The Hydrogeology of Peat

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University of Birmingham

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2016 YEAR OF WATER

BRITISH HYDROLOGICAL SOCIETY

Programme

9:00	Registration, refreshments & (early bird) posters
10:00	Welcome & Introduction *Rob Low (Rigare Ltd)*

Morning session: Conceptual aspects

10:15	The curious case of a peatland with a hydraulic conductivity like that of gravel but no ground-water flow *Prof. Andy Baird (University of Leeds)*
10:35	Microtopography, Drainage and Scrub – Factors Controlling Groundwater Levels on Rusland Valley Mosses *Alex Jones (JBA Consulting)*
10:55	Geophysical imaging and characterisation of peatland thickness and hydrogeology: Cors Caron, mid-Wales *Neil Ross (Newcastle University)*
11:15	Refreshments
11:45	Parched peatlands – the invisible effects of peatland drainage *Richard Lindsay (University of East London)*
12:05	Assessing the Impact of Marginal Drainage on Raised Bog Topography and Conservation *Alister Best (QUB/RPS) and Raymond Flynn (QUB)*
12:25	Are raised bog ecosystems groundwater-dependent? *Shane Regan and Paul Johnston (Trinity College, Dublin)*
12:45	Poster pitch (two minute introductions to posters on display)
13:00	Lunch

Afternoon session: Modelling aspects

14:00	Modelling raised bog water-table fluctuations *Hugh Cushnan (QUB)*
14:20	Modelling the effects of gullies, ditches, and restoration on the ecohydrology of blanket peatlands *Dylan Young (University of Leeds)*
14:40	The effects of peat hydraulic properties and depth to confining geology on water fluxes in peatlands *Simon Dixon (University of Birmingham)*
15:00	Refreshments
15:30	Coupled modelling of groundwater and surface water in Suffolk fen peat *Jo Thorp (Atkins)*
15:50	Integrated hydrological modelling of valley mires in hard-rock regions, Massif Central, France *Arnaud Duranel (University College London)*
16:10	Concluding discussion & close of meeting (~16:30)

Thank you to Vattenfall for sponsoring this event

Integrated hydrological modelling of valley mires in hard-rock regions: application to water balance estimation and impact assessment of catchment afforestation in a mire of the Massif Central, France

Arnaud Duranel[1,2], Julian R. Thompson[1], Helene Burningham[1], Hervé Cubizolle[2] and Philippe Durepaire[3]

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The understanding of the hydrogeology of hard-rock aquifers has changed substantially over the last 20 years. In particular, it has been recognised that they are not limited to the superficial and often discontinuous saprolite layer, but are, in many cases, continuous composite aquifers in which the presence of a layer of densely fissured rock ensures a transmissive function. Accordingly, classic concepts regarding the hydrogeology of acidic valley mires located at the bottom of etch-basins in Hercynian Europe may require revision. Here we present the results of a field and modelling study investigating the water balance of such a mire and the impacts of catchment afforestation on its hydrological condition, using the integrated distributed hydrological model MIKE SHE coupled to the HYLUC interception model. Groundwater from the fissured granite upwelling through the peat deposits make for a quantitatively important and functionally essential part of water inputs to the mire. The model suggested that replacement of open habitats by conifer plantations within the catchment may lead to a substantial reduction in surface and groundwater inputs to this type of mire. A substantial drop in groundwater levels in the peat is also predicted, but only along the mire margins.

Coupled modelling of groundwater and surface water in Suffolk fen peat

Jo Thorp and Hari Mehta

Atkins

Atkins has constructed a numerical groundwater and surface water flow model to represent a 100 hectare area of fen peat at a site in Suffolk. The coupled model was built in FEFLOW-MIKE11, and calibrated to simulate observed water levels from an extensive groundwater and surface water monitoring network for the period December 2013 - August 2015.

Model calibration indicated that anisotropy is important in the Peat at this site. The best calibration was achieved using horizontal hydraulic conductivity of 0.2 m/d, and vertical hydraulic conductivity of 0.05-0.2 m/d (anisotropy was increased with depth to simulate increased compression of the Peat).

The model shows that although, on a macro-scale, Peat groundwater flow follows regional trends, on a more local scale Peat groundwater flow is dominated by discharge to drainage ditches. This interaction is affected by seasonal variation in Peat groundwater levels: in winter average discharge to drains is modelled to be nearly twice as much as in summer.

The model also shows that seasonality in Peat water levels impacts the interaction between Peat groundwater and groundwater in the underlying Crag aquifer: in summer Peat groundwater levels are supported by upflow from the Crag, while in winter Peat groundwater recharges Crag groundwater.

The curious case of a peatland with a hydraulic conductivity like that of gravel but no ground-water flow

Prof. Andy Baird

University of Leeds

We measured the hydraulic conductivity (*K*) of the peat in five vegetation zones across a tropical bog in Panama. We found that peat *K* was similar to that of a coarse sand or fine gravel, with mean values from the vegetation zones ranging from 7.5 to ~472 m per day. It is, perhaps, natural to assume that a system with such a high *K* experiences high rates of subsurface flow and that, during seasonal dry periods or larger-scale droughts, water tables drop rapidly once they are no longer sustained by rainfall. To test this assumption we used a variant of the Boussinesq equation to model the effects of the high *K* values on water tables in a typical tropical peatland. We found that ground-water seepage losses from the peatland’s margin comprised only ~10% of incoming rainfall; most water in the model peatland was lost via evapotranspiration and overland flow. The reason for the low rate of ground-water flow is the very low hydraulic gradients in the modelled peatland. Although there was a ~6 m drop in altitude of the peatland’s surface between its centre and margin (we modelled a domed bog), the distance over which this occurred was ~4 km. Therefore, the low hydraulic gradient ‘trumps’ the high hydraulic conductivity. This case study serves as a useful reminder that Darcy’s law has two components.

Microtopography, Drainage and Scrub – Factors Controlling Groundwater Levels on Rusland Valley Mosses

Alex Jones

JBA Consulting

Rusland Valley Mosses SSSI, South Cumbria, is a raised mire system with three distinct domes. The mire has been damaged by historical peat cutting and drainage activities, and by the gradual encroachment of non-mire vegetation, including scrub and woodland. Natural England is committed to restoring the site to an intact, fully-functioning, peat bog and aims to restore a more stable water table to within 10cm of the surface across much of the site.

JBA Consulting was commissioned in 2011 to undertake a restoration design for the site. The areas requiring restoration were identified through assessing likely water level conditions, based on proxies such as vegetation type and drainage features, rather than direct water level monitoring. A detailed water level monitoring network was installed in 2012, to provide further evidence as to the degraded nature of the site.

Across the site the water table is relatively close to the surface and therefore the role of small scale variations such as microtopography, drainage grips and vegetation cover can have a significant impact on water levels experienced at a given location. Micro-siting of monitoring locations is key in producing representative data for the site and in gathering information on factors influencing the site condition.

The effects of peat hydraulic properties and depth to confining geology on water fluxes in peatlands

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The ecohydrological and hydrogeological controls on water fluxes within peat-building Sphagnum mosses is key to understanding the hydrological functioning of peatland systems. Supply of water to the surface layer and high surface layer soil-water pressures are needed to prevent desiccation under evaporative stress. Despite its importance, understanding of water transport in unsaturated peat and the controls exerted on it by peat hydrological properties and underlying geology remains partial.

In recent years numerical modelling approaches have helped improve understanding of peat hydraulic properties and water use efficiency in peat. A key unanswered question is the effects of peat hydrological properties when combined with the different surficial geology and depth to water table upon water transport in unsaturated peat. This is particularly important in the context of designing restored peatlands and in understanding the range of behaviours expected in different peat niches, including hummocks, hollows and marginal interface zones.

In this study we used a one-dimensional unsaturated flow model (HYDRUS-1D) and apply a theoretical ecosystem ecohydrological approach with the aim of enhancing understanding of peatland hydrological function under evaporative stress. We present a conceptual model suggesting how different peat macroforms can be expected to respond to periods of evaporative stress.

Modelling the effects of gullies, ditches, and restoration on the ecohydrology of blanket peatlands

Dylan Young

University of Leeds

Erosional gullies and drainage ditches are long-standing features associated with blanket peatland degradation in the UK and Ireland. As a result, both are commonly dammed with the aim of restoring typical blanket peatland hydrological regimes to prevent the continued loss of peat via erosion and oxidation. Studies that investigate the impact of gully and drain damming on peatland water tables are carried out over relatively short timescales, and few consider the effect on water tables of the change in peat properties, such as permeability, caused by drainage. Here we use a 2D version of the DigiBog peatland development model – that simulates peat accumulation on slopes – to explore the impact of damming of gullies and ditches on the oxidation of peat stocks and water-table behaviour over annual to centennial timescales. Our simulations suggest that dams prevent the continued loss of peat from oxidation but also that peat losses incurred from 100 years of drainage will not be recovered 200 years after damming takes place. We also show how peat structure and water tables vary across the hillslope and respond differently to damming, and propose that such information could be useful for restoration managers.

Geophysical imaging and characterisation of peatland thickness and hydrogeology: Cors Caron, mid-Wales

Neil Ross[1], Pete Brabham[2], Bernd Kulessa[3], Devin Harrison[1], Andy Polkey[4] and Lestyn Evans

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Hydrogeological characterisation and modelling of peatlands often relies on point measurements (i.e. boreholes) to constrain peat thickness, and subsurface water levels and chemistry. The potential of geophysical methods for enhancing our understanding of peatland hydrogeology has often been overlooked.

We report geophysical surveys from raised bogs at Cors Caron, mid-Wales. In 2015, a systematic ground penetrating radar (GPR) survey was undertaken using a 40 MHz Utsi GV7 system towed behind a tracked vehicle. Extensive (>20 km) high-quality GPR data were acquired, imaging the 3D geometry and thickness of the peat (~10 m), and providing insight into long-term bog evolution. Peat volumes at Cors Caron substantially exceed those predicted by a simple geometry and localised coring. Future investigations will apply electrical resistivity tomography, self-potential, and monitoring of water fluxes to determine the electrical and hydrogeological properties of the peat, and depth-to-bedrock.

Geophysical-derived peatland geometries and physical properties of peat and underlying sediments/bedrock provide critical input data for peatland hydrogeological modelling. Our approach demonstrates that highly-portable near-surface geophysical methods, integrated with 'traditional' site-investigations, can provide rapid and spatially-extensive 3D characterisation of peatland geometry and hydrogeology. Installation of automated geophysical systems have the potential to generate high-resolution temporal data to characterise hydrogeological variability.

Parched peatlands – the invisible effects of peatland drainage

Richard Lindsay

Sustainability Research Institute, University of East London

When hydrologists talk about peatland drainage there is a general tendency to focus on the response of the water table to such drainage. This has given rise to a widespread belief that the impacts of drainage are limited in extent because measurable draw-down is often restricted to a zone which extends no more than 5-10 metres from the drain margin. These measurements are, however, commonly made only relative to the peat surface and often over relatively short time periods – perhaps 3 to 5 years. Meanwhile engineers may focus on the structural properties of the peat and on this basis generate models which identify, for example, the presence of weak layers which may influence slope stability under certain hydrological conditions. In both cases these assessments tend to generate 'snapshots' of the peat at a given moment in time but provide little insight into the long term effects of drainage. Peatland drainage is, however, generally undertaken as a long-term process – two to three decades in the case of windfarms or into the indefinite future for estate tracks and agricultural drainage. Any comprehensive attempt to assess the impact of peatland drainage must also therefore incorporate 'time since drainage' as a factor because many of the key effects are time-dependent and are only evident if time-series data are obtained.

In particular, with a material which consists almost entirely of water, removal of that water almost invariably results in a change in volume of the peat, and as with most soils when undergoing shrinkage as a result of water loss, cracks develop and the surface subsides. Cracks and sub-surface pipes resulting from such deformation may substantially increase the heterogeneity of the peat matrix and short-circuit many modelling systems, while changes in the surface gradient as a result of subsidence will tend to bring about changes in the living layer of vegetation, potentially leading to replacement of peat-forming species by species which have a tendency to dry out the peat even further and thus intensify the effects of drainage.

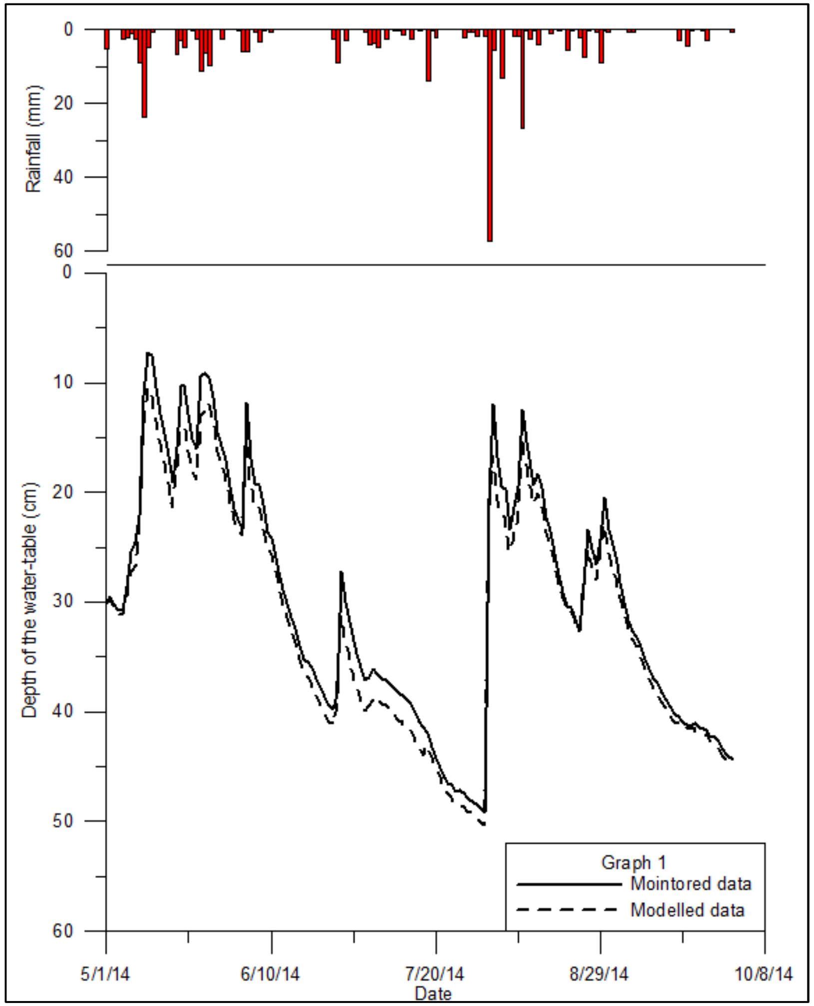

Figure 1: Graph showing the relationship between monitored and modelled water-table data in area of non-peat accumulating raised bog

Modelling raised bog water-table fluctuations

Hugh Cushnan

QUB

Peat-accumulating Active Raised Bog (ARB) once covered over 300,000ha of Ireland, of which less than 0.5% remains due to reclamation. Re-establishment of ARB within the Irish Natura 2000 Raised Bog Network is required under the EU Habitats Directive. Quantifying ARB's hydrological supporting conditions forms the basis of defining restoration targets. Automated water level monitoring in peat at four field sites has demonstrated that different hydrological regimes operate in areas of ARB compared to non-peat-accumulating areas. For ARB, the water table needs to remain within 20cm of the ground surface; achieving this requires an understanding of recharge processes.

A mathematical model that reproduces water-table fluctuation in response to rainfall in areas of non-peat accumulating (Figure 1) and ARB provides a means of characterising the influence of climate on ARB occurrence. The model is based on the water-balance method and utilises rainfall and evapotranspiration data in conjunction with hydrological properties of the peat such as storage characteristics and water-table recession constants.

Modifying the model parameters allowed simulation of impacts on peatland hydrology due to restoration measures. This approach has potential for use in assessing impacts to ARB if restoration measures are not put in place to provide necessary hydrological supporting conditions.

Most of these effects are invisible without appropriate time-series data. Changes in vegetation must be monitored over time (though the recent peat archive can be examined for indirect evidence of drainage-induced change). Surface subsidence can only be detected if measurements of surface level are taken over time. The presence of cracks and sub-surface pipes can only be attributed to drainage if the condition of the peat *prior* to drainage is first determined. Peatlands have become a key topic in the carbon and climate-change debate, with oxidative losses from peatland ecosystems now forming part of the UK carbon-reporting process. Carbon loss means volume loss, yet appropriate time-series data are so rarely gathered when assessing peatland drainage impacts that the knowledge-base on which to form judgements about likely long-term impacts is absurdly small.

Assessing the Impact of Marginal Drainage on Raised Bog Topography and Conservation

Alister Best[1] and Raymond Flynn[2]

1 QUB/RBS

2 QUB

Irish peatland conservation programmes need to be implemented sustainably and in accordance with the law. Any approach needs to consider not only legal and technical issues, but also the social and financial elements of conservation and restoration strategies. Article 6.3 of the EU Habitats Directive provides a mechanism allowing on-going human activity within Natura 2000 areas, protecting priority habitats, provided these do not conflict site conservation objectives. Allowing continued localised peat cutting on SACs, containing priority habitats, requires a robust site characterisation strategy to predict changes in hydrological supporting conditions and their impact on site-specific conservation objectives .

Water loss caused by drainage installed on bogs to facilitate turf cutting increases the volumetric percentage of organic matter (OM%) in the soil, therefore measurement of OM% can give an indication of the condition of an area of a bog in relation to intact areas. This is especially relevant when assessing the potential impact on a site proposed for Article 6 (3). Field data collection at two sites has allowed a prediction of the impacts of localised cutting and drainage on raised bog hydrological supporting conditions and the confidence with which it may be applied for determining site suitability for continued cutting.

Are raised bog ecosystems groundwater-dependent?

Shane Regan and Paul Johnston

Department of Civil, Structural and Environmental Engineering, Trinity College Dublin

Restoration design for areas of raised bog systems in states of degradation typically addresses the hydro-morphological conditions required to sustain active peat formation. However, design rarely accounts for the often complicated sub-surface hydrological processes impacting on bog ecology. Degradation of bog systems is intrinsically related to drainage, not only on the surface of the bog, but also in surrounding areas. Marginal drainage can alter the hydrogeological properties of peat, thereby affecting peat storage capacity and the near-surface flow processes. Evidence from research in Ireland finds that the effect is greatly amplified when marginal bog drainage intersects the regional groundwater table, thereby inducing local dewatering/subsidence, with measured effects extending as far as 800m inside the bog. The interactions between head gradient, hydraulic resistance, geological environment and drain depth appear to be the most significant controlling physical factors influencing peat hydrology and its sustainability. These interactions need investigation on a regional scale, as the hydrological regime within a bog system is inherently supported by regional groundwater flows in the surrounding catchment. Nevertheless, the sensitivity of a bog system to environmental change (such as drainage) will vary depending on the connectivity of the bog to the regional hydrological regime.