memo

Project Name		Settlers Glen Iron Enhanced Sand Filter	**Date**		5/1/2024
To / Contact info		BCWD Board of Managers		
Cc / Contact info		Karen Kill, District Administrator		
From / Contact info		Ryan Fleming, PE & John Sarafolean		
Regarding		Project Performance & Cost Summary with 2024 Scope of Services		

Background

The purpose of this memorandum is to provide a project performance and cost summary of the Settlers Glen Iron Enhanced Sand Filter (IESF). This project was constructed in 2013, with its first season of operation in 2014. It was the first application of its kind using stream stage to control a pump that charges the IESF (Stormwater "Pump-and-Treat"). In 2023, the Board requested that the annual performance report provide a summary of project costs and overall performance to date.

2022 – 2023 Performance Evaluation

1. Overview

The experimental nature of the project led the District to implement a monitoring program that included influent and effluent sampling of a variety of pollutants. Due to consistent filter performance during the first seven years of monitoring, only the effluent concentration has been sampled since 2021. This was done to monitor whether the average total phosphorus concentration leaving the filter exceeds 0.07 mg/L which may suggest the phosphorus binding capability of the iron is diminished[1].

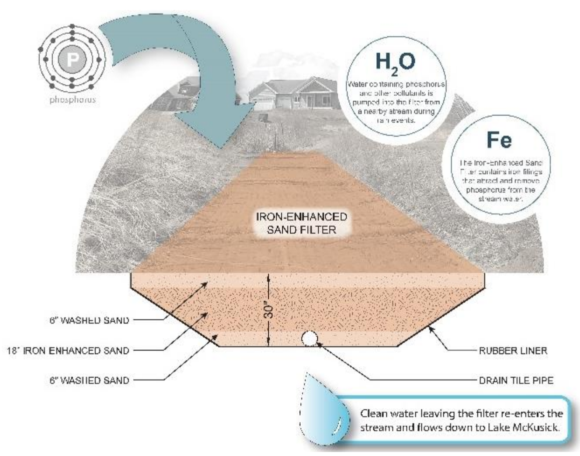

Figure 1: IESF Cross-Section

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[1] The Minnesota Stormwater Manual Suggests that total phosphorus at the outlet of an iron-sand filter that consistently exceeds 0.06 to 0.07 milligrams per liter may be used as an indicator that the phosphorus binding capacity of the iron-enhanced sand bed has been consumed.

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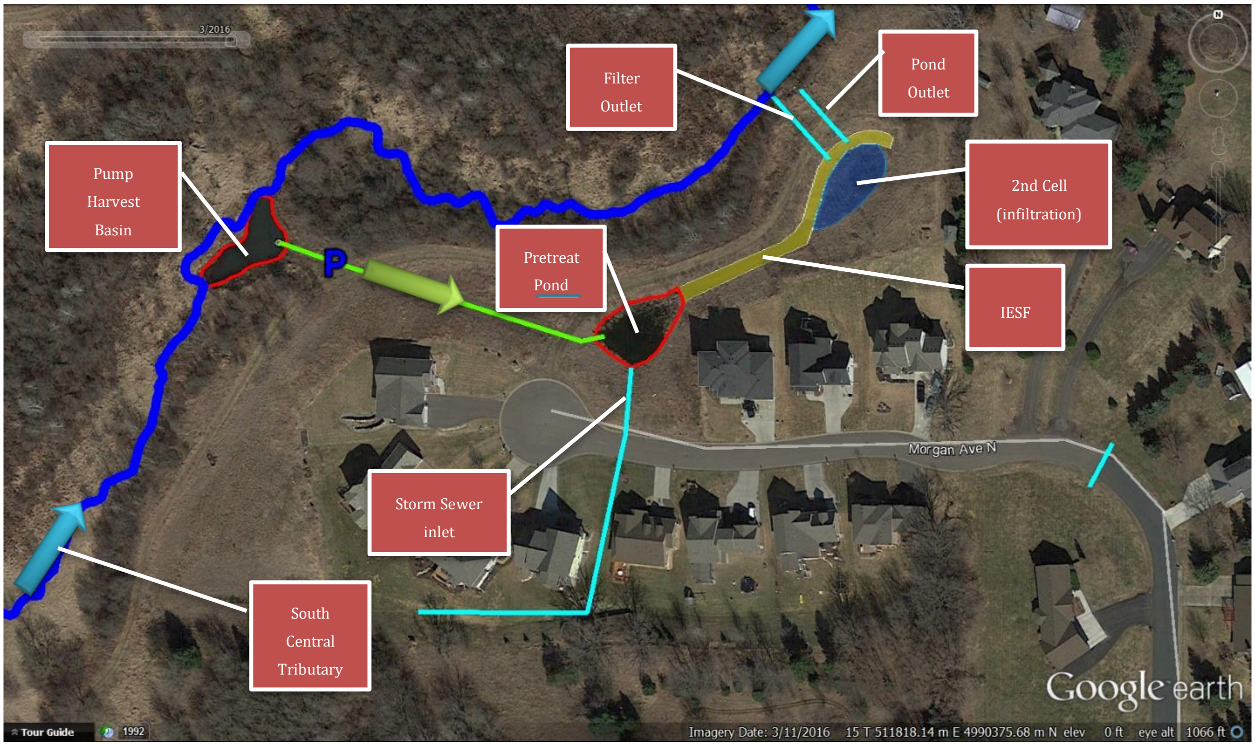


Figure 2: IESF Project Layout

2. Performance Analysis

Evaluation of the filter performance was not completed in 2022, therefore, this report combines the performance observed in 2022 and 2023. Four water quality sample events occurred in 2022 and seven occurred in 2023. They included manual grab sampling (discrete time) as well as automatic sample capture (spans a duration of time) during a rain event.

a. Inflow

Though the influent concentration has not been sampled since 2020, a reasonable assumption is that previously sampled average influent concentration of 0.235 mg/L is representative of the current inflow given very few changes occurred in the contributing drainage area. This concentration can be applied to the amount of water that passed through the filter to estimate the annual phosphorus load to the filter.

There are two sources of water entering the IESF:

a) Morgan Avenue neighborhood runoff (7-acre drainage area)
b) Pumped from the tributary (1,200-acre drainage area)

The water from these two sources mixes in a small, permanently inundated pretreatment pond prior to entering the IESF (Pretreat Pond in Figure 2).

The phosphorus load and removal in pounds can be estimated by comparing the volume of flow and phosphorus concentration into the filter with what left the filter. Water pumped to the filter is recorded by the lift station. However, the volume of water contributed to the filter from the Morgan Avenue neighborhood cannot be measured due to backflow of the pretreatment pond into the catch basin structure. Using the precipitation record and the District's calibrated hydrologic and hydraulic model, the runoff volume from the Morgan Avenue neighborhood can be estimated.

An analysis of precipitation records, combining data from the BCWD weather station (for April-October) and NOAA Minneapolis-St. Paul (for November-March), reveals that the years 2022 and 2023 received approximately 28 and 33 inches of precipitation, respectively. When examining these data sets, it was found that the runoff volume from the Morgan Avenue neighborhood constituted about 19 percent of the total volume passing through the filter. The remaining 81 percent was pumped from the stream.

b. Outflow

Flow leaving the filter is measured during the growing season using a sensor which records depth and velocity of the water leaving the underdrain of the filter. The total phosphorus concentration leaving the filter ranged from less than the reporting limit of 0.05 mg/L to 0.105 mg/L with an average concentration of 0.075 mg/L as shown in Table 1. The high concentration on 8/19/2022 of 0.105 mg/L was significantly higher than what has typically been observed; other factors may have been influencing the concentration such as the untreated stream backing into the outflow pipe. The monitored depth at the discharge pipe does not indicate mixing with the stream occurred at that time, therefore the result is still considered valid, and it is included in this performance analysis. However, given the low number of sampling events, this value skews the annual average removal performance to be lower. Table 1 includes the range and average sample concentrations that were observed.

Table 1: Observed Phosphorus Concentrations

Location	Minimum [mg/L]	Average [mg/L]	Maximum [mg/L]
*Inlet (2016 to 2020)	0.172	**0.235**	0.482
Outlet (2022-2023)	<0.05	**0.075**	0.105

*Reflects range of years influent, representative of the two water sources to the filter, was monitored

During 2022 and 2023, the discharge volume from the filter was approximately 31 percent of the combined Morgan Avenue neighborhood runoff and the pumped inflow. Figure 3 & Figure 4 display the pump inflow in red and the effluent discharge rate blue on the bottom graph. The discrepancy is likely a result of following:

1. Infiltration occurring in the 2nd cell of the stormwater pond. Water begins to pond in this cell when the inflow rate exceeds the filtration rate through the sand filter. This infiltration is not represented in the monitoring record.
2. Water bypassing the monitoring equipment has been observed during periods of high flow as it splashes out the sides of the pipe apron.
3. The flow monitoring equipment was malfunctioning in 2023 until it was replaced on August 30, 2023. Therefore, the shortened monitored period may not be representative of that entire season.

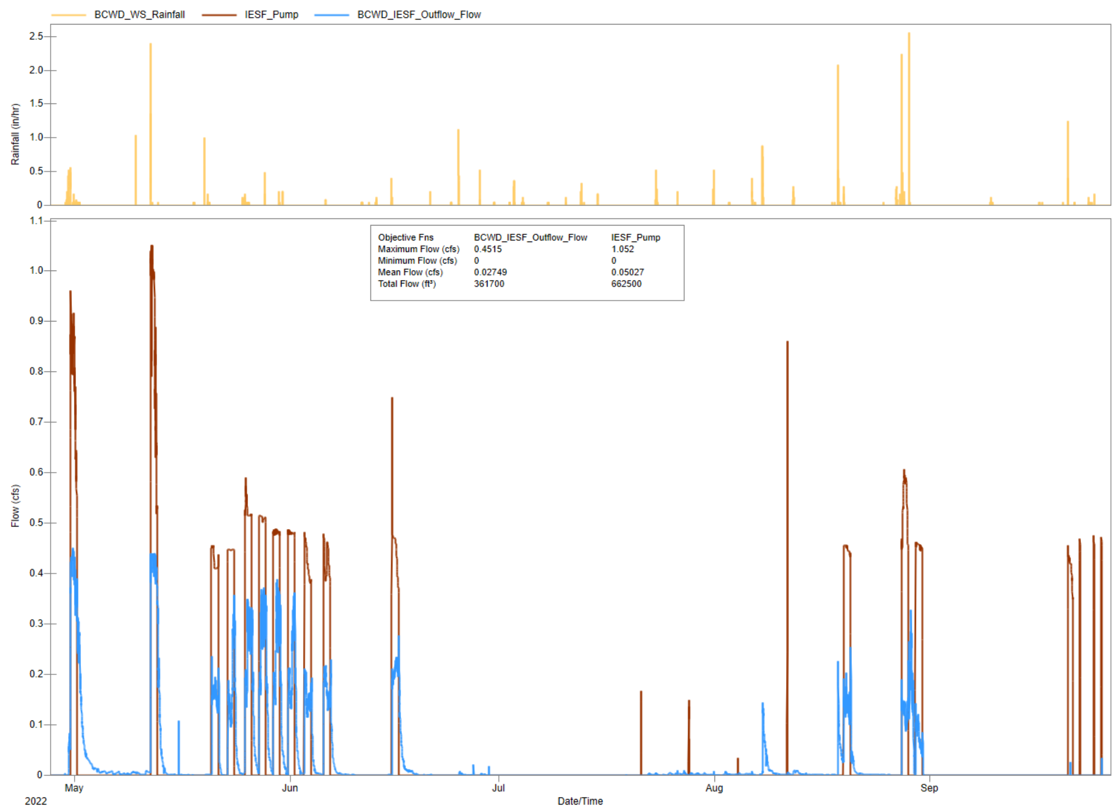


Figure 3: 2022 Precipitation, Pump Inflow, and Filter Outflow

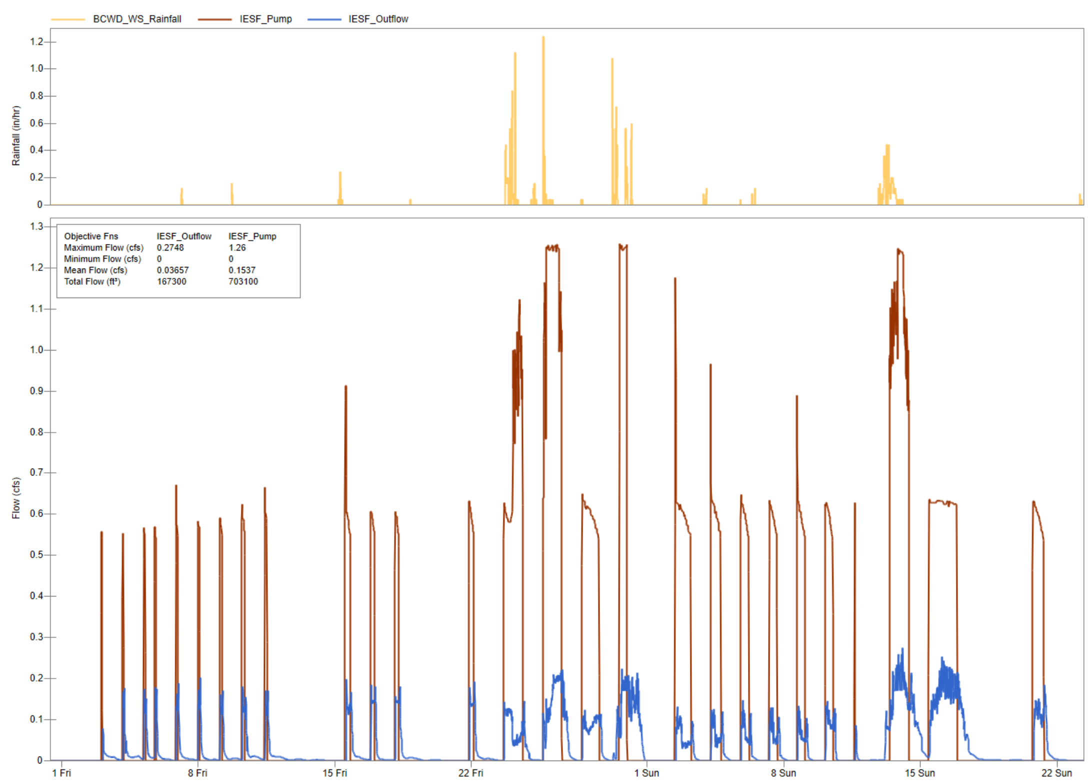


Figure 4: 2023 Precipitation, Pump Inflow, and Filter Outflow

Due to the discrepancy between inflow and outflow, two methods were used to estimate the phosphorus removal of the filter. The first method, which may overestimate the system's efficiency, assumes correct discharge volume monitoring, 69% inflow infiltration in the pond's 2nd cell with full phosphorus treatment, and 31% discharge at the average effluent concentration. The second method, likely underestimating the system's efficiency, assumes all runoff entering the filter is discharged and treated at a 69% removal rate, despite known infiltration in the pond's second cell. Table 2 displays the estimated range of phosphorus removal for these two calculation methods.

Table 2: 2022 & 2023 Total Volume and Phosphorus Treatment Summary

	Method 1: Over-Estimate		Method 2: Under-Estimate	
Influent/Effluent Description	**Volume [acre-feet]**	**Total Phosphorus [Pounds]**	**Volume [acre-feet]**	**Total Phosphorus [Pounds]**
Total Flow In (Pumped & Direct Runoff)	75.5	48.3	75.5	48.3
Discharged from Filter	23.4	4.7	75.5	15.0
Total Removed	**52.1**	**43.6**	**0.0**	**33.3**
System Treatment Efficiency	**90%**		**69%**	

3. 2022 – 2023 Performance Conclusions

The total phosphorus removal for 2022 and 2023 is in the lower range of the observed annual treatment over the last ten years, as shown in Figure 5. The following factors are believed to be the driving influences for this:

1. The pump flow rate is variable based on the water level in the pump harvest pond. Lower volume and intensity rainfall does not "bounce" the pond to higher stages that would result in greater pump flow rates during events. Adjustments were made to the pump program to increase to the maximum flow rate for lower stream stages, but the adjustment can only compensate so far before drawing the pond down to the point where the pump turns off, which triggers a 24-hour filter drying period holdout.
2. There were fewer rainfall events in 2022 and 2023 than in previous years. There were 26 pumping events each year compared with 30 to 54 per year between 2019 and 2021.
3. Nearly half of the rainfall volume in 2023 occurred in the months of October thru March, when ice over the pump harvest pond interferes with the ability of water to be drawn into the lift station. As shown in Figure 6, October was the wettest month of 2023, however most of the rainfall occurred in two large events which results in volume bypassing the pump intake since the inflow exceeds the pump capacity. Therefore, less of the runoff was able to be treated through the filter.
4. Encouragingly, the dissolved phosphorus concentration leaving the filter was at or below the analysis reporting limit of 0.05 mg/L for four of the eleven sampling events. Conditions leading up to these events varied, with some following a weeklong dry period, and one followed 2.5 inches of rain two days before. This suggests that the filter still has the capacity to perform with a great deal of efficiency in certain conditions. However, on average, the effluent phosphorus concentration has been increasing over the last several years, with the

average concentration leaving the filter of 0.075 mg/L being the highest observed over the ten years of monitoring. This may suggest the binding capacity of the iron is reduced as discussed in the next section.

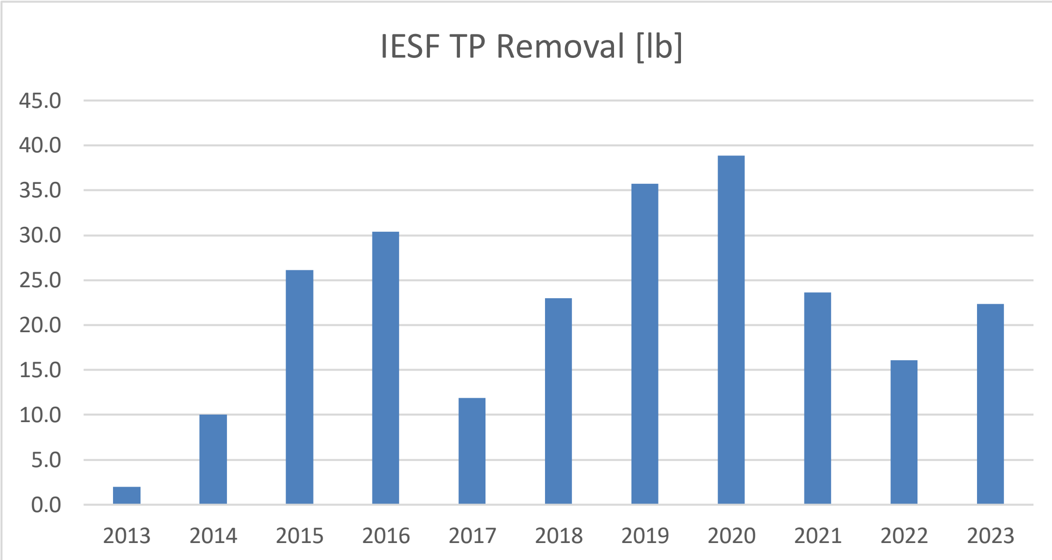
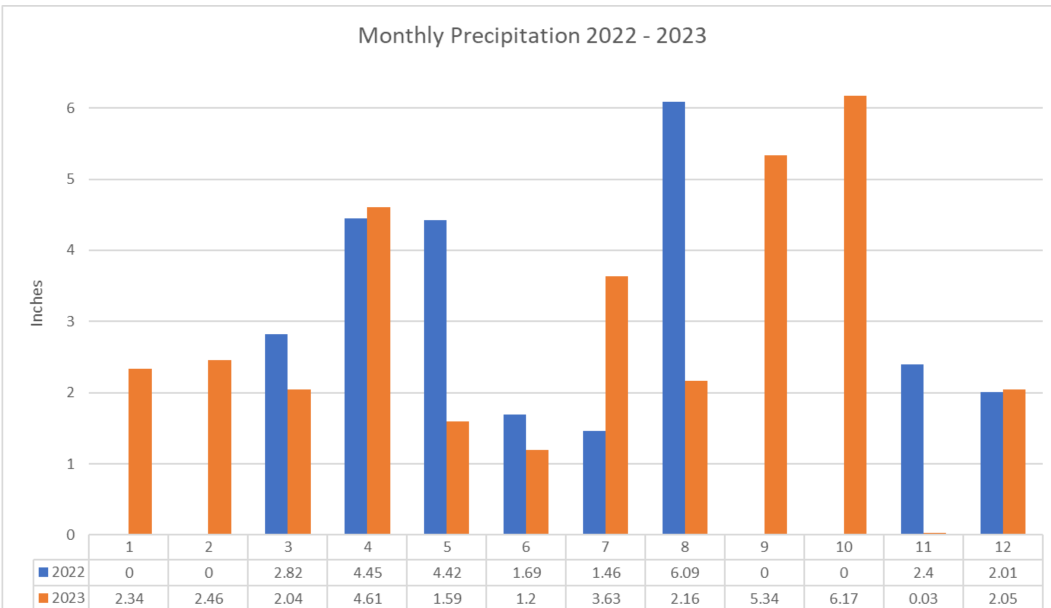


Figure 5: IESF Annual Total Phosphorus Estimate.



	1	2	3	4	5	6	7	8	9	10	11	12
2022	0	0	2.82	4.45	4.42	1.69	1.46	6.09	0	0	2.4	2.01
2023	2.34	2.46	2.04	4.61	1.59	1.2	3.63	2.16	5.34	6.17	0.03	2.05

Figure 6: 2022 & 2023 Monthly Precipitation (MnDNR)

10-Year Project Cost/Benefit Summary

1. Background

The Board of Managers requested a summary outlining all project costs including maintenance activities and overall phosphorus removal benefit that's been realized for downstream resources. All costs that have been incurred for the project are outlined below, beginning after the site was selected through the 2009-2010 feasibility process.

2. Cost Summary

Table 3 summarizes all the costs including sub-categories of the activities falling within the Engineering, Construction, Major Maintenance and Upgrades, Utilities, and Routine Operation & Maintenance. Table 4 indicates when the activities have occurred over the course of the project. On-going costs are indicated with an asterisk (*). These ongoing items have included:

- Routine operation and maintenance items:
  - Adjustments to the pump system based on fluctuating water levels in the stream (via remote monitoring and site visits)
  - Vegetation maintenance (Subcontracted invasive management)
  - Filter surface raking (Coordinated by EOR & WCD Staff)
  - Pump & lift station performance inspection (Subcontracted pump & control specialist)
- Periodic maintenance items:
  - Pump harvest pond dredging ($25,000 to $40,000)
    - Cost depends on findings of sediment sampling
    - Five-year frequency; it's possible it will be less frequent now that the tributary stabilization is in place.
- Utilities
  - Cellular data for remote monitoring & control
  - Electricity to the lift station

In addition, the following maintenance items may be required over the project life. Cost estimates are provided, though combining this work with the periodic dredging of the pump harvest pond may result in a cost savings:

- Removal/replacement of the 6-inch sand filter surface maintenance layer (~$24,000)
  - Depending on the depth that organic material has worked down into the maintenance layer, only removal of the top 2" may be required (to be explored in 2024).
- Removal and replacement of the sand filter media (~$115,000).

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Table 3: IESF Project Cost Summary by Category

Cost Sub-Category	Sum of Amount
Construction	$ 203,095
Engineering	
Preliminary Design	$ 45,871
Construction Documents	$ 56,730
Construction Admin	$ 33,651
Sub-Total $136,252	
Major Maintenance/Upgrades	
Outlet Repair	$ 4,336
Pond Dredge*	$ 64,911
Pump Repair	$ 5,500
Pump SCADA & Flow Meter	$ 12,577
Stream Stabilization	$ 19,030
Sub-Total $106,354	
Utilities	
Cellular & SCADA*	$ 4,074
Electrical*	$ 4,500
Sub-Total $8,574	
Routine Operation & Maintenance	
O&M*	$ 137,821
Pump Inspection*	$ 2,355
Vegetation Maintenance*	$ 8,805
Sub-Total $148,981	
Grand Total	**$ 603,257**

*On-going cost

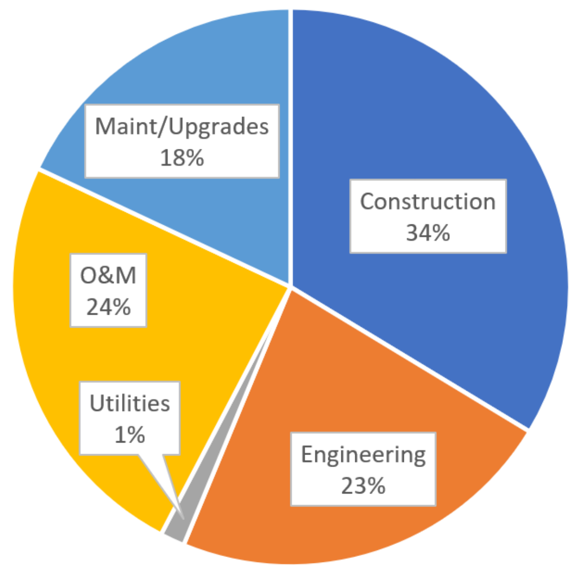

Table 4 IESF Project Cost Summary by Year

Year	Sum of Amount	Description
2010	$ 45,871	*Prelim Design*
2012	$ 56,730	*Const. Documents*
2013	$ 196,743	*Construction*
2014	$ 20,867	*O&M/Upgrades*
2015	$ 25,287	" "
2016	$ 30,072	" "
2017	$ 22,867	" "
2018	$ 56,197	*O&M + Dredging*
2019	$ 14,612	*O&M/Upgrades*
2020	$ 38,430	" "
2021	$ 13,181	" "
2022	$ 12,916	" "
2023	$ 69,483	*O&M + Dredging*
Grand Total	**$ 603,257**	

3. Treatment & Benefit Summary

The total phosphorus removal has been estimated each year based on the methodology outlined in the 2022-2023 Performance Analysis above. Table 5 shows that the IESF system has removed approximately 240 pounds of phosphorus since project installation. What sets the IESF system apart is the ability to remove dissolved phosphorus, the form that poses a significant threat to aquatic ecosystems. The observed ratio of 25 percent dissolved phosphorus in the sampling record implies that the IESF system has captured an estimated 60 pounds of dissolved phosphorus. This is particularly noteworthy considering that dissolved phosphorus is effectively removed by a select few systems, including IESF, other enhanced filtration media, or infiltration systems.

In addition to the phosphorus removal through the IESF, dredging maintenance of the pump harvest pond is also attributed to prevention of phosphorus from discharging downstream into Lake McKusick. Based on the dredged volume and sampled total phosphorus concentration of the sediment, approximately 1,400 pounds of total phosphorus was removed from the pump harvest pond each time it was dredged.

Table 5: Annual Total Phosphorus Removal by IESF System

Year	IESF TP Removal
2013	2.0
2014	10.0
2015	26.1
2016	30.4
2017	11.9
2018	23.0
2019	35.8
2020	38.9
2021	23.7
2022	16.1
2023	22.4
Total	**240**

Table 6: Total Phosphorus Removal with Dredging

Treatment Method	TP Removal [lb]
IESF	240
Pond Maintenance	2,810
Total	**3,050**

4. Cost Benefit Summary

A common metric for assessing a water quality project value is to determine the cost per pound of phosphorus removed. There are several ways in which to look at it through the timeline of the project and they often include many different cost components such as construction, land acquisition, and maintenance over different durations depending on the life expectancy of the project. The 10-year life period project cost per pound of removed phosphorus is calculated in Table 7, and derived from a total of $603,257 and the removal amounts in Table 6.

Table 7:Phosphorus Cost per Pound (10-year period)

Treatment Method	Phosphorus $/lb
IESF	$ 2,513
IESF & Dredging	$ 198

For reference, treatment system lifecycle (25-30 years) returns of < $1,000/lb of phosphorus are favorable as an industry general rule of thumb. Considering major cost items like the lift station, piping, electrical, and pond excavation will not repeat through the lifecycle, this project cost per pound is expected to decrease over time assuming the on-going and periodic maintenance mentioned above.

2023 Filter Media Sampling

1. Background

The Minnesota Stormwater Manual Suggests that total phosphorus at the outlet of an iron-sand filter that consistently exceeds 0.06 to 0.07 milligrams per liter may be used as an indicator that the phosphorus binding capacity of the iron-enhanced sand bed has been consumed. Six of the sampling events exceeded this range, three were within this range, and two events were below this range for the 2022 and 2023 seasons. Due to observing an increasing effluent phosphorus concentration trend in the last several years, sampling and testing the filter media for phosphorous binding capacity was conducted in 2023. The samples were tested for both remaining iron binding capacity, and phosphorous leaching potential from the media.

Following guidance from Saint Anthony Fall Laboratory (SAFL), five locations were sampled at depths of 8 and 20 inches along the length of the filter shown in Figure 7. These depths were specified such that the iron-sand media near the surface, but beneath the six-inch sand "maintenance" layer was sampled, as well as at a depth just above the perforated drain tile, to determine whether there is a vertical gradient of iron remaining or a gradient of phosphorus leaching potential. Likewise, samples were spaced along the filter to determine whether there is a horizontal gradient of treatment capacity given the linear orientation of the filter where the west end of it has been subject to more influent volume than the eastern end. Below is summary of the report that is attached to this memorandum.

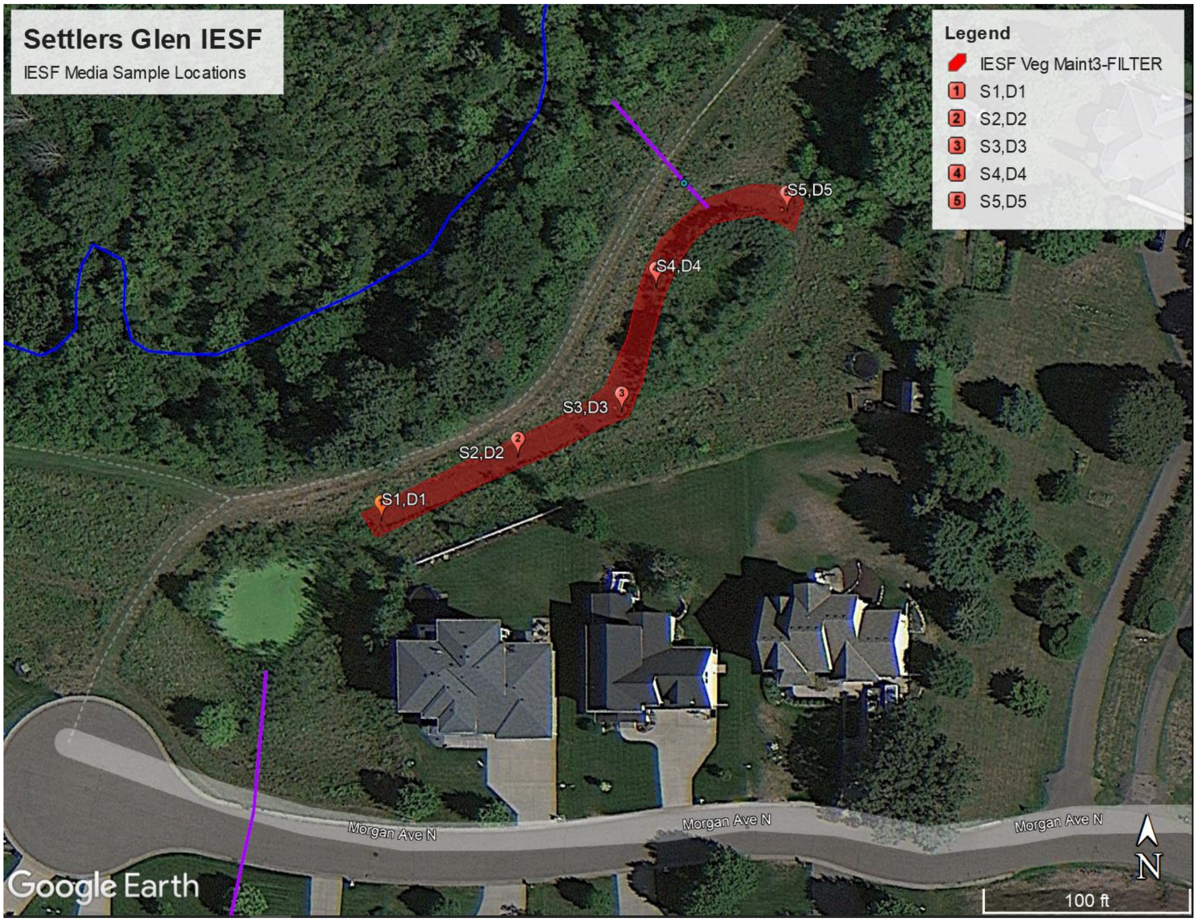

Figure 7: IESF Media Sample Locations

2. Method

Batch experiments were conducted that subjected the samples to a known concentration of phosphorus and analyzed for soluble reactive phosphorus concentrations remaining in the water at durations from 1 to 96 hours of mixing period. Next, the phosphate leaching potential of the IESF media was determined by mixing the samples in water that did not contain phosphate and analyzed for soluble reactive phosphorus in the water following a protocol similar to the batch sorption experiment.

3. Results

The batch study results showed that the IESF media still has the ability to remove phosphate, but that the capacity is substantially reduced when compared to column analysis studies conducted in a lab setting, i.e. not a real-world/field setting. The removal capacity varied depending on the location in the IESF filter. The surface media generally showed lower removal than the bottom media, and the phosphate sorption capacity varied more greatly across the surface than at the bottom. This is expected for a vertical flow filter system.

The phosphate leaching experiment showed that a small amount of phosphate may release from the IESF media into solution over time and at a very low concentration (<0.02 mg/L increase). The phosphate leaching results are in agreement with the sorption results, i.e., the surface media is already holding onto more phosphate than the bottom media. Also, the western, upstream end of the filter does not exhibit as high of sorption capacity than the eastern, downstream end of the filter. This may be since the upstream end has been subject to more stormwater volume over the past 10 years than the downstream end, where the filter takes more time to become inundated throughout a rain event.

This was the first media that has been analyzed from an IESF facility, and the impact the reduced adsorption capacity has on sorption rates is currently a research topic that SAFL is studying.

Given the remaining sorption capacity of the sampled filter media, we estimate the remaining total phosphorus capture capacity to be approximately 80 pounds. Dividing this amount by the average annual removal of 25 pounds yields Three years remaining before the capacity for the iron to adsorb dissolved phosphorus is extinguished. Once this has occurred, the filter will still function to remove particulate phosphorus until the iron-sand media is replaced.

Maintenance Update & Recommendations

1. The filter surface was aerated and raked monthly from April to September to loosen the upper portion of the sand and encourage movement of water into, rather than across, the filter. It is recommended the Washington Conservation District seasonal BMP maintenance staff continue to conduct this maintenance at this frequency.
2. The monitored discharge and inflow discrepancy has increased for the past two years (though the limited 2023 monitoring period may be a factor). Discharge from the pond normal outlet pipe is not monitored but evidence that it has occurred has been observed, albeit infrequently. EOR will time routine system inspections with rain and pumping events to establish if discharge out the normal outlet is becoming a normal occurrence and establish whether it is due to larger volume rainfall, frequency of rainfall and pumping, or clogging of the filter bed.
3. The stream where the filter underdrain discharges widened significantly prior to the tributary stabilization project. This widening and downcutting was improved by the tributary stabilization project, however, it is suggested that the immediate area around the outfall be stabilized with class 1 riprap. This maintenance work is included in the IESF 2024 Operation and Maintenance Scope of Services below.
4. Vegetation management to control invasive species on all areas that were disturbed by the project should continue to be conducted throughout the year (this is being conducted under the Districtwide vegetation maintenance contract with Natural Shores Technologies approved at the March 2024 Regular Meeting of the Board of Managers).
5. Due to the observation of a gradient in the remaining capacity potential during the batch testing by SAFL, it is recommended that a valve be installed midway down the underdrain to avoid short circuiting of flow through the upstream, more used portion of the filter media, to force flow through the less used, downstream areas of filter before reaching the underdrain. SAFL concurred with this approach to improve the phosphorus removal efficiency during the remaining filter life. The cost to install this valve is included in the IESF 2024 Operation and Maintenance Scope of Services below.

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IESF 2024 Scope of Services

The budgeted amount for the approved **1/11/2023** IESF Operation and Maintenance Scope of Services was 100% invoiced as of March 2024, prior to fulfilling all the 2023 outlined tasks. The overrun was attributed to several unanticipated items throughout the year such as replacement of the cellular modem in the control cabinet, field review of the lift station for leakage and addressing a sinkhole, coordination with UofM RAL and SAFL, as well as responding to beaver activity causing raising water levels and leading to design review for the submerged inlet conditions.

At the direction of the Administrator, EOR continued to fulfill the tasks included in the 2023 scope, and include the cost overrun as Task 1 of the following scope of services.

The on-going operation and maintenance of the project involves remote desktop monitoring and adjustment of the pump settings based on stream stage and weather conditions, site visits to check operation, vegetation, sediment accumulation, erosion, and filter surface condition. EOR will coordinate with WCD staff to maintain the filter surface with monthly raking and aeration as well as install additional armor at the filter outfall where the stream has widened and eroded the bank. EOR staff will also install the underdrain valve as described earlier.

An end of year performance evaluation from the sampling results will be supplied as well as updating the project operation and maintenance manual based on the activities throughout the year (pump on/off or variable speed drive setting alterations, additional maintenance performed outside of the norm, etc.).

Scope

The following table outlines the hours and cost anticipated for the 2024 season.

Task	Description	Hours	Cost
1. 2023 Scope Overrun	Unanticipated tasks and continued operation and maintenance through April 2024	24	$5,440
2. System Status	Remote desktop monitoring & pump setting adjustments, Monthly site visits, mileage, and documentation	35	$4,860
3. Site Maintenance	Filter surface maintenance coordination, riprap armor placement at outfall, valve installation	35	$5,870
4. Performance Report, O&M Manual Update	Review of 2024 monitoring data, system performance evaluation, and reporting. Update project Operation & Maintenance Manual	38	$5,400
Total		**108**	**$21,570**

*Given the weather-dependent nature of the work, the costs are estimates only. Additional project needs will be brought to the attention of the District Administrator and outlined in a separate scope of work. Vegetation maintenance of this project is included in a separate, District-wide vegetation maintenance scope.

Requested Action

Consider approval of this scope of services for an estimated cost of $21,570 from account 948-0000.

ST. ANTHONY
FALLS LABORATORY

Evaluation of Iron-Enhanced Sand Filter Media for Phosphorus Removal: Results of Batch Studies

Technical Memorandum

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COLLEGE OF Science & Engineering
UNIVERSITY OF MINNESOTA

Evaluation of Iron-Enhanced Sand Filter Media for Phosphorus Removal: Results of Batch Studies

Objective

The objective of this study is to estimate the remaining ability of an existing iron-enhanced sand filter installation to remove dissolved phosphorus from storm water runoff using results from laboratory batch studies. The iron-enhanced sand filter (IESF) is part of a pump and treat BMP located in Stillwater in the Brown's Creek Watershed District. The IESF has been in operation since 2014, resulting in nine years of operation. Filter media samples collected from the IESF facility were tested for phosphorus adsorption capacity and phosphorus leaching potential under controlled conditions in the laboratory.

Method

Filter media sample collection

Filter media samples were collected from the IESF facility by EOR personnel. Media from five locations distributed across the filter's surface and the filter's bottom were collected (total samples = 10).

Batch experiments

The batch studies were performed using acid-washed Nalgene bottles (500 mL capacity) and a Labline orbital shaker at room temperature. Based on typical phosphorus concentrations in stormwater runoff (Maestre and Pitt 2005), a concentration of 0.30 mg/L dissolved phosphorus was selected for the batch experiments to represent extreme phosphate loading conditions. A standard phosphate solution was prepared by mixing potassium phosphate (KH_2PO_4) in Milli-Q (ultrapure) water to a mean concentration of 0.29 mg/L (± 0.056 Std Dev.), and 300 mL of this solution was filled into each batch bottle. The experiment was performed using a media:solution ratio of 1:20 (by weight), with three replicates for each media sampling location (total batch bottles = 3 replicates x 10 locations = 30). An initial sample (0 hour) was collected before the addition of the media samples from 50% of the batch bottles to verify the initial phosphate solution concentration. The batch test bottles with media and blank bottles (no media) were placed on the shaker table at 150 RPM, and water samples were collected after 1-, 24-, 48-, and 96-hour mixing period. The water samples were filtered through a 0.45-micron filter to remove particulates and analyzed for soluble reactive phosphorus (orthophosphate) concentrations using the ascorbic acid method (Standard Methods 4500 P, APHA 1995).

The phosphate leaching potential of the IESF media was also determined by mixing the media samples in MilliQ water that did not contain phosphate. Media samples from five locations in the filter (two surface and three bottom media samples) were tested in this experiment (total batch bottles = 3 replicates x 5 locations = 15), following a protocol similar to the batch sorption experiment described above.

Results

Phosphate sorption experiment

The batch study results (Figure 1) showed that the IESF media still has the ability to remove phosphate (PO_4-P), but the PO_4-P adsorption capacity varied depending on the location in the IESF filter. The surface and bottom media samples tested removed approximately 8.2 to 22% (10% mean ± 6.8 % Std. Dev.) of the available phosphate (0.288 mg PO_4-P/L) after a short contact time of one hour. Over time, the PO_4-P removal increased to 11 to 65% (38% mean ± 17 % Std. Dev.) after 24 hours, and then 21 to 83% (55% mean ± 19 % Std. Dev.) after 48 hours. At the end of 96 hours, the media removed 39 to 89% (68% mean ± 16 % Std. Dev.) of the initial PO_4-P mass in solution. The surface media generally showed lower removals than the bottom media.

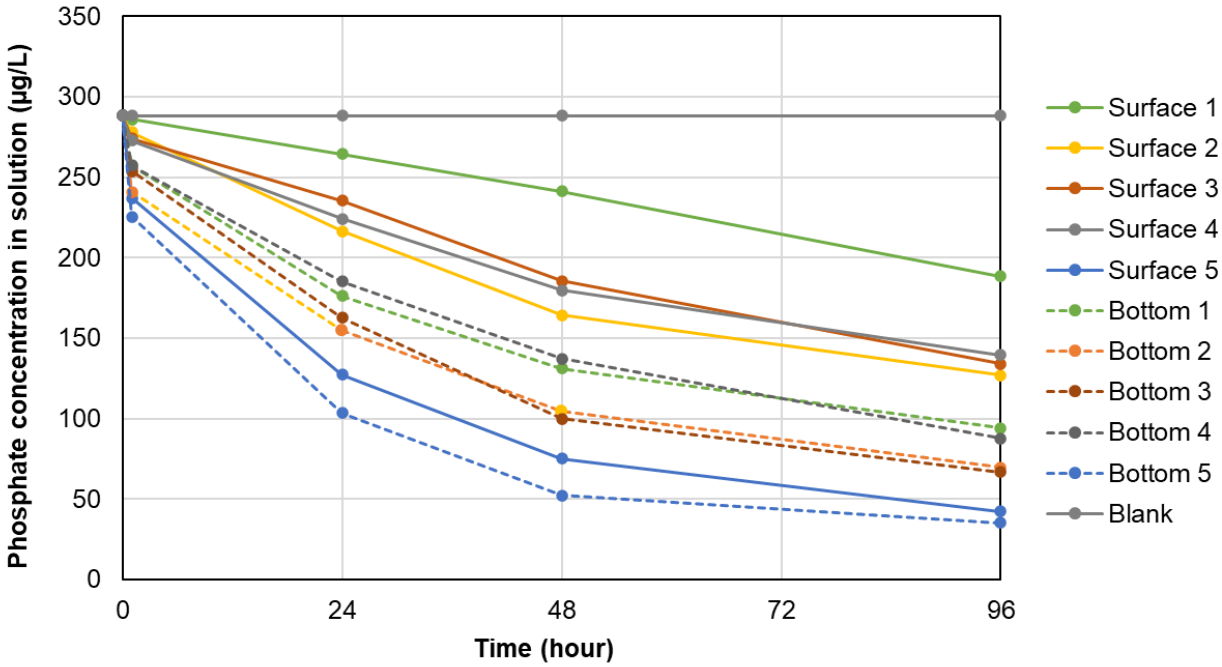

Figure 1. Phosphate removal by filter media samples collected from the IESF BMP located in Burnsville. The media samples (15 ± 0.0091 g) were added to a standard phosphate solution (initial concentration =~300 ppb) and mixed for 96 h to determine the phosphate sorption capacity of the media. Blank test bottles did not receive any media. Concentrations shown are mean for three replicates for each sample.

The PO_4−P sorption capacity (mg PO_4−P / g of media) calculated for 96-hour mixing duration is summarized in Table 1. Differences in PO_4−P removal capacities were more apparent across the filter surface than at the bottom. The mean sorption capacities of 0.59 mg/g (± 0.17 Std. Dev.) in the surface media and 0.77 mg/g (± 0.074 Std. Dev.) in the bottom media indicate that there is lower PO_4−P removal capacity remaining in the surface than at the bottom portion of the IESF. This result is consistent with a vertical-flow filtration system.

Table 1. Phosphate adsorption capacity of the filter media samples (mg PO_4−P / g of media) collected from an IESF BMP located in Burnsville. The calculated phosphate adsorption capacity is based on the results of the batch experiments performed by mixing the media (15 g) in a standard phosphate solution (initial concentration =~300 ppb) for 96 hours. Media:solution ratio = 1:20 (by weight). Values reported are mean for three replicates per media sample.

PO_4−P sorption capacity of surface media samples (mg/g)					**PO_4−P sorption capacity of bottom media samples (mg/g)**				
1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
0.394	0.592	0.569	0.551	0.865	0.698	0.777	0.785	0.719	0.887

Phosphate leaching experiment

Batch experiments with MilliQ water containing no phosphate were performed to determine the maximum phosphate (PO_4−P) leaching potential of the media. The experiment results (Figure 2) showed that a small amount of PO_4−P may release from the IESF media into solution over time. The resulting PO_4−P concentration in the solution was very low (< 0.02 mg/L increase) for all media samples after one hour contact. Only one surface media sample (location 1) leached PO_4−P at the end of 96-hour contact, and concentrations were still low for the bottom media samples. Phosphate release from the media was not observed beyond 48-hour contact time for all samples. The PO_4−P leaching results are in agreement with the PO_4−P sorption results; i.e., the existing surface media is already holding on to more phosphate than the bottom media.

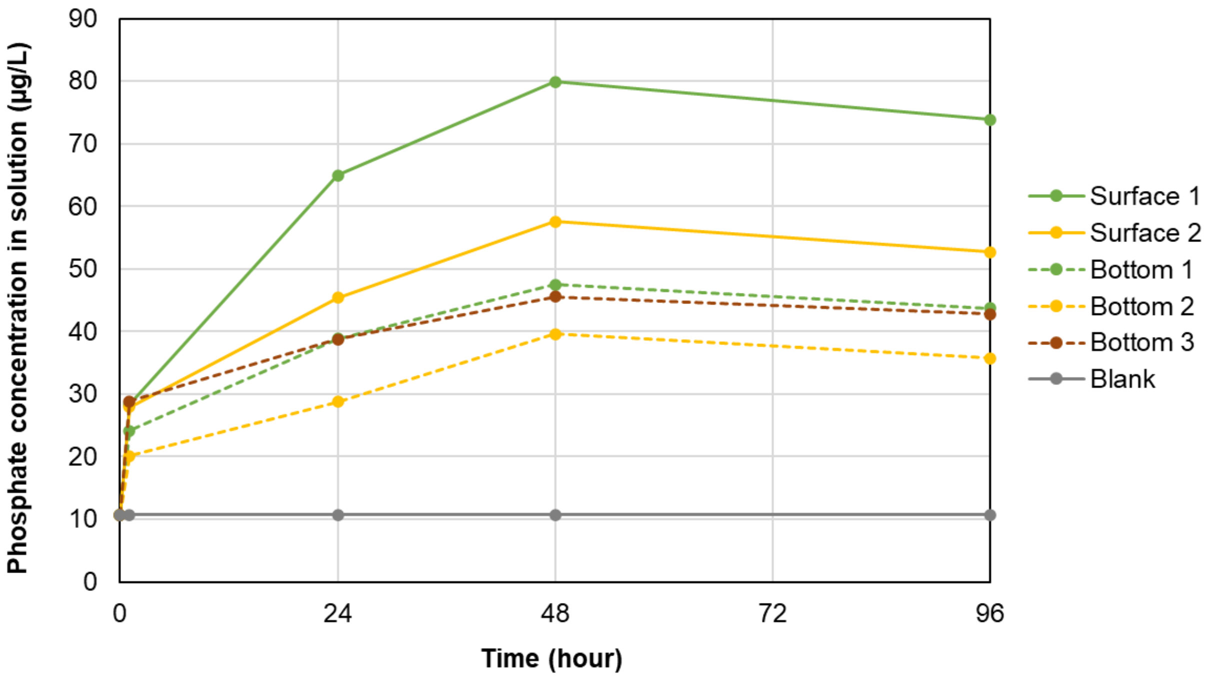

Figure 2. Results of the batch phosphate leaching studies on five filter media samples collected from an IESF BMP located in Burnsville. The media samples (15 ± 0.0096 g) were added to ultrapure water (initial phosphate concentration ~ 10 ppb) and mixed for 96 h to determine the phosphate leaching potential of the media. Blank test bottles did not receive any media. Concentrations shown are mean for three replicates for each sample

Analysis

Erickson et al. (2012) found in column studies that a maximum of 4.8 mg of phosphate could be retained on each gram of iron filings of the size used in most IESFs. The bottom media phosphate adsorption capacities of 0.77 mg/g (± 0.074 Std. Dev.) indicates that the iron sorption sites have been substantially reduced. The impact on sorption rates, however, has not been determined and is currently a research topic. This is also the first media that has been analyzed from an IESF facility, and comparison with other IESF media would also be illuminating. It is apparent, however, that the media is still adsorbing phosphate.

Conclusions

1. The batch studies showed that the filter media tested from the Stillwater IESF facility still has phosphate removal capacity.
2. Some areas of the filter surface appear to have less capacity to adsorb phosphate than other areas. Also, the surface media has diminished phosphate sorption capacity than the bottom media. These results are expected for a vertical-flow filtration system.

3. There is a small potential for the surface media to release the already-captured phosphate; however, the amount of phosphate released from the media is not expected to result in significant increases in phosphate concentration in the water flowing through the filter.

The actual performance of the filter is currently difficult to determine, because research is underway to estimate the relationship between media studies and filter performance at retaining phosphate.

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