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CONSTRUCTED WETLANDS FOR TERTIARY TREATMENT OF DOMESTIC WASTEWATER AND CREATION OF WILDLIFE HABITAT

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ABSTRACT

Hundreds of constructed wetlands for the treatment of wastewater have been built in Europe and the United States. The benefits and function of these wetlands as wastewater treatment systems have been documented in numerous books, and symposia, as well as hundreds of peer-reviewed scientific papers. A new, value-added approach is to design constructed wetlands to optimize their wastewater treatment efficiency and value as wildlife habitat.

Construction of two wetlands at River Hebert River, Nova Scotia, Canada was completed in October, 1994. The purpose of these wetlands is to create wildlife habitat and treat domestic wastewater that is currently being discharged from a primary/secondary aerated lagoon system. Segment 1 is a 1.9 ha highly engineered wetland that has two internal berms to maximize retention time. The bottom of this wetland has been cleared of all vegetation and graded level. Segment 2 is a 6.5 ha wetland that has a morphology similar to natural wetlands. There is slight variation in the elevation of the wetland, with deeper areas created during the excavation of materials to build the external dikes and nesting islands.

The objectives of this study is to evaluate the cost-effectiveness of the two wetland designs in treating wastewater and providing wildlife habitat. It is planned for water chemistry, primary productivity, and wildlife use of the constructed wetlands to be monitored over the next 10 years.

INTRODUCTION

The use of free-surface-water constructed wetlands has gained much attention during the last decade because of their ability to offer a low-cost alternative to traditional sewage treatment systems (Hammer, 1989; Moshiri 1993). Many wetlands in Atlantic Canada are oligotrophic and this lack of available nutrients results in low levels of primary and secondary productivity as well as waterfowl use (Kerekes *et al.* 1986, Underwood *et al.* 1986, Bateman *et al.* 1994). Wetlands that receive anthropogenic nutrients are known to have increased primary productivity and wildlife use (Melanson and Payne 1988). In fact, some of the highest waterfowl densities observed in Atlantic Canada have been on sewage lagoons or wetlands receiving effluent discharged from sewage systems (Stacier *et al.* 1994). The basis for this project is the philosophy that domestic sewage is an under-utilized resource containing valuable nutrients and where possible we should construct wetlands instead of sewage lagoons.

Atlantic Canada is characterized by many small towns (<5,000 people), widely dispersed along the coast or inland water systems. Because of the small tax base and easy disposal of effluent, many communities have no sewage treatment facilities or facilities that do not provide adequate levels of sewage treatment. With population growth and an increased understanding of how sewage effluent affects water quality and the environment, there is growing pressure for the development of sewage treatment facilities. The harvesting of shellfish such as soft-shelled clams (*Mya arenaria*), and blue mussels (*Mytilus edilus*) are an economically important industry, but increasingly, shellfish areas are being closed due to bacterial contamination. Moreover, the discharge of effluent with high nutrient levels and biological oxygen demand creates conditions unfavourable to salmonids. Angling for brook trout (*Salvelinus fontinalis*) and Atlantic salmon (*Salmo salar*) is an important recreational activity and a key component of the tourism and guiding industries. Thus, there is an economic as well as environmental benefit of sewage treatment.

The majority of existing sewage treatment facilities in Atlantic Canada consist of aerated primary and secondary lagoon systems. These facilities are relatively efficient at reducing suspended solids and biological oxygen demand but the effluent can still remain high in nutrients. These high levels of nutrients can be responsible for eutrophication and subsequent undesirable algal blooms in the receiving waters.

Constructed wetlands and natural wetlands have the same nutrient cycles, mechanisms and rates (see Moshiri, 1993). Wetlands develop unique floral and faunal communities in response to high levels of nutrient availability. The majority of existing constructed wetlands have been designed to maximize their sewage treatment efficiency and minimize their size (Knight *et al.* 1993). This maximization of efficiency per unit area of wetland results in highly engineered wetlands with high construction costs. Wetlands were constructed at River Hebert River to optimize their efficiency of wastewater treatment and optimize their suitability as wetland habitat. The objectives of this study are to evaluate the cost-effectiveness of constructed wetland designs in treating wastewater and providing wildlife habitat. This evaluation includes determining the relative merits of a highly engineered internal berm constructed wetland compared to a constructed wetland with a natural morphology. It is planned for water chemistry, primary productivity, and wildlife use of the constructed wetlands to be monitored over the next 10 years.

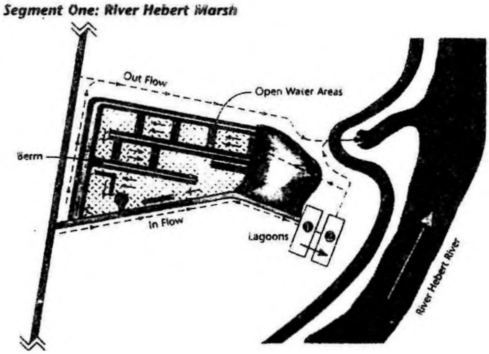
METHODS

Study Site

River Hebert River, Nova Scotia, Canada (45° 41' 45"N, 64° 22'45" W) was chosen as the site for construction of wetlands. Existing sewage treatment facilities consist of primary and secondary aerated lagoons with no chlorination. The sewage treatment facilities are built on land reclaimed from tidal river, and the underlying Acadian Soils are of marine silt origin and water impermeable. The sewage system at River Hebert River treats 250 m^3 of water per day. The sewage system services 1100 people and is primarily domestic wastewater, with no stormwater or industrial wastewater going into the system. Constructed wetlands clean wastewater by transferring material into the sediments, atmosphere, or biota. Therefore the use of constructed wetlands for wastewater treatment and creation of wildlife habitat should only be promoted when the sewage does not contain heavy metals, PAHs, OCs, or other deleterious substances. As part of this program, a public awareness campaign was initiated to make residents more aware of the environmental consequences of improper disposal of hazardous household materials.

Wetland Design

Two wetlands were constructed at River Hebert River to treat wastewater (**Figure 1**).



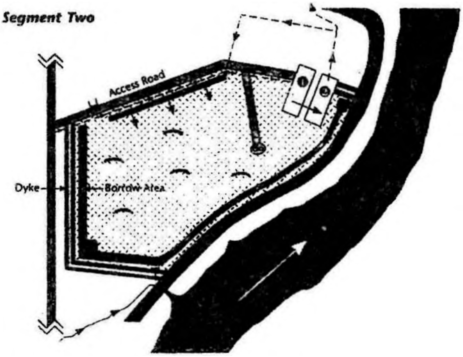


Figure 1: Constructed wetlands at River Hebert River consist of two segments. After being treated in a primary/secondary aerated lagoon, wastewater can be treated in either Segment 1 or Segment 2. Internal berms and deep water areas were constructed in Segment 1, while Segment 2 had crescent shaped nesting islands, a loafing bar and an internal perimeter ditch constructed.

The size of the constructed wetlands were determined by the availability of land and construction techniques. Data collected on flow rates, precipitation, and evapotranspiration were used to determine hydraulic loading rates and retention time in these wetlands. Hydraulic loading rates and data collected on effluent quality were used in models which predict removal performance (e.g. Knight *et al.* 1993). These models predicted that very good removal efficiencies would be obtained in both wetlands. The primary design objective of the constructed wetland is that it meets water quality discharge guidelines. After this objective has been met, then the fact that larger wetlands create more wildlife habitat, and other wildlife habitat considerations should be incorporated into the design. Designing a wetland that is larger than required to meet current loading rates also gives improved water quality and the ability to maintain discharge quality even if loading rates increase in the future.

Segment 1 is 1.9 ha in size and highly engineered. Internal berms in the wetland ensure that the effluent must travel the entire area of the wetland and thus retention time is maximized. Deep water zones were created by digging ditches 0.6 m deep, 10 m wide, perpendicular to water flow, approximately 37 m apart. Alternate areas of shallow water (0.6 m) and deep open water (1.2 m deep), decreases channelization and increases retention time. Nitrogen removal is increased because the marsh contains both deep water 'anaerobic zones in addition to the aerobic shallow water conditions that exist throughout the marsh. All vegetation was removed from Segment 1 and the bottom of the marsh graded to within 3 cm of design specifications. Cattail (*Typha latifolia*) and wildrice (*Zizania aquatica*) seeds were sowed, and water from a nearby freshwater marsh was added to expedite the colonization of submergents. There are two water control structures in this wetland, giving the capability to discharge water into the River Hebert River River or into Segment 2. All water control structures are fabricated off-site, and are constructed of concrete with steel I-beams as guides for planks which act as the dam. By varying the number and dimensions of the planks, the water levels in the wetland can be manipulated or the marsh completely drained.

Segment 2 is a 6.5 ha wetland designed to minimize construction costs while maximizing the amount of wetland habitat created. Dikes were constructed around the wetland with material obtained from the excavation of internal borrow pits. A shallow header ditch 0.6 m deep was excavated along the western side of the wetland originating at the sewage inflow point. This ditch gradually broadens from 1.3 m wide to 4 m wide at its terminus. The header ditch is designed to evenly distribute the sewage influent throughout the marsh and thereby increase retention time. Crescent shaped nesting islands, aligned to provide a lee against prevailing winds were constructed, and Tree-swallow (*Tachycineta bicolor*) and Wood Duck (*Aix sponsa*) nest boxes erected.

A determination of the relative merits of the two wetland designs will incorporate a cost analysis. Construction of internal berms in Segment 1 added substantially to construction costs ($62,000) when compared to the larger Segment 2 ($32,000). Land costs were minimal with Segment 1 costing $3,000 and Segment 2 costing $8,000.

Sampling Protocol

i) Hydrology

The volume of wastewater entering the system is determined using data obtained at the lift station located at the base of the access road. Sewage is pumped from the collection well to the primary lagoon. Having determined the volume of sewage pumped per unit time, the amount of sewage entering the system will be determined based on the amount of time the pump has been in operation. Evapotranspiration, precipitation and other climactic data will be obtained from an Environment Canada weather station located 10 km away, which is also situated adjacent to a tidal river. Water discharge from the constructed wetlands will be monitored by measuring the water level of the marsh. Discharge curves will be calculated based on the volume of water being discharged from the water control structure in relation to water levels.

ii) Water Chemistry

Water samples have been collected weekly at the outflow of the secondary lagoon to determine the level of treatment of the existing lagoon system as well as temporal variability. Water samples were analyzed for: ionic constituents (specific conductance, alkalinity, pH, dissolved sodium, dissolved magnesium, silicate, sulphate, chloride, dissolved potassium, dissolved calcium); nutrients (nitrate, total nitrogen, inorganic phosphorous, soluble reactive phosphorous, total phosphorous, dissolved organic carbon); metals (aluminum, arsenic, barium, beryllium, calcium, cadmium, cobalt, chromium, copper, iron, magnesium, manganese, nickel, lead, strontium, vanadium, and zinc); common wastewater parameters (suspended solids, biological oxygen demand, faecal coliform bacteria, total coliform bacteria); and toxics (PAHs, PCBs, Ocs) Once the constructed wetland begins treating wastewater in the summer of 1996, water samples will be collected at the inflow and outflow. Water samples will be analyzed for the water chemistry parameters already listed as well as phytoplankton abundance (chlorophyll-a concentrations). On site measurements of dissolved oxygen, conductivity, and pH will also be taken.

(iii) Sediments

Sediments were collected from the constructed wetlands in October 1994 and analyzed for toxics (PAHs, PCBs, and Ocs), metals (aluminum, arsenic, barium, beryllium, cadmium, cobalt, chromium, copper, iron, magnesium, manganese, nickel, lead, strontium, vanadium, and zinc); nutrients (total nitrogen, total phosphorous, potassium, calcium), conductivity, pH, cation exchange capacity, and soil particle size. Sediments will be again sampled in 1997. Redox potential of the sediments will also be measured in the field beginning in 1996.

Wildlife

Waterbird use of the wetlands will be measured by conducting hour long bird counts from elevated viewing platforms. Muskrat use of the wetland will be estimated based on the number of lodges observed. Muskrat carcasses were obtained through a local trapper from the lagoons and ditches that carried effluent from the lagoon to River Hebert River. River muskrats were also collected from wetlands in the area not exposed to sewage effluent. General nescropsies were performed and tissues will be analyzed for metal and toxin levels. Muskrats and fish will also be collected in the future to determine risk to wildlife from exposure to sewage effluent.

RESULTS AND DISCUSSION

Evaluating the treatment efficiency and wildlife use of the constructed wetlands will begin during the summer of 1996.

The use of constructed wetlands for the treatment of wastewater gained public attention and acceptance because it is a cost-effective alternative to traditional wastewater treatment facilities. Constructed wetlands are land intensive and rely on natural wetland organisms and processes to treat wastewater. Conventional systems are resource ($$) intensive, because they are constructed of steel and cement and require electricity and chemicals to operate. It is of paramount importance that the system adequately treat the wastewater and meet legislated standards of treatment. Constructed wetlands can not make heavy metals or toxic chemicals disappear, rather they are buried in the sediment or incorporated into the food chain. Therefore the use of constructed wetlands should be promoted for domestic sewage only, i.e. wastewater that is high in faecal matter and low in solvents, heavy metals, or other toxic chemicals. Constructed wetlands will operate more efficiently and have lower maintenance costs if they are associated with a primary lagoon system.

Although this project has only recently been established, considerable interest has been expressed by wildlife agencies, municipalities, and environmental agencies. Because of the benefits to many sectors, cost-sharing relationships can offer financial impetus towards the construction of wetlands for treatment of sewage and creation of wildlife habitat. We encourage other groups to promote the multi-resource benefits of using constructed wetlands to treat domestic wastewater and create wildlife habitat.

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