Eastern Regional Fisheries Board
Bord Iascaigh Réigiúnach an Oirthir

Fisheries Ireland
Our Natural Heritage

Reg. No: P0822-01
Our Ref: NMcG/MFox/MH



Stuart Huskisson
Inspector
Office of Licensing & Guidance
Environmental Protection Agency
Regional Inspectorate
McCumiskey House
Clonskeagh Road
Dublin 14

2nd August 2007.

**Re: IPPC application by Cooksgrove Limited trading as Euro Farm Foods (Reg. No: P0822-01)**



Dear Sir

We wish to object to the above application to the EPA based on the following:

**1 – The use of Integrated Constructed Wetlands (ICW) in treating wastewaters**

The Board is concerned about the final effluent quality from constructed wetlands, based upon performance from similar systems already in existence in Ireland. The Board is concerned about the attributed performance of such systems especially the performance criteria over the winter months when most farmyard run-off occurs. This is mainly due to the relative recent introduction of such systems to Ireland. We would also like to highlight a number of references regarding ICWs which in our opinion cast some doubts about this form of wastewater treatment.

- The EPA publication *Waste Water Treatment Manual of Treatment Systems for Small Communities, Business, Leisure Centres and Hotels (1999)* states that *constructed wetlands remain unproven for other than BOD & Suspended Solids removal, that there is some removal of Total N and Total P but this low.* The Board has serious concerns that the developer hopes to provide primary, secondary and tertiary treatment of the effluent from this farm with a treatment system which is unproven for the removal of phosphorous and nitrogen.
  The EPA publication, *River Water Quality in South East Ireland* (2003) states,

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*In recent times constructed wetlands (also called Reed beds or Artificial Wetlands) are being promoted in the region as a low cost system for the disposal of soiled water from farmyards. This departure (where farm waste is discharged to surface water via an artificial pond that contains various plants) is of serious concern for a number of reasons, as follows:*

1. *Previously, the disposal of farm waste to surface waters was generally prohibited,*
2. *Constructed wetlands, unless well managed, have the potential to cause serious water pollution,*
3. *Section 4 of the Water Pollution Act, 1977, prohibits the discharge of trade effluents to any waters without a licence from the Local Authority – most constructed wetlands on farms do not have such a licence,*
4. *Farm wastes should be recycled by proper land spreading – not disposed of to surface waters,*
5. *Constructed wetlands are being installed in farms without planning permission,*
6. *There is no monitoring or regulation of constructed wetlands on farms – in some cases constructed wetlands will be used for the disposal of slurry*

- In a scientific paper entitled *A farm-scale Integrated Constructed Wetland to treat farmyard dirty water* published by Teagasc in January 2005 (Appendix I), A number of issues were highlighted which I wish to bring to you attention. This study was carried out by the competent Irish authority for agriculture research over two and a half years.
    - According to the literature review ICWs remove up to 95% total suspended solids (TSS) and upto 94% of Phosphorous (P). These all depend on *incoming form.* Therefore the alleged influent of 1500 mg/l TSS, and 90 mg/l Total P will at an optimum result in a TSS of 75 mg/l (not 5 – 10 mg/l as per planning submission) and a Total P of 5.4 mg (not < 1 or <0.02 mg/l P as per planning submission).
    - In relation to the Teagasc survey (carried out in Irish conditions) the maximum P removal (soluble reactive phosphorus or SRP) was 84% and this occurred in the Spring. Therefore the maximum removal of 90 mg/l Total P (not SRP) may result in an effluent of 14.4 mg/l P.
    - Of even more significance from our point of view is the 5 % removal of SRP in the winter months, when most run-off occurs. This may result in an effluent of 85.5 mg/l P.
    - The Teagasc study mentions that *the study focused on the more biologically available fractions such as SRP: however large amounts of P may exist in particulate form, as farmyard dirty water has typically high concentrations of BOD and total suspended solids*. Therefore the 84% and 5% P removal rates (as discussed above) are probably themselves too high as they only measure SRP.



- I also enclose a paper entitled *Are Constructed Wetlands a Viable Option for your Waste Management System?* Published by Purdue University, Indiana, USA (Appendix II). These recommend that there is at least 180 days storage during the winter months and that *Regulations specify that constructed wetland systems must* *be designated as no-discharge systems so wetland treated water cannot be discharged into either surface waters or groundwaters.*

## 2- Receiving Waters

The watercourse to which the effluent is discharging to is the main channel of the Hurley River, which is a significant salmonid watercourse and is already subject to a high pollution risk. Based on the effluent figures as discussed above, we believe that there will be a deleterious effect on the receiving waters. The applicant should resubmit figures with regard to the assimilative capacity of the receiving waters of the River Hurley, especially as we predict the P levels will be excessive with farmyard effluent alone i.e. ranging from 5.4 mg/l to 85 mg/l. Normally, a discharge licence to waters allows for a maximum Total P level of 1 mg/l.

## 3- Waste Water Treatment Plant Effluent

The Board is concerned at the potentially high polluting effects of the raw waste water treatment plant (WWTP) effluent from this operation. There are no figures enclosed as to the various parameters expected.

## 4- Proximity to watercourses



The Board is concerned at the close proximity of all this stored deleterious matter to the River Hurley (approximately 70m) as well as the considerable distance (over 400 m) the farmyard effluent will have to be piped to the wetland area, which will be located in a remote part of the farm. This would also include decaying plant matter and the considerable volume of P that may be bound up in the ICW that is if it has not been released to the River Hurley already through the effluent pipe. Any leakages or structural failure will result in contamination of the local ground and surface water supplies. There is also a very steep slope between the proposed ICW and the River Hurley. Furthermore a tributary of the River Hurley that has been contaminated in the past flows alongside proposed ponds 2 and 3 before entering the River Hurley, a short distance away.

## 5- Maintenance

An ICW such as this will need constant observation and monitoring. This site is quite remote from the farmyard premises and a special effort would have to be made to visit it on a regular basis. Ongoing maintenance such as adjusting water levels and monitoring would have to be carried out by a competent person.

## 6- Potential for other effluents

The Board is concerned that there is the potential that effluent other than the stated farmyard effluent and WWTP effluent may be discharged to the constructed wetland via the manhole system. While we are not in any way implying that any such activity would occur it is impossible to police once the potential is there.

**8 – Comments of Planning Inspector (See Appendix III)**

Mr. Roger Dean, An Bord Pleanala Planning Inspector, who examined Mr. Fox's planning file (Ref: PL17.215281 or NA/50189) had the following comments to make with regard to ICWs in his planning report:

*The nub of the issue is therefore whether the proposed ICW would perform as projected. I am concerned that there is conflicting evidence about this but it is my opinion that this matter cannot be resolved without detailed scientific research that, in my submission, would be beyond the remit of the Board in regard to its planning responsibilities. It may well be that uncertainties would remain until further national research was carried out and, even then, the true performance of the proposed ICW could only be evaluated when it is operational and its actual impacts analysed.*

This statement causes us some concern on the viability of this treatment system for such a highly polluting waste.

**9 – The situation at present**

The Board has a number of concerns with regard to the situation at present on site. As of 19th April, 2007 our staff observed the following:

- The ICW had already been constructed. but we are concerned that the It now appears that the construction process had been carried out prematurely in contravention of Condition 4 of the grant of permission as outlined below:

  *Prior to commencement of development, a scheme detailing the management, maintenance and monitoring processes to be undertaken in relation to the proposed integrated constructed wetland system shall be submitted to and agreed in writing with the planning authority. The monitoring of the performance of the proposed integrated constructed wetland system shall be carried out by a suitably qualified person as agreed with the planning authority.*

  ***Reason:** In the interest of environmental protection and the prevention of water pollution.*

- We noted that there was a substantial amount of slurry-like effluent entering the ICW. We were concerned that this was occurring prior to the grant of a discharge licence (recently refused) and may contaminate local ground and surface water sources. We are also concerned that this action may be in breach of Condition 7 of the grant of permission as outlined below:

7. *Only soiled waters resulting from rainfall on dirty yards in this farmyard complex shall be discharged to the integrated constructed wetland system. No effluent from the slatted units or silage areas shall be disposed of via this system. All uncontaminated rainwater, that is, from clean roofs, shall be disposed of separately to the existing surface water system. Detailed drawings of the farmyard complex shall be submitted to the planning authority (showing the separated systems for clean water, dirty rainwater, effluent, and farm effluent) for written agreement prior to commencement of development.*

***Reason:*** *In the interest of clarity and orderly development.*

- We expressed these concerns in writing to the Directors of Planning and Environment of Meath County Council and appropriate action was taken including a notice from the Planning Section and a Section 12 Notice from the Environmental Section warning that Mr. Fox is in breach of the Planning and Water Pollution Acts by importing WWTP waste from Euro Foods and by not constructing the ICW as given planning for.

- We are very concerned that even though Mr. Fox's planning application regarding the ICW concerned only farmyard effluent the ICW now becomes convenient for the WWTP effluent.

- We enclose a copy of a letter from Meath County Council to Mr. Fox (See Appendix IV), outlining the 5 reasons for refusal. The Board concurs with all of these.



We would ask you to refuse this application based on our submission.

We also wish to fully concur with your request for information regarding the ICW in accordance with Article 11(2) (b) (ii).

Yours sincerely

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Appendix I

# A FARM-SCALE INTEGRATED CONSTRUCTED WETLAND TO TREAT FARMYARD DIRTY WATER

## END OF PROJECT REPORT

## RMIS 4649

## Authors

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**Johnstown Castle Research Centre Wexford**

**January 2005**

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Teagasc

AGRICULTURE AND FOOD DEVELOPMENT AUTHORITY

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## INTRODUCTION

Nutrient loss from agricultural practices both in Ireland and the U.K. has caused point source pollution, which has resulted directly or indirectly to the eutrophication of surface waters (Tunney et al., 1997; Withers et al., 2000). Eutrophication is the major threat to water quality in Ireland and water quality continues to decline (Clenaghan et al., 2001). Point source pollution from agricultural practices can include inappropriately managed agricultural dirty waters such as dairy farmyard dirty water. In Ireland and the U.K., dairy farmyard dirty water is commonly composed of farmyard runoff, parlour washings, silage and farmyard manure effluents along with general farmyard washings (Brewer et al., 1999; Cumby et al., 1999; DAFRD, 2000). Land-spreading is the most widely used practice for managing dairy farmyard dirty water in Ireland; however in some cases this method of management may cause the degradation of surface and ground waters (Healy et al., 2003).



Constructed wetlands, which may be one method of managing such waters, are ecologically engineered systems that are akin to natural wetland systems that are built using quantitative approaches, founded on basic ecological principles (Mitsch and Jørgensen, 1989). Agricultural wastewater management using wetland systems has received interest in countries such as the USA, Norway, Finland, Italy, New Zealand and U.K (Cronk, 1996; Sun et al., 1998; Kern and Idler, 1999; Knight et al., 2000; Newman et al., 2000; Nguyen, 2000, Schaafsma et al., 2000; Koskiaho et al., 2003; Mantovi, et al., 2003; Poach et al., 2003). They are often used as alternatives to, or components of, conventional nutrient management practices to reduce or eliminate contaminant and nutrient loads in agricultural wastewaters (Cronk, 1996; Peterson, 1998; Geary and Moore, 1999; Knight et al., 2000; Borin et al., 2001; Hunt and Poach, 2001; Szögi and Hunt, 2001; Braskerud, 2002). Wetlands used to improve water quality within agriculture typically intercept and retain contaminants and nutrients from incoming waters through a series of vegetated ponds, before waters leave or are reused in farm-scale operations (Knight et al., 2000). Processes involved in contaminant and nutrient retention in wetlands include: sedimentation of particulates (Johnston et al., 1984; Braskerud, 2001; Koskiaho, 2003); nitrification/denitrification (Hammer and Knight, 1994; Phipps and Crumpton, 1994; Poach et al., 2003; Tanner et al., 1999); phosphorus

(P) sorption/desorption, precipitation and burial of P with accreting peat (Walbridge and Struthers, 1993; Richardson et al., 1997; Pant and Reddy, 2003; Reddy et al., 1999; Bridgham et al., 2001) and microbial and vegetation nutrient uptake and release (Smith et al., 1988; Shutes, 2001; Findlay et al., 2003). Most of the processes are regulated by wetland hydrology, which is the single most important factor in wetland function and structure (Kadlec and Knight, 1996, Mitsch and Gosselink, 1993; Werner and Kadlec, 2000).

Percent mass pollutant removal by surface flow constructed wetland treatment of agricultural dirty waters can vary between 48% and 95% of total suspended solids (TSS) (Sievers, 1997; Newman et al., 2000; Reddy et al., 2001); 50% and 99% of nitrogen (N), depending on form; and 30% to 94% of phosphorus inputs, depending on incoming form (Cathcart et al., 1994; Hunt et al., 1994; Humenik et al., 1997; Newman et al., 2000; Reddy et al., 2001). Constructed wetland performance data vary with site, wastewater characteristics, wetland design, application, and water treatment goal; therefore a "systems approach" is often required for successful management of agricultural waters (Payne Engineering and CH2M Hill, 1997; USDA NRCS, 2002). A systems approach recognises site-specific conditions, typically adopting an integrated, multidisciplinary approach to water pollution (Mitsch and Jørgensen, 1989).



In Ireland, the use of constructed wetlands to manage agricultural waters such as farm yard dirty water has been primarily based on an ecosystems approach. Integrated constructed wetlands, which are a design specific approach of conventional surface flow constructed wetlands, were first used in the Anne Valley, Waterford, Ireland (Harrington and Ryder, 2002). At present, 13 farms in the Anne Valley catchment use integrated constructed wetlands to manage farmyard dirty water (Harrington et al., 2004). Fundamental to their design is water quality improvement, landscape fit (designing the wetland into the topography of the landscape) and that the wetland provides an ecological habitat within the agricultural landscape. Typically, integrated constructed wetlands have greater land area requirements than conventional surface flow constructed wetlands in order to provide for these other fundamental ecological services.
Few studies (Ryan, 1990) have addressed the issue of quality and quantity of farmyard dirty generated at farm-scales in Ireland. No studies were readily available documenting the effectiveness of a farm-scale constructed or integrated constructed wetland in Ireland to remove nutrients such as phosphorus (P) from dairy farmyard dirty water on a mass basis. To address such, the main objectives of this

research were to (i) determine the quality and quantity of farmyard dirty water generated at a farm-scale (ii) determine the effectiveness of three treatment cells of an integrated constructed wetland to treat farmyard dirty, using the difference between input and output mass loadings, (iii) investigate if there were seasonal effects in the wetland's performance to retain phosphorus, and (iv) assess the impact of the integrated constructed wetland on the receiving environment by monitoring soil-water parameter concentrations up gradient, down gradient and within the wetland system using piezometers at different soil depths.

## MATERIAL AND METHODS

### Site Description

The integrated constructed wetland was situated at a semi-state research centre (Teagasc Research Centre, Johnstown Castle, Wexford) located in the southeast of Ireland (Irish national grid reference E: 3011524.33 m; N: 116290.22 m). Ireland has a cool temperate west maritime climate. In the southeast, annual rainfall is about 1,000 mm and mean temperature is 10°C (Gardiner and Radford, 1980). The wetland was built in the summer of 2000, on soils that were a complex of imperfectly drained gleys and well to moderate draining brown earths. The wetland system was not lined with compacted clay; rather in situ soils were used. In situ soils had a relatively high silt and medium clay content (33% ± 0.2% and 12% ± 0.9%, respectively).



Farmyard dirty water, which was comprised of rainfall on open farmyard areas (2,031 $m^2$), farmyard manure and silage effluents, along with dairy and yard washings from a 42-cow organic dairy unit, was collected in a central storage facility. This storage facility was a three-chambered tank where farmyard dirty water underwent some primary treatment (sedimentation). The tank effluent was then discharged to the wetland by a pump-operated system, but there was also a facility to direct tank effluent to a sprinkler system for spreading waters onto grassland areas. The integrated constructed wetland comprised of three surface flow treatment wetland cells with a total area of 4,265 $m^2$ and one final monitoring pond (490 $m^2$) (Figure 1). Up gradient and surrounding the wetland system was unfertilised organic grassland pastures. There was also a 30 cm deep surface drain around the up gradient side of the wetland site. Within the first wetland cell there was a deep-water sump (250 $m^2$ x 2 m deep) to aid sedimentation. Generally, wetland cells were flooded to a water depth of about 30 - 40 cm. Water levels in the final monitoring pond were maintained at about one to two meters. The purpose of the final monitoring pond was to aid further reduction of $BOD_5$, sedimentation of particulates, but also to aid ease of monitoring by providing a potentially suitable environment for biological indicators of water quality such as freshwater fish. Wetland-treated waters were point discharged (whenever there was outflow) to adjacent riparian woodland, which drained down to a nearby stream.

Piezometers were installed at various soil depths (one to three meters) up gradient, within and down gradient of the wetland site (Figure 1, b) to monitor nutrient concentrations in soil-water.

Several macrophytic species, which were generally sourced locally, were planted at about one square meters spacing in the wetland. Predominant plant species included *Carex riparia* Curtis., *Typha latifolia* L., *Phragmites australis* (Cav.) Trin. ex Steudel, *Sparganium erectum* L., *Glyceria fluitans* (L.) R. Br., *Iris pseudacorus* L., *Phalaris arundinacea* L. and *Alisma plantago-aquatica* L. During the monitoring period of the study, percentage vegetation cover in the three treatment wetland cells was qualitatively assessed to range from 80 to 90% during the growing season, whereas during late autumn and winter periods (October to January) percentage cover was somewhat less about 50%. Monitoring of the integrated constructed wetland was conducted for two and a half years (April 2001 until September 2003).

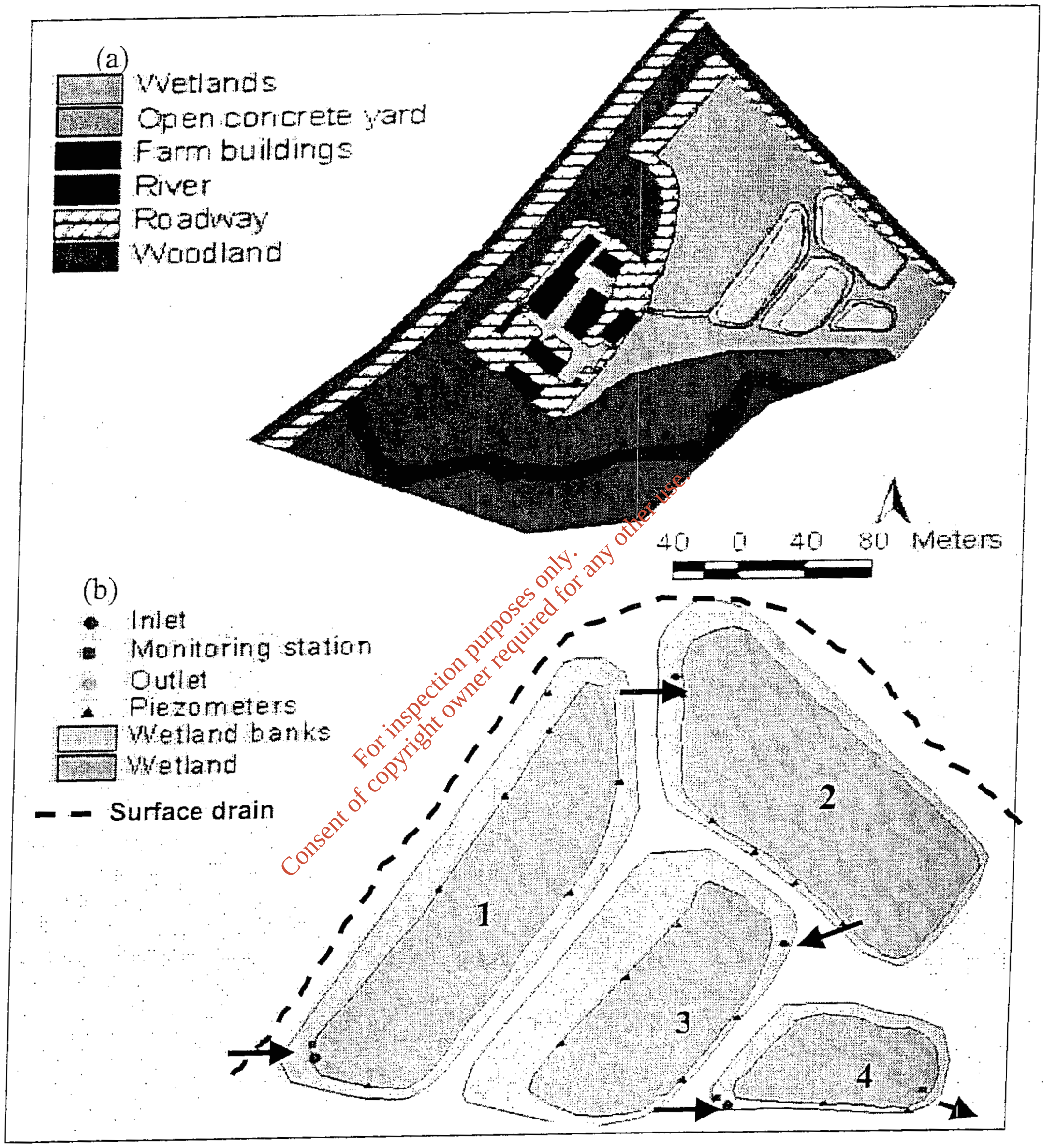




**Figure 1:** Sketch of (a) farmyard and (b) integrated constructed wetland layout with installed monitoring stations.

**Weather Data**

Daily rainfall and class A pan evaporation data were recorded at the weather station located at Johnstown Castle Research Centre. Rainfall was measured using a standard rain gauge and evaporation data was measured using a standard evaporation device called a "Class A pan." Both parameters were manually recorded and the weather station was about 750 meters from the actual wetland site. Class A pan evaporation data (mm $d^{-1}$) was used to determine evapotranspiration (ET) from the wetland system. Kadlec and Knight (1996) suggest that wetland ET is about 70 to 80% of class A pan data as the presence of vegetation retards evaporation. For this particular study, 80% of class A pan data was used to estimate wetland ET.

**Water Sampling**

Prior to wetland operation, piezometer water samples were taken fortnightly for three months to establish baseline water quality data on soil-water parameter concentrations. Pre and during wetland monitoring, water quality monitoring stations were installed at the wetland inlet (inlet one) and wetland outlet (outlet of treatment wetland cell three) pipes in April 2001 and December 2001, respectively. Stations were equipped with portable water samplers (Plate 1) (American Sigma, Inc., Loveland Colorado; Model 900 MAX). Pipe flows were measured on a continuous basis using submerged velocity probes that were interfaced with the portable sampler, thus for each sampling period a flow proportional sample was taken. Depending on flow events the portable samplers were programmed to take samples every 1 $m^3$ or 5 $m^3$ at the wetland inlet and every 10 $m^3$ or 20 $m^3$ at the wetland outlet. At the end of each sampling period, flow proportional samples were composited and a one-litre sub-sample was taken for laboratory analyses. During February 2003 no inflows were measured to the wetland, as the inlet water sampler was removed for maintenance.



Fortnightly, one litre grab samples were taken from wetland inlets two (I2), three (I3), and outlet of final monitoring pond (O4). Also, piezometer water samples were taken about every two months. All water samples (automatic sampler, grab and piezometer) were immediately brought back to laboratory and stored at 4°C until analyses.

**Plate 1**. Portable water sampler with interfaced velocity probe and intake sampling tube at wetland inlet one monitoring station.

**Water Analyses**

Water samples were collected, stored at 4°C and analysed for $BOD_5$ according to APHA method 5210-B (APHA, 1992). The $BOD_5$ analysis measures oxygen required for biochemical degradation of organic material and the oxygen used to oxidise inorganic material over a five-day incubation period. Total suspended solids were determined by filtering water samples through glass fibre filter paper (Whatman GF/A). The residue retained on the filter was dried to a constant weight at 104°C. Increase in weight of filter paper represented the TSS content of the sample (Method 2540-D; APHA, 1992). To determine soluble reactive P (SRP), samples were filtered to 0.45 μm using membrane disc filters. Filtrate was analysed for SRP using an automated ascorbic acid method (Method 424-G; APHA, 1992). Water samples were also analysed colorimetrically for ammonium ($NH_4^+$-N) and nitrate ($NO_3^-$-N). Ammonium was measured following Berthelot reduction using the salicylate method (Houba et al., 1987). Nitrate was determined as the difference between nitrite ($NO_2^-$-N) and total oxidisable nitrogen (TON) using the hydrazine reduction method (Method 4500-$NO_3^-$ H; APHA, 1992). All ion concentrations were measured using an automated discrete auto analyser (Konelab Corporation, Espoo, Finland; Model Konelab 30). Many constructed wetland systems that are used to treat agricultural wastewaters have documented total phosphorus and total nitrogen content of wastewaters. This study focused on the more biologically available fractions such as SRP; however large amounts of P may exist in particulate form, as farmyard dirty water has typically high concentrations of $BOD_5$ and total suspended solids.



**Parameter Determination**

A site-specific water balance equation was used for this study [Equation 1].

$$\frac{dv}{dt} = Q_{in} + P_w + P_b - ET_w - Q_{out} \quad [1]$$

where $Q_{in}$ is farmyard dirty water inflow, $P_w$ is the precipitation on the wetland surface area (wetland cells one to three), $P_b$ is inflow from precipitation on the surrounding wetland bank area, ET is the evapotranspiration from the wetland surface area (wetland cells one to three), and $Q_{out}$ is the wetland surface outflow. All units are in cubic meters.

The wetland banks were grass covered, steep sloped and were isolated from surrounding surface hydrologic inflows, as there was a surface drain (30 cm deep) surrounding the up gradient side of the wetland. Soluble reactive P concentrations were not measured in surrounding wetland bank inflows to the wetland; therefore to allocate mass loads to this contributing area, literature values were used instead. Tunney et al. (1997a) found that in a site about one kilometer away from the wetland study site, SRP concentrations in surface runoff from a small, low intensity grassland catchment during a six month period ranged between 0.005 and 0.054 mg $l^{-1}$ SRP. The maximum value (0.054 mg $l^{-1}$) was used in this study, in conjunction with inflow volumes from the grass covered wetland banks, to estimate the SRP mass load associated with bank inflows to the wetland.

Input and output mass rates (g $d^{-1}$) were determined for each sampling period. Mass removal or release rate by the wetland was determined as the mass loading rate difference between input and output mass rates [Equation 2].

$$R = M_i - M_o \qquad [2]$$

where $R$ is the mass removal or release rate (g $d^{-1}$), $M_i$ is mass input rate (g $d^{-1}$) of all wetland inputs (farm yard dirty water, wetland bank inflow and rainfall), and $M_o$ is mass output rate (g $d^{-1}$) of the wetland surface outflows. A wetland area based specific mass retention (kg ha $yr^{-1}$) was also determined. Mean monthly farmyard dirty water wetland inlet one and wetland surface outflow, flow-weighted water quality parameter concentrations were determined using Equation [3].

$$FWC = \sum_{i=1}^{n} M / \sum_{i=1}^{n} Q \qquad [3]$$

where $FWC$ is the mean flow weighted water quality parameter concentration per month (mg $l^{-1}$), $M$ is the sum of contaminant or nutrient mass per month (g), $Q$ is the sum of flow volume per month (l) and $n$ = total number of sampling time periods per month ($i$ = 1, 2, 3, …$n$).

### Data Analyses

Data distributions were tested for normality. If data was not normally distributed it was log transformed. Statistical analyses were conducted on transformed data, while data presentation uses means of actual measured values. Statistically significant differences were determined at the $P < 0.05$, unless otherwise stated. Comparisons of means were by paired student t-tests and analysis of variance (ANOVA). Within ANOVA, all pairs were compared using Tukey-

Kramer's honest significant difference (HSD). Multivariate linear correlations were determined using the Pearson product-moment correlation. Regression analysis used the standard least squares fit. All statistical analyses were performed using the JMP software programme (SAS Institute Inc., Cary, North Carolina).

## RESULTS AND DISCUSSION

### Flows

During the monitoring period (April, 2001 until September, 2003) highest monthly rainfall was recorded in July 2001 (5.1 ± 2.9 mm $d^{-1}$) (mean ± standard error); October 2002 (8.8 ± 2.3 mm $d^{-1}$); and November 2002 (7.9 ± 1.4 mm $d^{-1}$). There was no significant seasonal variation in daily rainfall. However, there was large variability in maximum daily rainfall between seasons (Table 1).

Figure 2 shows that farmyard dirty water inflow rate to the wetland varied from month to month. There was a significant positive relationship between measured farmyard dirty water inflow rate to the wetland and rainfall during the monitoring period ($r = 0.55$; $P < 0.01$; $n = 27$). This suggests that rainfall on impervious surfaces such as open yard areas maybe an important component in the generation of farmyard dirty water that is collected, stored and subsequently discharged to the wetland system. However, the low r value implies that there are other interacting factors that need consideration, as there was no simple cause an effect relationship. Cumby et al. (1999) also indicated that volumes of dirty water produced cannot be determined by anyone parameter. For example, they found no simple relationship between dirty water produced and cow numbers in a survey of 20 dairy farms in the U.K. Amount of farmyard dirty water generated in dairy farms can vary with climatic factors such as rainfall (Cronk, 1996; Brewer et al., 1999; Cumby et al., 1999), farm management practices such as volumes of water used to wash down parlour units and milking machines (Ryan, 1990; Cronk, 1996), timing and method of storing farm yard manure and silage in farm yard areas (NRCS, 1991; Cronk, 1996; Brewer et al., 1999; Cumby et al., 1999; DAFRD, 2000).

**Table 1: Within season mean daily rainfall and mean class A pan evaporation ± one standard error along with within season maximum daily rainfall for the monitoring period (April 2001 - September 2003).**

| Season | Month | Mean daily rainfall | | Class A pan evaporation | | Maximum daily rainfall |
|---|---|---|---|---|---|---|
| | | mm d⁻¹ | | | | mm |
| Spring | 1st Feb. - 31st Apr. | 3.14 | ± 0.33 | 2.25 | ± 0.34 | 28 |
| Summer | 1st May - 31st Jul. | 2.88 | ± 0.43 | 1.74 | ± 0.22 | 85 |
| Autumn | 1st Aug. - 31st Oct. | 2.97 | ± 0.44 | 3.47 | ± 0.26 | 52 |
| Winter | 1st Nov. - 31st Jan. | 3.53 | ± 0.36 | 0.71 | ± 0.19 | 27 |

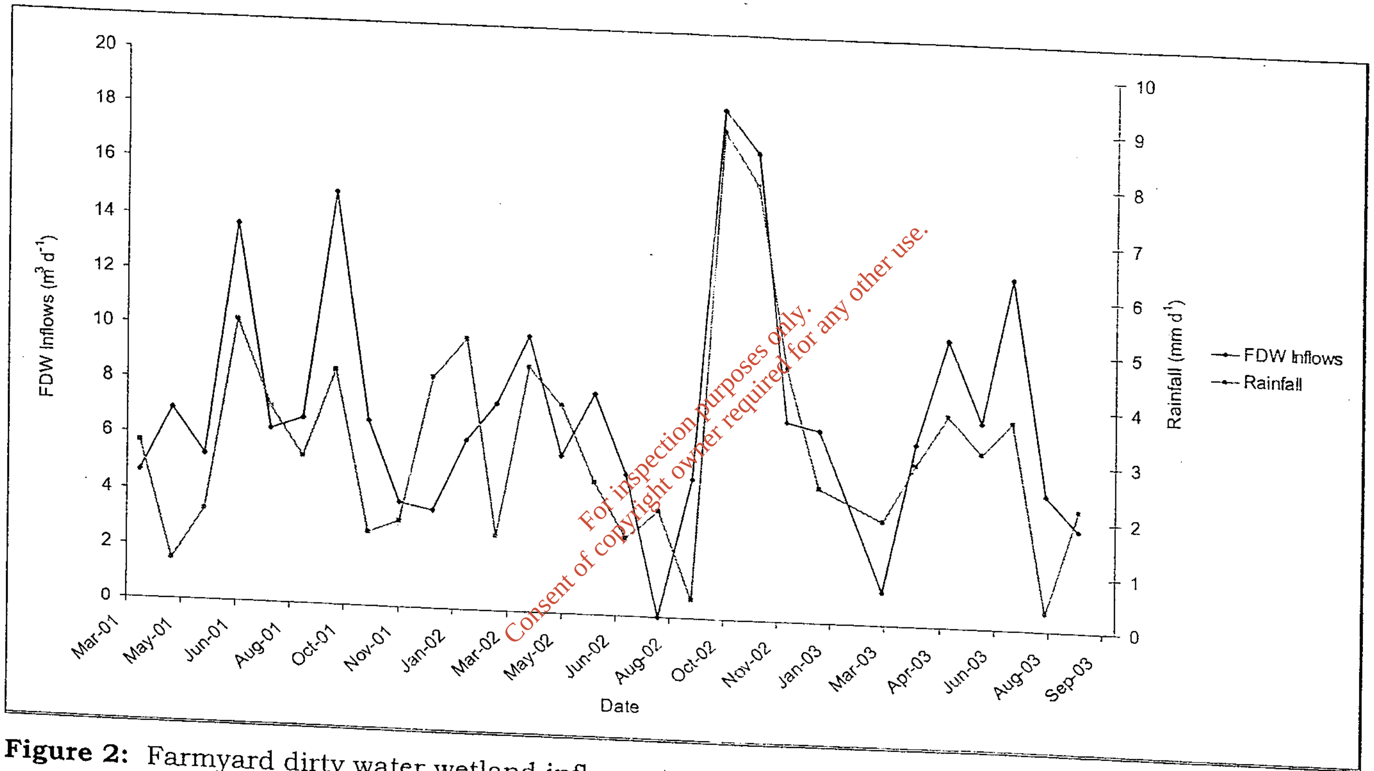


**Figure 2:** Farmyard dirty water wetland inflow rate measured at wetland inlet one and rainfall per month during monitoring period (April 2001 - September 2003).

When there was inflow to the integrated constructed wetland, monthly farmyard dirty water inflow rate varied from 3.6 - 18.5 $m^3 d^{-1}$. This was similar to Geary and Moore (1999) who observed dairy wastewater inflow rates of 4.5 - 10.6 $m^3 d^{-1}$ to a surface flow constructed wetland that treated dairy wastewaters from a 110-cow dairy herd in Australia. The Livestock Wastewater Treatment Wetland Database, USA reports that inflow rates of agricultural wastewaters to treatment wetlands are typically less than 10 $m^3 d^{-1}$ (Knight et al., 2000) suggesting that most wetland applications to retain contaminants and nutrients from livestock wastewater are relatively small-scale. Farmyard dirty water inflow to the wetland at inlet one was greatest during autumn and smallest in spring, while wetland outflow was greatest in winter and lowest in spring (Table 2). During autumn and winter periods, there was a large range in farmyard dirty water inflow rates, while there was a large range in surface outflow rates during winter periods. This is probably due to high rainfall in October and November 2002, which in turn resulted in high farmyard dirty water inflow rates to the wetland and subsequently high wetland outflow rates in November and December 2002. During November and December 2002, there was a significant relationship between rainfall and wetland surface outflow rates ($R^2 = 0.70$; $P < 0.01$; $n = 8$). Newman et al. (2000) suggested that at their particular study site (a surface flow constructed wetland used to treat milkhouse wastewater in Connecticut, USA) seasonal variation was controlled by evapotranspiration, rather than hydrologic inputs such as rainfall.

**Table 2. Seasonal farmyard dirty water hydraulic load rate inflow rates measured at wetland inlet one and wetland surface outflow rates measured at the wetland outlet during the monitoring period (April 2001 - September 2003).**

| | | Inflow | | | | Outflow | | | |
|---|---|---|---|---|---|---|---|---|---|
| Season† | *n* | Mean | Standard error | Min. | Max. | Mean | Standard error | Min. | Max. |
| | | $m^3\ d^{-1}$ | | | | | | | |
| Spring | 5 | 5.92 | 1.23 | 1.23 | 13.94 | 13.94 | 4.02 | 7.11 | 32.3 |
| Summer | 9 | 8.39 | 1.07 | 5.15 | 20.99 | 20.99 | 6.79 | 3.33 | 39.7 |
| Autumn | 8 | 8.62 | 2.16 | 3.87 | 37.46 | 37.46 | 13.43 | 14.41 | 60.9 |
| Winter | 6 | 7.54 | 1.99 | 3.56 | 51.85 | 51.85 | 21.37 | 15.10 | 133.0 |

† Spring is 1st of February until 31st of April, Summer is 1st of May until 31st of July, Autumn is 1st of August until 31st of October, and Winter is 1st of November until 31st of January.

During the monitoring period, there was no significant seasonal difference in farmyard dirty water wetland inflow and wetland surface outflow rates. Thus, the average farmyard dirty water inflow and wetland surface outflow rates were 7.5 ± 0.8 and 30.9 ± 7.6 $m^3$ $d^{-1}$, respectively, for the time period December 2001 to September 2003. The discrepancy between flows suggests that there were other hydrologic inputs to the wetland other than farmyard dirty water. Regression analysis between the total cumulative wetland inputs and total cumulative wetland outputs at this site suggest that most inflows and outflows to and from the system were accounted for (Figure 3) using the site specific water balance equation [Equation 1]; therefore groundwater inflows and outflows to and from the wetland were not an important consideration at this particular constructed wetland site. The wetland bank areas surrounding the wetland were about 52% of the total wetland surface area. In terms of hydraulic loading during the monitoring period, precipitation onto wetland surface areas accounted for 45% of the hydrological inputs, while precipitation on wetland bank areas and inputs of farm yard dirty water accounted for 28 and 27%, respectively. The net effect of these contributing waters is a reduction in hydraulic residence time (HRT) of wastewaters within a treatment wetland system, which ultimately results in degraded wetland outflow water quality (Kadlec and Knight, 1996).

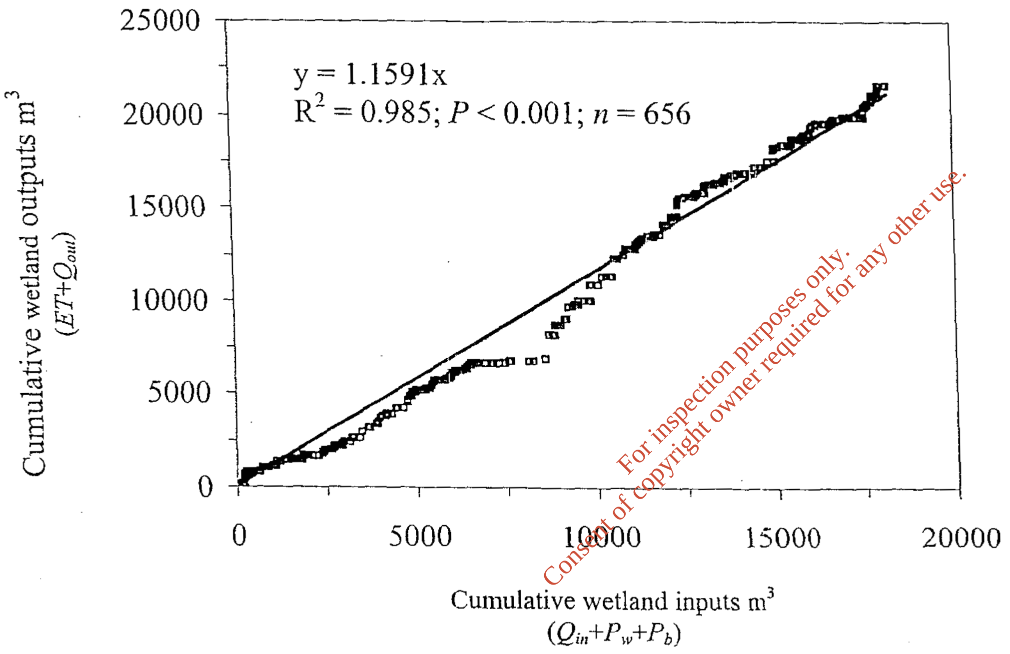


**Figure 3:** Relationship between cumulative wetlands inputs (farmyard dirty water in ($Q_{in}$), precipitation on wetland surface area ($P_w$), and inflow from precipitation on surrounding wetland banks ($P_b$)) and cumulative wetland outputs (evapotranspiration from the wetland surface area ($ET$), and wetland surface outflows ($Q_{out}$)).

### Water Quality Parameter Concentrations

Five-day biological oxygen demand and TSS concentrations of farmyard dirty water at wetland inlet one were highest during winter, while SRP and $NH_4^+$ concentrations were highest in spring and autumn, respectively (Table 3). However, one would expect low parameter concentrations in winter due to dilution effects of rainfall and higher concentrations in summer due to lack of it. Although water quality parameter concentrations of farmyard dirty water varied, there was no significant seasonal difference, which is contrary to Brewer et al. (1999) in their study of 20 days farms in the U.K. where they found that contaminant and nutrient concentrations were likely to vary between seasons. Average concentrations of water quality parameters that were discharged to the integrated constructed wetland during the monitoring period were 2806 ± 120 mg $l^{-1}$ $BOD_5$, 905 ± 43 mg $l^{-1}$ TSS, 44.98 ± 2.29 mg $l^{-1}$ $NH_4^+$, and 18.86 ± 0.87 mg $l^{-1}$ SRP. These concentrations were within ranges reported by other studies (442 to 6,600 mg $l^{-1}$ $BOD_5$, 111-1645 mg $l^{-1}$ TSS, 8-500 mg $l^{-1}$ $NH_4^+$, 25-100 mg $l^{-1}$ TP, and up to 415 mg $l^{-1}$ SRP) where concentrations varied depending on management practices, site characteristics, and climate (Hammer, 1989; Cronk, 1996; Cumby et al., 1999; Knight et al., 2000; Newman et al., 2000; Schaafsma et al., 2000).

Water quality parameter concentrations decreased between wetland inlet and outlet of final monitoring pond during the monitoring period (Figures 4 and 5). Concentrations of SRP and $NH_4^+$ were significantly reduced between wetland inlet one and two ($P < 0.05$); however there was no significant difference in parameter concentration reduction between inlet three and inlet to monitoring pond, which was probably the result of a short HRT in the third treatment wetland cell (Mitsch and Gosselink, 1993; Kadlec and Knight, 1996). Significant reductions of $BOD_5$ and TSS were observed between all of the wetland inlets ($P < 0.05$). Five-day biological oxygen demand and TSS concentrations of wastewaters typically decrease steeply once wastewaters are discharged to wetlands (Kadlec and Knight, 1996).

**Table 3. Farmyard dirty water at wetland inlet one parameter concentrations for monitoring period (April 2001 - September 2003).**

| Season | | n | Farmyard dirty water parameter concentrations† | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | SRP | | $NH_4^+$ | | $BOD_5$ | | TSS | |
| | | | mg $l^{-1}$ | | | | | | | |
| Spring | 1st Feb. - 31st Apr. | 7 | 21 | ± 2 | 53 | ± 8 | 2703 | ± 457 | 941 | ± 154 |
| Summer | 1st May - 31st Jul. | 10 | 19 | ± 3 | 36 | ± 6 | 2682 | ± 482 | 978 | ± 190 |
| Autumn | 1st Aug. - 31st Oct. | 5 | 19 | ± 3 | 61 | ± 10 | 2303 | ± 351 | 921 | ± 55 |
| Winter | 1st Nov. - 31st Jan. | 6 | 15 | ± 3 | 42 | ± 7 | 2828 | ± 412 | 1078 | ± 161 |

† SRP, soluble reactive phosphorus; $BOD_5$, five day biological oxygen demand; and TSS, total suspended solids.

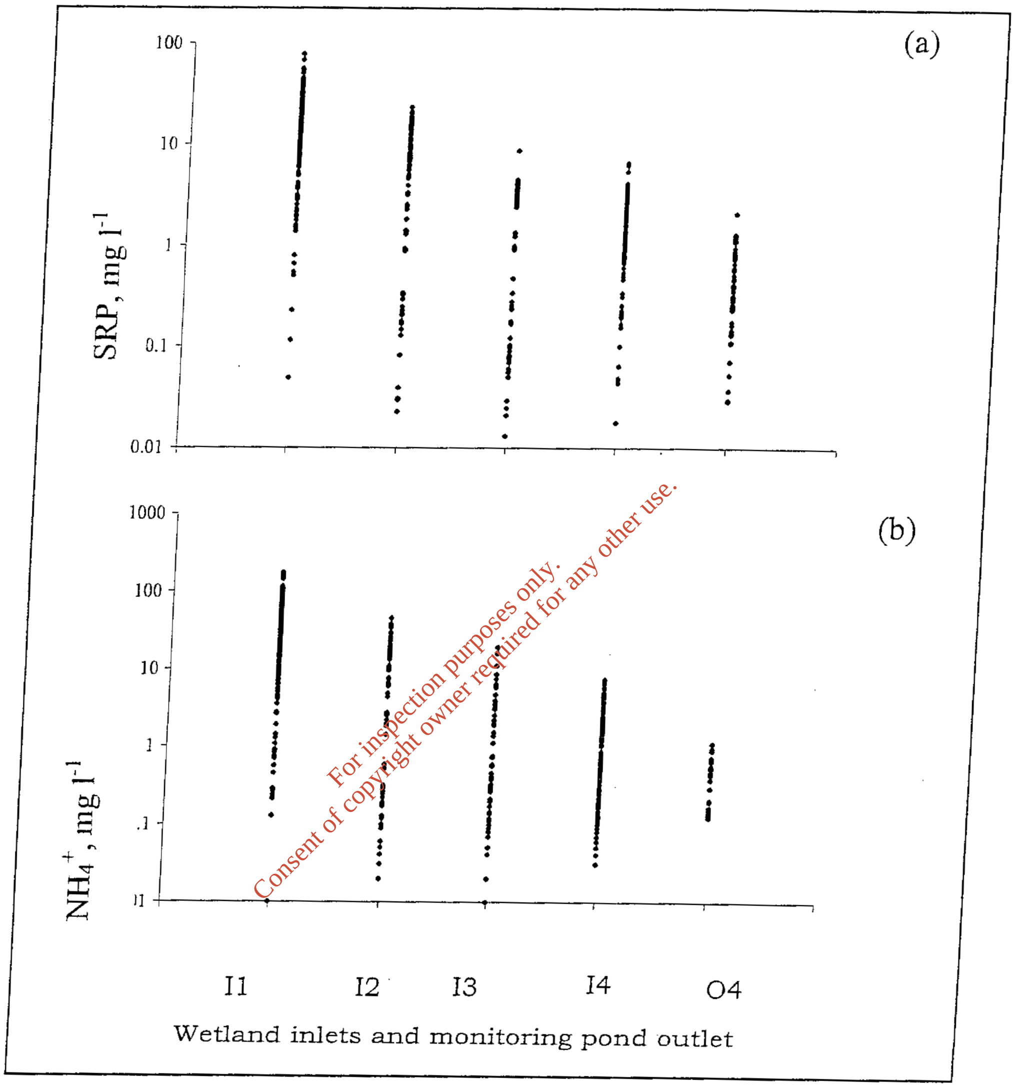



**Figure 4:** Log reduction of (a) soluble reactive phosphorus (SRP) and (b) ammonium ($NH_4^+$) in mg $l^{-1}$ between wetland inlets (I1-I3) and inlet and outlet of final monitoring pond, respectively (I4-O4) during the monitoring period (April 2001 - September 2003).

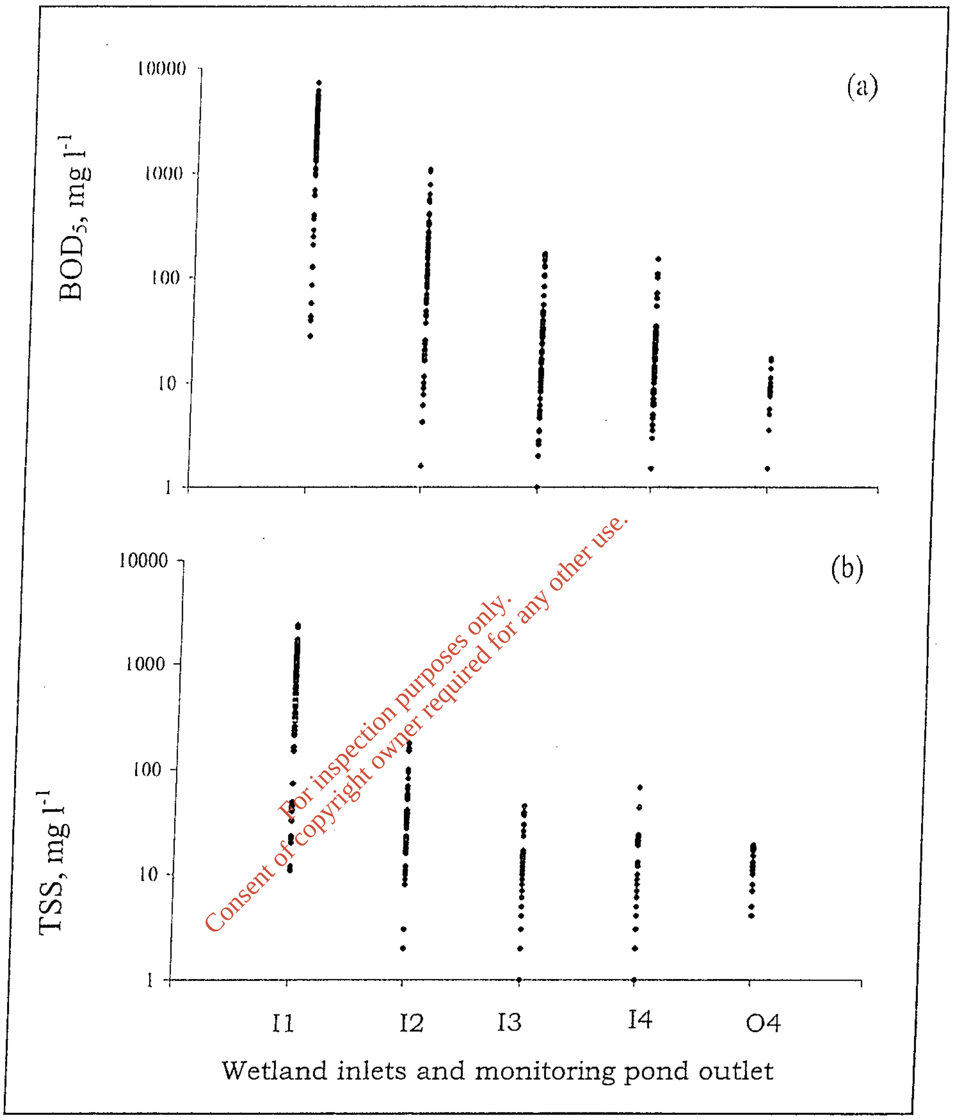




**Figure 5:** Log reduction of (a) five day biological demand ($BOD_5$) and (b) total suspended solids (TSS) between wetland inlets (I1-I3) and inlet and outlet of final monitoring pond, respectively (I4-O4) during the monitoring (April 2001 – September 2003).

There was some seasonal variation in water quality parameter concentrations at each inlet. At wetland inlet one, concentrations varied but not significantly so (Table 3). At wetland inlet two, the highest seasonal SRP concentration was in spring (13.40 ± 1.88 mg $l^{-1}$), which was significantly higher than autumn concentrations ($P < 0.05$). At wetland inlet three, concentrations of $NH_4^+$ were highest and TSS concentrations lowest during winter (4.47 ± 1.14 mg $l^{-1}$ and 8 ± 3 mg $l^{-1}$, respectively) relative to summer and autumn ($P < 0.05$). Finally, at the inlet to the monitoring pond, concentrations of SRP (2.2 ± 0.21 mg $l^{-1}$) and $NH_4^+$ (3.41 ± 0.46 mg $l^{-1}$) were highest during winter ($P <$ 0 .05). It is hypothesised that SRP and $NH_4^+$ concentrations were highest during winter because of increased surface outflow rates (Mitsch and Gosselink, 1993; Kadlec and Knight, 1996; Koskiaho et al., 2003).

There were significant correlations between flow weighted mean monthly farmyard dirty water parameter concentrations at wetland inlet one with wetland surface outflow parameter concentrations (Table 4). The most significant relationship was between $BOD_5$ and TSS concentrations in farmyard dirty water. This suggests that most of the organic material in dirty water is in a suspended form or vice versa. Cumby et al., (1999) observed that there was a good correlation (87%) of $BOD_5$ concentrations with total solid (TS) concentrations in dairy farm wastewaters. There were also significant relationships between farmyard dirty water concentrations of SRP and $NH_4^+$ ($P < 0.05$) prior discharge to the integrated constructed wetland. Simple relationships such as those established allow prediction between parameters (Cumby et al., 1999) and between inlet and outlet concentrations of the same parameter (Kadlec and Knight, 1996), which can help to generate empirical relationships that are useful for wetland design.

**Table 4. Correlation matrix of mean monthly farmyard dirty water and wetland surface outflow, flow-weighted concentrations for period April 2001 - September 2003 (*n* = 16).**

| | Water quality parameter concentrations | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $SRP_{in}$ | | $NH_4^+{}_{in}$ | | $BOD5_{in}$ | | $TSS_{in}$ | | $SRP_{out}$ | | $NH_4^+{}_{out}$ | | $BOD5_{out}$ | | $TSS_{out}$ |
| $SRP_{in}$ | 1 | | | | | | | | | | | | | | | |
| $NH_4^+{}_{in}$ | 0.5606 | * | 1 | | | | | | | | | | | | | |
| $BOD5_{in}$ | 0.0325 | NS‡ | 0.1129 | NS | 1 | | | | | | | | | | | |
| $TSS_{in}$ | 0.156 | NS | 0.1725 | NS | 0.9083 | *** | 1 | | | | | | | | | |
| $SRP_{out}$ | 0.6104 | ** | 0.1819 | NS | -0.3514 | NS | -0.2339 | NS | 1 | | | | | | | |
| $NH_4^+{}_{out}$ | 0.1385 | NS | 0.1839 | NS | -0.26 | NS | -0.3042 | NS | 0.3707 | NS | 1 | | | | | |
| $BOD5_{out}$ | 0.0438 | NS | 0.1023 | NS | 0.5875 | * | 0.4521 | NS | -0.0799 | NS | 0.3273 | NS | 1 | | | |
| $TSS_{out}$ | -0.0297 | NS | -0.2374 | NS | 0.7136 | ** | 0.656 | * | -0.4037 | NS | -0.1782 | NS | 0.4939 | * | 1 | |

*, **, *** Significant at the 0.05, 0.01 and 0.001 probability levels, respectively
† SRP, soluble reactive P; BOD5, five-day biological oxygen demand; and TSS, total suspended solids
‡ Not significant.

**Farmyard Dirty Water Loading Rates**

Mass input rates of SRP, $NH_4^+$, $BOD_5$, and TSS in farmyard dirty water to the wetland, did not vary with season (Table 5) as there was no significant seasonal difference in hydraulic inflows (Table 2) or water quality parameter concentrations (Table 3). Thus, during the monitoring period, *mass-loading rate of* $BOD_5$ *to the integrated* constructed wetland averaged 3.57 ± 0.49 g $m^{-2}$ $d^{-1}$. This was about five fold less than that indicated by Newman et al. (2000). Other studies reporting the effectiveness of constructed wetlands to treat dairy wastewaters have determined mass loading rates of up to 9 g of $BOD_5$ $m^{-2}$ $d^{-1}$ (Reaves et al., 1994; Skarda et al., 1994; Geary and Moore, 1999). The Natural Resource Conservation Service (NRCS), USA as cited from Cronk (1996) and Newman et al. (2000) recommend a maximum $BOD_5$ mass loading rate of 7.3 g $m^{-2}$ $d^{-1}$. The mass loading rate of TSS to the integrated constructed wetland was 1.04 ± 0.15 g $m^{-2}$ $d^{-1}$, whereas TSS mass loading rates reported from other constructed wetlands used to treat dairy wastewaters were slightly higher (2-8 g $m^{-2}$ $d^{-1}$) (Reaves et al., 1994; Skarda et al., 1994; Newman et al., 2000).

**Table 5: Mass input rates from farmyard dirty water at wetland inlet one during monitoring period (April 2001 - September 2003).**

| Season‡ | *n* | Farmyard dirty water mass input rate† SRP | | $NH_4^+$ | | $BOD_5$ | | TSS | |
|---|---|---|---|---|---|---|---|---|---|
| | | g $d^{-1}$ | | | | kg $d^{-1}$ | | | |
| Spring | 5 | 126 | ± 17 | 307 | ± 54 | 15.0 | ± 2.6 | 4.1 | ± 1.0 |
| Summer | 8 | 140 | ± 39 | 513 | ± 184 | 17.5 | ± 6.3 | 4.4 | ± 1.5 |
| Autumn | 9 | 149 | ± 33 | 321 | ± 87 | 15.7 | ± 3.3 | 5.0 | ± 1.3 |
| Winter | 6 | 101 | ± 24 | 259 | ± 59 | 11.9 | ± 3.5 | 3.7 | ± 1.3 |

† SRP, soluble reactive P; BOD5, five day biological oxygen demand; and TSS, total suspended solids.
‡ Seasons are spring (1st Feb. - 31st Apr.), summer (1st May - 31st Jul.), autumn (1st Aug. - 31st Oct.) and winter (1st Nov. - 31st Jan.).

Ammonium loading rates (83 ± 13.64 mg $m^{-2}$ $d^{-1}$) to the integrated constructed wetland were lower than those reported by Reaves et al. (1994) and Skarda et al. (1994). Geary and Moore (1999) recorded a loading rate of 3,200 mg $m^{-2}$ $d^{-1}$. Total P loading rates to surface flow constructed wetlands receiving dairy farm wastewaters are often variable (30 mg $m^{-2}$ $d^{-1}$ to 1.5 g $m^{-2}$ $d^{-1}$) (Reaves et al., 1994; Skarda et al., 1994; Geary and Moore, 1999; Newman et al., 2000; Jamieson et al., 2001). Soluble reactive P was loaded at rate of 30.89 ± 3.67 mg $m^{-1}$ $d^{-1}$ to the wetland. In general, farmyard dirty water loading rates to the integrated constructed wetland were lower than those documented for other similar studies.

Finally, in terms of yearly mass loads and independent of season, farmyard dirty water was discharged to the integrated constructed wetland at a rate of 47 ± 10 kg SRP $yr^{-1}$, 128 ± 35 kg $NH_4^+$ $yr^{-1}$, 5484 ± 1433 kg $BOD_5$ $yr^{-1}$, and 1570 ± 465 kg TSS $yr^{-1}$. These loadings rates during the monitoring period resulted in average outflow concentrations (from the three treatment wetland cells to the final monitoring pond) of 1.7 ± 0.14 mg $l^{-1}$ SRP, 1.9 ± 0.4 mg $l^{-1}$ $NH_4^+$, 20 ± 3 mg $l^{-1}$ $BOD_5$ and 11 ± 1 mg $l^{-1}$ TSS.



**Phosphorus Inputs and Retention Rates**

Total mass SRP input rates to the wetland were determined as the sum of SRP loading rates from farmyard dirty water, rainfall and wetland bank surface inflows. There was no significant seasonal variation in total mass SRP inputs between December, 2001 and September, 2003 (Table 6) as most of the SRP load was from farmyard dirty water, which was relatively stable. However, there was some seasonal variation in wetland SRP mass output rates. The wetland generally discharged output loads at highest levels during winter periods ($P < 0.05$). The higher SRP output rates in winter may reflect the high rainfall months of October and November, 2002 as wetland surface outflows typically increased during these periods.

**Table 6. Seasonal total mass soluble reactive phosphorus (SRP) input, output and rate to and from the wetland ± one standard error for period between December 2001 and September 2003.**

| Season† | *n* | Total Inputs‡ | | Total Outputs§ | | Retention | |
|---|---|---|---|---|---|---|---|
| | | ---kg $yr^{-1}$--- | | | | kg ha $yr^{-1}$ | % |
| Spring | 7 | 40 | ± 8 | 7 | ± 3 | 79 | 84 |
| Summer | 9 | 54 | ± 12 | 10 | ± 4 | 104 | 81 |
| Autumn | 8 | 45 | ± 14 | 8 | ± 7 | 86 | 81 |
| Winter | 6 | 37 | ± 9 | 35 | ± 18 | 4 | 5 |

† Seasons are spring (1st February until 31st of April), summer (1st May until 31st of July), autumn (1st August until 31st of October) and winter (1st November until 31st of January).

‡ Total inputs include SRP mass load from farmyard dirty water, precipitation on wetland surface areas and wetland bank inflow.

§ Total outputs are the SRP mass load in wetland surface outflow.

Table 6 shows that SRP percent mass retention by the wetland was seasonally variable. During spring, summer and autumn retention rates were similar, whereas during winter, the wetland retained least amounts of P and in some instances released P, also a probable result of decreases in HRT. Wetlands used to treat dairy farm wastewaters have retained between 27 to 68% of incoming P loads (Reaves et al., 1994; Skarda et al., 1994; Geary and Moore, 1999; Newman et al., 2000). Specific SRP mass retention by the integrated constructed wetland varied from 4 to 104 kg SRP ha $yr^{-1}$ depending on season. These values are within the ranges reported for other surface flow constructed wetlands that are used to treat dairy wastewaters (Cronk, 1996).

Mechanisms involved in P removal by a wetland ecosystem include: sedimentation, precipitation, plant uptake, peat accretion, sorption reactions (Craft and Richardson, 1993; Mitsch and Gosselink, 1993; Reddy et al., 1999; Kadlec and Knight, 1996; Braskerud, 2002; Koskiaho et al., 2003).

Generally, the variability in treating dairy wastewaters by surface flow constructed wetlands has been attributed to differences in wastewater management practices, site specific characteristics, wetland design and layout, hydrologic inputs, scale of operation and climate (Cronk, 1996; Peterson, 1998; Knight et al., 2000 Schaafsma et al., 2000). This makes direct comparisons between wetland studies somewhat difficult.



**Environmental Impact**

Water quality parameter concentrations in piezometers that were installed at various depths (one to three meters) up gradient, within and down gradient of the integrated constructed wetland indicate that there was very little difference between concentrations of SRP, $NH_4^+$ and $NO_3^-$ in soil-water before and during wetland operation (Table 7). This suggests that waters infiltrating from the wetland are having little impact on soil-water nutrient concentrations.

## CONCLUSIONS

Contaminant and nutrient loss from agriculture can cause point source pollution. Constructed wetlands are often used as alternates to or components of conventional nutrient management practices to reduce or eliminate contaminant and nutrient loads in agricultural wastewaters around the world.

In this study, there was little variation in seasonal inflow rates and seasonal water quality parameter concentrations of farm yard dirty water. Mass loads of SRP, $NH_4^+$, $BOD_5$, and TSS on a yearly basis suggest that farm yard dirty water contains considerable amounts of nutrients and contaminants, thus management of those resources are important at farm-scales.

There was a positive relationship between farmyard dirty water inflow rate to the wetland and rainfall, indicating that rainfall on impervious surfaces such as open yard areas may be an important factor in the generation of dirty water at this farm-scale. Precipitation on wetland surface areas and inflows from surrounding wetland bank areas were the main controlling hydrological factors, whereas mass loads in farm yard dirty water were the main loading factor.



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**Table 7. Nutrient concentrations (soluble reactive phosphorus, SRP, ammonium, $NH_4^+$, and nitrate, $NO_3^-$) in sampled piezometersbefore and after farmyard dirty water discharge to the wetland ± one standard error. Data refers to March 2001 - September 2003.**

| Piezometer location | Piezometer number | SRP | | | | | $NH_4^+$ | | | | | $NO_3^-$ | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Before | | After | | | Before | | After | | | Before | | After | | |
| Up† | 1 | 0.013 | ± 0.006 | 0.026 | ± 0.005 | NS§ | 0.42 | ± 0.14 | 0.28 | ± 0.09 | NS | 0.19 | ± 0.093 | 0.09 | ± 0.015 | NS |
| Wetland cell 1 | 2-7 | 0.023 | ± 0.007 | 0.043 | ± 0.015 | NS | 0.55 | ± 0.08 | 0.43 | ± 0.1 | NS | 0.28 | ± 0.085 | 0.23 | ± 0.059 | NS |
| Wetland cell 2 | 8-13 | 0.016 | ± 0.003 | 0.030 | ± 0.01 | NS | 0.44 | ± 0.10 | 0.18 | ± 0.03 | * | 0.24 | ± 0.074 | 0.17 | ± 0.048 | NS |
| Wetland cell 3 | 14-18 | 0.058 | ± 0.024 | 0.033 | ± 0.008 | NS | 0.44 | ± 0.09 | 0.19 | ± 0.04 | * | 0.10 | ± 0.002 | 0.15 | ± 0.056 | NS |
| Wetland cell 4 | 19-20 | 0.023 | ± 0.004 | 0.033 | ± 0.007 | NS | 0.37 | ± 0.15 | 0.57 | ± 0.15 | NS | 0.27 | ± 0.098 | 0.93 | ND | ND |
| Down‡ | 21-23 | 0.030 | ± 0.015 | 0.007 | ± 0.005 | NS | 0.74 | ± 0.30 | 0.24 | ± 0.02 | NS | 0.35 | ± 0.253 | 0.17 | ± 0.020 | |

* Significant at the 0.05 probability level
† Piezometers located up gradient of wetland
‡ Piezometers located down gradient of wetland
§ Not significant
¶ Not determined

## REFERENCES

**APHA. (1992).** Standard methods for the examination of water and wastewaters. 18th Edition. American Public Health Association. Washington, D.C.

**Borin, M., G. Bonaiti, G. Santamaria, and L. Giardini. (2001).** A constructed surface flow wetland for treating agricultural waste waters. *Water Science and Technology.* 44: 523-530.

**Braskerud, B. (2001).** The influence of vegetation on sedimentation and resuspension of soil particles in small constructed wetlands. *Journal of Environmental Quality.* 30:1447-1457.

**Braskerud, B. C. (2002).** Factors affecting Phosphorus retention in small constructed wetlands treating agricultural non-point source pollution. *Ecological Engineering.* 19:41-61.

**Brewer, A.J., T.R. Cumby, and S.J. Dimmock. (1999).** Dirty water from farms, II: treatment and disposal options. *Bioresouce Technology.* 67:155-160.

**Bridgham, S. D., C.A. Johnston, J.P. Schubauer-Berigan, and P. Weishampel. (2001).** Phosphorus sorption dynamics in soils and coupling with surface and pore water in riverine wetlands. *Soil Science Society of America Journal.* 65:577-588.

**Cathcart, T.P., D.A. Hammer, and S. Triyano. (1994).** Performance of a constructed wetland-vegetated strip system used for swine waste treatment. pp. 9-22. *In* DuBowy, P.J., and R.P. Reaves. (eds.). Proceedings of a workshop on constructed wetlands for animal waste management, 4-6 April 1994, Lafayette, IN.

**Clenaghan, C., C. Collins, and M. Crowe. (2001).** Phosphorus regulations national implementation report, 2001. Environmental Protection Agency. Wexford, Ireland.

**Craft, C.B., and C.J. Richardson. (1993).** Peat accretion and N, P and organic C accumulation in nutrient unenriched Everglades peatlands. *Ecological Applications*. 3:446-458.

**Cronk, J.K. (1996).** Constructed wetlands to treat wastewater from dairy and swine operations: a review. *Agriculture Ecosystems and Environment*. 58:97-114.

**Cumby, T.R., A.J. Brewer, and S.J. Dimmock. (1999).** Dirty water from farms, I: biochemical characteristics. *Bioresource Technology*. 67:155-160.

**DAFRD. (2000).** Agri-environmental specifications for REPS. Department of Agriculture, Food and Rural Development, Dublin, Ireland.

**Findlay, S., P. Groffman, and S. Dye. (2003).** Effects of *Phragmites australis* removal on marsh nutrient cycling. *Wetlands Ecology and Management*. 11:157-165.

**Gardiner, M.J. and T. Radford. (1980).** Soil associations of Ireland and their land use potential: explanatory bulletin to soil map of Ireland 1980. An Foras Talúntais, Dublin.

**Geary, P.M., and J.A. Moore. (1999).** Suitability of a treatment wetland for dairy wastewaters. *Water Science and Technology*. 40:179-185.

**Hammer, D.A. (ed). (1989).** Constructed wetlands for wastewater treatment: municipal, industrial and agricultural. Lewis Publishers, Chelsea, MI.

**Hammer, D.A. and R.L. Knight. (1994).** Designing constructed wetlands for nitrogen removal. *Water science and technology*. 4:15-27.

**Harrington, R., and C. Ryder. (2002).** The use of integrated constructed wetlands in the management of farmyard runoff and waste water. *In* Proceedings of the National Hydrology Seminar on Water Resource Management: Sustainable Supply and Demand. Tullamore, Offaly. 19th Nov. 2002. The Irish National Committees of the IHP and ICID, Ireland.

**Harrington, R., E. Dunne, P. Carroll, J. Keohane, and C. Ryder. (2004).** The Anne Valley project: the use of Integrated Constructed Wetlands (ICWs) in farmyard and rural domestic wastewater management. pp. 51-58. *In* Lewis, D., and L. Gairns. (eds.). Agriculture and the Environment, Water Framework Directive and Agriculture. Proceedings of the SAC and SEPA Biennial Conference, 24-25 March 2004. Edinburgh, U.K.

**Houba, V.J.G., I. Novozamsky, J. Uittenbogaard and J.J., van der Lee. (1987).** Automatic determination of total soluble nitrogen in soil extracts. *Landwirtschaftliche Forschung.* 40:295-302.

**Humenik, F., M. Rice, M. Cook, S. Broome, P. Hunt, A. Szogi, G. Stem, M. Sugg, and G. Scalf. (1997).** Constructed wetlands to treat swine wastewater Duplin County, North Carolina. pp. 1-4. *In* Payne Engineering and CH2M Hill. Constructed wetlands for animal waste treatment: a manual on performance, design and operation with case histories. Alabama Soil and Water Conservation Committee, Montgomery, AL.

**Hunt, P.G. and M.E. Poach. (2001).** State of the art for animal wastewater treatment in constructed wetlands. *Water Science and Technology.* 44:19-25.

**Hunt, P.G., F.J. Humenik, A.A. Szogi, J.M. Rice, K.C. Stone and E.J. Sadler. (1994).** Swine wastewater treatment in constructed wetlands. *In* Proceedings of the 2nd conference on environmentally sound agriculture. University of Florida,

**Jamieson, T.S., G.W. Stratton, R. Gordon, and A. Madani. (2001).** Phosphorus adsorption characteristics of a constructed wetland soil receiving dairy farm wastewater. *Canadian Journal of Soil Science.* 82:97-104.

**Kadlec, R.H. and R.L. Knight. (1996).** Treatment wetlands. Lewis Publishers, Boca Raton.

**Kern, J., and C. Idler. (1999).** Treatment of domestic and agricultural wastewater by reed bed systems. *Ecological Engineering.* 12:13-25.

**Knight, R.L., V.W.E. Payne Jr., R.E. Borer, R.A. Clarke Jr., and J.H. Pries. (2000).** Constructed wetlands for livestock wastewater management. *Ecological Engineering.* 15:41-55.

**Koskiaho, J. (2003).** Flow velocity retardation and sediment retention in two constructed wetland-ponds. *Ecological Engineering.* 19:325-337.

**Koskiaho, J., P. Ekholm, M. Räty, J. Riihimäki, and M. Puustinen. (2003).** Retaining agricultural nutrients in constructed wetlands-experiences under boreal conditions. *Ecological Engineering.* 20:89-103.

**Mantovi, P., M. Marmiroli, E. Maestri, S. Tagliavini, S. Piccinini, and N. Marmioli. (2003).** Application of a horizontal subsurface flow constructed wetlands on the treatment of dairy parlour wastewater. *Bioresource Technology.* 88:85-94.

**Mitsch, W.J. and J.G. Gosselink. (1993).** Wetlands. 2nd Edition. Jon Wiley and Sons, Inc., New York.

**Mitsch, W.J., and S.E. Jørgensen. (1989).** Classification and examples of ecological engineering. pp. 12-19. *In* Mitsch, W.J., and S.E. Jørgensen (eds.). Ecological engineering: an introduction ecotechnology. Jon Wiley and Sons, New York.

**Newman, J.M., J.C. Clausen and J.A. Neafsey. (2000).** Seasonal performance of a wetland constructed to process dairy milkhouse wastewater in Connecticut. *Ecological Engineering.* 14:181-198.

**Nguyen, L.M. (2000).** Organic matter comparison, microbial biomass and microbial activity in gravel-bed constructed wetlands treating farm dairy wastewaters. *Ecological Engineering.* 16:199-221.

**Pant, H.K., and K.R. Reddy. (2003).** Potential internal loading of phosphorus in a wetland constructed in agricultural land. *Water Resources.* 37:965-972.

**Payne Engineering and CH2M Hill. (1997).** Constructed wetlands for animal waste treatment: a manual on performance, design and operation with case histories. Alabama Soil and Water Conservation Committee, Montgomery, AL.

**Peterson, H.G. (1998).** Use of constructed wetlands to process agricultural wastewater. *Canadian Journal of Plant Science.* 78:199-210.

**Phipps, R.G., and W.G. Crumpton. (1994).** Factors affecting nitrogen loss in experimental wetlands with different hydrological loads. *Ecological Engineering.* 399-408.

**Poach, M.E., P.G. Hunt, M.B. Vanotti, K.C. Stone, T.A. Matheny, M.H. Johnson, and E.J. Sadler. (2003).** Improved nitrogen treatment by constructed wetlands receiving partially nitrified liquid swine manure. *Ecological Engineering.* 20:183-197.

**Reaves, R.P. P.J. DuBowy, and B.K. Miller. (1994).** Performance of a constructed wetland for dairy waste treatment in LaGrange County, Indiana. pp. 43-52. *In* P.J. DuBowy and R.P. Reaves (eds.). Proceedings of a Workshop on Constructed Wetlands for Animal Waste Management, 4-6 April, 1994, Lafayette, IN.

**Reddy, G.B., P.G. Hunt, R. Phillips, K.Stone, and A. Grubbs. (2001).** Treatment of swine wastewater in marsh-pond-marsh constructed wetlands. *Water Science and Technology.* 44:545-550.

**Reddy, K.R., R.H. Kadlec, E. Flaig, and P.M. Gale. (1999).** Phosphorus retention in streams and wetlands: a review. *Critical Reviews in Environmental Science and Technology.* 29:83-146.

**Richardson, C.J., Qian, A., C.B. Craft, and R.G. Qualls. (1997).** Predictive models for phosphorus retention in wetlands. *Wetlands Ecology and Management.* 4:159-175.

**Ryan, M. (1990).** Properties of different grades of soiled water and strategies of safe disposal. pp. 43-58. Proceedings of Environmental Impact of Landspreading of Wastes. Wexford, Ireland. 30-31 May, 1990, Teagasc, Dublin.

**Schaafsma, J.A., A.H. Baldwin, and C.A. Streb. (2000).** An evaluation of a constructed wetland to treat wastewater from a dairy farm in Maryland, USA. *Ecological Engineering.* 14:199-206.

**Shutes, R.B.E. (2001).** Artificial wetlands and water quality improvement. *Environment International.* 26:441-447.

**Sievers, D.M. (1997).** Performance of four constructed wetlands treating anaerobic swine lagoon effluents. Transactions of the ASAE (American Society of Agricultural Engineers). 40:769-775.

**Skarda, S.A., J.A. Moore, S.F. Niswander, and M.J. Gamroth. (1994).** Preliminary results of wetland for treatment of dairy farm wastewater. pp. 34-42. *In* P.J. DuBowy and R.P. Reaves (eds.). Proceedings of a Workshop on Constructed Wetlands for Animal Waste Management, 4-6 April, 1994, Lafayette, IN.

**Smith, C.S., M.S. Adams, and T.D. Gustafson. (1988).** The importance of belowground mineral element storage in cattail (*Typha latifolia* L.). *Aquatic Botany.* 30:343-352.

**Sun, G., K.R. Gray, and A.J. Biddlesone. (1998).** Treatment of agricultural wastewater in downflow reedbeds: experimental trials and mathematical model. *Journal of Agricultural Engineering Research.* 69:63-71.

**Szögi, A.A. and P.G. Hunt. (2001).** Distribution of ammonium-N in the soil water interface of a surface-flow constructed wetlands for swine wastewater treatment. *Water Science and Technology.* 44:157-162.

**Tanner, C.C., J. D'Eugenio, G. B. McBride, J. P.S. Sukias, and K. Thompson. (1999).** Effect of water level fluctuation on nitrogen removal from constructed wetland mesocosms. *Ecological Engineering.* 12:67-92.

**Tunney, H., A. Beeuwsma, and P. Withers. (1997).** Fertilizer strategies: present and future. pp.177-204. *In* Tunney, H., Carton, O.T., Brookes, P.C., and Johnston, A.E. (eds.). Phosphorus loss from soil to water. CAB (Centre of agriculture and biosciences) International. Oxon.

**Tunney, H., T. O'Donnell, and A. Fanning. (1997).** Phosphorus loss to water from a small low-intensity grassland catchment. pp.358-361. *In* Tunney, H., Carton, O.T., Brookes, P.C., and Johnston, A.E. (eds.). Phosphorus loss from soil to water. CAB (Centre of agriculture and biosciences) International. Oxon.

**Tunney, H., T. O'Donnell, and A. Fanning. (1997a).** Phosphorus loss to water from a small low-intensity grassland catchment. pp.358-361. *In* Tunney, H., Carton, O.T., Brookes, P.C., and Johnston, A.E. (eds.). Phosphorus loss from soil to water. CAB (Centre of agriculture and biosciences) International. Oxon.

**USDA NRCS. (2002).** Constructed wetlands. *In* Environmental engineering national engineering handbook. United States Department of Agriculture and Natural Resources Conservation Service. Washington D.C.

**Walbridge M.R. and J.P. Struthers. (1993).** Phosphorus retention in non-tidal palustrine forested wetlands of the mid-Atlantic region. *Wetlands*. 13: 84–94.

**Werner, T.M., and R.H. Kadlec. (2000).** Wetland residence time distribution modeling. *Ecological Engineering*. 15:77-90.

**Withers, P.J.A., I. A. Davidson, and R. H. Foy. (2000).** Prospects for controlling nonpoint phosphorus loss to water: A UK Perspective. *Journal of Environmental Quality*. 29:167-176.

Appendix II

Purdue University
Forestry and Natural Resources

FNR-202-W

PURDUE UNIVERSITY

# Are Constructed Wetlands a Viable Option for Your Waste Management System?

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*Department of Forestry and Natural Resources, Purdue University*



## Introduction

Efficient and practical manure management systems are an important component of livestock operations; and typical options such as lagoons, storage pits, and recirculation or irrigation systems have been used alone or in combination to treat animal manure. But a new option that is growing in popularity is the use of constructed wetlands to assist in the treatment of animal wastewater. This publication will assist you in evaluating whether constructed wetlands can be a viable, economically feasible option as one piece of your total manure management system.

When the Federal Water Pollution Control Act Amendments were passed in 1972, most of the regulatory attention focused on pollution from industries and municipalities. Regulations and management for the past 25 years have considerably reduced pollution resulting from point sources, or a definable point (such as a pipe) at which pollutants enter a body of water. The Environmental Protection Agency (EPA) has delegated regulatory authority to the Indiana Department of Environmental Management (IDEM). Under this authority, IDEM has developed management guidelines and a permit system that applies to all producers who manage at least 300 cattle, 600 sheep, 600 swine or 30,000 poultry in confined animal feeding operations, or CAFOs (IC 13-11-2). Operations at or in excess of these numbers must comply with the Indiana Confined Feeding Law. In Indiana, producers may not discharge animal wastewater into any surface waters. All CAFOs must have a management plan approved by IDEM that allows for a minimum 180 days storage of all animal manure and runoff, a plan to apply the stored material by land application, and documentation that sufficient acreage exists for land application of waste.

In many cases, producers are seeking management options to reduce the number of acres needed for land application or reduce salt (struvite) buildup in recirculating systems. Many also desire a reduction in maintenance and handling costs of animal waste. Constructed wetlands may help solve these issues for producers.

## Advantages of Constructed Wetland Systems

Substantial improvements in farm wastewater quality have been made by reducing nutrient loads in wastewater. Natural biological, chemical, and physical processes act to eliminate or transform much of the nutrient and waste load in water moving through wetlands. Landowners also may derive the additional benefits of wildlife use and aesthetic appeal.

Constructed wetland treatment of wastewater occurs for the following reasons.

1) Water moves slowly through the wetland, allowing extended contact time with microorganisms. The velocity of the water is reduced and particulate matter settles out.

2) Suitable environments for both aerobic and anaerobic microorganisms are present in the wetland and carry out the biological processes necessary to remove or transform pollutants such as nitrates, phosphates, ammonia, manganese, sulfur, and carbon carried by the water.

Microbes (microscopic organisms) provide most of the treatment. Plants in the wetland remove nutrients and improve aesthetics, but their primary function is to provide a surface area for the growth of microbial films. More plant stems in the water column translate into more microbes cleaning the water. System design and operation should be aimed at enhancing features that improve these characteristics of the wetland system.

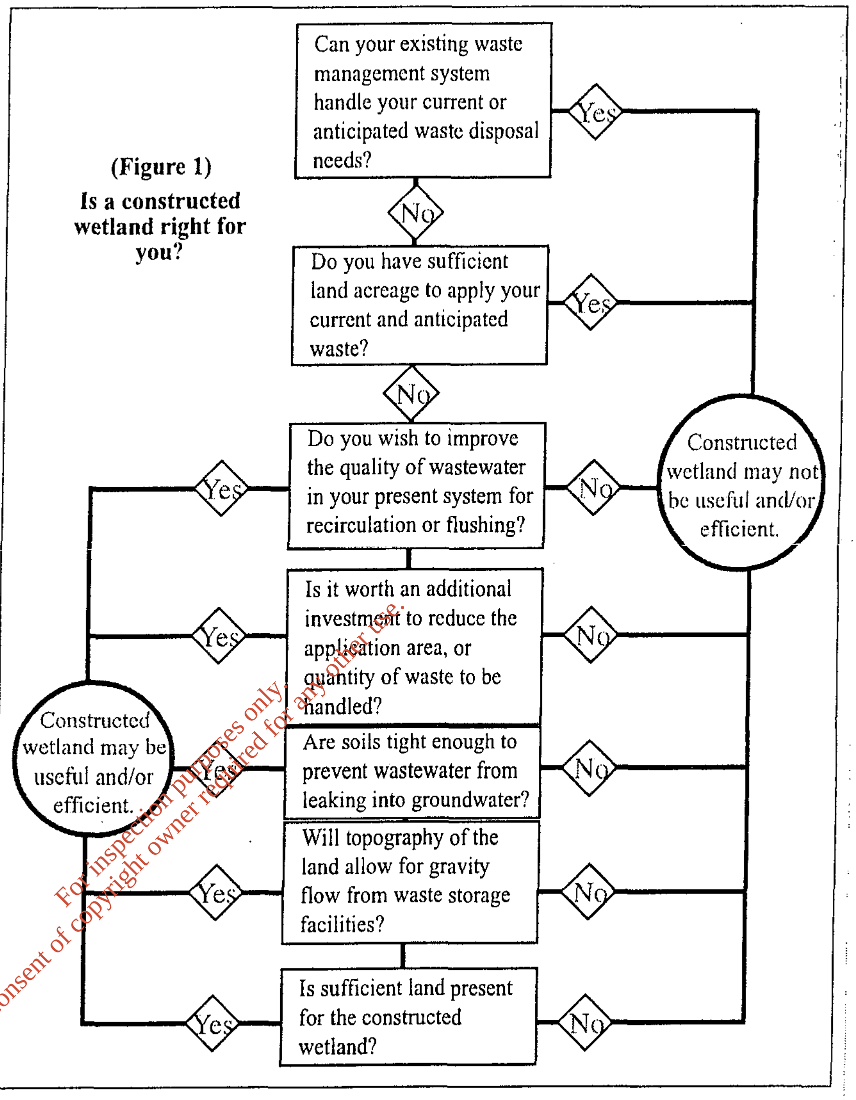
Spring to late fall operation is possible, and wetland systems provide improvements in water quality during these times. Significant reductions in effluent concentrations of ammonia, nitrogen, fecal coliform, phosphorus, and biochemical oxygen demand can be achieved with constructed wetlands during the growing season in Indiana as wastewater passes through them.

## Limitations of Constructed Wetland Systems

Year round operation of low-flow constructed wetlands in the climate found in the upper-Midwest is impossible. As the weather cools, treatment levels decrease. However, reductions have been recorded as late as December in north-central Indiana. Wetland cells freeze during much of the winter, rendering microbial treatment of wastewater impossible. During the first half of spring, temperatures are low enough to retard treatment, and then vegetation will not become established until May in the northern parts of the state. For constructed wetland systems to be functional, livestock producers must have a method of storing wastewater during winter (180 days). A lagoon system or holding pond combined with the constructed wetland can provide the necessary storage.

Regulations specify that constructed wetland systems must be designated as no-discharge systems so wetland treated water cannot be discharged into either surface waters or groundwater. Therefore, the waste management plan must include provisions for reusing wetland effluent or eliminating it through non-discharge means. Effluent may be land applied where appropriate, or it may be recirculated as flush water in recirculating systems. Another option may be disposal through an infiltration strip. Producers should determine if these infiltration strips will be approved by IDEM prior to investing in wetland systems. Discharge into surface waters may be possible, but would require a NPDES (National Pollution Discharge Elimination System) permit from IDEM and regular water quality monitoring to maintain the permit. As research continues and these systems become perfected, accepted discharge from these systems may be feasible in the near future.

**(Figure 1)**
**Is a constructed wetland right for you?**

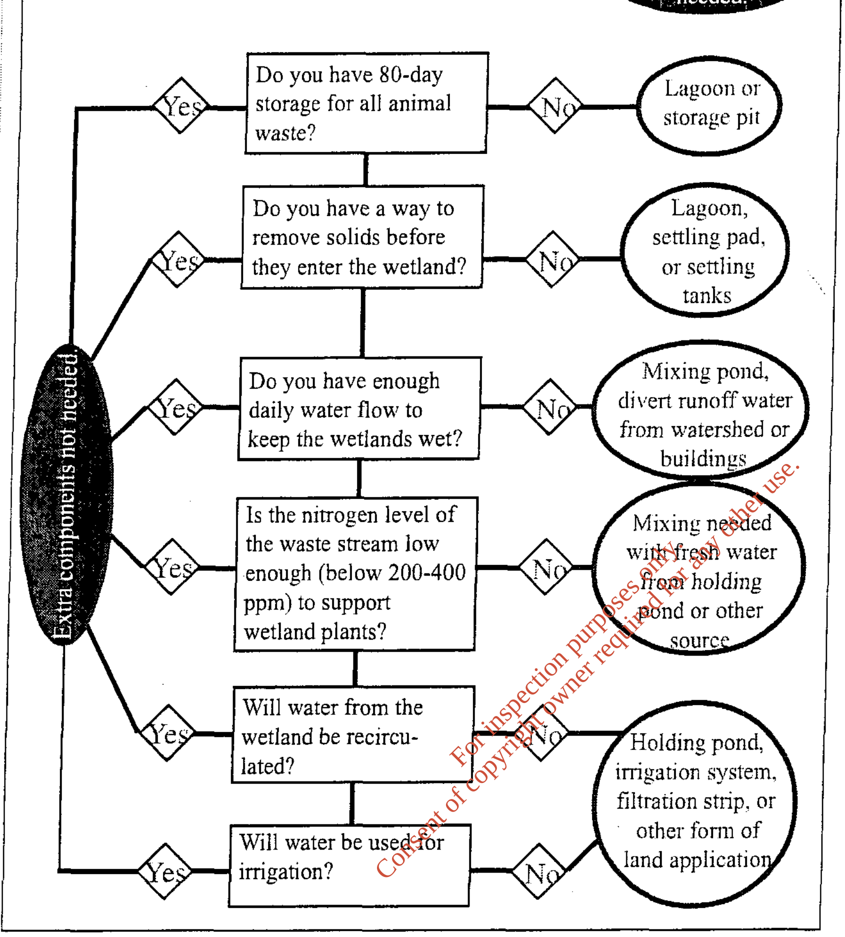





## Design Considerations for Constructed Wetland Systems

Design of constructed wetland systems is important and should be tailored to best fit each individual operation. The first question to be addressed is whether a constructed wetland will be suitable (Figure 1). Constructed wetlands require sufficient acreage and suitable soils. Most constructed wetlands are 0.5 to 2.0 acres. If the soil is incapable of retaining water for an extended period of time, it is unlikely that a wetland can be developed without expensive artificial liners to retain the water and prevent groundwater contamination. This may make the cost prohibitively expensive. Research at Purdue University has found that infiltration into groundwater does not occur in wetland systems placed in unlined compacted soils with very low hydraulic conductivity. Mesic or hydric soils should be suitable for construction. The natural topography of the farm landscape should be incorporated into wetland design to reduce earthmoving expenses and to facilitate water flow.

There is no one correct way to design a constructed wetland system to fit every situation (Figure 2). General design guidelines are based on levels of contaminants in the




(Figure 2)
**Animal waste management components needed to allow the constructed wetland to function properly.**



wastewater and the amount of wastewater flowing through the system. There are certain aspects of design that are regulated.

Design requirements by both USDA Natural Resources Conservation Service and U.S. Environmental Protection Agency mandate that agricultural constructed wetland systems be able to handle a 25-year, 24-hour rainfall event. However, there is flexibility in how a specific system will comply with this requirement. Individual components of the constructed wetland system can be sized to accommodate this level of water flow. A system of storage structures, either lagoons or holding ponds, can be built to accommodate excess wastewater. The latter approach is preferable. System size is important in determining how well the wetland functions. A wetland should be sized to accommodate the normal expected flow, including rainfall, but should be conservative in treating contamination levels in the wastewater. For example, BOD (Biochemical Oxygen Demand) should be below 50 pounds per day per acre and nitrogen levels should be below 400 ppm (parts per million) for incoming wastewater, and preferably below 200 ppm. Samples of typical wastewater that will be treated by the constructed wetland should be analyzed to determine the expected levels of ammonia, nitrates, phosphates, and BOD. This will provide a more accurate basis for sizing the treatment system rather than relying on typical published values. Wetland cells should be sized to allow for 7 to 14 days retention time, meaning it will take 7 to 14 days for water to move from the inlet to outlet of the system. The quality of water exiting the system is dependent on the quality of water coming in and the length of time the water is retained.

If wetland cells are sized to retain open lot runoff from an extreme storm event, there will be insufficient water during the dry parts of the year to maintain plants and microbial populations of the wetland. If the wetland system dries, microbes will be lost. When water is returned to the system, treatment will be greatly reduced because of the lack of microbes. A significant amount of time will pass before these organisms are reestablished. This problem can be overcome by placing a structure with water storage capacity upstream of the wetland system, an arrangement that allows gravity to do the work of moving additional water through the system as needed. If the holding pond is at the downstream end of the system, additional piping and pumps may be needed to transport water from the pond to the head of the wetland system during dry periods. Upstream storage capacity also allows for wastewater to be captured during wet times of the year, typically winter and spring in Indiana, when a wetland system will not provide a high level of treatment. Wastewater can be held and released during warmer and drier parts of the year when wetland treatment will be at its peak. Captured precipitation can also be used as dilution water, reducing the possibility of overloading the system with a sudden pulse of wastewater with a high concentration of contaminants. Upfront storage capacity of both contaminated and fresh water allows greater control of water levels in the constructed wetland system throughout the year.

## Multiple Cell Operating Systems

Wetland systems using multiple cells operating in series provide the best level of treatment (Figure 3). These systems develop a gradient of water quality from the point of entry into the first cell in the series to the end of the wetland complex. Multiple cells allow for one cell to be removed for maintenance while the system continues to operate. In addition, cells can alternately be drained for a 1-week period to break the mosquito cycle if needed. Periodic short dry cycles mimic natural processes and increase oxidation of minerals and nutrients and reduce buildup of plant litter. With multiple cells, alternating unvegetated and vegetated cells is possible. This arrangement provides additional treatment benefits by allowing oxygen to reenter the system as oxygen more readily diffuses from the atmosphere into water across an unvegetated surface. Increased levels of sunlight reaching the water surface on unvegetated cells may lead to increased levels of algal production and greater precipitation of ammonia and phosphate compounds.

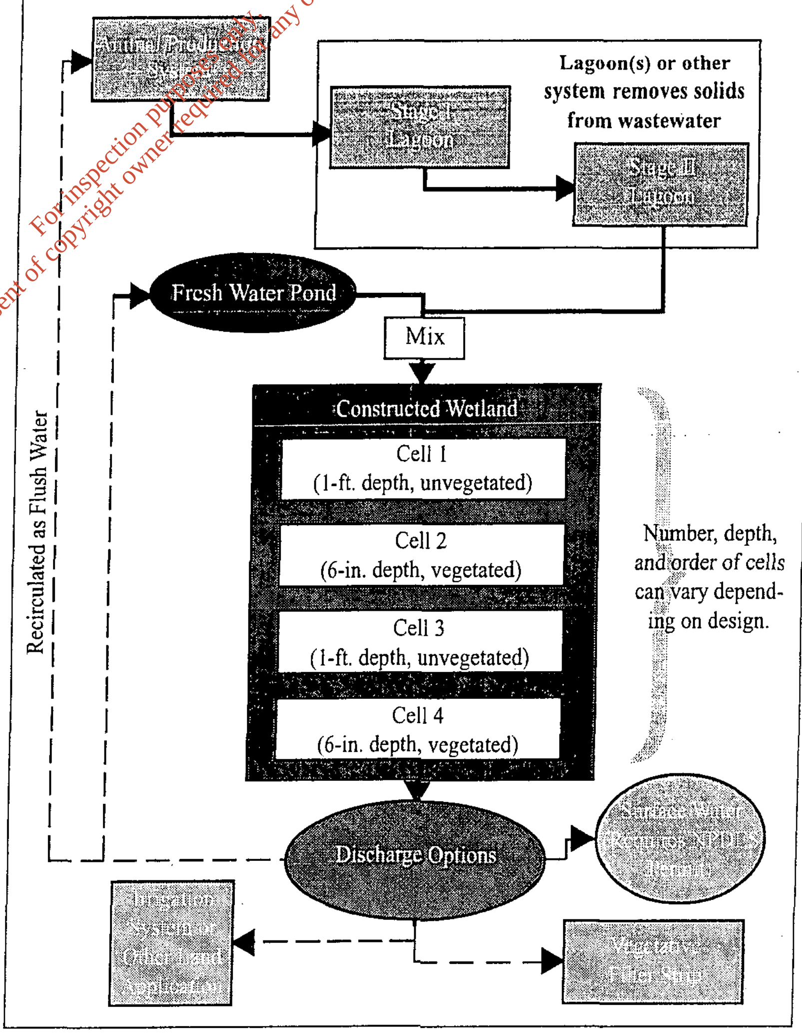
Unvegetated cells should be interspersed with vegetated cells. Shallow vegetated cells should have an effective water depth of approximately 6 inches (15 cm). Unvegetated cells should have a depth of 1 foot (30 cm) with steep sides to discourage the invasion of plants. Begin a series with an unvegetated cell to help alleviate high ammonia-nitrogen levels and act as a buffer to sudden changes in the quality of wastewater entering the system. It will act as an aerobic detention pond and provide an initial trap to further remove solids should the solids removal system prior to the wetland fail. Long-term system maintenance is facilitated by having an unvegetated zone first because it can be maintained without disturbing vegetation.

Wetland functional life expectancy can be incorporated into the design. Even with efficient solids removal systems, there will be an accumulation of solids and dead plant material in wetland cells. It would not be unreasonable to have buildup of ≥ 1 inch (2.5 cm) per year. Wetland cell berm height should allow for this. A berm height of three to four feet (90 to 120 cm) should result in a 20- to 30-year functional life. After this, the system may be rejuvenated by dredging and revegetating cells.

It is imperative that constructed wetland systems be combined with efficient solids removal systems, because constructed wetlands will not degrade large quantities of solids. If solids are not removed, the system will become overloaded and water treatment efficiency will be greatly impaired. This accumulation of solids also shortens the functional life of the wetland. By keeping solids out, water treatment is enhanced and functional system life can be extended. Solids must be removed before wastewater reaches the wetland. Lagoon systems eliminate solids. However, farms without lagoon systems can still utilize constructed wetlands as a part of a fully integrated waste management plan. Properly maintained manure pits or settling basins can effectively reduce solids from open lot runoff to a level that can be handled by the wetland.

Vegetation for constructed wetland cells can be obtained from a variety of sources. If commercial stock is desirable, nursery transplants should be used. Establishment of

**(Figure 3)**
**Diagram of basic waste management system components.**



wetland vegetation from seed is unpredictable and management intensive. Spoil from maintenance of wet roadside ditches can be used as a source for wetland plants since it contains good soil, plant stocks, and an assemblage of natural wetland microbes. You may be able to obtain ditch spoil from county highway departments during periods of the year when routine roadside maintenance is underway.

## Operation and Management of Constructed Wetland Systems

Part of the appeal of these systems is that operation is neither costly nor labor intensive. However, this is not to say that constructed wetland systems will run themselves with no input from the operator. Farm management has a great impact on the performance of constructed wetland systems. Do not allow livestock access to constructed wetlands. Livestock can create problems when allowed access to a wetland system; overgrazing can eliminate vegetation and trampling can damage vegetation. Trampling may result in damage to the wetland berms, which could lead to water leaking from the system. Livestock deposit manure directly into the wetland, and increase solid levels. Check berms often to make sure burrowing animals don't cause a leak in the wetland.

Water level management will be necessary throughout the year. This can be accomplished by installing conventional water control structures at the inlet and outlet of each cell. In Indiana, an early-winter drawdown will provide additional storage volume for winter and spring rains. This can be followed with a mid-spring drawdown to facilitate plant establishment. Plant establishment, both at system start-up and each spring, will necessitate careful water level management by the operator. Always keep the level of the water in wetland cells below the height of the plants. Plants that are overtopped for any extended period during early growth will die. Young plants are more susceptible to stress from high concentrations of contaminants like ammonia and phosphate. A readily accessible source of dilution water during these periods increases plant vigor and decreases the time necessary to reach full system operation. Loading with full-strength effluent should not start until plants are 2.5 ft tall (75 cm). Plants that volunteer in wetland cells should not be discouraged unless they pose a weed risk to the remainder of the farm. Plants provide a surface area for microbial growth and enhance the treatment ability of the wetland. It may be necessary to periodically replant vegetation. Plants could be lost due to either a severe winter or a sudden contaminant shock during the growing season.



## Frequently Asked Questions

*How big do constructed wetlands have to be?*

The minimum size of a constructed wetland is dependent on the following:

1. The volume of water and animal waste entering the system.
2. The level of key pollutants (ammonia, BOD, and phosphorus) in the waste stream entering the wetland.
3. The amount of treatment (pollution reduction) required. Generally for most farm operations in Indiana, the system would require 0.5 to 2 acres.

*How much do constructed wetlands cost?*

The cost is highly variable and depends on the following:

1. Size of wetland needs.
2. Potential requirement of a liner. Plastic liners or sealing wetland with bentonite clay can add $10,000 to $20,000 to the cost of construction.
3. Topography of site. How much excavation and grade modification is required? The greatest cost of a constructed wetland is the excavation, piping, and water control structures. Generally, a constructed wetland system that does not require a liner would cost $10,000 to $20,000 per acre if built by a contractor.

*Will constructed wetlands solve all of my waste management problems?*

A constructed wetland should be viewed as one component of a total waste management system. Under present regulations, water cannot be discharged from wetlands into surface water without a NPDES permit. Therefore, the ultimate fate of wastewater will be the same with or without a constructed wetland. The advantages a wetland can offer are:

1. Reduce the amount of acreage required for land application.
2. Provide additional treatment to water that will be recirculated and used as flush water.
3. Reduce salt buildup in recirculating systems.

If this technology develops to the point that discharge regulations change, constructed wetlands would have an additional advantage of allowing for discharge after sufficient treatment was achieved.

*How much paperwork is involved?*

The proper local, state, and federal permits must be obtained prior to construction. If there are at least 300 cattle, 600 swine or sheep, or 30,000 poultry, an approval must also be obtained from IDEM; and, the condition of the soil, hydrology, and vegetation must be documented prior to construction. The design of the wetland must be shown to be in compliance with the permit requirements. The NRCS can help with getting the permits, documentation, and engineering of the wetland.

*Are constructed wetlands considered as jurisdictional (regulated) wetlands?*

No. As long as constructed wetlands are maintained as waste treatment systems, they are regarded as created wetlands and are not treated as natural wetlands subject to state and federal regulations. This also means they cannot be used as mitigation credits for natural wetlands destroyed elsewhere.

## Where to Go for Help

If you think constructed wetlands may be an appropriate part of your total waste management system, contact your local USDA Natural Resources Conservation Service office for assistance. They have expertise in evaluating your operational needs and in animal waste management system design.

## Other Sources of Information

In April 1994, Purdue University hosted the first national meeting dealing exclusively with the use of constructed wetlands for the treatment of animal wastes. A publication (Constructed Wetlands for Animal Waste Management: Proceedings of Workshop, edited by P.J. DuBowy and R.P. Reaves) resulted from that meeting. This publication details agency positions and experimental work, and also includes examples of systems in operation. It can be purchased for $10.00 from Purdue University Agricultural Media Distribution Center, 231 South University Street, West Lafayette, IN 47907-2064, 1-888-EXT-INFO.

USDA-NRCS has published design guidelines for agricultural constructed wetland systems. This, and other technical references are available at www.in.nrcs.usda.gov/PlanningandTechnology/fotg/Section4/section4.htm, or by calling the Indiana NRCS state office at (317) 290-3200.

U.S. EPA developed a five-volume handbook on constructed wetlands. This work contains a volume dealing with general aspects of constructed wetlands and another volume dealing with agricultural applications. More information can found by writing to:

National Service Center for Environmental Publications
P.O. Box 42419
Cincinnati, OH 45242-2419

You may also call 1-800-490-9198, or visit www.epa.gov.

The Indiana Department of Environmental Management (IDEM) has a Web site on guidelines and regulations for confined feeding operations.
Visit www.in.gov/idem/land/cfo/ or www.in.gov/idem/guides/permit/waste/confinedfeeding.html for more information, or call (317) 232-8732.

## Other Related Purdue Publications

These publications can be ordered from:

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West Lafayette, IN 47907-2064
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| | | |
|---|---|---|
| ID-101 | $1.00 | *Animal Manure as a Plant Nutrient Resource* |
| ID-205 | $2.00 | *Swine Manure Management Planning* |
| ID-206 | $2.00 | *Poultry Manure Management Planning* |
| AY-278 | $.50 | *Estimating Manure Spreader Capacity* |
| WQ-7 | | *Animal Agriculture's Effect on Water Quality--Pastures and Feedlots* |
| WQ-8 | | *Animal Agriculture's Effect on Water Quality--Waste Storage* |

## Acknowledgements

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## Glossary

The following is a list of common terms encountered in dealing with water resources. Not all terms are used in this paper, but they may be encountered with other water quality issues. The list is intended as an educational guide and is not presented as a list of legal definitions. Many published texts contain material for legal definitions and also provide more detailed technical information.

**Aerobic:** An environment where oxygen is available or pertaining to organisms adapted to such environments.

**Anaerobic:** An environment where oxygen is not available or pertaining to organisms adapted to such environments.

**Aquifer:** A geologic formation capable of storing, receiving, and transmitting water. It is capable of supporting a well or spring.

**Confined Aquifer (artesian aquifer):** An aquifer separated from the atmosphere by an impermeable geologic layer.

**Unconfined Aquifer:** An aquifer exposed to the atmosphere and in equilibrium with atmospheric pressure.

**Baseflow:** The water in a stream resulting from groundwater flow.

**Berm:** Earthen structures placed around constructed wetland cells to create the wetland basin.

**Biochemical Oxygen Demand (BOD):** A measure of the level of organic contamination in water. It measures the amount of oxygen needed to decompose the material in the water. High BOD levels can lead to oxygen depletion and fish kills in surface waters.

**Catchment:** A surface from which runoff is collected (examples: roofs, pavement).

**Channel:** The bed of a natural or human-made waterway that transports a concentrated flow of water.

**Concentrated Flow:** Runoff that moves through well-defined channels.

**Contaminated Water:** Water that contains disease-causing agents or toxic substances.

**Diversion:** A channel placed across the land slope to intercept runoff and conduct it to an outlet.

**Drainage:** The removal of water from either the land surface or the soil profile.

**Surface Drainage:** The diversion or removal of water from the land surface through natural or constructed channels. It may be supplemented by grading land surfaces leading to these channels.

**Subsurface Drainage:** The removal of water from the soil profile through drain tiles, perforated pipes, or other devices.

**Drainage Area (drainage basin):** The land area drained by a ditch, stream, river, or subsurface system.

**Effluent:** Water flowing out of a system.

**Grass Waterway:** A natural or constructed watercourse planted with suitable vegetation for the purpose of dispersing runoff without causing erosion.

**Groundwater:** Subsurface water that fills the spaces in the saturated zone of geologic formations.

**Hydraulic Conductivity:** The rate at which water moves through a soil or rock layer. Hydraulic conductivity in the horizontal direction will not necessarily equal hydraulic conductivity in the vertical direction.

**Hydric Soils:** Soils which have low hydraulic conductivity and tend to be waterlogged for a portion of the year if not drained.

**Hydrophytic (hydrophilic) Vegetation:** Vegetation that grows well in the presence of saturated soil conditions or standing water. Plants in the USF&WS wetland plant classification that receive a ranking of obligate, facultative plus, or facultative may be considered hydrophytic.

**Infiltration:** The downward movement of water into the soil or subsurface.

**Infiltration Strip:** A confined vegetated area used for water disposal.

**Influent:** Water flowing into a system.

**NPDES:** National Pollutant Discharge Elimination System, federal program limiting pollutant discharges by point source polluters.

**Polluted Water:** Water containing natural or human-made impurities that exceed the acceptable standards for a particular use.

**Point Source Pollution:** Polluted water that is discharged through pipes or other human-made structures. Polluted water enters a body of water through a well-defined point of entry.

**Non-point Source Pollution:** Polluted water that enters waterways without moving through a pipe or other human-made structure. There is no well-defined point of entry.

**Runoff:** That portion of precipitation or irrigation water that flows across the surface and enters receiving waters.

**Spoil:** Waste soil containing plant stocks generated through the maintenance of roadside ditches.

**Volunteer Plants:** Plants that begin growing in a system without having been put there by humans.

**Wastewater:** Water that has been used non-consumptively for some purpose (wash water, sewage water, etc.).

**Watershed:** An area of land that drains into a single water outlet.

**Waterway:** Any natural or constructed channel through which water flows.

**Wetland:** An area with hydric soils where the ground is saturated at or near the surface during a portion of the growing season and which supports hydrophytic vegetation.

**Created Wetland:** A wetland built by humans.

**Constructed Wetland:** A wetland built by humans to perform a specific waste treatment function.

**Restored Wetland:** A wetland reestablished in an area that was previously converted from a wetland for some human use.

**Wetland Cell:** A single contained basin in a constructed wetland system. A system may have one or many cells. Multiple cells in a system may operate independently or in series.



Knowledge to Go
Purdue Extension

NEW 03/03

Appendix III

An Bord Pleanála Ref.: PL17.215281

# An Bord Pleanála

# Inspector's Report

| | |
|---|---|
| **Development:** | Integrated constructed wetland system to treat dirty yard and run off waters from farm complex at Rathfeigh, Tara, Co. Meath |



**Planning Application**

| | |
|---|---|
| Planning Authority: | Meath County Council |
| Planning Authority Reg. Ref.: | NA/50189 |
| Applicant: | Michael Fox |
| Type of Application: | Permission |
| Planning Authority Decision: | Grant permission conditionally |

**Planning Appeal**

| | |
|---|---|
| Appellants: | 1) Eastern Regional Fisheries Board<br>2) Anne Gallacher<br>3) Leo Curran<br>4) Basil Curran |
| Type of Appeal: | Third parties v Grant of permission |
| Observers: | None |
| Date of Site Inspection: | 22 May 2006 |
| **Inspector:** | **Roger Dean** |

## SITE LOCATION AND DESCRIPTION

The appeal site is located in the eastern central part of Meath County, about 1.5 km to the west of the N2 highway and about 10 km to the north-west of Ashbourne. It is part of an agricultural holding which has its cattle units and yard located in its south-eastern corner accessed directly from the CR398.

The site has a stated area of 1.4625 hectare and comprises part of an open and gently sloping pasture field approximately 0.5 km to the north-west of the farm yard. The intervening land is also gently sloping. Immediately beyond a post and wire fence to the west of the site, however, the land falls steeply where it forms the valley of the River Hurley, a tributary of the River Nanny. Other boundaries of the site are unmarked.

There are no residential properties in close proximity to the site, the nearest being the applicant's house about 350 metres to the north-east and another about 380 metres to the east of the site.

## THE PROPOSED DEVELOPMENT

The proposed wetland will comprise five ponds of varying size with a total area of 11,700 square metres. Effluent will be discharged into one of the ponds from the farmyard by gravity via a 150 mm pipe. This would then flow successively through each of the ponds, the last being specifically for monitoring purposes. Discharge to the River Hurley stream watercourse would be via a sampling chamber.



A report accompanying the application explains that the basic requirement of an Integrated Constructed Wetland (ICW) is that it should intercept and retain polluted water in a bunded planted area, retaining it long enough to be cleansed and discharged in a way that does not negatively impact on the receiving ground or surface water. It states also that the relatively large land area used in ICWs compared with that of other treated wetlands facilitates a greater range of the physical, chemical and biological processes that occur in the wetland environment, including that required for the removal of the more difficult contaminants of phosphorus and nitrates.

The report explains also that trial holes at the site had revealed that the water table was further than 2 metres below ground level and that the clay subsoils would be suitable for the construction and sealing of the proposed wetland. Effluent water would be retained in the ponds at an average depth of 30 cm and the ponds would be contained and separated by banks 2 metres wide and one metre higher than water level. The ICW is stated to be designed to treat an average volume of 13.5 cubic metres of effluent a day, with the volume of the ponds facilitating a nominal residence time of 265 days. The life expectancy of the ponds is considered to be 50 years.

## THE DECISION OF PLANNING AUTHORITY

By Order dated 14 November 2005, Meath County Council granted permission subject to four conditions. These relate to compliance with submitted plans and particulars, no direct discharge of effluent to surface waters, removal of construction waste off-site to a licenced site and the avoidance of nuisances in the construction and operation of the proposed development.

## REPORTS

### *Environment Section*

The Senior Engineer of the County Council's Environment Section noted that the area of the proposed ICW had been calculated using Duchas/National Parks and Wildlife Service Guidelines, had been calculated to ensure sufficient residence time in the wetland and had been designed to provide a generous margin of flexibility. The report observed that wetlands have an ability to clean dirty water through physical, chemical and biological processes but that it was important to establish that the receiving waters in this case have sufficient waste assimilative capacity (WAC) to accept discharges of treated effluent. Further information was requested on this basis.



### *Health Service Executive*

A letter from the Environmental Health office notes that the proposed ICW requires a Discharge Licence from the County Council and that environmental controls will be dealt with by way of conditions on the licence.

## FURTHER INFORMATION

A hydrological report addressing the requested further information was sent by the applicant's agent with a covering letter dated 11 November 2005. It assesses the river catchment area upstream of the proposed point of discharge to be approximately 44.15 square kilometres. An estimate was then made of the mean flow and the 95-percentile flow of this watercourse at the point of discharge using a particular software package. This is one used to define the hydrological potential for ungauged watercourse sites in Europe but modified for Irish conditions.

The long-term annual rainfall and potential evaporation for the catchment area was then estimated and predictions of mean flow, 95-percentile flow and dry weather flow in the watercourse were made by computer modelling.

The waste assimilative capacities of the receiving watercourse in terms of Biochemical oxygen demand ($BOD_5$), phosphorus (P) and ammonia (N) were then predicted with formulae that in each instance identifies the maximum permissible level of each constituent, existing background levels, predicted discharges from the proposed ICW and levels of flow in the watercourse.

The predictions were that there would be adequate $BOD_5$ assimilative capacity in the River Hurley, even in dry weather flow conditions. The report states that for the purposes of phosphorus and ammonia assimilative capacity, mean flow estimates in the watercourse are utilised. Under such conditions it is predicted that there would be no measurable increase in ortho-phosphate or ammonia levels in the watercourse due to the discharge from the proposed ICW.

The Senior Engineer of the Environment Section then issued a further report on the basis of the further information provided. He considered that, based on EPA monitoring and estimates of another river in the area, the submitted 95-percentile flow estimates in this case were inaccurate and should be of the order of half that predicted. However, another error in the calculation was identified which cancelled out the inaccuracy to the 95-percentile flow estimate. The Engineer then made a detailed analysis of the waste assimilative capacities predicted in the applicant's agent's report and made some refinements to the prediction methodology. He concluded that the discharge of treated effluent at the standard proposed would have no appreciable impact on the water quality in the river in terms of $BOD_5$. With regard to phosphorus, he considered that the concentration of this element in the receiving waters would not increase above background levels such is the available dilution.



No further analysis was made with regard to the dilution of nitrates. However, the overall conclusion of the Senior Engineer was that the flows in the receiving waters are sufficient to ensure that there would be no significant impact on water quality from the discharge of treated effluent at the discharge standards proposed.

## HISTORY

The Planner's report records the following site history:

**88/247** Permission granted for a slated shed, silage pit and wall.

**89/270** Permission granted for a 2 storey house, garage and septic tank.

**90/918** Decision to permit the erection of effluent treatment tanks and the erection of a lean-to for general agricultural purposes. Permission then refused by An Bord Pleanala.

**91/1263** Permission refused for the retention of soil water tank.

**93/510** Permission granted for slatted slurry tank and lean-to. Decision upheld by An Bord Pleanala on appeal.

**96/549** Permission granted to retain existing entrances to retain roof to slatted shed, to enlarge and reconstruct soiled water tank, to retain new feeds and machinery sheds and to provide concrete yard.

**97/585** Permission granted to retain tank for the storage of molasses.

**GROUNDS OF APPEAL**

*The appeal submitted by the Eastern Regional Fisheries Board*

This is set out in a letter dated 1 December 2005 from Noel McGloin, Senior Fisheries Environmental Officer and may be summarised as follows:

*The use of ICWs in treating waste waters*

- The proposed final effluent quality is based on performance from similar systems in Ireland but these have been relatively recently introduced and there is concern about attributed performance. There are a number of references regarding ICWs which cast doubt upon this form of waste water treatment.

- These references include the EPA publication *Waste Water Treatment Manual of Treatment Systems for Small Communities, Business, Leisure Centres and Hotels (1999)* which states that *constructed wetlands remain unproven for other than BOD & suspended solids removal and that there is some removal of total N and total Ps but this is low.* Hence the appellant is concerned that the proposed system is unproven for the removal of phosphorus and nitrogen.

- Another reference is the EPA publication *River Water Quality in South East Ireland (2003)* which states:

  *In recent times constructed wetlands (also called Reed Beds or Artificial Wetlands) are being promoted in the region as a low cost system for the disposal of soiled water from farmyards. This departure (where farm waste is discharged to surface water via an artificial pond that contains various plants) is of serious concern for a number of reasons as follows:*

  1. *Previously, the disposal of farm waste to surface waters was generally prohibited.*
  2. *Constructed wetlands, unless well managed, have the potential to cause serious water pollution.*
  3. *Section 4 of the Water Pollution Act, 1977, prohibits the discharge of trade effluents to any waters without a licence from*

*the Local Authority – most constructed wetlands on farms do not have such a licence.*

4. *Farm waters should be recycled by proper land spreading – not disposed of to surface waters*
5. *Constructed wetlands are being installed on farms without planning permission.*
6. *There is no monitoring or regulation of constructed wetlands on farms – in some cases constructed wetlands will be used for the disposal of slurry.*

- A further reference is a paper entitled: *A farm-scale Integrated Constructed Wetland to treat farmyard dirty water*, published by Teagasc in 2005. This was carried out by the competent national authority for agricultural research over a period of two and a half years. The findings cast doubt upon the anticipated removal rates of phosphorus that have been projected by the applicant, particularly so in respect of the winter months, when most run-off occurs, and with regard to particulate form.

- National Parks and Wildlife Service Guidelines have been quoted by the applicant but the appellant understands that no such official document exists. The appellant has been reliably informed that there is an interagency group formulating a protocol with regard to ICWs but this has not been completed.

- The water course to which the effluent is proposed to be discharged is the main channel of the Hurley River which is a significant salmonid watercourse and is already subject to a high pollution risk. From the foregoing, the projected low figures submitted in the planning application are disputed and it is considered that there would be a deleterious effect on the receiving waters of the River Hurley.

- The Fisheries Board is concerned about the high polluting effects of raw farmyard effluent at this farm and it is suggested that the applicant should employ more stringent anti-pollution controls. By proper nutrient management practice and land-spreading of effluent, there is no need for an ICW on this site. Roof water does not need to be treated and can be directed to local watercourses.

- The Fisheries Board is also concerned about the proximity of the stored deleterious matter to the River Hurley (70 metres) and the steep slope down to the river. There is also concern about the considerable distance from the farmyard. Any leakages from the pipe would contaminate local ground and surface water supplies.

- The ICW would require constant observation and monitoring. The site is quite remote from the farmyard and maintenance costs would probably be prohibitive.

- There is concern that there is potential for other effluent to be discharged to the ICW through the manhole system. Whilst there is no implication that such activity would occur, policing would be impossible whilst the potential exists.

*The appeal submitted by Anne Gallacher*

As contained in her latter dated 30 November 2005. Although expressed as observations, the representations were accompanied by the correct fee for these to be treated as an appeal. The grounds may be summarised as follows:

- The EPA document *Waste Water Treatment Manual of Treatment Systems for Small Communities, Business, Leisure Centres and Hotels (1999)* is also referred to The disadvantages of ICWs concluded in that document include the low level of nitrogen & phosphorus removal and the unreliability of faecal and total coliforms.

- The site is in the heart of a scenic river valley and the proposal would impact on the landscape.

- There is potential for polluting the river. The County Council does not have the resources to inspect and ensure compliance.

- The farm complex is not a dairy farm. It already generates unpleasant odours because of the spreading of waste from the appellant's abattoir nearby.

- The doubts raised by the Council's engineer on some of the figures raised in the applicant's submission raises concerns about other measurements in the report accompanying the application.



*The appeal submitted by Leo Curran*

As in a submission dated 28 November 2005 and summarised as follows:

- Planning permission 96/549 granted to the applicant for the operation of his enclosed livestock unit contains 21 conditions. The appellant is not convinced that these have been implemented and adequately supervised by the planning authority.

- Material from the applicant's slaughterhouse is transported to the Rathfeigh area for disposal. Samples of blood and guts spread on the land have been taken and submitted to the County Council but no action has been taken.

- The Council has not taken into account the potential for such disposal through the wetlands system. Human and livestock health would be compromised, increased by the presence of birds on or in the wetland vegetation.

- The Hurley River provides an exploration ground for children during the summer when water levels are low. Their health should not be placed at risk.

*The appeal submitted by Basil Curran*

The grounds of appeal are set out in a letter dated 29 November 2005 and may be summarised as follows:

- The Hurley River valley is to be protected under a local 'Pride of Place' initiative, this being a Council sponsored initiative to enable rural community groups to upgrade a walk in their area.

- The schedule of conditions as recommended by the Council in this case refers to a system appropriate to farmyard water but the project is a factory farm with two beef producing feed lots.

- The owner is known to spread waste from an abattoir on to nearby land. He is also spreading slurry from the feedlots which causes annoyance in the locality.



## RESPONSES

### By the planning authority

The response simply identifies the reports of the Council's Senior Engineer particularly that following the submission of further information. The conditions as attached to the decision to grant permission are considered to satisfactorily address any environmental concerns that may arise.

### By the applicant

As set out in a letter from the applicant's agents dated 5 January 2005 which may be summarised as follows:

*With regard to the appeal by the Eastern Regional Fisheries Board*

- The EPA publications cited by the appellants does not refer to ICWs which have been an initiative of the National Parks and Wildlife Service for a number of years. It is stated that reed bed systems and constructed wetlands are referred to in the manual but that ICWs have a much larger land requirement and have demonstrated a greater level of treatment.

- The Teagasc paper cited by the appellants focuses on an ICW that is undersized and is receiving inflows from external sources. The proposal in this case is larger than that recommended by the National Parks and Wildlife Service.

- Discharges to the River Hurley will be confined to periods of heavy or prolonged wet weather when the capacity in the receiving watercourse is higher. There will be no discharge when flows in the river are low.

- Calculations carried out in relation to the assimilative capacity of the river show that there will be no negative impact on the receiving watercourse.

- A discharge licence will require a number of monitoring procedures to be undertaken to ensure that the system is functioning effectively and that no untreated effluent is discharged to the River Hurley.

*With regard to the appeals made by local residents*

- There will be no significant odours due to the treatment of agricultural waters in the wetland. In fact the occurrence of odours will reduce since the landspreading of effluent will cease.

- The ICW will have the appearance of a natural wetland system and will not negatively affect scenic value.

- ICWs are operational in a number of locations throughout the country. There are 12 in a valley in Co. Waterford that are being monitored by that County Council and DoEHLG as part of an on-going research programme on the performance of ICWs. Present results are positive showing that river quality has improved significantly.

- The applicant has written to appellants stating that there has never been any spreading of abattoir waste on these lands. That which is done is approximately a mile from the subject holding. The proposed ICW is for the treatment of soiled water from this holding only, to avoid landspreading during the winter months.



## THE DEVELOPMENT PLAN

In the County Development Plan 2001 there are no specific features shown on the site by the relevant rural amenity map. A SRUNA (Sustainable Recreational Use of Natural Assets) site is shown at Rathfeigh Church and Motte about 400 metres to the north of the site and there are monuments shown in the vicinity.

Section 3.6.4 in the Written Statement of the Plan covers agricultural development. It states that the provision of well located structures and facilities necessary to good and environmentally sound agricultural practice will be supported by the Planning Authority. The suitability of a given proposal will be determined *inter alia* by the following factors:

- The comprehensiveness of information in relation to waste management with particular emphasis on developments within existing farm complexes.
- The availability of an effective means of farm waste management to ensure nutrient balancing between application of farm wastes to land and the balanced uptake by agricultural use of land.
- The availability of measures to ensure good supervision in relation to the management of farm wastes including ownership of spreadlands or control of same through agreements capable of effective enforcement.
- Consideration of the "Measures Report" prepared by Meath County Council pursuant to the Local Government (Water Pollution) Act 1977 and the Water Quality Standards for Phosphorus Regulations 1998 (S.I. 258 of 1998) in the assessment of all agricultural or agri-business proposals including the modification and or rejection of proposals as necessary.



## ASSESSMENT

The principal issues that arise in this case are firstly, the effects of the proposed development on water quality in the receiving waters of the River Hurley and secondly, the impact of the proposal on the landscape of the area. I shall consider these issues in turn.

*Water quality*

The source of the proposed disposal system is clearly the faecal waste arising from the farmyard wherein the cattle sheds are located and also rain water runoff from the yard surfaces and buildings. One of the appellants has claimed that the occupancy of cattle in this yard is greater than that which is allowed under a previous planning permission. However, this in my opinion is a matter is for the planning authority to consider separately under its enforcement powers if indeed any breach of planning control has occurred.

With regard to the concern of the Fisheries Board about what it considers to be the unnecessary inclusion of surface water in the system, it is my opinion that a dilution of the cattle waste would be necessary in view of the shallow fall of the lengths of drainage pipe to the proposed ICW.

A principal concern of appellants is that other elements of waste may be introduced into the system. This is categorically denied by the applicant who acknowledges that he has spread abattoir waste on other lands in the area.

However, he states that he has not done so on the subject lands nor does he ever intend to do so. He explained in a letter to the appellants, as attached to his agent's response to the appeals, that his abattoir at Duleek is an export licenced establishment with a full time veterinary inspector on the premises. Verification is given by a veterinary inspector from the Department of Agriculture and Food that all waste from the abattoir is sent for rendering except wash water and rumen content. The former is spread onto land as is the latter after being stored in a sealed pit and dried. The applicant explained also that he is in the process of applying for permission to build a treatment plant at the abattoir which would eliminate any wash water being transported to lands at Rathfeigh and the adjoining townland.

It is my opinion that there is little foundation for the expressed concerns that sources of waste other than that arising from the subject site would be directed to the proposed ICW. However, I consider that if permission were to be granted in this case, a condition preventing the import of waste to the site would be appropriate.

My assessment of this issue now turns to the pathway of the proposed waste disposal. Initially, the route to the ICW is via underground pipework with manholes where changes in falls occur. In my opinion, the submitted drawings show appropriate construction details and there is no rational basis for concerns about system failure if the scheme is constructed as proposed.



The principal pathway for the disposal of waste is of course the construction and operation of the ICW itself. Documentation supporting the application explained that the area of the four treatment ponds would be double that of the farmyard and its roof area. It is stated that the National Parks and Wildlife Service Guidelines recommend a minimum wetland area of 1.5 times the interception area at source. The application documentation states also that the proposed ICW system has been designed to deal with farmyard water run-off with the following characteristics: BOD 2000mg/l, suspended solids 1500mg/l, total nitrogen 90mg/l, total phosphorus 90mg/l and ammonia 60mg/l.

I am satisfied with the applicant's agent's projections to the effect that the construction of the ponds with a water depth as proposed would allow for the storage of volumes of waste water for a nominal period of 265 days. Precipitation falling on the ICW would be layered, maintained on the top of the waste waters and flowing preferentially into the clean zone. The ecosystem of the proposed ICW would be of plant types that are stated to be capable of coping with prolonged periods of drought after establishment.

The predicted performance of the proposed ICW through the five pond system is the output of treated effluent with concentrations of each of the constituents as follows: $BOD_5$ 3.6 mg/l, suspended solids 6.0 mg/l, total nitrogen less than 1.5 mg/l, total phosphorus less than 0.02 mg/l and ammonia at 0.01 mg/l.

These performances are stated by the applicant's agent to be based on that of similar systems in Ireland. The principal basis of the Fisheries Board appeal is its doubt that this can be achieved especially with regard to phosphorus and nitrogen removal. Of the various sources cited in support of this appeal, the EPA publication *Waste Water Treatment Manual of Treatment Systems for Small Communities, Business, Leisure Centres and Hotels (1999)* clearly does not apply to the proposed development in this case. Significant points about the quoted EPA document *River Water Quality in South East Ireland (2003)* are its concern about constructed wetlands that are not authorised and the need for good management to avoid water pollution. Clearly the former does not apply in this case and the latter is capable of being addressed by environmental controls as well as by planning condition.

The Teagasc paper referred to by the Fisheries Board is a detailed scientific analysis in the form of an end of project report of one particular constructed wetland. A further reference is a short paper from a representative of the Department of Agriculture and Food. This states that constructed wetlands are to be welcomed for their ecological value and that when correctly constructed and performing as designed, they are a useful addition in treating waste waters. However, the paper expresses doubts, saying that misuse has occurred in the past at farms and that intermittent checks by local authorities may not pick up consequent damage to watercourses.



My overall findings on this review of published material are that there is some uncertainty in the scientific community about the performance of ICWs but that there is widespread agreement about the need for effective management, monitoring and control. It is relevant to note also the applicant's point that there is ongoing research on the performance of ICWs in County Waterford involving DoEHLG.

I find also that the report of the Council's Senior Engineer following the submission of further information is a cogent analysis of the effects of the proposed system on the principal receptor i.e. the receiving watercourse. The analysis is that conditions would be favourable if the ICW performs as is projected by the applicant.

The nub of the issue is therefore whether the proposed ICW would perform as projected. I am concerned that there is conflicting evidence about this but it is my opinion that this matter cannot be resolved without detailed scientific research that, in my submission, would be beyond the remit of the Board in regard to its planning responsibilities. It may well be that uncertainties would remain until further national research was carried out and, even then, the true performance of the proposed ICW could only be evaluated when it is operational and its actual impacts analysed.

Undoubtedly, the prevention of pollution in watercourses is a material planning consideration but the key factor in this case is that the discharge of waters to the receiving waters would require a licence from the local authority under the Local Government (Water Pollution) Acts 1977 and 1990. Such a licence would be geared to specific criteria to prevent pollution and this would require proper monitoring and evaluation. The concern that has been expressed by some appellants about the local authority's capacity in this regard has not been indicated by the authority itself.

I am satisfied that, with the specific provision of the fifth ponds for monitoring purposes and the incorporation of a sampling chamber on the discharge route to the watercourse, the design of the proposed system provides for effective monitoring and inspection. The applicant's agent has stated that an aftercare and maintenance system will be designed to include guidance to the applicant on daily upkeep. Whilst such maintenance requirements may be required in connection with the licensing regime operated by the County Council, I consider that an appropriate planning condition would also be necessary in this case.

Additionally, whereas a condition requiring the project to be the subject of a licence from the local authority under the relevant legislation may not be strictly necessary, I note that an informative would have been attached to the decision had it been issued by the planning authority. I note also that such a condition was attached by the Board when granting retention permission to an ICW in Co. Waterford in 2002 (appeal reference PL24.129738).

Subject to such requirements, I conclude that there are sufficient safeguards to ensure that water quality in the receiving waters of the River Hurley would be satisfactorily protected.



*Landscape impact*

The location of the proposed ponds is at some distance from public viewpoints, the nearest being that from a county road approximately 0.7 km to the west. The limited height of the proposed banks surrounding the ponds is such that there would be no appreciable alteration of the landform of the area. The present grass of the pasture field would be replaced by low lying plants within the ponds but this change would hardly be incongruous. Bearing in mind also the absence of any special landscape protection in the County Development Plan, my finding is that the effect on landscape character would not detract significantly from the amenity of the area.

The concerns raised by one of the appellants with regard to the local Pride of Place initiative are not easily understood since this is stated to be a project directed towards enhancing the attractiveness of walks along tertiary roads. The valley of the River Hurley is mentioned with regard to this project but there is neither a clear walkway along the valley nor is it evident that a right of way exists. Nonetheless, it is my opinion that the banks and the planting of the ponds would only have a very limited impact on the outlook of persons walking alongside the river at lower level.

My conclusion, therefore, on this issue is that the scheme would cause no material harm to the character and appearance of the surrounding landscape.

With regard to other matters raised, concerns were raised about potential odours but I have noted that there are no dwellings in close proximity to the proposed ICW and it is therefore most unlikely that any harm to residential amenity would occur in this respect. In any event, a condition as was attached to the planning authority's decision would act as a further safeguard. With regard to archaeology, there is no evidence that any monuments in the area would be affected. On the question of biodiversity, it is my opinion that this would be enhanced by the habitats created in the proposed wetland.

## RECOMMENDATION

In the light of the foregoing and having taken account of all other matters raised, I recommend that permission be granted as set out below. My recommended conditions incorporate those in the planning authority's decision but augmented by those highlighted in my foregoing assessment.

## REASONS AND CONSIDERATIONS



Having regard to the existence of pollution controls under other legislation, the landscape of this rural area and the pattern of development in the vicinity, it is considered that subject to compliance with the following conditions, the proposed development would not be prejudicial to public health or be visually obtrusive and would not seriously injure the amenities of the area. The proposed development would therefore be in accordance with the proper planning and sustainable development of the area.

## CONDITIONS

1) The development hereby permitted shall be constructed in accordance with plans and particulars received by the planning authority on 26 July 2005 and 12 October 2005 except where conditions hereunder specify otherwise.

**Reason:** In the interests of proper planning and development.

2) All surface water run-off from dirty yards and from clean roofs and yards shall be directed to the constructed wetland system comprising five ponds or lagoons prior to final discharge by gravity to surface water. Under no circumstances shall any effluent be permitted to discharge directly to waters.

**Reason:** In the interests of environmental protection and the prevention of water pollution.

3) No waste shall be imported to the site and no waste other than that arising from the dirty yards and farm buildings as indicated in the application shall be directed to the proposed integrated constructed wetland system.

**Reason:** In the interests of environmental protection and the prevention of water pollution.

4. Before any development is commenced a scheme detailing the management, maintenance and monitoring processes to be undertaken in relation to the proposed integrated constructed wetland system shall be submitted to and approved in writing by the planning authority, and these shall be carried out as approved. The monitoring of the performance of the proposed integrated constructed wetland system shall be carried out by a suitably qualified person.

**Reason:** In the interests of environmental protection and the prevention of water pollution.

5. All waste generated during construction, including surplus excavation material to be taken off-site shall only be recovered or disposed of at a site which has a current Waste Licence or Waste Permit in accordance with the Waste Management Acts 1996 to 2003. This shall not apply to disposal of waste excavation material within the applicant's site boundary.

**Reason:** In the interests of public health.

6. The development hereby permitted shall be so constructed and operated so as to ensure that there will be no emission of malodours, fumes, gas, dust or other deleterious materials, no industrial effluent and no noise vibration or electrical interference generated on the site such as would give reasonable cause for annoyance to any person in any residence or public place in the vicinity.



**Reason:** In the interests the amenity of the surrounding area.

7. The developer shall make application to Meath County Council for a licence to discharge treated effluent from the proposed integrated constructed wetland system to surface waters in accordance with Section 4 of the Local Government (Water Pollution) Acts 1977 and 1990.

**Reason:** In the interests of environmental protection and the prevention of water pollution.

Roger Dean

Inspector

June 2006

Appendix IV

Comhairle Chontae na Mí
Halla an Chontae, An Uaimh, Contae na Mí
Fón: 046 - 9097000
Cl. ar Fáilte Roimh Chomhfhreagras i nGaeilge

Tré Neart le Chéile

Meath County Council
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*Environment Section*

*21st June 2007*

*Our Ref: DL 07/10*

Mr Michael Fox
C/O Aila Carty
Environmental Consultant
1 Beechwood Avenue
Newtown
Cobh
Co Cork

*RE: Application for a Discharge Licence – Section 4*
*Michael Fox*

Dear Ms Carty

I refer to the above discharge licence application received by Meath County Council on 12th April 2007 on behalf of Mr Michael Fox, Tara Manor, Rathfeigh, Tara, Co Meath.

I wish to inform you that by Approved Officers Order dated 21st June 2007, Meath County Council refuses to grant a licence under Section 4 of the Local Government (Water Pollution) Acts 1977-1990 and Local Government (Water Pollution) Regulations 1978-1992 to Mr Michael Fox, to discharge trade effluent to waters from an Integrated Constructed Wetland to the River Hurley at Rathfeigh, Tara, Co Meath.



The reasons for refusal are as follows:

1. The IPPC licence application no. P0822-01, in respect of the Euro Farm Foods meat factory in Duleek, proposes to use the Integrated Constructed Wetland in Rathfeigh to treat waste from the meat factory. This is inconsistent with the details submitted as part of the discharge licence application. This is also in breach of the planning permission granted for the site.

2. The site layout of the Integrated Constructed Wetland as submitted with the discharge licence application is inconsistent with the actual site layout on the ground. The application shows that the ICW was designed to have 5 ponds. At the time of the Meath County Council inspection, the ICW had 8 ponds, and the total area of the ICW appeared to be greater than that outlined in the discharge licence application. As the drawings and particulars do not reflect what is on the ground, the existing Integrated Constructed Wetland is in breach of the planning permission granted for the site, and is an unauthorised development. The Planning Section have served a planning enforcement notice on Mr. Fox directing him to comply with the aforementioned planning permission.

2. The existing MRP levels in the River Hurley are elevated, and until such time as background MRP levels are reduced, Meath County Council cannot consider permitting any further Phosphorous loads to a river which has seriously elevated MRP levels.

3. In accordance with the Water Framework Directive, Meath County Council is obliged to prevent deterioration of existing water quality status, and to restore water quality to at least 'good status' by 2015. This proposal goes against these objectives.

5. Following recent site inspections, and concerns regarding the migration of effluent to groundwater's, the applicant has failed to demonstrate that this development will not cause pollution of groundwater's.

Meath County Council hereby advises that Michael Fox is **not permitted** to discharge trade effluent to waters from an Integrated Constructed Wetland to the River Hurley at Rathfeigh, Tara, Co Meath.

Meath County Council hereby informs Michael Fox that it is an offence in accordance with Section 4 of the Local Government (Water Pollution) Act, 1977 as amended in 1990, to discharge any trade effluent or sewage effluent to any waters except under and in accordance with a licence under this section.

Yours sincerely

Mary McCarthy

**Mary McCarthy**
**Assistant Staff Officer**