

Feedlot Stormwater Runoff Treatment Using Constructed Wetlands

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Abstract

In the Interlake area of Manitoba, two treatment wetlands were designed and then constructed to demonstrate and monitor alternative waste treatment technology for the livestock industry. The treatment systems consist of a runoff collection system, storage pond(s), and wetland treatment cell(s) vegetated with cattails and other emergent wetland species. Flow is pumped to the wetland on a seasonal basis beginning in late spring as water temperature within the holding pond(s) begin to rise to late fall prior to freeze up. In this paper the design and construction process is reviewed and three to four years of performance results is presented.

INTRODUCTION

Feedlot stormwater runoff and livestock wastes contain the major plant nutrients of phosphorus and nitrogen as well as high concentrations of organic material and bacteria, which contribute to water quality degradation in receiving streams and lakes. In prairie waters that are already nutrient rich, additional nutrient loading can greatly accelerate the process of eutrophication and the proliferation of aquatic plants and algae. This can impair recreational and biological values, as well as degrade water quality for domestic or livestock consumption. Best management practices including the planting of buffer strips, denying livestock direct access to rivers and lakes, and stormwater retention ponds have all contributed to the improvement of surface water quality. However, cost effective sustainable treatment systems are required to further polish these streams.

Wetlands – A Treatment Option

As effluent discharge limitations become more restrictive, innovative technologies may offer new, affordable methods of meeting compliance requirements. Constructed treatment wetlands provide one approach to meet these challenges. Realizing the potential for wetland applications in Manitoba, PFRA conducted a limited survey in the province to determine which farmers had interest in this technology and willingness to form partnerships for designing and building a full scale demonstration project. Several site tours were conducted to see how others had used the technology and what they had learned. PFRA organized a wetland workshop at the Ducks Unlimited Oak Hammock (Manitoba) facility in June of 1996 and invited CH2M HILL Canada Limited, among others, to present papers on treatment wetlands. Based on the level of interest and the advanced state of the treatment technology, PFRA and Manitoba Agriculture invested in developing two full-scale demonstration projects to treat feedlot runoff.

PROJECT OBJECTIVES

Demonstration of the treatment wetland technology was the prime objective in constructing two full-scale wetland systems in Manitoba. Evaluation of treatment performance was also important so as to provide local data on the technology to producers and regulators. Comparison of the wetland

system to other treatment and disposal methods was also incorporated into the project in part to determine if cost was a likely constraint to use of the technology.

In summary, the project was developed to meet several objectives. They included:

- Develop two constructed wetland systems to treat feedlot runoff in Manitoba
- Evaluate the treatment performance through an intensive monitoring program
- Compare the cost and practicality of design, construction, and operation with other options
- Assess potential for adoption of treatment wetland technology in Agro-Manitoba

THE PROJECTS

In 1996 a Green Plan project was initiated to demonstrate constructed wetlands and evaluate the potential for use on Manitoba livestock farms. Wetland projects were constructed at two cattle feedlot operations in the Interlake Region of Manitoba. Both projects were designed to capture the feedlot runoff, store it in a holding pond and then treat the wastewater in constructed wetland cells. The wetlands operate for approximately 150 days each year from mid-May through mid-October and are set at an operating water depth of approximately 30 cm. The systems operate on a continuous flow basis during the growing season. In dry years there may be no outlet discharge due to lack of stormwater runoff or by water removal through high rates of evapotranspiration.

Actual operation of the system is quite simple involving the setting of an automatic pump timer and flow control valves to provide settled stormwater flow to the wetland and adjusting the height of stoplogs at the outlet level control structure to set the wetland water depth in the shallow zones. The submersible pump is installed in the wetwell each spring and removed in the fall. Periodic monitoring ensures pump operation and wetland water levels and controls.

The maintenance requirement for the system is minimal, as annual harvest of cattail is not required. It is estimated that the wetland cells may require clean-out of collected organic debris only after approximately 15 years or more. This will be based on reduction in wetland volume over time.

Site 1 – Near Riverton

The first site developed with a treatment wetland system is a 3ha 800 head feedlot operation that is located approximately one mile from Lake Winnipeg. Drains were constructed around the feedlot and empty into a settling pond. From here, accumulated water flows through the remainder of the treatment system during the late spring, summer, and early fall periods. The treatment wetland was commissioned in 1998. Each process component is described below.

Settling Pond

The 0.2 ha settling pond with a working volume of approximately 1,500 m³ is where suspended solids and other debris settle out of the collected feedlot runoff providing primary removal of contaminants bound up with the solids. This pond will remain full during normal operation to maximize the treatment capability offered by the long hydraulic retention time. The overflow from the settling pond discharges to the holding pond. During periods of low precipitation when the holding pond can no longer supply water to the wetland and the wetland vegetation is in danger of being stressed, water from the settling pond can be pumped to the wetland cell.

Holding Pond

The 0.4 ha holding pond has a working volume of approximately 3,200 m³. It can store seven months of accumulated precipitation from the drainage area during an average rainfall year. The

average hydraulic retention time (HRT) in the pond is approximately two months during the operating season. The long HRT provides additional time for solids settling and for anaerobic reduction of BOD₅. The collected water is transferred to the treatment wetland by a pump since the topography does not allow for gravity flow. When pumping from the holding pond to the treatment wetland, a floating intake reduces the potential for drawing up accumulated settled solids from the bottom of the holding pond.

An emergency overflow is provided at the inflow end of the holding pond to prevent overtopping of the embankments in the event of high levels during high volume runoff that cannot be contained in the holding pond.

Treatment Wetland

The water is then pumped to a weir box where the flow is measured and discharged to the wetland. The wetland is a single cell 0.5 ha system with an average depth of 0.3 m and a working volume of 1,500 m³. A gate valve controls flow to the wetland cell. The flow enters the wetland in the centre of the influent distribution deep zone where the flow is distributed across the width of the cell. After passing through the wetland, the flow is discharged at the effluent control structure where stop logs control the water surface elevation of the cell.

Site 1: Wetland Performance

The overall performance of the wetland at Site 1 has met expectations with significant reduction in organic strength and lesser reductions in phosphorus. The data that has been collected to date shows much lower wetland inflow concentrations than what was predicted using water quality data from other feedlot operations. It is apparent that the settling and holding ponds are providing considerable treatment of the stormwater prior to the wetland. This is in keeping with the focus on using the wetland for polishing rather than primary treatment. Table 1 presents the average annual data from monthly samples collected during each growing season of operation.

TABLE 1
SITE 1 – AVERAGE ANNUAL WETLAND INFLOW AND OUTFLOW DATA

Parameter	Average Value 1998		Average Value 1999		Average Value 2000		Average Value 2001	
	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow
BOD ₅ (mg/L)	69	4	5	9	12	4	34	9
NH ₃ -N (mg/L)	22.3	0.2	0.6	0.2	10.9	0.1	9.6	0.2
TKN (mg/L)	39	6	12	7	23	9	34.3	6.5
TP (mg/L)	2.6	1.6	0.9	1.2	2.7	2.5	4.4	2.8
TSS (mg/L)	70	12	25	17	23	10	69	6
pH	8.2	7.5	8.7	7.7	8.0	7.6	7.9	7.4
Conductivity (µs/cm)	1408	1430	2020	2590	1778	1662	2123	1316
COD (mg/L)	303	188	196	280	270	222	447	197
Fecal Coliform (col/100ml)	1508	182	74	31	103	87	726	1646
Total Coliform (col/100 ml)	7242	1533	445	4161	597	556	1123	3976
D.O. (mg/L)	5.4	2.63	9.1	3.66	2.7	1.78	1.1	1.50

Site 2 – Near Lake Manitoba Narrows

The second constructed wetland site developed was at an 1800 head feedlot bordering Lake Manitoba in the Interlake area. The treatment system was commissioned in 1998. The treatment wetland was constructed to reduce the nutrient and solids loading to Lake Manitoba.

Holding Pond

The 0.25 ha holding pond with a working volume of approximately 3,300 m³ collects and stores contaminated runoff from the feedlot area during the late fall, winter, and early spring. The average hydraulic retention time (HRT) in the pond during the wetland operating period is approximately 2 months. The stored water is pumped, having been drawn through a floating intake, to the treatment wetland during the treatment period by a pump since the topography does not allow for gravity flow.

Treatment Wetland

The treatment wetland consists of two 0.5 ha cells operating in parallel with an average depth of 0.3 m and a working volume of about 3,000 m³. The holding pond effluent is pumped to a weir box at the inflow end of the wetland cells where the flow is measured. Gate valves control flow to each of the wetland cells. For normal operation, the gate valves at the weir box are opened to allow a maximum flow of about 100 L/min to each cell. The gate valves at the splitter structure also allow isolation of either cell or throttling of the flow to either cell. The flow enters the wetland in the centre of the length of the influent distribution deep zone where it is distributed across the width of each cell. After flowing through the wetland cells, the treated water is discharged at the effluent control structure through a weir box for flow measurement. Stop logs in the effluent control structures control the water surface elevation of each cell.

Site 2: Wetland Performance

The overall performance of the wetland at Site 2 also has met expectations with significant reduction in contaminant concentration. The data that has been collected to date at this site also shows much lower wetland inflow concentrations than was predicted using water quality data from other feedlot operations. As was experienced at Site 1, the holding pond is providing considerable treatment prior to discharging the contaminated stormwater to the wetland. Table 2 presents the average annual data from monthly samples collected during each growing season of operation.

TABLE 2
SITE 2 - AVERAGE ANNUAL WETLAND INFLOW AND OUTFLOW DATA

Parameter	Average Value 1999		Average Value 2000		Average Value 2001	
	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow
BOD ₅ (mg/L)	20	4	27	7	124	13
NH ₃ -N (mg/L)	2.1	0.4	1.4	0.1	26.5	0.7
TKN (mg/L)	25	16	32	15	81	12
TP (mg/L)	6	4.3	8.5	5	8.6	2.9
TSS (mg/L)	21	6	73	31	205	34
pH	8.1	8.1	8.3	8.2	8	8
Conductivity (µs/cm)	3377	3139	3629	2954	3042	1934
COD (mg/L)	247	280	303	222	926	255
Fecal coliform (col/100ml)	420	201	1082	324	1235	209

TABLE 2
SITE 2 - AVERAGE ANNUAL WETLAND INFLOW AND OUTFLOW DATA

Parameter	Average Value 1999		Average Value 2000		Average Value 2001	
	Inflow	Outflow	Inflow	Outflow	Inflow	Outflow
Total Coliform (col/100 ml)	11848	1496	14044	2558	18910	589
D.O. (mg/L)	1.2	2.2	3.1	4.8	1.3	3.5

DESIGN CONSIDERATIONS

There are lessons that have been learned over the past three and four years of operation. They include:

Pre-Treatment and storage: A primary treatment lagoon or settling pond is required upstream of the treatment wetland. A lagoon or pond allows initial removal of settleable contaminants, particularly suspended solids that typically are high in phosphorus and BOD₅, and provides storage where the contaminated stormwater can accumulate during the winter months and be discharged at a controlled rate to the wetland for maximum removal efficiency. This also prevents solids build up in the wetland cell that will reduce the hydraulic retention time and decrease performance.

Set reasonable targets for pollutant reduction: Setting reasonable effluent targets is an important task in developing a treatment wetland that meets producer and regulator expectations and is economically feasible for widespread adoption of the technology. Targets should be set based on average strength of feedlot runoff and empirical performance data from cold climate livestock wetlands.

Configuration and size: The wetland system must be designed in such a way that it will not negatively impact the normal farming practices. It is difficult to sacrifice productive land and so the wetland footprint must be minimized. While channelized systems are attractive and have potential for landscape features, they also take up two or three times the land area of a rectangular system and do not provide any benefit. During the design stage, consideration can be given to reducing the amount of over capacity designed into the system and locating it such that extra treatment cells can be constructed if increased capacity is required in the future.

Pumping requirements: This passive treatment option has the advantage of not requiring pumping as long as the relief of the land allows for gravity flow throughout the system. This is another siting consideration that can reduce the construction, operations, and maintenance costs. In relatively flat areas, however, pumping may be required to move the water through the system. This is especially true for seasonal systems where the holding pond must be emptied by the end of the treatment season and the holding pond invert is below the wetland operating water level as is the case in the Manitoba systems.

Siting and setback restrictions: Manitoba Livestock regulations were followed for setbacks from property lines, residences and wells

Cost Considerations: For the farming community, the cost of any treatment option will be a major factor that will determine whether it will be considered. The construction costs associated with a treatment wetland depend on the topography, site soil conditions, and infrastructure requirements.

Liners: Wetland and storage pond lining is required in permeable soils to prevent vertical movement of contaminated water. Synthetic or clay liners add significant cost to a wetland project

especially when clay is not readily available. Since the Manitoba wetlands were both built in areas that had high clay content in the soils, this cost was not incurred.

Land Costs: Land purchase can drive up the cost of a farm treatment wetland considerably. For most on-farm systems the land area required for the project has been readily available. Whether purchased or donated the value of the land does represent a cost of development. As such wetland sizing is the main determinant and will vary with feedlot size and livestock numbers. The footprint of the two Manitoba projects excluding feedlot drainage area was approximately 2 hectares.

Muskrat Control: Muskrat colonization of the constructed wetland can be devastating to the integrity of the wetland dikes and the vigour of wetland vegetation. The repair of muskrat damage at Site 1 cost approximately \$2500 after the first year of operation. Burrowing into the surrounding dikes was the principle damage that caused collapse and a near breach of the dike. To prevent further occupation and damage a muskrat exclusion fence was designed and built around the wetland cell. The cost of the fencing was about \$10,000.

Permitting: Currently in Manitoba, agricultural treatment wetlands do not require permitting although if there is federal funding or permitting required then they are subject to a federal environmental screening process. Manitoba livestock regulations do, however, prohibit release of manure to surface or groundwater.

SUMMARY

The agricultural industry in Manitoba and across the rest of Canada has expressed considerable interest and acceptance of the wetland technology for polishing high- and low-strength agricultural wastewater and stormwater. The systems in Manitoba have clearly demonstrated a capability to reduce contaminant loadings to the water environment and have the potential for operation on a much wider scale. The experience of all involved in these projects from planning and construction through to operation has been positive. As a result, PFRA has added treatment wetlands to their list of potential natural treatment systems. Brochures have been prepared and are now available to provide information to farmers and others about this technology. They have hosted tours to these wetland facilities to help potential end users get a sense of the size and ease of operation that these natural systems offer. The demand for treatment wetlands for water quality improvement in the livestock and agricultural industry will increase as new legislation for controlling non-point source discharges and nutrient management is put into place in Manitoba and across Canada.