GROWING AWAY WASTEWATER

Constructed ecosystems that clean wastewater are a budding market for landscape architects.

By Carol Steinfeld and David Del Porto

When constructed wetland specialist Heather Shepherd of Sebastopol, California, was hired to design a showcase wastewater-treatment wetland for a winery, she found herself longing for a landscape design partner who could integrate the system into the surrounding landscape as well as propose variations beyond the rectangles and ovals she typically designs. She says, "It would have been great to work with a landscape architect"—but she didn't know any who were competent to collaborate on these systems.

In the future, however, Shepherd says she expects that engineers will be able to find landscape architects they can team up with to design double-duty landscapes that "grow clean water"—especially as wastewater regulations tighten and water costs rise. In the conceivable future, the gardens that landscape architects design will also filter, clean, and stabilize wastewater from buildings and their sites. The client will receive one bill for site and wastewater treatment design—and enjoy lower costs for irrigating and fertilizing landscapes.

Landscape architects who learn the biology and hydrology of these systems—from constructed wetlands to planted rock filters—are poised to capitalize on this market by either designing the systems or partnering with wastewater engineering firms that do. Landscape architects have the mind-set and skills to design these systems, skills that engineers are only now learning. Essentially, the technology is all about how many "biofilm" areas are needed to reduce "wastewater constituent."

Demand for ecological wastewater treatment will grow steadily as scientists and engineers find that landscape-based root-zone systems clean wastewater better than the conventional wastewater disposal drainfield, even in colder regions. Studies show 99.9 percent pathogen destruction in these constructed ecosystems. At the same time, municipalities increasingly favor decentralized solutions that treat effluents at their sources.

At the Root of It All

Some use the term "natural systems" to describe these landscape-based wastewater systems, but this is a bit of a misnomer, as conventional treatment also uses natural biology. The ecological engineering field calls them "constructed ecosystems."

Some constructed ecosystems are wet, or "saturated," and some of them are not. They drain to a leachfield or—with a special permit—into a stream, river, lake, or ocean. Some, by design, use up all of the wastewater.

Treating wastewater involves destroying pathogens, reducing "biological oxygen

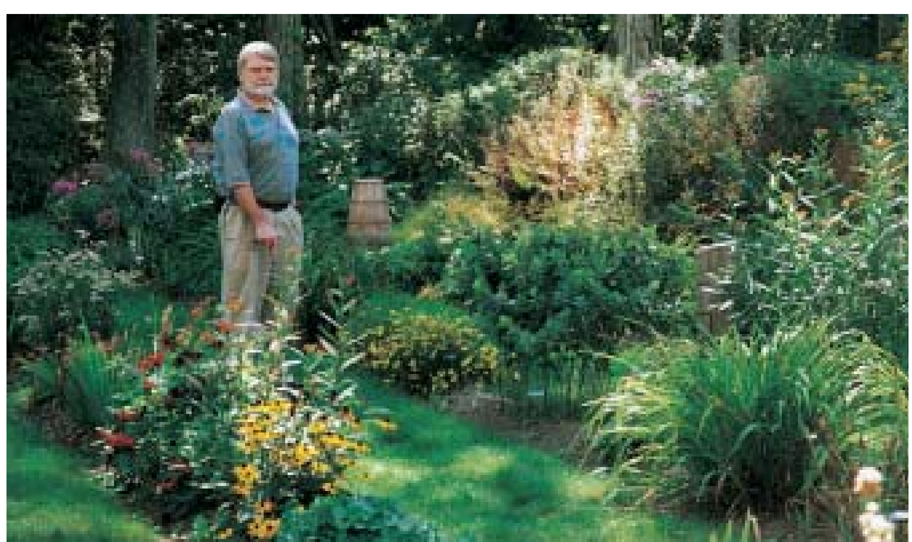
The greenhouse *above* is also an enclosed planted evapotranspiration system that uses up wastewater from a home built in an environmentally sensitive area in Massachusetts. The owners like the system because it provides another room as well as solar heat.

CAROL STEINFELD

demand" (BOD), filtering out particles, reducing or using up nitrogen and phosphorus, and stabilizing or disposing of toxins. All of this happens faster in constructed ecosystems than in conventional treatment systems. In a septic tank, for example, effluent is not treated; it is just settled. All pathogens, toxins, and nitrogen (mostly from urine) still drain from the tank into the soil, where some transformation occurs. Instead of disposing of the "leachate"—effluent that leaves the septic tank—two to six feet underground as conventional leachfields do, constructed ecosystems keep effluent in the first 18 inches or the "biological zone."

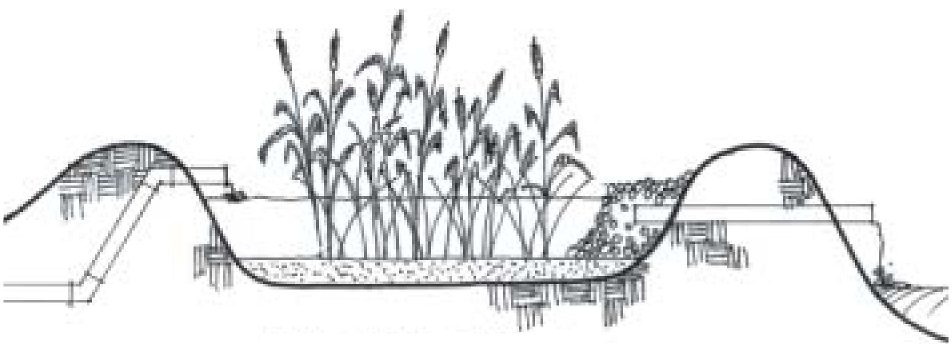
The key difference is air. Oxygen-using (aerobic) bacteria transform and stabilize effluent 10 to 20 times faster than anaerobic bacteria. The second advantage is plants. They establish the root system, or rhizosphere, where the real transformation occurs. The roots provide a home for beneficial bacteria to transform effluent. In the terminology of wastewater treatment plant operators, the substrate and the roots behave like "fixed-film reactors," supporting microbes that like to be attached to something while preying on pathogens, turning nutrients into a form that plants can use, and converting nitrogen to gas. Plants also add air to the system through "capillarity" (think of plant roots and stems as drinking straws).

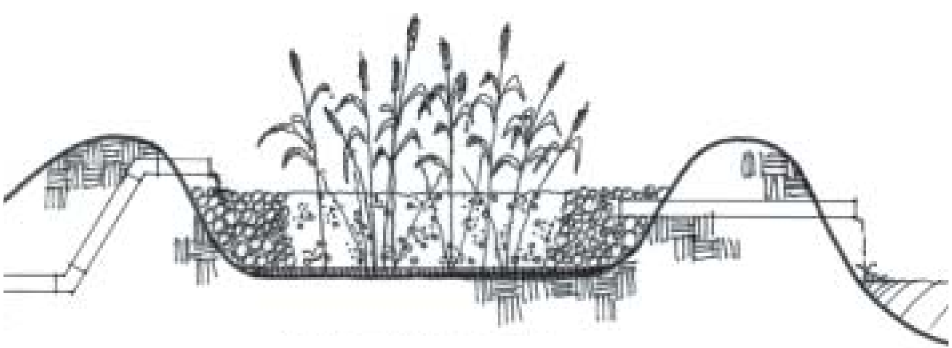
It is a commensal relationship. The pollutants feed the microbial community, and its by-products are absorbed by the plants. In turn, the plants support the microbial community: Through photosynthesis, their roots



CAROL STEINFELD, ALL

***Top,* a "living machine" in Burlington, Vermont, is a sequence of aquaculture ponds hosting different habitats that clean wastewater. *Center right,* a planted rock filter in an office building's courtyard treats wastewater—and provides a setting for lunches and breaks. *Center left,* the finishing marsh in a solar aquatics system is part of a system that treats the wastewater of the village center of Weston, Massachusetts. A planted evapotranspiration system, *bottom,* is disguised as a nineteenth-century flower garden at the historic Old Manse in Concord, Massachusetts.**





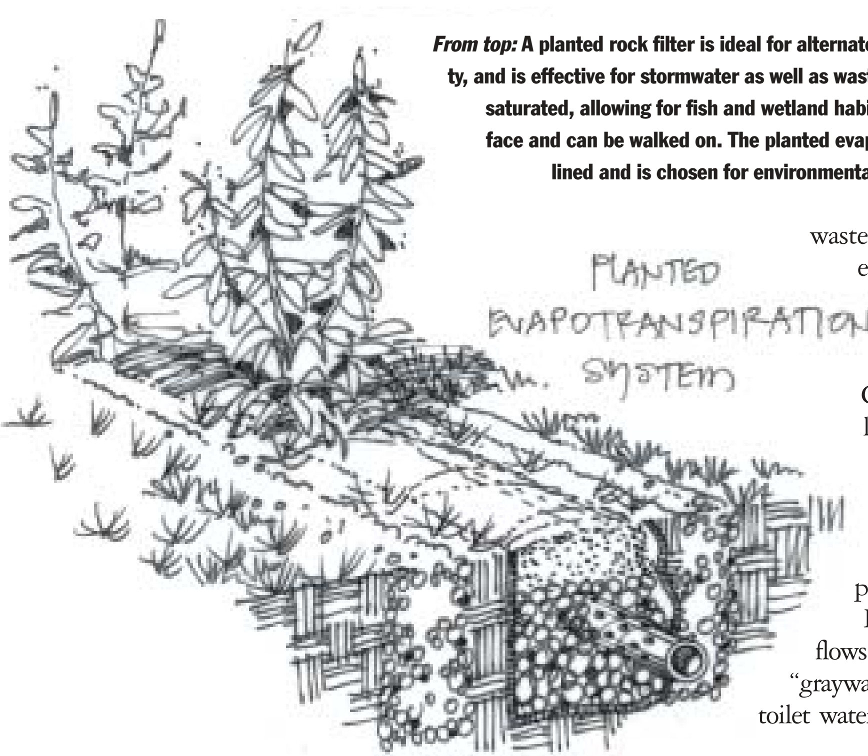
receive nutrients—called "exudates"—in the form of complex carbohydrates (mostly sugars) that help maintain the microbes.

As the roots decay, they provide the carbon required by the denitrifying bacteria to convert nitrates into nitrogen gas. (In mechanical treatment systems, sugar is added for this purpose.)

What's more, constructed ecosystems are self-organizing and adaptive. Plants provide responsive treatment that adapts to changing wastewater strengths and climate changes.

Although biological systems work faster in warm environments, they are successful in colder climates, too. By and large, microbes do the work, and microbes are poikilothermic: Their metabolic processes are directly proportional to the temperature. For every 19 degrees Fahrenheit, their metabolic rate doubles. At 40 degrees Fahrenheit, most microbes are dormant. But

***From top:* A planted rock filter is ideal for alternately wet and dry conditions, provides more planting flexibility, and is effective for stormwater as well as wastewater. A freewater surface constructed wetland is always saturated, allowing for fish and wetland habitat, whereas the subsurface-flow wetland is dry at the surface and can be walked on. The planted evapotranspiration system is by design unsaturated or dry and lined and is chosen for environmentally sensitive sites where no wastewater can be discharged.**



wastewater is usually warm, and microbial action generates heat, so treatment may slow during cold seasons but rarely, if ever, stop.

Know the Systems

Generally, a wastewater system starts with a collection system and settling tank, such as a septic tank. If the site requires higher pretreatment before discharge, packaged treatment plants, media filters, or treatment systems can be used. These are essentially boxes containing aerators, peat, geotextiles, or complex plastic shapes.

In a very environmentally oriented building, the flows may be kept separate: Water used for washing, called "graywater," may be drained separately from high-nitrogen toilet water, or "blackwater," so that it can be strategically used.

CRAIG FARNSWORTH, ALL

The discharge then flows to a constructed ecosystem. This is often a bed or series of trenches full of aggregate—such as gravel, peastone, sand, crushed concrete, and even crushed glass and mulch—of various depths and lengths, lined and unlined, with or without outflow, and wet, damp, or dry. And, ideally, planted. On a restricted site, further denitrification and disinfection may be required.

Five Constructed Ecosystems

Perhaps the best-known constructed ecosystem, although its name is often incorrectly used to describe the others, is the constructed wetland.

Constructed wetlands, typically chosen when there is plentiful land, are planted beds or trenches filled with coarse media such as gravel that support aquatic vegetation and provide both aerobic and anaerobic conditions. To reduce phosphorus, wetlands require periodic plant harvesting; this should be performed before the onset of summer.

There are two types of constructed wetland: the freewater surface constructed wetland and the subsurface-flow constructed wetland. In **freewater surface constructed wetlands,** water flows on top. One can sometimes paddle boats on them but cannot walk on them. These wetlands are chosen where habitat that attracts wildlife, such as birds and fish, is desired (remember, however, that animals can contribute their own e-coli bacteria to the water). They also provide opportunities for waterfalls and waterflow features, enhancing both evaporation and aeration. Ideally the water will flow fast enough that mosquito larvae cannot take hold in the moving flow; if not, mosquito-eating fish and birds should be present. As land becomes pricier, freewater surface wetlands will slowly fall into disfavor because they require too much land.

With **subsurface-flow constructed wetlands,** water flows three to eight inches under the surface, so the system can be walked on, driven over (even paved over), and integrated into pathways. These work better than free-flowing wetlands in cold climates as they are insulated from surface air and retain more heat. The sizing is about the same as free-flowing wetlands.

The deeper they are, the more anaerobic, which assists with denitrification, the conversion of nitrogen to nitrogen gas. Five-foot-deep and deeper subsurface-flow constructed wetlands are used for denitrification. A shallow system is more aerobic, promoting nitrification (which changes ammonia to nitrate—NH3 to NO3—a form of nitrogen accessible to plants) as well as evaporation. However, the shallower the system, the more susceptible it is to cold weather; depending on the climate, designers might make a hybrid system.

To reduce BOD, aerobic processes work best. The first 12 inches is the zone of aeration, so a system may start at 12 inches deep to reduce BOD and to nitrify and then head to greater depths of 19 inches to 5 feet for denitrification.

Planted rock filters are less-understood ecosystems. Unlike their cousins the constructed wetlands, these are more like constructed "damplands" and not always saturated. Common in some southern states such as Arkansas, these systems were designed and tested by NASA. Very flexible, they can be used for both stormwater and wastewater.

Effluent enters the system three to eight inches below the surface. The advantage of the system is that stormwater provides an ebb and flow that both flushes the system and optimizes all of the biological processes by providing a complex and diverse ecology. Because they do not require wetland plants, they are more versatile for landscape features. Rain flows through the rock filter but doesn't collect and saturate, so non-aquatic plants including shrubbery and vines can be used.

Planted evapotranspiration systems, also known as "recirculating wastewater gardens" are designed to use up effluent. Evapotranspiration systems are typically trenches filled with gravel and distribution pipe and planted with especially thirsty plants, or "phreatophytes." Treatment is primarily unsaturated and aerobic. These systems are usually chosen to reduce or eliminate the cost of pumping a septic or holding tank on sites where effluent cannot be discharged at all.

Effluent first enters a tank then is pumped into a bed of media such as gravel. Anything

Getting Started

For those seeking to enter this market, Tom Benjamin, ASLA, of Rizzo Associates, David Del Porto of Ecological Engineering Group, and Chris Webb of 2020 Engineering suggest learning more about:

- **The plants used in these systems.**
- **The regulations for on-site systems and discharge permits: A professional engineer stamp is not required for all systems in all places.**
- **Hydrology—such as how fast water travels through gravel: Webb suggests knowing "direct infiltration, general retention (hold and slow release), and treatment in the biological zone."**
- **Soil science and wastewater biology: It's useful to know average and peak flows and biological requirements of anaerobic and aerobic systems, typically called "reaction kinetics." For example, "if a biofilm forms around gravel in a bed," says Del Porto, "you've got to know how much and over what time it will take microbial populations to degrade the constituents in stormwater and wastewater."**
- **The engineer's lexicon: "You need to know enough hydrology and soil science to enter an intelligent dialogue with engineers," says Benjamin. A quick primer: Secondary treatment stabilizes pathogens. Tertiary treatment converts, takes up, or denitrifies nutrients. Advanced tertiary treatment usually disinfects.**
- **Public education and participation: Learn how to include the public and other stakeholders in wastewater decision making.**

They also offer the following recommendations:

- **Get training. Certified staff members can conduct soil evaluations and wetlands studies.**
- **Make it visible. "We need to inspire beyond the bounds of the site and make the process visible," says Robert France, professor of landscape ecology at Harvard University's Graduate School of Design. "By celebrating and using water as a design element, we increase sensitivity, appreciation, and awareness of the fate of wastewater," he says.**
- **Educate your market. Clients cannot hire a firm to create solutions they do not know about. Offer presentations and informational materials. Educate the public about the ability of constructed ecosystems to adapt and treat effluents better than mechanical systems.**

not evapotranspired away is drained back to the tank. Because these systems are almost always specified where wastewater must be completely used up and not discharged, they are often lined. A good lining is a 20- to 40-millimeter, chlorine-free, low-density polyethylene film, as chlorine can leach out of PVC liners, leaving the material brittle and prone to breaking.

Solar aquatics systems, or "living machines," are sequences of aquatic tanks (think of aquaria filled with plants) and indoor constructed wetlands, often enclosed in greenhouses. They replicate a vertical pond system. Inside the tanks, aerators bubble in oxygen and agitate the mix. At their best, they resemble towers of flowers, foliage, and even trees. They are chosen when super cleaning is required, such as for reuse in a building. These systems can also process sewage solids or "sludge."

Methods of distributing the outflow (if there is any) include

- Subsurface irrigation: After treatment, effluent is distributed under six inches of suitable pervious soil, typically by pressure-dosed, small-diameter perforated pipe or through flexible drip tubing with emitters. Remember that drip irrigation is for dispersal, not treatment, and effluent must be extremely well filtered to prevent clogging of emitters.
- Surface irrigation: Effluent is disinfected and distributed on the surface, typically through conventional sprinklers or other clean-water irrigation systems.

To complete a full, ecologically elegant, on-site water-management strategy, add plumbing for reuse. Treated and disinfected effluent from the constructed ecosystems can be filtered, possibly disinfected, and piped back to the building for use in toilet flushing and make-up water for evaporative cooling systems.

Success Factors

Designers must take into account legally mandated design flows from the building. Precipitation and temperature must be factored in, as well as leaf drop—fallen leaves add carbon to the system—unless leaves are raked off.

Many wetlands fail because the substrate is too small, causing clogging. Designers are currently using as large as 3/4- to 3-inch stones. The larger the pore spaces, the less the likelihood of clogging.

Plant Palettes

Plant palettes for constructed ecosystems that empty out ideally include facultative plants that do not mind having their roots wet or dry. In wetlands, only obligative plants (roots are always wet) are used.

Start with fast-growing plants such as grasses and water hyacinth for a base of workhorse plantings, then accent with showy plants. Look for broad-leafed plants, as the more leaf area, the more evapotranspiration. Vines allow for maximum leaf area with minimal footprint.

Select plants that look good and smell good to keep people taking care of them, as well as plants that do not need care, such as bamboo and holly. For shallow nitrogen-removal systems, clumping bamboos such as *phyllostacys aurea, phyllostacys bisetia,* and *phyllostacys nuda* work well. Most of these systems are lined with 20-millimeter polyethylene liners to prevent spreading.

If wetlands are planted with reeds, both the foliage and the leaf mass may need to be harvested to remove carbon. Where phosphorus is an issue, such as where the outfall is surface water, both the leaf mass and the roots should be harvested periodically.

For cold-climate systems, select evergreens that are cold tolerant. Hardy evergreens do not go dormant in the winter, so their root zones are active even in the snow. As in any landscape, 10 to 40 percent of the plants may have to be replaced during the start-up period. Also, there is a start-up time before optimal treatment is seen: The warmer it is, the sooner it occurs.

Constructed ecosystems often self-select what plants work best—which may disrupt the landscape architect's carefully chosen plant palette.

In systems with no outflow that are sheltered from precipitation and so are not regularly flushed out, salt buildup can occur. This can be flushed out with water, or the system can be planted with halophytes—plants that take up salt—such as mangrove and tamarax (salt cedar).

Who Can Design Them?

In most states, a local permit is required for an on-site wastewater system managing less than 10,000 gallons per day (GPD). (The design flow per bedroom is usually about 110 GPD.) Systems managing more than 10,000 GPD require a federal permit. Many states certify professional engineers to design smaller systems; however, exceptions may be made for those who can demonstrate the necessary skills. Some states, such as Iowa and Vermont, allow anyone to design systems, as long as the systems comply with state guidelines. Landscape architects should check with the state's wastewater or health departments.

Where an engineer's stamp is needed, a landscape architect can design a system and have a certified wastewater consultant or professional engineer sign off on it. The landscape architect knows the landscape, the topography, and the aesthetic goals. The consultant knows the wastewater regulations and is certified to design systems.

For example, the engineer or other

wastewater consultant can design a wetland or other system according to characteristics of the wastewater stream: how much and how strong. Climate and land area determine size and configuration. Then, the landscape architect works with the consultant to configure that consultant's specification into the design. Shape and plant palette can all be determined by the landscape architect. They can decide together whether it will be, for example, a vegetated submerged wetland or a combination of systems.

As states regulate for higher treatment of wastewater, constructed ecosystems will become increasingly common treatment modalities. Civil engineers will seek out the services of landscape designers and architects to help them integrate these systems into their clients' sites. The distinction between landscape and wastewater treatment system will soften, as the ability of soils, substrate, and plants to clean wastewater and runoff is recognized. As this land-based approach replaces the current plumbing approach to wastewater management, landscapes will be commonly called on to both clean the effluents of their inhabitants and provide valuable plant products and beauty. LAM

Carol Steinfeld, author of *The Composting Toilet System Book and Reusing the Resource: Adventures in Ecological Wastewater Recycling* (February 2004, Chelsea Green Publishing), is projects director for EcoWaters Projects, a nonprofit advocating ecological wastewater recycling. David Del Porto is principal and senior designer of Ecological Engineering Group, which specializes in advanced and ecological wastewater systems.

Resources

Some ecological wastewater system consultants:

- 2020 Engineering, Bellingham, Washington; *www.2020engineering.com.*
- Ecological Engineering Group, Concord, Mass.; *www.ecologicalengineering.com.*
- Living Machines, Inc., Taos, New Mexico; *www.livingmachines.com.*
- North American Wetland Engineering, Forest Lake, Minnesota; *www.nawe-pa.com.*
- Natural Systems International, Santa Fe, New Mexico; *www.natsys-inc.com.*
- Cahill Associates, West Chester, Pennsylvania; *www.thcahill.com.*

Books to read:

- *Treatment Wetlands,* by Robert Kadlec and Robert Knight; CRC Press.
- *Small and Decentralized Wastewater Management Systems,* by Ronald Crites and George Tchobanoglous; McGraw-Hill.
- *Growing Clean Water: Nature's Solution to Water Pollution,* by Bill Wolverton; Wolverton Environmental Services.
- *Wetland Design: Principles and Practices for Landscape Architects and Land Use Planners,* by Robert L. France; W.W. Norton.
- *Constructed Wetlands in the Sustainable Landscape,* by Craig Campbell and Michael Ogden; Wiley & Sons.
- *Start at the Source,* by Tom Richmond; Bay Area Stormwater Management Association.
- *Water Use and Conservation,* by Amy Vickers; WaterPlow Press.