seasonal Load (lbs)		
Bormans Outlet	1.61	745.89	1644.39		
Outlet to Lake	17.23	6449.63	14218.98		
2019 Seasonal Loading	Mean TP (mg/L)	Total Seasonal Load (kg)	Total Seasonal Load (lbs)		
Bormans Outlet	0.076	35.21	77.62		
Outlet to Lake	0.088	32.94	72.62		

Nearly 98,886,301 gallons of water left the bottom of the outlet and flowed into Sand Lake. Nearly 14,219-lbs (just over 7 tons) of sediment and other suspended solids, and 73-lbs of phosphorus were carried with that water into Sand Lake.

A cubic yard is equal to 27 cubic feet. As a general guide, 1 cubic yard of aggregate, sand, or dirt is equivalent to 1.5 tons. With that thought in mind, about 4-2/3 cubic yards of sand and other solids (about one-third of a commercial frac-sand dump truck load) was carried into Sand Lake between March 27 and June 10 (Figure 14).

Figure 14: Quad-axle dump truck like what is used for hauling frac sand

The phosphorus introduced to the lake between March 27 and June 10 would equate to about 36,500-lbs (18.25-tons) of algae in the lake if using the old adage that “1-lb of phosphorus can grow 500-lbs of algae”. It is important to keep in mind though that not all of the phosphorus coming into the lake will be turned into algae. Much of it will settle out in the water column, be used up by the growth of large aquatic plants, and some will continue on through the system and go out through the outlet of the lake.

Data Interpretation

A few things can be inferred by the data collected in the spring of 2019. The phosphorus moving through the system and being carried into Sand Lake was already in the water before it made it to Bormans Pond. The phosphorus going into Bormans Pond is pretty much the same as the phosphorus that is entering the lake at the bottom of the NE Wash. What this means is that the upstream portions of the watershed that feeds the NE Wash are contributing the majority of the phosphorus, not the ravine itself.

Conversely, the amount of sediment/suspended solids being added to Sand Lake is almost entirely coming from the steep ravine part of the NE Wash (from Bormans Outlet to the Bottom). This stretch of the wash contributes more than 88% of the suspended solids to Sand Lake.

What to do?

The data suggest that there are really two things to focus on to reduce the impact of the NE Wash on Sand Lake. First, reduce the amount of phosphorus entering the NE Wash upstream of the culvert under the road. This means focusing on land use and retention in the mid to upper reaches of the entire 2,400 acre watershed to reduce pollutant laden runoff into the waterways that converge to fill the NE Wash. Land uses including agricultural land, pasture land, wetlands, and forests all contribute different levels of TP. Farm fields that are in crop rotation, particularly when best management practices like nutrient management plans, conservation tillage, grassed waterways, and stream buffers are not in place. Grazing from cattle and other livestock can add to the issue. Spreading of manure and other forms of fertilizer also add to the amount of TP entering the waterway from the watershed. Figure 15 shows a coarse breakdown of land use in the NE Wash watershed.

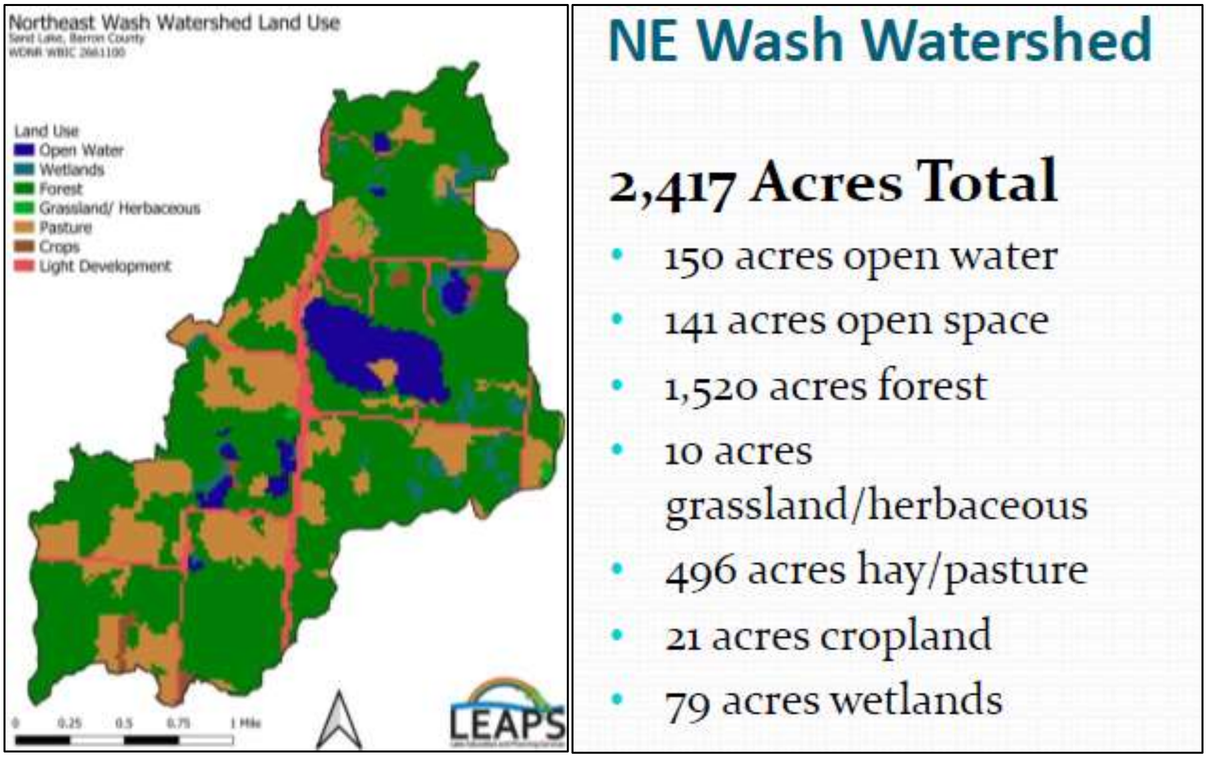

Figure 15: Land use in the NE Wash watershed

The second task is to figure out how to shore up areas of the NE Wash between Bormans Outlet and the Bottom of the wash to reduce the amount of sediment and other suspended solids being eroded away and carried into the lake. This was the main issue with the NW Wash, however it was only 600-ft long, drained only a 16.3 acre watershed, and only changed in elevation 50-ft from top to bottom. To repair the NW Wash, a culvert was buried to carry the water from the top of the wash to the lake, thereby eliminating the erosion. Then the wash itself was stabilized by flattening and planting of vegetation (Figure 16). This will likely not be possible in the NE Wash, at least not for the entire length.

Figure 16: NW Wash repair project (LEAPS, 2016)

Walking the NE Wash again with professional resource people and contractors could identify project to help stabilize the wash. These could include but are not limited to placement of buried culverts like in the NW wash, rock-lined waterways to minimize downward erosion, restoration of gully banks to prevent further erosion, check dams to slow water movement, and perhaps even smaller retention areas to hold back more water. Determining access to the property along the NE Wash would also be important.

Installation of a Dam, Dike, or Pond on Bormans Property

When this project began, a preliminary plan drawn up by Barron County had been pitched to local landowner along the wash. The gist of the plan was to increase the capacity of existing basins along the top of the wash between 28th Ave and Bormans Pond. These basins could potentially be deepened to hold more runoff, and a dam or dike could be put in to raise the level of water the areas hold. Suffice it to say, that most of the property owners were not in support of this plan, at least not until some proof was gained that would suggest it would make a difference. This was the main reason the 2018-2019 NE Wash Project was initiated. Unfortunately, data from the project falls short of supporting the construction of a dam or dike and deepening the existing retention basins. While increasing the capacity of these areas to hold back water is a legitimate idea, the amount of water it would prevent from reaching the lake would seem to be minimal. It might take a couple of more days to completely fill the new basins, but once full, they would contribute just as much as they currently do.

Currently, the Big Pond is estimated to be approximately 3.2 acres in size when “full” of water with an estimated average depth of 2.6-ft. Bormans Pond is estimated to be approximately 0.70 acres in size when “full” of water with an estimated depth of 1.36-ft. Together they hold an estimated 9.27-acft of water when completely full, after which the water would begin flowing down the wash eventually making it to the lake. The roughly 9.27-acft of water is only 3% of the total volume of water that reached Sand Lake over the 75 day period in the spring of 2019. If a dike, dam, or existing or new retention basin was created that would even double the amount of water in these two ponds, it would still have only handled 6% of the water that moved through the system over that 75 day period.

The construction of such a structure might trap a small amount of the sediment, although most of the sediment would still be getting into the lake from the wash itself. The existing ponds are already holding back much of the sediment and other solids as is evidenced by a couple of the spring 2019 samples collected from Bormans Outlet, returning “no detect” (ND) or “’zero” readings for TSS. An additional 9.27-acft of water stored under the scenario that played out in the spring of 2019 would have held back only an additional 2.2-lb of phosphorus.

The immediate watershed that feeds the NE Wash is about 2,423 acres. If a new runoff construction project is completed that would store an additional 9.27 acre-feet of water, and the ground and all the basins within the NE Wash sub-watershed were filled to capacity, it would have only taken an additional 0.046 inches of rain over the entire NE wash watershed to fill it, thus again enabling water to flow through the system to the lake. A lot of money would be spent with little benefit to the lake.

Final Thought

Perhaps this means that the focus of the NE Wash should be similar to what was done on the NW Wash. With the NW Wash, property owners (farmers) were approached and encouraged to implement best management practices including no-till and installing buffer areas at the head of the wash itself, which is still in place today. This could be done with the properties bordering the wash above the Culvert up on top of the wash all the way back to Horseshoe Lake. Then the NW wash itself was “shored up” by putting in the underground culvert system from the top to the bottom. This likely cannot be done along the entire reach of the NE Wash from Bormans Pond to the Outlet to the lake, but there may be areas where it can be done. Other practices mentioned earlier in this report could also be evaluated.

WDNR lake protection funding may be able to be used to help fund this type of project, much like what was done with the NW Wash. However, it might be beneficial to use WDNR lake management planning grant funds to evaluate practices in the wash itself that could be done, and to come up with a plan to implement. Property owners along the wash may be more interested in supporting this type of project, than they were to support the previous plan of modifying existing water retention areas.