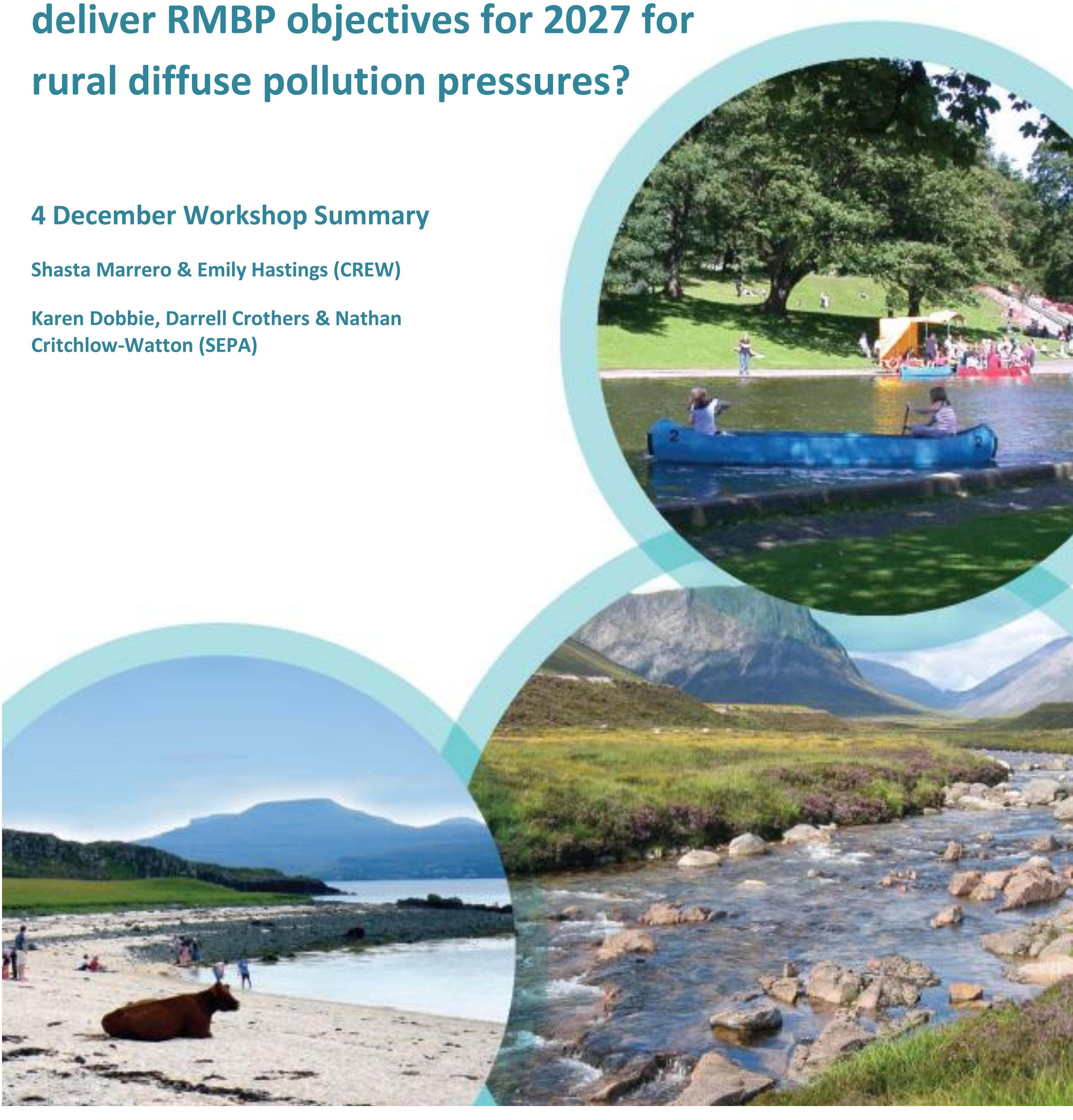
What evidence does SEPA need to deliver RMBP objectives for 2027 for rural diffuse pollution pressures?

4 December Workshop Summary

Shasta Marrero & Emily Hastings (CREW)

Karen Dobbie, Darrell Crothers & Nathan Critchlow-Watton (SEPA)



Introduction

Rural diffuse pollution is the main cause of downgrades to the water quality of Scotland. The objective for this workshop was to confirm the evidence gaps in our understanding of rural diffuse pollution, which are hindering the delivery of the ambitious RBMP improvement objectives set for 2027.

Experts attended the workshop to help SEPA understand the state-of-knowledge and determine what the priorities should be for research and evidence gathering for the next six years.

Workshop summary

On 4th December 2017, 14 attendees (Appendix 1) participated in a workshop to confirm SEPA's evidence needs for rural diffuse pollution. Building on a previous workshop, the areas for discussion were grouped into three topic areas:

1. Do we need action beyond the focus of current General Binding Rules compliance?
2. Better understanding of the source, pathway and fate of phosphorus in the water environment
3. Importance of private sewage discharges

The topics were introduced by SEPA, followed by experts who presented the state-of-knowledge for each.

Key points from each of these presentations are presented below. To support their presentations, the experts have each provided a short paper (Appendices 3-5).

Breakout sessions (notes in Appendix 2) developed research ideas around 'Beyond GBR Compliance' and 'Private sewage discharges'', with phosphorus-related topics spanning both. With expert input, the knowledge gaps were refined into specific questions.

Next steps

The proposed research suggestions will be further developed and presented to the RBMP prioritisation meeting in February 2018. Specifications for prioritised projects will be prepared, with the aim of projects starting by late May 2018.

Wrapping up, all agreed that the workshop was a success and more specifically that:

1) there are fewer unknowns than originally anticipated, making the topics feel more manageable; and

2) this knowledge exchange exercise was very valuable and should happen more often.

Notes from speaker's talks

Do we need action beyond the focus of current GBR compliance by land managers in PCs if we are to effectively tackle diffuse pollution?

Darrell Crothers (SEPA)

- How far will GBR compliance get us?
- What are the options/type of measures needed?
- What will the impact be in the relevant sectors?
- Some catchments are now at 100% compliance
- PP: Examples of farmers who go well beyond compliance – some very profitable examples. These farms are viewing DP as resource wastage and therefore take action to prevent it
- DEFRA now require soil analysis every 5 years. Maybe opportunity to look at applying this in Scotland?

Steven Anthony (ADAS)

- There are new regulations for both England and Wales with some key differences with Scotland's.
- General recommendations from the talk for consideration in any revision of GBRs
    - Containment of dirty yards
    - Alleviation of soil compaction (loosening or subsoiling)
    - Do not apply P fertiliser to high index soils (compulsory soil testing and advance planning)
    - Tramline management to reduce runoff
- Models show to date, we have not done enough to achieve compliance
- Tracer studies are underused - need to look at fields and not just in water
- Monitoring should be at the field scale to understand the breaches
- Buffer strips: Variable effectiveness – buffer strips need to be bigger, more strategically placed. Need to think about long-term, advice in simple rules. Steer towards soil types, slope etc. rather than a focus on crops
- Land drains are a very important P and sediment source. Need controlled drainage. Lessons can be learnt from historic literature
- Yard runoff control is crucial. No field evidence at a large scale however to demonstrate effectiveness
- Soil compaction is difficult to accurately assess and therefore hard to enforce, although 10-20% fields are thought to be severely compacted
- Soil nutrient status: More needs to be done on feeding the crop, not the soil.
- Previous CREW work identified a surplus of P in animal feeds and scope for mineral P reduction
- Tramlines are a very important source of P and sediment. Range of management techniques inc. running lower tyre pressure. Guidance is now robust. Instead of being prescriptive, have something generic like 'you must have a tramline management plan in place'.

Would a better understanding of the fate of P in the water environment help us better target action?

Karen Dobbie (SEPA)

- Does soil P risk status have any relationship to soil as a contributor to water P pollution?
- Are some sources of P/forms of P more important than others when they find their way into the water due to chemical/physical/biological properties?
- There is a large body of work in the last 2 years at ADAS on the extent to which we can feed the crop vs feeding the soil (see AHDB project pdfs below)

Marc Stutter (James Hutton Institute)

- Undertaking work to build on the source -> pathway -> receptor framework to include impacts and sensitivity factors (hillslope sensitivity factors, point source vs diffuse, etc.)
- New paper: 30% increase in winter P loads, must be matched with 20-80% decrease in application
- Summary of CREW Eco P project: Source chemistry, timing, properties of receiving waters
- Nutrient concentrations are not the only important factor – balances and ratios can be important too

How important is the contribution of private sewage discharges to diffuse pollution risks and where are the hot spots?

Brian McCreadie (SEPA)

- Do we have confidence in the modelled source apportionment?
- Discharges not all equal – which ones are contributing to impact? (maintenance, connectivity to receptor, level of treatment, dilution available, P retention/FIO die-off)
- Can we model export loads more accurately using these other variables? If so, can we incorporate into SAGIS for better source apportionment?
- Can we robustly identify 'zone of influence' around impacted waterbodies/areas for targeting measures?
- Would like to apply previous CREW work on effectiveness of measures in reducing FIOs in a real life case study to determine change in compliance
- LM: not just SRP, total load is very important especially in lakes as P behaves differently
- MA: seeing more types of P being applied to land as waste streams to divert waste from landfill
- LM: how P is moving through the system is changing with changing rainfall patterns (short duration high rainfall events). Will the current recommended practices continue to work under these changes?

Linda May (CEH)

- In order to assess risk from private sewage discharges, we need to know fundamentals, like number, location, system type. There are options to get this:
    - Compulsory registration (like Wales)
    - Alternative: use sewer map (septic tanks in sewered areas increases uncertainty)

- Risk factors that determine highest risk tanks are: Slope, distance from waterbody, height of water table in winter (big risk)
- 20-25% private sewage discharges in Scotland discharge directly to water
- Septic tank risk factors & mitigating impacts (CREW report: Onsite Wastewater Treatment Review)
    - Does desludging work? Is the advice correct?
    - P-free detergents – Dishwasher detergent important
    - Septic tank removal – We see improvement when tank removed
    - Do wetland systems work? (Case study shows it seems to help)
    - Temporal variability in output – problems with monitoring (what signal are we seeing?); seasonal/holiday homes
    - Waterbody sensitivity factors important
- Research needs
    - Use Welsh example to assess uncertainty & need for full registration
    - Seasonal, daily, sub-daily variability – What does this tell us about uncertainty?
    - Assess current recommendations for septic systems for efficacy across multiple pollutants
    - Validation of models/assumptions at catchment scale
    - Need to do more to pull existing research together
- How sustainable are practices that are currently in place? (struvite, sludge, digestates)
- No evidence for measures for septic tanks and loss coefficient is only an estimate
- Could the CEH septic tank risk model for NE be applied more widely?

Appendix 1: Breakout sessions and research questions

SESSION 1: 'Beyond GPR Compliance'

All the project opportunities were discussed and placed on a spectrum that goes from 'Defining the problem' to 'Figuring out the solutions' to 'Applying the solutions'? For most measures (with exception of tramlines), we are still identifying the problem. For tramlines, we are up to 'applying the solutions'.

Soil compaction/structure

- How do we get everyone on the same page concerning assessment of compaction?
    - In order to provide advice for areas with serious compaction, the first step is to be able to consistently assess when a soil is severely compacted or not.
    - Knowledge exchange activities to teach groups the technique - Visual Examination of Soil Structure (VESS)
    - Main goal: To demonstrate consistency can be achieved by everyone who needs to perform these assessments
    - Audience includes: Farmers, agricultural advisors, others
- What are the options for field management?
    - Review the currently available remediation/prevention options. How feasible are the options in a Scottish context?
    - If implemented fully, how far will it get us towards 'good' status?
    - Use risk maps to tailor recommendations at a smaller scale e.g. catchment scale (expand N. Baggaley work from CREW)
    - Combine existing risk maps with land use history (risk history) to determine future risk

- Fundamental evidence needed: Tracer-based study
    - Demonstrate in a trial catchment the quantitative benefits of preventing/repairing compaction
    - Use this as a concrete example of why to implement measures, help to convince farmers and other decision-makers
    - Sediment fingerprinting

<u>Drains</u>

- What are the potential end-of-drain solutions?
    - Review end-of-drain solutions used in other locations (e.g. New Zealand, US) and see which of these are appropriate/feasible for Scotland
- What is the efficacy of drains in Scotland?
    - Are the drains working?
    - Are they appropriate to the circumstances? (Designed correctly, built to specifications)
- How much P/FIOs/nutrients are lost/exported through drains?
- Fundamental evidence needed: Comparison study of free vs compacted drains
    - When should we remediate compaction? Are there times/situations when this is not advantageous for the drain operation? (PhD? Requires field experiments)
    - Advice is being given – Use this research to show if the generic rules are applicable
    - How does export of P change if compaction is removed?
    - Where is compaction remediation compatible with field drainage issues? Use catchment typologies to create a targeted study

<u>Buffers</u>

- What is current state of knowledge on buffers?
    - Literature review for recommendations. Include UK sources, but also sources outside the UK that might be applicable; include nutrient literature
    - Should recommendations be based on site details (slope, etc.) or crop? Consensus on this yet?
    - Focus on surface pathways
    - Marc Stutter: special volume will include international research on this topic. Autumn 2018. Wait for this to see what is resolved and issues remain?

<u>Tramlines</u>

- How do we encourage implementation of good practice?
    - Technology/research base is advanced, but it is less clear how to actually encourage people to implement the ideas. What options are feasible (financially and otherwise)? What routes will have best chances of success (regulation, grants, other community-based methods)?
- How can we use this topic (tramlines) to help other topics reach this readiness level?
    - This is a topic that is advanced in terms of readiness. The research has been done and they worked in partnership with industry to test things, etc. It might be useful to map out the steps needed to reach this point in the process and use that to help progress/map out how to achieve success for other less-advanced topics.

Nutrients

- Novel materials/waste disposal
- Soil-testing plan – robust
- Investigate sensitivity factors
- FIOs: revisit screening tool? (after VIPER results in Feb?)

General research ideas:

- Were there any long-term changes from the previous farm study?
    - New study to revisit farms that were contacted/sampled in a previous study
        - Did they use any of the advice that was previously given? Changed behaviour?
        - Were there any measurable changes in the soils?
        - Was the advice sound?
- How 'future proof' are existing recommendations/models?
    - Do we need to rerun any models for new climate scenarios? (e.g. lots of drizzle replaced with short duration, high intensity events)
    - How robust are existing recommendations under these climate scenarios?

Discussion topics

- Add 'previous management' or 'previous land use' to risk maps
- Develop typologies – to help target areas suitable for studies in specific topics (compaction, drains) or target recommendations
- If all soils are at optimal level/implement good practice, how far does this get us to 'good' status for waters? In general, we lack the ability to predict the impact of implementation of measures.
- All of these ideas eventually require people to adopt changes. How do we get people to make behavioural changes? Discussion: Demonstrate value, win/win scenarios, show successes. Use the concept of unrecognised yield loss to help make the case.
- Stay informed about what is going on in forest research and how it might link with DP
- Need to make links: Compaction <-> drains; drains <-> nutrients; buffers <-> nutrients

SESSION 2: 'Private sewage discharges'

- What are the risks and impacts from private sewage discharges to water quality? Notably in protected areas
    - Protected areas: bathing waters, shellfish protected areas, ground waters (where used for drinking water provision)
    - Areas of concern: FIOs, sediments, Nitrates, P (and in what form)
    - Are the impacts an issue? At what scale? Mostly interested in the cumulative impacts but even one sewage discharge in the wrong place i.e. in close proximity to a bathing water, can lead to failure
    - Risk mapping for FIOs and their die off rate
    - Limited existing information to address this questions

- Have we got adequate confidence in our source apportionment models for private sewage discharges?
    - It is not currently possible as not mechanistic at the moment, but would be ideal if SEPA were able to adjust the model, run scenarios etc.

- Where are the private sewage discharges across Scotland?
- How far away does a private sewage discharge need to be to stop being a direct issue for a protected area?
    - Zone of influence
    - Where did 1.5km as a buffer come from?
    - Do we have confidence in this figure?
    - Risk mapping with high, medium, low risk as a potential approach but this will vary with factors other than distance i.e. tank maintenance and treatment type
    - Are FIOs transported via attachment to biofilms and algal blooms?

- Where are the issues with bathing waters and how do we target action?
    - Encouraging home owners
    - Grant availability

- Which measures actually work? How effective are they? How much would they cost?
- Can we detect discharges and their source i.e. detection of private sewage discharges vs sewage treatment works
- How do you calculate decreasing risk along the zone of influence?
- How do you deal with cumulative risk?
- Can we develop a tool taking factual information on private sewage discharges to identify the risk level categories (H, M, L)?
    - GIS based information for some categories
    - National averages for others i.e. house age = sewage treatment type
    - Proximity to channel

- What is the role of re-suspended sediments and the impact of changing flows?
    - Impact of temperature
    - Die off
    - Life time of FIOs
    - Weather events lead to significant changes to the baseline

- Do we understand lags and travel times?
    - Sediment type
    - Stream flow
    - Tracing studies

- If we undertook measures to improve all private sewage discharges within 1.5km, would it make enough of a difference to improve bathing waters?

Appendix 2: Attendees (SEPA unless noted)

Nathan Critchlow-Watton
Karen Dobbie
Marc Stutter (James Hutton Institute)
Linda May (CEH)
Steven Anthony (ADAS)
Janet Shepherd
Ruth Stidson
Peter Pollard
Brian McCreadie
Mark Aitken
Ian Milne
Jannette MacDonald (CREW)
Emily Hastings (CREW)
Shasta Marrero (CREW)

Appendix 3: Steve Anthony

Effectiveness of Measures: Do we need action beyond the focus of current General Binding Rules compliance?

Dr Steven Anthony, ADAS RSK Ltd.

Introduction

General Binding Rules (GBRs) are a mandatory set of rules followed by farmers in Scotland which cover *specific low risk activities* contributing to diffuse pollution from agriculture (DWPA) and are intended to be *broadly applicable to all farms* and relate to widely accepted *standards of good agricultural practice*. The existing GBRs (*below*) can be characterised as prevention of potentially polluting activities within high risk areas and/or at high risk times:

- GBR10: Discharge of water run-off from a surface water drainage system to the water environment;
- GBR11: Discharge into a surface water drainage system;
- GBR18: Storage and application of fertilisers;
- GBR19: Keeping of livestock;
- GBR20: Cultivation of land;
- GBR21: Discharge of surface water run-off;

The primary focus of Scotland's DWPA control strategy is centred on achieving compliance with the GBRs. Monitoring and modelling studies (see, for example, Gooday *et al*., 2016) indicate that the existing GBRs will not be sufficient in themselves to achieve Good Ecological Status under the Water Framework Directive, nor microbial water quality standards under the Bathing Water Directive and Shellfish Water Protected Area designations, in all catchments. SEPA seek to understand whether there are gaps in the scope of the existing GBRs that could play an important role in meeting water quality objectives.

Smith *et al*. (2017) have recently submitted a report to Welsh Government on the identification of agricultural 'Basic Measures' that address the most common causes of DWPA and are broadly applicable to all farmers. Defra (2017) have also published a policy paper on 'Farming Rules for Water' that introduces a final set of GBR equivalents that will take effect in England from April 2018. A rapid reading of these reports suggest that explicit guidance on the following are gaps in the existing GBRs, and the workshop presentation considered each in turn, anticipating a recommendation for strong guidance on tramline management to be incorporated into the existing GBRs:

- Containment of dirty yards;
- Alleviation of soil compaction by loosening or subsoiling;
- Do not apply phosphorus fertiliser to high index soils (Compulsory soil testing and advance planning);
- Tramline management to reduce runoff;

Note that the focus of the workshop presentation, and the following discussion, was on phosphorus control. This reflected our own (ADAS) expertise in modelling phosphorus emissions to watercourses and being able to directly compare predicted concentrations with regulatory standards for priority catchments. We have developed a modelling framework for Scotland that explicitly disaggregates pollutant emissions from agricultural and non-agricultural sectors, and by a range of sources, areas and pathways for the agricultural sector, allowing prediction of the long-term effects of full GBR implementation. The framework predicted that only one third of river catchments that presently fail phosphorus standards would achieve GES following full implementation of the existing GBRs, and that half of the diffuse phosphorus load is delivered via sub-surface drain flow that is largely unaffected by edge-of-field mitigation.

The framework predictions have been verified against measured pollutant concentrations at Harmonised Monitoring Scheme (HMS) stations across Scotland (Gooday *et al*., 2016), and by comparison with independent diffuse *vs* point source apportionment based on chemical mixing models (*sensu* Bowes *et al*., 2008). However, we recognise that considerable catchment specific uncertainty remains in the relative importance of source areas and delivery pathways, especially in the characterisation of critical source areas, and this impacts on our ability to predict the effect of the existing GBRs in individual catchments. Remote sensing of the extent of the baseline spatial extent of critical source areas (as in a current SEPA sponsored study, delivered by ADAS and Glasgow University) and wider application of sediment finger-printing and particle tracking techniques are critical in verifying assumptions that may lead to the over or under prediction of existing GBR impact.

Nevertheless, we are confident that drain flow is an important pathway for the delivery of phosphorus and sediment to watercourses. Tracer studies (Chapman, *et al*., 2001; 2003; 2005) and a recent synthesis of United Kingdom field measurements of surface and drain flow phosphorus concentrations with respect to soil phosphorus levels (Withers *et al*., 2017) generally corroborate the pathway apportionment.

What is less certain is the impact of failing drain function (in the context of climate change, Ockenden *et al*., 2017; or a consequence of the age of existing installations; Hallett *et al*., 2016) and the consequences of drain reconditioning and remediation of widespread soil structural damage. Intensive site investigation of the consequences for the relative importance of surface and sub-surface sources and delivery of soluble (more ecologically relevant) and particulate phosphorus, would help improve our understanding of the effectiveness of GBRs on the artificially drained soils of Scotland. This should also scope the impact on climate change emissions, as soil water status is critical in controlling nitrous oxide emissions.

Existing GBR Enhancement

Before considering gaps in the existing GBRs it was appropriate to consider whether any of the existing GBRs could be enhanced or made more explicit.

No Cultivation Strip (GBR 20)

General Binding Rule No. 20 'Cultivation of Land' requires that land must not be cultivated for crops if it is within 2 m of any surface water. The resulting grass margin can act to trap particulates and encourage the re-infiltration of surface runoff from adjacent land. However, meta-analyses of field studies have shown that such narrow margins are relatively inefficient (see, for example, Collins *et al*., 2009), especially in the context of rill rather than sheet flow that is common in arable areas of Scotland (Watson and Evans, 2007) and accounts for the majority of surface erosion losses (Evans *et al*., 2016). There should be sufficient field evidence in the peer reviewed literature that could be synthesised to propose a site specific increase in the margin width, to take into account of crop, soil and topographic risk factors (see, for example, Kronvang *et al*., 2003; Balana *et al*., 2012; Palmer and Smith, 2013) that would enhance the impact of the GBR. However, the significant productive 'land take' associated with an increased margin would require a detailed cost impact assessment, to overcome anticipated protest and a serious consideration of the alternative for prevention (*see tramline disruption below*) rather than mitigation or capture of surface runoff.

Keeping of Livestock (GBR 19)

Cattle spend a disproportionate amount of time in water courses or in the riparian area if given free access, and survey data from the SEPA Catchment Characterisation Walks (2012) within 14 Priority Catchment Areas of Scotland indicated that only 50% of the watercourse length was fenced. Direct excretion into the watercourse circumvents the bacterial die-off that occurs in manure storage and in between runoff events following spreading / direct excretion to land. The exclusion of livestock from watercourses could therefore have a significant impact on the microbial water quality of shellfish beds and bathing waters that ultimately receive the contaminated runoff. Kay *et al*. (*in prep*), for example, have recently measured order-of-magnitude reductions in faecal indicator concentrations at times of high flow following total exclusion of cattle from watercourses in the south-west of England; and Kay *et al*. (2007) measured similar reductions in a study of fencing at Brighouse Bay, Scotland. Kay and Crowther (*in prep*), in a review of interventions to reduce microbial pollution from livestock farming to coastal waters during the summer bathing season in the United Kingdom, also prioritised direct defecation into watercourses.

A total of 84 Shellfish Water Protected Areas have been designated in Scotland, whilst 19% of bathing waters achieve sufficient and 13% achieve only poor quality against Bathing Water Directive (2006/7/EC) objectives (SEPA, 2017 Bathing Water Season). Reduction in direct faecal indicator and pathogen emissions from agricultural (and non-agricultural) sources should therefore be an important objective of GBR implementation.

General Binding Rule No. 19 'Keeping of Livestock' does not explicitly require that livestock are excluded from watercourses, although earlier modelling work by Gooday *et al*. (2016) took this view in projections of the best possible outcome of existing GBRs for Scotland. They calculated that direct excretion into watercourses accounted for 9% of faecal indicator emissions from grassland areas. Fencing of watercourses (*and provision of watering points*) would provide complete control of this pollutant source. A further benefit of fencing is combating river bank erosion, which is accentuated by removal of vegetation cover by cattle trampling. Collins *et al*. (2010), for example, reported an average 31% reduction in the contribution of eroding river banks to interstitial sediment input to salmonid spawning gravels using sediment tracing techniques in the south-west of England.

There are few field studies of the direct impact of stock fencing on microbial water quality in the United Kingdom (see, Millington and Randall (2014) for a quick scoping review). A policy challenge in requiring stock exclusion of all farmers in Scotland as part of a GBR is that not all agricultural land will be directly contributing runoff to a failing water body. Further intensive site investigation would therefore be required for imposition on a case by case basis.

Discharge for Surface Water Runoff (GBR 10)

General Binding Rule No. 10 'Discharge of Surface Water Runoff' provides for construction of a Sustainable Urban Drainage System (SUDS) for buildings, roads and yards constructed after 2007, and that all reasonable steps must be taken to ensure that the discharge will not result in pollution of the water environment. Current guidance on rural SUDS (Duffy *et al*., 2016) indicates that they are not appropriate for the more contaminated areas of steadings, specifically yards with regular livestock access for gathering and/or feeding.

There is a large evidence base for the effectiveness of treatment wetlands (Kay *et al*., 2012; Vyzmazal, 2005; Knight *et al*., 2000) and we should consider a targeted review of their effectiveness for the more contaminated areas of steadings, with appropriate adjustment to guidance, and GBR enforcement for steadings of *any* construction date. National modelling by Gooday *et al*. (2008) indicates that containment of steading runoff would make only a small contribution to national emissions in Scotland, but this does not preclude a significant local impact on microbial emissions in the immediate vicinity of bathing waters and shell fish beds.

Candidate GBR Gaps

The remainder of the presentation considered some specific gaps in the existing GBRs that could have a widely applicable and positive impact on DWPA:

Alleviation of Soil Compaction

Damage to soil structure, resulting from long-term machinery wheeling and livestock treading, is associated with increased ponding, surface runoff and pollutant emissions from agricultural land. Hallett *et al*. (2016) sampled fields from four Scottish catchments, reporting severe soil structural degradation in 18% of top soils and 9% of soil subsoils, a rate similar to that surveyed by Newell-Price *et al*. (2013) in England and Wales.

Methods of rapid visual assessment of soil structure have been successfully developed in Scotland and would be simple enough for farmers and their advisors to use (see, for example Ball *et al*., 2007; 2016). Different methods of visual soil evaluation have been shown to be well related. For example, Newell-Price *et al*. (2013) found a high correlation between soil evaluations using the Landcare Visual Soil Assessment (VSA) and Peerlkamp Soil Structure (ST). A recent review of evaluation techniques has also concluded that the methods are robust, and recommends work to develop on farm sampling procedures (Emmet-Booth *et al*., 2016).

It is therefore recommended that regular soil structural evaluation of grassland soils and remediation of compaction by, for example, sward lifting is considered for inclusion in the GBRs. However, at 'action levels' there will undoubtedly be some disagreement between the available tests and leniency in implementation would be required, supported by expert advice on the best method and timing of remediation. Paul Newell-Price also advised that it was critical to avoid 'recreational sward lifting' at considerable cost of time, money and energy (*pers. comm.*).

Note that there have been just five studies of the agronomic benefits of alleviation grassland soil compaction in the United Kingdom and Republic of Ireland, dating from 15 to 25 years previous (Bhogal *et al*., 2011), so there would also be a need for further demonstration of the farm business benefits.

Soil Phosphorus Testing

Soil phosphorus levels have a direct and proportion effect on phosphorus concentrations in both surface and drain flow from agricultural land (Withers *et al*., 2017) and a significant proportion of fields in Scotland have high or very high phosphorus levels that are surplus to crop requirements (Sinclair *et al*., 2011). Enforced regular soil phosphorus testing and planning in advance to meet soil and crop nutrient needs should therefore be considered for inclusion in the GBRs, as included by Defra in the 'Farming Rules for Water' in England and recommended by Smith *et al*. (2017) for Wales.

We should be cautious in forecasting the effect, however, as soil phosphorus levels have remained constant in the period 1996 to 2010 despite a long-term reduction in the agricultural phosphorus balance of input and offtake (Edwards et al., 2015). Also, phosphorus concentrations at the agronomic optimum soil phosphorus level may still pose a eutrophication risk, especially in surface runoff (Withers *et al*., 2017).

A significant programme of work has recently reported on routes to improving phosphorus use efficiency in arable crops (Sylvester-Bradley *et al*., 2016; Edwards *et al*., 2015) and questions the current approach of relying on soil phosphorus storage rather than fresh applications of phosphorus to meet crop requirements. There is a need to develop targeted fertiliser technologies with as complete phosphorus recovery as possible, exploiting the potential of slow release fertilisers, seed dressings and foliar sprays, but critically also the breeding of crop varieties capable of exploiting fresh applications at low background levels of soil phosphorus.

In the meantime, following new guidance on the amount of phosphorus required to run up or down soil phosphorus levels that varies with the sorption capacity of mineral soils in Scotland (Sinclair, 2016) should be encouraged.

Tramline Management

Field studies on a range of soil textures at multiple sites across Britain have shown that the autumn tramline wheelings of combinable crops can represent the most widespread and important surface pathway for phosphorus and sediment loss from moderately sloping fields (Silgram *et al*., 2010; Withers *et al*., 2006). Runoff and pollutant transport can be up to ten times greater from compacted and repeatedly wheeled tramlines than from field areas without tramlines. This is supported by the field observations of Watson and Evans (2007) in north east Scotland, and Chambers and Garwood (2000) in England and Wales, where rill erosion is commonly associated with wheelings and tramlines.

Silgram (2015; 2008; 2005) has led a programme of work over the past ten years to measure the effectiveness and farm costs of alternative methods for preventing tramline runoff, including the use of flexible and low pressure tyres to prevent compaction, rotary harrow or tine to disrupt or remove compaction, and surface profilers to channel water back into the crop rather than into the tyre imprint. Runoff and pollutant load have been consistently reduced by 75 to 95% compared to conventional practice. The work is well developed, with industry stakeholders and advice being including in guidance issued by Natural England (Natural England, 2011). A partial capital grant towards the cost of tramline management equipment is now available under the higher tier of the Countryside Stewardship Scheme in England. Other tramline management practices to avoid the risk of compaction, runoff and soil erosion include increasing the tramline spacing, contour drilling and spraying, and careful timing of spraying operations to avoid very moist soil conditions.

The prevalence of tramline erosion, and the varied choice of low-cost control methods, means that a requirement for some form of management as a GBR is strongly recommended for consideration.

Addendum on Source Control

As an aside, there are potentially other ways to reduce direct nutrient inputs and potential environment emissions, which may be applicable to a large number of farms in Scotland.

Dietary Phosphorus Supplementation

Phosphorus levels in the diet of cattle generally exceed those required for performance, welfare and fertility. The potential for dietary manipulation to reduce excess nutrients that are excreted and present an environmental risk, has been the focus of recent research in Northern Ireland and Scotland.

Ferris *et al*. (2010; 2010) reported that the phosphorus content of dairy cow diets can be reduced by *c*. 20% with no detrimental performance on performance, health or fertility, with a concomitant reduction in phosphorus excretion. Gooday *et al*. (2016) worked with animal nutritionists to assess the potential for reducing dietary phosphorus intake of dairy cattle in Scotland, and used a national modelling framework to calculate the reduction in emissions to surface waters. National reductions in phosphorus emissions of 3% are feasible, with local reductions in catchments dominated by dairy farms achieving 10% that are comparable to the reductions achieved by agri-environment scheme options (Gooday *et al*., 2016). There are costs associated with sourcing different compound feed ingredients. However, there may be an opportunity for coordinated research on the reduction of both phosphorus and protein (nitrogen; see for example, Sinclair *et al*., 2014) levels in cattle diets, that could make a significant contribution to reducing air quality (ammonia; see for example, Misselbrook *et al*., 2005) and climate change (nitrous oxide; see, for example, on-going Defra projects AC0209 and AC0122) emissions, that are also important policy issues and may help justify costs.

Repeated Manure Applications

Systems of fertiliser recommendations (SRUC Technical Note No. TN650) generally take account only of the readily available manure nitrogen value in the year of application, whereas the mineralisation of organic nitrogen could prove a significant nitrogen source beyond the year of application if the same field is manured regularly (Jaap *et al*., 2013; Bhogal *et al*., 2016). Enforced soil testing to establish the background soil mineral nitrogen supply on regularly manure fields could be considered as a GBR requirement, else some adjustment to recommendation system, that should result in a reduction in application of manufactured nitrogen fertiliser.

References

Balana, B., Lago, M., Baggaley, N., Castellazzi, M., Sample, J., Stutter, M., Slee, B. and Vinten, A. (2012) Integrating economic and biophysical data in assessing cost effectiveness of buffer strip placement. Journal of Environmental Quality, 41, 380-388.

Ball, B. (2013) Soil structure and greenhouse gas emissions: a synthesis of 20 years of experimentation. Soil Science, 64, 3, 357-373.

Ball, B., Batey, T. and Munkholm, L. (2007) Field assessment of soil structural quality – a development of the Peerlkamp test. Soil Use and Management, 23, 329-337.

Ball, B., Guimaraes, R., Cloy, J., Hargreaves, P., Shepherd, G., McKenzie, B. (2016) Visual soil evaluation: a summary of some applications and potential developments for agriculture. Soil and Tillage Research, 173, 114-124.

Bhogal, A., Bentley, C., Newell-Price, P. and Chambers, B. (2011) The alleviation of grassland compaction by mechanical soil loosening. Defra, Project BD5001, Final Report, 27 pp.

Bhogal, A., Williams, J., Nicholson, F., Chadwick, D., Chambers, K. and Chambers, B. (2016) Mineralisation of organic nitrogen from manure applications. Soil Use and Management, 32, 32-43.

Bowes, M., Smith, J., Jarvie, H. and Neal, C. (2008) Modelling of phosphorus inputs to rivers from diffuse and point sources. Science of the Total Environment, 395, 2-3, 125-138.

Chambers, B. and Garwood, T. (2000) Monitoring of water erosion on arable farms in England and Wales, 1990 to 1994. Soil Use and Management, 16, 2, 93-99.

Chapman, A., Foster, I., Lees, J. and Hodgkinson, R. (2005) Sediment delivery from agricultural land to rivers via subsurface drainage. Hydrological Processes, 19, 2875-2897.

Chapman, A., Foster, I., Lees, J., Hodgkinson, R. and Jackson, R. (2003) Sediment and phosphorus delivery from field to river via land drains in England and Wales: a risk assessment using field and national databases. Soil Use and Management, 19, 4, 347-355.

Chapman, A., Foster, I., Lees, J., Hodgkinson, R. and Jackson, R. (2001) Particulate phosphorus transport by sub-surface drainage from agricultural land in the United Kingdom. Environmental significance at the catchment and national scale. The Science of the Total Environment, 266, 95-102.

Collins, A., Hughes, G., Zhang, Y. and Whitehead, J. (2009) Mitigating diffuse water pollution from agriculture: riparian buffer strip performance with width. CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources, 4, 39, 15 pp.

Collins, A., Walling, D., McMellin, G., Zhang, Y., Gray, J., McGonigle, D. and Cherrington, R. (2010) A preliminary investigation of the efficacy of riparian fencing schemes for reducing contributions from eroding channel banks to the siltation of salmonid spawning gravels across the south west United Kingdom. Journal of Environmental Management, 91, 6, 1341-1349.

Defra (2012) Ruminant nutrition regimes to reduce methane and nitrogen emissions. Defra project AC0209, Final Report, IBERS.

Defra (2016) Optimising the efficiency of dietary nitrogen use to reduce emissions and waste in dairy systems. Defra, project AC0122. Ongoing Project. Reading University, IBERS, SRUC and Rothamsted.

Duffy, A., Moir, S., Berwick, N., Shabashow, J., D'Arcy, B. and Wade, R. (2016) Rural sustainable drainage systems: a practical design and build guide for Scotland's farmers and land owners. CREW, CRW2015/2.2, 54 pp.

Edwards, A., Kay, D., McDonald, A., Francis, C., Watkins, J., Wilkinson, J., and Wyer, D. (2008) Farmyards, an overlooked source for highly contaminated runoff. Journal of Environmental Management, 87, 4, 551-559.

Edwards, A., Sinclair, A., Coull, M., Crooks, W., Rees, R. and Lumsdon, D. (2015) Regional trends in Scottish advisory soil acidity and phosphorus results: significance of management history, land use and soil attributes. Soil Use and Management, 32, 44-53.

Edwards, T., Withers, P., Sylvester-Bradley, R. and Jones, D. (2015) Routes to improving the efficiency of phosphorus use in arable crops. HGCA, Research Review, 74 pp.

Emmet-Booth, J., Forristal, P., Fenton, O., Ball, B. and Holden, N. (2016) A review of visual soil evaluation techniques for soil structure. Soil Use and Management, 32, 4, 623-634.

Evans, R., Collins, A., Foster, I., Rickson, J., Anthony, S., Brewer, T., Deeks, L., Newell-Price, J., Truckell, I. and Zhang, Y. (2016) Extent, frequency and rate of water erosion of arable land in Britain – benefits and challenges for modelling. Soil Use and Management, 32, S1, 149-161.

Ferris, C., McCoy, M., Patterson, D. and Kilpatrick, D. (2010) Effect of offering dairy cows diets differing in phosphorus concentration over four successive lactations: health, fertility, bone phosphorus reserves and nutrient utilisation. Animal, 4,4, 560-571.

Ferris, C., Patterson, D., McCoy, M. and Kilpatrick, D. (2010) Effect of offering dairy cows diets differing in phosphorus concentration over four successive lactations: foot intake, milk production, tissue changes and blood metabolites. Animal, 4, 4, 545-559.

Foster, I., Lees, J., Jones, A., Chapman, A. and Turner, S. (2002) The possible role of agricultural land drains in sediment delivery to a small reservoir, Worcestershire, United Kingdom: a multi-parameter fingerprint study. Proceedings, Structure, Function and Management Implications of Fluvial Sedimentary Systems, IAHS Publication No. 276, 433-442.

Gooday, R., Anthony, S., Calrow, L., Harris, D. and Skirvin, D. (2016) Predicting and understanding the effectiveness of measures to mitigate rural diffuse pollution. SNIFFER Project DP1, 290 pp.

Gooday, R., Gittins, J., Moorhouse, D., Wheeler, K. and Wright, E. (2016) To what extent could water quality be improved by reducing the phosphorus content of animal feed? CREW, Final report, 84 pp.

Hallett, P., Hall, R., Lilly, A., Baggaley, B., Crooks, B., Ball, B., Raffan, A., Braun, H., Russell, T., Aitkenhead, M., Riach, D., Rowan, J. and Long, A. (2016) Effect of soil structure and field drainage on water quality and flood risk. CREW, CRW2014/03, 35 pp.

Jaap., S., Luca, B., Shabtai, B., Miguel, B., Sofia, D., Stan, L., Thierry, M., Chambers, B., Ruben, S. and Peter, S. (2013) Residual nitrogen effects from livestock manure inputs to soils. Proceedings, RAMIRAN,

Kay, D. and Crowther, J. (*in prep*) A preliminary empirical database to inform the prioritisation of interventions for reducing microbial pollution fluxes from livestock farming to coastal waters during the summer bathing season in the United Kingdom.

Kay, D., Aitken, M., Crowther, J., Dickson, I., Edwards, A., Francis, C., Hopkins, M., Jeffrey, W., Kay, C., McDonald, A., McDonald, D., Stapleton, C., Watkins, J., Wilkinson, J. and Wyer, M. (2007) Reducing fluxes of faecal indicator compliance parameters to bathing waters from diffuse agricultural sources: the Brighouse Bay study, Scotland. Environmental Pollution, 147, 1, 138-149.

Kay, D., Clarke, A., Crowther, J. and Wyer, M. (*in prep*) Effectiveness of constructed farm wetlands in attenuating faecal indicator fluxes to watercourses from steading runoff on livestock farms.

Kay, D., Crowther, J., Kay, C., McDonald, A., Ferguson, C., Stapleton, C. and Wyer, D. (2012) Effectiveness of best management practices for attenuating the transport of livestock derived pathogens within catchments. In Bos, R. and Bartram, J. (Editors) Animal Waste, Water Quality and Human Health. London, International Association and World Health Organisation, pp. 1955-255.

Kay, D., Crowther, J., Stapleton, C. and Wyer, D. (*in prep*) Faecal indicator organism inputs to watercourses from streamside pastures grazed by cattle: before and after implementation of stream bank fencing.

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

Kronvang, B., Laubel, A., Larsen, S., Andersen, H. and Djurhuus, J. (2003) Buffer zones as a sink for sediment and phosphorus between the field and stream: Danish field experiences. Diffuse Pollution Conference, Dublin, Proceedings, 3-7.

Millington, A. and randall, N. (2014) How effective are farmland interventions for reducing Faecal Indicator Organism (FIOs) in bathing water and shellfish waters (especially Escherichea Coli. And Intestinal Enterococci) coming from river catchments: a quick scoping review. Harper Adams University, 15 pp.

Misselbrook, T., Powell, J., Broderick, G. and Grabber, J. (2005) Dietary manipulation in dairy cattle: laboratory experiments to assess the influence on ammonia emissions. Journal of Dairy Science, 88, 1765-1777.

Natural England (2011) Protecting water from agricultural runoff: an introduction. Natural England Technical Information Note, TIN098, 8pp.

Newell-Price, P., Whittingham, M., Chambers, B. and Peel, S. (2013) Visual soil evaluation in relation to measured soil physical properties in a survey of grassland soil compaction in England and Wales. Soil and Tillage Research, 127, 65-73.

Ockenden, M., Holloway, M., Beven, K., Collins, A., Evans, R., Falloon, P., Forber, K., Hiscock, K., Kahana, R., Macleod, C., Tych, W., Villamizar, M., Wearing, C., Withers, P., Zhou, J., Barker, P., Burke, S., Freer, J., JOhnes, P., Snell, M., Surridge, W. and Haygarth, P. (2017) Major agricultural changes required to mitigate phosphorus losses under climate change. Nature Communications, 8, 161, 9 pp.

Palmer, R. and Smith, R. (2013) Soil structural degradation in south-west England and its impact on surface-water runoff generation. Soil Use and Management, 29, 4, 567-575.

Silgram, M. (2005) Towards understanding factors controlling transfer of phosphorus within and from agricultural fields. Final report to Defra, Project PE0111, 18 pp.

Silgram, M., Jackson, B., McKenzie, B., Quinton, J., Williams, D., Harris, D., Lee, D., Wright, P., Shanahan, P. and Zhang, Y. (2015) Reducing the risks associated with autumn wheeling of combinable crops to mitigate runoff and diffuse pollution: a field and catchment scale evaluation. AHDB, Report No. 559, 123 pp.

Silgram, M., Quinton, J., and Bailey, A. (2010) Hillslope scale surface runoff, sediment and nutrient losses associated with tramline wheelings. Earth Surface Processes and Landforms, 35, 699-706.

Silgram, M.,, Deasy, C., Quinton, J., Jackson, B. and Bailey, A. (2008) Field testing of mitigation options. Defra, Project PE0206, 54 pp.

Sinclair, A. (2016) SRUC Technical Note No. TN668, 8 pp.

Sinclair, A., Crooks, B., and Edwards, T. (2011) Soil phosphorus levels in diffuse pollution priority catchments. SEPA project 30107, Final Report, 142 pp.

Sinclair, K., Garnsworth, P., Mann, G. and Sinclair, L. (2014) Reducing dietary protein in dairy cow diets: implications for nitrogen utilisation, milk production, welfare and fertility. Animal, 2014, 8, 2, 262-274.

Smith, K., Gooday, R., Jones, R., Lathwood, T., Newell-Price, P. and Williams, J. (2017) Welsh Government basic measures project: draft final report. 44 pp.

Sylvester-Bradley, R., Withers, P., Rollett, A., Talboys, P., Walker, R., Edwards, T., Payvandi, S., Heppell, J., Roose, T. and Jones, D. (2016) Improving the sustainability of phosphorus use in arable farming – 'Targeted P'. HGCA project No. 569, Final Report, 194 pp.

Vyzmazal, J. (2005) Removal of enteric bacteria in constructed treatment wetlands with emergent macrophytes: a review. Journal of Environmental Science and Health, Part A Toxic/Hazardous Substances and Environmental Engineering, 40, 1355-1367.

Watson, A. and Evans, R. (2007) Water erosion of arable fields in north-east Scotland, 1985 to 2007. Scottish Geographical Journal, 123, 2, 107-121.

Withers, P., Hodgkinson, R., Bates, A. and Withers, C. (2006) Some effects of tramlines on surface runoff, sediment and phosphorus mobilisation on an erosion prone soil. Soil Use and Management, 22, 3, 245-255.

Withers, P., Hodgkinson, R., Rollett, A., Dyer, C., Dils, R., Collins, A., Bilsborrow, P., Bailey, G. and Sylvester-Bradley, R. (2017) Reducing soil phosphorus fertility brings potential long-term environmental gains: a United Kingdom analysis. Environmental Research Letters, 12, 20 pp.

Appendix 4: Marc Stutter

A better understanding of the source, pathway and fate of P in the water environment ….and how it would help target actions

Marc Stutter, with research outputs from a range of Hutton colleagues

Introduction: In relation to the brief given for the meeting it is crucial to understand the scientific issues behind the questions. I use a summary table here to show some of these and links to sections of the talk.

Questions asked in the meeting remit and background	Scientific points on interpretation	Relevant 'message' sections of this summary
Is organic P worse than inorganic?	Organically-complexed P (dissolved/and/or particulate state) needs to be understood as distinct issue from general usage of the term 'organic' materials (linked to alternative P fertilisers). In a river inorganic dissolved P may be considered immediately available to biota, whereas organically-complexed dissolved P may become available over time/increased residence/to specialist biota.	2, 1, 3
Are some organic materials worse than others? What is the relative importance?	Following from the above row, P applied in the field as 'organic' materials/soil amendments may comprise, and lead to runoff of, P forms that can be dominantly inorganic available P, or may take time to mineralise to that.	2, 3
Is the pH of the material/water important?	pH affects P solid:solution partitioning but also many aspects and is too complex to consider at this level. But, it should be recognised a part of the issue below (aspect (ii)) of what the wider pollution (effluent/runoff) constituents do to the river/lake water where we assess the biology and chemistry.	4
Does it matter what its attached to e.g. soil/sewage? Does particle size matter?	Yes in terms of (i) the transport and fate/bioavailability of the P, also (ii) for other effects. E.g. (i) Residence is key to ecological exposure and dissolved vs different particle sizes of transport/(re)mobilisation lead to residence in different river/biotic compartments (headwater/downstream, water column/bed, or algal uptake/filter feeder uptake). Also, (ii) Accompanying contaminants could outweigh the negative P effect (e.g. emerging contaminants) or a dissolved organic matter matrix could greatly affect P solubility.	2, 4
Does the amount of water matter? Does the location in the watercourse matter? Does season matter?	These impact related factors concern the condition/sensitivity of receiving waters in terms of ecological exposure and P residence time governing access to not immediately-bioavailable P forms (e.g. pollution into a summer, low flow condition exposes biota more and allows time to realise P from complexed-P forms, compared with opposite say for winter delivery.	1, 2

Message 1: The concept of pressures (e.g. delivery of P loads/conc to watercourses) realising impacts according to differing waterbody sensitivities

This is vital to unravel differing responses and focus effective management. The evidence suggests that many catchment to waterbody/within-channel factors affect the receiving water's responses in space and time to a given P delivery. The best way to deal with this is using source-pathway-receptor-impacts concepts since sensitivity (risk cf. resilience factors) are inherent in source-pathway (e.g. erosion risk, septic tank delivery) risk components but crucially also waterbody condition (natural flow/sediment regimes, riparian corridor condition etc).

Message 2: How to account for differences in P sources (both chemistry and timing/seasonality) of source behaviour in our estimations of likely impacts under WFD SRP conc and ecological condition compliance?

This is a honing in on the general point 1 by reinforcing source aspects of the system whereby impact = source nature * waterbody state. The evidence is that sources differ by (i) the P chemistry (varying proportions of readily bioavailable phosphate, to moderate to recalcitrant forms of organically-complexed dissolved P and organic matter and mineral-bound particle P forms), (ii) the delivery dynamics, being rainfall-driven for some (e.g. field erosion, or effluent with a strong CSO effect), or consistent for others (often effluents). These may be devised into a system to determine their Eco-P weighting. It is being recognised that much of the dissolved P in the environment in waters and soils exists as organically-complexed P and developing research (e.g. NERC DOMain project) is looking at how different biota access organically-complexed P forms via enzymes.

Message 3: P delivery via field drains and what is the 'background' P leaching.

Often P from agriculture is considered to be dominated by particle, erosion-driven P losses from fields to waters. Partly this is since dissolved P sorbs strongly to soil particles. However, artificial drains bypass the soil matrix and preferentially connect runoff pathways of dissolved and particulate/colloidal P from P-enriched topsoils to watercourses by lessening time for P 'filtering' by Fe and Al rich subsoils. Evidence suggests that (i) artificial drainage is an important P pathway from cropped and grassland soils related to their soil P status, (ii) that in all but the most organic matter depleted cropped soils the drain P is dominantly organically-complexed, (iii) that the dradient of water P concentration to soil agronomic P status is lower (ie less P conc) in reality in the landscape than indicated by laboratory experimental extraction work.

Message 4: We need to be able to predict the impact for dissolved P waterbody concentrations (e.g. WFD) from our actions on the land that dominantly affect particulate P pathways/delivery.

Many management actions (e.g. erosion management) affect particulate P delivery but the standards in the WFD are water SRP concentrations. Hence, we need to predict the effects on water column dissolved P of changing inputs of eroded soils and their residence in channel. This requires knowing the amount and conditions of the exchange of P from the solid to water, related to particle sizes of the sediment/P carrying capacities and dynamics (where it resides following the erosion event, if/how it becomes remobilised from the bed). I believe this is yet to be successfully incorporated in modelling and lacks certain technical knowledge. The effect of runoff/effluent (and the combined signal of the upstream catchment chemistry e.g. peatland runoff) is important here also for the background matrix of the water column. This is one aspect where the P sorption/desorption balance is affected by ionic strength, pH and especially by DOC background conditions. But such effects may also be outweighed by certain key dynamics of release at the bed (e.g. redox) that can only be understood when examined in situ (seldom done), but should be capable of being modelled sufficiently.

Appendix 5: Linda May

Assessing the importance of private sewage discharges (PSDs) as a sources of rural diffuse pollution

Linda May, CEH, with contributions from Marc Stutter & colleagues, JHI

Introduction

Private sewage systems discharge treated wastewater to the environment, causing diffuse pollution problems. Effluent from these systems is high in phosphorus (P) and nitrogen (N), which cause nutrient enrichment (eutrophication) problems in receiving waterbodies. As such, they need to be included in River Basin Management Plans (RBMPs). However, there are evidence gaps that need to be filled before it will be possible to do that. Dodd & Hastings (2017) have identified these gaps as follows:

- Number, location and type of systems
- Level of discharge of nutrients and bacteria
- Effectiveness of soakaways & constructed wetlands at removing pollutants
- Better models to reflect the above

The current state of our knowledge on the above is summarised below.

Number, location & type of systems

The best approach to gathering evidence on the number, location and types of systems is compulsory recording or registration. This has been implemented for all systems in Wales (registration) and Northern Ireland (Census records). In Scotland, systems can be registered at any time, but this takes place mainly when a property is sold. There is no registration system in England for small discharges.

An alternative approach is to derive the locations of PSDs from geographical data on property locations combined with areas served by mains sewerage networks (the ‘postcode’ approach; May et al., 1999). This method assumes that all properties that lie outside of sewered areas PSDs. Although this is not always the case, the number of PSDs located in sewered areas is probably low. The uncertainty on these values could be determined using data from areas, such as Wales, where full registration has been in place for some time.

Level of discharge of nutrients and bacteria

The level of discharge of nutrients and bacteria from PSDs depends on the level of inputs to the system. This may change over time. For example, in 2008, laundry detergents accounted for about 18% of P in domestic wastewater (Defra, 2008). By 2015, this had fallen to almost zero due to the increased use of P-free laundry detergents (Richards et al., 2015). This demonstrates the importance of using current P-values when estimating discharges from PSDs. In addition, the type of PSD and the level of treatment that it provides also affect discharge quality. However, detailed information on system type or size is rarely available on a catchment or national scale. In general, about 90% of PSDs provide primary treatment of wastewater, only (O’Keefe et al., 2014).

In addition to nutrients, other pollutants such as metals and pathogens are also discharged from these systems (Richards et al., 2016). Little is known about the levels and rates of discharge of such pollutants.

Effectiveness of soakaways & constructed wetlands at removing pollutants

There is considerable evidence that soakaways, constructed wetlands and buffer strips can reduce the concentrations of pollutants in PSD effluent as it travel through the environment towards a receiving water (O'Keefe et al., 2014). The level of mitigation provided by these systems depends on the distance from the watercourse, the slope of the terrain, the hydraulic gradient and properties of the soil, and the vegetation and management of the drainage field (Stutter et al., 2014). However, there are few measured values to inform modelling of how these factors affect mitigation processes.

Better models to reflect the above

Modelling diffuse pollution from PSDs at the catchment scale requires accurate data on sources, PSD types and pollution retention coefficients of tanks and soakaways. These may vary depending on the size, location and type of system. The level of variation was illustrated by May et al. (2017) who estimated the average P discharge to water from PSDs across the whole Loch Leven catchment to be about 0.4 kg P property^{-1} year^{-1}, whereas a relatively new package treatment plant discharging to water *via* a constructed wetland system discharged only about 0.08 kg P property^{-1} year^{-1}.

Specific research needs

- Validation of the 'postcode' approach to estimate data uncertainty (& provide evidence to support full registration), because this is widely used in pollutant delivery models (e.g. SAGIS).
- More detailed examination of seasonal, daily, sub-daily variation in effluent quality – how much uncertainty does this generate in measured data?
- Assessment of whether best management practices recommended for PSDs (e.g. desludging; soakaway construction, mitigation measures) are effective, especially across multiple pollutants.
- Ground truthing/validation of models and assumptions at catchment scale.

References

Department for Environment, Food and Rural Affairs (Defra) (2008) Consultation on options for controls on phosphates in domestic laundry cleaning products in England. Available from: http://www.endseurope.com/docs/80215a.pdf [Accessed January 2018]

Dodd, N. & Hastings, E. (2017) What evidence does SEPA need to deliver RBMP objectives for 2027, for rural diffuse pollution pressures? Report from SEPA/CREW Workshop held 8 February 2017. 13 pp.

May, L., Moore, A., Woods, H., Bowes, M., Watt, J., Taylor, P. & Pickard, A. (2017). Loch Leven nutrient load and source apportionment study. Scottish Natural Heritage Commissioned Report, 70 pp.

May, L., Place, C.J. & George, D.G. (1999) Estimating the phosphorus load to surface waters from septic tanks in rural catchment. In: Petchey, A., D'Arcy, B. & Frost, A. (eds.) Diffuse Pollution and Agriculture II, Proceedings of a Conference held in Edinburgh, 9-11 April 1997, 212 - 216.

O'Keeffe, J., Akunna, J., Olszewska, J., Bruce, A., May, L. & Allan, R. (2015). Practical measures for reducing phosphorus and faecal microbial loads from onsite wastewater treatment system discharges to the environment: a review. Craigiebuckler, CREW, 49pp.

Richards, S., Paterson, E., Withers, P.J.A. & Stutter, M. (2015) The contribution of household chemicals to environmental discharges via effluents: Combining chemical and behavioural data Journal of Environmental Management 150: 427-434.

Richards, S., Paterson, E., Withers, P.J.A. & Stutter, M. (2016) Septic tank discharges; as multi-pollutant hotspots in catchments. Science of the Total Environment 542: 854-863.

Stutter, M.I., Jackson-Blake, L., May, L., Richards, S. & Vinten, A. (2014) Factoring Ecological Significance of Sources into Phosphorus Source Apportionment. Report to CREW, 75 pp.

crew

Scotland's centre of expertise for waters

CREW Facilitation Team

Craigiebuckler

Aberdeen

AB15 8QH

Tel: +44 (0)1224 395395

Email: enquiries@crew.ac.uk

www.crew.ac.uk