A Preliminary Summary of Approaches to Evaluate the Effectiveness of Agricultural Best Management Practices

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Prepared by Dan Bittman, Mari Veliz, and Abigail Gutteridge

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Executive Summary

Nutrient, sediment, and bacterial impacts can sometimes limit both the human uses and the ecological integrity of the near-shore waters of the Great Lakes. Agricultural Best Management Practices (BMPs) can help to reduce non-point sources of nutrients, sediment, and bacteria and improve downstream surface water quality. Ten years of water and land management data at the field and watershed scales have been collected about the implemented BMPs. Watershed trends have been developed and different watershed models (*e.g.,* Soil and Water Assessment Tool, Agricultural Non-Point Source Pollution, a modified Stormwater Management Model) have helped to explain water quality conditions. The different approaches have resulted in different outcomes. In light of the paucity of long-term data, further investigation into discrepancies and consistencies between the monitored data and the modelled data will be necessary. Due to the cumulative nature of landscape practices, understanding the costs and benefits of BMPs can only be accomplished in a manageable ecosystem framework – which is a long-term watershed study. Evaluation cannot be done everywhere, but, it does need to be done somewhere.

1.0 Project Overview and Introduction

The near-shore area of the Great Lakes provides many residents of Ontario with drinking water and recreational opportunities (*e.g.*, swimming and fishing). However, nutrient, sediment, and bacterial impacts can sometimes limit both the human uses and the ecological integrity of these near-shore waters. Agricultural activities contribute non-point sources of nutrients, sediment, and bacteria to the near-shore waters of the Great Lakes, but these contributions have been difficult to quantify due to the temporal and spatial variability of their sources. Reducing non-point source pollution is an important goal for federal and provincial agencies and local communities.

Agricultural Best Management Practices (BMPs) can help to reduce non-point sources of nutrients, sediment, and bacteria and improve surface water quality. There are many different practices that could be considered BMPs, including:

- nutrient and manure management practices (*e.g.*, following nutrient management guidelines and building adequate manure storage);
- field soil erosion reduction strategies (*e.g.*, conservation tillage and cover crops);
- structural practices (*e.g.*, Water and Sediment Control Basins – WASCoBs);
- fragile land retirement; and
- tile drain management approaches.

Kroger *et al.* (2012) outlined a framework that puts nutrient and sediment management practices into three tiers, with first-tier practices avoiding the introduction of nutrients and sediment into the aquatic system and additional tiers controlling their distribution. The first tier, input management (*i.e.*, nutrient management), avoids the introduction of the pollutant. The second tier controls the movement of the pollutant through field management (*i.e.*, conservation tillage). A third management strategy is to treat or trap the pollutant in primary aquatic systems (*i.e.*, swales, grassed waterways, WASCoBs, and ditch BMPs).

Beginning in 2010, the Watershed Based BMP Evaluation (WBBE), Huron, looked at the effectiveness of Avoid, Control, and Trap/Treat (ACT) BMPs by assessing the BMPs for their environmental effectiveness at the field and watershed scales (see Simmons *et al.* 2013 for a review of the broader study). Monitoring and evaluation of the BMPs continued in 2015 with the Great Lakes Agricultural Stewardship Initiative (GLASI) project. The purpose of this document is to summarize the ongoing water quality monitoring completed to verify the environmental efficacy of agricultural BMPs at the watershed and field scales. Furthermore, the water monitoring program described herein addresses some of the results of environmental models that are further described by Guelph University's Watershed Evaluation Group (WEG 2017a, WEG 2017b).

2.0 Field Scale Monitoring

The field scale monitoring data have consistently documented peak flow reductions with the installation of Water and Sediment Control Basins (WASCoBs). Bittman *et al.* 2016 and Bittman and Veliz (2018b) reported reductions in the peak flow rate into and out of two WASCoBs in Huron County of up to 97 percent. Although, BMP loadings are difficult to obtain there is some suggestion of reduced loads from the basins as a result. Significant improvements in the quality of surface runoff were observed as it entered a WASCoB before exiting the field through a Hickenbottom® outlet in the basin. Bittman *et al.* (2016) found that phosphate-phosphorus, total phosphorus, and total suspended solids loads declined between the WASCoB inflow and outflow by an average of 35, 24, and 65 percent, respectively, over 14 runoff events. In this regard, the model results concur. We also have documented that a modified tile inlet to increase filtration can improve water quality. For instance, Irvine *et al.* (2017) found that a silt sock placed over top of a tile riser significantly reduced TP loads by five percent over six events. For further information on the above studies, please request the inlet monitoring report (Irvine *et al*. 2017) and WASCoB evaluation reports (Bittman *et al.* 2016, Bittman and Veliz 2018b).

Measuring the effectiveness of the management BMPs has been more difficult. Observations show reduced flow in relation to some changes on the landscape, but obtaining before and after measures in all locations in the watershed is not feasible. In 2012, the ABCA started to use the WASCoBs as replicate study areas to evaluate the role of cover on flow generation. We are beginning to get enough data to accurately predict flow/no-flow conditions in different cropping scenarios. In addition, crop cover was found to reduce flow potential, particularly during the non-growing season (Bittman *et al.* 2016). Supplementary data would improve this understanding. Further investigation is required to understand why there appears to be different loads leaving different basins.

The time it takes to begin to generate enough data to measure changes related to vegetative cover is a main reason we need to rely on watershed models to document effectiveness of land management activities, especially in the short-term. A second important reason models are needed is that it may be very difficult to measure the negligible differences for some practices at the field scale. It is the cumulative nature of the effects that act to reduce flow, and thereby downstream channel erosion. Only an ecosystem model will be able to “measure” this in a relative manner.

In light of the paucity of long-term data, further investigation into discrepancies and consistencies between the monitored data and the modelled data will be necessary.

3.0 Watershed Monitoring

No statistically significant trends ($p>0.05$) in monitored water quality were determined for Gully Creek or Garvey-Glenn Drain between October 2010 and September 2017. By contrast, significant declines in flow-weighted mean concentrations of TP (Gully Creek), TSS (Garvey-Glenn Drain and Gully Creek), and nitrate-N (Gully Creek) were observed between October 2010 and September 2016 (Bittman *et al.* 2017). A possible reason for this discrepancy is that the 2017 water year had a number of very large rainfall events throughout the year (including one event that exceeded 100 millimetres of rain), which resulted in elevated pollutant concentrations. These differences exemplify the volatility of shorter-term monitoring trends and highlights the need for longer term data sets (*e.g.,* >15 years) to reduce the impact of extreme data.

As pollutant concentrations are often influenced by streamflow, we endeavoured to remove the streamflow variable from our trend analysis using flow-adjusted concentrations. Flow-adjusted concentrations allow us to differentiate times when load is influenced by changes in flow (natural streamflow variability) or when anthropogenic impacts (*e.g.,* land management actions) affect loads (Sprague and Lorenz 2009). By adjusting concentrations for flow, Gully Creek saw significant reductions in TP, phosphate-P, and nitrate-N (p<0.05), while no trends were observed in Garvey-Glenn Drain (Bittman and Veliz 2018a). For further information on the above studies, please request the Healthy Lake Huron priority watershed monitoring reports (Bittman *et al.* 2017, Bittman and Veliz 2018a).

4.0 Ecosystem Process Monitoring

Due to the complexity of climate and hydrologic conditions, a Soil and Water Assessment Tool (SWAT) was developed for Gully Creek and the Garvey-Glenn Drain to determine the effectiveness of BMP implementation. The University of Guelph's Watershed Evaluation Group (WEG) (2017b) documented that between 2002 and 2016, reductions in TP, TSS, and total nitrogen loads of up to 22, 25, and 18 percent per year, respectively, could be attributed to the current level of BMP adoption in Gully Creek. WEG (2017a) also documented that reductions in TP, TSS, and total nitrogen loads of up to 16, 31, and 13 percent per year, respectively, could be attributed to the existing level of BMP adoption in the Garvey-Glenn Drain. In addition, the SWAT models showed that structural BMPs (e.g., WASCoBs) are more cost effective than land management BMPs (e.g., conservation tillage or nutrient management) when considering reductions in phosphorus loss.

However, there is a discrepancy between the modelled results and the monitored results, as the model presents a 25 percent reduction in sediment loads in Gully Creek due to the construction of berms, whereas the monitoring data shows no significant decrease, when we look at results from 2010 to 2016 (Bittman *et al.* 2017). These results are difficult to explain to producers and the broader community. It is hoped that, with more investigation the SWAT model might help us explain the monitoring results further.

When work in Gully Creek first began in 2010, it was hoped that monitoring data would show that when BMPs are employed, water quality would improve. We thought that water quality improvements could be shown with water quality data collected during low flow months of the year – some still think this way. An early lesson learned was that year-to-year variations in climate and land management practices can overwhelm the effectiveness of BMPs. It was hoped that a watershed model would provide important insights on land management, or the role of climate on loads. The results included in the reports submitted from Gully Creek and Garvey-Glenn Drain monitoring and modelling suggest that perhaps different iterations of the model need to be run to better understand the role of climate and other land management activities on water quality trends.

The land management BMPs modelled in 2017 are field specific and do not show watershed magnitude effectiveness. In the 2013 WBBE SWAT (Simmons *et al.* 2013), results documented the application of cover crops and other land management BMPs on all relevant fields to provide an indication of the types of reductions of sediment and nutrients that might be possible. It may be helpful to re-run SWAT with these types of scenarios to further understand the potential impact of land management BMPs. For further information on environmental modelling results, please request the SWAT modelling reports for Garvey-Glenn Drain (WEG 2017a) and Gully Creek (WEG 2017b).

5.0 Conclusions

By pulling together the various components of our research efforts, we can start to draw a few conclusions about targeted BMP implementation in small agricultural watersheds. Firstly, targeted stewardship accompanied by high funding amounts will encourage BMP uptake within a small watershed. It has made landowners aware of the various BMPs that can be implemented on the landscape, and helped some producers use these practices sooner than they may have of their own volition.

We can also see positive trends in water quality results, both at the field scale and at the watershed scale (modelled results). Watershed scale monitoring results are less clear due to variability in climate variables, such as streamflow. However, removing streamflow variability from our monitoring data helped us see improvements in water quality that concur with the environmental models. At this early stage of reviewing research efforts, it is difficult to make conclusions about the effectiveness of BMPs in the context of the water quality data. The scenarios that were run in the SWAT model bring us closer to answering that question; however, there are many more scenarios that could be run through this model that would help to find some more definite answers.

Targeted agricultural stewardship programs are time consuming and expensive in terms of BMP implementation, monitoring and modelling efforts. However, they do seem to have a positive impact within a small watershed. Going forward, it would not be possible to maintain this kind of project in many different watersheds; however, ongoing efforts should continue in some places to gain better data, and draw accurate conclusions about the reduction of phosphorus loading, then apply those lessons learned in other areas. Additionally, there may be other more cost effective ways of reaching out to agricultural producers to encourage BMP implementation, such as mapping and property walks to identify potential projects.

We are beginning to see positive impacts on small agricultural watersheds due to past funded projects. However, more monitoring and modelling efforts are needed to determine the extent of that impact. These efforts should continue to help us further understand what it takes to reduce phosphorus loading, and apply those lessons throughout the Great Lakes basin in an effort to prevent further degradation of the Great Lakes and to sustain and improve the agricultural sector.

6.0 References

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