Planning and Zoning News
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USING CONSTRUCTED WETLANDS FOR WASTE TREATMENT

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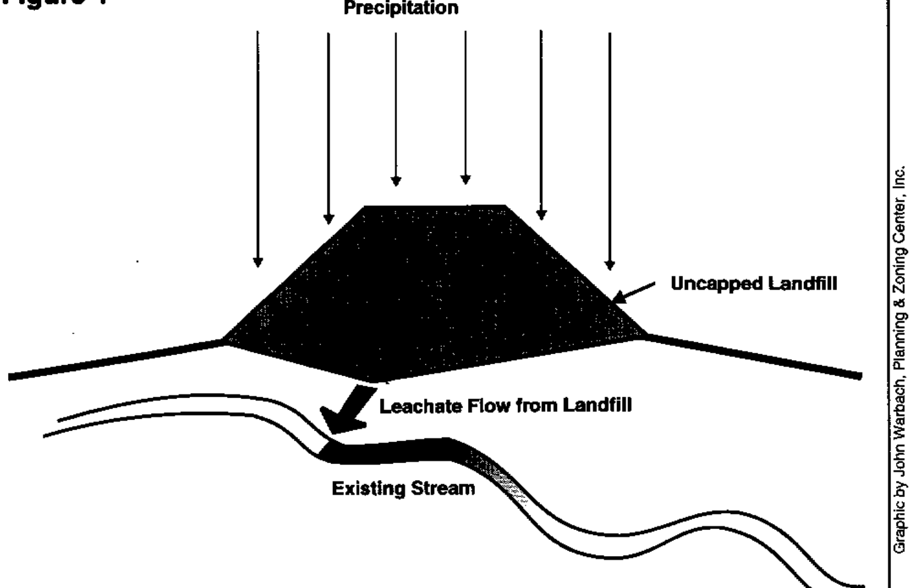
Following centuries of misunderstanding, neglect and abuse, wetlands are gaining recognition for important values such as stormwater retention and filtering, wildlife habitat, food chain production and real estate amenity. Now another important wetland value is emerging: waste treatment. Scientists and engineers around the world are learning how to use wetlands to treat waste from various sources. Their methods involve careful application of wastes into constructed wetlands (generally not naturally occurring wetlands) and should not be confused with the age-old habit of dumping in swamps. Wetlands have, for centuries, served as dumping grounds for debris, excess excavated material, toxic materials, yard waste, household solid waste, sewage, appliances and abandoned cars—simply because wetlands appeared to be useless land of uncertain ownership. Those activities are not environmentally friendly and are generally illegal.

Any official in a community where there are existing landfills and dumps, or where landfills are being proposed should investigate wetland treatment methods. Officials and property owners should also be aware of the potential to use wetlands as part of the treatment system for residential and municipal waste.

Wastes currently being treated using wetlands as part of the process include domestic and municipal sewage, landfill leachate (the liquid that oozes, or sometimes nearly gushes, from landfills) and oil refinery sludge. It is important to note that where treatment of those wastes is provided, no waste enters naturally existing wetlands untreated. Where wetlands are part of a treatment plan, some form of pretreatment occurs. However, there are locations, perhaps an uncountable number, where untreated wastes from landfills and other sources enter naturally occurring wetlands because there is no treatment system for those wastes. These wetlands are simply down hill or down stream from a landfill. It was not until the 1970's that society learned that there were flows of liquid containing undesirable materials coming from landfills.

Waste is treated because dumping it raw into lakes and rivers is hazardous to human health. Sewage wastes contain harmful bacteria and other pathogenic (and nonpathogenic) organisms, high nutrient levels and often other pollutants such as toxic metals. Landfill wastes may contain any of dozens of harmful materials, such as metals (lead, cadmium, zinc, iron, arsenic, mercury, etc.), salts (chloride), organic chemicals (phenols, PCB, benzines, etc.) and high levels of nutrients (ammonia, nitrate, nitrite, phosphorus, phosphate), pesticides and pathogenic organisms. In many communities, an advanced level of treatment is applied because partially treated wastes can still be harmful to both humans and other organisms, such as fish and birds, living in the environment.

Figure 1



Landfills exude a leachate (liquid containing chemicals from materials in the buried solid waste).

Landfill Waste

The characteristics of the leachate that flows from a landfill depends on what has been buried in it. At different periods in the history of landfills, even those managed under an established authority, the materials accepted at landfills has varied. Few, or no, highly toxic wastes are accepted any longer in landfills in the developed countries, unless the facility has been specially designed to contain those materials. In those cases the landfills are sealed to prevent leachate from exiting without a catchment and treatment system.

Landfills produce a leachate because water from various sources passes through the buried material (see Figure 1). This water originates either as precipitation or as a component of the material deposited (tipped) in the landfill. For example, yard waste (which was banned from landfills in Michigan in 1995, but constituted up to 25% of the volume of waste until that time) may contain plant matter that is nearly all water. Other materials may have a small amount of water as a component and the soil used to cover the layers of tipped materials contains some moisture. Look in your trash container and you may find wet paper towels, meal left-overs that can't be composted and vegetable matter if you don't compost. Most new landfills have a liner to prevent leachate from infiltrating to the groundwater and a cap to limit the water that enters from precipitation. However, there is still a water component to the material in the landfill and there are many landfills that were built before those standards were devised.

Water acts as a solvent, and as water passes over the materials in the landfill, it picks up component chemicals. By the time water percolates from the top of the landfill, over old tires, batteries, metal food cans, discarded paint cans, bug spray containers, fast food wrappers, paper and plastic, the solution may contain a high concentration of chemicals. Some concentration of undesirable chemicals, such as iron, in the leachate may have its origin in the soil used to bury the solid wastes. Where landfill leachate flows from the bottom of a landfill, there is often a multi-colored "river of death" where no plants grow. Regulations in most developed countries now prohibit the ingredients in a landfill leachate or in sanitary waste from reaching surface and ground waters, except at greatly reduced concentrations.

The quantity of flow of leachate from a landfill depends on several factors. These include whether there is a cap and how effective it is at excluding precipitation, the composition of the tipped materials and the amount of precipitation. Quantities of leachate flow can reach into the millions of gallons per year from a single, large landfill.

The leachate may exit the landfill above ground if there is a liner to divert the liquid or if the landfill is built over an impermeable layer of soil. Otherwise the leachate, or a portion of it, may infiltrate to the groundwater, causing contamination.

In the last two decades, landfills have generally been constructed with a drainage system that collects leachate and directs it to a location where it can be trucked or piped to a waste water treatment system. This has been an expensive process.

Leachate Treatment

It is the cost of off-site treatment that has created the interest in on-site systems that include constructed wetlands. Transport of leachate by truck or pipe can cost between several hundred thousand dollars per year for trucking to several million dollars in capital outlay and several hundred thousand dollars in operating expenses each year for a piped system. The average cost of treatment in a public treatment facility is about $1 per 1,000 gallons of waste water.

The treatment of wastes has, in the latter half of this century, followed either of two courses. One is the municipal treatment system, in which wastes are piped to a central facility, treated, and the effluent discharged into a river for dilution. The second course is the individual septic system, usually including a septic tank and an infiltration field. Septic systems are generally used in areas where municipal systems have not been extended. There are usually not enough homes to economically finance a municipal sewage treatment system in rural locations. Where municipal systems have been constructed in rural areas, it has usually been to address a water pollution problem due to malfunctioning septic systems. Most rural municipal systems were financed with federal cost sharing.

Septic systems rely on bacterial digestion in the tank and the septic field and soil filtration in the field to remove pollutants. Where soils or the water table are not suitable for septic systems, then a mounded septic system, or hauling stored waste to a treatment plant is usually necessary.

The municipal sewage treatment systems generally screen large debris, allow organic matter to settle as a sludge and then rely on the aeration of a waste slurry to hasten bacterial action in breaking down the remaining waste. The liquid waste is piped into large tanks and *"fountains"* in the middle of the tanks spray the waste into the air to aerate the liquid. This introduces more oxygen into the mixture, allowing bacteria to feed on the suspended organic matter in the liquid. Other treatment regimes may be used to precipitate chemicals or kill harmful organisms.

There are over 500 treatment systems using wetlands in the United States treating over 50,000 gallons per day. They are being used to treat domestic waste, stormwater, industrial waste, mine wastes, animal wastes, landfill leachate and sludge consolidation wastes.

Other variations of municipal sewage treatment systems include land spraying and lagoon treatment. In land spraying, liquefied waste is sprayed through irrigation heads onto open or forest lands. Bacteria in the soil break down the organic matter and the soil acts as a trap for other ingredients, such as phosphorus. In the lagoon systems, waste is pumped into large ponds, where it sits while bacteria in the water (in conjunction with sunlight and oxygen) break down the wastes. After a period in the first lagoon, the effluent is pumped into a second, and later a third. By the time the liquid is ready to leave the third pond, it is safe for body contact or release to a river or stream.

Land spraying and lagoon treatment may prompt concerns by public health authorities and neighbors over odors and safety from pathogenic organisms. While these concerns are often exaggerated, location and access are important considerations. Microorganisms in the treatment process feed on harmful bacteria. Many viruses settle out in the early treatment phases or become electrically bonded to soil particles in the septic field or sand/gravel filters. Many pathogenic organisms cannot survive outside of a specific host, so they pose no threat once in the treatment system.

The use of wetland systems to treat wastes raise some of the same red flags with regulators since wetland treatment does not always provide 100% removal of pathogenic organisms either. However, the apprehensions are slowly being overcome. There are over 500 treatment systems using wetlands in the United States treating over 50,000 gallons per day. They are being used to treat domestic waste, stormwater, industrial waste, mine wastes, animal wastes, landfill leachate and sludge consolidation wastes. A 3,700 acre wetland in Florida is being used to treat agricultural runoff, which is high in phosphorus and nitrogen. Houghton Lake, Vermontville and Ionia are Michigan communities using wetlands as part of the treatment system for municipal waste. In northern Minnesota, a domestic waste treatment wetland operates in temperatures as low as 65 degrees below zero without freezing.

The results of waste treatments that utilize wetlands can be spectacular. If one looks at photographs of turbid, discolored landfill leachate before it enters the treatment system, and the sparkling water after it exits the system, the results appear miraculous.

Resources

There are a number of sources for information on constructed wetlands for waste treatment.

Crites, R. and G. Tchobanoglous, **Decentralized Wastewater Management Systems**. McGraw Hill, Inc., New York. In press.

Kadlec, R. and R.L. Knight, **Treatment Wetlands**, CRC Press, Boca Raton, Florida, 1996.

Tchobanoglous, G. and F.L. Burton, **Wastewater Engineering: Treatment, Disposal and Reuse**. 3rd ed. McGraw Hill, Inc., New York. 1991.

Gerald R. Steiner, P.E. and James T. Watson, P.E., **General Design, Construction, and Operation Guidelines: Constructed Wetlands Wastewater Treatment Systems for Small Users Including Individual Residences**. Tennessee Valley Authority, (TVA/WM—93/10) 1993.

Michigan is fortunate to have one of the leading, international experts in the field, Dr. Robert Kadlec, of Wetland Management Services, 6995 Westbourne Drive, Chelsea, MI, 48118-9527, phone (313) 475-7256.

You may also want to contact Dr. Ted Loudon Michigan State University, Agriculture Engineering, (517) 353-3741.

For more information on the Sumpter Township project, contact Glen Bowles, Sumpter Township Administrator and doctoral student, School of Natural Resources and Environment, University of Michigan, 237 Crest Avenue, Ann Arbor, MI 48103, phone (313) 461-6201.

Also look for articles in **Water Environment & Technology**, published by the Water Environment Federation and **The Small Flows Journal**, published by the National Small Flows Clearinghouse. ❑

Where there is a need to treat wastes in a remote location, wetlands can be a viable alternative. In some parts of the world, small wetland treatment systems are being used to treat wastes from individual homes or small groups of homes.

The results of waste treatments that utilize wetlands can be spectacular. If one looks at photographs of turbid, discolored landfill leachate before it enters the treatment system, and the sparkling water after it exits the system, the results appear miraculous. Test results of the chemical composition of leachate before and after treatment can also show dramatic results.

Limitations to Wetland Treatment

However, there are several limitations to wetland treatment that need to be considered. These are:

- The concentration of some pollutants may remain too high by the end of treatment to permit discharge into public waters. There are two reasons for this problem. One is that certain metals and pathogenic organisms are not always effectively removed by wetland treatment methods. The other is that the gravel or soil materials over which the leachate moves, either during or after treatment, may contain some pollutants and pass it to the treated waste flow. Many metals occur naturally in nature and could be present in relatively high concentrations in materials used to construct the wetland. Sludge from municipal waste water treatment plants is often used to provide an initial boost to growing plants in constructed wetlands. Municipal wastes can sometimes contain high concentrations of metals and could contribute these to the treated flow.
- Treatment results may differ over time with changes in leachate concentration. This change is due to variations in water content of the landfill, to variations in the degree of contact of leachate with contaminated materials and to exhaustion of the contaminates. Water content varies with precipitation and age. As a landfill ages, the water content of buried materials declines and eventual leachate flow will be dramatically reduced. While this means that there is substantially less leachate to treat, it can result in a higher concentration of contaminates in the leachate. Leachate can develop enlarged flow channels deep within the landfill that concentrate volume and increase the amount of contaminate picked up in the flow. Over the years following closure of an uncovered landfill, water continues to flow over buried debris with the result that the contaminates in the debris is washed out. Certain pollutants will reduce in concentration in the leachate.
- Treatment processes can slow with cold weather, depending on the design of the facility. If there is a winter slow-down in treatment effectiveness, wastes need to be stored for treatment in the warmer weather.

Wetland treatment is not an effective first stage of treatment.

- Wetland treatment is not an effective first stage of treatment. Both domestic waste and landfill leachate requires aeration prior to wetland treatment to deal with solids, which can clog the soils of wetlands. Domestic waste is high in organic solids that are broken down in aeration tanks. Landfill leachate is generally lacking in solids when it exits the landfill, but exposure to air releases precipitates, often a form of iron, that develop a substantial obstructive mass. Aeration of landfill leachate precipitates iron, which is retained in sedimentation basins before the leachate is pumped to a wetland. Fortunately, the precipitating iron combines with phosphorus, removing some of that nutrient chemical.

Many scientists and engineers recommend using constructed wetlands rather than naturally occurring wetlands.

Many scientists and engineers recommend using constructed wetlands rather than naturally occurring wetlands. There are both cost and engineering considerations for this choice. Surprisingly, a constructed wetland can "cost" less than a naturally occurring wetland for treatment purposes. A constructed wetland may cost about $20,000 per acre to build but the costs to perform an environmental impact study on a naturally occurring wetland can be many times higher. A naturally occurring wetland may not be hydrologically appropriate for treatment purposes. First, it may not be in the right location, requiring extensive pumping to bring the waste to the wetland. Second, the flow of liquid wastes through the wetland should be uniform over the entire surface for greatest treatment effect, and the natural wetland may not readily permit such a flow without extensive alteration. Third, the soils in the wetland may not be appropriate for treatment purposes. Fourth, there may be a connection between the surface waters of the natural wetland and groundwater. If the leachate contains some harmful pollutants that are not readily removed by wetland treatment, there is a high risk of groundwater contamination.

There are three components of a wetland that contribute to waste treatment. These are the soil, plants and water. Treatment actions take place in each component, and many of these actions are different, requiring all three for complete treatment.

The soil works both chemically and physically. Chemically, elements that cling to soil particles may combine with pollutants to form other, harmless compounds. In addition, electrical charges on soil particles and pollutant molecules serve to bind the pollutant to the soil particle. Phosphorus is an example. At some point, the soil in the wetland could "fill up" with that pollutant, and with no soil particles with unused charges available, the pollutant would continue through the wetland in the waste solution. This fate is one that septic fields can meet. There may also be some simple filtering action of suspended matter in the waste solution by the soil.

Plants participate in the treatment process in several ways. First, plants help circulate the waste solution through the soil bed. They do this by setting up a pumping action that draws water from the soil, into the roots, up into the aboveground portions of the plant and out into the air in the process of evapotranspiration. As the waste solution is pulled deeper into the soil bed, pollutant molecules are filtered and placed in contact with microbes. Second, plant roots exude oxygen, which oxidates certain pollutants, rendering them harmless. Third, plant roots, as well as the lower portions of plant stems (above the soil level) host an incredible array of micro organisms (requires a microscope to see) and macro organisms (can be seen without the aid of a microscope). These organisms perform much of the digestion of organic matter and assimilation of chemicals from the waste solution. They are able to break down some of the most toxic organic chemicals, because they are able to remove carbon. Usually, the process of removing carbon renders new compounds that are not toxic.

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Some portion of certain chemicals (usually metals such as cadmium and lead) in the waste solution enter the plants and can be found in the roots and the aboveground

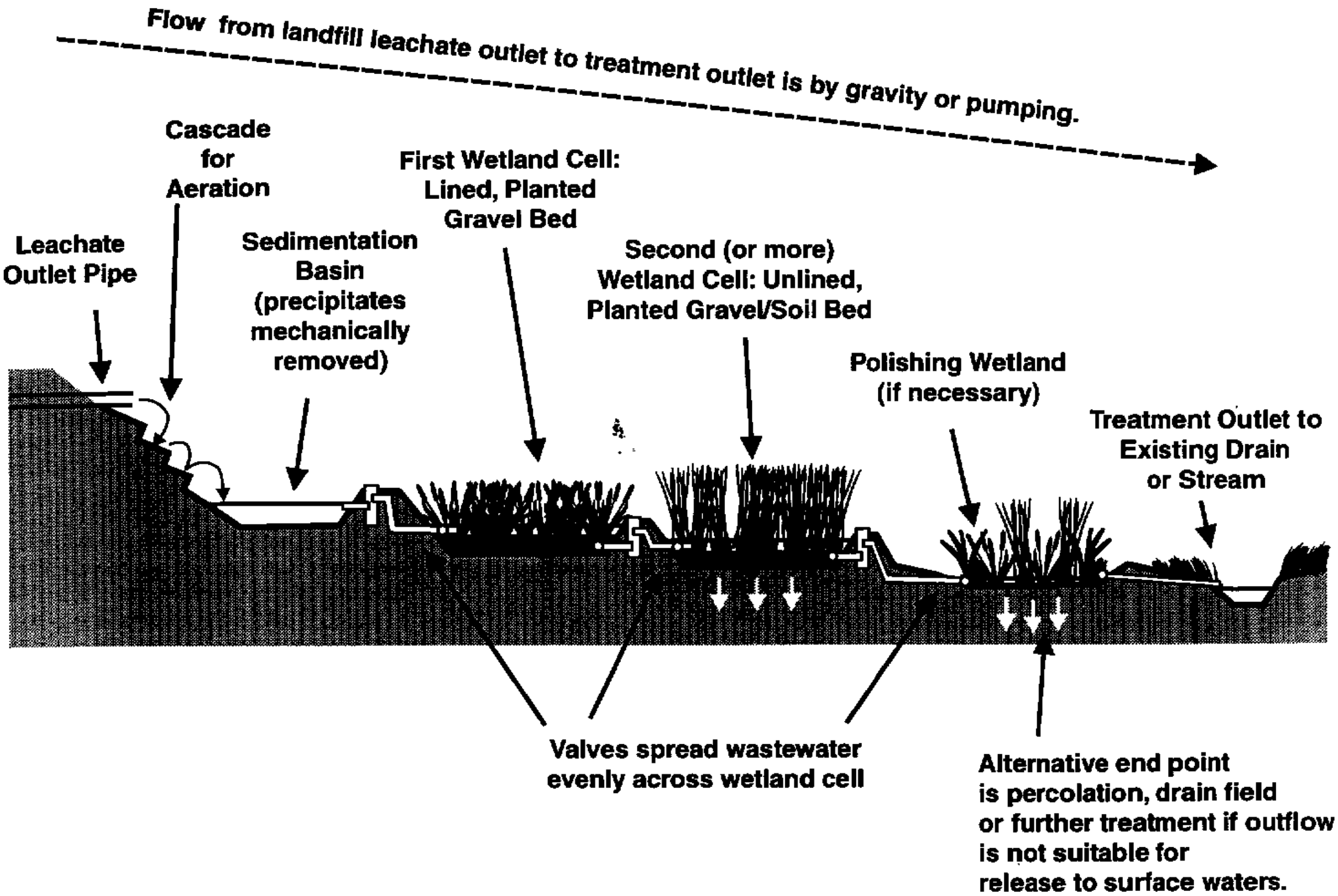

Figure 2

Diagram of Constructed Wetland Treatment of Landfill Leachate (surface flow system)

portion of the plants, such as stems and leaves. If these plant parts were removed from the wetland, they might require disposal methods for hazardous wastes to avoid reintroducing those chemicals into the environment. Depending on the composition of the waste being treated, such plants could not be used as organic matter for farming, for compost or as landscape mulch. However, the plants used in treatment wetlands are rarely harvested, and are instead left in place for the subsequent growing season.

Water serves to reduce pollutants in two ways. First it acts as a medium for many microorganisms that consume organic matter and the carbon portion of organic chemicals. Second, water serves to dilute pollutants that the treatment methods can't completely eliminate. At reduced concentrations, many pollutants are less harmful.

The process of removing organic matter and many chemicals requires an adequate supply of oxygen in the system. Two important measures of water quality are linked to this need for oxygen. One is Biological Oxygen Demand (BOD) and the other is Chemical Oxygen Demand (COD). Oxygen demand is the use of oxygen by microorganisms to break down organic matter and chemicals. It is a natural process. As long as there is oxygen in the water, it will be used to break down organic matter and chemicals. Other users of oxygen, such as fish, come second to this relentless process. If the supply of oxygen is depleted, the breakdown ceases and the liquid waste turns anaerobic, with associated foul odors and death of organisms that require oxygen. Some species of fish will die with relatively little reduction of dissolved oxygen while other species can tolerate lower oxygen levels. Oxygen naturally occurs in surface waters unless the BOD or COD is very high.

Since BOD and COD are usually very high in domestic and landfill wastes, oxygen must be added (aeration) to the system. Aeration is often done by passing the liquid waste over an artificial rapids, letting it fall from a pipe opening into a lower basin, or forcing it into the air in fountains.

Variation in Constructed Wetlands for Treatment

Researchers are trying a variety of constructed wetland designs for the treatment of wastes. The recent international symposium, "Constructed Wetlands for the Treatment of Landfill Leachates", held in Romulus in June, 1997, revealed that there is no single approach, and the science of designing treatment wetlands is still young. Researchers reviewed nearly a dozen different approaches. Participants described treatment systems that included constructed wetlands in Great Britain, Hong Kong, Norway, Italy, Canada and in the United States, Alabama, Florida, New York, Massachusetts, Minnesota, Georgia and Michigan.

All of the systems employed the same basic components, although the design of those components varied. The basic components of a treatment wetland are:

- **Solids removal.** In a treatment system that handles domestic wastes, this can range from a septic tank to aeration ponds, such as is typical in a municipal waste water treatment plant. Small aeration ponds (or tanks) have been built to serve a cluster of houses, with wetland treatment systems to further handle wastes. Landfill leachate leaves the landfill without significant solids, but on contact with air, precipitates form which can be substantial in volume. A sedimentation basin is the usual method for handling precipitates. These are periodically removed mechanically.

- **Wetland cell(s).** Once solids are largely removed, the waste water is evenly distributed over the prepared bed of the first wetland cell. This cell usually contains a liner to prevent leaking to the groundwater, a substrate of gravel, sand, peat or other soil-like materials to filter the waste water and to serve as a plant growing medium, and wetland plants thickly growing in the substrate. The cell also will have raised walls or a berm to hold the waste water. The cell is sized so that the waste water can be contained for a period of time (weeks or months) during initial treatment. Waste water flows through the cell either as ponded surface water or it is drawn through the substrate by underdrains and is pumped into the next cell. Treatment systems for residences usually use a subsurface system to avoid odors and to eliminate the chance for contact between people and the waste-water. Treatment facilities will employ a series of cells, the number and size depending on the amount of waste water and the contaminates it contains. For small systems, the second cell is usually unlined, to begin the process of infiltration.
- **Post treatment.** While constructed wetlands can be a cost-effective form of treatment of wastes, they usually do not remove all pollutants to the extent that the waste water can be released into surface waters and still satisfy water quality regulations. It may be necessary to either pass the waste water through a mechanical treatment facility or to place it so that the effluent percolates into the ground rather than entering a stream or river. Post treatment can involve the use of ozone to kill remaining pathogens, the use of drain fields to absorb waste water and never let it enter surface waters and the use of constructed or natural wetlands to "polish" the wastes over an extended time period.

Designers of treatment wetlands use different soil materials for filtering the wastes and to grow the plants, including gravel, sand, peat and mixtures. Different wetland plants are grown, including Common Reed (Phragmites), Cattails (Typha), Sedges (Carex) and Reed Canary Grass (Phalaris). While considerable variation in soil and plant materials in the different treatment wetlands around the world can be attributed to research efforts to find the most suitable combinations, variation is also due to local factors. For example, in Great Britain, Reed, which grows quite readily, is used almost exclusively. While Reed is used in some American constructed wetlands, the EPA in the northeast region prohibited it because the plant was seen as an invasive weed that could spread to natural wetlands. Cattails were specifically used in Alabama because of a fast growth rate and high metals retention. Cattails are widely used in constructed wetlands in America.

Treatment Wetlands in Cold Climates

Constructed wetlands are being used successfully for the treatment of both landfill leachates and domestic waste in cold climates. An experimental constructed

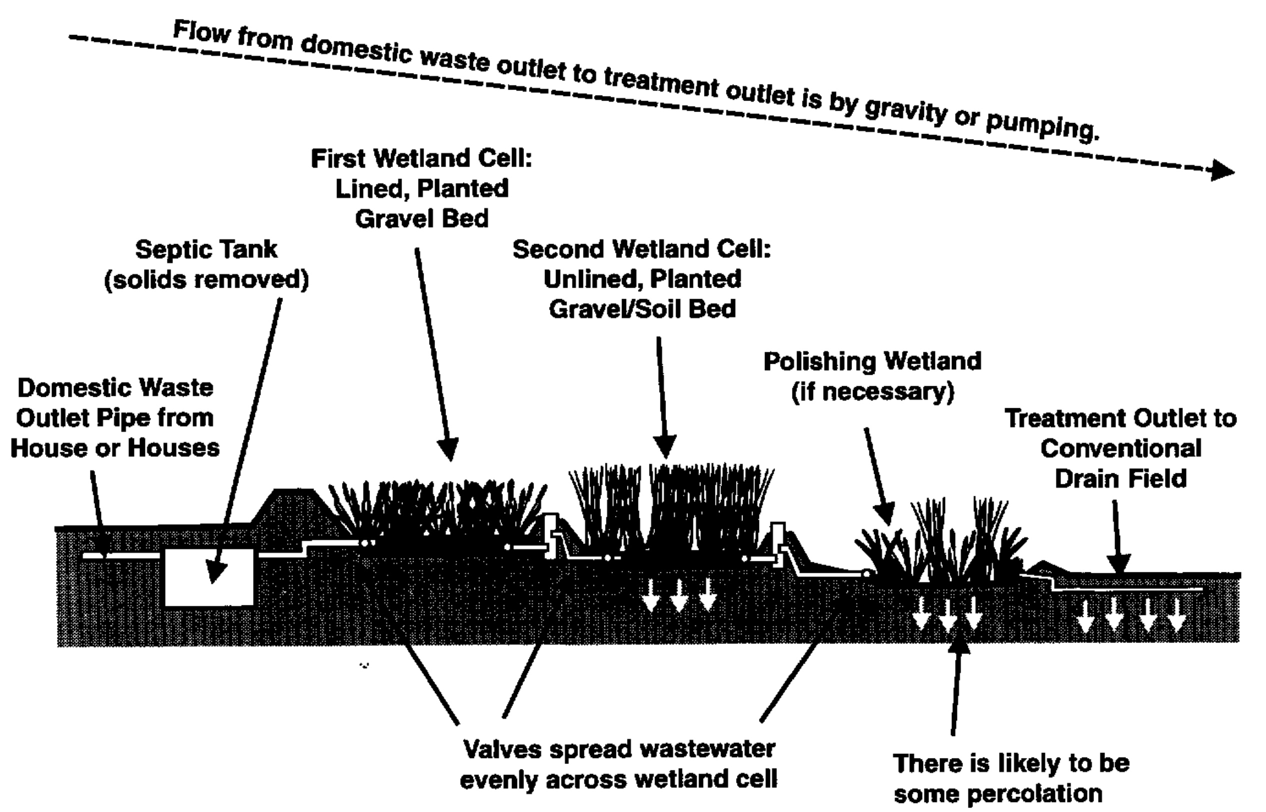

Figure 3

Diagram of Constructed Wetland Treatment of Domestic Sanitary Waste (subsurface flow system)

Graphic by John Warbach, Planning & Zoning Center, Inc.

treatment wetland has been operating in Minnesota, and there are more than 20 systems operating in Norway.

A cold climate wetland may require different engineering than one constructed in a warm climate. The wetland cells may have to be built deeper and be covered with mulch in the winter to prevent freezing. A pond for storage of waste water may be necessary so that treatment can wait until warmer weather. Certain biological process slow in cold temperatures, such as virus removal and nitrogen transformation, while the breakdown of organic matter is not temperature dependent. Snow cover can help insulate, but snow melt in the spring can add water to the system, a design consideration. Other likely design considerations are to increase the area of the wetland cells, use a subsurface flow to avoid frozen, standing water, provide aeration as a first treatment step and have a gravel layer in the substrate to create a flow channel below a potentially frozen upper layer of soil in the wetland cells. Wetland treatment systems for landfill leachate may benefit from captured heat that landfills generate.

Case Study - Sumpter Township

A constructed wetland treatment system is planned for treating landfill leachates and municipal domestic wastes in Sumpter Township, Wayne County, Michigan. Existing wetlands, formed in the borrow area for a now-closed landfill will be reshaped to provide treatment for 15 million gallons per year of landfill leachate and over 70 million gallons per year of sewage from a portion of the Township. Blending the two effluent sources will provide a balance of nitrogen and carbon that will aid in conversion of pollutants. The waste water flow will pass through the following stages:

- Landfill leachate will first be directed to settling basins to permit iron precipitates to be collected.
- Landfill leachate next goes to a pond where pretreated domestic waste and untreated stormwater from the landfill site will be blended.
- Blended waste water then passes through a two acre series of vertical volatilization and nitrification beds where certain chemicals are released as gasses.
- Surface flow constructed treatment wetlands, 32 acres in size with a two month detention time.
- Polishing in an additional 32 acres of tertiary wetlands managed as a natural wetland restoration complex.
- Discharge into a local drain.

This project is a joint effort by Sumpter Township and City Sand and Landfill, which owns the closed landfill. Currently, the landfill leachate is being trucked to a treatment plant.

Summary

In a cost conscious society, a waste treatment system that employs constructed wetlands can be highly effective. Wetland treatment systems can help remove many pollutants at lower cost than a completely mechanical solution. While treatment results are often very good, there is not 100% removal of pollutants from the wetland portion of the system. But neither are mechanical treatment plants that effective, and aging sewage treatment plants are often less effective. Small mechanical additions to the system can, in combination with constructed wetlands, result in remarkably pure effluent.

Depending on the nature and quantity of the wastes, the land area needed can be small—treatment wetlands are frequently the size of tennis courts or smaller, rather than football field size.

While treatment wetlands are still being researched, and efforts to find improvements continue, the technology is sufficiently advanced to where they can be effectively used now. ❑

Constructed Wetlands for Residential Waste Treatment

"We had the treatment wetland designed and the County Health Department was receptive, but my wife nixed it." This is the comment of the owner of a rural property in Ingham County, Michigan. *"The wetland system cost about a thousand dollars more, and when the bills started coming in on the new house, we went back to a conventional system."*

Michigan homeowners and water quality and health officials are on the cutting edge of *using* constructed wetlands for treatment of wastes from individual residences. Experts predict that people are eventually going to build such systems here. It just hasn't taken off yet for the individual homeowner in Michigan. Officials are long past *being* on the cutting edge of the technology. Residential waste has been treated using wetlands as part of the system for a considerable time in Michigan. The municipal system in Houghton Lake has been using a wetland as part of its treatment program for 20 years. Other systems are in place in Vermontville and Ionia. According to Robert Godbold, Ingham County Health Department, *"A properly designed system using a constructed wetland as part of the treatment system would be acceptable."*

The system proposed for the Ingham County homeowner was designed by Dr. Robert Kadlec, of Wetland Management Systems, Chelsea, Michigan. The proposed system was composed of a septic tank and two wetland cells in succession. The wetland was designed as subsurface system (see feature article and illustrations), with a lined first cell, and an unlined second cell to serve as the infiltration bed. The entire system relied on gravity flow, which the topography made possible.

Use of a constructed treatment wetland for individual residences has merit in many areas of Michigan where high water tables or soils that don't meet percolation requirements eliminate the use of a conventional system. Two other approaches are sometimes used when a conventional system is not permitted: trucking the effluent away to a treatment plant or building a mounded drainage field. Both of these are more expensive than a constructed wetland system. A third alternative exists: don't build a house.

Some feel the engineering community may be dragging its feet on using constructed wetland treatment systems. Engineering consultants may feel more at risk in designing a different system. Also, design fees may not be very high on the relatively low-tech wetland approach.

There is a built-in momentum for continuing to build conventional residential treatment systems. While many county health departments appear enthusiastic about treatment wetland systems, the code books used for the design of residential waste treatment systems only show the traditional septic tank and drain field. In addition, many property owners and probably many drain field installation contractors don't even know about constructed wetland treatment systems. According to Dr. Kadlec, *"There is a well-developed technology."* The Tennessee Valley Authority did some of the pioneering work in this field and others around the world have been refining it for several decades.

As knowledge of the usefulness of wetland treatment systems spreads, it is likely that these systems will be considered more often. As more communities consider limiting the extension of public sewer due to cost concerns and to better manage growth, more individual property owners and groups of owners will need to consider alternative residential waste treatment systems.

Research is continuing on treatment wetlands. Both the EPA and the state of Minnesota are helping to fund research on the technology.

One type of development that can be appropriate for constructed treatment wetlands is the conservation subdivision, promoted by Randall Arendt. In a conservation subdivision, the zoning density is retained but the houses are all placed on smaller lots. Substantial open space is reserved. Wetland treatment systems for multiple houses, or for all the houses in the subdivision could be built within the reserved open space. ❑