05 - Assessing the conservation status of GWDTEs under the Habitats Directive and Water Framework Directive; A case study from Tory Hill Fen SAC

Shane Regan[1], Laurence Gill[1], John Connaghan[2], Tony Brew[3] and Nathy Gilligan[3]

[1] *Department of Civil, Structural and Environmental Engineering, Trinity College Dublin*
[2] *Enviroscope, Co. Galway*
[3] *Office of Public Works, Headford, Co. Galway*

Abstract

Under European Union (EU) legislative directives the state is responsible for protecting and maintaining groundwater bodies and catchment areas in good condition and ensuring the long-term sustainability of water resources. The often conflicting requirements of human and environmental water needs must be balanced; water resource management under the Water Framework Directive (WFD), and daughter Groundwater Directive, dictates that the protection of wetlands dependent on groundwater must also be considered in this balance. Environmental pressures that disrupt either groundwater flow, in terms of abstraction/drainage or quality by e.g. nutrient inputs, have the potential to affect the maintenance of supported ecology that can lead to the deterioration of wetland systems.

However, whilst protection is provided to groundwater dependent terrestrial ecosystems (GWDTEs) through the Habitats Directive (HD), which is aimed primarily at protecting biodiversity by designating sites of interest as Special Areas of Conservation (SAC), and the WFD, which is aimed at protecting the water environment, there is a lack of consistency in how conservation status is assigned as the two assessments are based on different criteria. As an example, a major disconnect is the idea that if a GWDTE suffers ecological "damage", under the HD, then this can imply that the supporting groundwater body should therefore considered as being of "poor" status under the WFD. However, such damage may be due to local-level pressures, and not necessarily related to the wider groundwater body (GWB).

Fen habitats are largely groundwater fed, being located in topographic hollows or below springs or seepages of water that has been in contact with mineral soils, and like bogs, they accumulate peat. Of the fen habitats designated as SAC, fifteen are located adjacent to arterial drainage schemes managed by the OPW. Base-rich fens, such as Alkaline and *Cladium* fens, are one of the most threatened habitats, due to drainage and eutrophication, in Europe, making conservation of the remaining examples paramount. The National Peatlands Strategy states that there '*is a particular lack of environmental baseline data for fen habitats' and that 'baseline data will be required for fens to allow more detailed evaluation of these habitats and the identification of conservation or restoration measures'*. As per Action A 12 in the National Peatlands Strategy, the OPW in co-operation with DAHG are now progressing a pilot Conservation Management Plan for a fen SAC, including specific examination of the implications for drainage.

This paper presents the results of this pilot work which comprises an investigation of Tory Hill SAC in Co. Limerick which is an arterially drained site that was designated as SAC. It finds that the wetland is degraded and water tables are unable to support vegetation communities associated with calcareous conditions as well as other issues such as a lack of livestock grazing. However, this can be taken as a local pressure rather than a regional hydrogeological pressure as the drain is increasing lateral seepage from the fen, rather than taking groundwater from the source aquifer/GWB. Restoration of the fen, by raising the level of water in the adjoining arterial drain is complicated by a history of flooding in adjoining agricultural land. This paper presents the approach taken to assess the conservation status of the fen, and discusses the restoration measures necessary to improve its ecological condition, which is complicated by the necessity to continue to minimise flooding impact on surrounding land.

1. Introduction

In the past 100 years, two thirds of Europe's wetlands have been lost, and those that remain are often heavily degraded, making them among Europe's most threatened ecosystems (EC, 2007). Though the scale of wetland losses in Ireland has been less than in other European countries, significant losses have occurred and between 1990 and 2006 it is estimated that there was a 10% decrease in area covered by wetlands in Ireland (CORINE). Despite this, Ireland still contains one of the highest concentrations of wetlands in Western Europe. A key wetland habitat are base-rich fens and are one of the most threatened habitats in Europe (Kooijman, 2012), requiring the highest level of conservation within member states (Foss, 2007).

2. Protection

Protection of biodiversity is primarily afforded by the Habitats Directive (HD) and its principal aim is to 'contribute towards ensuring bio-diversity through the conservation of natural habitats and of wild fauna and flora in the European territory of the Member States' (Article 2). Cladium fens are listed on Annex I of the Directive and are considered Priority Habitats under threat. Member States must maintain or restore Annex I habitats to favourable conservation status and are obliged to monitor their status under Article 11 of the Directive. Conservation status is assessed holistically and based on the range, area, structures and functions and threats to the existing and future prospects of the habitat.

Additional protection to wetlands is afforded by the Water Framework Directive (WFD) (2000/60/EC). The WFD is receptor-orientated and has progressed water management from being focused on local pollution control to ensuring ecosystem integrity as a whole and deterioration and improvement of 'ecological quality' is defined by the response of the biota, rather than by changes in physical or chemical variables (Hering *et al*., 2010). The WFD provides a framework for integrated river basin management and an assessment of terrestrial ecosystems that depend directly on groundwater as part of the classification of groundwater bodies (GWBs) is required under Annex V of the Directive. Such wetlands are referred to as groundwater dependent terrestrial ecosystems (GWDTEs).

Sites considered ecologically important in European conservation policy are integrated into the WFD courtesy of the Natura 2000 network, which groups sites designated as Special Protection Areas (SPAs) under the Birds Directive (BD) and Special Areas of Conservation (SACs) under the HD. Natura 2000 sites that contain GWDTEs are therefore integrated into WFD river basin management planning and their conservation is approached on a catchment basis. Under the EU Groundwater Directive (2006/118/EC), a 'daughter' directive of the WFD, a GWB can be classed as being at either poor or good status based on quantitative and chemical pressures. If such pressures on a GWB result in 'significant damage' to GWDTE, the GWB will be classified as being at 'poor status' under the WFD and require mitigation measures (Kilroy *et al*., 2008).

The objective of the HD is to achieve favourable conservation status of habitats and species of Community interest (EC, 2011). For those terrestrial ecosystems that belong to the Natura 2000 network, the failure to meet conservation targets of the Natura 2000 area can be interpreted as significant damage under the WFD (as far as groundwater status is concerned) (EC, 2011a; 2011B; 2015). However, the degree to which pressures in the GWB impact on the environmental flows of the GWDTE receptors is unclear and a poor HD conservation status may not necessarily be the result of hydrogeological impacts, meaning poor GWDTE status does not always equate with poor GWB status.

3. Fens

Fen habitats are largely groundwater fed, being located in topographic hollows or below springs or seepages of water that has been in contact with mineral ground (Proctor, 2010).). The composition of the fen vegetation reflects (1) the chemical composition of the dominant water supply and (2) the duration of a mean water level. The combination of these factors dictates what type of fen develops and its hydrological regime (McBride *et al.*, 2011). Put simply, a "poor" fen has very low concentrations of plant nutrients and floristically has similarities to a bog, while a "rich" fen has relatively high

concentrations of mineral nutrients and a more diverse plant and animal community (Foss, 2007). Current fen area estimates (Foss, 2007) are 22,180 ha of fen habitat in Ireland of which 31% is Alkaline fen, 7% is Cladium fen, 9% is Transition mire, 0.2% is Petrifying Spring (all Annex I habitats). As fens are directly connected to the groundwater table they can be subject to hydrochemical/nutrient loading pressures, as well as abstraction and drainage pressures. Base-rich fens, such as Alkaline and Cladium fens, can also be threatened by acidification due to eutrophication, especially with phosphorus (Kooijman, 2012). Water supply should be calcium-rich, but nutrient-poor.

4. Case Study: Tory Hill SAC

Of the fen habitats designated as SAC, fifteen are located adjacent to arterial drainage schemes managed by the Office of Public Works (OPW, 2009). An eco-hydrological investigation was carried out on one such fen, Tory Hill, in 2015 (Regan and Connaghan, 2016), with the aim of classifying its current ecological condition and identifying any pressures impacting on the quality of the distribution of that vegetation. The results from the investigation will guide OPW on how best to carry out restoration works, as necessitated by the HD and WFD, whilst accounting for flood risk on adjoining agricultural land.

4.1. Location

Tory Hill SAC (Site No. 000439) is located in the centre of Co. Limerick, approximately 2 kilometres north-east of the village of Croom. The site comprises Tory hill (elevation of ca. 100 metres) and an associated lake, Lough Nagirra, with an area of fen/marsh vegetation between the hill and the lake (Figure 1) (Grid reference R535432).

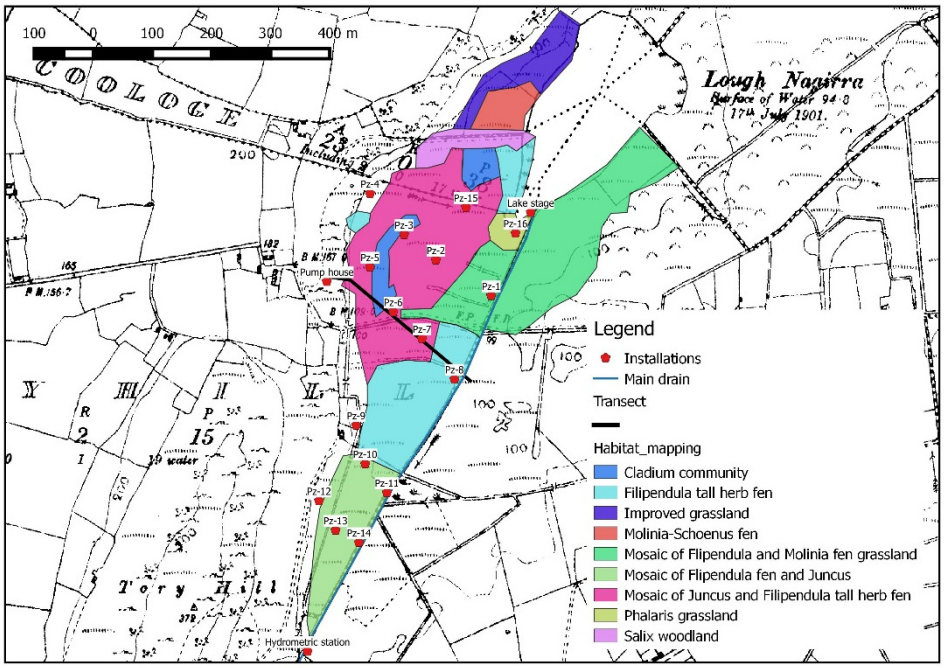

***Figure 1**: Tory Hill habitat mapping and hydrological investigation points*

4.2. Geo-hydrological setting

There are no features on the surface of the fen that significantly divert or obstruct surface water flow (such as drain ditches). Surface depressions, from old cutaways associated with scraw cutting are present, but do not form drainage channels. The main hydrological feature of the fen is an arterial drain which bounds the eastern boundary of the habitat and flows southwest from Lough Nagirra (Figure 1). This drain is maintained by OPW for land management purposes, as agricultural land to the east of the

drain is susceptible to flood episodes. The drain has been deepened and straightened in the past, with the invert level now 2.0m below the ground surface level of the fen.

The peat in the fen is shallow, with an average depth of 0.5m and a maximum depth of 1.4m. The peat mass is underlain by lake clay substratum that is almost 13m thick. The underlying source aquifer/groundwater body, classified as being a regionally important karstified aquifer by the Geological Survey of Ireland, is therefore confined by a significant thickness of lake clay. A series of phreatic tubes, to measure unconfined water table, and shallow piezometers, in the peat and upper sequences of clay, to measured hydraulic head, were installed to help understand the groundwater environment (Figure 1), as well as surveying for wells in the general catchment region.

4.3. Eco-hydrological functioning

Wells located close to the western margin of the fen, and in regional catchment area, show water levels that are approximately 1 and 7m above fen ground level. There is therefore sufficient head gradient to drive groundwater flow at the fen margins. Groundwater from the elevated topography west of the fen must then flow in the low permeability clay deposits close to the surface, albeit slowly, and via springs at the fen surface-groundwater interface. One spring was mapped in the study in the northwest area of the fen, and this water feeds Lough Nagirra. Upward hydraulic gradients, implying a driving head gradient, are encountered in the central areas of the fen, in the area mapped as 'Cladium Community' on Figure 1. Downward gradients are encountered in the remaining fen area (i.e. the majority of the habitat).

One of the main diagnostic characteristics of an alkaline fen habitat is the presence of well-developed layer of "brown moss" species. Ecological mapping finds that these brown moss species are either absent of very rare within the alkaline fen areas at Tory Hill. The general absence of a brown moss layer coupled with the absence/low cover of the majority of the vascular indicator species, such as sedges (Carex spp.) suggests that the fen habitat at Tory Hill is a relatively poorly-developed example of the habitat which is also relatively species-poor. The hydraulic gradient is not strong enough to maintain groundwater levels in most areas of the fen. The high cover of the poor fen species *Calliergonella cuspidata* in most of the wet fen areas suggests that not enough groundwater is getting to the surface for a sufficient period of the year. As such, alkaline vegetation is concentrated in old wet cutaways where the upwelling, base-enriched water, is at or above the ground surface for the majority of the year. This is indicated by areas such as Pz-6, where groundwater level was above ground level > 70% of the study period (Figure 2).

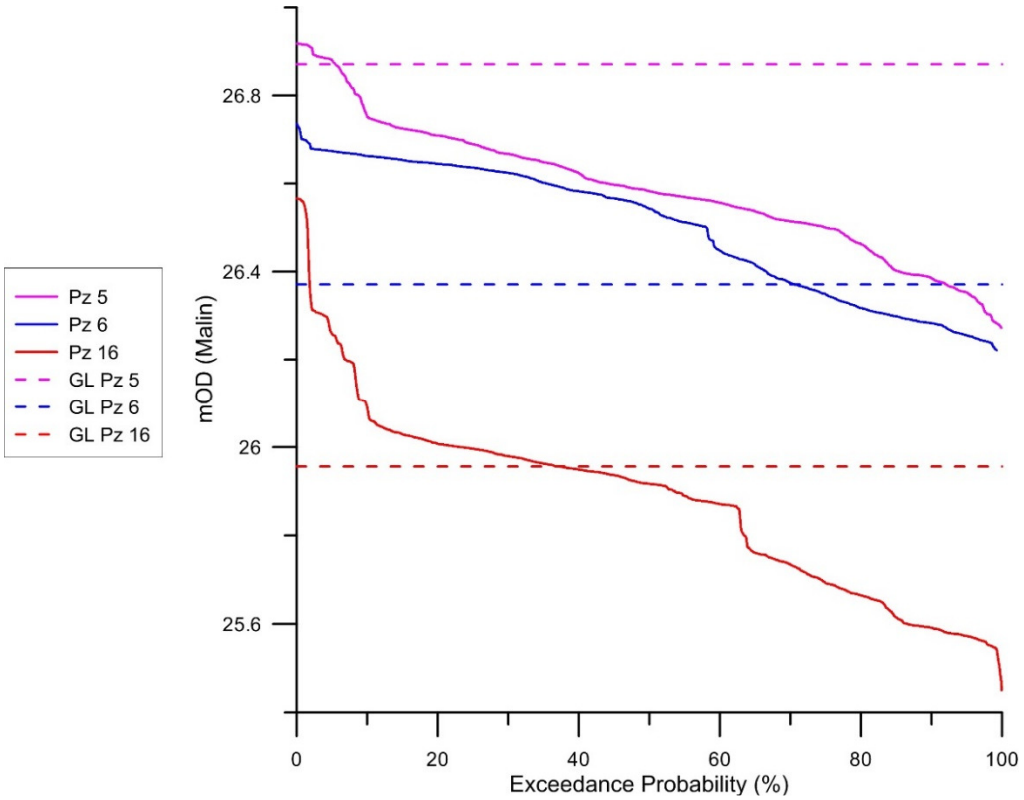

***Figure 2**: Head frequency duration curves for piezometers 5, 6 and 16 between July and November 2015.*

4.4. Effects of arterial drainage on fen hydrology

The main drain originating from Lough Nagiraa is a key control on the hydrological functioning of the Tory Hill fen. The drain has been actively maintained by OPW to help reduce the duration of winter flooding in the area, which due to the topography of the surrounding land, east of the drain, is highly susceptible to flood episodes when rainfall durations have been sufficiently long.

However, though the fen is underlain by low permeability the clay deposits underlying the fen, the drain is drawing down the groundwater table. This is most apparent at low flow/ the summer period (Figure 3 and 4). Groundwater levels are deep, at > 0.5m below the ground surface for most areas of the fen, and rise when the drain becomes filled and reduces the hydraulic gradient of the groundwater table. The reduction in the groundwater table is in the order of 60% for much of the fen. This reduces the lateral seepage rate by approximately 45% (when analysing the maximum and minimum water levels/ flows encountered during the period of study).

The drain invert level has been deepened in the order of 0.5m since drainage works in the 1970s. It is probable that the hydraulic gradient supplying groundwater to the fen surface has never been strong; however, this makes it more sensitive to drainage. Raising the drain invert level in the order of 0.5m, where the Main Drain borders the fen, will raise the groundwater level, restore upward hydraulic gradients and reduce lateral seepage rates.

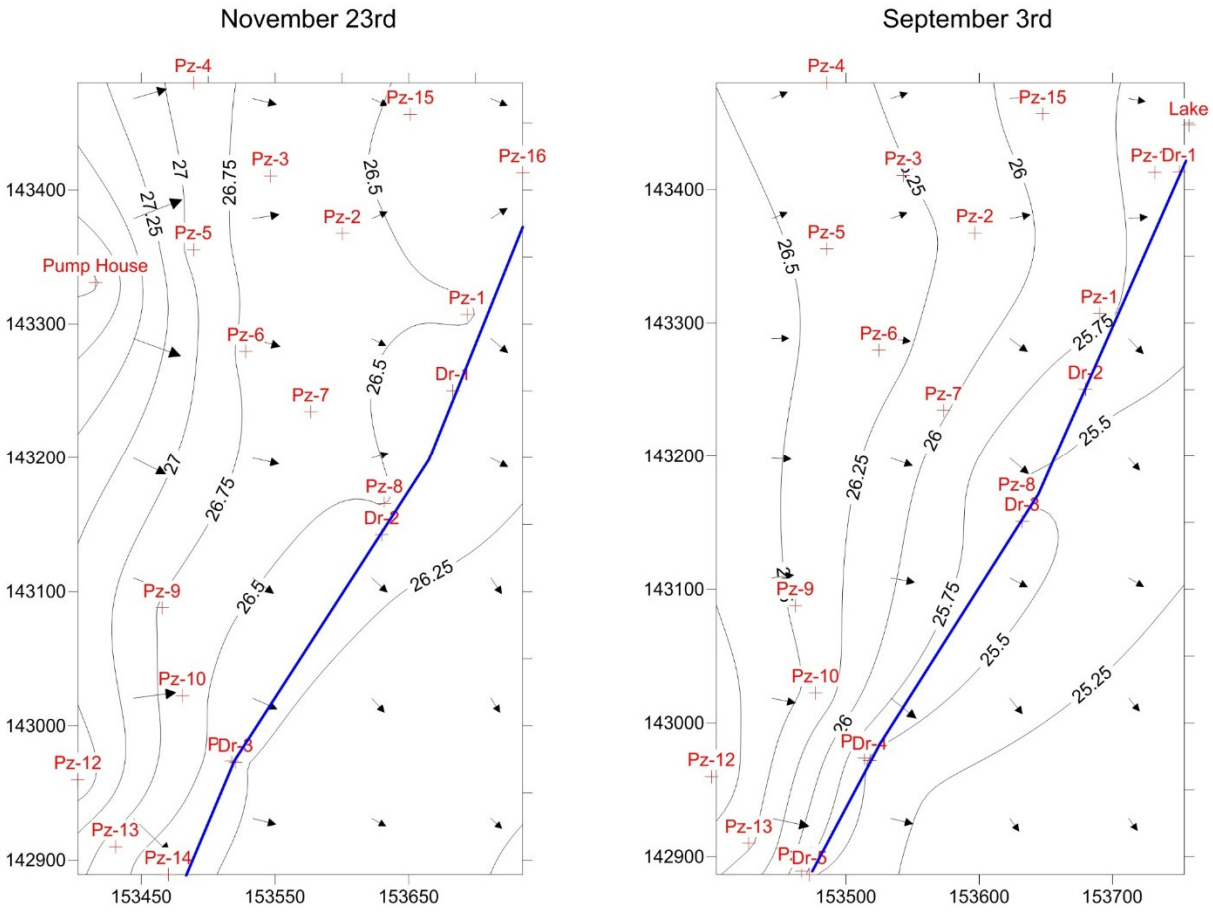

***Figure 3**: Potentiometric surface map for November 23rd (winter) and September 3rd (summer) periods.*

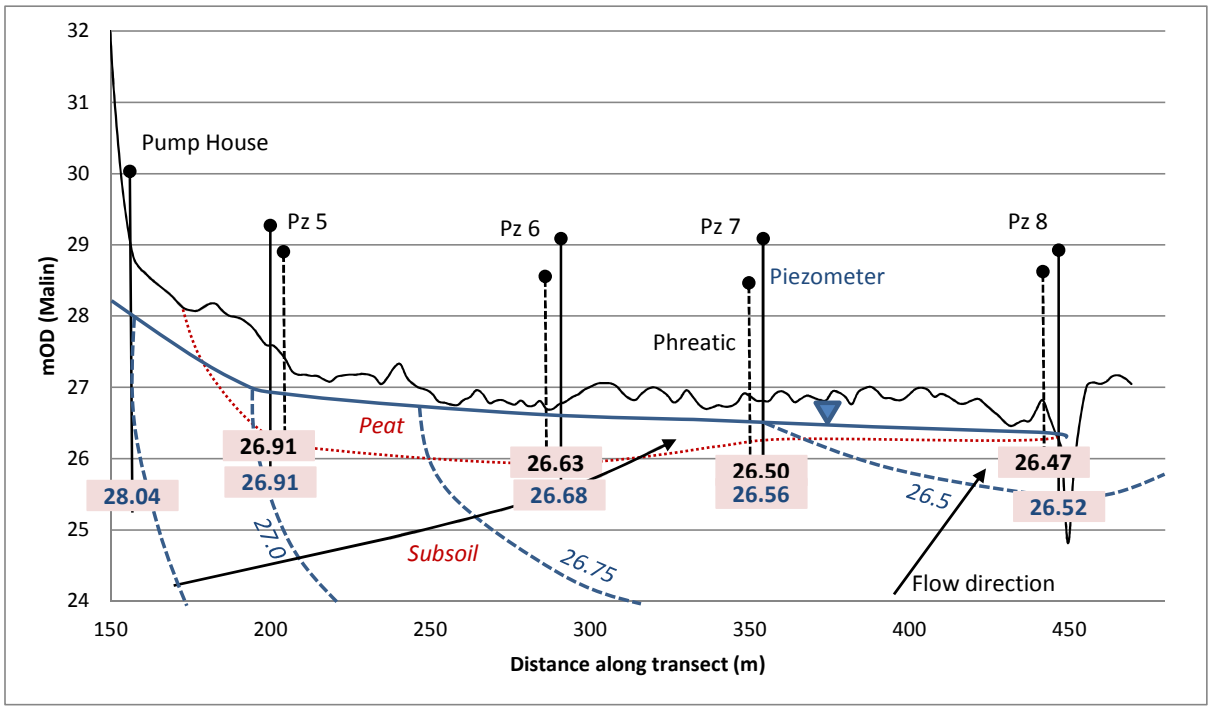

***Figure 4**: Hydro-geological cross-section in September 4th 2015 (see transect on Figure 1)*

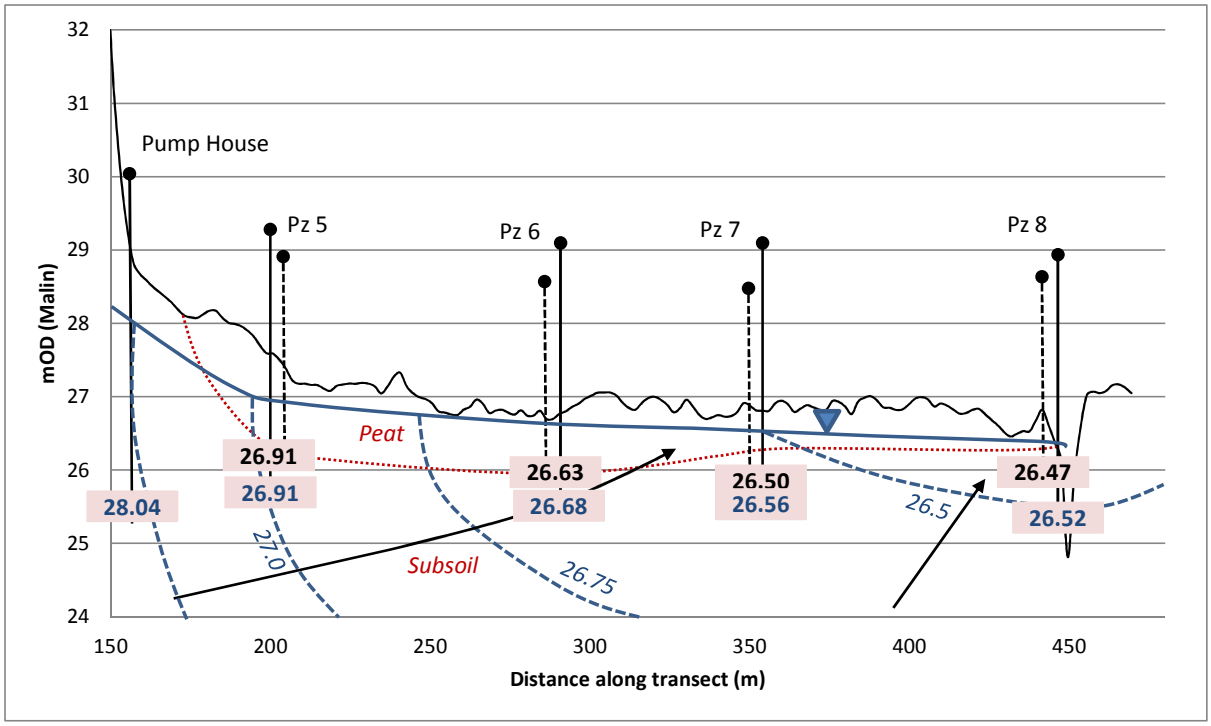

***Figure 5**: Hydro-geological cross-section in November 23rd 2015 (see transect on Figure 1).*

5. Restoration

The arterial drain from Lough Nagirra exerts a considerable influence over the hydrology of the fen/wetland areas at Tory Hill. Increasing the water levels in the drain by either (1) raising the level of the drain invert or (2) partially blocking the drain by a series of dams, where the drain borders the fen, would elevate and stabilize the water levels in the adjoining fen/wetland areas, especially during low flows/ the drier periods of the year, and this would improve the quality of the habitat over time. In periods when the drain water level is high, upward hydraulic gradients are restored in the fen, but this is short-lived, and also corresponds with periods when the water system is at capacity and flooding occurs. It is clear from historic Ordnance Survey Ireland 6-inch mapping that the improved agricultural grasslands adjoining the Main Drain have traditionally been prone to flooding, and the drain has been deepened and maintained to minimise flood risk If the restoration of the Tory Hill fen SAC is deemed a conservation priority, which it is under the HD and WFD, appropriate drainage design is necessary, that somehow marries the conservation objectives with flood/land management.

6. Summary

An extensive eco-hydrological investigation was carried out on the fen habitat at Tory Hill, Co. Limerick. The ecological investigation classified the fen as being a 'poorly developed alkaline fen' due to the widespread occurrence of vegetation indicative of dry conditions. Alkaline fens characteristically require high water tables that are maintained by sustained groundwater inputs/flows. However, the quality of the alkaline fen habitat in Tory Hill is poor and this is attributed to low groundwater levels. Fen-rich communities do occur and are confined to areas where there are surface depressions, possibly due to past scraw cutting, meaning groundwater and base-rich water only reaches the surface in localised areas. The surface of the fen is also characterised by a distinct absence of introduced drainage features that could influence water tables. Whilst localised ditches do occur, such as where the fen-rich communities develop and at old access tracks, they are relatively minor features of the habitat and do not account for the observed low groundwater tables. The reasons for the low fen groundwater tables can be the result of two processes: (1) there is regional drainage/abstraction of the aquifer/groundwater

body recharging the fen and (2) the drain that borders fen is causing a drawdown of the fen groundwater table.

The OPW require practical solutions that can improve the conservation status of the fen under the HD, while minimising flooding impact on surrounding land. The hydrological investigation attributes the low groundwater levels to drain drawdown as (1) there is little evidence of regional groundwater drainage (though it cannot be discounted) and (2) the invert level of the marginal drain is 1-2m below the surface of the fen and works to reduce hydraulic gradients and lower fen groundwater tables. It is therefore apparent that engineering measures to restore a favourable conservation status to the fen must focus on this 'main' drain. This will pertain rising drain water levels by introducing structures, such as a series of small dams, in the drainage channel. However, the drain is currently maintained by OPW to control and minimise flooding events on marginal agricultural land, on the eastern side of the drain. Thus, a rise in fen groundwater table may have undesirable effects in the context of rising water levels on surrounding land. This highlights the complexity, both in terms of scientific understanding and social consideration, involved in restoring ecological systems where arterial drainage is also required for land management.

This study has also highlighted the significance in attributing reasons for the causes of environmental damage in wetland systems, particularly those sustained by groundwater in the context of the WFD. Fen habitats are obvious GWDTEs and groundwater abstraction has been shown to cause significant damage at Pollardstown Fen (Johnston *et al*., 2015), leading the EPA to currently classify the supporting Curragh aquifer as being at bad status under the WFD. The study at Tory Hill fen indicates that it is also in an unfavourable ecological condition under the HD, and that groundwater pressures have led to this degradation. However, the pressures are not directly associated with the groundwater body, as the arterial drain does not directly drain the groundwater body/aquifer, but rather draws down the fen water table in the peat which appears to be sustained by groundwater flows moving either laterally through the fen or through the underlying clay mass. This may be considered a local pressure rather than a regional groundwater body pressure.

As the status of supporting GWBs is essentially based on the HD status of GWDTEs, without (1) the GWB necessarily being affected by anthropogenic pressures or (2) there being an immediate or recognisable impact on wetland ecology from pressures associated with the GWB, there is an incentive to better link and connect status assessment synonymous to both HD and WFD.

7. References

European Commission (2007). LIFE and Europe's wetlands: Restoring a vital ecosystem.

European Commission (2009). Groundwater Status and Trends Assessment. CIS Guidance Document No. 18, European Commission, Brussels, Belgium.

European Commission (2011a). Technical Report No. 6. Technical Report on Groundwater Dependent Terrestrial Ecosystems.European Commission (2011b). Links between the Water Framework Directive (WFD 2000/60/EC) and Nature Directives (Birds Directive 2009/147/EC and Habitats Directive 92/43/EEC). Frequently asked questions: European Commission, Brussels, Belgium

Foss P.J. (2007). *Study of the Extent and Conservation Status of Springs, Fens and Flushes in Ireland 2007*. Internal report for the National Parks and Wildlife Service, Department of the Environment, Heritage and Local Government, Ireland.

Hering, D., Borja, A., Carstensen, J., Carvalho, L., Elliott, M., Feld, C., Heiskanen, S., Johnson, R., Moe, J., Pont, D., Solheim, A., van de Bund, W (2010). The European Water Framework Directive at the age of 10: A critical review of the achievements with recommendations for the future. *Science of The Total Environment*, 408(19), 4007-4019.

Johnston, P., Regan, S., Naughton, O., and Osman, H. (2015). Defining hydrological damage in Groundwater Dependent Terrestrial Ecosystems. Proceedings of the International Association of Hydrogeologists. 2015.

Kilroy G., Dunne F., Ryan J., O`Connor A., Daly D., Craig M., Coxon C., Johnston P., Moe H. (2008). *A framework for the assessment of groundwater dependent terrestrial ecosystems under the Water Framework Directive* (2005-W-FS-5).

Kooijman A. (2012). 'Poor rich fen mosses': atmospheric N-deposition and P-eutrophication in base-rich fens. *Journal of Lindbergia* 35, 42-52

McBride A., Diack I., Droy N., Hamill H., Jones P., Schutten J., Skinner A., Street M. (2011). *The Fen Management Handbook*, Scottish Natural Heritage, Perth.

Regan S., Connaghan J. (2016). *Eco-Hydrological Investigation of Tory Hill fen SAC, Co. Limerick*. Report to the Office of Public Works.