Case study 2: Off-line bioreactor bed Lower Burdekin

Project leader and partnerships	Department of Agriculture and Fisheries collaborating with Queensland University of Technology
Funding source	Department of Environment and Science (Queensland Government Reef Water Quality Program)
Project length	One year (May 2019 – April 2020) of high-frequency monitoring completed.
Region	Burdekin (Ayr)
Production system	Sugarcane
Date of installation	May 2019
Length of installation	Five working days for installation (two weeks including design and site selection)
Bioreactor type	Modified off-line bed systems receiving water via large drainage pipe
Project objective	Research trial to quantify nitrate removal performance.

Summary of the landscape

The modified off-line bed style bioreactor received run-off from 25.7 ha sugar cane paddock divided in two irrigation sets. At the time of monitoring the upslope blocks consisted of 11 ha of plant cane and 14.7 ha of ratoon cane. The soil at the bioreactor site is a vertosol. The site slopes from the cane block to a low-lying area, eventually leading to a highly modified surface water distribution system used by farmers to access open water for irrigation. This system becomes a drainage system after medium to large rain events. The site of the bioreactor is subject to flooding during large rainfall events due to the proximity to a large channel.

Average rainfall and temperature

The area can be classified as tropical savannah with maximum and minimum average annual temperatures of 29.4 °C and 18.7 °C, respectively, during 2010 to 2017. The mean annual rainfall during the same period was 834 mm.

Sizing and volume capacity

26 m long, 0.7 m deep, and 2.0 m wide. Approximately 37 m^3 (softwood woodchip).

Design features

The bioreactor (Figure 1) features a 600 mm ‘T’ pipe junction that diverts water into the bioreactor through a gravel inlet. Once the bioreactor has reached capacity excess water bypasses the bioreactor, via the pipe and inlet overflow, and flows into the low lying non-production area. The bioreactor has piezometers at inlet, outlet and within woodchips and woodchip analysis piezometers. The outlet consisted of a quad 50mm PVC outlet pipe, 1.5 m long that drains from the lowest point of the bioreactor.

Water source

The bioreactor received predominantly flood furrow irrigation run-off that is sourced from three bores combined with channel water (when required). The irrigation water is pumped and applied to the paddock through gated pipes located at the top of the field. Irrigation water flows down furrows between the cane rows. When irrigation run-off reaches the bottom of the furrows it enters a collection drain and is diverted under the road to the bioreactor. The bioreactor also receives run-off from rainfall events with larger volumes predominantly in the wet season (November – April).

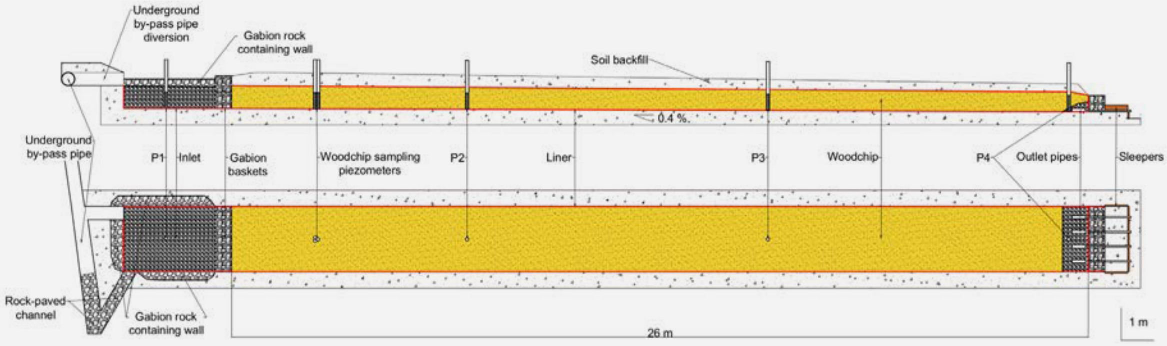

Figure 1 Design of the bioreactor bed in cross section (top) and plan (below) view, showing key design features. Source: QUT

Construction methods and materials

A 30 m long trench was excavated on a soil platform to permit the installation of the bioreactor bed and associated inlet structure. The trench on the soil platform was excavated at a shallow depth ranging from 0.7 m (near the inlet) and 0.4 m (near the outlet) to minimise the risk of outlet flooding.

A laser level was used to ensure that the trench bottom had a 0.4% slope (0.1 m height difference over 26 m between the inlet and outlet). Heavy-duty plastic liner was laid in the trench to create a waterproof seal to prevent ingress of surface and sub-surface water into the woodchip section of the bioreactor.

Four 100 mm (diameter) PVC piezometers were installed in the centre of the bioreactor at intervals along the length of the bioreactor. The first piezometer was positioned at the inlet (P1) to facilitate sampling of water entering the bioreactor and the fourth piezometer was at the outlet (P4) for monitoring water leaving the bioreactor. The piezometers were prepared by drilling 5 mm perforations around the base of the pipe for a 0.5 m length to allow for water flow. Piezometers were wrapped in a 2 mm geo-fabric, to avoid fine particles clogging the piezometers.

Figure 2 Bioreactor looking from the inlet toward the outlet, showing the rock gabion separating the inlet from the woodchip.

Figure 3 Completed bioreactor showing inlet structure with pipe from upslope cane block directing water into the inlet pit filled with washed river gravel (left). Excess flow bypasses the structure to a low-lying area on the right.

The inlet structure consisted of a trench filled with washed river gravel (diameter = 25 mm), with two stacked gabion baskets (2.0 m long, 0.5 m deep, and 0.5 m wide) filled with gabion rocks (diameter ≥75 mm) with a total volume of approximately 4.6 m^3 (Figure 2). A 600 mm underground pipe directed the water from the sugar cane block into the inlet of the bioreactor (Figure 3). A T-junction in the pipe enables excess run-off to bypass the bioreactor and discharge directly into the low-lying area through a rock-paved channel to minimise erosion.

The outlet of the bioreactor was constructed using four separate drilled 100 mm PVC pipes wrapped in geo-fabric connected with reduction sockets to four 50 mm PVC pipes, equipped with valves to regulate the outflow if necessary (Figure 4). The 50 mm PVC pipes passed through a gabion basket (2.0 m long, 0.5 m deep, and 0.5 m wide), placed to contain the woodchip. Hardwood sleepers were installed at the outlet to minimise erosion and soil collapse.

The trench was backfilled with softwood woodchips with a depth ranging from 0.7 m (at the inlet) to 0.6 m (at the outlet). More heavy-duty builder plastic was placed on the top of the woodchip with gaps and joins sealed with silicon to seal the woodchip section of the bioreactor before backfilling with soil.

Figure 4 Bioreactor outlet showing four outlet pipes.

Costs

	Total cost $	Bioreactor $/m³
Excavator inc. driver and float	7056	191
Woodchip inc. delivery	1925	52
Pipes	151	
Inlet gravel	165	
Gabion basket and rock	1900	
Other miscellaneous (liner, pickets, sealer etc)	717	
Total Cost	$11,914.00	$352/m³

Performance

Average influent nitrate concentration (mg N L^{-1})	4.4
Nitrate Removal Efficiency Average	44.90%
Nitrate Removal Efficiency Range	0.6 – 100%
Nitrate Removal Rate Average (g N m^{-3} d^{-1})	7.1
Nitrate Removal rate Range (g N m^{-3} d^{-1})	0.7 - 9.3
Hydraulic Residence Time (Hours)	2.3
Carbon Longevity Average (Years)	35.5

Monitoring regime (intensity and frequency)

High frequency monitoring conducted, with water samples analysed for the following water quality parameters: nitrate, ammonium, dissolved organic carbon, dissolved oxygen, temperature, and dissolved greenhouse gas analysis (nitrous oxide, carbon dioxide, and methane).

Two automated samplers were installed to collect samples every 6-8 hours from the inlet and the outlet. Four pressure transducers were placed in each of the piezometers within the denitrification bed to monitor both water temperature and pressure.

Troubleshooting

Inlet gravel blockages occurred. This was remediated by replacing the gravel and removing the sediment.

The bioreactor flooded during a large rainfall event, however the flooding did not damage the bioreactor.

What would you do differently?

Create a larger sediment settlement basin and situate the bioreactor higher in the landscape to avoid flooding and site access issues.

For more information:

Manca, F., Wegscheidl, C., Robinson, R., Argent, S., Algar, C., De Rosa, D., Griffiths, M., George, F., Rowlings, D., Schipper, L. and Grace, P. (2021) Nitrate removal performance of denitrifying woodchip bioreactors in tropical climates, Water, 13, 3608.

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