# Baseline hydraulic performance of the Heathrow constructed wetlands subsurface flow system

**K.M. Richter*, J.R. Margetts*, A.J. Saul*, I. Guymer* and P. Worrall****
*University of Sheffield, Sir Frederick Mappin Building, Mappin Street (E-mail: *k.richter@sheffield.ac.uk*)
**Penny Anderson Associates

**Abstract** A constructed wetland treatment system has been commissioned by BAA (formerly the British Airports Authority) in order to attenuate airfield runoff contaminated with de-icant and other potentially polluting materials from Heathrow Airport. Airfield runoff containing de-icants has the potential to impose significant oxygen demands on water bodies. The site consists of a number of integrated treatment systems, including a 1ha rafted reed bed canal system and a 2 ha sub-surface flow gravel reed bed. This research project is concerned with the performance of the subsurface flow reed beds, though attention will be paid in this paper to the operation of the whole system. Prior to the planting of the subsurface flow reed beds, flow-tracing experiments were carried out on the three different types of subsurface flow beds, so that the baseline performance of the system could be quantified. In association, data regarding the soil organic matter content was also collected prior to the planting of the beds. As expected, soil organic matter content is observed to be negligible within the bed, though a small amount of build up was observed in localised areas on the surface of the beds. This was attributed to the growth of algae in depressions where standing water persisted during the construction phase. Few studies exist which provide detailed measurements into the cause and effect of variations in hydraulic conductivity within an operational reed bed system. The data presented here form the baseline results for an ongoing study into the investigation of the change in hydraulic conductivity of an operational reed bed system.
**Keywords** Constructed wetlands; organic matter; subsurface flow reed bed; tracer studies

Water Science and Technology **Vol 47 No 7–8 pp 177–181** © IWA Publishing 2003

## Introduction

The Heathrow Constructed Wetlands subsurface flow reed bed system is designed to treat surface runoff from Heathrow Airport. Constructed wetland systems have been successfully used in the UK for the past two decades to remove pollutants from a variety of wastewaters. Common applications of these systems include the treatment of secondary or tertiary sewage, industrial wastewaters (pulp mill, tanneries, acid mine waste, landfill leachates), farm wastes and urban runoff. The use of constructed wetland systems to treat airport runoff is a relatively novel application. There is little literature detailing the use of these systems for treating runoff from airports. Bausmith and Neufeld (1999) and Rice *et al*. (1997) detail the use of vegetated soil systems, and Revitt *et al*. (1997) and Chong *et al*. (1999) presented data on the performance of Heathrow Airport's own trial system.

As a result of a successful experimental reed bed system (Worrall, 1995), Heathrow Airport Limited commissioned the construction of a £20 million integrated wetland treatment system that utilises a combination of hydraulic balancing ponds, aeration lagoons, rafted reed beds and subsurface reed beds. To prevent serious contamination of the receiving waters, surface runoff from the glycol susceptible catchments of Heathrow Airport is first passed through an initial 100,000 $m^3$ reservoir (Eastern Reservoir), where up to 43,000 $m^3$ of "dirty" laden inflow is retained separate from "clean" flow by a floating butyl curtain. Polluting surface runoff is conveyed 3 km to the constructed wetland system using Heathrow Airports' fire main system. The transferred flow may have a BOD of up to 170 mg/l and a flow rate of approximately 100 l/s. It is first discharged to a 1 ha rafted lagoon, before being passed to an aerated balancing pond, mixed with runoff from a similar but “cleaner” catchment, and subsequently discharged to 2 ha of horizontal subsurface flow gravel reed beds. This paper describes the interim results of a research study to assess the hydraulic performance of the reed beds. A general layout of the system can be seen in Figure 1.

## The Heathrow constructed wetlands subsurface flow reedbeds

This 2 ha subsurface flow reed bed consists of three distinct areas or terraces that have differing sizes and input flow rates, though similar hydraulic loading rates. Each bed comprises of a number of individual cells approximately 400 $m^2$ in area. As can be seen in Figure 2, the Upper Terrace consists of 2 discrete beds of 6 cells in series (Beds 1 and 2). The Middle Terrace A consists of 7 discrete sets of 4 cells in series (Beds 3 to 9). Lower Terrace B consists of 3 discrete sets of 2 cells in series (Beds 10 to 12). Each bed is hydraulically isolated from the adjacent series. Between individual cells in each bed there is a 1 m wide-open section. These are present in an attempt to limit short-circuiting along the whole length of a bed. The gravel beds are 600 mm in depth and comprise of 10 mm sub-angular flint/chert with a varying degree of limestone. An impermeable liner to prevent loss from or ingress to the system underlies each bed.

The design hydraulic loading rate for the whole system is 20 litres/second/hectare, based on a design flow rate of 40l/s. Due to the different surface area of each bed, the design inflows vary between bed types to maintain a constant hydraulic loading rate across the system.

## Baseline data

Table 1 details the measured and design flow rates into each bed. Due to the different configuration, and thus size, of beds the flow rate to each type of bed varies, so that a similar hydraulic loading rate and thus level of performance is achieved between beds.

Prior to the planting of reeds (*Phragmites australis* species), a period of hydraulic testing of the gravel beds was carried out. Using a fluorescent dye technique with instantaneous injections, the Residence Time Distribution (RTD) curves were observed at two points (midway channel and outlet control channel) at one of each bed type of the upper, middle and lower terrace. An example for the observed RTD’s is shown in Figures 3 and 4 for Beds 4 and 11.

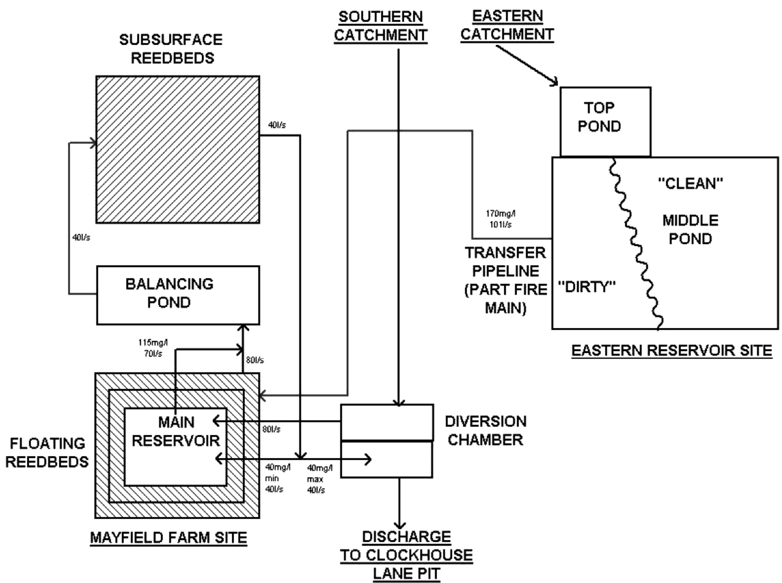


**Figure 1** Plan of whole system

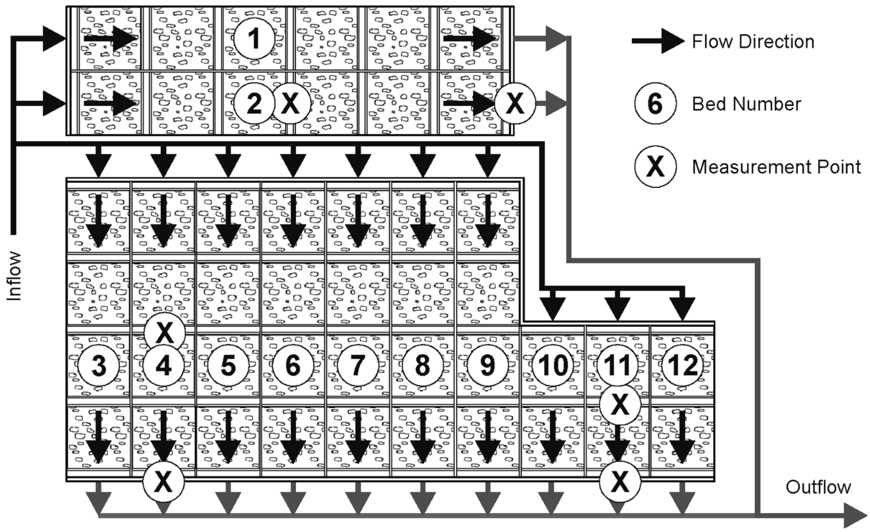


**Figure 2** Base map of the subsurface reed bed system



**Table 1** Measured and design inflows to the system

| Terrace | Upper terrace (Beds 1 and 2) | Middle terrace (Beds 3–9) | Lower terrace (Beds 10–12) |
|---|---|---|---|
| Measured inflow (l/s) | 5.25 | 3.98 | 2.03 |
| Design inflow (l/s) | 5.26 | 3.61 | 1.39 |

Detention times have been determined from the observed RTD curves and are in the range of 39–43 hours, which are similar to the design values. These are detailed in Table 2.

The observed detention times, calculated from the RTD, indicate that the hydraulic performance of the subsurface flow reed beds is generally more efficient than the assumed condition (based on the measured flows).

Hydraulic conductivities have been estimated from field observations as well as from laboratory tests of the unplanted gravel and are in the range of 1.0 to $2.4 \times 10^{-1}$ m/s.

In addition to the hydraulic tests, gravel samples were taken at different depths from a number of locations throughout the beds and analysed for organic content. Little organic matter was expected in this early stage prior to planting of the reeds and development of a bio-film. This was confirmed with observed values in the range of 0.18 to 1.33 g/l. Interestingly, a variation of organic matter has been observed with the highest value at the surface, a much lower quantity in the depth of 100 mm and then a further increase towards

**Table 2** Calculated and nominal detention times for different beds

| | Location | Calculated detention time (hrs) | Nominal detention time based on measured flows (hrs) | Nominal detention time based on design flows (hrs) |
|---|---|---|---|---|
| Probe 1 | Open channel between cells 3 and 4, Bed 2 | – | 21.3 | 21.2 |
| Probe 2 | Open channel at outlet of Bed 2 | – | 43.8 | 43.7 |
| Probe 1 | Open channel between cells 2 and 3, Bed 4 | 23.1 | 18.7 | 20.6 |
| Probe 2 | Open channel at outlet of Bed 4 | 44.7 | 39.0 | 43 |
| Probe 1 | Open channel between cells 1 and 2, Bed 11 | 27.5 | 18.3 | 26.8 |
| Probe 2 | Open channel at outlet of Bed 11 | 49.4 | 39.9 | 58.3 |

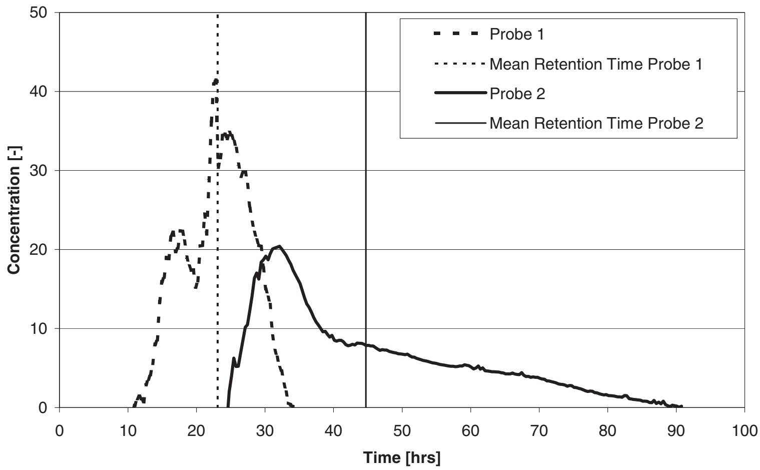


**Figure 3** Tracer response for Bed 4

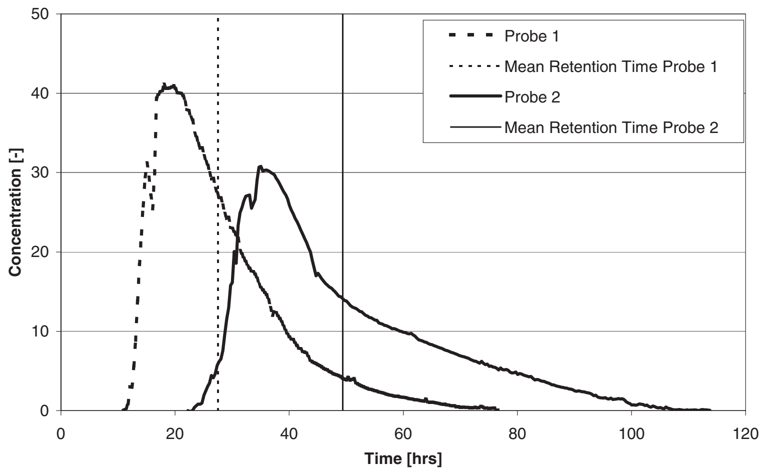


**Figure 4** Tracer response for Bed 11

the base of the bed. In comparison, a control sample from a matured 5-year-old experimental bed gave an organic matter content of 19.26 g/l.

## Conclusion

The results of this initial study indicate that the subsurface flow constructed reed beds at Heathrow Airport are operating as intended in terms of hydraulic efficiency.

There is little, or no, data relating to the long-term performance of subsurface flow reed bed systems for treating airport runoff, which is unique in its polluting characteristics due to the presence of glycol. At present, inferences at the design stage are applied from other constructed wetland applications, often treating wastewaters with very different characteristics. It is obvious at this early stage that there is a need for a pragmatic research programme to collect data from this novel application, so that future design of systems treating airport runoff can be optimised.

Detailed pollutant removal and hydraulic performance data will be collected for the Heathrow Constructed Wetland subsurface flow system over a period of five years, to assess the long term performance suitability of these systems for treating airport runoff. This initial data provides a control to compare the hydraulic performance as the bed matures. The ultimate aim of the work is to present a series of guidelines for use by practising engineers in the design and management of such systems. Best Management Practices and maintenance regimes will also be investigated, for example the drying/composting of the beds or alternating the operation of the beds.


## Acknowledgements

The authors are very grateful to BAA for giving permission to undertake research on the Heathrow Constructed Wetlands at Mayfield Farm.


## References


Bausmith, D.S. and Neufeld, R.D. (1999). Soil biodegradation of propylene glycol based aircraft de-icing fluids, *Wat. Env. Res.*, **71**(4), 459–464.

Chong, S., Garelick, H., Revitt, D.M., Shutes, R.B.E., Worrall, P. and Brewer, D. (1999). The microbiology associated with glycol removal in constructed wetlands, *Wat. Sci. Tech.*, **40**(3), 99–108.

Revitt, D.M., Shutes, R.B.E., Llewellyn, N.R. and Worrall, P. (1997). Experimental reedbed systems for the treatment of airport runoff, *Wat. Sci. Tech.*, **36**(8–9), 385–390.

Rice, P.J., Anderson, T.A. and Coats, J.R. (1997). Evaluation of the use of vegetation for reducing the environmental impact of deicing agents, *Phytoremediation of Soil and Water Contaminants ACS Symposium Series*, **664**, pp 162–176.

Worrall, P. (1995). Reed beds for glycol treatment, *IAWQ Specialist Group on the Use of Macrophytes in Water Pollution Control: Newsletter*, No **12**, pp 13–14.