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Rural Wastewater

EXPERT REVIEWED

Recirculating Vertical Flow Constructed Wetlands for Treating Residential Wastewater

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In parts of the United States where soils are very permeable, conventional septic tank and absorption field systems are considered the largest contributor to waterborne disease and pollution of water bodies. However, an economical, recirculating vertical flow (RVF) constructed wetland, used as a pretreatment system, can significantly improve the performance of conventional onsite wastewater treatment systems while requiring relatively little space.

RVFs have been used in the United States for many years, but their use as a treatment for residential wastewater is relatively new. The first RVF was installed in Indiana in LaGrange County in 2001. Five were in place in the state, and all were performing well in 2007.

Residential Use

Homeowners faced with space limitations (such as around lakes), located in subdivisions without sanitary sewers, or confronted by replacement or recovery of failing septic systems should benefit from RVF constructed wetlands. They should place the RVF wetland after the septic tank and before final soil treatment and dispersal (conventional leach field, mound system, drip irrigation, or other approved soil absorption system). An RVF wetland's relatively small footprint and high degree of treatment should improve the performance of the soil absorption system by minimizing the amount of solids and nutrients entering the soil infiltration system. In some cases, county and state codes may even permit a smaller soil infiltration area because of the high level of treatment.

Design

The size of the RVF constructed wetland (Figure 1a and 1b) should be based on the expected gallons per day (GPD) of sewage produced, as determined by Indiana State Department of Health (ISDH) rules. The recommended design parameters for individual residences are in Table 1.

Table 1. *Sizing recommended for RVF in Indiana.*

Residence	Wastewater	Septic Tank	RVF Constructed Wetland
Bedrooms (#)	Daily Flow (Gallons Per Day)	Size Volume (Gallons)	Cell Size (Feet)
1	150	1000	8.5 x 8.5
2	300	1000	12 x 12
3	450	1000	15 x 15
4	600	1250	17 x 17
5	750	1500	19 x 19

As a general guideline, the minimum cell size of the RVF constructed wetland is based on 0.48 ft^2 of surface area per gallon of sewage treated daily. The constructed wetland cell is from 42–48 in deep, and it is square (Figure 1a and 1b, see page 2).

Construction

As in a conventional septic system, a home's wastewater should first collect in a septic tank with a solids retention-time of at least 48 hours and with an effluent filter installed at the tank outlet (Figure 2, see page 3). The septic tank overflow should direct effluent to the inlet at the bottom gravel layer of the RVF constructed wetland. Across the bottom of the wetland, place a 4-in diameter, two-row PVC perforated pipe with holes in the 4 and 8 o'clock positions or a three-row pipe with holes at the 4, 8, and 12 o'clock positions. In early designs, a PVC perforated pipe was also placed at both the inlet and outlet ends of the gravel to distribute and then collect the effluent after it traveled through the gravel layer at the bottom of the wetland. More recently, plastic soil absorption chambers (often used in place of septic stone in absorption trenches) have been used as an inlet

Figure 1a. *Cross sectional view of a Recirculating Vertical Flow (RVF) Constructed Wetland.*

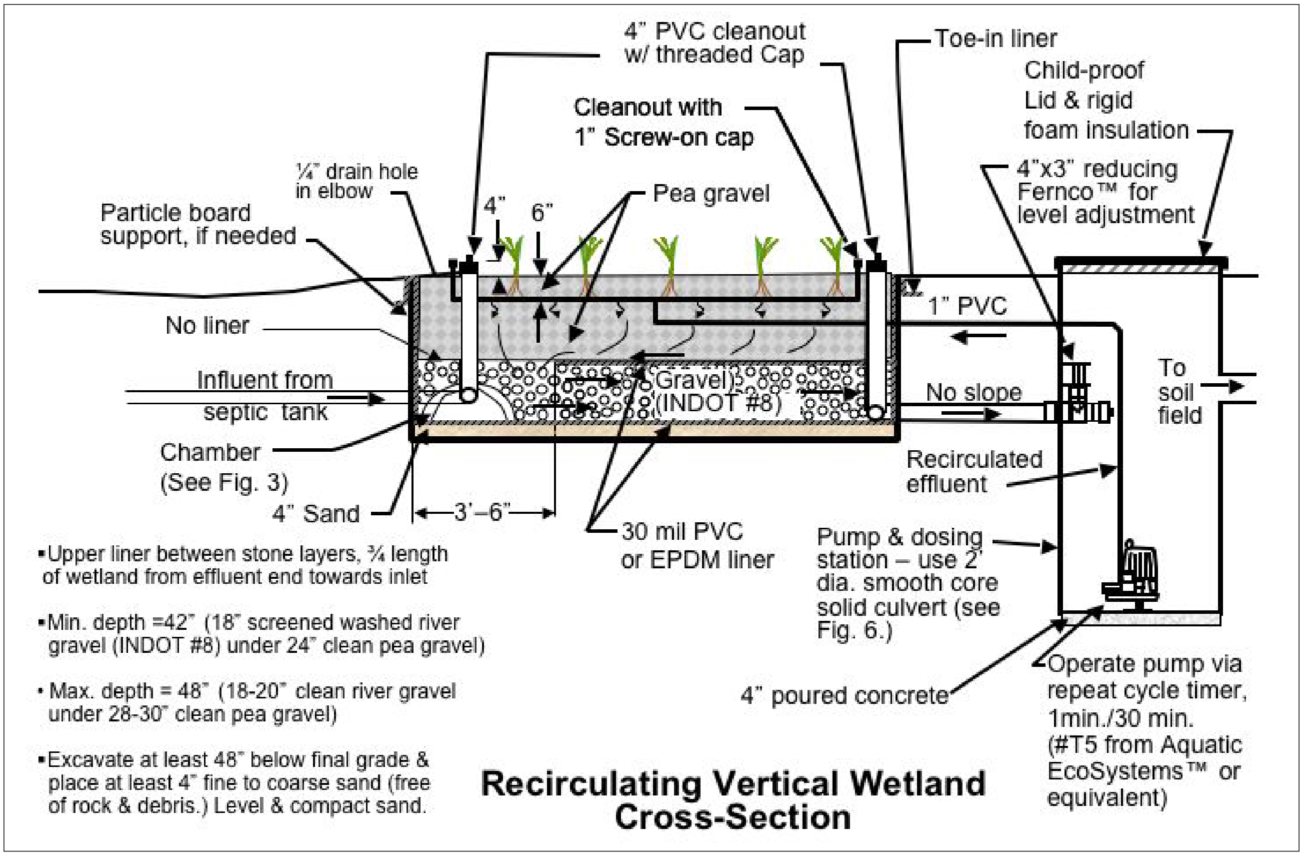

Figure 1b. *Top sectional plan view of a RVF Constructed Wetland.*

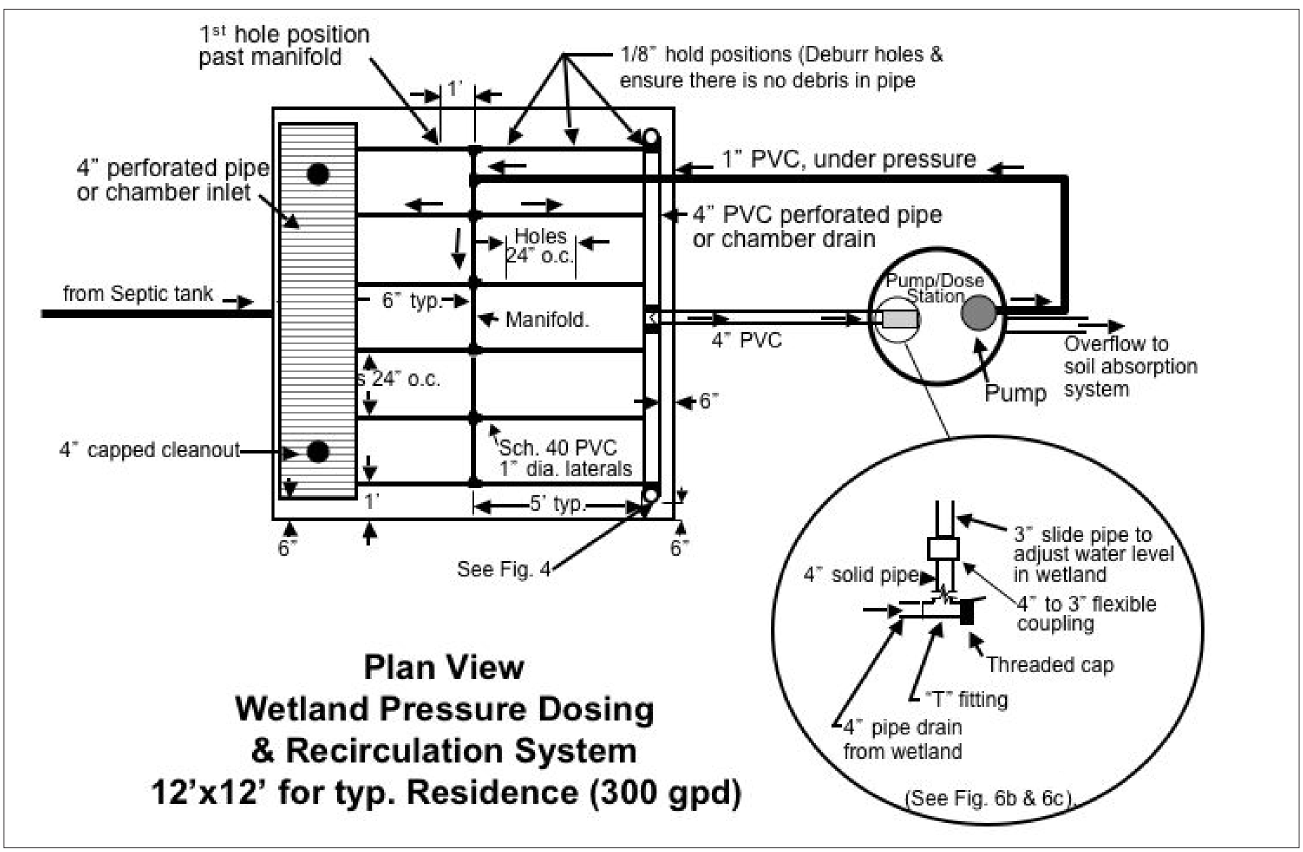

Figure 2. *Effluent filter in place at the septic tank outlet.*

manifold to distribute effluent across the width of the RVF and have been found to work as well as or better than perforated pipe (Figure 3). Chambers can hold more than traditional 4-in diameter manifold pipes and their innovative design facilitates periodic cleanout. In Indiana, the Indiana State Department of Health currently approves plastic chambers from several providers. The outlet manifold uses regular perforated 4-in sewer pipe (Figure 4).

Figure 3. *Wetland cell using a plastic chamber as an inlet-end manifold and 4" PVC pipe as an outlet-end manifold with clean-outs.*

To begin construction, line an appropriately sized, excavated area with a 30-mil geomembrane PVC liner or comparable impermeable material such as a 45-mil EPDM (Ethylene Propylene Diene Monomer) rubber sheet. Cover the impermeable liner and inlet/outlet manifolds with a layer of 13–25 mm (1/2–1 in) diameter gravel. Then, place a second layer of impermeable material (PVC or EPDM) over most of the top area of the gravel to separate the aerobic from the anaerobic sections of the RVF wetland, leaving the 25% of the bottom gravel layer nearest the wetland inlet uncovered (Figure 5).

Figure 4. *Collection 4" PVC manifold at the outlet end of the wetland.*

Next, put a top layer of 4-mm (1/4-in) diameter gravel (pea gravel) over the membrane and gravel. Position a set of perforated pressure-distribution lines about 6 in deep in the top of the pea gravel layer to uniformly load the wetland with effluent.

Effluent overflowing the septic tank, as well as treated effluent that has passed through the top portion of the wetland, passes through the gravel at the bottom of the wetland and drains to the sump basin.

Figure 5. *Upper or second liner covering 75% wetland cell.*

The sump basin consists of a 5-ft long section of 24-in diameter black corrugated drain tile, installed vertically (Figure 6a). Pour concrete in and around the bottom of the sump basin to seal the tile and prevent the entry of ground water and the outward seepage of effluent into the surrounding ground. Fit the top of the sump basin with a secure, insulated plastic or concrete cover. Position the bottom of the sump below frost line to prevent freezing. The sump basin holds the recirculation pump (Figure 6b), which distributes the effluent over the top of the wetland; the wetland water level adjustment mechanism (Figure 6c), which consists of a 4-in PVC “T” with end screw cap; and a 4 x 3-in PVC-to-PVC flexible sewer coupler reducer and 3-in PVC pipe at the top to adjust and maintain the water level. The water level in the wetland is normally set around 20 inches above the wetland bottom. An electronic repeat cycle timer (Figure 7) controls the effluent pump.

Figure 6a. *Sump basin station using 24" drain tile.*

Figure 6b. *Sump basin station showing pump, water level adjustment, and quick disconnector to service the pump.*

Figure 6c. *Wetland water level adjustment showing the PVC to PVC 4" x 3" flexible sewer couple reducer.*

Figure 7. *Electronic repeat cycle timer.*

Every 30 minutes, the timer activates the pump for a 2-minute cycle to pressurize a 1-in PVC manifold and perforated distribution pipe and to distribute effluent uniformly across the top pea gravel layer. The pressure distribution system consists of a closed piping network using 1-in diameter PVC lateral pipes fed through a manifold by the cycle pump. Place the laterals no more than 2 ft apart with equally spaced 1/8-in holes drilled in the top every 2 ft and protected with an orifice shield to disperse the effluent. The orifice shields prevent plugging of 1/8-in openings (Figure 8).

Figure 8. *Recirculating 1" PVC manifold, pressure laterals, and orifice shields.*

Place the last hole (air relief point) in each lateral just ahead of the screw-on cap. The manifold and force-main pipe must drain back to the sump after each cycle. You can drill a ¼-in pressure relief hole in the feed line inside the sump pit to facilitate draining, and use a quick-disconnect pipe coupling to facilitate pump servicing. Completely cover both the manifold and lateral distribution lines with 6 in of pea gravel (Figure 9).

Figure 9. *Pea gravel covering pressure laterals.*

Figure 10. *Finished RVF wetland with regular stone around edges.*

The outside edges of the wetland are typically finished with regular leach field stone (Figure 10) or other locally available material.

Plant the top of the pea gravel layer in rows with river bulrush (*Scirpus fluviatilis*), hard-stemmed bulrush (*Scirpus acutus*), soft-stemmed or great bulrush (*Scirpus validus creber*), prairie cord grass (*Spartina pectinata*), common rush (*Juncus effuses*), dark green rush (*Scirpus atrovirens*), sedges (*Carex spp.*), and great spike rush (*Eleocharis palustris*) with a density of one plant per square foot (Figures 11a and 11b), with a foot separation between rows. These plants have deeper root systems than cattails or bulrushes and function better in constructed wetlands. Wetland flowering plants, such water iris (*Iris virginica*), swamp milkweed (*Asclepias incarnata*), cardinal flower (*Lobelia cardinalis*), swamp rose mallow (*Hibiscus palustris*), great blue lobelia (*Lobelia siphilitica*), and New England aster (*Aster novae-angliae*) can be planted between the sedges and bulrush. Conventional garden plants such as morning glory vines (*Ipomoea leptophylla*), cheddar bath's pinks (*Dianthus gratianopolitanus*) and ferns have also performed well in LaGrange county RVF wetlands (Figure 11c).

Figure 11a. *Wetland immediately after planting.*

Figure 11b. *Wetland two months after planting*

Figure 11c. *Wetland planted with garden plants.*

Figure 12. *Landscaping around the wetland edges.*

Landscaping with low flowering plants and a border around the wetland edge of perennial flowers can create the visual effect of a conventional flower garden (Figure 12). When the system is fully operational, it can be walked on, since the sewage effluent is well below the surface.

Operation

As sewage effluent leaves the septic tank, it enters the inlet manifold at the front of the RVF constructed wetland where it is treated by passing horizontally across the bottom gravel layer. The timer-controlled pump in the sump basin periodically recirculates effluent back to the buried distribution pipe in the top layer of pea gravel. The effluent trickles vertically down through this aerobic upper zone, flows laterally across the impermeable liner separating the two layers of stone, and drops down into the uncovered front portion of the bottom gravel, after which it passes horizontally back to the sump basin. As treated effluent builds up in the sump basin, the pump starts another wetland recirculation cycle (timer is in the "on" position) or if the pump is in the resting cycle (timer is in the "off" position), the overflow effluent is discharged to a conventional leach field, mound sand system, drip irrigation, or other approved soil absorption system.

Maintenance Requirements

Removal of all solids from the septic tank every three to five years is highly recommended to prevent the overflow of solids. Depending on daily water usage or site specific circumstances, the tank effluent filter may require more frequent cleaning service. Ideally, you should check and/or service the filter at least annually to maintain peak performance. Cleaning the effluent filter is very simple and usually just involves hosing the solids off the exterior of the filter with a garden hose back into the septic tank (Figure 13). Wear protective, waterproof gloves when cleaning the filter or performing other maintenance to the onsite system as a safety precaution to ensure you do not directly contact the wastewater, especially if you have open wounds.

When the wetland is first used, some pea gravel can fall down into the larger stone at the uncovered section. If this creates a shallow depression at the top surface, fix the surface by raking the pea gravel to level it.

Green, vegetative leaves should appear in a wetland in Indiana by early spring (April-May), grow vigorously throughout the warmer months, and turn brown in late fall or early winter as the plants enter dormancy. Leave this brown, vegetative material in the RVF constructed wetland during winter, because it provides insulation during the winter months. Old growth can remain in place for several growing seasons, but should be removed after three to four seasons by cutting the plants at ground level.

Figure 13. *To clean a septic tank effluent filter, simply lift it out of the tank and hose it off. Let solids fall back into the tank.*

Pulling them can damage roots of other plants. If you must remove old vegetation, cut it in early spring before new growth appears. *NEVER BURN* old growth in place, since this can damages both growing and dormant plants, and possibly even the liner or PVC distribution pipe. Wetland plants do not require much maintenance, but should be checked annually. Consider a maintenance contract with a local installer to ensure that the pumps, floats, and plants function as intended and that a pump failure or other problems can be repaired quickly.

Expected Performance

When compared to a conventional septic tank and soil absorption system, which discharges 100% of the septic tank effluent contaminants into the

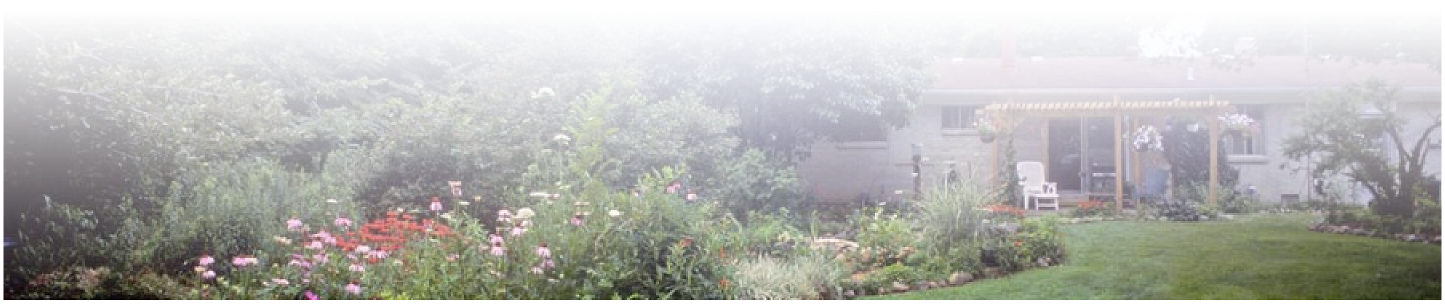

Figure 14a. *Septic tank (left) versus wetland (right) effluent.*

Figure 14b. *Effluent from the RVF constructed wetland installed at the LaGrange County Animal Shelter.*

ground, a well designed, constructed, and maintained RVF constructed wetlands removes up to 99% of the fecal bacteria (*E. coli*) and 80%–99% of other contaminants even before the effluent is discharged to the soil absorption field (Figures 14a and 14b). The physical, chemical, and biological treatment processes, and the alternating aerobic (oxygen is present) and anaerobic (oxygen is not present) environments created in the constructed wetland layers should destroy most pathogens and remove most contaminants. While unusual, the first RVF constructed wetland installed in LaGrange county in 2001 has not discharged effluent to the conventional absorption field during the last three years (2005–2007) because of water uptake by the plants, the evapo-transpiration process, and the low occupancy of the three-bedroom home (only two people present).

Figure 15 shows water quality performance of three RVF constructed wetlands regularly monitored in LaGrange County over the past seven years. The first Lagrange County residential RVF constructed wetland was designed for 450 GPD, with a wetland size cell of 15 x15 ft. For specific details about this system and its water quality performance go to the following Internet Web page: http://www.nesc.wvu.edu/nsfc/Articles/SFQ/SFQ_f06_PDF/Juried2.pdf.

The LaGrange County Animal Shelter was designed to treat 480 GPD using a 20 x 20-ft wetland cell, and the Brushy Prairie wetland received wastewater from a poultry processing plant generating 1600 GPD. It is designed with two 26 x 26-ft cells.

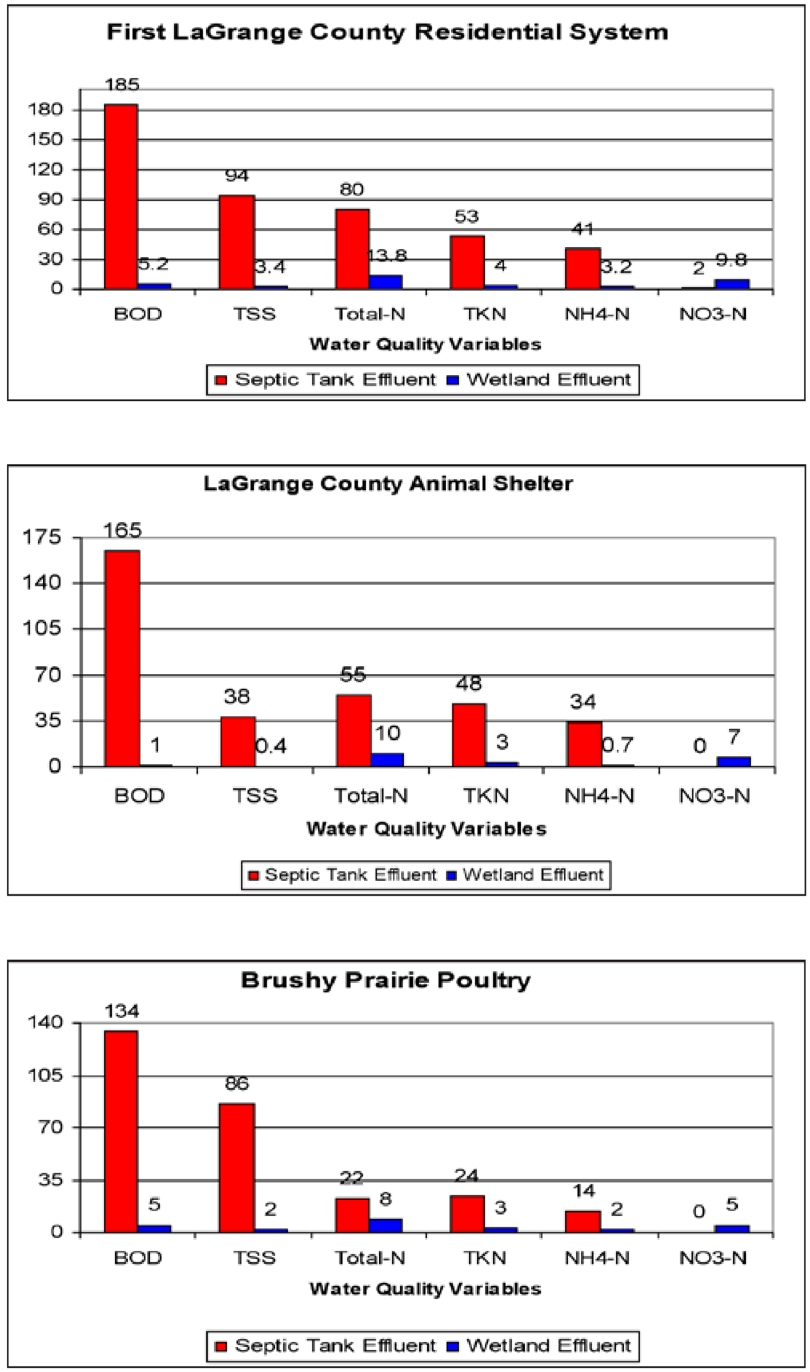

Figure 15. RVF constructed wetlands water quality performance. *Biochemical Oxygen Demand (BOD) measures the decomposition of organic material and Total Soluble Solids (TSS) measures the removal of particulate material suspended in the sewage. Total Kjeldahl Nitrogen (TKN) is the sum of Ammonia Nitrogen (NH3) plus organic Nitrogen, such as proteins. Total Nitrogen (TN) is the sum of all nitrogen forms present in the effluent [TKN + NO2–. (Nitrite) + and NO3– (Nitrate)]. Fecal Coliform bacteria testing is an indicator that other more dangerous bacteria could be present.*

Costs

The cost for an RVF constructed wetland depends on a number of local factors, such as availability of distributors, type of final disposal system, local labor and material costs, time of the year, and installer experience. It also depends on distance from a local gravel pit, capital costs, plant availability, and regulatory compliance.

The first RVF constructed wetland was installed in LaGrange County at a home with space limitations where the existing system needed to be upgraded. At that time (2001), the cost was about $3,000 for both the constructed wetland and 300 square feet of soil absorption area. The existing 1000-gal septic tank was used in the new system, and all work was done by the property owner. The RVF constructed wetland at the LaGrange County Animal Shelter, completed more recently, cost fifteen thousand dollars ($15,000), including construction by a licensed installer, but the system was considerably larger. It consisted of two 1000-gal septic tanks, a 20 x 20 x 4-ft deep RVF wetland, a dosing pump station (1000-gal tank) and a subsurface drip irrigation soil absorption system (2400 ft^2) as well as electronic controllers, two pumps, plumbing material and labor. In LaGrange County, the average 2007 cost for an RVF constructed wetland for a three-bedroom home (15 x 15 x 4 ft) was around $4,000 including installation, plus the cost of the septic tank and soil absorption field.

Legal Requirements and Restrictions

Proper authorization, as required by state and local regulations, must be obtained before installation of an RVF constructed wetland. In Indiana, the State Department of Health regulations consider constructed wetlands as experimental systems at this point and as such, state-level approval will be approved in most counties.

Summary

Recirculating, vertical flow constructed wetlands are sometimes defined as vegetated recirculating gravel filters. They treat wastewater by passing sewage through the constructed wetland where it is filtered through the gravel media in the bottom layer and then recirculated back around the roots and rhizomes several times for more filtration and treatment before it is finally discharged to the soil absorption area. This simple sewage treatment system is a reasonable, economical, and effective alternative to conventional wastewater treatments with low maintenance requirements.

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