Quantifying the Effectiveness of Saturated Buffers to Reduce Nutrient Loading from Tile Drainage Waters

Agricultural Drainage Management Coalition

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Executive Summary

The Farm Services Agency (FSA) has made significant investments through the Conservation Reserve Program (CRP) at addressing nutrients, specifically nitrogen, reaching America's surface waters through the riparian buffer programs CP 21 and CP 22. Riparian buffers have been shown to be effective at removing nitrogen from surface flows as well as shallow subsurface ground water, but in the tile-drained landscape of the Midwest, a significant portion of the nitrogen lost from agricultural fields does not have the opportunity to interact with the carbon rich buffers.

FSA began allowing the incorporation of saturated buffers, as well as denitrifying bioreactors, into CP 21 and CP 22 enrolled acres in 2016 through the Clean Lakes, Estuaries and Rivers (CLEAR) program. ADMC entered into a contract with FSA to monitor seven saturated buffers located in Illinois, Iowa, and Minnesota to provide a larger dataset to support the decision to invest in saturated buffers within the CLEAR initiative. The buffers were equipped with water level sensors to gage flow and monitoring wells to determine nitrate-N reductions. The outcome of the project is to estimate the effectiveness of saturated buffers in reducing nitrate-nitrogen loadings into streams to support the development of a decision support tool for practice site selection. To achieve the outcome the objectives of the project are to: (1) measure and estimate nitrogen concentrations and flow data in real time at 7 saturated buffers in Iowa, Illinois, and Minnesota; (2) incorporate these data with cost data to assess the cost effectiveness of saturated buffers in terms of $/lb. of nitrate-nitrogen removed; (3) develop outreach materials to increase awareness of suitability and effectiveness of saturated buffers; and (4) develop a decision support tool for identifying sites where saturated buffers are most likely to be most cost effective that uses readily available data and minimum technical expertise.

Nitrate-N Concentration Reduction

The seven saturated buffers had an average nitrate-N concentration reduction ranging from 41-97% during the October 2017 – August 2018 monitoring period. Table 1 displays the average nitrate-N concentrations of the untreated field tile discharge and of the water after it has flowed through the saturated buffer treatment area into the lower sampling well for each of the seven sites. Saturated buffers continue to demonstrate they are effective at removing nitrogen from the water that is diverted through the system.

Table 1 ADMC monitored saturated buffer nitrate-N concentration reductions.

Site	Average nitrate-N concentration, mg/l		% Reduction
	Field	Lower Well	
IA 1	10.8	0.4	97%
IA 2	5.4	1.4	74%
IA 3	11.0	<0.1	98%
IL 2	13.4	2.8	79%
IL 5	7.8	2.4	69%
MN 2	4.1	0.5	41%
MN 4	9.7	2.6	73%

Nitrate-N Load Removal

The saturated buffers removed an average of 32% ± 28% of the nitrate-N load. IL 2 was excluded from the load reduction calculations since wet conditions required stop logs to be managed in a way which prevented flow measurements and only concentration data could be collected. The flow diverted ranged from 9% at IA 3 up to 99% at IA 2 (Table 2). IA 2 diverted nearly 100% of the flow while removing 194 lbs. of nitrate-N. IA 3 had the lowest load reduction at 10 lbs. of nitrate-N, and only diverted 9% of the flow. The low load reductions and amount of flow treated at IA 3 were due inconsistent flow from the tile system during the monitored period. MN 2 also experienced a low amount of nitrate-N load removal due to the low incoming nitrate concentration, as well as the buffer being oversaturated at times which reduced the amount of flow volume from the field tile that could be diverted into the buffer profile.

Table 2 October 2017 – August 2018 ADMC monitored saturated buffer nitrate-N load reductions.

Site	% Flow Diverted	Flow Through Buffer (gallons)	% Nitrate-N Load Reduced	Nitrate-N Load removed (lb.)
IA-1	96%	2,028,578	69%	87
IA-2	99%	11,666,856	66%	194
IA-3	9%	107,034	7%	10
IL-5	25%	3,566,192	17%	177

MN-2	18%	579,238	14%	16
MN-4	22%	496,160	20%	41

Cost Effectiveness

Table 3 displays the cost effectiveness of the seven saturated buffer sites monitored by ADMC. The table represents 20 site years of data. The $/lb. of N removed ranged from $0.80 at IL 2 to $10.04 at MN 2 with a median value of $1.22. Installation costs ranged from $2,440 at IL 2 up to $5,019 at IA 3. The average cost of installation was $3,584. Additional unreported nitrate-N reduction likely occurs in the winter months when the control structure can be used as a drainage water management system to minimize tile discharge. This would further lower the $/lb. of N removed when quantified.

Table 3 Cost effectiveness of seven saturated buffers monitored by ADMC.

	Nitrate-N removed, lbs.							
	2013	**2014**	**2015**	**Sep. 2016 - Feb. 2017***	**Oct. 2017 - Aug. 2018**	**Average**	**Installation Cost**	**$/lb. N removed****
IA 1	99	94	139	18	87	87	$3,802	**$2.20**
IA 2	--	--	--	--	194	194	$4,015	**$1.04**
IA 3	--	--	408	342	9.53	253	$5,019	**$1.00**
IL 2	--	293†	--	13.5	NA	153	$2,440	**$0.80**
IL 5	--	--	161	60	177.31	133	$3,205	**$1.22**
MN 2	--	--	26	--	15.8	21	$4,152	**$10.04**
MN 4	11	--	3	148	41	51	$2,453	**$2.44**

*Data only collected over 6 months
** Assuming a 4% discounting rate and 40-year lifespan
† Estimated using DRAINMOD

With a median $/lb. N removed value of $1.22, saturated buffers are one of the most cost-efficient nitrogen removal practices. The relatively low installation costs, long expected lifespan, and minimum maintenance makes the practice a low risk option to reach nutrient removal goals.

Scalability of Saturated Buffers

ADMC contracted with the Department of Crop Sciences from the University of Illinois, Urbana-Champaign to develop a decision support tool to identify sites that will likely provide cost-effective locations for saturated buffer installations in the Midwest. The tool was developed by using publicly available datasets in a stepwise fashion within a geographic information system. Sites were identified by 1) being located adjacent to a perennial stream system, 2) having ≥2.5% organic matter in a 330 ft zone around the stream, 3) somewhat poorly drained or worse soils within a 980 ft zone around the stream, and 4) having only a corn or soybean land use. This step-wise model revealed a conservative estimate of 23,460 miles of stream had potentially suitable areas for saturated buffers. This would mean that there would be 46,920 miles of cumulative stream bank suitable for saturated buffers. Typical saturated buffer lengths ranging from 690 ft to 1000 ft would generate 248,000 – 360,000 potential sites throughout the Midwest. This would lead to 9.5 million acres, or 22%, of the 44 million tile drained acres in the Midwest being suitable to be treated with a saturated buffer. Using an estimated yield 20.5 lb. N/ac and a conservative load reduction of 23% reported by Utt et al. (2015), there is potential to remove approximately 22,000 tons of N from the tile drained landscape in the Midwest. Increasing the load reduction percentage to 44%, which was reported by Jaynes and Isenhart (2018), would result in approximately 43,000 tons of nitrate removal. Meaning that a 5-10% overall load reduction from Midwest tile-drained lands or a 2-5% load reduction to the Gulf of Mexico is possible with the full-scale implementation of saturated buffers.

The seven saturated buffers in this study had an average installation cost of $3,584. The Midwest has an estimated 248,000 – 360,000 suitable sites. Full-scale implementation would cost $889 million - $1.3 billion using this data set. Assuming a 40-year practice lifespan and a 4% discounted rate, the equal annual cost of full-scale Midwest saturated buffer adoptions would range from $45 million - $65 million.

Conclusions

Saturated buffers continue to be a cost-effective method at removing nitrogen from tile drain discharges in the Midwest. Flow diverted through the buffer shows high nitrate concentration reductions between 41% and 98%. The average load reduction in this study was 32% ± 28%. The amount of water which can be diverted through the buffer limits how much load a site can remove. Balance must be struck between soils that are conductive enough to allow water to flow through the system as well as provide enough residence time for denitrification to occur. Areas with water tables that remain high for long periods of time after rains, or with streams known to rise quickly and remain elevated after rain events will generally limit water from being diverted from the outlet to the saturated buffer. These sites still perform under baseflow conditions but will experience large amounts of sustained bypass during intense precipitation events or extended wet periods.

This study once again exhibited that saturated buffers are a cost-effective method in removing nitrogen. The developed decision support tool exhibited in a conservative manner that saturated buffers could potentially be installed to treat nearly 9.5 million acres of tile-drained Midwest land and remove 5% to 10% of the tile contributed nitrate-N load or 2-5% of the overall load delivered to the Gulf of Mexico. Enhancing a standard buffer with a saturated buffer where possible could remove approximately thirteen times the annual amount of N, while making the practice six to ten times more efficient in terms of $/lb. of N removed. Efforts should be made to incentivize landowners to install the practice as well as to increase the awareness of the agencies and private sector to recognize where the practice is appropriate and how to develop a timely design.