Irrigation
FACTSHEET

BRITISH COLUMBIA
Ministry of Agriculture, Food and Fisheries

Order No. 512.000-2
July 1999

TREATMENT OF GREENHOUSE RECIRCULATION WATER

◆ BIO-SAND FILTRATION ◆

RECIRCULATION OF NUTRIENT SOLUTION

The greenhouse vegetable industry in British Columbia is fully aware of the need to recycle used nutrient solution (overdrain), as local, provincial and federal governments continue to legislate against effluent discharge. In addition, the industry recognizes the potential benefits of recycling overdrain. These benefits include:

- Saving on fertilizer cost
- Reduced demand for water, therefore saving on water cost,
- Reduced risk of ground water contamination, and
- Continuing to promote the industry's 'green' image.

Recirculating of overdrain raises one major concern, that is, the spread of water-borne plant diseases which are caused by *Fusarium* spp. and *Pythium* spp. To manage this problem, overdrain can be subjected to a range of disinfestation methods. These methods include:

- Pasteurization or heat treatment
- Ozonation
- UV-radiation
- Bio-sand filtration
- Chemical treatment with chlorine, bromine, iodine, or hydrogen peroxide.

All these methods have their advantages and disadvantages on cost and efficiency as listed in Table 1. The decision to select a workable system for a greenhouse is based on cost, availability of space, size of greenhouse, and efficiency.

TABLE 1: A COMPARISON ON THE ADVANTAGES AND DISADVANTAGES OF DIFFERENT METHODS OF DISINFESTATION

METHOD OF DISINFESTATION	ADVANTAGES	DISADVANTAGES
1. Bio-sand Filtration	• Highly efficient • Low capital investment	• Requires more space relative to other systems
2. Pasteurization or heat treatment	• Highly Efficient • Does not require large amount of space	• High capital investment in equipment and high maintenance cost
3. Ozonation	• Does not require large amount of space • Highly efficient on clean water	• High capital investment and maintenance cost • Efficacy reduces with high organic matter
4. UV-radiation	• Does not require large amount of space	• Efficacy reduces with high organic matter and age of the bulb
5. Chemical treatment	• Highly Efficient • Low capital investment	• Can cause phytotoxicity at high concentrations

BIO-SAND FILTRATION (BSF) SYSTEM

The method of disinfestation shown in this fact sheet is a combination of two techniques to provide an efficient and cost effective system for recirculation of used nutrient solution. This system uses bio-sand filtration to reduce or remove the high load of pathogens and organic matter, and a small amount of bleach to disinfect the filtered overdrain.

Bio-sand filtration is an adaptation of traditional systems used for treating drinking water. It is a water purification process in which water is passed through a porous bed of filter medium. Bio-sand filters are typically characterized by certain design components:

- the water column (water above the filter sand that provides hydraulic head for the process),
- filter sand varying in depth,
- the under-drainage medium (usually consisting of graded gravel), and
- a set of control devices.

In a mature sand bed, a thin upper sand layer will be formed. This layer consists of biologically active micro-organisms that break down organic matter while suspended inorganic matter is removed by straining. Numerous trials have demonstrated that the bio-sand filters are effective in removing *Phytophthora* spp. and *Pythiurn* spp. from the overdrain. High efficiency was recorded against *Fusarium spp., Cylindrocladium, Verticillium dahliae, Thielaviopsis,* and *Xanthomonas* bacteria.

The design parameters indicated for the bio-sand filtration flow chart shown in Figure 1 are based on a 2 hectare greenhouse. To size tanks for larger or smaller greenhouses, scale up or down accordingly as shown in Table 2.

Greenhouse Sump Tank - Item 1 (Figure 1)

The greenhouse sump tank collects all overdrain produced in the greenhouse. The sump tank can be located underground, in or outside the greenhouse depending on the existing plumbing and irrigation system. The following are the requirements of the sump tank:

- The tank size should be 1m^3 or 1,000 liters minimum. If this is not available, a larger tank can be used.
- One tank should be used for every 2. 0 to 2.5 ha. Therefore if the size of the greenhouse is 3 ha, it is recommended that two 1,000 L tanks are installed, one on each side of the walkway.
- The tank should be secured into the ground with concrete.
- The tank should have a cover as a safety precaution and to prevent algae built up.
- A 10 mesh screen should be installed over the inlet to remove large debris.
- Water levels should be monitored with a high and low level alarm.
- The sump pump should have a capacity of 50 gpm/ha.
- The sump pump is turned off and on by floats in the tank.
- An overflow pipe is required that drains to an emergency collection tank.
- A by-pass line should be installed between the sump tank and the overdrain collection tank for diverting overdrain to the emergency collection tank when pesticide is used.

TABLE 2: THE CORRESPONDING NUMBER OF SUMP TANKS REQUIRED, MINIMUM VOLUME OF THE OD HOLDING TANK, MINIMUM DIAMETER OF THE BSF TANK TO THE SIZE OF THE GREENHOUSE, AND RECOMMENDED DIAMETER OF BSF TANK.

Size (ha.)	Sump Tank Required	#Minimum Diameter of BSF Tank (m)	*Minimum Diameter of BSF Tank (m)	Recommended Diameter of BSF Tank (m)
1	1	70,000	6.0	7.5
2	1	140,000	9.0	10.5
3	2	210,000	10.5 – 11.0	12.5
4	2	280,000	12.0 – 12.5	14.5
5	2	350,000	14.0	16.5
**6	3	420,000	15.0	18.0
**8	4	560,000	18.0	20.5
**10	4	700,000	20.0	23.0

#The minimum size of the OD holding tank is determined by the maximum amount of overdrain collected on a peak watering day. The above figures are based on a dripper density of 2.2, 50 waterings per day at 100 ml each, and allowing for a 60% overdrain, and are calculated as follows:

OD = size of greenhouse (m^2) x dripper/m^2 x number of watering/day x amount of nutrient solution/watering x % overdrain

*The minimum diameter of the BSF tank is calculated based on the desired flow rate of 100 L/m^2/h and a 24 h of process time.

** Larger greenhouses should consider using two BSF tanks instead of one large tank.

Overdrain Collection Tank - Item 2
(Figure 1)

This tank serves as a holding tank for overdrain as well as a settling tank for spore removal. This tank can be located in or outside the header house. If it is installed outside the greenhouse, it should be insulated to prevent the overdrain from freezing in the winter. The following are the requirements of the overdrain holding tank:

- Sized to store at least one day of overdrain during the peak watering season (Table 2).
- A round, bolted galvanized steel tank with a black top is preferred.
- A grill that hold 25 mm gravel should be placed 0.2 m off the bottom of the tank to assist the settling of organic matter. A layer (0.03 m) of 25 mm gravel is placed on the grill. An outlet should be constructed at the base/side of the tank for sludge removal.
- The inlet (from sump tank) should be installed into the upper region of the tank and on the opposite side of the outlet (to BSF tank).
- The outlet (to BSF tank) should be located at least 0.5 m off the bottom of the tank.
- A 30 mesh screen over the outlet (optional).
- A high and low alarm to monitor water level.
- Sump pump of no less than 50 gpm.
- The sump pump is turned off and on by floats in the tank.
- An overflow pipe that drains to an emergency collection tank.

Fast Sand Filter Units - Item 3
(Figure 1)

Fast sand filters serve as physical filters for removal of organic and inorganic matter from the overdrain prior to being added to the bio-sand filter. The following are the requirements of the fast sand filter:

- The fast sand filters should be sized on the basis of 20 gpm/ft^2 of sand bed area. For a flow rate of 50 gpm, two 18 inch sand filters with #11 crushed granite or #16 silica sand are sufficient.
- While not necessary, the back-flush water for these fast sand filters can come from the clean water supply. A line from the fresh water supply can be connected to the distribution manifold on the bottom of the fast sand filter unit. The fast sand filters can be back-flushed at a preset time or pressure differential. It may be better to set the back-flush at a preset time to control when the back-flush cycles will be done.
- The back-flush material should be directed to the emergency collection tank.

Bio-Sand Filtration Tank - Item 4 **(Figure 1 a)**

The bio-sand filtration (BSF) tank serves as the site for the removal of pathogens and organic/inorganic matter from the overdrain. The following are the requirements of a BSF tank:

- The tank should be constructed from bolted galvanized steel or concrete and covered with a black top.
- It should be round for optimum filtration efficiency and have a minimum height of 3.0 m.
- If it is installed outside the greenhouse, it should be insulated so that the water temperature is no lower than 16 ^{o}C.
- The inlet and outlet should be designed as shown in Figure 2. The inlet is placed at least 0.15 m off the surface of the sand bed so that overdrain flowing into the BSF tank does not disturb the top layer of the sand bed. The outlet is placed 0.1 m off the bottom of the tank.
- A pressure reducing valve should be installed on the incoming pipe to minimize water pressure coming out from the inlet.
- An overflow pipe connected to the overdrain holding tank is recommended.
- The BSF tank is divided into five operational sections.

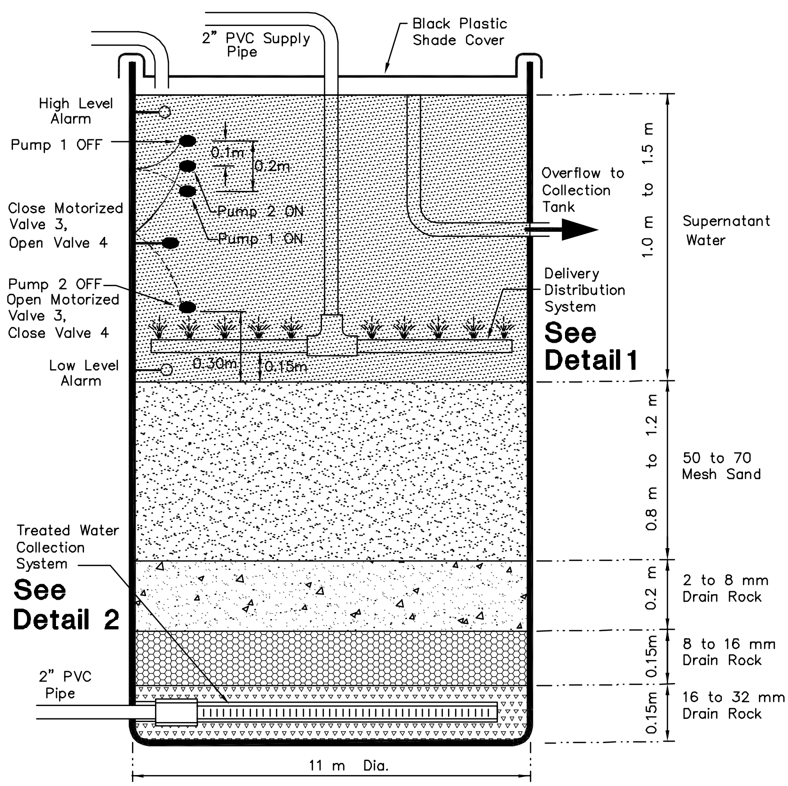


Figure 1 (a) Bio-Sand Filtration Tank

I. Under-drainage system

The under drainage system serves two purposes:

a. It provides unobstructed passage for the collection of filtered overdrain
b. It supports the bed of filter medium.

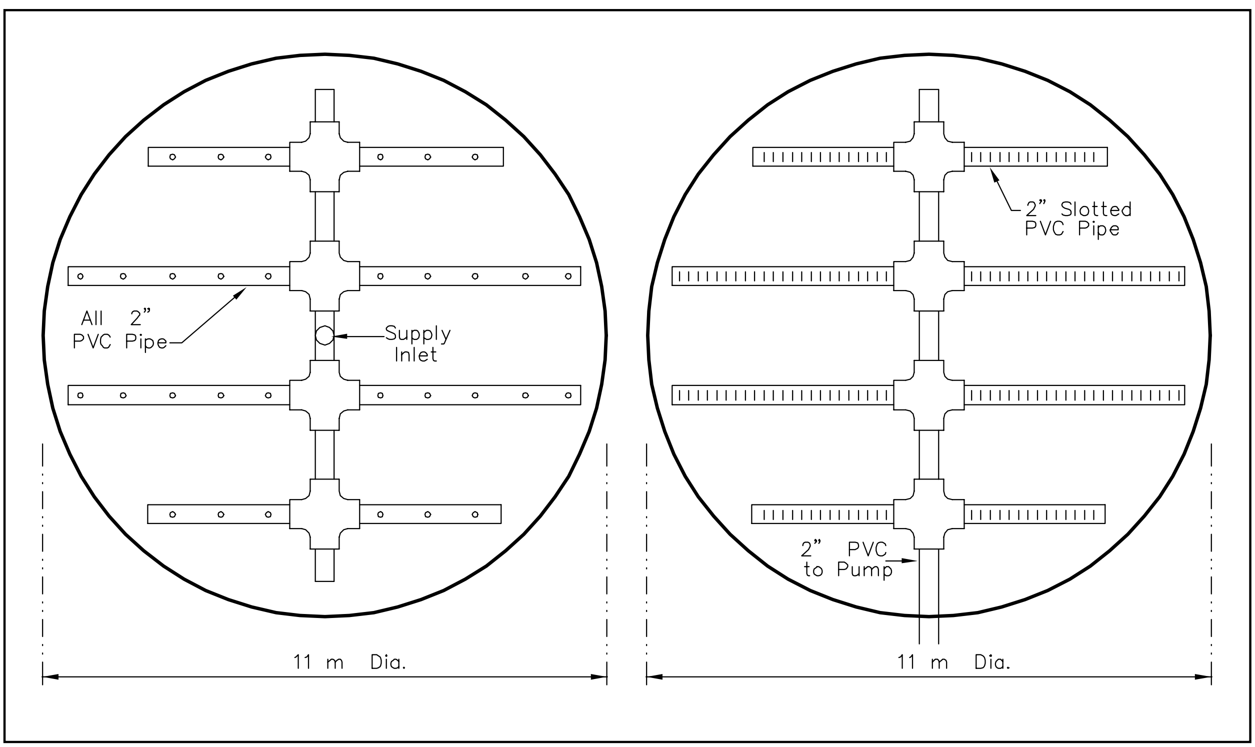
The under drainage system is divided into two layers:

a. A bottom layer of 0.3 in of pea gravel (5-8 mm) surrounding the lateral perforated drain pipes which lead to a main pipe.
b. A top layer of 0.2 in coarse sand (2-5 mm) is recommended to realize a smooth change between the pea gravel and the filter sand.

II. Filter bed

The physical characteristics of a filter bed are important in maintaining the BSF's efficiency. The following are the basic requirements of the filter bed:

a. A uniform sand grain with the effective size (ES) in the range of 0. 15 to 0.35 mm, preferably 0.2 mm and the uniformity coefficient (UC) of less than 3.
b. Sand should be washed so that it is free of loam, clay and organic matter.
c. A depth between 1.0 and 1.2 in.
d. **IMPORTANT:** The filter bed should be prepared by pouring the sand into the tank pre-filled with water. This prevents air entrapment.



Detail 1 **Detail 2**

III. Water column

The water column which stands on top of the sand bed serves two distinct purposes:

a. It provides the driving head to push the water through the filter bed to the under drainage system.
b. It creates a detention time of several hours for the treatment of overdrain.

Basic requirements of the water column are:

a. This section should be between 1.0 and 1.5 m.
b. It should not be use as a reservoir for sedimentation.

IV. Flow control system

The optimum flow rate for the bio-sand filter is 100 $L/m^2/hr$ (the square area in question is the surface area of the sand bed), and is monitored with the help of a flow meter. An alarm system is installed to the flow meter to ensure the flow rate is within the desired range. (For higher flow rates, please check with your greenhouse consultant).

The size of the BSF tank should be designed to process the maximum amount of overdrain expected from the greenhouse in no more than 24 hr during peak conditions.

For example:

A 2 ha greenhouse with a density of 2.2 emitters/m^2, 50 waterings per day, 100 ml per watering and a maximum overdrain of 60% will generate 132,000 L of overdrain. To process the overdrain within 24 hours, the tank/sand bed should have a minimum surface area of 55 m^2 that translates to a diameter of approximately 8.5 m (minimum diameter).

However, it is recommended that the diameter of the tank/sand bed be wider to allow room for errors and future expansion. We proposed that the BSF should have the capability to process the overdrain within 16 hours. Therefore, the tank/sand bed should have a surface area of 82.5 m^2 which translates to a diameter of approximately 10.5 m.

Table 2 (page 2) provides further information on the sizing of the BSF and overdrain holding tank.

The water level in the BSF tank is controlled as follows:

a. The inflow is controlled by a float which turns pump 1, the supply pump, on and off. The float is on a short lead so that the range of operation is quite small. The float is located at the top of the tank so that pump 1 will keep the bio-sand filter full as long as there is overdrain available.
b. A second float controls pump 2, which draws the treated water out of the bio-sand filter. This float is on a longer lead, shutting the pump off when the water level drops to 0.3 m above the sand level and turns the pump back on when the tank water level is close to being full. The on point should be just below the off point for pump 1.

V. Aeration system

The aeration system oxygenates the overdrain to encourage the build up of aerobic microorganisms. It can be attached into the delivery distribution system. Another option to oxygenate the overdrain is to place the delivery distribution system above the water level.

Figure 2 shows the layout of the under-drainage system, filter bed, water column, and flow control system of the BSF tank.

Bleach Injection - Item 5 (Figure 1)

Bleach is injected at the concentration of 3 to 5 mg/L (3-5 ppm) for the disinfestation of pathogens that are not filtered out. A free/total chlorine probe attached to an alarm system should be installed to ensure correct amount of bleach is injected into the filter overdrain. Sample valves should be installed before and after bleach treatment to allow for sample collection. Greenhouses that are considering running at a higher flow rate (> 100 $L/m^2/h$ should make necessary adjustments to the bleach concentration.

Filtered Overdrain Holding Tank - Item 6 (Figure 1)

This tank serves as a holding tank for filtered overdrain, and can be located in or outside the header house. If it is installed outside the greenhouse, it should be insulated to prevent the treated overdrain from freezing in the winter. The following are the requirements of the filtered overdrain holding tank:

- Sized to store at least a day of filtered overdrain during the peak watering season. The larger the tank size the more flexible the system will be.
- A round, bolted galvanized steel tank with a black top is preferred.The inlet (from BSF tank) should be installed above the maximum water layer to allow as much water agitation as possible.
- The outlet should be located at the bottom side of the tank

- An overflow pipe that drains to the overdrain holding tank or the emergency collection tank.
- The water level in the holding tank is controlled as follows:

  The inflow is controlled by a float which turns pump 2, from the bio-sand filter, on and off. The float is on a short lead and located at the top of the tank so that pump 2 will keep supplying the holding tank with filtrate from the bio-sand filter. A second float controls motorized valve 1, which draws water out of the filtered overdrain holding tank. This float is on a longer lead, shutting the valve off when the water level drops just above the low level alarm.

By-pass Line - Item 7 (Figure 1)

The by-pass line is used to recirculate filtered overdrain back into the BSF tank when fresh overdrain is not available. This line is used to keep the bio-sand filter active. Motorized valve 3 is turned on when fresh overdrain is not available, and this in turn closes valve 4.

Motorized Valves - Item 8 (Figure 1)

Both valve 1 and valve 2 are normally closed valves, requiring power to open the valves. The function of the motorized valves is to control the amount of freshwater and treated overdrain coming into the mixing tank.

Fresh Water Supply - Item 9 (Figure 1)

The source of fresh water supply may come from well or city supply.

Mixing Tank(s) - Item 10 (Figure 1)

The mixing tank is where water coming from the filtered overdrain holding tank is mixed with the fresh water supply. The following are basic requirements of the mixing tank(s):

- This tank with lid can be made from fiberglass.
- The floats in the mixing tank control both of the motorized valves, turning them "off" at the high setting and "on" at the lower setting.
- The float in the filtered overdrain holding tank controlling valve 1 must also be in the correct range for both of these valves to open. The valves must be adjusted so that the water coming from the filtered overdrain holding tank is mixed with the correct amount of fresh water to achieve the desired EC.

Fertilizer Injectors - Item 11 (Figure 1)

Fresh fertilizer can be injected into the irrigation system in two ways.

- Directly into the irrigation pipe (option 1)
- Into the mixing tank (option 2)

The fertilizer injector will add fertilizer mixes to the premixed nutrient solution (filtered overdrain and fresh water) to bring it up to the desired final EC.

Day Storage Tank (Optional) - Item 12 (Figure 1)

The day storage tank serves as a holding tank for the nutrient solution used to irrigate the greenhouse. The following are the requirements of the day storage tank.

- Sized to store at least a day of nutrient solution required during the peak watering season.
- A round, bolted galvanized steel tank with a black top is preferred.
- A high and low alarm to monitor water level.
- Floats to control water level by turning pump 4 on and off.
- An overflow pipe that drains to an emergency collection tank.

Fast Sand Filters - Item 13 (Figure 1)

Fast sand filters are required to protect the drip irrigation system from plugging in the event of insoluble fertilizers or other material entering the final mixing tank.

Emergency Overflow Tank

All storage tanks should be equipped with an overflow for emergency purposes. The overflows should be piped to an overflow tank or pumped back into the start of the treatment system.

Pumps

Pumps 1, 2, 3 and 4 should all be sized for 42 gpm as this is the flow rate through the treatment system. Pump 5 must be sized to handle the peak irrigation flow rate, which is 120 gpm in this case.

Piping

All piping for the recirculation system should be 50 mm (2") PVC. Pipes laid above ground should be black to prevent algae contamination.

STARTING UP RECIRCULATION

Greenhouses can recirculate their overdrain at any time of the growing season. The following recommendations should be taken into consideration:

- Allow 4-6 weeks overdrain to cycle through the bio-sand filter in order to establish the biological

- balance before the bio-sand filter is ready for nutrient recycling.
- Begin recirculation at the end of February or beginning of March when plants have established.
- If growers would like to start earlier, ensure that the filtered overdrain is free of pathogens.
- In the spring, a third of the water for preparing nutrient solution can come from filtered overdrain. This ratio can increase slowly to 1: 1 by the month of June.
- Tests should be conducted weekly (weeks 1-15) on the feed and overdrain to ensure the correct amount of macro- and micro-nutrients are present. Testing can be extended to every 2 weeks when irrigation feed rates exceed 5 L/m^2

MAINTENANCE

Greenhouse Sump Tank

Remove debris collected by the 10 mesh screen at least once month.

Overdrain Holding Tank

Sludge at the bottom of the tank should be removed monthly by turning the bottom outlet on. This will prevent the sludge from caking, and becoming difficult to remove.

Fast Sand Filters

Ensure all fast sand filters are back-flushed at a preset time or pressure differential.

Bio-Sand Filter Tank

- Ensure the filtration rate is maintained at an acceptable level.
- If the flow rate drops to an unacceptable level, the sand bed must be cleaned. Such work can be done manually and very carefully with broad flat-bottomed shovels. A typical operation involves draining the overdrain to 0.1 m below the sand surface, skimming off 1 cm of the upper layer.
- For maintenance purposes, drain the overdrain to a height roughly 0.1 m above the sand bed and rake the top layer. This can be done at least twice a year.
- Efficiency of the bio-sand filter may be temporarily reduced and bleach concentrations may have to be adjusted.

Filtered Overdrain

Overdrain treated with bleach should be sent to the laboratory to test for the presence of pathogens at least once a month. This is to ensure that an effective concentration of bleach is used for disinfestation of pathogens, and also to monitor for signs of trouble.

EC and pH Probes

Before recirculating, these probes should be cleaned more frequently than the conventional drain-to-waste method when sawdust is used as the growing medium.

Irrigation Lines and Pipes

To ensure minimum amount of organic matter accumulation at the end of irrigation lines and pipes as the result of the recirculation, flushing the irrigation system with pressurized air or water once a month is recommended.

END OF SEASON CLEAN-UP

The **BSF tank** does not require clean up at the end of the season. However, there are a few procedures to follow that will allow other sections of the irrigation system to be cleaned.

1. Allow the BSF tank (Item4) to fill up.
2. Turn off pump 1 or redirect the raw overdrain from the collection tank away from the BSF tank and into the emergency collection tank.
3. Turn off the bleach injector.
4. Ensure motorized valve 3 is turned on when fresh overdrain is not available, which in turn closes valve 4. This will keep the filter bed activated during the clean up period.
5. Flush and clean the rest of the irrigation system, i.e., filtered overdrain holding tank, mixing tank, day storage tank, greenhouse sump tanks, overdrain collection tank, fast sand filters, and all the irrigation pipes and lines using the conventional procedures.

ACKNOWLEDGMENT

The Bio-sand Filtration Research Committee would like to thank the following organizations for their financial, or in-kind, contributions to this project.

B.C. Greenhouse Vegetable Research Council
B.C. Investment Agriculture Foundation
B.C. Ministry of Agriculture, food and Fisheries
Pacific Agri-Food Research Centre
Gipaanda Greenhouses Ltd.
Robinson Farms Inc.

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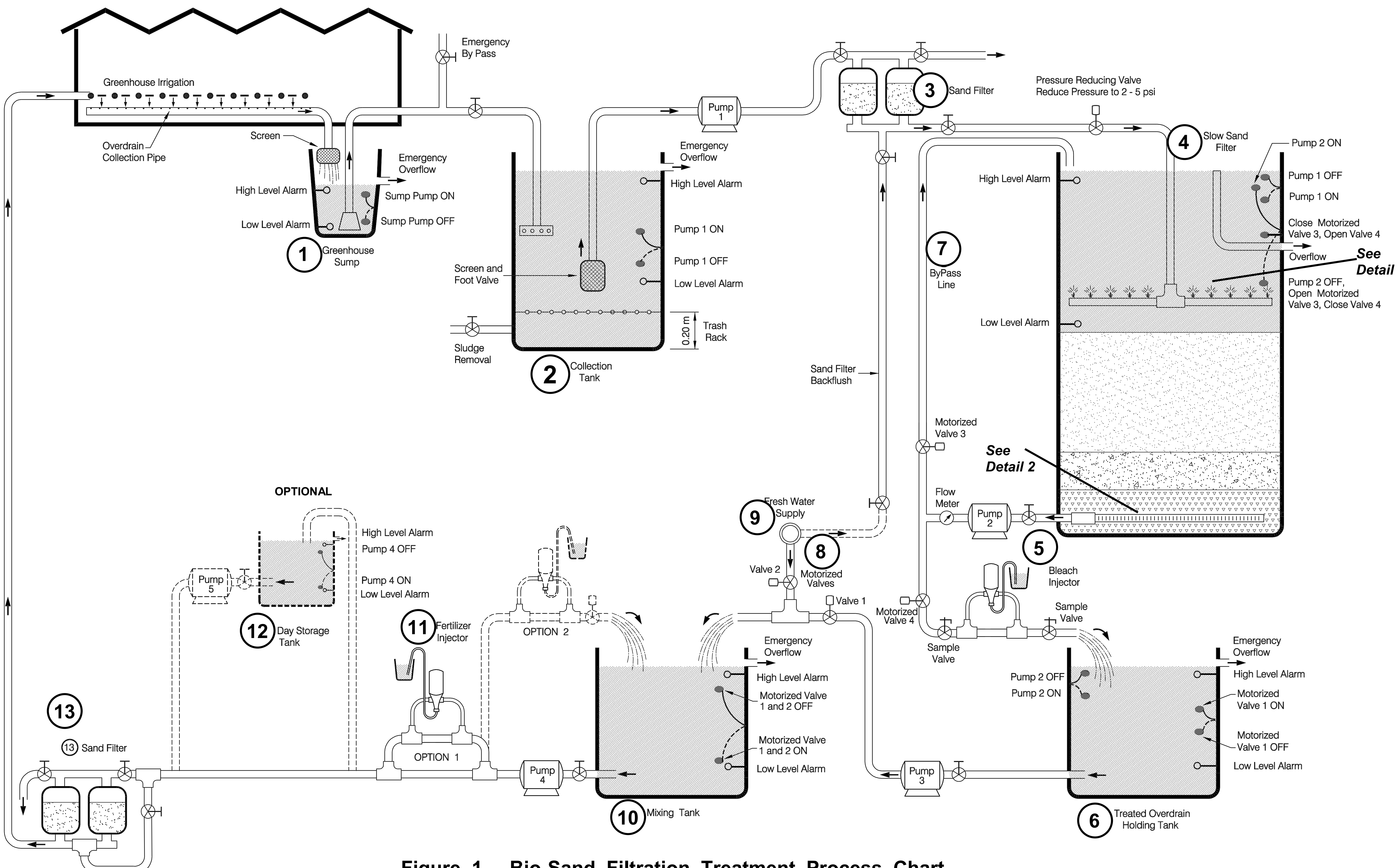

Figure 1 Bio-Sand Filtration Treatment Process Chart