# 7.0 Future Work

## 7.1 Assessment of Tile Drainage Systems in the Lake Champlain Basin

With the exception of a few specific cases of data collected for localized studies, precise estimates of the extent of cropland tile drainage in the LCB do not exist. Even on fields known to be drained, the characteristics of the drainage system are largely unknown, especially for older systems. Where P loads in tile drainflow are found to be a significant management issue, knowledge of the extent and design of drainage systems will be essential, at both the watershed and the field scales, before mitigation efforts are undertaken.

7.1.1 Watershed scale assessment

Few options exist for assessment of the extent of tile drainage at the watershed scale. Some researchers have estimated the likely extent of drainage based on Geographic Information System (GIS) analysis of soil characteristics and cropping patterns. The underlying assumption of this approach is that relatively flat, poorly drained soils that are in active crop production must be drained for crop production to be carried out. Using this approach, Jaynes and James (2007) published state-level estimates of drained cropland ranging from 2% (New York) to 28% (Indiana). Using similar assumptions, the World Resources Institute (2007) estimated 39.3 million tile-drained acres in eight U.S. corn-belt states (Iowa, Illinois, Ohio, Indiana, Minnesota, Michigan, Wisconsin, and Missouri); these states were estimated to have from 3% (Missouri) to 48% (Illinois) of their cropland acres underlain by subsurface drainage (Sugg 2007). In the Missisquoi River Basin (MBB) within the LCB, Winchell et al. (2011) assumed that all poorly-drained cropland (hydrologic soil group C or D) with slopes less than 6% must be tile drained and thereby estimated that 40% of the MBB was tile drained. Subbasin estimates ranged from <20% for Mud Creek, Trout River, Tyler Branch, and Upper Missisquoi River to >75% for Rock River and Hungerford Brook. Application of this approach to the entire LCB would be a relatively straightforward GIS exercise and could be accomplished at a moderate cost.

In addition, several remote sensing techniques – including aerial imagery analysis and ground penetrating radar – and have been tested in other geographic areas for watershed and field scale detection of tile drain systems. Stone Environmental will be conducting a detailed literature review of the use of remote sensing techniques that may be applicable to identifying tile drain systems within the Lake Champlain Basin under separate contract with the Vermont Department of Environmental Conservation (VT DEC). This work will start soon and is scheduled to be complete by the end of calendar year 2016.

On a less technically demanding level, the long-used technique of smoke testing for inappropriate connections into urban storm drainage systems (e.g., Pitt 1993) has been adapted to detect the location of tile lines on agricultural fields. In Canada, Fleming and Bradshaw (1992) used smoke bombs and a blower to force smoke into tile outlets. Smoke emerged from the ground via soil macropores in a band over the tiles, ranging from 0.5 – 2 m in width and supported demonstration of the location of tile lines. More recently, Nielsen et al. (2015) reported from Sweden that smoke testing can not only locate tile lines but can also provide information on the magnitude of soil macropores and thereby predict the risk of contamination of tile drainflow by surface applied agrichemicals. In their experiments, size and hydraulic conductivity of soil macropores were highly correlated with the strength of smoke emission. Finally, in their work with tile drains in the New York LCB, Young et al. (2016) used smoke testing to document tile line location.

It should be noted that smoke testing is likely to be effective in locating buried drains only where soil macropores exist. However, as research has shown that water, sediment, and P transmission to tile drains is largely controlled by preferential flow, positive smoke testing results could not only locate tile lines but also identify priority sites for load reduction efforts.

## 7.2 Research Needs

A great deal is known about P transmission in tile drainwater, certainly enough to conclude that tile drainage is a potentially significant source of P at field and watershed scales in the LCB. However, additional research is needed to answer some important outstanding questions. This research is needed for three principal reasons. First, given the potential P contributions in tile drainwater, greater knowledge on the location and extent of tile drainage in the LCB is needed in order to fully understand the magnitude of the issue at the basin scale. Second, even though important data have been reported from Quebec and other regions near the LCB, most of the current knowledge of P transmission in tile drainage has come from work in the U.S. Midwest, Europe, and elsewhere and the quantitative transferability of these results to the LCB is uncertain. There is a need to confirm some of this knowledge under the climate, soil, and management conditions of the LCB. Third, uncertainties and contradictions reported in the global literature need to be explored and resolved.

The research needs identified below fall into three general categories: assessment of tile drainage extent in the LCB, quantification of P concentrations and loads in drainflow, understanding of factors controlling P transmission in tile drainage, and evaluating the effectiveness of management practices to reduce P losses in tile drainwater. While some of this work may be currently underway (e.g., at the Miner Institute in New York and in the Jewett Brook watershed in Vermont), all the recommended elements are listed below.

### 7.2.1 Quantify P concentrations and loads

* At the field scale,:
  + Collect data on P concentrations and loads in tile drainwater. Such monitoring should meet several criteria:
    - Monitoring must be conducted over full annual cycle(s), not restricted to growing season or a few high-flow events. Short-term data collected under limited conditions may explain contradictory reports of very low or very high P outputs in tile drainwater.
    - Flow should be measured continuously and sampling conducted either flow-proportionally or at a high frequency (i.e., weekly or better) to ensure representative concentration data and to permit an accurate load estimate.
    - Where possible, surface runoff should be monitored at comparable intensity so that information on the proportion of total field P export in surface and subsurface flows can be determined.
  + Collect data on P speciation in tile drainwater, at minimum total P, soluble reactive P, and particulate P. In specific cases, data on other P fractions such as total soluble P or bioavailable P may be of interest.
  + Use monitoring data to evaluate seasonality of P concentration and load. Reports on the seasonal distribution of P loads from tile drainflow have been somewhat conflicting. Most research indicates that P export is low during the growing season, with the majority of the annual P export occurring outside the growing season. Some researchers have identified the spring snowmelt period as the most critical. These issues need to be explored under LCB-specific climate and management conditions.
* At the watershed scale:
  + Estimate the P contribution from tile drainflow to the total watershed P export. Tile drainflow has been shown to be a significant source of P at the watershed-scale in several studies, although high-quality data quantifying contributions of tile drainflow loads as a fraction of the overall watershed load are scant and essentially non-existent in the LCB.

Note that for all the efforts to quantify P concentrations and loads at the field or catchment scale, the research should not only monitor tile drainwater but also collect simultaneous site data (e.g., slope, soil texture, soil test P) and agricultural management data (e.g., cropping, tillage, manure/fertilizer application rates, timing, and method). These are likely to be important covariates useful in explaining observed P output and in understanding critical factors driving P loads in tile drainwater.

### 7.2.3 Investigate factors controlling P transmission in tile drainwater

The following research items could be conducted at plot or field scale. Results from plot studies would need to be confirmed by field-scale studies because plot data may not be directly transferrable to larger systems. Note that some of these questions could be addressed by the same studies proposed above, if sufficient site and agronomic data are collected during monitoring.

* **Manure/fertilizer applications**: Document P loses in tile drainwater under different manure/fertilizer application scenarios. Published results on the influence of P application on tile drainwater have been conflicting; better data are needed on the influence of land-applied P on P losses in tile drainwater. Manure or fertilizer applications to soils prone to preferential flow, close in time to storm events, or at rates in excess of crop need can lead to significant P losses. However, P applications do not always generate high losses in tile drainwater. Studies of this issue should focus on rate, timing, and method of application and weather. Manure applications by surface broadcast, incorporation, and injection, as well as minimum tillage should be considered. The influence of preferential flow should also be evaluated.
* **Soil texture**: Evaluate correlations between soil texture and P losses in tile drainwater. The reported influence of soil texture is variable; greater drainflows have been reported on coarse-textured soils and attributed to higher permeability, but high drainflows have also been observed on fine-textured soils attributed to preferential flow.
* **Cropping and tillage**: Document P losses in tile drainwater under different crops and tillage practices common to the LCB. The reported influence of crop and tillage on P in tile drainflow is variable. High P loss in tile drainflow sometimes occurs from grassland and no-till cropland due to the prevalence of preferential flow pathways. The influence of crop type is also unclear, as results may be confounded by differences in nutrient application and tillage inherent for specific crops. In the LCB, evaluation of P loss in tile drainwater should focus on land in continuous corn, corn-hay rotations, soybeans, and permanent grass.
* **Soil test P**: Determine the influence of soil test P on P losses in tile drainwater. Although research results are variable, it has been widely observed that elevated levels of soil test P or soil P saturation (e.g., from long-term over-application of manure and/or fertilizer) lead to greater concentrations of P in tile drainflow. Research has suggested that a soil test P threshold or “change point” exists, above which a unit increase in soil P results in elevated P concentrations and losses in drainflow. This threshold is soil-specific and data for LCB agricultural soils do not currently exist. Studies to identify thresholds – as well as the influence of other soil factors such as clay content, soil P saturation, and water-extractable P – should be conducted on common LCB agricultural soils.

### 7.2.4 Evaluate effectiveness of management measures

The effectiveness of management measures to reduce P losses in tile drainwater is not fully understood at the global scale and is essentially unknown within the LCB. The effectiveness of various Best Management Practices (BMPs) should be tested at either the plot or field scale.

* **Drainage water management/controlled drainage (DWM/CTD)**: Evaluations of the effectiveness of DWM/CTD on P loads in tile drainwater have yielded mixed results. Reductions in P loads have sometimes been observed, in spite of increases in P concentration, due to significant reductions in flow. However, DWM/CTD is uncommon in the LCB and its potential to reduce tile drainage P loads needs to be tested under local conditions.
* **P sorption/treatment:** Research should be conducted on the practicality and effectiveness of P sorption treatments (e.g., slag, water treatment residuals) to reduce P loads in tile drainwater.
* **Tillage to close soil macropores:** Research results on the effectiveness of shallow or periodic tillage to close soil macropores and reduce potential transmission of water, sediment, and P to tile drains have been conflicting. The effectiveness of this approach should be tested in the LCB.

# References to be added:

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