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EC 1408
Reprinted June 1993

Using Constructed Wetlands to Improve Water Quality

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Marsh, bog, swamp, slough, fen—these are just a few of the names commonly applied to the class of natural habitats called "wetlands." Broadly defined, wetlands are land areas that have prolonged high water tables or are at least covered with shallow water. As a transition habitat between dry land and a deep water environment, they support plants specially adapted to grow in alternating wet and dry conditions.

Historically, wetlands have not made good farm land. For this reason, people viewed wetlands negatively and systematically removed them from large portions of the United States.

Research now shows that wetlands are highly productive ecosystems that support vigorous plant growth and a broad variety of animal life.

Wetlands also improve the quality of water that flows through them by filtering out impurities, actively degrading waste matter, and removing some chemicals that flow from upstream. The discovery of this attribute led to the idea of intentionally using wetlands to treat wastewater.

At first, individuals and cities did not build special wetlands to treat wastewater. They dumped treated or untreated wastewater into local downstream natural wetlands to improve wastewater quality.

In some cases, the wetland environment became overloaded with waste materials and was seriously degraded. Later, cities intentionally built wetlands to treat municipal wastewater. As others recognized the advantages of this method, the applications broadened.

Now, constructed wetlands treat acid mine drainage, pulp mill wastewater, swine waste, poultry rendering wastes, landfill leachate, urban runoff, textile wastewater, and effluent from the photography industry.

While no long term research studies have been made to determine how efficient wetlands are at treating these types of wastewater, most users find that constructed wetlands are an efficient, cost-effective way of removing pollutants.

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Figure 1.—*Concrete control boxes (foreground) regulate flow rate and water depth in constructed wetlands*

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How wetlands treat wastewater

Wetlands incorporate physical, biological, and chemical processes to treat wastewater. The water flows in and slows down as it spreads across the wetland surface. This slowing of the flow allows soil and sediment particles to filter or physically settle out.

This process also removes nutrients such as phosphorous and chemicals that are attached to the sediments. Biological and chemical treatment processes transform materials rather than just physically remove them.

Constructed wetlands maximize treatment by ensuring slow flow rates, and plants provide lots of surface area. Plant stems and roots provide surface areas that support communities of microorganisms, which use some of the nutrients and organic matter carried in the runoff water.

For example, microbe communities on plant stems convert organic nitrogen to the inorganic ammonium nitrogen form. Other biological treatments involve plant uptake of nutrients such as nitrates and phosphates.

Chemical treatment occurs when incoming compounds react with oxygen or soil minerals in the wetland. The rate and extent of these reactions is influenced by the wetland acidity and other environmental factors.

For example, if the wetland has high concentrations of ferrous iron, a chemical transformation can occur between the iron and incoming sulfides, forming insoluble ferrous sulfide, which settles to the bottom of the wetland.

The soil characteristics of wetland systems that make them particularly productive are also partly responsible for the highly efficient way in which they treat water. Specifically, it is the layering of an oxygen-containing (aerobic) soil above a layer without oxygen (anaerobic) that supports much of these degradation and transformation processes.

Plant roots anchored in the anaerobic environment below the water surface exude oxygen in a layer surrounding the plant's root hairs. This layer, a very large area indeed, is called the rhizosphere and is where much biological and chemical activity occurs.

It provides an environment for a wide range of oxygen-using aquatic organisms, some of which directly or indirectly use additional nutrients in the runoff water. The interface between the aerobic and anaerobic layers allows many complex reactions to occur.

All of these treatment processes work simultaneously, so that by the time water flows out of the wetland, the water's nitrate, phosphorus, sulfur, and bacterial content can be greatly reduced. A variety of other water pollutants can usually be reduced in constructed wetlands through these same processes.

The specifics depend on the characteristics of the wastewater delivered to the wetland and the amount of time spent in the wetland system.

Development and design considerations

Constructed wetlands generally fall into one of two categories:

Free water surface wetlands are the most common. They consist of the following:

- basins or channels with natural or constructed subsurface barriers of clay or impervious material to prevent seepage;
- soil or another suitable medium to support the emerging vegetation; and
- wastewater flowing slowly over the soil surface at a relatively shallow water depth.

The second type is called a *subsurface flow system*. This system consists of a trench or bed, at the bottom of which is an impenetrable layer of clay or a plastic liner. The bed contains rocks or other material that can support the growth of new vegetation. Wastewater flows about 6 to 12 inches below the bed surface. The local geology and soil conditions must be investigated before developing a design.

The rainfall, ground water conditions, and water flow patterns for all seasons of the year influence the design. Local climate, such as maximum and minimum temperature, will affect biological activity and treatment efficiency. During the development of the system, the wetland operating depth, flow rate, and how long the wastewater must stay in the wetland for proper treatment all influence the final design.

Wastewater can contain such pollutants as nitrogen compounds, phosphorus compounds, sulfates, heavy metals, complex organic compounds, and pathogenic bacteria and viruses. From some industries, the concentration of some of these materials can be toxic and could damage the very wetland plants and microbial communities that help treat the water, so it is important to monitor closely the effects of such toxins.

A wetland treatment system will fail if it is loaded with heavy solids or wastewater with high amounts of organic matter. When these materials are

Figure 2.—*Constructed wetlands commonly use earthen dikes to control flow of effluent and treatment time.*

present, the wastewater is usually pretreated at another facility.

Constructed wetlands are typically the second or third stage in wastewater treatment. Depending on what the wastewater contains and how well it is pretreated, a well-designed wetland treatment system can remove 95 percent of the original organic matter and suspended solids concentrations and produce an effluent that can be discharged to a nearby stream.

Considerations when constructing wetlands

Before construction ever starts, planners look at the area's land use. They consider whether a constructed wetland will fit into the setting in this part of the community while still providing efficient treatment with low maintenance requirements. Wetlands can require large land areas. Fitting a constructed wetland into the local slope and lay of the land can influence physical configuration options. Questions about such nuisances as potential odors and mosquitoes also must be discussed.

Wetland developers have learned that public perceptions can play a key role in whether or not a wetland wastewater treatment system is ever built. With that in mind, they often dedicate their efforts to keeping the public informed of the many benefits a constructed wetland can have for a community.

Developers often make plans to add aesthetic and recreational opportunities so the public can enjoy constructed wetlands. Such features can lead to an enthusiastic welcome from the local community; a valuable asset that goes a long way toward helping the proposed wetland gain the necessary permits and municipal approval.

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Other benefits

Depending on the design, constructed wetlands can provide many benefits in addition to their water treatment capacity. One potential benefit is the increase in wetland wildlife habitat, but more research is necessary to determine whether constructed wetlands are good for all wildlife. Some industrial and municipal wastewater could contain levels of organic and inorganic chemicals that may be harmful to animals, fish, or birds attracted to a particular wetland area.

On-site studies to determine the impact of constructed wetlands on wildlife can also provide valuable information about how wetlands work generally and about how plant and animal species interact in a wetland environment. This would add to the limited knowledge available about these unique ecosystems.

While wetlands are primarily built to treat wastewater, there are good opportunities for nature education as well. Scientists and the general public can both benefit from access to wetland environments, especially if boardwalks are built, and tour guides and self-guided interpretive trails or other aids are available.

Constructed wetlands also present some interesting recreational opportunities such as hiking, biking, and horseback riding, and, depending on the water depth and quality, even boating and canoeing.

The Future

Constructed wetlands are an exciting new application of technology that is very effective at improving water quality. While they don't solve all water quality problems, they hold much promise as a new type of water treatment system that combines low cost and high efficiency. Those attributes alone make them attractive systems, especially to small and medium-sized cities and many industries.

For more information

EC 1407, *Understanding Natural Wetlands*, Single copy, no charge. This publication and the one you're holding, EC 1408, *Using Constructed Wetlands to Improve Water Quality*, are available from: Publications Orders, Agricultural Communications, Oregon State University, Administrative Services A422, Corvallis, OR 97331-2119.

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U.S. Environmental Protection Agency, Office of Research and Development, *Design Manual: Constructed Wetlands and Aquatic Plant Systems for Municipal Wastewater Treatment,* (Cincinnati, OH: Center for Environmental Research Information, September 1988).

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