FINAL REPORT

LAKE ERIE PROJECT FUND GRANT

PROJECT ID: SG 92-98

FIELD DEMONSTRATION FOR MECHANICAL CONTROL OF ZEBRA MUSSELS

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PROJECT OBJECTIVE

This project has the objective for installing a field demonstration of the developed mechanical device, based on the mechanical regulation of dissolved oxygen using a vacuum system, for zebra mussel control in water conduits at a water treatment plant.

Specific Tasks

1. Construct the mechanical device using a vacuum system for regulating the dissolved oxygen of nature water.

2. Select a demonstration site at the Avon Lake Water Treatment Plant in Avon Lake of Ohio and plumb the mechanical device for regulating the dissolved oxygen of nature water taken from Lake Erie.

3. Connect a bio box to the mechanical device to demonstrate the effectiveness of the device for dissolved oxygen regulation and zebra mussel control.

MECHANICAL DEVICE

The major components of the mechanical device are:

- vacuum chamber;
- water pumps;
- vacuum pump;
- water level control system; and
- low- and high-level water checks.

Other components include pipes, hoses, fittings, and gauges. Following is a brief description of each component and the process through which each was selected.

The vacuum chamber (Figure 1) is constructed of PVC with welded reinforcement hoops at both ends. There are 1 inch (2.5 cm) thick circular end pieces welded to the chamber's top and bottom. For intake and discharge ports of 1 inch diameter or less, the ports are drilled and tapped into PVC blocks cemented to the chamber's external surface. For ports with diameter greater than 1 in, the port is drilled into a PVC block and a threaded PVC adapter of appropriate size is cemented into the port hole. Fittings for vacuum line, sensor rods and pressure gauge are drilled and tapped into the chamber top. A photograph of the chamber top is shown in Figure 2.

The chamber is fitted with two site glasses. One is mounted on the side of the chamber in a fashion similar to the ports and permits siting of liquid level. The second is drilled into the top of the chamber and permits observation of the intake spray. The site glass at the top of the chamber is made of thick tempered glass and is held in place via a PVC collar bolted to the chamber top and sealed on its under-surface by an O-ring. The spray site glass is sealed via the collar and 1/8 inch (3.2 cm) diameter rubber O-ring protruding from a groove machined into the chamber top.

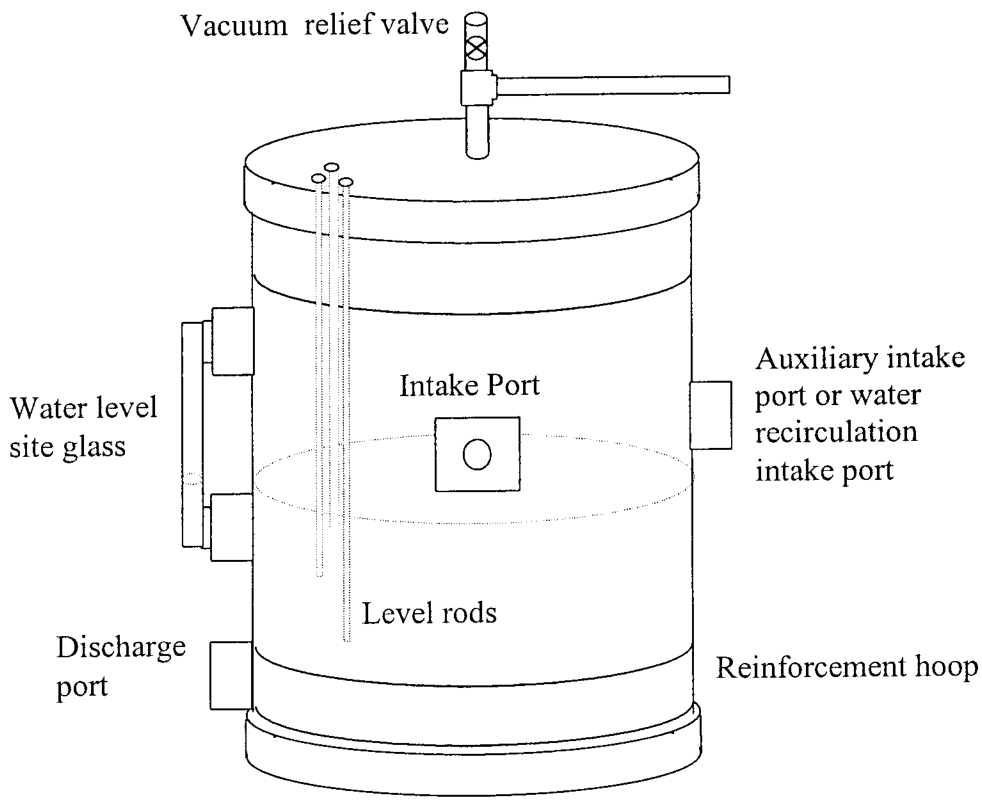


Figure 1. Schematic diagram of vacuum chamber

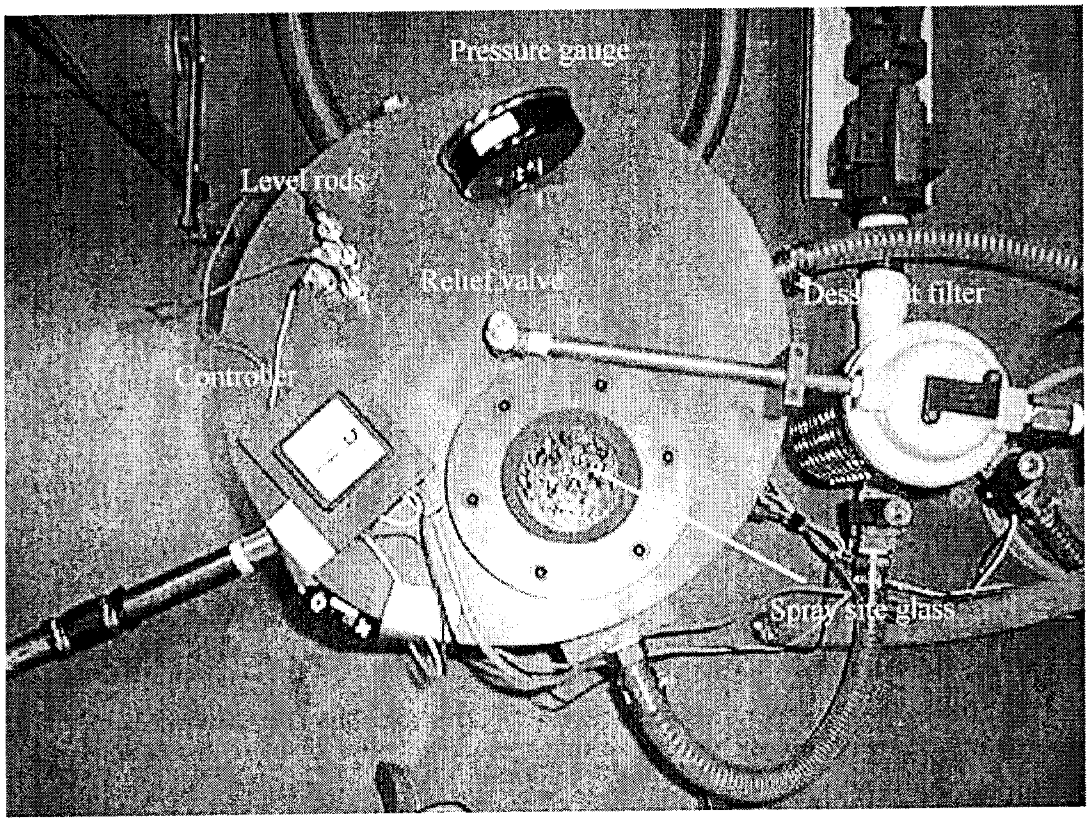


Figure 2. Top photograph of the vacuum chamber

FIELD INSATALLATION

The system employs two water pumps as shown in Figure 3. The pumps pull water from the chamber into the test section and recirculate water within the chamber. Because the pumps must pull water against a substantial vacuum pressure and because a wide range of flow rates was desired, centrifugal pumps were chosen as water pumps. The disadvantages of using centrifugal pumps are that they are subject to cavitation at the pressures encountered in the system and that small leaks in the lines between the chamber and the pump can cause the pumps to unprime. In the vacuum apparatus, the pumps run at non-optimal operating conditions, so manufacturer pump data cannot be used to predict pump performance. As such, experiment and experience are currently used for water pump selection.

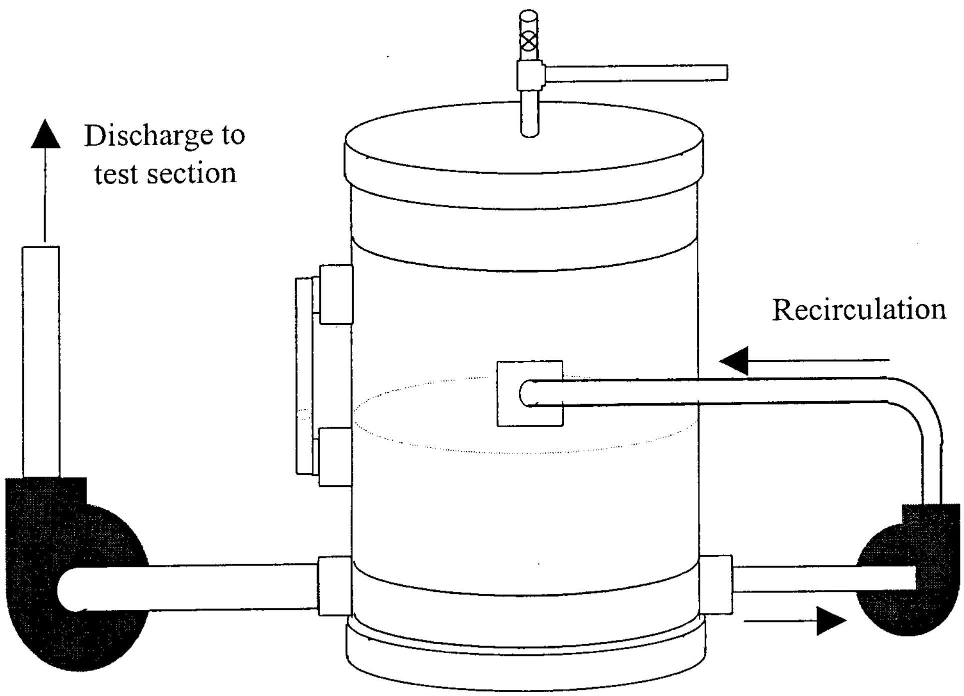


Figure 3. Discharge and recirculation pumps

The vacuum pump used is a Gast model 4Z470 1 hp (0.7 kW) rotary vane type vacuum pump (Gast Manufacturing Corporation, Benton Harbor, MI) as shown in Figure 4. Upstream of the pump are a desiccant filter and a felt filter intended to remove water vapor and solid particles from the pump intake air stream. Water vapor can cause corrosion of the pump housing and particles could scratch the housing surface. There is a felt filter downstream of the pump for collecting carbon particles from the exhaust stream. The carbon particles are generated as the vanes wear during operation. This pump was chosen because of its ability to pump at medium vacuum pressure (between 15 and 25 in Hg [0.5 and 0.8 bars]) and its low maintenance needs.

The pump runs oil-less and the only maintenance required is replacement of intake and exhaust felt filters. The pump was sized based on anticipated gas extraction rate from the water. Assuming a maximum water flow rate of 10 gpm (37 L/s), saturated dissolved gas concentration for the intake water, 50% saturated concentration for discharge water and water temperature of 10°C, the volume of dissolved oxygen and nitrogen the vacuum pump from the chamber is 47 L/min (1.7 cfm). Details of this calculation are given in the analysis portion of this chapter.

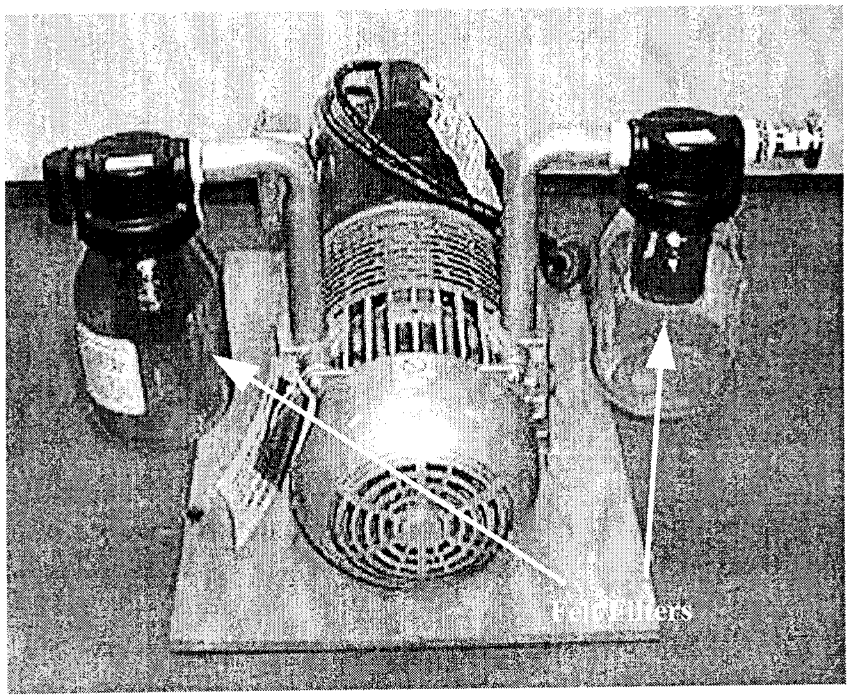


Figure 4. Vacuum Pump with Particle Filters

The water level in the chamber is regulated by a single solenoid valve controlling the intake flow. The solenoid valve is normally closed (closed when no current is supplied) and requires no pressure differential to open. The signal to the solenoid valve is generated by a controller (model LVC551intrinsically safe controller, Omega Engineering Inc., Stamford, CT) mounted to the top of the chamber and connected to three sensing rods inserted into the chamber and sealed with Swagelock vacuum fittings. There are three sensing rods: a high water level rod; a low water level rod; and a reference rod. When the water level falls below the low level rod, there is no conductivity between the high and low level rod and the controller activates the solenoid valve. The solenoid valve remains open until the water level reaches the bottom of the high level rod. The solenoid valve is a brass direct-action normally closed solenoid valve. Early in the development of the apparatus, a pilot actuated solenoid valve was used. However, the extreme vacuum downstream of the valve caused the pilot to work improperly and the water level fluctuated widely.

The device is outfitted with controls that account for several failure modes. These controls were developed based on both laboratory and field failures. There are three potential failure modes, as listed in Table 1.

Table 1. Summary for controls

Failure mode	Sensor	Remedial Action
Water level in tank too low	Low level water float sensor	Stop all pumps and de-energize the solenoid valve
Water overflows tank	Float rises in vacuum line float check	Passive float check checks water from entering vacuum line
Power loss to any component	Relay system	Power cut to all components

The low water level float sensor is shown in Figure 5(a). When the water level is above the float level, the circuit in which the float sensor is wired is closed (current flows). When the water level falls, the float falls and the circuit is opened. When this happens, electricity is cut off from all components via a system of relays. The high water float check is shown in Figure 5(b). When water enters the check, the solid buoyant balls in the bottom of the check float to the top and seal the gas flow path. Air still enters the system via the air relief valve mounted on the top of the check.

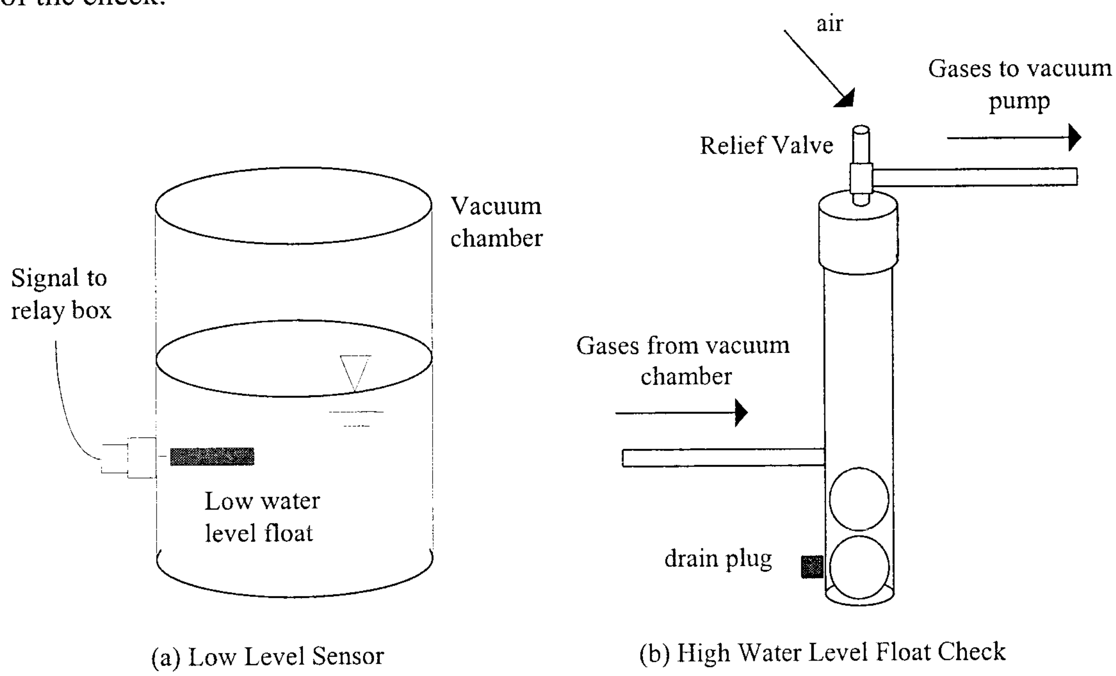


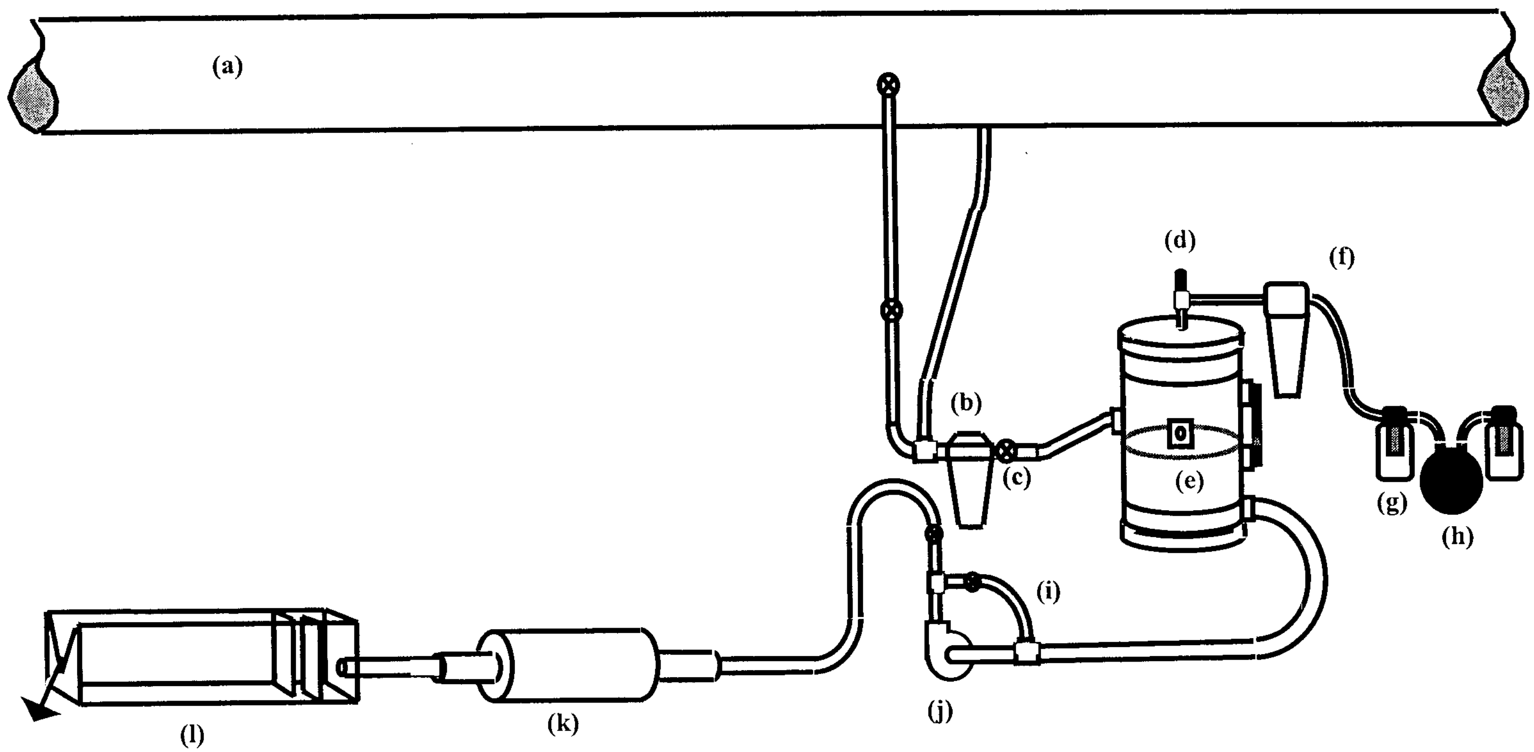
Figure 5. Control mechanism

DEMONSTRATION

The mechanical device was designed for a demonstration at the Avon Lake water filtration plant. The design was conservative, using all components that had been proven in the laboratory. The device treats water from the plant's auxiliary raw water supply. The auxiliary raw water supply is drawn from an intake 1500 ft (500 m) from shore in Lake Erie. The plant's main intake lines, which convey water to the plant in normal conditions, are located 3200 ft (1000 m) from shore. The auxiliary raw water is used to meet emergency demand and during maintenance on the plant's main intakes. Water in the main intake lines is treated with potassium permanganate but the auxiliary raw water is not.

Figure 6 is a schematic diagram of the installation at the Avon Lake plant. The apparatus employs a single discharge line and a single intake line. Downstream of the discharge pump are two test sections. There is a biobox, which is a large baffled flow region through which water flow with a mild preferable velocity for zebra mussels. The biobox was designed as a prime location for zebra mussel veligers to settle. Downstream of the biobox is an open channel and a weir. The channel and weir provide a convenient means for oxygen concentration measurement and flow rate measurement. The only control fitted to the device is the high water level float check. Not including the biobox and weir, the installation at Avon Lake requires about 16 ft^2 (1.5 m^2) of floor space, stands about 3 ft (1m) high, and uses 25A of electric current. If needed, the apparatus could have been installed more compactly. All components drawing electric current use 110V lines located in the plant.

At the demonstration site, the flow rate was set to a minimum level to ensure reliable discharge pump operation. The vacuum pressure was set to ensure discharge dissolved oxygen concentration well below 50% of the saturation concentration. Because the auxiliary line from which water was taken was not in use, it was not possible to treat high flow rates of water. This is because in the auxiliary line is low when the line is not in use and because the capacity of the apparatus was limited to the capacity of the auxiliary line. Once the flow rate and vacuum pressure were set, they were not changed for the duration of the demonstration. On each site visit the discharge dissolved oxygen concentration, flow rate and solenoid cycle time were measured and recorded and a log entry was made detailing the biobox contents. Roughly each month it was necessary to take the system off line to perform periodic maintenance including changing vacuum pump felt filters, changing desiccant in the vacuum line and cleaning the trap upstream of the solenoid valve. The oxygen concentration is measured at the discharge of baffles preceding the flow measurement weir. This measurement site was chosen both for its accessibility and because the water velocity at that site is greatest. The oxygen measurement location at the demonstration site is shown in Figure 7. Results from this installation of the demonstration device show that the device can run dependably, the dissolved oxygen level can be regulated to any desired level, and no zebra mussels have been sighted in the biobox.



(a)	Water supply	(e)	Vacuum chamber	(i)	Discharge pump
(b)	Sediment trap	(f)	Desiccant filter	(j)	Pump recirculation line
(c)	Solenoid valve	(g)	Particle filter	(k)	Biobox
(d)	Vacuum relief valve	(h)	Vacuum pump	(l)	Weir

Figure 6. Demonstration at the Avon Lake Water Filtration Plant

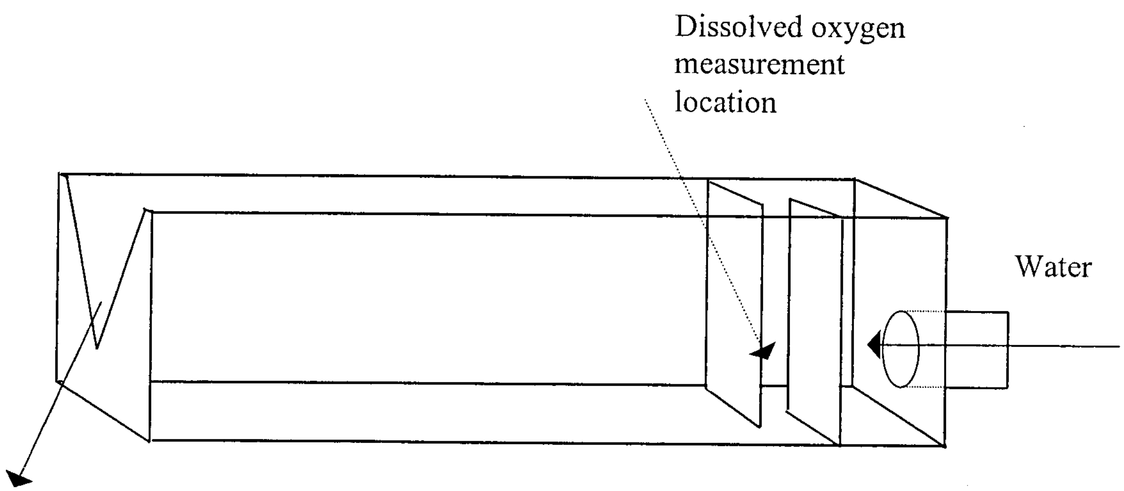


Figure 7. DO measurement location at the demonstration site