Appendix 2

PEDAL 2 Phosphorus Expert Workshop report 17th and 18th November 2009

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1. Workshop Aims

The primary aims of the workshop were; (i) to review the PEDAL1 Visual Assessment (VA); (ii) to think about the way in which the VA could be integrated with the decision tree modelling approach for phosphorus (P); and (iii) to consider how the effect of mitigation measures for P (primarily those acting upon delivery mechanisms) can be represented in the model.

2. PEDAL2

The PEDAL decision-tree model estimates a fuzzy delivery coefficient (DC) for headwater catchments using the ratio of the DESPRAL measure of P mobilization and catchment P fluxes. The PEDAL2 project aims to expand this model to be able to estimate the likely effect of mitigation measures on DCs (i.e. by modification of the fuzzy estimate). A secondary aim is to consider mitigation of mobilisable P e.g. by modification of DESPRAL directly or modification of soil P status (used to estimate DESPRAL in the expanded model – Figure A2.1).

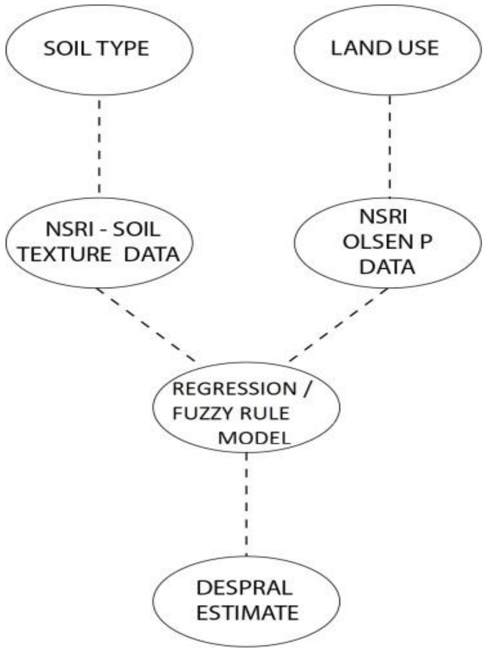

Figure A2.1: Schematic structure of the PEDAL sub-model to estimate DESPRAL P at locations with no observations. The DESPRAL estimate is subsequently used as an input to the PEDAL fuzzy decision tree.

2.1 The PEDAL1 Visual Assessment structure

Evaluation of the VA considered the variables represented in the structure, their relative weights and how they were combined to form the overall score (The VA for each of the PEDAL2 catchments is provided in Appendix 4). In general there was a consensus that they should all carry equal weight in the absence of any solid evidence to suggest what the weightings should be. There were, however, some instances where discussions indicated that some of the variables should be weighted higher than others. For example, on day 2 the discussion on strategically located ponds indicated that they may have a major effect on P delivery when well constructed and well located (see also estimates in Fig A2.6 below): the effect of other measures (e.g. location of gates) may not have as great an impact. So perhaps the VA variables could be ranked in order of likely effectiveness, even if in a very general manner? LS suggested that it may be a good idea to get more expert opinion using a web-based system where distributions of rankings can be obtained and that there should be a greater degree of desk-top based input to the VA (e.g. using GIS, aerial photography etc.). RB suggested that a desk top study be part of the PEDAL2 VA.

PW suggested that there should be a desk study before the VA to help guide it. PS confirmed that this was done for PEDAL1 by at least a catchment map or a high resolution DEM to score and divide the riparian area, the actively connected area and the non-connected area before fieldwork, but that the procedure could be more formalised. A GPS or a tablet computer to record the changes of these boundaries may be helpful. It was also noted that Google Earth and Google Maps may be helpful (although may be out of date to some degree). It was also noted that it would be interesting to look at the difference between every VA and desk top study.

A number of people expressed the opinion that the use of erosional and depositional features was potentially problematic as some may be hard to detect at different times of year. The members of the group wanted a better explanation of the VA variables to help in the interpretation of the VA rankings and scores (e.g. the field size and shape really refers to the density of field boundaries where a higher density indicates higher retardation of P delivery).

CD made the point that location of accelerating/retarding features is important and should be included in the VA. It was discussed that while this should be implicit in any experienced persons assessment it should be made explicit in any revised VA protocol. RB suggested that this was already the case in the PEDAL1 protocol. PW also said that the VA provides a strong indication of land-management status even with a stand-alone assessment.

The variability of the VA between assessors was discussed at length. Many of the VAs for the original PEDAL1 project were carried out by the same person and so were deemed to be consistent. However, for future use, with different assessors, the VA must be as structured as possible to assure consistency. Within the workshop we carried out an exercise from the documented VA reports from two of the catchments from the original PEDAL1 project (Waveney and Colworth) which showed that VA score varied between by 100% and 250% for Waveney and Colworth respectively.

2.2 Uncertainty associated with the decision tree

The decision tree model developed for the PEDAL1 project was trained upon discrete best estimate values of DESPRAL and catchment P fluxes. Uncertainties associated with these inputs were not explicitly propagated through the tree. In PEDAL2 we are considering implementation of a decision tree which accepts uncertain inputs where the uncertainty can allow classification of catchments into multiple model nodes (e.g. see the representation in Figure A2.2). The workshop discussions highlighted improvements that could be made using PS's analysis using sub-samples of the Oona catchment data, to uncertainty estimates associated with DESPRAL from the previous project data and to uncertainty estimates associated with catchment P fluxes. In particular uncertainties that give biased P flux estimates (assuming that other catchments have similar event P flux characteristics) as long as it is a fair assumption that these data are representative for other sites.

The issue of P fluxes from septic tanks was also highlighted as a potential bias for catchment P flux estimates: it was thought that fluxes should be corrected if enough information is available. However, as we don't always know the location, type and condition of septic tanks in a given catchment it is difficult to know what correction to use. One option raised was a correction based upon a septic tank survey, which could be included in the VA.

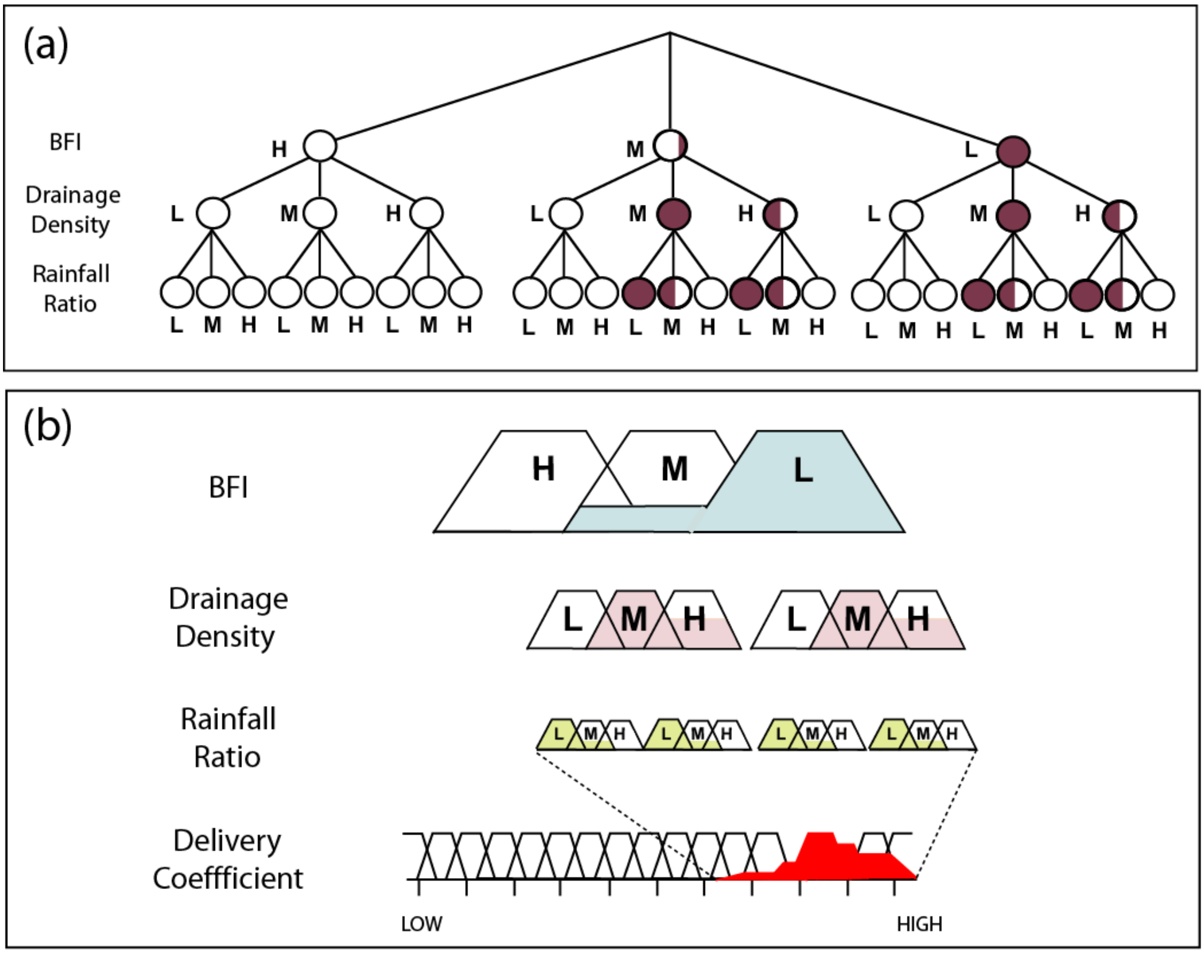

Figure A2.2: Schematic representation of the proposed P model framework. Pane (a) shows how catchments with characteristics (as described by the variables BFI, drainage density & rainfall ratio) are classified through the model (from top to bottom). Where a node is fully shaded then the variable of interest is a full member the fuzzy set, Low (L), Medium (M) or High (H) and where partial members they are shown partially shaded. The fuzzy sets for an example catchment with properties that fall in the BFI (L = full, M = partial), Dd (M = full, H = partial) and Rr (L = full, M = partial) are shown in pane (b) along with the subsequent fuzzy DC range highlighted in red.

The issue of having a DC of > 1 and up to about 5 was raised – this was not seen to be a major problem and was thought to be part of the uncertainty associated with calculation of DESPRAL and P fluxes, and also systematic errors such as point sources, agricultural point sources, stream bed and bank erosion and incidental losses.

2.3 Use of the Visual Assessment information in combination with the DCs

During the PEDAL1 project the VA was not combined within the decision tree model because there was no clear relationship between the VA score and the observed DC, even though the DCs implicitly include all phenomena included in the VA. PS confirmed that he had analysed these data and found no relationship.

KB suggested that rather than use the VA to modify the DC we should use the VA to estimate likely changes to the DC given mitigation measures. However, when using the model in predictive mode it is required to estimate delivery at unmonitored locations where no VA is available. Thus we will also need rules that act directly on the DC range. The point was made that mitigation may also change the actively connected areas, as well as just the rankings, in the scoring system of the VA.

NP asked if it would be possible for the VA to be used to say whether or not the DC is of low, medium or high confidence – i.e. where both are in agreement give higher confidence to the DC estimate and vice-versa. This implies we count them both as valid (although not necessarily equally valid). However, the VA was never designed to estimate delivery coefficients, but only to standardise or shift predictions.

It was discussed that, as originally proposed in PEDAL and shown schematically in Figure A2.3, it may only be valid to modify the DC within the range output by the model; this assumes that the model output DC range has been trained on sufficient and unbiased data.

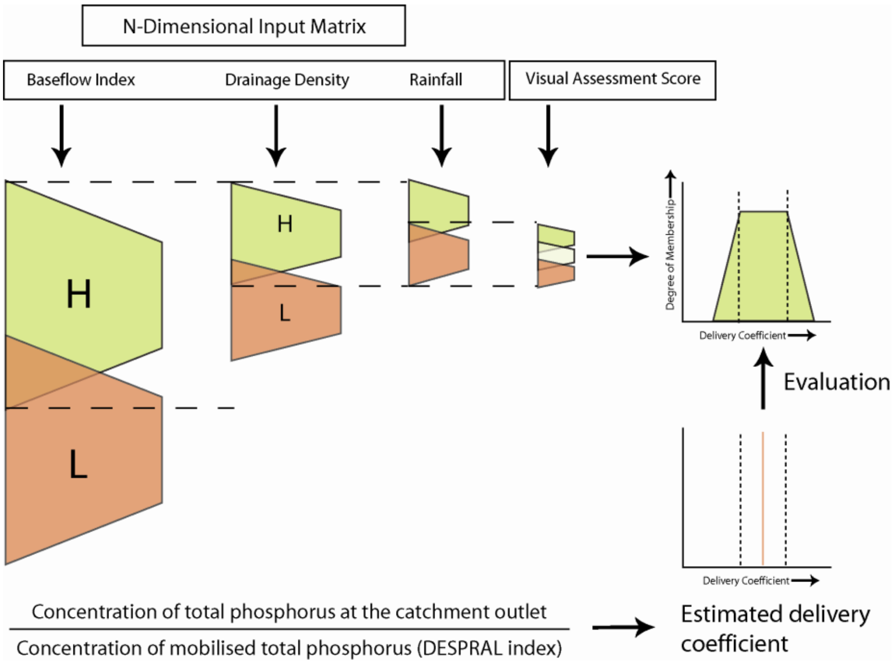

Figure A2.3: Schematic diagram summarising the PEDAL approach and dual lines of approach used to evaluate the risk of P delivery. Modelled values for P delivery are obtained from a fuzzy decision tree approach using the BFI, drainage density and rainfall index to give coarse but nationally applicable fuzzy estimates of P delivery. The uncertainty of these derived estimates may be constrained by field measures of P delivery risk using the Visual Assessment

2.4 The delivery coefficient distributions and what they represent

The theoretical range of DCs for the entire UK is shown as a pink trapezoidal fuzzy distribution in Figure A2.4, i.e. **the population of DCs**. There is also is a theoretical range of DCs for each PEDAL2 catchment classification (described by the model variables) shown as grey trapezoidal fuzzy distributions in Figure 4): i.e. the population of DCs **for each PEDAL2 classification**. Both of these DC ranges include the variability of intrinsic catchment characteristics and the variability of anthropogenic infrastructure: the VA collected information describing both of these categories.

The data collected at the PEDAL2 catchments provide ‘observed’ DCs from a sample of the population which were used to calibrate the model (shown as a purple trapezoidal fuzzy distribution in Figure A2.4). Thus the model estimates provide bounded distributions classified by the model variables of the population of DCs from these classifications (shown as yellow trapezoidal fuzzy distributions in Figure A2.4).

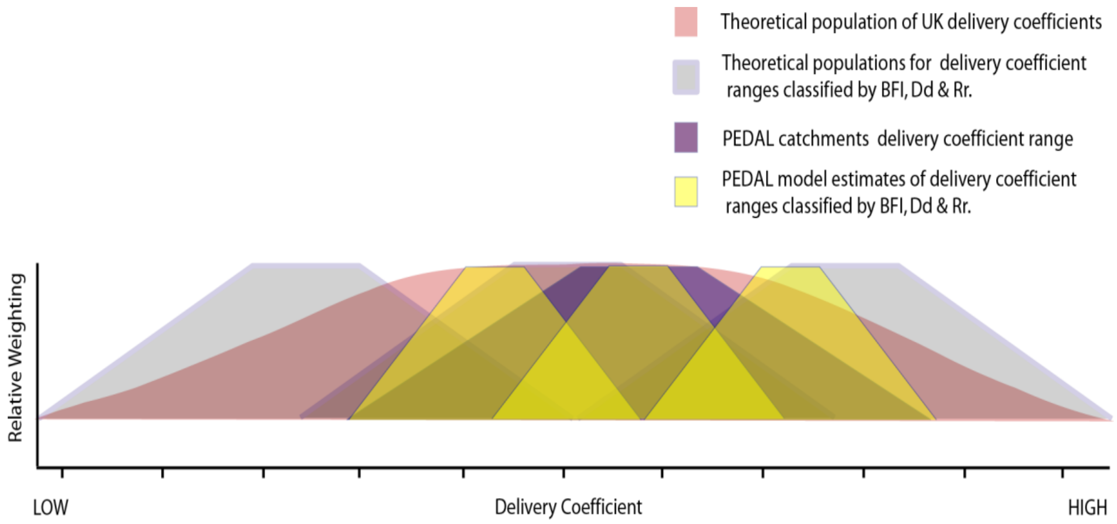

Figure A2.4: Idealised plots of delivery coefficient ranges and visual assessment scores (simplified to low, medium and high)

2.5 Rules for describing mitigation measure effects: the evidence

Incorporation of mitigation measure effects within the model structure is proposed by means of fuzzy rules that describe the modification of the delivery fuzzy coefficient form (e.g. see Figure A2.5). As the discussion progressed, there seemed to be greater agreement that we need to modify DCs directly with mitigation rules. JQ suggested that we could modify the DC and we generally know in which direction the modification should be (JQ presented some figures from previous MOPS work). The magnitude of change is variable depending on the catchment, the spatial location of mitigation and on the baseline mitigation already in the catchment.

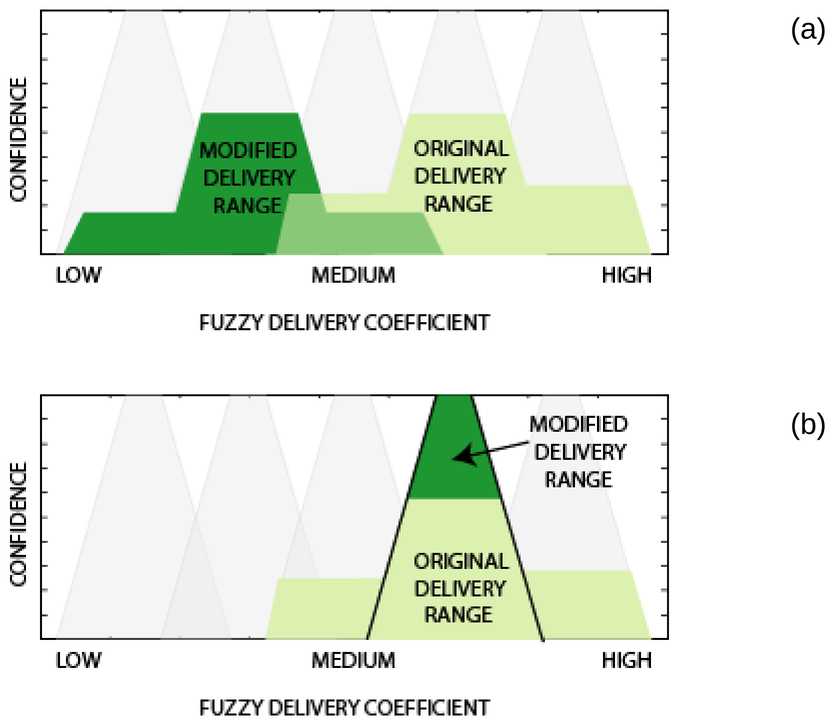

Figure A2.5: An example of the modification of a fuzzy DC range where (a) the distribution has been shifted along its axis and (b) the shape of the distribution has been modified.

Quantification of the effects of mitigation measures on P delivery is relatively sparse in the literature and, of course, only for a few locations. However, there are a number of recent reviews that can be drawn upon to inform our fuzzy rule base including: Cherry *et al*., 2008; Maguire *et al*., 2009; Makarewicz *et al*., 2009, Sharpley *et al*., 2009 Stevens and Quinton 2009a,b. Many of these studies also call for more assessment of effectiveness at larger scales and highlight significant uncertainties. These publications also emphasise the variability of mitigation effectiveness depending on site/catchment specific characteristics and the type of P sources present (e.g. see Withers *et al*., 2009). Coupled with the lack of studies at larger scales there is also a lack of studies running for long enough to enable estimation of how long it will take to see an effect (Sharpley *et al*., 2009). Estimates that have been published are a mixture of expert opinion, interpretation of small scale studies and a few catchment scale studies. A very full collation of methodologies, at 'the farm scale' related to model farm types (arable, arable plus manure, dairy suckler, beef broilers, breeding pigs (Indoor) breeding pigs (outdoor)) has been produced by Cuttle *et al.* (2007); this study also considered likely effectiveness of measures in combination as did the Cost Curve Project (Haygarth *et al*., 2009).

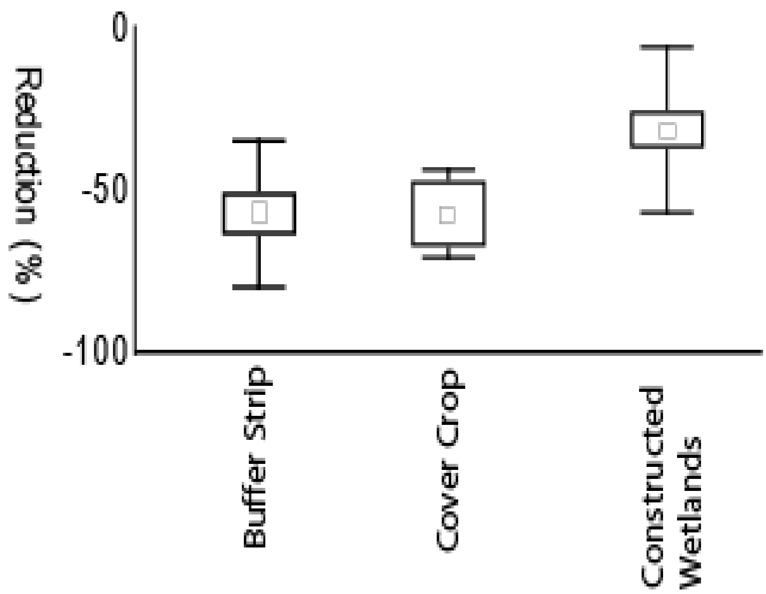

Figure A2.6: Percent TP reduction from mitigation measures when compared to control plots – adapted from Stevens and Quinton (2009b).

The effects of mitigation measures quoted in these literature sources are normally for P loss reduction, rather than a reduction in P DC *per se*: we however are assuming as a first approximation where the mitigation measure is one that primarily acts upon P delivery the information is valid for use. Estimates of variation of likely effectiveness from a literature review (Stevens and Quinton, 2009b) of example individual mitigation measures (in isolation) are presented in Figure A2.6. Ideally, we will need different rules for how these mitigation measures will affect different catchment typologies. An example of the expected reduction in losses after implementation of riparian buffer strips is presented in Table A2.1 for different land use types (from Cuttle *et al*., 2007). In addition to mitigation measures in isolation, we also need to implement measures in combination. It was agreed that the rules generated for the Cost Curve project (PE0203)[1] presented by PH should be used as a basis to work from in the model.

Ideally, rules should also be elicited for source and mobilization control. PJ highlighted some work (in draft form at present) which shows the decline in soil-P overtime owing to reduction in P inputs. He

1 http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=10324&FromSearch=Y&Publisher=1&SearchText=PE0203&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description

said that the likely reduction in P source could be best predicted using initial soil P concentration and farm P balance. PW also mentioned a draft paper on the Psychic P index which may be of use.

Table A2.1: Reduction in TP loss after the introduction of riparian buffer strips for model farms – adapted from Cuttle et al., (2007).

Reduction in pollutant loss at the farm scale (baseline loss for the farm type is shown in parentheses)		
Farm type	Total P (kg P/ha)	
	sandy loam	clay loam
Arable	0.10 (0.3)	0.05 (2.3)
Arable + manure	0.11 (0.4)	0.06 (2.5)
Dairy	0.07 (0.2)	0.06 (2.8)
Beef	0.06 (0.2)	0.02 (1.0)
Broilers	0.13 (0.4)	0.07 (3.2)
Indoor pigs	0.14 (0.5)	0.08 (3.7)
Outdoor pigs	3.29 (10.5)	

3. Conclusions

There was consensus that the VA summarises useful information on accelerating and retarding features with respect to P delivery. There was a lack of consensus over how this information should be combined with delivery coefficients estimated from observations and from the decision tree model. This lack of consensus led to the conclusion that the effect of mitigation measures should be used to modify directly the fuzzy delivery coefficient using a fuzzy rule base. The experts agreed that, although sparse and uncertain, the literature information on mitigation measure effectiveness in isolation would be enough for a set of 'first-approximation' rules to be implemented in the model. For mitigation measures in combination it was agreed that the expert opinion elicited during the Cost Curve project should be used in the first instance. Mitigation of soil P sources may best be represented using initial soil P concentration and farm P balance.

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