Engineered Wetlands Lead the Way

by Scott Wallace, P.E., Vice President, North American Wetland Engineering

Introduction

OUR country has not seen residential growth equal to the last decade since the end of the Second World War. At the same time, aging water and sewer infrastructure must be upgraded and replaced, leading to a number of redevelopment challenges. The creation of open space for recreation and wildlife habitat is often a top priority in creating livable, people-friendly communities. Successfully meeting these challenges requires combining the talents of a variety of professionals including engineers, landscape architects, planners, environmental scientists, and contractors.

Engineered wetlands are playing a leading role in the new, "green" infrastructure of the 21st century. As experience with wetlands has grown, new types of wetland systems have been developed. Within the last 30 years, there has been a progression from using natural wetlands to the use of man-made constructed wetland systems. Today, even more highly engineered wetland reactors are being developed. The greater treatment capacity of these "engineered wetlands" expands the application of wetlands to solve environmental problems around the world.

Development of Engineered Wetland Systems

The practice of building sewers in urban areas dates back to about 7,000 BC and it is likely that natural wetlands have been used as receiving waters ever since.

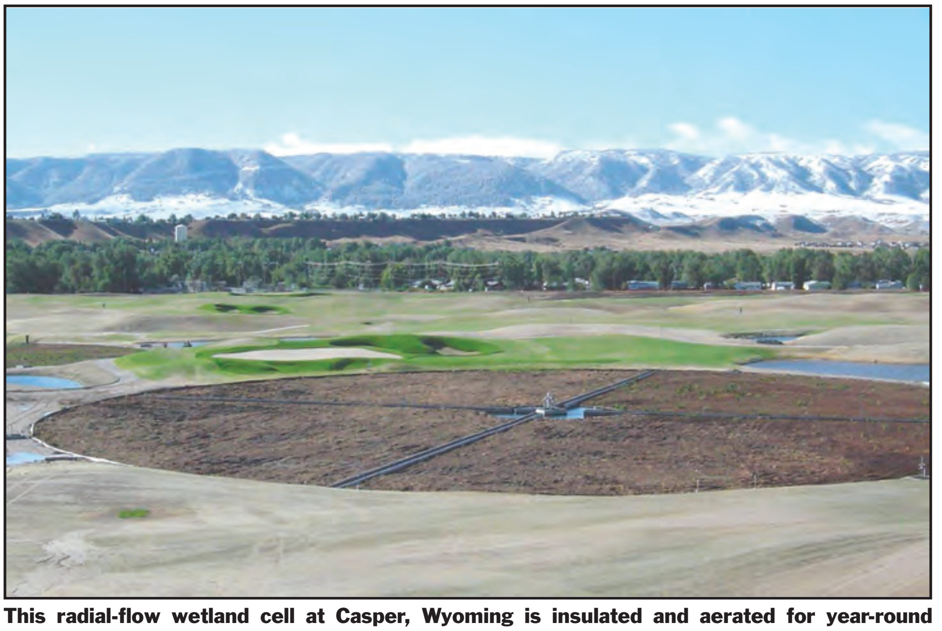
The sewage farming experiences of the 1870s in the United Kingdom led to an appreciation of the link between wastewater application rates, wetland hydrology, plant adaptation, and wastewater purification. It was noted in 1877 that wastewater loadings at about 0.25 m^2 per person per day (2.7 ft^2 per person per day) were sufficient to maintain wastewater application areas as "grass plots."

It is apparent that by 1900, the idea of creating wetlands specifically for wastewater treatment had been developed. An essay to the Hornsby Literary Institute, NSW, Australia in 1904 states in part:

"If every householder disposed of his own drainage on his own premises as he might very well do, the health of all of us would be much improved. Anyone who has a little ground about his house can dispose of his dirty water as follows: Dig up a plot of ground thoroughly to a depth of fifteen to eighteen inches. Cut a channel leading from the kitchen and washhouse into the highest side of the plot and let all the dirty water drain into it. Plant the plot with plants that grow rapidly and require a great deal of water such as Arum Lilies, for instance. The dirty water will be all absorbed by the roots of the plants and a most luxuriant garden will be produced which will defy the hottest weather and will always be green and beautiful. By this means a curse will be transformed into a blessing."

The use of a wetland within a deliberately engineered treatment vessel was documented in a U.S. Patent dating back to 1901.

In 1952, a German scientist, Dr. Kathe Seidel, began investigating the water purification capabilities of bulrush (Schoenoplectus lacustris) grown in artificial rooting environments. Her discoveries gave birth to modern constructed wetlands. In the early 1960s, in collaboration with Dr. Seidel, Dr. Reinhold Kickuth at the University of Göttingen, Germany, developed a wetland treatment process known as the Root Zone Method, which was first used for a full-scale wetland system at Othfresen, Germany in 1972. Interest in these subsurface flow wetlands spread throughout Europe by the mid 1980s. Use of these wetlands expanded dramatically in the United States after the Tennessee Valley Authority published a design manual in 1993 targeted primarily for single-family homes.



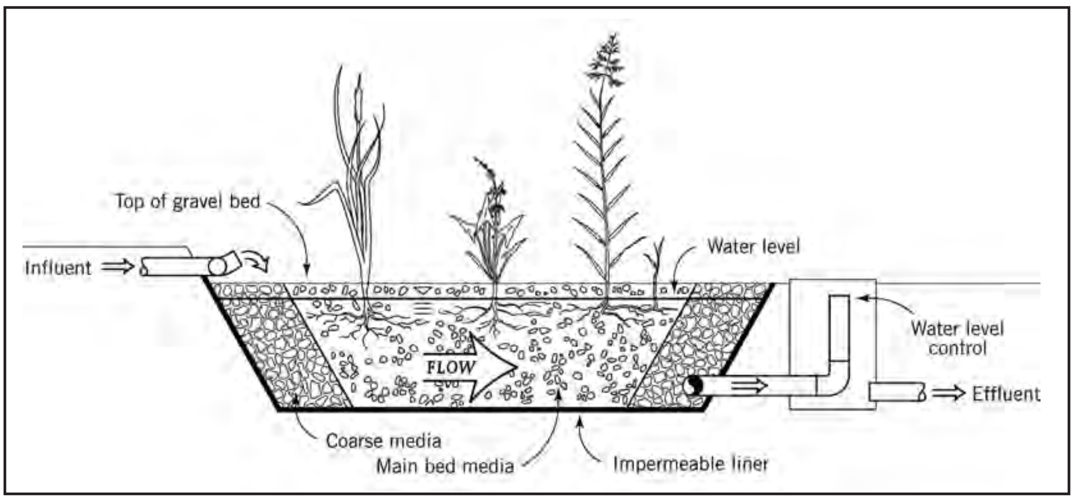
This radial-flow wetland cell at Casper, Wyoming is insulated and aerated for year-round operation at temperatures as low as -35°F. (Photo courtesy of the RETEC Group, Inc.)

Because the water is not exposed during the treatment process, subsurface flow wetlands do not produce mosquitoes or odors. They can be insulated with a mulch layer in areas where winter freezing is a concern. This makes them ideal for residential applications, where the wetland can be combined with a septic tank and soil absorption system.

The primary factor that limits the performance of wetland systems is the availability of oxygen for treatment. This has led to the development of aerated wetland systems. These systems either use a fluctuating water level or distributed aeration to introduce oxygen into the treatment zone. These aerated wetland reactors are far more efficient in removing the pollutants commonly found in residential wastewater. Because they can be insulated, they are suitable for cold-climate applications.

Engineered Wetlands for Residential Development

In many areas of the country, the loss of open space due to suburban sprawl is a growing concern. One solution is the use of "smart growth" platting, where homes are clustered within the development and the remaining area is preserved as permanent open space. By preserving large areas as open space, wildlife habitat can be protected, trails and other recreational amenities can be developed, and environmental impacts from residential developments can be minimized.



However, there are challenges in successfully creating open-space developments. One major challenge is sewer service. In most cases, traditional sewer service (the Big Pipe) requires high-density housing to become cost effective. Because open-space plats preserve large amounts of undeveloped land (often 50% or greater), conventional sewer designs often result in very high per-lot costs. The smaller lot sizes used with open space developments often create problems for individual on-site septic systems. With on-site septic systems, the setbacks required from the property lines, structures, wells and other features, combined with the need for a dedicated back-up area result in space requirements that exceed the desired lot size. The solution is to match the infrastructure to the development density, a concept that in 1997 was termed decentralized wastewater management by the United States Environmental Protection Agency. In the case of open-space developments, that means using community sewer systems.

A classic example of this type of development is Jackson Meadow, a residential development in the City of Marine on St. Croix, Minnesota. The concept for this open space development was created during the course of over 40 meetings between the developer and local officials. The 64-lot development protects over 250 acres of open space. However, the capacity of the city's existing sewer system was limited and sewer service was not available for Jackson Meadow. The smaller lot sizes (resulting from the open space preservation) were not suitable for individual on-site sewage treatment systems. A number of sewage alternatives were explored and the recommended alternative was to construct two engineered wetland systems. The first system was constructed in 1998 to serve the north half of the development. The second wetland was constructed in 2002 to serve the south half of the development. Each wetland system was integrated into the community open space.

The Jackson Meadow development has won numerous awards for its architecture, planning, and environmental protection. Since 1998, Jackson Meadow and other open space developments have created a new paradigm in land use, resulting in over 40 similar developments throughout the Twin Cities area.

Engineered Wetlands for Groundwater Remediation

An engineered wetland system implemented by British Petroleum (BP) in Casper, Wyoming is the largest and most recent remediation wetland in the United States. This treatment system needed to handle up to 3 million gallons per day of gasoline-contaminated groundwater, blend into the middle of a premier golf course, and operate for over 100 years. Although this may sound impossible, this was the challenge presented to the design team.

The site was one of the oldest and largest Amoco refineries in the West, which started operation in 1908. It was the largest refinery in North America during the 1920s and continued operation until 1991. As a result of common operating practices during the first 50 years of operation, much of the site is underlain with residual hydrocarbons. Since 1981, over 9 million gallons of light non-aqueous phase liquids (LNAPL) have been removed from the groundwater. Faced with the rising cost of environmental cleanup, Amoco Oil Company decided to close the refinery in 1993. In 1998, the Wyoming Department of Environmental Quality finalized a Consent Decree establishing the framework for site remediation. Under the Consent Decree, British Petroleum (BP) and the City of Casper agreed to convert the former refinery site into a golf course and office park with a trail system along the North Platte River.

In order to clean up the site, BP negotiated an innovative agreement with the City of Casper. BP would demolish the old refinery structures and convert the property into an 18-hole premier golf course (designed by Robert Trent Jones II) complete with an office park, river front trails, and a whitewater kayak course (designed by Recreation Engineering and Planning).

The problem was the presence of a

The Casper wetlands use a patented aeration process (Forced Bed Aeration™) to achieve extremely uniform air distribution in the wetland cells.

large amount of contaminants below the water table. Maintaining gradient control requires the pumping of groundwater for decades before the contaminants can be adequately removed. Because of the time required for remediation (50 to 100 years), BP became very interested in biological treatment processes due to potential cost savings. Knowing that organic chemicals such as benzene, xylene, and toluene are biodegradable, BP turned toward engineered wetland technology. The engineered wetland system, which was constructed for $3,400,000, eliminated the need for a mechanical plant (air stripping with catalytic oxidation) that was projected to cost $15,900,000.

A pilot plant was built in 2001 to establish site-specific degradation parameters. Full-scale design started in 2002 after extensive permit negotiations with the Wyoming Department of Environmental Quality.

The wetland treatment system designed was based on the results of the pilot system operated at the project site. In order to meet site objectives, the full-scale wetland had to be capable of operating at very high flow rates, and the iron fouling of the subsurface flow wetland media, observed during the pilot operation, had to be addressed. To solve this problem, a cascade aeration system (for iron oxidation) and a surface-flow wetland (for iron precipitation) was added to the system.

The surface flow wetland was designed to allow the precipitation of iron that had oxidized in the cascade. Without iron removal in these wetlands, precipitation would occur in the aerated subsurface flow wetlands, which could conceivably create a fouling problem, given the 100-year operating life of the system.

The subsurface flow wetland was designed using an aeration process (US Patents 6,200,469 and 6,406,627) that accelerates the treatment of BTEX and MTBE compounds in the wetland treatment cells.

To address flow distribution, an innovative radial-flow wetland configuration was adopted. Because the gravel media for the

Casper Reuse Plan. This former refinery site was converted into an office park and 18-hole golf course. The wetland treatment system is an intergel part of the golf course.

wetland was made of crushed concrete recycled from tank foundations, it was possible to tailor the media to provide the needed hydraulic conductivity.

The full-scale system was put on line in May 2003. Since startup, the system has been hydraulically loaded at approximately 700,000 gallons per day.

System performance to date is summarized in Table 1:

Table 1. Casper Engineered Wetland Treatment Performance

Compound	Influent	Cascade Effluent	Wetland Effluent
Benzene, mg/L	0.33	0.15	Non Detect
BTEX, mg/L	0.53	0.26	Non Detect
DRO, mg/L	11.41		Non Detect
GRO, mg/L	2.46	2.02	Non Detect

Conclusions

The cost benefits of engineered wetlands can be summed up in a simple phrase: "Plants and bacteria work for free; people and machines don't."

Because they are a land-based technology, wetlands cannot be used everywhere. However, on sites with adequate space, the benefits of wetlands can create substantial cost savings, especially for systems that have to operate over long periods of time. Wetland systems, through their complex assemblages of plants and bacteria, can provide treatment of recalcitrant, difficult-to-degrade compounds.

New challenges in land development (and redevelopment) are forcing innovative approaches to infrastructure service. By using new, "green" technology, as embodied by engineered wetlands, environmental professionals can continue to solve their client's problems in innovative, creative ways. **L&W**

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