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United States
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Constructed Wetlands for Wastewater Treatment and Wildlife Habitat

17 Case Studies

Wetland

The symbol on the cover of this report was developed in Washington State by a group of state and federal agencies working in cooperation with a private real estate firm, Port Blakely Mill Company. It is available free of charge for use in any program dealing with wetland preservation and enhancement. To date, organizations in 33 states are using the symbol. For more information, contact:

Ellin Spenser
Port Blakely Mill Company
151 Madrone Lane
North Bainbridge Island, WA 98110

or call (206) 842-3088.

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The operational experience and research results reported in the available literature suggest that the growing interest in the use of constructed wetlands as a part of water treatment offers considerable opportunity for realizing sizable future savings in wastewater treatment costs for small communities and for upgrading even large treatment facilities.

Robert A. Gearheart; Humbolt State University

Arcata, CA

Jon C. Dyer,
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Jackson Bottom Wetlands Preserve

In addition, insights on the habitat value and wildlife usage of many of the facilities described were provided by field data collected and summarized by the EPA Environmental Research Lab., Corvallis, OR, in cooperation with ManTech Environmental Technology Inc.; the Cooperative Fish & Wildlife Research Unit, Dept. of Wildlife & Range Sciences, University. of Florida-Gainesville; and the Nevada Department of Wildlife.

The case studies were not subject to the Agency's peer and administrative review. Mention of specific case studies does not constitute endorsement or categorical recommendation for use by the U.S. EPA. While EPA believes that the case studies may be very useful to the reader, EPA does not select or endorse one alternative technology over other approaches to treat or reuse wastewater effluents.

Foreword

Extensive research efforts have provided considerable insight into the design, operation and performance of natural and constructed wetlands treatment systems.

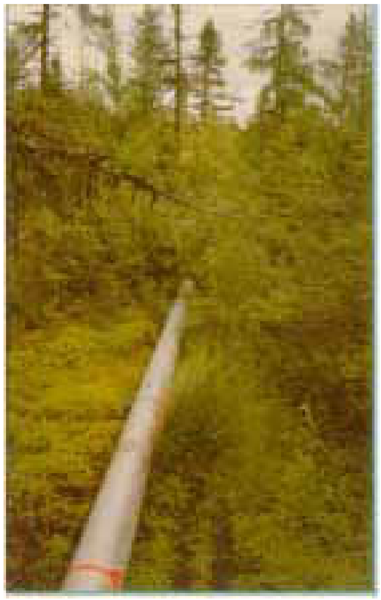
Wastewater treatment is a problem that has plagued man ever since he discovered that discharging his wastes into surface waters can lead to many additional environmental problems. The Clean Water Act (P.L.92-500 passed in 1972 and its more recent amendments) led to the construction of many new wastewater treatment facilities across the country to help control water pollution. In the future add-on processes will be needed to upgrade many of these treatment facilities. In addition, more attention will need to be given to controlling the many small volume, point sources as well as the numerous non-point sources of water pollution if the water quality objectives of the Clean Water Act are ever to be fully realized.

Intensive studies carried out for over 5 years at Santee, CA, evaluated the performance of constructed wetlands experimental units planted with reeds, cattails, and bulrush..

Today, a wide range of treatment technologies are available for use in our efforts to restore and maintain the chemical, physical, and biological integrity of the nation's waters. During the past 20 years, considerable interest has been expressed in the potential use of a variety of natural biological systems to help purify water in a controlled manner. These natural biological treatment systems include various forms of ponds, land treatment and wetlands systems. As a result of both extensive research efforts and practical application of these technologies, considerable insight has been gained into their design, performance, operation and maintenance. Much of this experience has been summarized in project summaries, research reports, technical papers and design guidance.

Some of the earliest investigations to explore the capabilities of various wetland and other aquatic plant systems to help treat wastewater were undertaken in various European countries by Seidel, Kickuth, de Jong and others. Related studies were eventually undertaken by Spangler, Sloey, Small, Gersberg, Goldman, Dinges, Wolverton, Reddy, Richardson and others in numerous locations across the U.S.

Kadlec, Odum and Ewel, Valiela, Teal, and others have undertaken long-term assessments of the capabilities of several types of natural wetlands to handle wastewater additions. Funding provided by the National Science Foundation, U.S. Department of the Interior, National Aeronautics and Space Administration, Environmental Protection Agency, U.S. Army Corps of Engineers, U.S. Department of Agriculture and others has played an important role in stimulating the development of the available information and guidance on constructed wetland treatment systems in the U.S.



Long-term observations and studies of northern wetlands receiving wastewater effluents have followed the impact of changes in nutrient loadings and hydrology on vegetation and wildlife use at projects such as the Drummond Bog in Northern Wisconsin.

The operational experience and research results reported in the available literature suggest that the growing interest in the use of constructed wetlands as a part of water treatment offers considerable opportunity for realizing sizable future savings in wastewater treatment costs for small communities and for upgrading even large treatment facilities. At the same time, as is demonstrated by the 17 wetland treatment system case studies located in 10 states that are presented in this document, these systems can provide valuable wetland habitat for waterfowl and other wildlife, as well as areas for public education and recreation. Clearly such systems create an opportunity to contribute to the Nation's efforts to restore, maintain and create valuable wetland habitat.

Michael B. Cook, Director
Office of Wastewater Management

Robert H. Wayland III, Director
Office of Wetlands, Oceans, and Watersheds

Constructed wetlands are being effectively used to help protect the quality of urban lakes by improving the quality of stormwater runoff in urban areas such as at the Greenwood Urban Wetland, a former dump site, in Orlando, Florida.

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Introduction

The potential for achieving improved water quality while creating valuable wildlife habitat has lead to a growing interest in the use of constructed wetlands for treating and recycling wastewater. While land intensive, these systems offer an effective means of integrating wastewater treatment and resource enhancement, often at a cost that is competitive with conventional wastewater treatment alternatives. This document provides brief descriptions of 17 wetland treatment systems from across the country that are providing significant water quality benefits while demonstrating additional benefits such as wildlife habitat. The projects described include systems involving both constructed and natural wetlands, habitat creation and restoration, and the improvement of municipal effluent, urban stormwater and river water quality. Each project description was developed by individuals directly involved with or very familiar with the project in a format that could also be used as a stand-alone brochure or handout for project visitors.

Many of the same values associated with natural wetlands can also be realized by wetlands constructed for wastewater polishing.

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Background

In the Southeast alone, over 500 natural wetlands such as this cyprus strand in Florida receive discharges from POTWs and other point sources.

Natural wetlands (e.g., swamps, bogs, marshes, fens, sloughs, etc.) are being recognized as providing many benefits, including: food and habitat for wildlife; water quality improvement; flood protection; shoreline erosion control; and opportunities for recreation and aesthetic appreciation. Many of these same benefits have been realized by projects across the country that involve the use of wetlands in wastewater treatment.

Many freshwater, brackish, and saltwater wetlands have inadvertently received polluted runoff and served as natural water treatment systems for centuries. Wetlands, as waters of the U.S., have been subjected to wastewater discharges from municipal, industrial and agricultural sources, and have received agricultural and surface mine runoff, irrigation return flows, urban stormwater discharges, leachates, and other sources of water pollution. The actual impacts of such inputs on different wetlands has been quite variable.

However, it has only been during the past few decades that the planned use of wetlands for meeting wastewater treatment and water quality objectives has been seriously studied and implemented in a controlled manner. The functional role of wetlands in improving water quality has been a compelling argument for the preservation of natural wetlands and in recent years the construction of wetlands systems for wastewater treatment. A growing number of studies have provided evidence that many wetlands systems are able to provide an effective means of improving water quality without creating problems for wildlife. However, in some cases evidence has shown a resulting change in wetland community types and a shift to more opportunistic species.

There remain, however, concerns over the possibility of harmful effects resulting from toxic materials and pathogens that may be present in many wastewater sources. Also, there are concerns that there may be a potential for long-term degradation of natural wetlands due to the addition of nutrients and changes in the natural hydrologic conditions influencing these systems. At least in part due to such concerns, there has been a growing interest in the use of constructed wetlands for wastewater treatment.

Constructed wetlands treatment systems are engineered systems that have been designed and constructed to utilize the natural processes involving wetland vegetation, soils, and their associated microbial assemblages to assist in treating wastewater. They are designed to take advantage of many of the same processes that occur in natural wetlands, but do so within a more controlled environment. Some of these systems have been designed and operated with the sole purpose of treating wastewater, while others have been implemented with multiple-use objectives in mind, such as using treated wastewater effluent as a water source for the creation and restoration of wetland habitat for wildlife use and environmental enhancement.

A recently expanded Subsurface Flow constructed wetland system serves the small community of Monterey in Highland Co., Virginia.

Constructed wetlands treatment systems generally fall into one of two general categories: **Subsurface Flow Systems** and **Free Water Surface Systems**. Subsurface Flow Systems are designed to create subsurface flow through a permeable medium, keeping the water being treated below the surface, thereby helping to avoid the development of odors and other nuisance problems. Such systems have also been referred to as "root-zone systems," "rock-reed-filters," and "vegetated submerged bed systems." The media used (typically soil, sand, gravel or crushed rock) greatly affect the hydraulics of the system. Free Water Surface Systems, on the other hand, are designed to simulate natural wetlands, with the water flowing over the soil surface at shallow depths. Both types of wetlands treatment systems typically are constructed in basins or channels with a natural or constructed subsurface barrier to limit seepage.

Constructed wetlands treatment systems have diverse applications and are found across the country and around the world. While they can be designed to accomplish a variety of treatment objectives, for the most part, Subsurface Flow Systems are designed and operated in a manner that provides limited opportunity for benefits other than water quality improvement. On the other hand, Free Water Surface Systems are frequently designed to maximize wetland habitat values and reuse opportunities, while providing water quality improvement.

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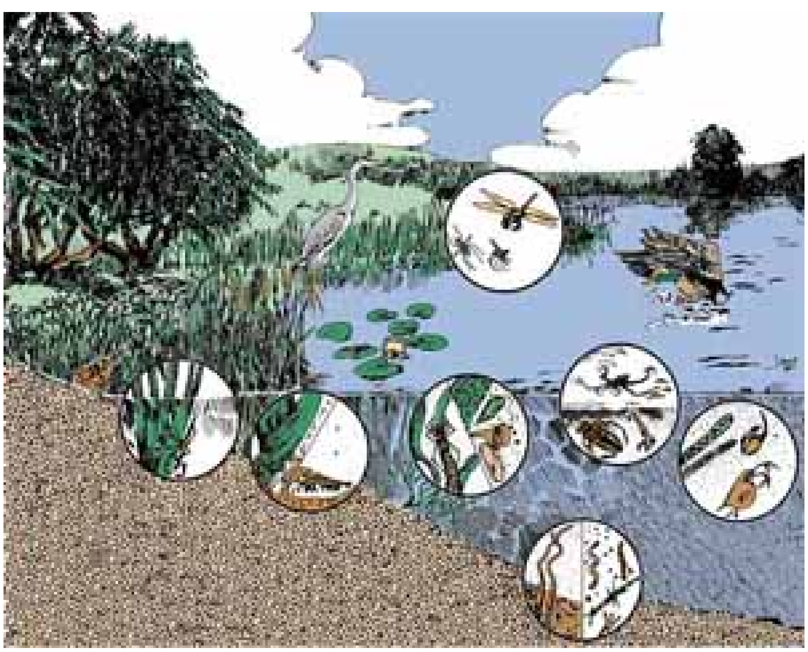
Free Water Surface Constructed Wetlands Systems

"The wide diversity of organisms coupled with the high level of productivity makes a marsh a hot bed of biological activity. The most striking improvement is the removal of suspended solids. Suspended solids in the Arcata STP are algae which supply oxygen in their secondary treatment ponds. These algae solids become entrapped, impacted, and isolated in small quiescent areas around the stems and underwater portions of aquatic plants as the water moves through marshes. The algal solids in these quiescent areas become food sources for microscopic aquatic animals and aquatic insects. This predation plays an important part in removing the solids and in moving energy through the food chain in the wetland. Over time, wetlands continue to separate and deposit suspended solids building deltas comprised of organic matter. At some point this detrital layer in the bottom of the marsh along with dead aquatic plants may need to be removed. Based on Arcata's experience this maintenance requirement is not expected until at least 8-10 years of operation at design loads."

Just how do constructed wetlands, in this case free water surface systems, remove pollutants from the wastewater effluent? These systems affect water quality through a variety of natural processes that occur in wetlands. An explanation of the major processes involved are effectively described by Robert A. Gearheart in a paper contained in the proceedings of a conference on wetlands for wastewater treatment and resource enhancement at Humbolt State University in Arcata, CA, during 1988 [1]:



Dissolved biodegradable material is removed from the wastewater by decomposing microorganisms which are living on the exposed surfaces of the aquatic plants and soils. Decomposers such as bacteria, fungi, and actinomycetes are active in any wetland by breaking down this dissolved and particulate organic material to carbon dioxide and water. This active decomposition in the wetland produces final effluents with a characteristic low dissolved oxygen level with low pH in the water. The effluent from a constructed wetland usually has a low BOD as a result of this high level of decomposition.

Aquatic plants play an important part in supporting these removal processes. Certain aquatic plants pump atmospheric oxygen into their submerged stems, roots, and tubers. Oxygen is then utilized by the microbial decomposers attached to the aquatic plants below the level of the water. Plants also play an active role in taking up nitrogen, phosphorus, and other compounds from the wastewater. This active incorporation of nitrogen and phosphorus can be one mechanism for nutrient removal in a wetland. Some of the nitrogen and phosphorus is released back into the water as the plants die and decompose. In the case of nitrogen much of the nitrate nitrogen can be converted to nitrogen gas through denitrification processes in the wetland."

Free Water Surface constructed wetlands treatment systems and related natural systems used as a part of treatment systems have been successfully used across the country. Many of these systems have been designed and operated to not only improve water quality, but to also provide high quality wetland habitat for waterfowl and other wildlife. Many of the systems are operated as wildlife refuges or parks as well as a part of wastewater treatment, reuse or disposal systems. In some cases these systems also provide an area for public education and recreation in the form of birding, hiking, camping, hunting, etc.

U.S. Bureau of Reclamation/Eastern Municipal Water District Wetlands Research Facility, San Jacinto, California. This site is a popular spot for local schools to tour and study wetlands ecology. One of the multi-purpose elements of the project is public education and recreation.

The operational experience and research results reported to date suggest that the growing interest in managing constructed wetlands systems as a part of wastewater treatment and habitat creation/maintenance efforts offers considerable opportunities for the future. The technical feasibility of implementing such projects has been clearly demonstrated by full-scale systems in various parts of the country. However, it is also clear that there is still a long way to go before such systems will be considered for routine use. While existing projects have demonstrated the potential for future use of constructed wetlands systems, there is an obvious need for further study to improve our understanding of the internal components of these systems, their responses and interactions, in order to allow for more optimum project design, operation and maintenance.

[1] *Allen, G.H. and R.A. Gearheart (eds.). 1988. Proceedings of a Conference on Wetlands for Wastewater Treatment and Resource Enhancement. Humbolt State Univ., Arcata, CA.*

Case Studies

Descriptions of 17 carefully selected projects located in 10 states (see Figure 1) are provided that help describe the full range of opportunity to treat and reuse wastewater effluents that exist across the country today. They include systems involving both constructed and natural wetlands, habitat creation and restoration, and the improvement of municipal wastewater effluents, urban stormwater and river water quality. Many of the projects received Construction Grants funding and several were built on Federal lands. All experience extensive wildlife usage, some providing critical refuge for rare plants and animals. Several are relatively new projects while others have been operating for 15-20 years. There are projects involving as few as 15 acres and several with more than 1,200 acres of wetland habitat. Among those described in this document are projects which have received major awards such as the ASCE Award of Engineering Excellence, the ACEC Grand Conceptor Award, and the Council Award, the ESA Special Recognition Award, and the Ford Foundation Award for Innovation in a Local Government Project.

The case studies demonstrate that wastewater can be effectively treated, reused and recycled with free water surface wetland systems in an environmentally sensitive way. They also demonstrate that wastewater treatment and disposal can be effectively integrated into recreational, educational, and wildlife habitat creation/wetland restoration efforts so as to enhance the value of a city’s capital investment in wastewater treatment facilities. Greater recognition of these model projects may help lead to projects of high quality being developed in the future.

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Bottles with representative samples (taken from the influent [on left] to final [on right] sample stations) from the Houghton Lake, MI, wetland treatment system which has been in operation since 1978.