Meeting E.U. Water Framework Directive groundwater quality objectives: the challenge posed by phosphorus in western Irish karst aquifers.

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1. Introduction:

Groundwater can be a significant pathway for phosphorus transfer to surface water in certain circumstances. The transfer of ecologically significant quantities of phosphorus has been established in the western Irish limestone lowlands (Kilroy and Coxon, 2005). Thin, or absent, soils and subsoils which overlie conduit dominated karst aquifers provide little opportunity for phosphorus attenuation (See Figures 1 and 2). In addition, in this karst region, groundwater often provides the majority of surface water flow (see Table 1). Therefore the contribution of groundwater phosphorus to surface water bodies can be important.

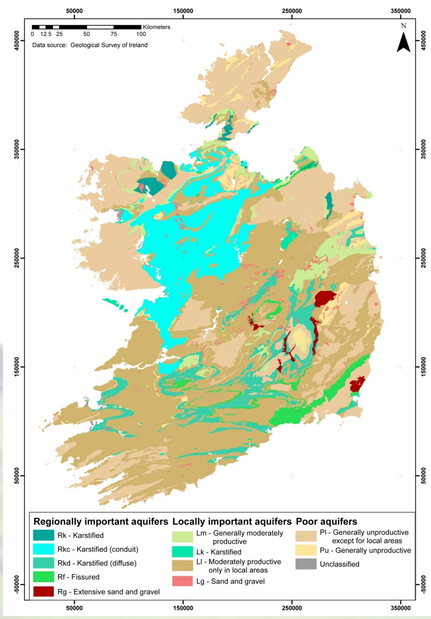

Figure 1 Map of aquifer types in Ireland

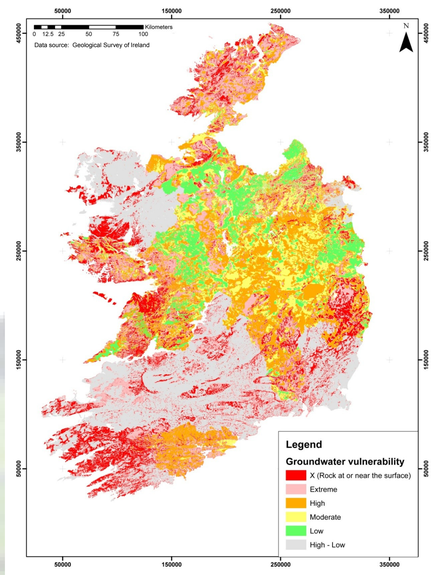

Figure 2 Map of groundwater vulnerability in Ireland

Aquifer type	Groundwater contribution to surface water (%)	
Rg / Lg	median	**90**
Sand and Gravel	range	-
Rk / Lk	median	**74**
Karstified aquifer	range	46 - 86
Rf / Lm	median	**65**
Fissured bedrock	range	43 - 69
Ll	median	**27**
Moderately productive in local zones	range	19 - 37
Pl Pu	median	**21**
Generally unproductive	range	14 - 48

Table 1 Groundwater contribution to surface water per aquifer type. The percentages were calculated by i) conceptual understanding, ii) numerical (NedbØr AfstrØmnings Model (NAM) rainfall-runoff model, a module of DHI's MIKE 11 modelling suite) and iii) spreadsheet and iv) GIS modelling. The groundwater includes both deep groundwater and "top of rock" shallow groundwater.

2. Groundwater phosphorus:

The Irish Environmental Protection Agency's (EPA) national groundwater quality monitoring network consists of 279 monitoring locations (as of April 2010). Groundwater samples are presently taken from these sites and analysed quarterly for total phosphorus, filtered and unfiltered molybdate reactive phosphorus (MRP).

Figure 3 shows the average MRP groundwater concentrations for groundwater body groups. Monitoring point concentrations are weighted to ensure the Impact Potential (see Figure 4) within the zones of contribution match the Impact Potential of the groundwater body groups.

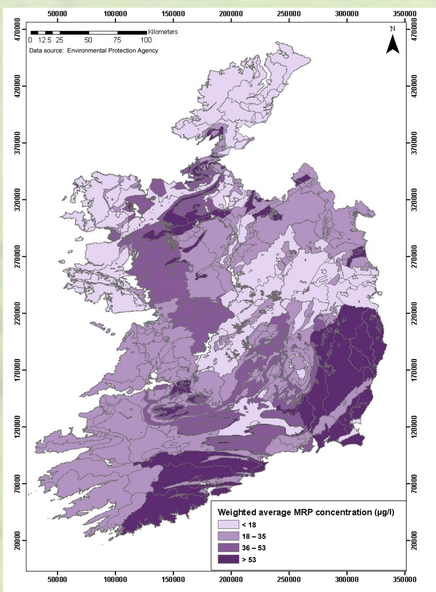

Figure 3 Map of weighted six year average (to 2008) unfiltered molybdate reactive phosphorus groundwater concentrations for groundwater body groups in Ireland

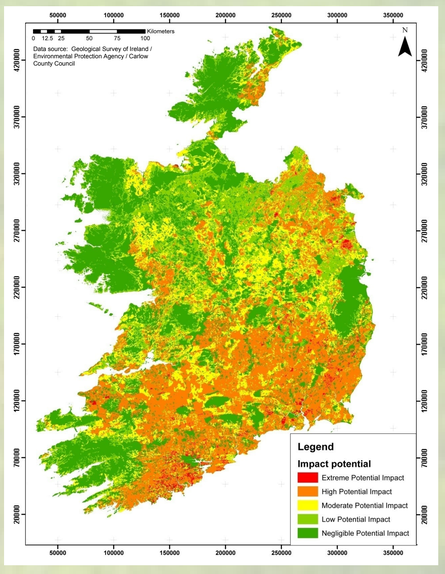

Figure 4 Map of Impact Potential - a measure of pressure magnitude and groundwater vulnerability

Groundwater MRP concentrations are highest where the pressure magnitude is high (i.e. high animal stocking densities and percentage tillage e.g. in the south east and south) or where the groundwater is vulnerable (i.e. the west; see Figures 1 and 2).

3. Impact of groundwater phosphorus on surface water

The E.U. Water Framework Directive (2000/60/EC) required an evaluation of the status of all water bodies, prior to establishing management plans to achieve good status by 2015.

The environmental quality standard (EQS) for molybdate reactive phosphorus (MRP) set for rivers in the Republic of Ireland is 35 µg/l P (as an annual mean). Rivers failing to meet this standard are deemed to be at less than good status. In the Irish Western River Basin District, this includes a large proportion of river channel, much of which lies within the karst lowlands, and this has implications for groundwater body status (see Figure 5).

The classification of Ireland's groundwater bodies was undertaken in 2008 by the EPA using data from the national groundwater monitoring programme. One of the Water Framework Directive status assessments includes a determination of whether the contribution from groundwater is sufficient to threaten the Water Framework Directive objectives for associated surface water bodies. In the case of phosphorus, the test requires consideration of both groundwater phosphorus concentrations and groundwater flow contributions to surface water.

Assessment of adverse impacts of the chemical inputs from groundwater on associated surface water bodies (after Daly, 2009):

Key concept:

The test is designed to determine whether the contribution from groundwater quality to surface water quality is sufficient to threaten the WFD's objective for these associated water bodies.

Conditions for good chemical status are not met when:

- associated river surface water body does not reach its objective, AND
- groundwater threshold values are exceeded, AND
- groundwater contributes more than 50% of the pollutant load required to cause poor status in the associated surface water body i.e. in the case of phosphorus, to cause the EQS of 35µg/l P to be exceeded.

The results of this assessment were that 101 groundwater bodies (13.3% of area) in the Republic of Ireland were at poor status due to the contribution of phosphorus from groundwater bodies to associated surface water bodies (Daly, 2009; see Figure 6). The vast majority of these groundwater bodies are in karst aquifers (see Figures 1 and 6).

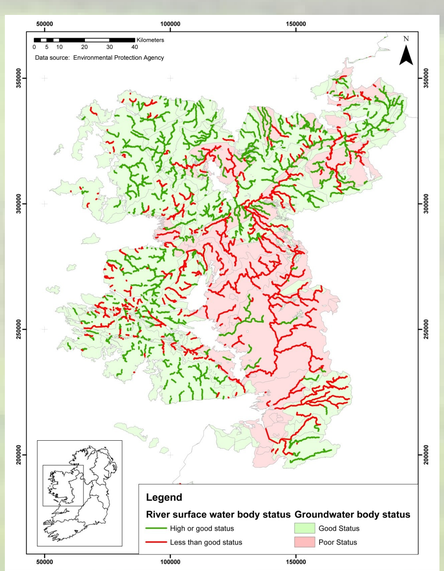

Figure 5 Map of river surface water body status in Ireland's Western River Basin District. Groundwater body status from the assessment of adverse impacts of phosphorus from groundwater on associated surface water bodies is also shown.

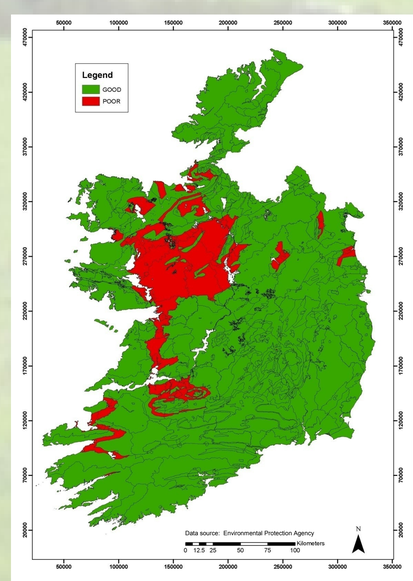

Figure 6 Map of Ireland's groundwater body status from the assessment of adverse impacts of phosphorus from groundwater on associated surface water bodies.

4. Conclusions / Further work:

The transfer of ecologically significant quantities of phosphorus has been established in the western Irish limestone lowlands. This scenario translated into a significant number of Irish groundwater bodies being classified as poor status due to the potential adverse impact of phosphorus from groundwater on associated surface water quality. This situation presents a challenge for those working to attain the required Water Framework Directive objectives of good status by 2015. Further research is required on phosphorus sources and transfer pathways within poor status groundwater bodies, and on the implications for river basin management plans.

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References:

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