Stony Brook University

NYS Center for Clean Water Technology

Recirculating Gravel Filters & Vegetated Recirculating Gravel Filters for Onsite Wastewater Treatment

ACCEPTED BY THE SUFFOLK COUNTY DEPARTMENT OF HEALTH SERVICES (DEPARTMENT) BASED ON INFORMATION PROVIDED BY VENDOR.

The Department has reviewed this submittal for completeness and is hereby approved for use in Suffolk County. This approval is solely for the model(s), units(s) and/or structure(s) included in the engineering report provided by the technology Vendor. Any changes or modifications to the approved design must be submitted for review and approval by the Department prior to its use in Suffolk County. The Department is not responsible for any errors, omissions, failures, construction defects or installation errors that may occur due to design professional, manufacturer, distributor or installer oversight or negligence.

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FOREWORD

This document provides guidelines for the design, installation, operation and maintenance (O&M) of vertical flow **recirculating gravel filters** (RGF) and **vegetated recirculating gravel filters** (VRGF) coupled to **woodchip biofilters** (WCB) in Suffolk County (SC), New York, for the treatment of on-site wastewater in accordance with Article 6 of the SC Sanitary Code, §760-603. The document addresses both residential and non-residential applications for sanitary wastewater design flows that are under 30,000 gallons per day (gpd) and where the treatment goal is 19 mg-N L^{-1} or less, as required under Article 19 of the SC sanitary code and related standards for Innovative and Alternative Onsite Wastewater Treatment Systems (I/A OWTS). Finally, sanitary flows of 30,000 gpd or greater require the design of a full treatment facility that reduces nitrogen (N) to below 10 mg-N L^{-1}.

While there are no comprehensive State or County standards or guidelines specifically for RGFs coupled to WCBs or VRGF coupled to WCBs in New York, standards pertinent to the design and installation of components of these technologies are scattered across multiple NY State and County publications. Where there are standards for components of these technologies (e.g., septic tanks, pipes, d-boxes, pumps, distribution systems, under-drains), this document references the corresponding sections from: (1) *SC Department of Health Services (DHS) "Standards for Approval of Plans and Construction for Sewage Disposal Systems for Single Family Residences" (2022) and (2) SC DHS "Standards for Approval of Plans and Construction for Sewage Disposal Systems for other than Single-Family Residences (2020).* For applications of wastewater flows between 1,000 to 30,000 G d^{-1}, standards and guidelines are available for recirculating <u>sand/media</u> filters in *NYS Design Standards for Intermediate Wastewater Treatment Systems* for <u>the purpose of secondary treatment</u>. Since this document describes <u>gravel</u> filters intended for <u>tertiary treatment</u> to achieve Article 19 targets for final effluent, design configurations and specifications here do not necessarily conform with those specified in the NYS standards for sand/media filters used in intermediate wastewater treatment systems. Where the standards specified in the intermediate systems for recirculating sand filters provide applicable and useful guidance for tertiary treatments, such guidelines are cited. Where neither relevant NYS or SC standards and guidelines are available, this document references guidance in publications from other states and the US EPA. Finally, the document also includes design specifications and guidance developed by the NYS Center for Clean Water Technology ('NYS CCWT') based on reviews of published engineering and scholarly articles, its own research experiments and discussions with professionals involved with septic designs and installations. The document is subject to further revision based on ongoing research.

The technologies described in this document operate by vertical flow where wastewater is pumped from a recirculation tank to a gravel filter from which it percolates downward by gravity through gravel media. Although the chemistry and purpose of VRGFs and 'horizontal flow' constructed wetlands are the similar, the technologies use different hydraulics and offer different planting options. Horizontal flow constructed wetlands are described in US EPA Wastewater Technology Fact Sheet: Subsurface Flow. This document refers only to RGFs and VRGFs coupled with WCB.

For readability, the authors use the acronym 'RGF' to refer to both RGFs and VRGFs when the context includes both types of gravel filters and use the 'VRGF' acronym when its meaning applies specifically to vegetated gravel filters.

This document is intended to provide general guidance to engineers, installers and maintenance providers for purposes of designing, installing and maintaining RGFs capable of producing final effluent meeting Article 19 standards of < 19 mg-N L^{-1}. None of its contents are meant to contravene or replace existing New York State (NYS) or SC standards for septic systems and, in the event of uncertainty about interpreting a standard, the reader is referred to definitive regulations contained in: (1) NYS Appendix 75-A: Wastewater Treatment Standards- Residential Onsite Systems; (2) NYS Department of Health's *Residential Onsite Wastewater Treatment Systems Design Handbook* (2012); (3) SC Sanitary Code- Article 6 "Single-Family Residences, Realty Subdivisions, Developments and Other Construction Projects; SC Sanitary Code- Article 19 "Management of Innovative Onsite Wastewater Treatment Systems"; (4) SC Department of Health Services (DHS) *Standards for Approval of Plans and Construction for Sewage Disposal Systems for Single Family Residences* (2022); (5) SC DHS *Standards for Approval of Plans and Construction for Sewage Disposal Systems for other than Single-Family Residences* (2020) and (6) SC DHS *Standards Promulgated under Article 19 for Approval and Management of Innovative and Alternative Onsite Wastewater Treatment Systems* (2020). Applications of the described technology will vary depending on site characteristics and town jurisdictional rules and should be carefully considered by a licensed engineer and permitting authorities. Information regarding SC's septic application and permitting process can be found on the Department of Health Service's Office of Wastewater Management's website (https://www.suffolkcountyny.gov/Departments/Health-Services/WWM).

This document was prepared by the New York State Center for Clean Water Technology, Stony Brook University in collaboration with SC, TF Engineering, Roux Environmental Engineering & Geology, D.P.C., and P.W. Grosser Consulting, Inc..

INTRODUCTION

Waterbodies with high levels of nitrogen (N) loading are often associated with significant water quality impairments as evident by the increased occurrence of harmful algal blooms, loss of benthic diversity and incidences of hypoxic events (fish kills). Additionally, N loading to Long Island's drinking water aquifers (the Upper Glacial and Magothy) from onsite wastewater poses human health risks as nitrate, an oxidized form of N, has been associated with various illnesses in multiple epidemiological studies. Conventional on-site wastewater treatment systems (OWTS) achieve limited or no N removal and locally OWTS effluent accounts for the majority of N delivered to groundwater and discharged to estuaries and lakes (SC Subwatersheds Wastewater Plan (SWP), 2020).

Recirculating gravel filters (RGFs) and vegetated recirculating gravel filters (VRGFs) are non-proprietary technologies capable of reducing biological oxygen demand (BOD) and total suspended solids (TSS) below 30 mg L^{-1} (MA DEP 2006). Regulatory authorities in many states also recognize these technologies can remove N (e.g., IDEQ 20MA DEP 2006; RI DEM 2010; WA DoH 2021). In Massachusetts, RGFs are approved for use in areas necessary to reduce total nitrogen (TN) below 25 mg-N L^{-1} in final effluent (MA DEP: 310 CMR 15.202); in Rhode Island, RGFs have been approved for general use since the mid-1990's to meet the state standard for TN of 19 mg-N L^{-1} in sensitive watersheds (RI DEM 2010). Washington State's Department of Health distinguishes between RGF's which are expected to reduce residential strength influent TN by 50% and RGF's with vegetated denitrifying woodchip biofilters which are expected to reduce residential strength influent TN to or below 20 mg_N L^{-1} (WA DoH 2021). Academic and government studies of different configurations of RGFs and VRGFs have reported mixed N removing capacity and generally required woodchip biofilters or other anaerobic chambers to achieve TN in final effluent substantially below 20 mg-N L^{-1} (e.g. US EPA 1999; Grinnell 2013 and Wei 2013).

When properly designed, installed and operated woodchip biofilters (WCB) offer the potential for > 80% removal of available residual nitrate (Gobler et al. 2021). Grinnnell (2013) reported a VRGF achieved TN in final effluent of 15.1 mg-N L^{-1} (67% removal of influent TN) but a RGF coupled with a woodchip biofilter achieved TN of 8.1 mg-N L^{-1} (92% removal of influent TN). Because recirculation oxidizes ammonia to nitrate (US EPA 1999), directing effluent to an anoxic woodchip box can enhance nitrogen removal by denitrification by providing an external source of carbon. Based on the weight of published evidence, the NYS CCWT considers a woodchip biofilter as described herein a necessary component of a RGF or VRGF for purposes of ensuring sufficient denitrification to consistently achieve annual average TN in final effluent below 19 mg-N L^{-1}. Additionally, certain species of plants (see Appendix B) can be planted above the RGF to aid in soil oxygenation which enhances the microbial degradation of raw wastewater, including the transformation of ammonia N to nitrate which is necessary for subsequent denitrification. The plants also contribute to N removal by assimilating available nitrate for biomass growth. Therefore, the design principals provided in this document include the use of RGF or VRGF coupled with a WCB, for the purpose of meeting a TN final effluent of 19 mg-N L-1, as required under Article 19 of the Suffolk County Sanitary Code for I/A OWTS.

SYSTEM PRINCIPLES & STRUCTURE

RGFs rely on recirculating wastewater to achieve effective treatment of organic matter or biological oxygen demand (BOD), total suspended solids (TSS) and ammonia with a smaller footprint than is possible with single pass sand filters. By pumping septic tank effluent (STE) which is anoxic to a distribution system from which it percolates through a gravel filter, wastewater is oxygenated beginning the process of BOD and TSS removal and the conversion of ammonia to nitrate. Recycling this wastewater thru the filter multiple times furthers these processes. A further benefit of recycling is nitrate can be denitrified (removed to an inert form of atmospheric nitrogen) when percolate from the RGF mixes with BOD under anoxic conditions in the recirculation or septic tank. But denitrification requires an anoxic or low suboxic environment. And recycling oxygenated percolate back to these chambers increases the dissolved oxygen concentration of the wastewater in these chambers. Additionally, recycling consumes alkalinity which is necessary for denitrification. Consequently, requirements for N removal sets an upper limit on the amount of recirculation.

A properly sized and partitioned septic tank provides primary treatment by allowing the settling of TSS and aiding in the reduction of BOD (Fig. 1, all). Wastewater then flows by gravity to the pump/recirculation chamber where it is pumped to the surface of the RGF in frequent, cycled doses and percolates vertically down through gravel media where it is treated through physical, chemical and biological processes. With each dose, oxygen is drawn down into the filter bed promoting aerobic treatment which removes BOD and TSS and oxidizes ammonia (or more specifically the ammonium ion) to nitrate through the process of nitrification (Fig. 1, all). The percolate from the gravel bed then collects in an underdrain at the bottom of the filter from where it drains either directly back to the recirculation tank (Fig. 1a) or to a flow splitting structure which divides flow between the recirculation tank and either the septic tank (Fig. 1b) or the woodchip box (Fig. 1c). The purpose of recirculating a portion of percolate from the gravel filter back to the septic tank instead of the recirculation chamber is to enhance the system's overall denitrification capacity (Fig. 1b). As percolate from the gravel filter has been oxygenated, splitting the recirculated flow between the two tanks lowers the proportion of DO mixing with the wastewater in each one and thereby reduces the chance of wastewater in either tank becomes oxic thereby inhibiting denitrification. The wastewater makes multiple passes through the gravel filter depending on pumping frequency and duration. The portion of wastewater which is not recirculated flows by gravity to a woodchip box for further denitrification prior to final disposal in a leaching structure (Fig. 1, all). Discharge to the woodchip box and final disposal can either occur during periods of high flow by means of a buoyant ball valve in the recirculation tank (Fig. 1 (a) & (b)) or as a fixed proportion of recirculation flow by a mechanism in the splitter basin (Fig. 1 (c)). Schematics of RGFs with and without splitting to the septic tank are shown in Fig. 1(b) and Fig. 1 (a) respectively. Plants (see recommended species in Appendix B) can be added above the nitrifying recirculating gravel filter aid in oxygenating wastewater percolate and assimilate nitrogen.

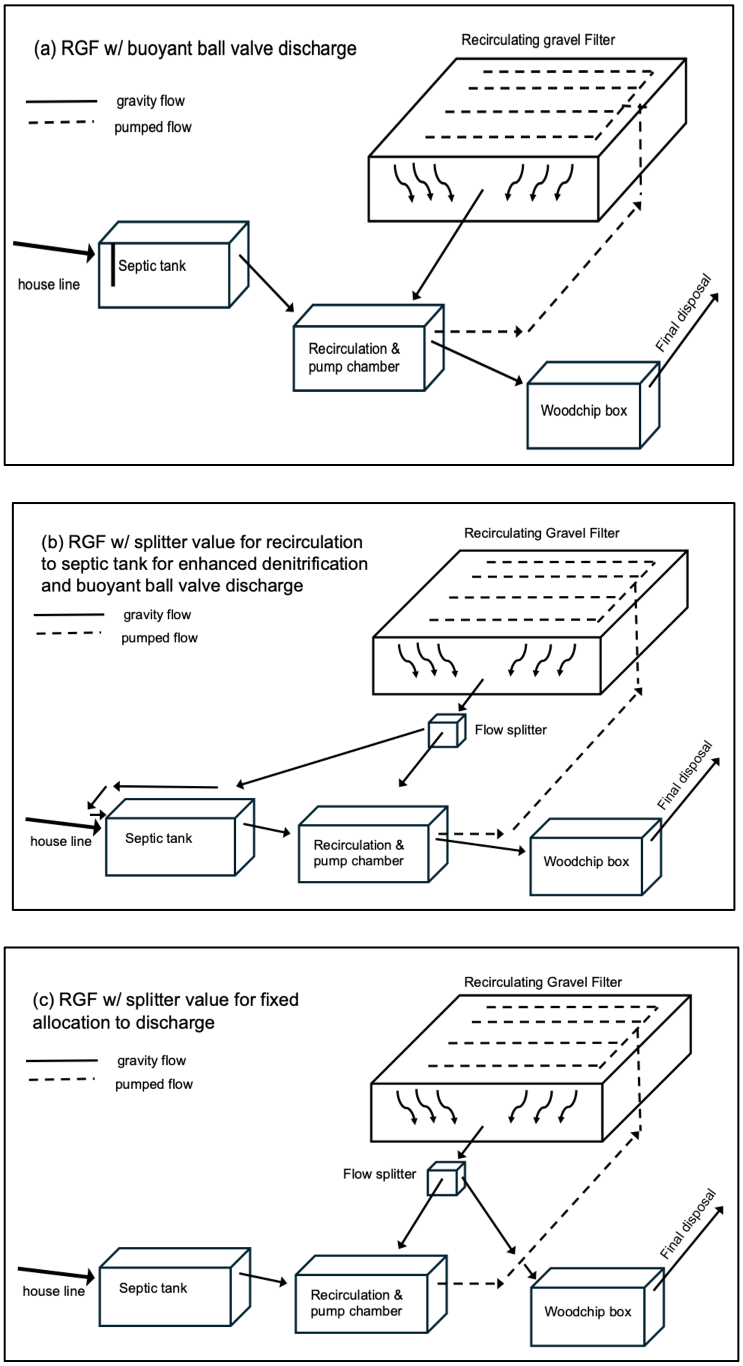


Fig. 1. Flow schematics of (a) recirculating gravel filter (RGF) coupled to a woodchip biofilter (WCB) with effluent discharge by buoyant ball valve located in recirculation & pump chamber; (b) RGF with flow splitter to septic tank to enhance denitrification capacity and effluent discharge by buoyant ball valve located in recirculation & pump effluent chamber and (c) RGF with effluent discharge of fixed % of flow at flow splitter. With fixed % discharge, pump controls must include a redundant off switch to prevent pump from overheating during no flow conditions.

DESIGN PARAMETERS

Site Selection

RGFs have the same siting and set-back requirements as other OWTS as documented in the *Standards for Approval of Plans and Construction for Sewage Disposal Systems for Single-Family Residences (2022)* and *Standards for Approval of Plans and Construction for Sewage Disposal Systems for Other than Single-Family Residences (2020)*.

Design Flow

Design flow for residences in SC is regulated by number of bedrooms as described in SC's *Standards for Approval of Plans and Construction for Sewage Disposal Systems for Single-Family Residences (2022)*; design flows for non-residential installations are described in SC's *Standards for Approval of Plans and Construction for Sewage Disposal Systems for Other than Single-Family Residences (2020)*.

For residential applications with post-1994 fixtures, design flow shall be 400 gallons per day for residences with one, two, or three bedrooms or 110 gallons per bedroom per day for residences with four or more bedrooms (SCDHS 2022). For non-residential applications, design flow is the sum of all hydraulic loads for each individual use within the building as described in Table 1 of SC's *Standards for Approval of Plans and Construction for Sewage Disposal Systems for Other than Single-Family Residences (2020)*.

Septic Tank

Primary treatment of wastewater upstream of the RGF by a watertight septic tank is required. Standards for residential and non-residential septic tanks are contained in SC's *Standards for Approval of Plans and Construction for Sewage Disposal Systems for Single-Family Residences* (2022*) Sec. 5-109 & Table 2A* and SC's *Standards for Approval Plans and Construction for Sewage Disposal Systems for other than Single-Family Residences (2020) Sec XIV*. After primary treatment, septic tank effluent (S.T.E.) should flow by gravity through an effluent filter to a recirculation tank. The effluent filter should be a minimum of 1/8th inch mesh and should be sized for the expected flowrate. Effluent filters may be manifolded together as necessary to meet flowrate requirements.

Recirculation Ratio, Recirculation Tanks, Pumps and Dosing

Recirculation Ratio.

Recirculation through the gravel filter helps the system to meet the treatment requirements of Article 19, particularly when limited space is available to install a system. The recirculation ratio is the total volume flowing through the gravel filter divided by effluent volume discharged.

Recirculation rates are not addressed in Suffolk County septic codes nor in NYS Appendix 75a. *NYS Design Standards for Intermediate Sized Wastewater Treatment Systems* (2014) specifies recirculation rates of 3:1 to 5:1. Typical recirculation ratios for gravel filters recommended in guidance documents from other States range from 3:1- 7:1, with 4:1 as a commonly used recirculation ratio for RGFs. As gravel filters are less prone to clogging than sand filters, they can tolerate influent with a higher proportion of STE and lower proportion of recirculated percolate.

The recirculation ratio impacts the chemical and biological treatment mechanisms taking place in the recirculation tank. Higher recirculation ratios are associated with higher BOD and TSS removal but there are limits to effective nitrogen removal at higher recirculation ratios. STE is anoxic and contains nitrogen, predominantly in the form of ammonia, and available carbon in the form of BOD; recycled effluent from the gravel filter is oxic, contains limited carbon (little to no BOD) and nitrogen predominantly in form of nitrate. If the dissolved oxygen in the recirculation tank remains low, the conditions will promote denitrification of the nitrate from the gravel filter effluent, using BOD in STE as a carbon source. If the recirculation ratio is high, denitrification may be inhibited by high oxygen concentrations in the gravel filter effluent. Additionally, at high recirculation ratios alkalinity can become depleted and pH levels can drop below those favorable for nitrification. Alkalinity is necessary for the conversion of ammonia to nitrate.

Recirculation Tanks.

For sanitary design flows up to 1,000 gpd, NYS Wastewater Treatment Standards- Residential Onsite System Appendix 75-A.7(b)(8) states pump chambers shall be sized to provide minimum storage capacity of one day's daily design flow above the alarm level. For sanitary design flows between 1,000 gpd and 30,000 gpd, *NYS Design Standards for Intermediate Wastewater Treatment Systems* (2014) provides a six step algorithm for determining minimum tank size as a function of recirculation rates and peak flows (see page F-13) for secondary wastewater treatment. For purposes of achieving Art. 19 target for TN in final effluent, the importance of maintaining anoxic or low oxygen conditions in the recirculation tank should also be considered in determining minimum tank size. The storage capacity of the recirculation tank should provide enough freeboard to accommodate power outages and servicing of the system

All tanks, risers, chimneys and associated (inlet/outlet) pipes and seams must be watertight. A monolithic, seamless recirculation tank is preferable to a tank consisting of component parts which must be assembled and properly sealed. The effluent pipe from the gravel filter should be positioned to maximize mixing of recirculated flow and STE. The effluent transport pipe from the recirculation tank should be sloped forward to the gravel filter or backward toward the recirculation tank to prevent freezing during cold temperatures. In addition, all tanks, risers, and chimneys must be traffic bearing HS-20 rated when installed within traffic bearing areas and are subject to approval from the SC DHS.

Pumps.

Submersible effluent pumps with programmable timers are required to pressure dose RGFs. Pumps should be located in the recirculation tank and screened. For systems receiving flows < 1,000 G d^{-1}, pumps should be sized to provide a minimum pressure of one pound per square inch (2.3 feet of head at the distal end of each distribution lateral in the gravel filter according to *NYS Wastewater Treatment Standards- Residential Onsite System Appendix 75-A.9 (d)(3))*. For systems receiving between 1,000- 30,000, pumps should be sized to provide a minimum of 5' head (water pressure) at the distal end of each distribution lateral in the filter. The number of pumps required depends on design flow and pump capacity.

Dosing.

Dosing should occur on a uniform, timed basis. Initial timer settings based on the design flow of the system are determined based on limiting the orifice discharge per dose cycle (e.g., WS DOH, 2015; p. 15) Impacts on the dissolved oxygen (DO) levels in the recirculation tank discussed above under "Recirculation Ratio" should be considered when setting dosing frequency and length of dose. Consequently, DO levels in the recirculation tank should be measured to determine optimal dosing patterns (i.e. frequency and length of dose).

High- and low-level float switches in the recirculation tank provide override options to timed dosing when flow volumes exceed or fall below float trigger-points. The recirculation tank should be sufficiently sized to minimize float switch operations

Recirculating Gravel Filter (RGF) & Vegetated Recirculating Gravel Filter (VRGF)

Distribution System.

Wastewater is pumped to the gravel bed in controlled, periodic doses via a manifold distributing pressurized flow equally to a series of lateral pipes drilled with orifices enabling uniform application of wastewater over the gravel bed. Manifold piping is typically 1 $^{1/4}$- 2" diameter SCH 40 PVC; lateral piping is typically 1- 1 $^{1/4}$" diameter SCH 40 PVC (SC DHS 2022). The number and configuration of distribution laterals is generally determined in connection with the type of distribution system chosen; e.g. Infiltrator Quik 4 plastic chambers (width 32") or Geomat 3900 (width 39") geotextile and the required footprint of the drainfield. Distribution laterals are generally have 1/8th - 3/16th" diameter orifices in upwards facing (Infiltrator) or downwards facing (Geomat) positions every 2-ft; every fifth orifice shall be drilled in the 6 o'clock position and fitted with an orifice shield (SC DHS 2022).

Turnups (long-turn or "sweep" elbows) of schedule 40 PVC should be installed at the distal ends of each lateral to facilitate cleaning of the lateral and for pressurized head measurement. The end should be sealable with a ball valve or threaded cap, and it should accommodate clear PVC pipes for pressure head measurement.

Filter Sizing.

The gravel bed of RGFs require an aerial footprint sized as a function of Design Flow (DF) and Loading Rate as described according to the equation:

$$\text{Gravel Bed footprint } (f^{2}) = \text{Design Flow } (G\ d^{-1}) \div \text{Loading Rate } (G\ f^{-2}\ d^{-1})$$

Hydraulic loading rates are set by most states between 3- 5 $G\ f^{-2}\ d^{-1}$ for sizing RGFs. Hydraulic loading refers to the quantity of STE received by the RGF and not the rate of instantaneous loading of wastewater onto the gravel bed which includes both non-recirculated septic tank effluent and recirculated percolate from the gravel filter. However, loading rates are also constrained by organic matter content of the STE distributed to the filter. Wastewater with higher BOD_5 is more likely to lead to biofilm accumulations which will clog a filter than wastewater with less BOD_5. For residential applications where wastewater strength contains BOD_5 in STE below 230 mg L^{-1}, most state guidance documents permit maximum hydraulic loading (i.e. 5 $G\ f^{-2}\ d^{-1}$) but recommended loading rates decline with increasing BOD_5 concentrations so at concentrations approaching 350 mg L^{-1}, the hydraulic loading rate will reduce to 3 $G\ f^{-2}\ d^{-1}$. Massachusetts, Iowa, Oregon and Washington provide the formula below for calculating loading rates as a function of BOD_5 concentrations in STE:

$$\text{Max Loading Rate } (G\ f^{-2}\ d^{-1}) = 1150 \div BOD_5 \qquad (2)$$

The constant is a factor which converts an upper limit of BOD_5 loading of.0096 lbs- $BOD_5\ f^{-2}\ d^{-1}$to a loading rate in units of $G\ f^{-2}\ d^{-1}$ when divided by wastewater strength as measured by BOD_5 (mg L^{-1}). This maximum organic loading rate is higher than the maximum values of 0.005 or .003 lbs $BOD_5\ f^{-2}\ d^{-1}$ commonly cited for recirculating sand filters including in *NYS Design Standards for Intermediate Wastewater Treatment Systems* (2014). This higher maximum only applies to gravel filters which are less prone to fouling than sand filters (Iowa DNR 2007). Washington State recommends RGFs not be used where BOD(5) or fats, oils and grease are above 400 mg L^{-1} and 30 mg L^{-1} in influent flows (i.e. STE). No states recommend RGFs at wastewater strength concentrations where BOD_5 exceeds 720 mg L^{-1} regardless of loading rates.

The depth of the filter media should be 24".

Filter Media.

Filter media should consist of gravel, with an effective particle size of 2 mm or greater. Typical gravel media size range recommended by various states is 2 mm to 6 mm. For sand filters, NYS Appendix 75A requires a uniformity coefficient of < 4; *NYS Design Standards for Intermediate Wastewater Treatment Systems* requires a uniformity coefficient of < 2.5. Media should be washed prior to installation. In general, the lower the uniformity coefficient, the lower the likelihood the filter could clog.

Filter Container

Gravel filters should be contained in a water-tight enclosure using either monolithic concrete or 30 ml HDPE liner (or equivalent) to prevent wastewater from infiltrating vertically or horizontally into the ground.

Underdrain Media

While other standards in NYS do not address underdrains, *NYS Design Standards for Intermediate Wastewater Treatment Systems* 2014 are specific and can apply to RGFs receiving flows < 1,000 G d^{-1}.

- A 4" diameter SCH 40 PVC perforated collection pipe is required at the bottom of the drainage layer, to collect effluent wastewater and direct it to the recirculation tank or splitter basin;
- the drain should have a maximum slope of 0.5 percent;
- slots should be cut into the drain pipe oriented upwards, sized ¼" by 2½" and spaced 4" apart;
- a minimum of 4" of ½"to ¾"clean washed stone should be placed between and over underdrain pipes. If a plastic liner is used, sharp, angular stone should be avoided to prevent liner punctures;
- eight inches of 3/8" clean washed pea stone should be placed carefully over underdrains and drainage stone to assure the filtering media is not washed down into the underdrain.

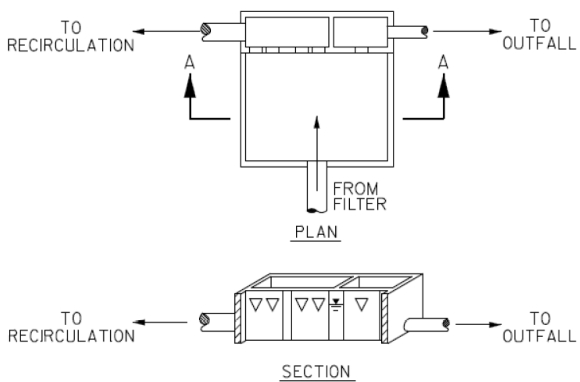
The bulkhead fitting connecting the collecting drain to the external effluent pipe to the recirculating tank/splitter should be watertight.

Flow Splitting Mechanisms

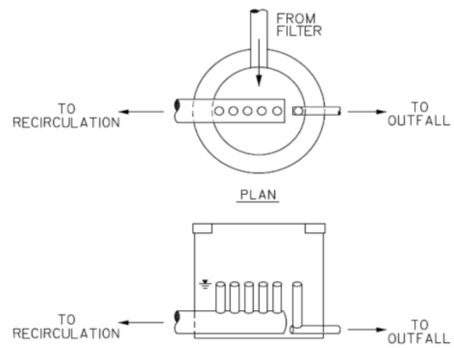
Flow splitting mechanisms control the volume of RGF percolate directed between the recirculation tank and either the septic tank or the woodchip box (Fig. 1). The mechanisms can be contained in a splitter basin (i.e., a d-box) or the recirculation tank itself. Flow splitting in the splitter basin occurs as one of several static mechanisms available direct a fixed portion of flow between recirculation tank and either septic tank (Fig. 1 (b)) or woodchip box (Fig. 1 (c)). Flow splitting in the recirculation tank flow is directed either back to the RFG or to the woodchip box and final disposition according to the height of a buoyant ball valve in the tank. So in the splitter basin, a fixed volume is always directed in the same proportions whereas in the recirculation tank the split between recirculated volume and effluent form the system is control by the height of volume in the recirculation tank. Either device should enable the operator to adjust the recirculation ratio to optimize effluent wastewater quality and electricity demand.

Splitter Basin

Percolate volumes from the RGF flow by gravity to a splitter basin or distribution box where fixed quantities of flow are directed between the recirculation tank and, dependent on the plumbing configuration of the system, either to the woodchip box/ final disposal (Fig. 1 (c) or back to the septic tank (Fig. 1 (b)). The quantities redirected can be set using a variety of mechanisms including weirs and pipes (Fig. 2(a) & (b)) or by installing leveling devices (sometimes referred to as speed levelers) on the pipe outlets of the splitter basin itself. These levelers allow for the pipe outlet aperture sizes to be adjusted and in turn regulate the volume of flow being recirculated or directed to the woodchip box and final disposal.



(a)



(b)

Fig. 2. Examples of flow splitting in splitter basin v-notch weirs and (c) pipes. (Source: Hantzsch 2007)

Buoyant-Ball Check Valve

The buoyant ball valve is illustrated in Figure 3. Flow to the recirculation tank and to final discharge is controlled by this ball valve which is located in the recirculation tank. As the water level in the recirculation tank rises, the ball rises and exerts pressure to create a firm seal on the downward outlet of the pipe which causes flow of recirculated percolate to route to the woodchip box.

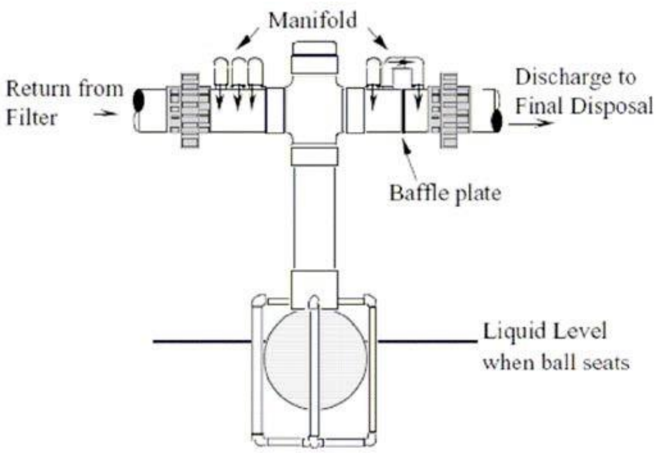


Fig. 3. Example of recirculation splitter valve (Source: Source: Ball & Denn 1997)

Effluent Bypass

A gravity bypass line from the septic tank to the final deposition (leaching galleys, ring or drainfield) should be installed as a fail-safe during experimental and pilot phases of Article 19 permitting. This line can be positioned at a higher level in the septic tank than the line to the recirculation tank. Bypass piping shall be pitched such that in cases of mechanical failure or hydraulic overload, the system can function by gravity as a system meeting conventional OWTS standards as required by Article 19 of the SC Sanitary Code (19-104 Paragraph A.4).

Woodchip Biofilter

The wood chip biofilter design shall follow the design requirements in the *Engineering Report: Woodchip Box Polishing Units,* approved by the SCDHS on September 9, 2024.The purpose of adding a woodchip biofilter (woodchip 'tank or 'box'; "WCB") to an RFG is to provide bioavailable carbon for enhanced denitrification. Denitrification in RGFs may be carbon limited because much of the carbon usually contained in onsite wastewater (in the form of BOD_5) is removed by physical or microbial processes in the septic tank, pump chamber or gravel filter. The biofilter should be installed between the splitter mechanism and final deposition. Nitrified percolate from the splitter mechanism flows by gravity to the woodchip tank (either precast concrete or monolithic plastic tank) through a pipe to 4" slotted PVC pipe on the bottom of the woodchip tank. Upflow then ensures full saturation of the woodchips which in turn provides the anoxic conditions necessary for denitrification and allows incremental nitrate removal. Final effluent then exits the woodchip tank by gravity through a pitched 4" PVC pipe to final disposal (e.g., leaching galleys, ring, drainfield or absorption bed). The level of the effluent line from the woodchip box should be at least 3" beneath the level of the effluent line from the recirculation tank or splitter.

Woodchips should consist of clean, primarily ¼" to 2 ½" clean chips free of debris and dirt.
The sizing of the woodchip tank is based upon the design flow divided by the porosity of the woodchips used (generally ~ 0.5) and a hydraulic residence time (HRT) of at least 1.2 days.

Volume of woodchip tank = Design flow X HRT / woodchip porosity

So, for instance, using oak chips with a porosity of 0.5 and a design flow of 660 gallons would yield a minimum tank size of 1,650 gallons or 220 f^3.

Plants for Constructed Wetlands

Wetlands plants function as a sink for nutrients including N and phosphate. Research by NYS CCWT and published literature has shown that VRGF can achieve additional N removal when compared to RGF alone (Nyer 2020; Nyer et al. 2022). Along with nutrient uptake by the plants themselves, the benefit may be especially enhanced by coupling a woodchip biofilter to the VRGF as certain plants have shown a capacity to transform reduced N forms (e.g. ammonia) to nitrate which can subsequently be denitrified by a woodchip biofilter (Nyer 2020). However, for the purpose of this document, design calculations and parameters presented are conservative and do not account for these potential benefits.

Plant species should be chosen based on suitability of the specific species for site specific conditions including climate, sunlight/shade and requirements for root depth. Appendix B has a sample list of plants for use in VRGFs as well as additional information on plant spacing and conditions. The top of the gravel filter should be graded in such a way that sheds surface water from its surface and does not allow intrusion of surface water from the surrounding area.

INSTALLATION GUIDANCE

RGF designs vary widely based upon site-specific parameters. Design professionals shall include a Sequence of Construction on the design drawings and/or construction/bid drawings. Design professionals should consider the following while preparing the Sequence of Construction.

After excavation of the drain-field, its depth should be verified (e.g., by self-leveling laser), the bottom surface leveled, raked and made free of stones or other material that could puncture the liner and compacted. Installing plywood walls along the sides of the trench can prevent side soil erosion and allow space to install water-tight bulkhead fitting and effluent piping.

30 mil HDPE liner should be fit into excavation allowing sufficient extra liner on all sides to accommodate downward pull on the liner. The bottom of the bed should be pitched with a 1% slope down to an underdrain at the center. Along the V-shaped bottom, a perforated 4” PVC peunderdrain should be placed on a bed of 3/8” pea stone and covered with pea stone. At the center of the side wall from which the effluent will flow to the woodchip box/final disposition a hole should be cut through the liner and plywood to accommodate a bulkhead fitting to which the underdrain is fitted. The bulkhead fitting should be sealed and verified as watertight.

Once the woodchip box had been installed, the installer should check to confirm the elevation of its effluent line is sufficiently below the effluent line from the recirculation tank or splitter to prevent effluent from backing up into the drainfield.

OPERATIONS & MAINTENANCE

As with all IA OWTS installations, RGFs and VRGFs must be operated and maintained as required under SC DHS “*Standards for the Approval of Plans and Construction for Sewage Disposal Systems for Other than Single-Family Residences*” § XVI Paragraph 1.d-e and “*Standards Promulgated under Article 19 for the Approval and Management of Innovative and Alternative Onsite Wastewater Treatment Systems*” § 19 -107.

RGFs and VRGFs consist of mechanical and living components, both of which can be expected to need regular maintenance and care to ensure proper operation. Most importantly, pumps require inspection and cleaning in accordance with the manufacturer’s recommendations. Proper cleaning of filters will reduce stress on the pumps and maintenance required due to clogging of pumps or distribution systems. Controls and electrical components should also be tested and maintained at least annually. The plants in VRGFs also need to be cared for on a routine basis including weeding for the first two years of operation. Once plants are established, they should be monitored to ensure adequate coverage at each growing season.

SC standards require the property owner to have an initial three-year O&M service contract with a licensed Liquid Waste professional and to maintain an O&M contract thereafter. The O&M provider must hold a Liquid Waste License pursuant to Chapter 563, Article VII and an Endorsement as an Innovative and Alternative Treatment System Service Provider issued through the SC Department of Labor, Licensing and Consumer Affairs. A sample O&M agreement can be found in **Appendix C**. Operators conducting routine inspections should follow guidelines such as those outlined in the Service Form in **Appendix D**.

The recommended minimum routine maintenance requirements are outlined below:

Every 6 Months

I. Visually check the septic tank effluent filter, if necessary clean the effluent filter
II. Visually check the recirculation pump effluent filter, if necessary clean the filter
III. Visually check the conditions of the plants within the system; pull weeds if needed
IV. Visually check for ponding on filter surface
V. Visually check the lysimeters and/or sampling ports of systems in pilot phase or provisional acceptance permitting to ensure they are free from debris and sludge that could adversely impact sampling and monitoring
VI. Visually check the distal end ports for debris, which may indicate clogging in the distribution piping, if necessary clean the distribution piping.
VII. Bio-solids hosed off of filters, pumps, pump vaults, and treatment material shall be placed into the inlet end of the septic/trash tank

Every 12 months

I. All electrical components should be checked annually for functionality and safety.
   a. All control switches shall be activated and timer should be checked to ensure accurate settings.
   b. All visual and audible alarms shall be tested.
   c. All submerged floats shall be activated and checked for proper function.
   d. If moisture is encountered in any splice box, the source shall be identified and corrections made
II. Inspect the sludge levels in the septic tank and, if necessary, pump the sludge from the septic tank
III. Perform pump maintenance tasks as recommended by the manufacturer (e.g. oil changes, seal replacement). Inspect system for infiltration, corrosion, and other structural issues
IV. Inspect the flow splitting device for solids build-up and confirm that settings are correct
V. Inspect the level of the woodchips in the denitrification filter; replenish or replace, if necessary
VI. Inspect leaching pools or galleys to ensure they are not full; if necessary, pump any sludge buildup from the leaching structure
VII. If low profile infiltration systems are installed, open the inspection ports (if any) on the rows, if necessary, bottle brush clean the distribution lines

Every 12 months (VRGF only)

I. Prune plants in fall or spring as required, based upon plant species
II. Remove plant litter in the fall from the top of the constructed wetlands
III. In the spring, remove plants that did not survive the winter and replace with new plants

As Needed

I. Confirm even flow distribution in gravel filter by measuring pressure at distal ends of laterals; if the head has changed, flush and clean the laterals
II. Adjust recirculation rate or dosing pattern
III. Assess any changes to building use or occupancy and evaluate their effect on the system
IV. Review monitoring results and evaluate performance in treating wastewater.

SAMPLING

According to Article 19 experimental and pilot IA OWTS must be sampled monthly for 12 months and samples analyzed for Total Kjeldahl Nitrogen (TKN), ammonium (NH_4^+), nitrate (NO_3^-), nitrite (NO_2-), 5 day biological oxygen demand (BOD_5), alkalinity and total suspended solids (TSS) by a laboratory certified by NYS Department of Health's ELAP program. Provisionally accepted systems must be sampled and samples analyzed bi-monthly for 24 months. An effluent sampling reservoir must be included in the design to allow for effluent quality monitoring as required under Article 19 of the SC Sanitary Code. The most effective sampling port depends on the method of final dispersal but could include either an in-line effluent sampling sump immediately downstream of the woodchip box or a distribution box ahead of final disposal structure (e.g., leaching ring or galleys or a drainfield/adsorption bed).

STANDARD PRODUCT 3-YEAR WARRANTY

In accordance with Article 19, all I/A OWTS require a minimum 3-year warranty. Since RGFs and VRGFs are considered field-built systems, warranties are required on the key system components including pumps, pump control panels, septic tank effluent filters, effluent perforated pipe and leaching structures. Since these items will be purchased through various vendors, it is recommended to purchase all equipment with extended 3-year warranties directly from the manufacturer.

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APPENDICES

A: Design Requirements Checklist

The following section outlines the minimum design requirements for the RGF and VRGF. The general design process should proceed as follows (modified from Iowa DNR, 2007):

1. Determine existing conditions including wastewater composition (i.e. BOD_5, TSS, TKN, alkalinity and other contaminants) which may impact system performance.

2. Determine design flow rates as stipulated per SCDHS design and construction standards.

3. Characterize influent wastewater composition; i.e. BOD_5, TKN, alkalinity, pH, grease, and other contaminants that the design professional feels may impact biological growth.

4. Determine:
   a. Soil types and leaching capacity;
   b. Depth to groundwater;
   c. Effluent discharge location and limits; and
   d. Electrical requirements and availability.
   e. Treated effluent disposal method (e.g., leaching pools, drainfields, etc.) based upon soil types, leaching capacity, and depth to groundwater in accordance with SCDHS standards.

5. Determine the sizing of the septic tank and configuration.

6. Determine the required size of the recirculation tank.

7. Calculate the hydraulic loading rate and organic loading rate.

8. Determine the recirculation ratio and method of flow splitting.

9. Determine the required size of the gravel filter that satisfies hydraulic and organic loading rates

10. Select the appropriate distribution system layout (lateral and orifice spacing) to promote even distribution of influent across the entire filter.

11. Determine sizing and number of dosing pumps and controls needed to achieve specified dosing intervals and duration.

12. Determine the dosing volume per orifice and method of flow dispersal across the filter bed.

13. Determine number and sizing of underdrains, including perforation size, location and spacing.

14. Select underdrain bedding media gradation and depth.

B: Sample Planting Information

Plants selected for VRGFs should consist of native perennial herbaceous plants (no shrubs or trees). As the availability of water is critical to wetland plant survival, the thickness of the planting media above the VRGF media is important to consider when selecting plants. Obligate (OBL) or Facultative-Wet (FACW) wetland plants must have sufficient access to water to survive and should be used for systems with planting media thickness between 3 and 10 inches. If planting smaller plugs, supplemental watering may be necessary for plants to establish. For thicker media (over 10-inches of planting media above the VRGF media), Upland (UPL) or Facultative-Upland (FACU) species are recommended. Other planting considerations include plant height, access to sun, flowering timing/color, and plant leaf shape and color.

Obligate and FACW Wetland Plants

Juncus effusus (soft rush)

- Flowers in July- no significant coloration
- Full sun
- Plant spacing ~2ft
- Best in wet- moist conditions

Carex vulpinoidea (fox sedge)

- Full sun
- Plant spacing ~1.5 ft
- 1-3 feet height
- Blooms May-June - no significant coloration

Iris prismatica (slender blue flag)

- Blooms May- July
- Full sun to partial shade
- Plant spacing 1ft
- Blue flower

Asclepias incarnate (swamp milkweed)

- Blooms June-July
- Full sun to partial shade
- Plant spacing 1.5-3 ft
- Handles variable moisture levels and is tolerant of well-drained soil
- Pink flower

Hibiscus moscheutos (swamp mallow)

- Blooms July to September
- Full sun to partial shade
- Plant spacing 2 ft
- White or pink flower

Caltha palustris (marsh marigold)

- Blooms April to June
- Full sun to partial shade
- Plant spacing 18-24 inch
- Moist conditions preferred but is drought tolerant

Eupatorium purpureum (purple joe pye)

- Bloom July to September
- Full sun to partial shade
- Plant Spacing ~2ft
- Moist soil preferred but can tolerate periods of dry

Upland and FACU Plants

Schizachyrium scoparium (little bluestem)

- Full sun
- August to February- no significant flower
- Plant spacing 1.5 ft
- Dry to medium preferred (no sitting water)

Monarda didyma- July to august (short flowering time)

- Full sun to part shade
- Medium
- 2 ft spacing
- Good with s*chizachyrium scoparium*
- Red flower

Aquilegia canadense (red columbine)

- Flowers April -May
- Full sun to partial shade
- Plant spacing 1ft-2ft
- Tolerant of range of moisture levels

Monarda fistulosa (wild bergamot)

- Bloom July to September
- Full sun to partial shade
- Plant spacing 1ft
- Dry to medium moisture preferred but is drought tolerant

Asclepias tuberosa (butterfly weed)

- Blooms June and July

- Full sun to partial shade
- Plant spacing 1.5 ft
- Prefers dry to medium moisture (dry is preferred)

Rudbeckia triloba (brown-eyed susan)

- Blooms July to October
- Full sun or partial shade
- Plant spacing 1-3ft
- Moist or d

C: Operations & Maintenance Agreement Template

Sanitary System O&M
SUPPLY AND SERVICES AGREEMENT

AGREEMENT DATE:

This agreement for and with:

Primary Point of Contact:
Name:
Address:

Phone:

EMail:

Accounts Payable Point of Contact:
Name:
Address:

Phone:

Email:

Position on project as (circle one): *Owner – Agent - if agent describe:*

Hereafter in this document to be referred to as: ***Customer***

Place of Performance - Residence or Business:

Location:

System Designer/Engineer:

Owner:

System Description: ____________________

Per Article 13, Basic Service fee. This does not include repair or tune-up services

Type of Agreement (circle one): Initial Three Year / One Year Continuance

Total Pricing for Basic Service: $ ________ For Period: One Year / Three Years / Other: ________

This agreement is for services for Operation and Maintenance (O&M) as required per Suffolk County Residential Standards 5-114, A – item 6.
This section requires Owners to begin with and maintain an O&M agreement to provide for the professional systems management by a licensed Liquid Waste professional.

Services Summary:

Three Year Warranty Services – 6 Inspections over a three-year period (approximately one visit every 6 Months)
Service visits shall include, General review of system, observe tank levels and conditions in tanks, leaching systems etc. Any adjustments to the mechanical or electrical systems necessary to maintain proper function shall be made during the site visits.

___________ will respond to property listed on page 1 of this agreement in event of alarm or reported unsatisfactory condition within 24 hours of notification.

NOTE: These inspections are observatory in nature and to assure proper function. In general routine service includes inspections for proper installation and function as intended as well as operational evaluation.

Service does not include repairs as result of damage, negligence, or items that would be classified as routine maintenance such as pumping of tanks etc.

___________ will notify the owner of any additional costs prior to executing any work not included in the basic service agreement.

Additional Costs: We expect your system to provide many years of satisfactory service. However, there will be the need to perform periodic “tune ups” which include a thorough cleaning and re-calibration of the system. The frequency of tune-ups is affected by the care and use of the owner. Please refer to O&M Manual for more information on best practices for NRB life and function.

Inevitably, some systems will incur damage from landscape or construction activity such as sprinkler installations, tree falls or other inadvertent damage. Repair costs for any such damage is not included in this contract price.

Changes: Changes in this agreement can be made via e-mail. Progress reports, cost increases, issues on the project site or other items will be addressed via e-mail.

Primary customer (financial responsibility) contact:
Secondary customer contact
Project manager contact
Subcontractor – interested party contact

Other:
NOTE: the above should represent all interested parties for notification of project progress and/or changes in scope.

Summary of Charges

Name:
Anticipated Total Project cost as of agreement: $
Total anticipated days:
Additional Supply: NONE

Schedule:

Number	Item	Date	Payment Due		Due Date
			%	Amount	
1	General Function Inspection Log pump hours			$	Upon Completion
2	Same			$	
3	Same			$	
4	Same			$	
5	Same			$	
6	Same			$	

NOTE: progress payments invoiced on 28th of each month due on 10th following month.

Payments:
The customer agrees to the proposal and the above payment schedule. In the event of default, the customer agrees that ___________ has the right to stop all work until alternate payment arrangements can be made. The customer further agrees that in the event of default, increased project costs due to re-mobilization and materiel staging fees could occur and ___________ has the right to pass the cost of this work onto the customer. Customer agrees to pay interest at the rate of 1.5% per month (18% per annum) and all costs incurred by ___________ for collections including, but not limited to, attorney fees at a cost plus 20% basis.

AUTHORIZATION

By signing below the customer acknowledges that they have read and understand this agreement, are authorized to sign this document on behalf of their organization and that they agree with all terms and conditions contained herein.

O&M Provider
Signature:
Title:
Date:

Property Owner:
Signature:
Date:

D. Example O&M Service Form

Location/Address:	
Type of system:	
Date:	Time: Ambient conditions:
Rain in last 48 hours:	If yes, list amount and timing:
Site Plan available: ☐ Y ☐N	

Inspection Item	Observations	Further Action Needed
Controls and Pumps		
Record no. of pump cycles		☐ Y ☐N
Record pump run time		☐ Y ☐N
Determine effective run time per cycle		
Check pump for signs of wear. Refer to manufacturer instructions for maintenance and cleaning as required		☐Y ☐N
Septic Tank		
Check that sludge accumulation < 6"		☐Y ☐N
Check that total depth of surface scum + bottom solids < 50% of total liquid depth of the tank.		☐Y ☐N
Clean effluent filter screen		☐ Y ☐N
Additional observations:		
Recirculation tank		
Check water level in tank and record position relative to floats and overflow line		☐Y ☐N
Ensure no scum and sludge is present		☐Y ☐N
If applicable clean filter		
Filter Bed		
Visually inspect surface and remove any unwanted weeds		☐Y ☐N
Inspect for ponding at the surface		☐Y ☐N
Check/clean out monitoring tubes/effluent pipes		☐Y ☐N

Check flow to distribution laterals		Y N
Clean orifices/flush laterals as necessary		Y N
Downstream Filter		
Inspect splitter valve mechanism (+ water level)		Y N
Adjust recirculation ratio if necessary		Y N
woodchip tank		
Visually inspect top of woodchip box to confirm saturation is maintained		Y N
Final Dispersal		
Check water level in D-Box or pump tank used for effluent dispersal		Y N
Visually inspect area of final effluent discharge for ponding.		Y N

E. Repair and Replacement Costs

Periodic Maintenance & Equipment Lifespans

Component	Estimated Frequency	Estimated Cost	Variables
Pipe Jetting / Structure Cleaning with Vacuum Truck	5 years	$2,500	Dependent on solids coming into system; cost includes disposal
Pump Replacement	10 years	$2,800	Average life expectancy
Wood Chips Replacement	30 years+	$750	Depending on characteristics of wood chips and carbon leaching rates
Gravel Replacement	30 years+	$3,000	Typically needed due to clogging – if solids are managed by pipe cleaning, structure cleaning, lifespan may be longer
Erosion Repairs	if necessary	$2,000	Dependent on vegetation stabilization, intensity of storms, etc.
Concrete Structure Repair	if necessary	$4,500	Sealing and joint construction, operations during low ambient temperatures

Note - the actual costs are dependent on the size and design of the system.