Constructed Wetlands

WS-02

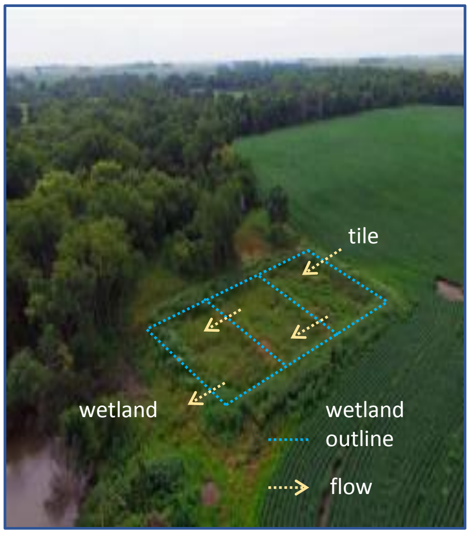

Figure 1. A multi-cell constructed wetland in Minnesota (modified from Lenhart et al., 2016).

What do constructed wetlands accomplish?

The objective of incorporating a constructed wetland in a tile drainage system is ***Improving Water Quality*** by removing nutrients from a portion of the tile water before it is discharged to surface water. A constructed wetland must be engineered and placed downstream of the tile outlet(s). When the tile water leaves the field, it flows through the wetland before being released to surface water.

Additional benefits of a constructed wetland may include removal of sediment and herbicides from tile water, water storage, carbon storage and wildlife habitat. A constructed wetland will also slow the release and/or decrease the volume of tile water discharged to surface water.

Constructed wetlands can be designed to store water for irrigation. If the water is used for irrigation, the system offers the additional benefits of nutrient reuse for crop production and reduction of crop water deficits.

Overview of wetlands

Basic design components of a constructed wetland include (Figure 2):

- An inlet;
- A treatment cell,
- Berms/embankments stabilized and covered with managed vegetation
- An outlet;
- A vegetated buffer.

Constructed wetlands will treat nutrients most effectively if they are shallow with emergent vegetation.

Nutrient reduction is achieved through soil biological processes (e.g. denitrification of nitrate) and uptake of nutrients by wetland vegetation. For maximum nutrient removal, particularly phosphorus, the vegetation in the wetland will have to be harvested periodically.

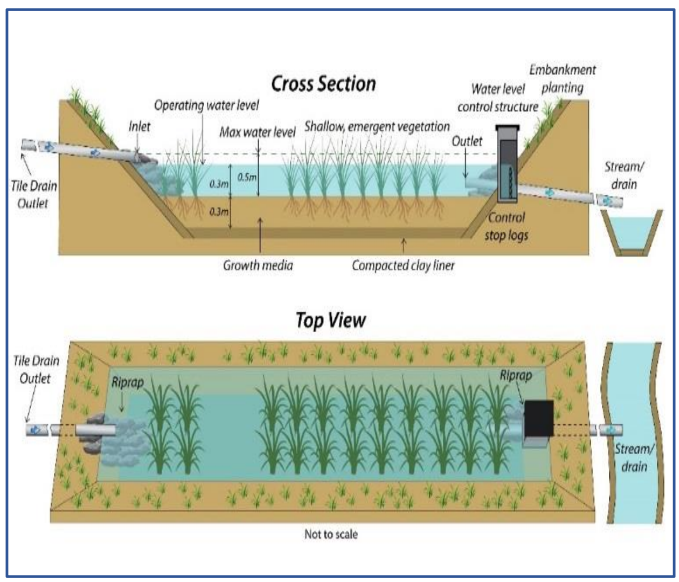

Figure 2. Conceptual diagram of components and layout of a constructed wetland.

Applicability to Manitoba

Constructed wetlands are broadly applicable in that they can be placed across various soil-landscapes in Manitoba. They have been used in Manitoba to successfully treat runoff from livestock operations (McGarry and Pries 2001), but there are no known constructed wetlands that treat tile drainage.

Constructed wetlands require site specific planning and design to ensure they are customized to local conditions. Land use and cost are two factors that may limit the adoption of constructed wetlands. They require a sizeable up-front capital cost, as well as a significant land area, which has longer-term, lost-opportunity costs associated with removing the land from production (Christianson et al., 2016).

Most of the research in the US has shown wetlands to be effective in reducing nitrogen loads. In Manitoba, phosphorus is also a significant surface water quality issue. In addition to removing nitrate, constructed wetlands in Manitoba should be designed and managed to retain water and remove phosphorus.

Current research findings

Research in the Midwest USA has shown the performance of constructed wetlands to be highly variable. Reductions in annual nitrate loads ranged from 16% to 85% (Christianson et al., 2016; Lenhart et al., 2016, Peterson, 2009). Phosphorus removal has also been found to be variable and related to the form of the nutrient (Lenhart et al. 2016). It is primarily removed via wetland plant uptake (and not biological transformations like nitrate), therefore its ultimate removal from the system is tied to the fate of the wetland vegetation (i.e. harvest).

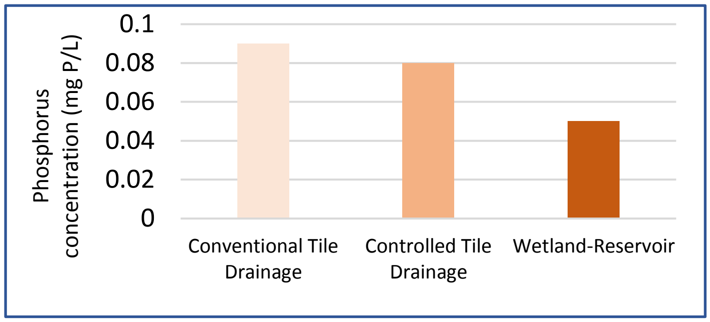

Figure 3. Total phosphorus concentration for a conventional tile drainage system, controlled drainage system and a wetland-reservoir in Ontario (modified from Tan et al. 2007).

At a study site in Ontario, tile drainage water and surface water runoff were diverted to a wetland-reservoir. Water from the wetland-reservoir had lower concentrations of nitrate and phosphorus than the tile water from conventional and controlled drainage plots (Figure 3). The authors hypothesized that this was due to uptake by the wetland vegetation (Tan et al. 2007), although dilution from surface runoff and precipitation could also have been factors.

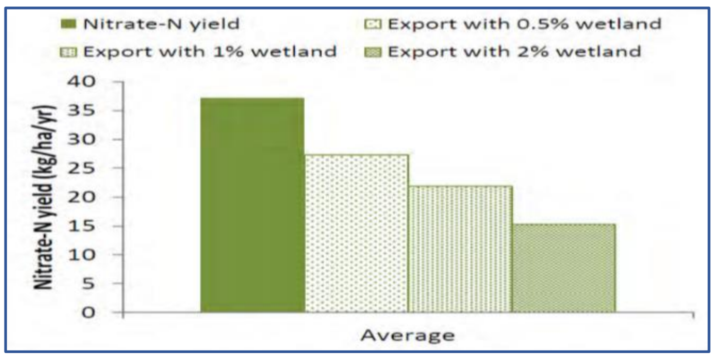

Figure 4. Nitrate export and wetland size (Crumpton et al. 2012).

Wetland performance depends on local conditions, size of the wetland in relation to the treatment area and wetland health and management. For example, an increase in nitrate-nitrogen removal was found with increasing wetland size from 0.5% to 2% of treated areas (Figure 4). Wetlands are generally more efficient at removing nutrients during flow periods in which:

- The weather is warm, and plant uptake and biological activity are high;
- Nutrient concentrations are high;
- Flow rates are low, allowing higher retention times in the wetland.

What are some important design considerations

Development of an effective constructed wetland must consider (adapted from Tanner et al., 2010 and Christianson et al., 2016): siting, design (including sizing of the wetland), construction of the wetland, vegetation establishment, operation and maintenance, and monitoring.

Figure 5. A constructed wetland within the drain in Iowa (Christianson et al., 2016).

Constructed wetlands can be sited at the edge of a field, between the tile outlet and the surface watercourse (Figure 1), or within an existing drainage course downstream of multiple tile outlets (Figure 5). The added benefit of placing the wetland within the drain is that it can treat tile outflow from multiple fields along with a portion of surface flow.

The size of the constructed wetland should accommodate the area being tile drained and the anticipated delivery from the tiles. Edge-of-field constructed wetlands are ideally placed in lower landscape positions where water naturally accumulates. These areas tend to be of lower productivity due to poor drainage. Siting of the constructed wetland on lower productivity land reduces the lost-opportunity cost of removing land from crop production and maintains productivity in more highly productive lands. Wetlands constructed within an existing drainage course generally require greater buffer area than edge-of-field types; and must also be designed to safely bypass larger surface flows resulting from rainfall or snowmelt events.

The Iowa Conservation Reserve Enhancement Program (Iowa CREP) recommends the following design components for wetlands constructed within the drain or waterway (adapted from Christianson et al. 2016):

- Locating wetlands to receive drainage from at least 500 acres of tile-drained cropland;
- Sizing the wetland at 0.5% of its drainage area. A wetland that is 1% of the drained area requires 6.4 acres for every section of land (i.e. 640 acres);
- Allowing no more than 25% of the wetland to be greater than 3 feet (0.9 m) deep;
- Surrounding the wetland with a buffer that is no more than twice the wetland area.

Edge-of-field constructed wetlands could conceivably be smaller in scale (e.g. ¼ section).

Construction of wetlands should be undertaken by an experienced contractor following the industry standard of care. Contractors should implement an engineered design under the guidance of the engineer.

Vegetation establishment within the treatment cell, on berms and embankments, and within buffer areas is important to ensure the wetland operates effectively. Establishing a productive stand of shallow, emergent wetland vegetation species is critical to performance through uptake of water and nutrients. Vegetation on berms/embankments and along buffer areas will help prevent wind and water erosion, and will aid in stabilizing these components (Figure 2).

Wetlands should normally be operated to maintain a shallow depth of water, allowing vegetation productivity. Freeboard should be incorporated in the design to prevent damage to berms/embankments and buffer areas (Figure 2). Regular maintenance of embankments, structures and vegetation will assure the longevity of the constructed wetland.

Performance monitoring is possible to confirm effectiveness and improve ongoing management (e.g. flows, vegetation management, water quality).

Outstanding questions and potential future improvements

Constructed wetlands are a proven technology for nitrate removal from tile water. However, more research is needed in Manitoba to:

- Validate practice feasibility and refine design, operation, management and performance monitoring protocols.

- Optimize design parameters including siting (e.g. suitable soil-landscape conditions, hydrologic settings), sizing relative to field areas, loading rates (nutrient, water), tile design, and wetland management.
- Set performance criteria for phosphorus and nitrate removal. In Manitoba, phosphorus is also a serious concern for surface water quality, especially that of Lake Winnipeg.
- Determine recommended practices for wetland management (e.g. vegetation harvest for phosphorus removal).
- Weigh the costs and benefits of this practice in various scenarios.

Complementary practices

Constructed wetlands are a complex BMP and require professional planning and regulatory permits/approvals support prior to implementation (see *EA-01 – Professional Services*).

Wetland are suited for combination with other BMPs that reduce nutrient in tile outflow:

- *IF-01-Nutrient Management* and *IF-02–Cover Crops,* agronomic practices to reduce nutrient concentrations.

Wetlands can be used as a reservoir and water can be re-used via surface irrigation or sub-irrigation:

- *WS-01 – Tile Water Recycling;*
- *IF-03 – Controlled Tile Drainage.*

Wetlands can work where the adoption of other tile water treatment BMPs are limited or not desired:

- *EF-01 – Bioreactors* and *EF-02 – Saturated Buffers,* two alternative end-of-pipe treatment BMPs.

Guidelines for constructed wetlands

Tanner, C.C., J.P.S. Sukias and C.R. Yates, 2010. New Zealand guidelines: constructed wetland treatment of tile drainage. NIWA Information Series No. 75, National Institute of Water & Atmospheric Research Ltd.

USDA, 2011. Constructed wetland – Conservation Reserve Program CCRP – CP39. Natural Resources Conservation Services, USDA Michigan, March 2011.

Alberta Environment, 2000. Guidelines for the approval and design of natural and constructed treatment wetlands for water quality improvement. March 2000.

Additional BMP resources

Christianson, L.E., J. Frankenberger, C. Hay, M.J. Helmers, and G. Sands, 2016. Ten ways to reduce nitrogen loads from drained cropland in the Midwest, Pub. C1400, University of Illinois Extension.

International Institute of Sustainable Development (IISD), 2017. How to best manage water retention sites to protect Manitoba's environment.

References

Crumpton, W.G., M.J. Helmers, G.A. Stenback, D.W. Lemke and S. Richmond, 2012. Integrated drainage wetland systems for reducing nitrate loads from Des Moines Lobe watersheds. Agricultural and Biosystems Engineering Technical Reports and White Papers. Paper 13.

Lenhart, C., B. Gordon, J. Gamble, D. Current, N. Ross, L. Herring, J. Nieber and H. Peterson, 2016. Design and hydrologic performance of a tile drainage treatment wetland in Minnesota, USA. Water. 8: 549.

McGarry, P. and J. Pries, 2001. Constructed wetlands for feedlot runoff treatment in Manitoba

Peterson, J., 2009; Conservation drainage practices for agriculture. 2009 Minnesota Association of Watershed Districts Meeting.

Tan, C.S., T.Q. Zhang, C.F. Drury, W.D. Reynolds, T. Oloya and J.D. Gaynor, 2007. Water quality and crop production improvement using a wetland-reservoir and drainage/subsurface irrigation system. Canadian Water Resources Association. Vol. 32(2): 129-136.