Scoping the use of the methodology set out in Chapters 2 and 3 of the '2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands in the UK GHG Inventory: Land Use, Land Use Change and Forestry (LULUCF)

Tender Reference Number: TRN860/07/2014

INTRODUCTION

The IPCC Wetland Supplement

The IPCC's 2013 Wetland Supplement (IPCC, 2014; hereafter 'Wetland Supplement') has set out methodological guidance for the quantification and accounting of greenhouse gas (GHG) emissions and removals associated with the management of different wetland types. The primary focus of the report, and the area of greatest relevance to the UK, is on the drainage and re-wetting of organic soils (i.e. managed peatlands). Guidance is also provided for other managed wetland categories including freshwater wetlands on mineral soils, coastal wetlands and constructed wetlands, but the significance of these activities for the UK GHG inventory is expected to be comparatively small, and the invitation to tender (ITT) prioritises the development of methods for organic soils. For this category, Tier 1 'default' emission factors (EFs) were provided in Chapter 2 of the Wetland Supplement for drained organic soils under grassland, cropland and forest land, and peatlands managed for extraction, which fall within the IPCC's 'wetland' category. In Chapter 3, Tier 1 EFs were presented for re-wetted peatlands.

In all cases, emission factors were included for 'on-site' emissions of CO_2, CH_4 and N_2O. A method was also presented to account for 'off-site' emissions of CO_2 associated with the waterborne export of dissolved organic carbon (DOC) and its subsequent conversion to CO_2, which can represent a significant indirect emission pathway in peatlands. Direct emissions of CH_4 from ditches were also incorporated in the methods for drained peatlands (replacing the previous 'default' assumption that CH_4 emissions from drained organic soils are zero (IPCC, 2006), although the effects of relic ditches or pools within re-wetted peatlands was not included in Chapter 3. Methods for including CO_2 emissions from peat fires were included in Chapter 2, but no EF was provided for prescribed burning of blanket bog due to lack of data. Particulate organic carbon (POC) was recognised as a potentially important emission source in some peatlands, notably eroding blanket bogs, but further methodological development was considered necessary before this could be included in Tier 1 accounting; a provisional methodology, based on UK data, was included in Appendix 2a.1 of the report.

In all cases, Tier 1 emission factors were derived from a collation of published, field-based measurement studies, screened by the author teams to exclude studies considered methodologically flawed, or of insufficient duration, to provide reliable estimates of fluxes. However, due to the lack of published studies for some peatland/land-use categories, it was sometimes necessary to set the threshold for inclusion of studies fairly low in order to obtain a sufficient number of studies from which to calculate an EF. In the high-latitude (temperate and boreal) climate regions, different EFs were provided (where possible given data constraints) for 'nutrient poor' (i.e. bog) and 'nutrient rich' (i.e. fen) peats. Further stratification by peat type (e.g. raised versus blanket bogs) was not carried out. In a small number of cases, EFs for drained organic soils were stratified within land-use category as a function of drainage intensity (for grasslands) or crop type (primarily for tropical peats). However re-wetted peatlands were only stratified by peat type (i.e. fen vs bog) and not by former land-use or by site condition following re-wetting (e.g. presence/absence of

vegetation, type of vegetation present) or time since re-wetting.

Status of the UK peat resource in relation to peatland drainage and re-wetting

As described in the ITT, large parts of the UK land area, as well as areas within the UK's Overseas Territories and Crown Dependencies (OTs and CDs), notably the Falkland Islands, are covered by deep peats and other peaty soils. Within the UK, the largest proportion of deep peat area is located in Scotland, however significant areas of peat exist in all four countries. Blanket bogs comprise around 83% of the total peatland area (JNCC, 2011), but raised bogs and fens also occupy significant areas, as do 'wasted' fen peats in lowland England (see below). Only a small part of the total peatland area is believed to be undisturbed, although the most pervasive form of anthropogenic pressure is atmospheric pollution, rather than land-management *per se* (e.g. Natural England, 2010). Pressures linked more directly to land-management include drainage, associated conversion to other land-uses including intensive grassland, cropland and plantation forestry, extensive livestock grazing and moorland burning, primarily for rearing red grouse.

The distribution of many of these management pressures, both spatially and between peat types, is highly asymmetric. For example, peat drainage for intensive arable and livestock agriculture is disproportionately focused on lowland fens and raised bogs, notably the Fens of Eastern England, whilst moorland burning is most intense in the English Pennines and Eastern Scotland. This leads to the perhaps counter-intuitive (and somewhat generalised) observation that whilst the largest carbon *stocks* are in the uplands of the North and West of the UK, the largest greenhouse gas *emissions* (and thus the largest potential emissions reductions through re-wetting) are concentrated in the South and East of the overall peatland area (e.g. Evans et al., 2014). This broad gradient in management pressure should not be treated as absolute, however; for example large areas of bog have been planted with conifers in some remote areas of Northern and Southwest Scotland, whilst many peatlands in Wales and Northern Ireland (as well as in the Falkland Islands) are subject to relatively high grazing pressures. In summary, both the UK peat resource and the anthropogenic pressures exerted on it are diverse, and some areas are subject to more than one pressure (e.g. drainage and afforestation, or burning and grazing). It is therefore important that the methods developed to account for peatland drainage and re-wetting in the UK LULUCF inventory adequately reflect this heterogeneity, and that the empirical data used to develop EFs for UK peatlands are based on appropriate sites, whether from the UK or elsewhere.

Issues for the implementation of the Wetland Supplement to the UK

From a UK perspective, the Wetland Supplement provides a rigorous and comprehensive methodological framework for LULUCF reporting. However, it also has several significant limitations, some of which have been noted in the ITT. A particular issue is that blanket bogs, which form the dominant part of the UK peat resource, are not specifically represented in the guidance or default EFs provided. This was a consequence both of the relative rarity of blanket bogs globally (being restricted to highly oceanic regions such as the western fringe of Europe, high-latitude coastal areas in North and South America, and some cool, high-rainfall mountain regions; Gallego-Sala and Prentice 2012), and of a resulting scarcity of data from which to define a separate emission factor (in effect, EFs for blanket bogs were considered a 'Tier 2' issue to be addressed by countries such as the UK with significant areas of this peat type). Developing UK-relevant EFs for blanket bog in different land use/condition categories will thus be a major focus of the project.

Related to the predominance of blanket bogs, the UK is also unusual in having large areas of peatland that were historically drained, but not converted to intensive agriculture or forestry, and which therefore retain a semi-natural (albeit modified) vegetation cover. Since there is no provision in the IPCC methodology for reporting on 'drained wetlands remaining

wetlands', these areas of drained bog currently fall within the 'drained grassland' category of the UK LULUCF inventory. However, Tier 1 default EFs for the most analogous category in the Wetland Supplement ('Grassland, drained, nutrient poor') are derived from studies undertaken on lowland agricultural grassland sites in continental Europe. Whilst the data from these sites may be applicable to some areas of the UK, such as the Somerset Levels, directly transferring these EFs to the drained blanket bogs of the UK uplands could potentially lead to an over-estimate of CO_2 emissions. A similar situation arises when transferring cropland EFs from the intensive arable systems of continental Europe and Southern England to the lower-intensity crops such as barley grown on some areas of peat in Northern Scotland.

Managed burning of blanket bogs is a practice that is largely confined to the UK, and therefore also provides some challenges for the implementation of the Wetland Supplement. CO_2 and other emissions from fires were included in Chapter 2 of the report, including emissions from both controlled burns and uncontrolled wildfires, and differentiated emissions from burning of above-ground biomass from those associated with burning of the peat itself. In principle, the methodology should be applicable to UK peatlands subject to burn management. However in practice, no literature was found from which a Tier 1 EF for prescribed burning of temperate or boreal peats could be derived. Including fire emissions for UK peatlands therefore requires a Tier 2 approach, based on new measurement data that were not available at the time (February 2013) that the literature sources used in the IPCC report were finalised.

More generally, there is a need to critically evaluate all Tier 1 EFs and associated data sources used in the Wetland Supplement, to ensure that all values used are appropriate to the UK situation. In some cases, the data should be transferrable (for example, measurements made on agricultural fens in continental Europe should be applicable to similar lowland areas of the UK), but in other cases this may not be the case; for example, a recent workshop organised by the IUCN Peatland Programme (attended by several members of the project team) highlighted several issues relating to the Tier 1 EF for temperate forest on organic soils, and the recent Climatexchange report on the implementation of WDR in Scotland (Artz et al., 2014a) highlights a number of other areas of uncertainty, emphasising the need to fully assess all EFs used.

Finally, it should be noted that the definition of organic soils used by the IPCC (IPCC 2006; 2014) effectively corresponds to the FAO's definition of Histosols, i.e. deep peats, although a minimum peat depth is not specified (to allow countries to apply their own depth thresholds). The ITT highlights the large area of 'peaty soils' (as distinct from deep peats) in the UK, noting that these may indicate where deep peats existed in the past, although this is not necessarily the case. Areas mapped as 'peaty soils' can effectively be divided into three categories, which we believe should be treated differently in the inventory, as follows:

i) Small areas of deep peat within larger areas mapped as shallower organo-mineral soils (so-called 'peaty pockets'). These areas represent true deep peat and therefore fall within the IPCC/FAO definitions of an organic soil, and should be included in the inventory. However, this will only become possible if the location of these areas can be determined, in order to determine the land-use and condition of these areas. This is essentially a problem of mapping resolution; ongoing work in Wales has addressed this by utilising high-resolution, field survey-based mapping data from BGS and Natural Resources Wales (NRW) in place of lower-resolution, more interpolated data from the Soil Survey of England and Wales, which allows smaller peat areas to be identified. We propose to address this issue for other parts of the UK through the use of higher-resolution mapping data where available.

ii) True organo-mineral soils, such as peaty podzols and peaty gleys, which have thin peaty surface horizons. These soils are not true peats, and do not meet the IPCC/FAO definitions. Although it is likely that some areas of upland organo-mineral soil were indeed formerly deep peats, this area cannot be defined, and the majority of organo-mineral soils may never have been deep peat. Since organo-mineral soils function differently to peatlands, are subject to different management pressures, and fall outside the remit of the Wetland Supplement, we recommend that these areas are not included in the wetland part of the UK inventory. The treatment of organo-mineral soils under key grassland and cropland management practices was considered in the recent Defra project SP1113 (Moxley et al., 2014). Although this project did not consider the effect of drainage explicitly, the impact of grassland improvement, potentially including drainage, was identified as an area needing further research.

iii) Areas of former deep peat affected by drainage and cultivation, leading to peat loss and the intermixing of remaining organic matter with underlying mineral material (so-called 'wasted peat'). This category includes very large areas of lowland fen peat, especially in Eastern England (estimated at 1922 km^2; Natural England, 2010). Whether or not these areas meet the IPCC/FAO definitions of an organic soil will depend on the depth and mineral content of the residual peat. Although much of the CO_2 emission from these areas will (by definition) already have taken place, it is likely i) that they continue to be emission sources; ii) that they were formerly deep peats; and iii) that re-wetting could lead to the re-establishment of peat formation and CO_2 sequestration. A decision on whether to include these soils in the wetland inventory will be made in consultation with DECC and the National Inventory Steering Committee.

Policy and strategic context

The need to report on greenhouse gas emissions and removal is driven by the UK's international obligations under the United Nations Framework Convention on Climate Change (UNFCCC), the European Union Monitoring Mechanism (EUMM), and the Kyoto Protocol (KP). These set out the requirements for international reporting and accounting of emissions from a number of sectors including LULUFC. Wetland Drainage and Rewetting (WDR) is a new activity which parties may chose to report for the second Commitment Period (CP2) of the Kyoto Protocol, but is not currently a mandatory reporting requirement under any international agreement.

The UK has not yet made a decision on whether or not to elect to report on WDR activity for CP2. However there are large areas of wetland, particularly peatlands in the UK, which have undergone drainage and for which there could a carbon credit for rewetting. Therefore, if the UK elected to report on WDR, emissions reduction from this activity could contribute to achieving emissions reduction targets. The IPCC 2013 Wetland Supplement provides an expanded and updated methodology for reporting of emissions from activities involving draining and rewetting of organic soils, as well as other wetland types. Some of these activities are more applicable to the UK than others. Peatland drainage and rewetting is an activity of the most important WDR activity for the UK, but other activities, particularly management of coastal wetlands, drainage of mineral soils and wetland creation for WWT could also make a small contribution.

The UK and the devolved administrations recognise the importance of wetland management to emissions reduction, and this is recognised in UK and devolved administration emissions reduction initiatives (Committee on Climate Change, 2014; Scottish Government, 2013). The Welsh Government's Glastir programme supports measures to protect peatlands. (http://wales.gov.uk/topics/environmentcountryside/farmingandcountryside/farming/schemes/glastir/?lang=en), and the role of peatland restoration and rewetting is recognised as a significant mitigation option in the Welsh Government's current review of land use and

climate change mitigation (Welsh Government, in prep.). Wetland management is often viewed as attractive option for reducing emissions from the LULUCF sector due to the anticipated co-benefits including habitat creation, improved water quality, and reduced flood risk.

WORK PLAN

Our approach adheres closely to the requirements set out in the ITT, and follows the work package (WP) structure and reporting schedule described therein. Our proposed approach for each of the WPs is described below, and is followed by a detailed description of the project management, which will effectively be run as an overarching activity with a dedicated lead. Each WP will also have an identified lead, responsible for ensuring the on-time delivery of all component tasks and outputs, supported by a team of contributors with relevant and complementary skills and knowledge. Most WPs have been subdivided into discrete tasks, with specific associated outputs as defined in the ITT.

Work Package 1: Interpretation of the wetland supplement requirement for drained and rewetted organic soils as it applies to the UK

Lead: C. Evans

Contributors: R. Artz, J. Moxley, MA. Smyth, A. Burden, S. Chapman

The task structure for WP1 will follow that set out in the ITT, as follows:

Task 1.1. Implementation requirements for the Wetland Supplement Chapters 2 and 3

Lead: C. Evans

This task will be undertaken at the outset of the project (reporting date Dec 20th 2014). As the team includes both lead authors of the Wetland Supplement and participants from the James Hutton Institute (JHI) who have independently reviewed the report and data sources used for the Scottish Government (Artz et al., 2014a), as well as the inventory team who will be responsible for implementing the guidance, we are uniquely positioned to provide both 'internal' and 'external' perspectives on the report; its strengths and weaknesses from a UK perspective; and the requirements for implementation of the guidance to the UK, OTs and CDs as part of the LULUCF inventory. The preceding introduction serves as an initial assessment of some of the key issues, based on our existing understanding of the requirements. This will be developed and formalised as a report during the first phase of the project. (**Output 1.1**).

Task 1.2. Development of a suitable definition of successful re-wetting

Lead: MA. Smyth

The ITT notes some ambiguity in the definition of rewetting applied by the IPCC, which has implications for where and how the equations presented in the Wetland Supplement are applied. It is worth noting here that some consideration was given within Chapter 3 of the report to differentiating between 're-wetted' and 're-wetted and restored', where the first category would simply imply a raising of the water table, whereas the latter would require the re-establishment of a semi-natural and ideally a peat forming vegetation cover. This approach was not adopted in the final report on the basis that there were insufficient data to differentiate between different re-wetted sites in order to calculate separate EFs. However as a large number of the data sources used to set EFs for re-wetted peatlands were actually derived from undrained (rather than re-wetted) sites (see Annex 3A.1 of the report) these values implicitly assume the re-establishment of a near-natural vegetation community as the

end point of restoration. Since the actual end-point may vary greatly depending on the restoration techniques used, with potential consequences for GHG balances (e.g. Cooper et al., 2014), an appropriate definition of successful re-wetting is essential. Taking account of the existing evidence base in relation to restoration outcomes and their effects on GHG balances, we will consider what (from a GHG perspective) can be considered a successful outcome, and develop an appropriate definition (**Output 1.2**). This assessment will also take account of the field evaluation methods currently being developed for the Peatland Code (Project NR0165), and of the criteria applied to peatland restoration actions within agri-environment programmes.

Task 1.3. Development of an approach to account for historically drained peatlands

Lead: J. Moxley

The vast majority of UK peatland drainage occurred prior to the 1990 base year for inventory accounting (although some exceptions exist, notably linked to wind farm developments). In contrast to other soil types, which can be expected to approach a new steady state carbon balance within decades of a land-use change, drained peatlands may continue emitting CO_2 for centuries, until most or all of the original peat mass is lost. This process is clearly occurring in areas of historically drained fen, where subsidence rates continue to be in the order of 1-2 cm yr^{-1} more than a century after drainage (e.g. Waltham, 2000). Work elsewhere suggests that emission rates remain fairly constant over time, until the water table intersects the underlying mineral soil, and/or the peat becomes intermixed with mineral material through cultivation (i.e. become 'wasted' peat) after which emissions from the dwindling amount of peat remaining will decline. For this task, we will examine the evidence base regarding rates of peat CO_2 (and other GHG) emission relative to time since drainage, consider how these ongoing emissions from historically drained peatlands are treated in the current LULUCF inventory, and identify whether the method should be amended for consistency with the guidance in the Wetland Supplement (**Output 1.3**). We note that, while inclusion of historically drained peatlands will increase the 1990 emissions baseline, subsequent emissions from these sources are likely to have been (approximately) constant since that time. Therefore, including emissions from historically drained peatlands will have an identical effect on total emissions in all subsequent years, and their impact on emissions changes calculated via net-net accounting relative to 1990 will therefore be zero. Emissions from new drainage activity since 1990 (e.g. for wind farms) will be reported as a small emissions increase, but we anticipate that this will be offset by larger emissions reductions due to peatland re-wetting during the same period. As a result, the net reduction in emissions since 1990 is likely to be larger following the inclusion of WDR in inventory reporting, albeit relative to a higher baseline.

Task 1.4. Identification of minimum activity data and sources for reporting

Lead: J. Moxley

For this task we will review the activity data requirements to undertake a basic level of inventory reporting for peatland drainage and re-wetting. Based on our understanding of the requirements, from work undertaken by members of the team to assess peatland condition as the basis for targeting restoration activities in Scotland (Artz et al., 2014b) and Wales (ongoing work within the Glastir Monitoring and Evaluation Programme, GMEP), we anticipate that the key requirements will be: i) a reliable base map of peat occurrence for all countries, as well as the OTs and CDs, which captures smaller peat units, particularly in lowland areas; ii) land-cover data at a resolution appropriate to determine land-use classes within each peat unit; iii) spatial data on the presence and density of ditches within areas of semi-natural blanket bog (for more heavily modified areas such as lowland peats converted to agriculture, or blanket bogs under plantation forest, the presence of ditches can be inferred from the land-cover data); and iv) information on land-use changes and restoration

activities that have taken place since the 1990 reference year. Note that, with the possible exception of wind farm developments (for which detailed spatial data should be available) it could initially be assumed that all drained sites were drained prior to 1990. Conversely, the majority of re-wetting projects have occurred since that year, but again detailed information should be available for these sites, e.g. from the compendium of peat restoration projects (SP0556) and data for Scotland collated for the assessment of climate mitigation potential by Chapman et al. (2012). It is clear that a fully spatially distributed approach will be required to account for peatland management in the inventory. These considerations will be further developed as a short report on data requirements and potential data sources, as well as implications for reporting change over time since 1990, as **Output 1.4**. This work will also guide the development of WP4.

Task 1.5. Implementation requirements for other chapters of the Wetland Supplement

Lead: A. Burden

Chapters 4-6 of the Wetland Supplement describe methods to account for GHG emissions and removals associated with the management of coastal wetlands, inland wetlands on mineral soils, and constructed wetlands for wastewater treatment. Some of the wetland categories and management activities described are of little or no relevance to the UK itself (e.g. mangroves) but a number of categories (e.g. tidal marsh, floodplain wetlands) and activities (e.g. coastal realignment, riparian buffer strip planting) may be associated with quantitatively significant GHG emissions, or changes in emissions (e.g. see Burden et al., 2013 in relation to coastal realignment). Furthermore, a number of the UK's Overseas Territories, such as the Turks and Caicos Islands, Cayman Islands, British Virgin Islands, Anguilla and Bermuda, contain significant areas of non-peat wetlands, including mangrove and freshwater swamps, coastal lagoons and wet forests, some of which are internationally designated as RAMSAR wetlands. We will undertake a short assessment of Chapters 4-6, identify any potentially important non-peat wetland/land-use categories from a UK and Overseas Territory perspective, and consider what data would be needed to implement reporting of these categories in the future (**Output 1.5**). This task will need to take account of where (and how) any areas of non-peat wetland in the UK are currently captured within the LULUCF inventory, and whether the Wetland Supplement provides relevant new guidance or EFs that would allow for improved accounting of these areas.

Work Package 2: Paper to support UK Position on election

Lead: C. Evans

Contributors: R. Artz, J. Moxley, A. Thomson, D. Birnie

A briefing paper (**Output 2**) will be produced to support the UK decision on whether to elect Wetland Drainage and Re-wetting (WDR) as a voluntary activity for LULUCF accounting and Kyoto Protocol reporting. As set out in the ITT, this paper will summarise the key operational issues for implementation of the IPCC's methodology for peatlands, and the potential implications of including WDR for the overall LULUCF emissions inventory. Recognising the tight timescale for this task, we will undertake the requested 'rough' assessment of the scale and direction of historic and projected future emissions/removals from this source based on readily available data. This is likely to entail:

i) Utilising the current base maps for peat in the LULUCF inventory

ii) Using the CEH Landcover Map to estimate the extent of different land-use categories on peat, and changes over time in these.

iii) Assuming that all peat under more intensive land-use (cropland, improved grassland, forest etc) has been drained

iv) Assigning a 'best guess' estimate of the area of peatland (primarily blanket bog) under semi-natural vegetation (e.g. unimproved grassland, heathland) that has been drained. This will however be informed by previous work to estimate drained peat area in England (Natural England, 2010), peat condition assessments in Scotland (Artz et al., 2012, 2014b) and ongoing work by BGS to map drained blanket bog area in Wales.

v) Assuming that all such areas were drained before 1990.

vi) Estimating the area of re-wetted peat from the SP0556 Compendium, and other readily available information sources (e.g. Chapman et al., 2012), assuming that all such areas were re-wetted since 1990, and that this re-wetting was 'successful' according to the definition in Task 1.2.

vii) Assigning Tier 1 EFs from the Wetland Supplement to each land-use/peat category. However, we believe that we are already in a position to conclude that the Tier 1 EF for CO_2 emissions from temperate nutrient-poor grassland is not applicable to drained UK blanket bogs remaining under semi-natural vegetation, and therefore propose that the new (considerably lower) EF developed under the Peatland Code project NR0165 for drained blanket bog (Smyth et al., 2014) should be applied for this category

viii) Realistic assumptions about the anticipated extent and rate of future peat re-wetting activities (as well as the possibility of any additional drainage, e.g. associated with wind farm development), stratified according to peat type and land-use (e.g. recognising the higher likely uptake of re-wetting in upland blanket bog compared to areas of lowland fen under intensive cultivation).

An additional component of the briefing paper will set out the implications of reporting WDR as a Kyoto Protocol (KP) activity, taking account of the recent Kyoto Protocol Supplement (IPCC, 2014b), the hierarchy of land-use activities within the KP, and the potential consequences of other aspects of KP reporting, notably the possibility that re-wetting and restoration of plantation forestry on peatlands may have to be reported as deforestation.

The paper will be written and structured in a way that ensures it is accessible to knowledgeable but non-expert stakeholders and policymakers, and will highlight assumptions made, data limitations and the associated uncertainties in emissions estimates.

Work Package 3: Emission Factors applicable to UK peatlands

Lead: R. Artz

Contributors: C. Evans, P. Levy, J. MA. Smyth, A. Burden, M. Saunders, J. Potts, D. Birnie, F. Renou-Wilson, D. Wilson

As noted in the ITT and the introduction above, a major gap in the IPCC's Tier 1 emission factor dataset exists for blanket bogs, due to their limited distribution outside the British Isles and other highly oceanic regions, as well as the limited number of flux measurement studies on blanket bog, which make it difficult to define EFs distinct from those for a broader 'temperate bog' category. However, a significant number of new flux estimates for drained and re-wetted blanket bog have either become available since the publication cut-off date of the Wetland Supplement, or are expected to become available within the next year (for a list of relevant studies see Artz et al., 2014a, Table 7). Similarly, we believe that new and forthcoming flux data will also enable us to develop improved Tier 2 EFs for several other

important peat type and land-use categories based on UK-relevant studies. We propose to split the work for this WP into two major tasks, capturing the 'key tasks' listed in the ITT.

Task 3.1. Development and assessment of Tier 2 emission factors for UK blanket bogs

Lead: R. Artz

This task will build on the recent report to the Scottish Government (Artz et al., 2014) which critically reviewed many of the studies included in the Wetland Supplement, and assessed their relevance to UK blanket bogs and other peatland types, and additional work carried out in order to derive initial EFs for blanket bogs to support the UK Peatland Code under project NR0165 (Smyth et al., 2014). This work proposes a classification system of blanket bog into near-natural, modified, drained and eroding categories, using ground-based survey of peat condition and vegetation at the scale of individual restoration sites. For this project, we will need to consider whether this classification scheme can be used as the basis for inventory reporting, i.e. utilising activity data available at a national scale (see WP4), or whether it will require amendment or simplification for application at this scale. We will also comprehensively review and collate new data (as well as any data overlooked during the IPCC assessment) in order to refine and, if appropriate, further stratify blanket bogs according to condition. For example, very large areas of blanket bog in Southwest England and South Wales have become dominated in the relatively recent past by *Molinia caerulea* (purple moor grass) which is believed to be at least partially due to grazing changes. The consequences of this major ecological shift for the peatland carbon balance is largely unknown, but could (due to the associated decline in peat-forming *Sphagnum* species) be substantial. Similarly, areas of burn-managed bog dominated by *Calluna vulgaris* and with low *Sphagnum* cover are likely to be either reduced sinks or sources for CO_2, but robust data to define EFs for these areas have until recently been lacking..

The following list provides a (non-exhaustive) illustration of some additional data sources we anticipate will be used to support the development of Tier 2 EFs for drained and re-wetted blanket bog:

- New data on CO_2, CH_4 and DOC fluxes from drained and re-wetted blanket bog which will be produced by the major Defra-funded experimental study of the impacts of ditch-blocking at a site on the Migneint, North Wales (project SP1202).
- Recently published CH_4 flux measurements from intact, drained and re-wetted blanket bog at other sites in the same region (Cooper et al., 2014).
- The meta-analysis of UK CH_4 flux data undertaken by Levy et al. (2012), and subsequently analysed in relation to plant cover type by Gray et al. (2013), which may provide a basis for estimating CH_4 fluxes for blanket bog as a function of measurable condition factors such as drainage status and broad vegetation type (linked to management)
- The results of ongoing flux measurements being carried out for the Mires on the Moors project in Southwest England, which should provide the first published measurements of GHG fluxes from *Molinia*-dominated blanket bogs.
- New eddy covariance-based estimates of CO_2 and CH_4 flux from the CEH Carbon Catchments at Forsinard and Auchencorth Moss in Scotland, Moor House in Northern England, and the Upper Conwy in North Wales.
- New eddy covariance-based estimates of CO_2 and CH_4 fluxes from forestry on peat and restoration sites at Forsinard (JHI, ERI, University of St. Andrews and University of Stirling).
- New chamber-based measurements of CO_2 and CH_4, as well as DOC and POC, fluxes from three sites in Northern England subject to varying intensities of burn management, for Defra project BD5104.
- Core-based estimates of carbon accumulation rates for burnt and unburnt blanket bog in Northern England (Garnett et al., 2000)

- Results of a similar core-based study of 48 blanket bog sites (including undrained, drained, afforested and previously burnt sites) being undertaken for GMEP in Wales
- Chamber based CO_2 and CH_4 flux measurements from a number of *Molinia*-dominated sites in Wales proposed during the next 2 years of GMEP, if funded.
- Data from flux studies undertaken on blanket bogs in the Republic of Ireland.

By far the largest set of UK-relevant flux measurements on peatlands outside the UK have been made in the Republic of Ireland, and a significant proportion of these data are unpublished. We have therefore included experts from Ireland (David Wilson and Flo Renou-Wilson) who have been responsible for many of these measurements, and who were also lead authors for Chapter 3 of the Wetland Supplement. They will provide expert input to this task, and will also help to facilitate possible links to the Irish government's implementation of WDR, and the potential development of a common set of EFs for UK and Irish peatlands.
In addition to the primary requirement to develop reliable EFs for CO_2 and CH_4 emissions and removals from drained and re-wetted blanket bogs, we also identify a number of other priority actions needed to support robust and comprehensive inventory reporting for blanket bogs, as follows:

1. Enhanced treatment of waterborne carbon. Whilst the Wetland Supplement provided a methodology to account for indirect CO_2 emissions associated with DOC loss, Tier 1 EFs were (as for other emissions) presented for a generic 'temperate bog' category, and there is potential to produce a revised Tier 2 value for blanket bogs based on the (comparatively rich) dataset available on DOC fluxes from the UK and Ireland. Results from Defra Project SP1202 will provide new information on DOC responses to re-wetting, and additional data are also expected from other studies (e.g. Mires on the Moors, Defra Project BD5104). We will also explore the potential to incorporate POC fluxes (which can be very large from eroding blanket bogs) in national accounting, based on the outline methodology presented in Appendix 2a.1 of the Wetland Supplement; subsequent results from Defra Project 1205 showing relatively high conversion rates of POC to CO_2; and efforts to quantify POC losses from eroding systems in the Peatland Code.

2. Assessment of emission factors for forestry on blanket bog. The Tier 1 EF for CO_2 emissions from forestry-drained temperate bog is based on a relatively small number of studies, of which only one is from a British blanket bog (Yamulki et al., 2012). At a recent workshop organised by the IUCN Peatland Programme, attended by several members of the project team as well as forestry experts, it was agreed that the reliability and applicability of this default value to UK blanket bogs was uncertain. We will therefore assess whether sufficient new data are available to support a Tier 2 approach for forestry on blanket bog, in light of existing data and new results (notably from ongoing work by JHI on forests in the Flow Country) expected to become available during the lifetime of the project.

3. Estimation of CO_2 emissions from prescribed burning. As noted above, the Wetland Supplement set out a method to account for CO_2 emissions due to burning or above ground biomass and near-surface peat, but did not provide a Tier 1 EF for prescribed burning on temperate bogs. We will evaluate existing and new data to see if a robust estimate of this potentially important flux can now be defined for the UK.

4. Consideration of timescales since re-wetting. It is widely believed that GHG emissions (particularly of CH_4) may peak in the years after re-wetting, before declining to low levels as a natural hydrological functioning and vegetation community re-establishes. The option of including different Tier 1 EFs for a five year transitional period after re-wetting was considered by the IPCC Chapter 3 author team, but was not included in the Wetland Supplement due to a lack of supporting data. We will re-visit this question in our

assessment, to establish whether the use of separate Tier 2 EFs for the post-rewetting period could be justified based on the available empirical data.

For all new Tier 2 EFs developed for blanket bog we will undertake a rigorous assessment of the robustness of the values obtained. This will include the calculation of uncertainty ranges (using on 95% confidence intervals, for consistency with the IPCC), and a statistical analysis of whether there are significant differences between a) the Tier 2 land-use categories defined for the UK; and b) between UK Tier 2 values and the relevant IPCC Tier 1 defaults. If differences are non-significant, a decision will be made (with DECC and the inventory steering group) as to whether categories should be merged, or should remain separate (for example to provide a placeholder in the inventory where further data are expected to provide more reliable flux estimates in future, as was recently done for grassland management categories in Project SP1113).

The output from this task (**Output 3.1**) will be a set of referenced, evaluated and quality assured Tier 2 EFs applicable for key land-use categories on UK blanket bogs. We anticipate that the Tier 2 values should also be relevant to the extensive blanket bogs of the Falkland Islands, as well as other countries with large areas of blanket bog and similar land-use histories, notably Ireland as discussed above.

Task 3.2. Development and assessment of Tier 2 emission factors for other wetland habitats

Lead: R. Artz

Lowland raised bogs and fens occupy a smaller part of the UK peatland area, but have been subject to comparatively intense human modification, including conversion to intensive or extensive grassland, arable and horticultural cropland and peat extraction. All of these activities involve varying degrees of drainage, as well as other forms of disturbance including changes to (or removal of) the natural vegetation cover, cultivation, fertilisation and active removal of biomass and/or peat organic matter from the site. Due to the large extent of drainage and intensity of associated disturbance, lowland peats are thought to make the largest contribution to current GHG emissions from UK peatlands on both a per unit area basis and in total (Worrall et al., 2011). This also means that re-wetting of these areas may, in theory at least, provide the greatest potential to reduce emissions.

Due to differences in the hydrological and biogeochemical functioning of fens and raised bogs, as well as the nature and severity of disturbance, it would not be appropriate to apply EFs derived for blanket bogs to these peatland types. On the other hand, the characteristics of, and land-use activities affecting, UK fens and raised bogs are fairly similar to the continental European (and other) peatlands from which the majority of studies used to derive Tier 1 EFs for drained and re-wetted temperate peatlands were drawn. On this basis, we propose to use the current Tier 1 EFs for these categories as a starting point for the task. Based on an initial assessment of the main land-use activities affecting UK lowland peats (Task 1.4 and WP4) we will prioritise the most relevant EFs in the Wetland Supplement, and review the source studies used in order to identify those which provide robust estimates applicable to the UK. We will then, as for Task 3.1, review all studies and new data that have become available since the finalisation of the Wetland Supplement, and use these additional data to derive new 'Tier 2' values for the UK. Based on a comparison of these new estimates with the Tier 1 default values (i.e. an assessment of uncertainty ranges and testing for statistically significant differences) we will identify those land-use/peat type categories for which a Tier 2 approach is justified, and those where the existing Tier 1 defaults remain adequate. We will also examine whether there is a need to further stratify any of the drained or re-wetted categories used in the Wetland Supplement to reflect differences in land-use practice within the UK. For example, it may be justified to differentiate between domestic and industrial peat extraction sites, or between re-wetted sites according to post-restoration

vegetation cover. The extent to which this is possible will depend not only on the available of measurement data, but also on the feasibility of mapping activity data on different land-use or condition categories at the required spatial scale, and on the practicability of including these categories in the inventory. This assessment will therefore be closely linked to work taking place in WPs 4 and 5.

Potential new sources of data to define Tier 2 EFs for other wetland types are likely to include (but will not limited to) the following:

- Comprehensive measurements of all aspects of the gaseous and fluvial carbon and GHG budget of 15 lowland peat sites in England and Wales, which include both fens and raised bogs, and major land-use classes including: near natural (conservation managed); extensive grassland; intensive grassland; arable (on both deep and shallow 'wasted' peat sites); peat extraction; re-wetted (Defra Project SP1210).
- Chamber based measurements of CO_2 (Artz et al., 2007) and CH_4 (unpublished) fluxes from peat extraction sites at different stages after abandonment, made at Middlemuir Moss (NE Scotland) during the EU RECIPE project.
- Flux measurements at near-natural, drained and re-wetted raised bogs in mid-Wales (Cors Fochno) and Shropshire (Whixall Moss) made during the EU PEATBOG project.
- Newly published full flux data from deep and shallow-drained grassland sites in Ireland (Renou-Wilson et al., 2014)
- A collation of recently published and unpublished Irish flux measurements from peat extraction sites, which will provide more UK-relevant data, and may enable different EFs to be assigned to industrial (unvegetated) versus domestic (typically vegetated) extraction sites (D. Wilson, in prep.)
- Recent publications from continental Europe reporting fluxes for one or more components of the peatland GHG balance for drained or re-wetted sites (e.g. Beyer and Hoper, 2014; Frank et al., 2014)

The output from this task (**Output 3.2**) will be a set of referenced, evaluated and quality assured Tier 2 EFs for all peat/land-use categories for which we are able to identify a need to revise or subdivide the Tier 1 default values, and for which sufficient data exist to support a UK-specific Tier 2 value. In relation to the final task specified in the ITT under WP4, we believe that the Wetland Supplement already provides clear grounds to conclude that EFs vary between drained peatlands according to peat and land-use type, and our expectation is therefore that different EFs will be required for different categories. If at the end of the project we conclude that the available data are insufficient to define a Tier 2 EF for a specific land-use/peat type category, or if we believe that a greater degree of land-use stratification would be desirable (and achievable) given additional data, these data gaps will be identified. If any data gaps are unlikely to be filled by ongoing research, this will be highlighted, and the additional measurements required to fill these gaps will be specified (**Output 3.3**).

Work Package 4: Activity data for drainage and rewetting of organic soils

Lead: M.A. Smyth

Contributors: B. Rawlins, R. Lawley, N. Archer, S. Chapman, M. Aitkenhead, D. Donnelly, J. Moxley, E. Taylor, G. Buys, C. Evans.

Based on the ITT, we interpret the main objectives of WP4 as being: 1) collation of spatially complete baseline dataset of peat land-use and condition; 2) sourcing of additional data on re-wetting activity and other land-use modifications since 1990; and 3) setting out a plan to obtain more complete or accurate data beyond the lifetime of the project if required. The following task structure reflects these main objectives. However we also note that, while

significant work is now ongoing in Wales and Scotland (funded by the DAs) to produce more comprehensive and systematic spatial assessments of peat condition, which should provide a basis for activity mapping during the lifetime of this project, equivalent work has yet to take place in England, Northern Ireland or the OTs and CDs. Since there is now an opportunity to apply the methods under development to these new areas, we have included an optional work package (Appendix 1) which describes the approach and costs required to undertake these tasks. We anticipate that such work would, if it were to take place, be funded separately by the relevant administrations.

Task 4.1. Sourcing and compilation of baseline activity data

Lead: M. Aitkenhead

In order to include WDR in the UK Inventory it will be essential to develop a 'base map' of peat extent, condition and land-use. Although much work to map UK peatlands has been undertaken previously (e.g. JNCC, 2011), members of the team have recently been engaged in the development of a new 'unified' peat map for Wales, which is based on high-resolution survey-based data from BGS and NRW rather than lower-resolution and partly interpolated 'association' level mapping by the National Soil Resources Institute (NSRI). As noted above, the new map appears more effective at capturing smaller peat units (previously referred to as 'peaty pockets' within other soil associations, often in lowland areas), which tend to be more affected by historic land-use modification than the larger (mainly upland) peat units captured by NSRI mapping. We believe that similar opportunities to develop a more accurate peat map exist for the other UK countries, making greater use of BGS data as well as detailed peat mapping data held for Scotland by JHI (see e.g. Chapman et al., 2009) and other detailed data for the UK. We have also identified a source of spatial data on peat occurrence in the Falklands, based on a geological survey undertaken by BGS during the 1990s (Aldiss and Edwards, 1999) which appears not to have been used in a previous assessment of peat extent and condition in the Overseas Territories (IUCN, 2011). BGS also hold mapping data for the Crown Dependencies, notably the Isle of Man which has a significant peat area. As part of this task, we will therefore undertake a short, targeted assessment of the available data on peat extent, in order to produce the best available peat base maps for use in the Inventory.

For the second part of this task, we will collate all existing data on peat land-use and condition for all UK countries as well as the relevant OTs and CDs. This will include liaison with DAs to obtain all relevant datasets, such as the land-use/condition maps generated by recent work in Scotland and Wales, as well as previous peat condition mapping in England (Natural England, 2010) and Northern Ireland. Additional sources of land-use data are likely to include the CEH Land Cover Maps (1990, 2000, 2007), Land Cover of Scotland (1988), NRW Phase I Habitat Map, national-level data on agricultural land-use from the Integrated Administration and Control System (IACS), and aerial photographic data previously analysed by BGS and JHI for Wales and Scotland (see also optional WP in Appendix 1). We anticipate that these data will be used primarily to develop a comprehensive spatial baseline dataset of land-use and peat condition in 1990, although where suitable time series data are available (e.g. sequential CEH Land Cover Maps) these may be used to evaluate changes in activity since 1990 (see below). As noted above, the vast majority of UK peat drainage pre-dates the 1990 base year, thus areas mapped as currently drained will be assumed to have been drained in 1990 unless there is evidence to the contrary (see below). We anticipate that, for Tier 2 reporting, we will need to develop a simple classification system for drainage intensity. This will need to reflect (as a minimum) the distance between ditches, but if data permit we will also consider the impacts of peat type, and ditch orientation relative to the topography. In areas of highly modified land-use on peat, such as intensive grassland arable, horticulture or plantation forestry, we will assume that drainage has also occurred, in line with previous work in support of the UK Inventory (e.g. Anthony et al., 2014) and the

IPCC guidance (IPCC, 2014).

For the OTs and CDs, we will seek to identify potential sources of activity data. The IUCN's brief summary of the UK's overseas peatlands (IUCN, 2011) concluded that relatively little information is available about peat condition in many OTs, meaning that it may not be possible to fully account for emissions from these sources within the timescale of the project. However, as part of this task we will assess the available evidence in order: i) to determine the extent of peatlands in the OTs and CDs; ii) to assess the extent to which this has been affected by land-use activities; and iii) where data permit, to produce a first estimate of the potential GHG emissions from these areas. This work will utilise BGS mapping data on peat extent where available, focusing on comparatively large peat areas (e.g. Falkland Islands, Isle of Man). In the Falklands, which are thought to contain the largest peat area, there is evidence that natural erosion has been exacerbated by burning, grazing (with introduced herbivores) and off road vehicles (IUCN, 2011). Some localised drainage and ploughing has also occurred. In the Isle of Man, around half of an estimated 5666 ha of heather moor is thought to be on deep peat, and this area has historically been affected by drainage, grazing, burning, afforestation and peat extraction (Weissert and Disney, 2013). In support of this work we will consult with experts with specialist knowledge of these areas, including James Fenton (ex CEO of Falklands Conservation, who has already provided information on the status and functioning of Falkland Island peat to the consortium) and Jim McAdam, (United Kingdom Falkland Islands Trust), Mike Pienkowski and Catherine Wensink, (UK Overseas Territories Conservation Forum), all of whom who contributed to the IUCN report. Consultations will be undertaken through emails and phone calls. We have also included costs of an optional work package (see Appendix 1) to hold two round-table meetings (one face to face) involving key experts on peatlands and other wetlands in the OTs, which would aim to provide a more robust and complete evidence base for reporting on GHG emissions and removals from these wetlands, should this be considered a high priority.

The output from this task (**Output 4.1**) will comprise a compiled set of activity data, including a report with summary tables and methods, an Oracle database and GIS shape files for the 1990 baseline year, based on consistent base maps of peatland extent, and best available data on land-use and peat condition for each of the UK member countries. For OTs and CDs with significant peat areas we will provide include an initial assessment of land-use impacts and potential emissions as part of the summary report, utilising spatial data where available, and qualitative information from expert sources where unavailable.

Task 4.2. Assessment of peat drainage and re-wetting activities since 1990

Lead: MA. Smyth

This task will involve the collation of available data on peat drainage, re-wetting and other land-use changes that have taken place since the 1990 reference year. As noted above, we expect that new drainage activity will largely be restricted to wind farm developments. GIS data on wind farm developments that have been applied for or taken place on organic soils are should be available from the national conservation agencies as a basis for mapping new drainage activities (see e.g. Artz et al., 2014b). Available data on other management activities since 1990 will also be collated, and their suitability as a basis for inventory accounting assessed. This is likely to include Forestry Commission data on management activities that have occurred in plantations on peat, and national data on livestock grazing changes from the IACS dataset (although Artz et al. (2014b) note limitations on the extent to which parish-level records can be used to infer changes in stocking density on peatlands). National-scale data such as the CEH Land Cover Maps will also be examined as a basis for quantifying land-use change since 1990.

The largest activity change in UK peatlands since 1990 is believed to have been peat re-

wetting. At present, there is no single source of data on drained and rewetted organic soils in the UK and overseas. The IUCN Peatland Programme website (http://iucn-uk-peatlandprogramme.org/peatland-gateway/gateway/uk), aims to be the information hub for peatland restoration case studies, international organisation, links and more resources from across the globe. This links to the Peat Compendium (http://peatlands.org.uk/?q=map/node) which is an interactive map of peat restoration projects in the UK, funded under Defra project SP0556. This questionnaire-based assessment was carried out in 2007-2008, and contains details of 145 UK peat restoration and management projects in total, while the interactive map shows 79 projects. Although new projects are invited to upload their details to the website, the map remains incomplete. There has been a boom in bog restoration across the UK since 2008, and many projects, for example all the Peatland Action projects in Scotland (2014), and several raised bog and blanket bog restoration projects in England and Wales, are not on the map. Furthermore, many public sector projects, supported through agri-environment schemes, as well as the extensive work initiated by the Forestry Commission in England, Scotland and Wales, have not been included. The Compendium thus provides a useful starting point for the assessment of re-wetting activity, but further work will be required to produce a comprehensive assessment.

We will work with the DAs and conservation agencies, as well as the IUCN, major stakeholders engaged in peatland restoration (e.g. National Trust, RSPB, Wildlife Trusts) as well as partnerships such as Moors for the Future and the Yorkshire Peat Partnership, the National Parks, Forestry Commission and some private landowners. This task will be carried out by e-mail questionnaire backed up by phone calls, using a similar method to that used to compile the Peatland Compendium. Potential stakeholders will be identified from published documents, the grey literature (conference proceedings and organisational websites and newsletters), and from lists suggested by this project team (which has good geographical representation across the UK). Previous or existing work to identify and map peat restoration projects in Scotland (Artz et al., 2014b) and Wales (work within GMEP) will feed directly into the assessment.

As a final component of this task, we will consider methods for quantifying the effectiveness of peat re-wetting schemes at large scales. In terms of GHG emissions, a key parameter is the post-restoration water table which, although difficult to measure directly at large spatial scales, is usually reflected in the vegetation community at the site. Previous work has demonstrated the value of 'vegetation proxies' for estimating the GHG emissions from drained and re-wetted peatlands (e.g. Couwenberg et al, 2011; Dias et al., 2010; Gray et al., 2013). This approach may well provide a suitable basis for Tier 2 GHG accounting (see below) and would also be conducive to remote mapping techniques based on aerial surveys. At present, however, a lack of regular, comprehensive aerial survey data is likely to limit the use of remote sensing methods, meaning that ground-based assessments may remain necessary. Methods being developed for assessing effectiveness of peat restoration for the Peatland Code (e.g. vegetation assessments, evaluation of the hydrological effectiveness of re-wetting, range of measures undertaken) will be considered. Since such assessments will be a necessary component of schemes supported through the Peatland Code, as well as public-funded schemes such as agri-environment programmes, these data could be collated as a basis for large-scale reporting. This assessment will link to work in WP3 to develop Tier 2 EFs for peatlands in different condition, and the possible development of transitional EFs for recently re-wetted peatlands.

The output from this task (**Output 4.2**) will comprise a collated dataset, with summary tables, describing all new peatland management activity between 1990 and 2013, including new drainage, re-wetting and land-use changes within areas of drained peatland. Any information that can be collated on the post-restoration condition of re-wetted peatlands will also be included. All data will be spatially explicit and included in a GIS dataset compatible with the baseline data collated in Task 4.1.

Task 4.3. Development of an approach for future gap-filling

Lead: MA. Smyth

The ITT recognises that it may not be able to source or compile all the activity data needed to report on GHG emissions and removals from managed peatlands within the lifetime of the project. Based on the preceding tasks, we anticipate that initial reporting should be possible for all of (at least) the UK land area, although collating data on all peat re-wetting projects is likely to be a significant (and ongoing) challenge. For this reason, we believe there will be a need to establish a long-term, regularly updated repository of peatland restoration projects as a basis for future reporting. This will build on the Peatland Compendium, but (as noted above) will need to include additional public-funded restoration activities, as well as additional information needed to reporting such as GIS files to define the spatial extent of re-wetting, as well as consistent measures of site condition as described above. In the long-term, it may be necessary to establish a single organisation to manage and update the repository.

For this task we will produce a report (**Output 4.3**) outlining a plan for filling future data gaps, and for improving the robustness and completeness of activity data. This will include i) a plan to assure that activity data on peat re-wetting are comprehensive and regularly updated; ii) options for more objective monitoring of peat condition based on ground-based and/or aerial survey methods (see Task 2); and iii) an assessment of whether other spatial data sources, for the UK or for the relevant CDs and OTs, could be used to improve or extend future activity reporting, for example making better use of aerial photography data to map drainage ditch extent (see Appendix 1).

Work Package 5: Calculation of annual emissions and removals from drainage and rewetting of organic soils

Lead: G. Buys

Contributors; J. Moxley, A. Thomson

Reporting on emissions from peatland drainage associated with Cropland are already included in the LULUCF inventory in the Lowland Drainage category. New estimates of emissions from improved grassland on drained histosols which have been published recently will allow for improvements to this reporting from the 1990-2013 inventory onwards. Once UK-appropriate emission factors and activity data have been developed in the preceding tasks, it will be possible to include WDR reporting in the UK LULUCF inventory.

The LULUCF inventory is currently moving from a data collection system to based on a series of Excel spreadsheets to a new system which will use a database containing all input information (i.e. activity data, and emissions factors, or where appropriate emissions trajectories). The input data in this database will be processed using R scripts to calculate emissions and removals in format compatible with the Common Reporting Format (CRF) tables. This database and scripts will be able to provide data which can be combined with data from the Agricultural sector inventory in the new category Agriculture, Forestry and Other Land Uses (AFOLU), which will be used from the 1990-2013 inventory onwards. The new reporting system is planned to be in place for the 1990-2014 inventory. This provides an opportunity to incorporate peatland drainage and rewetting activities in the new system from the outset.

The reporting system will be able to calculate emissions and removals of CO_2, CH_4 and N_2O resulting from wetland drainage and rewetting. Although not a specific requirement for this project, because a “bottom up” approach to inventory compilation will be used, emissions

and removals will be available for each of the UK administrations and for the whole of the UK as well as for the OTs and CDs.

The scripts developed will include quality assurance checks including scripts to "sense check" calculations, and to highlight changes between inventories produced in different inventory years. Details of all code (including validation carried out), and input requirements for WDR reporting to be included in the LULUCF inventory will be fully documented in a short report, and an operating procedure for this software will be produced to allow calculations to be performed in a repeatable and consistent manner. These procedures will form part of the quality assurance measures for the inventory calculations, and will include details of quality control checks to be carried out on the input and output data.

This reporting system will be used to calculate emissions and removal from wetland drainage and rewetting activities on peatlands from 1990 to 2013. If reliable activity data and EFs are available for other WDR activities these could also be included, if this is considered appropriate by DECC. If complete activity data for the timeseries is not available, appropriate techniques such as correlation with secondary data sources, averaging, extrapolating trends or transposing trends from one UK administration to another will be used to gap-fill. The rationale for adopting any gap-filling methods used will be documented in the report on the database and scripts.

Emissions will be calculated in a format which can be uploaded into the UNFCCC CRF tables for each LULUCF land use type, and for reporting within the hierarchy of land uses used for KP reporting. As part of the quality assurance of emissions calculation, the uncertainty associated with the calculations will be estimated. Outputs from WP5 will be:

Output 5.1: A description of the operational methodology for integrating drained and re-wetted organic soils into the LULUCF Inventory, and for reporting the associated emissions and removals for the UK, including Overseas Territories and Crown Dependencies.

Output 5.2: Estimated annual emissions and removals, itemised by peatland and land-use type, from 1990 through to 2013.As well as high-level summary tables and report, an Oracle database will be produced containing all input emissions factors and activity data, together with detailed documentation including the R scripts used to process data, and details of QA/QC checks carried out on input and output data.

Work Package 6: Scenarios to identify the realistic and maximum potential mitigation of peatland restoration

Lead: A. Thomson

Contributors: J. Moxley, G. Buys, S. Chapman

Scenarios to identify realistic and maximum mitigation potential will be produced based on 'Medium' (existing rates of re-wetting), 'High' (increased rates of re-wetting) and 'Maximum Feasible' scenarios for future WDR activity in the UK, as well as a 'Low' scenario (no additional re-wetting beyond 2013) as a reference. The scenarios will start from the current (i.e. degraded) state and progress to a final restored state based on realistic rates of re-wetting activity and other relevant land-use or management changes, together with any transitional changes in GHG emissions following re-wetting, based on work in WP3. At this stage we do not anticipate that full scenario assessments will be possible for the OTs and CDs, although this will be reviewed during the project based on the results of WPs 3-5. Scenarios will be developed in consultation with policy makers and stakeholders (e.g. DECC, UK administrations, representatives of land managers, conservation organisations, relevant academics) via email consultations, teleconferences or workshops (such as IUCN

meetings or a focused meeting) as appropriate. These will be used to produce input data to calculate projected emissions in 2020 and 2050 using the methodology developed in WP5. This task will also build on preliminary scenario assessments undertaken at JHI by Steve Chapman and others. Output from WP6 will be:

Output 6.1: Forecast annual emissions and removals to 2020 and 2050 for Low, Medium and High restoration scenarios. Forecasts will be presented as tabulated emissions estimates by country and peat/land-use category, as part of a report which will describe the scenarios used, methods applied and the underlying assumptions.

Output 6.2: An estimate of the total mitigation potential (taking account of C sequestration into above and below-ground stores, avoided CO_2 emissions and changes in CH_4 and N_2O emissions) based on the Maximum Feasible restoration scenario. This will be provided in the same format as Output 6.1.

Work Package 7: Ad-hoc support

Lead: Chris Evans

Contributors (provisional): J. Moxley, A. Thomson, G. Buys, R. Artz, MA. Smyth

The project team will provide ad-hoc support to DECC (which may be extended to other government departments, devolved administrations, agencies and non-governmental organisations if approved by DECC) on issues relating to emissions from WDR activity. We will aim to provide a response to requests within 2 working days of receipts, although may be possible to respond to requests for support in shorter times depending on the nature and urgency of the query. If more time is needed to respond to a more complex query, the project team will notify DECC of this on receipt of the query and will provide a schedule for dealing with the query. Responses to queries will normally be provided in writing via email, but short answers may be provided by telephone, backed up by an email to confirm the discussion. Chris Evans will act as the named contact within the team who will allocate any requests for ad hoc support to the most appropriate team member(s). Members of the project team with the appropriate expertise will be available to attend national and international meetings and events related to WDR activity (subject to availability and reasonable notification) following requests to do so by DECC.

Following the requirements set out in the ITT, we will assign a total of 10 days staff time per year to provide support under this WP, and CEH will hold a budget of £5000 for travel costs which will be made available to any project team members required to attend meetings.

A log of all ad hoc support provided will be kept and will be available for reference.

PROJECT MEETINGS AND REPORTING

We will maintain regular monthly contact with the DECC nominated officer via email and phone calls. This will be augmented by short quarterly progress updates, in a form that will be agreed with the Nominated Officer at the outset of the project (see also Communication Plan below)

Annual progress meetings will be held with the Project Board (DECC, Defra and representatives of the DAs), provisionally in early October 2015 and 2016. Members of the team will also be available for a start-up meeting in October 2014 if requested by DECC. Interim teleconference meetings will be arranged with DECC and DA representatives at the mid-points between annual meetings, i.e. in April 2015 and 2016.

An annual progress report will be provided to the Nominated Officer ahead of the first annual meeting, i.e. by the end of September 2015. The draft final report will be submitted eight weeks prior to the end of the project, by the end of August 2016. At least one project output will be delivered during each quarter of the project, allowing progress to be tracked via quarterly milestones (Table 2). Emissions factors will be delivered at the end of year 1, as part of the annual report, and the first full set of inventory estimates for 1990-2013 will be delivered after 18 months, in March 2016, to allow time for consultation, revision and the production of forecasts during the last 6 months of the contract. We note that the timing of Output 2 (the position paper to support the UK's decision on whether to elect WDR) is particularly critical, however there are only 15 working days from the proposed contract start date (which is itself only four days after the tender submission date) to the requested delivery date for this output. This timescale is clearly challenging, and the issue will be discussed with the Nominated Officer following notification of the award of the contract.

Table 1. Summary of project outputs and planned delivery dates

Output	Description	Date
1.1	Report on WS implementation	12/2014
1.2	Definition of successful rewetting	01/2015
1.3	Development of approach for historically drained peatlands	03/2015
1.4	Identification of activity data sources for reporting	03/2015
1.5	Implementation of WS for non-peat wetlands	09/2015
2	Position paper on election of WDR	10/2014
3.1	Tier 2 EFs for UK blanket bog	09/2015
3.2	Tier 2 EFs for other UK peat types	09/2015
3.3	Plan for filling remaining data gaps in EF database	09/2016
4.1	Collated baseline (1990) peat condition data	09/2015
4.2	Collated activity data post-1990	09/2015
4.3	Plan for filling remaining data gaps in activity dataset	09/2016
5.1	Methodology for implementing WDR in the LULUCF Inventory	09/2015
5.2	Estimated emissions and removals from 1990 to 2013	03/2016
6.1	Forecast future emissions and removals to 2020 and 2050	09/2016
6.2	Estimate of maximum GHG mitigation by WDR	09/2016

Table 2. Quarterly project milestones with associated outputs and costs

Milestone	Description	Date	Cost
1	Review of wetland supplement (O1.1), position paper on WDR (O2)	12/2014	£20,970.84
2	Definition of re-wetting, approach for historically drained peatlands and identification of activity data (O1.2, 1.3, 1.4)	032015	£19,356.85
3	Assessment of non-peat wetlands (O1.5)	06/2015	£12,269.71
4	Year 1 report, including Tier 2 EFs (O3.1, 3.2), Collated baseline activity data (O4.1), Inventory methodology (O5.1)	09/2015	£80,655.83
5	Collated activity data 1990-2013 (O4.2)	12/2015	£21,262.97
6	Annual emissions/removals for 1990-2013 (O5.2)	03/2016	£9,820.76
7	Plans for gap-filling EF and activity data (O3.3, 4.3)	06/2016	£16,113.13
8	Final report, including emissions forecasts to 2050 (O6.1) and estimated total mitigation potential (O6.2)	09/2016	£19,334.18

PROJECT MANAGEMENT

Lead: Heath Malcolm

CEH will manage the proposed work, with specified aspects sub-contracted to the British Geological Survey (BGS), James Hutton Institute (JHI), the Crichton Carbon Centre (CCC) and Earthy Matters Environmental Consultants (EMEC). CEH will have overall responsibility for successful delivery of this project to the standard required by the customer, within the resources and timescales agreed at the start of the contract.

All project partners have been involved in previous collaborations with CEH and with each other (see 'Project Team' below). The competency of individual staff to deliver this project is evidenced by short summary information in the Project Team section, and by CVs for all participants provided in Appendix 2.

CEH is currently in the process of applying for ISO9001 accreditation, and as such has effective quality management systems in place. CEH has also signed up to the Joint Code of Practice for Research and manages projects via PRINCE2 methodologies.

Heath Malcolm will be the appointed project manager, with Chris Evans as the scientific lead. Both will have dedicated time on a management task, along with lead participants from each of the subcontracted organisations (see Table 3). The project manager will be responsible for the ongoing management of the project and its successful delivery. CEH uses a software tool 'Resource Management System' to manage the timelines, tasks and milestones of the project. The Resource Management System is connected into the NERC Integrated Management Business System invoicing system (NIMBUS). Invoices will be issued through this system by the Research Councils Shared Business Service at appropriate intervals (as determined in the contract). Project managers are supported within CEH by administrative staff for finance and project management issues.

A Project Board will be appointed to guide progress, in accordance with PRINCE-2 protocols. This board will comprise representatives of DECC and other identified stakeholders from the Devolved Administrations and Defra, along with the project manager. The Project Board will assess progress in the project against agreed milestones, deliverables, and interim reports as set out in the reporting schedule above. Members of the project board will also be invited to join the LULUCF Scientific Steering Group which currently comprises representatives from stakeholders, data providers and the wider scientific community. The Scientific Steering Group meets in person at least once per year and also provides ongoing strategic advice on the science underpinning the LULUCF Greenhouse Gas Inventory. The Scientific Steering Group identify the most suitable datasets for the inventory and projections, and consider how best to encourage the continuing availability of suitable data in the future.

Heath Malcolm already attends the biannual meetings of the UK National Inventory Steering Committee (NISC) where he presents updates on LULUCF activities. This link will ensure that the project is delivered within the context of wider Inventory developments, and outcomes of the project can be presented to the NISC using existing resources.

A full GANTT chart for the project (based on an anticipated October 2014 start date) is given in Table 3. This shows the planned duration of each project task, delivery dates for each project output, and the dates of meetings and reports. The programme of work shown takes full account of dependencies between tasks in terms of methodological developments and data flows between tasks, as well as output delivery dates specified by DECC.

Table 3. Project GANTT Chart

Work package	Task	2014 Q4	2015 Q1	2015 Q2	2015 Q3	2015 Q4	2016 Q1	2016 Q2	2016 Q3
WP1	1.1 Review of Wetland Supplement	1.1							
	1.2 Definition of successful re-wetting		1.2						
	1.3 Approach for historically drained peatlands		1.3						
	1.4 Identification of activity data sources		1.4						
	1.5 Assessment of non-peat wetlands			1.5					
WP2	2 Position paper on election of WDR	2							
WP3	3.1 Tier 2 EFs for blanket bogs				3.1				
	3.2 Tier 2 EFs for other peat types				3.2				
	3.3 Plan for gap-filling EF data							3.3	
WP4	4.1 Collated land-use/peat condition data for 1990				4.1				
	4.2 Collated data for 1990-2013 activity changes					4.2			
	4.3 Plan for gap-filling activity data							4.3	
WP5	5.1 Methodology for implementing WDR in Inventory				5.1				
	5.2 Annual emissions/removals 1990-2013					5.2			
WP6	6.1 Forecast emissions/removals to 2020, 2050								6.1
	6.2 Estimate of total mitigation potential from WDR								6.2
WP7	7 Ad hoc support	Support provided on request throughout project							
	Annual project board meetings								
	Interim teleconferences								
	Annual/final report				Year 1				Final

Quality Assurance Plan

As part of CEH's existing work on the LULUCF Inventory, a Quality Assurance/Quality Management Plan has been developed to cover all inventory compilation activities. This plan will be expanded to document the process required for this contract, all of which will be undertaken with reference to the QA/QC Plan.

CEH will ensure that all project partners adopt the quality assurance principles set out in the Joint Code of Practice for Research. The CEH Policy Statement on Quality Assurance is given below:

- *CEH is dedicated to achieving and maintaining the highest possible standards of quality in order to meet the needs of its work programmes and the needs of internal and external customers*
- *In pursuit of its quality aims, CEH strives to create a working situation that enables all staff to contribute to the continuous and meaningful improvement of a Quality Management System through competence and effective communication*
- *It is the aim to ensure that all staff at CEH understand and are committed to their individual and collective responsibilities for quality*
- *To achieve these objectives, the suitability of working practices and the training needs for existing and new members of staff are appraised by management.*

The framework will ensure that all inputs are clearly defined, with fixed deadlines, and that the process is firmly managed with the Project Manager responsible for ensuring that all deliverables are correctly defined and received on time.

Quality will be maintained through careful and clear work instructions that fully specify all:

- **Tasks** - with clear and agreed deliverables and deadlines
- **Data inputs and outputs** - clearly defining their provenance and related quality control regime
- **File management** - ensuring that data management is appropriate to the task with data security and back up regime in place.

At the beginning of the project (and prior to all defined tasks with partner involvement), sub-contractor kick off meetings or telecons will be held to brief the partners on the current working practices. These will be designed to be designed to be inclusive, to ensure collaborative working within the team.

As Project Manager, Heath Malcolm will have full oversight of the work undertaken, but will not be directly engaged in the data processing or inventory modelling. He will therefore be in a position to independently evaluate and sign off the QA procedures used in the project prior to the handover of outputs to DECC Additional support for project QA will be provided by Annette Burden, who has previously managed the full JCoPR audit of a large NERC research project.

Communication Plan

As this is such a high profile contract, it is imperative that good communication is maintained between the contractors, DECC and each of the identified stakeholders, along with the wider scientific community. The Communication Plan includes separate strategies for communication with internal and external stakeholders.

Internal Communication

The project manager, Heath Malcolm, will be the main project point of contact for DECC and stakeholders on a day to day basis. The lead scientist, Chris Evans will also have frequent, informal contact with DECC and stakeholders, especially with regard to scientific queries. In order to effectively manage communication, an issue-management system is already in place to manage all incoming questions and requests for information. This allows all enquiries to be directed to the appropriate person in the project team so that an appropriate response can be generated in the required time period with progress monitored.

In addition to the *ad hoc* communication outlined above, formal communication will also be directed through the Project Board. The project board will receive summary monthly reports which outline progress achieved during the last month, detailing completion of contract deliverables, and giving an indication of planned progress on forthcoming deliverables.

The suggested headings for the monthly project reports are as follows:

- Update of routine and ongoing activities during the month, including problems encountered and how these were resolved
- Summary of tasks and deliverables completed during the month
- Stakeholder and other meetings attended
- A breakdown of *ad hoc* advice provided
- Forward Look
- Management/budget issues that need to be drawn to the customer's attention, including invoicing, resourcing, risks, changes to scope, proposed new tasks

External Communication

Due to wide-ranging scientific interest in the outputs of this project, these will be made available via the existing LULUCF web site which is available at http://ecosystemghg.ceh.ac.uk/. Note that this website is currently undergoing restructuring, with the new version on schedule to be launched by the end of the year. Due to the policy interests in this area, any updates for the website will only be published once they have been approved by DECC and the wider Project Board.

In addition, all data produced by this project can be made accessible via the CEH Information Gateway (https://gateway.ceh.ac.uk/) which includes the Natural Environment Research Council Environmental Information Data Centre for terrestrial and freshwater sciences. This brings together wide-ranging nationally-important datasets and expertise in managing diverse types of environmental data.

Communication with the wider scientific community will also be essential. In addition to the contract reports being made publically available, the outcomes of this project will be disseminated via attendance at conferences and workshops and publications in peer reviewed journals. Close collaboration with the Defra-funded Greenhouse Gas Research Platform is envisaged using existing links between the scientists working on this project and their collaborators, and members of the team are also actively engaged in Defra, Scottish and Welsh Government funded research projects.

Data Management Plan

The CEH data management planning process requires the Project Manager to complete a formal Data Management Plan (DMP). The DMP helps in identifying and planning tasks that need to be carried out to deliver science projects, mitigates risk to project deliverables and promotes appropriate long-term management and re-use of datasets.

The existing relational database (Oracle) used to store all data involved in compilation of the LULUCF inventory (input and output data) will be expanded to include ingestion and storage of all data produced by this project. The datasets will comply with all EU INSPIRE regulations to ensure appropriate future access and data curation. The database is stored in the digital archive at CEH Lancaster. Version control is used to document all changes to the calculations. This creates a transparent, auditable workflow, based on clearly structured and traceable input data. CEH Computing Services provide back-up of data stored on the CEH network to provide proper security for all data and programs, in accordance with good practice within the computer industry.

Risk Management Plan

An outline Risk Register which presents proposed mitigation measures for the risks to successful delivery of this project has been compiled. These risks have been classified according to staff, data and project management issues.

Risk	Risk level – likelihood and impact	Mitigation measures
Key Staff		
Loss or non-availability of key staff	Low risk, but potentially high impact given short duration of project and tight timescale for reporting.	1. Duplication of knowledge and skills within all aspects of project – e.g. Evans, Artz and Smyth all have detailed knowledge of the IPCC Wetland Supplement and of data sources for emission factors; Moxley, Thomson and Buys are all experts in the operation of the LULUCF Inventory. 2. Documentation of procedures – all data used to develop EFs will be held in a single clearly commented dataset, meta-data will be provided for all spatial datasets, and all procedures used to generate activity data and operate the inventory will be recorded in sufficient detail to permit new staff to repeat the analysis if required.
Data Security		
Lack of access to data for calculating emission factors	Medium risk, medium impact – reliable emissions data are scarce, especially for blanket bog, so it will be important to obtain all relevant data.	1. Members of the team are responsible for generating many of the primary data likely to be used to calculate UK-relevant EFs, for example through the CEH Carbon Catchments, Defra Projects SP1202 and SP1210, JHI research in the Flow Country. 2. Members of the team have begun the task of identifying, sourcing and collating suitable data through work for the Defra Peatland Code, Climatexchange and

Risk	Risk level – likelihood and impact	Mitigation measures
		IPCC Wetland Supplement. 3. International experts involved in the IPCC and in the collection of flux data from highly relevant sites in Ireland are involved as Project Partners. 4. Members of the team also have good contacts with other researchers making flux measurements in the UK and elsewhere. If necessary, direct requests will be made for relevant unpublished data to fill gaps in the EF dataset.
Lack of access to UK spatial data	Medium risk, medium impact – Access to most spatial datasets will be straightforward but a small number of datasets are expected to be harder to obtain, notably the IACS data which have been slow/difficult to access from Scottish and Welsh governments in previous projects.	1. Key data providers (JHI, BGS, CEH) are involved in the project and have agreed to provide data. 2. The CEH Inventory team already hold many of the spatial datasets required to undertake the work 3. Members of the team have established relationships with other data providers such as the conservation agencies and devolved administrations, and have already negotiated access to many of the relevant datasets 4. IACS data will be requested immediately after approval of the project. We will also allow for the possibility that these data will not be made available during the project by developing a method for activity mapping that does not rely on their use.
Lack of spatial data on peat extent and condition and land-use for Crown Dependencies and Overseas Territories	High risk, low impact – we anticipate that it will be difficult to obtain comprehensive spatial data for all overseas locations.	1. BGS peat mapping data have already been identified for the Falkland Islands and Isle of Man, which have the largest peatland areas, so an initial spatial assessment should be possible for these key locations 2. Members of the team have established contacts with key experts on the ecology and land-use of the Overseas Territories which should permit further data and information to be obtained. 3. A semi-quantitative or qualitative assessment of peat extent, condition and mitigation potential will be undertaken for OTs and DAs with limited data in the first instance.
Difficulty in obtaining spatially explicit data on peat re-wetting since 1990	Medium risk, medium impact – there is no comprehensive, current, spatially explicit database of all peat re-wetting activity in the UK since 1990, although some records do exist and others should be available.	1. The project team will utilise their strong contacts with organisations and individuals engaged in peat re-wetting, as well as the DAs and conservation agencies, to maximise the amount of information that can be obtained during the project. 2. The IUCN Peatland Programme will be asked to support the collection of data on restoration projects via their website and newsletter. 3. Members of the team will make

Risk	Risk level – likelihood and impact	Mitigation measures
		presentations at the IUCN annual conference and at other relevant events to raise awareness of the project. 4. Reporting templates and worked examples will be provided to practitioners to facilitate transfer of information and spatial data.
Data loss / Data Security	Low risk, high impact – Loss of key datasets would have a significant detrimental impact on project delivery	1. All data generated in the project, including collated emission factors, GIS files containing activity data and final emissions inventories will be held centrally on the CEH network, which is backed up daily to a remote data storage facility, thus minimising the risk of data loss. 2. Agreed file naming protocols and version control will be used to ensure that all data used are traceable, and if necessary retrievable if it becomes necessary to change the methodology or revert to earlier versions of the source datasets or inventory code.
Data errors	Low risk, high impact – errors in data processing could lead to incorrect inventory estimates of emissions and removals.	1. Data sources and calculations used to generate new data (such as emission factors) will be cross-checked by other members of the team with suitable expertise. 2. A qualified statistician (Jackie Potts, BioSS, JHI) will contribute to the project and ensure that analyses undertaken are statistically robust.
Project Management Issues		
Management issues	Low risk, medium impact – lack of coordination and communication within the team could lead to delays or problems in delivery	1. A highly experienced project manager (Malcolm) will lead a stand-alone management task to ensure adherence to the project plan, milestones and deliverables. 2. The team which has been constructed has a strong track-record of working together on highly relevant projects for DECC, Defra and the DAs, which should ensure efficient interactions between participants. 3. All work packages and their component tasks have named leads who will coordinate the work of all WP/task participants.
Poor external communications	Low risk, medium impact – lack of communication with DECC or other stakeholders, including DAs, could reduce the effectiveness of the project	1. The team will communicate regularly with the DECC Nominated Officer and the Project Board via emails, telecons and meetings 2. The work will be communicated to the broader stakeholder community via national and international meetings; a staff time and travel budget has been set aside for this as specified in the invitation to tender.

PROJECT TEAM

We believe that the project team assembled is uniquely positioned to deliver the requirements of the project, including leading UK research organisations: the Centre for Ecology and Hydrology (CEH), James Hutton Institute (JHI), British Geological Survey (BGS), Crichton Carbon Centre (CCC) with expertise in the field, and highly experienced individual researchers with complementary skills in this area and a record of successful collaboration. The team includes the CEH inventory group, several lead authors of the IPCC Wetland Supplement, the lead author of the recent report to Scottish Government on implementation of wetland drainage and re-wetting, and the leads for active Defra projects including the lowland peat project (SP1210) and the development of carbon metrics for the UK Peatland Code (NR0165). The team are thus experienced in all stages from the field measurement of peatland GHG fluxes, to their analysis and synthesis in support of policy, and the development and application of methods for GHG inventory accounting and reporting. The following briefly summarises the experience of members of the team; longer CVs are appended at the end of the proposal document. A detailed summary of staff allocations to project WPs and tasks is provided in Table 3.

CENTRE FOR ECOLOGY AND HYDROLOGY

Chris Evans was one of three UK lead authors who contributed to the IPCC Wetland Supplement, and the only one of these involved in the derivation of emission factors for temperate and boreal peatlands. He was also one of only two authors involved in both Chapters 2 and 3 of the report, and led the development of methods for waterborne carbon in both chapters, and for the inclusion of CH_4 emissions from drainage ditches in Chapter 2. He currently leads Defra project SP1210 (GHG balance of lowland peats) and a Welsh government-funded project with BGS to map the extent and condition of Welsh peatlands, and is a Co-PI on Defra project SP1202 (effects of ditch-blocking on the GHG balance of blanket bogs) and project NR0165 (developing carbon metrics for the UK Peatland Code). He is also the science lead for the CEH Carbon Catchments project, and coordinates the long-term peatland flux measurement study in the Upper Conwy, North Wales. He previously led Defra project SP1205 (role of fluvial carbon fluxes in the peatland GHG balance) and JNCC Report 433 on designing a programme to address evidence gaps in GHG and carbon fluxes from UK peatlands. He also previously led the Defra Critical Loads and Dynamic Modelling consortium, which was responsible for mapping and modelling the impacts of atmospheric pollutants on semi-natural ecosystems including peatlands at a UK scale. **Annette Burden** is the database manager for the Defra lowland peat project, co-led the systematic review of emissions data from managed lowland peats for this project, and also has expertise in the carbon and greenhouse gas dynamics of coastal wetlands.

The CEH Inventory team (**Heath Malcolm, Janet Moxley, Amanda Thomson, Gwen Buys**) have responsibility for the development, operation and reporting of the UK LULUCF Inventory. **Heath Malcolm** is the project manager for the LULUCF inventory. He also has experience of managing other projects including the Rural Heavy Metals Deposition Network, the Review of Transboundary Air Pollution, and the Predatory Birds Monitoring Scheme using PRINCE2 methodology. **Janet Moxley** is a soil scientist and was the scientific lead on the Defra SP1113 project on Capturing Cropland and Grassland Management Impacts on Soil Carbon in the UK LULUCF Inventory. She has contributed to Welsh Government projects to review the effectiveness of reporting systems in capturing the benefits of the Glastir sustainable land management scheme. She has worked with long term monitoring data to assess change in aqueous organic carbon concentrations and on factors affecting carbon monoxide exchange between soils and the atmosphere. **Amanda Thomson** has worked on LULUCF inventory compilation and improvement since 2005 and has been the Lead Scientist since 2009. **Gwen Buys** is the data modeller for the LULUCF inventory. She is experienced in the design and

management of Oracle databases and has programming skills in FORTRAN and R.

Pete Levy Is an ecosystems modeller with experience of modelling global-scale vegetation and the impacts of climate change, land use change and nitrogen deposition and of integrating remote sensing and surface flux measurements into ecosystem models. He leads the CEH Carbon Catchment at Forsinard, led a major synthesis of UK CH_4 flux data, and is a Co-PI on the NERC GREENHOUSE project.

JAMES HUTTON INSTITUTE

Rebekka Artz is a peatland ecologist specialising in evaluation of restoration success, with experience in providing policy advice, policy tools and scenario-based analysis of land management options. She has led and contributed to various policy briefings outlining the potential for restoration and carbon sequestration in peatlands in Scotland. Her research interests also include other ecosystem services of peatlands (supporting, regulating and cultural services), and she was co-author of a recent JNCC report on the ecosystem service delivery of UK designated sites. She currently leads a team within the Centre for Expertise on Climate Change that is developing a GIS-based spatially explicit decision support tool for peatland restoration in Scotland.

Steve Chapman is a microbial ecologist with particular experience in studying processes within the carbon cycle. He has focused on peatland ecology and associated GHG emissions. He has recently been involved in the Scottish Government's Centre of Expertise on climate change, advising on the impacts of peatland restoration for climate change mitigation.

Matt Aitkenhead is a soil scientist with extensive experience in data mining, remote sensing interpretation and land cover/land use mapping. He also works in proximal sensing of soils and the lining of spatial datasets with field observations. He works on the digital soil mapping of the NERC ESPA-ALTER project and has recently carried out work on peat depth and condition mapping for Scottish Water.

David Donnelly is a GIS and applications developer with experience of working with large and complex data sets. He has collaborated on the development of numerous spatial decision support systems, from standalone data models to interactive map-based web applications. He is also part of the Hutton team charged with the licensing of its data holdings.

Matt Saunders is an Ecophysiologist who specialises in the measurement of carbon, nitrogen and greenhouse gas (GHG) dynamics within terrestrial ecosystems. He is currently working on assessing the impacts of forest to bog restoration on ecosystem scale GHG emissions using eddy covariance techniques. He is a member of the Integrated Carbon Observation System (ICOS) and is the lead scientist on the development of a standardised measurement protocol to assess management and climate related disturbances on ecosystem carbon dynamics.

Jackie Potts is a statistician with 20 years' experience of consultancy and research in environmental statistics. In her current post at the James Hutton Institute she provides statistical consultancy for the Scottish Government's RESAS research programme and is also involved in external contract work for agencies such as JNCC, SNH, SEPA and SNIFFER.

CRICHTON CARBON CENTRE

Mary-Ann Smyth was originally a geomorphologist, but spent her mid career in strategic consultancy and reviews for government, and is now leading research on the greenhouse gas impacts of peatland restoration. She is a director of Crichton Carbon Centre, a member of ClimateXChange (Scotland's centre of expertise in climate change), was a peer reviewer for

VCS (Verified Carbon Standard - wetlands restoration), and is a member of Scotland's Peatland Working Group. She is a field scientist with pragmatic experience of peat bogs and peat retwetting, and of developing the relevant greenhouse gas metrics and protocols. She now specialises in sustainable development using carbon as a proxy, and peatland restoration using vegetation and ecosystem condition as a proxy.

Emily Taylor has been developing the field assessment protocol and peatland condition assessment for carbon flux estimates for use in the field for the Defra funded project NR0165 "Developing Peatland Carbon Metrics and Financial Modelling to Inform the Pilot Phase UK Peatland Code". She has researched and carried out field campaigns looking at carbon dynamics in peatlands for her PhD in the effect of fire on blanket bogs. Currently Emily is Peatland Action project Officer managing and designing restoration projects across south Scotland as well as working closely with SNH and the Peatland Action Team to deliver best practice restoration guidance and methodologies. She has extensive field experience of peatland restoration methods and techniques and has built up a strong network of peatland restoration contacts across the UK, from private landowners to conservation organisations**.**

Dr Richard V Birnie has thirty years experience of peatland field work, many of which were spent directing parts of the Macaulay Land Use Research Institute, as well as more recently being co-researcher in the development of the carbon metrics for peatland restoration. Dr Birnie has a BSc and PhD from the University of Aberdeen, and a PGCE from the University of Cambridge. He joined the Remote Sensing Unit at the Macaulay Institute in 1980 after a period of postdoctoral research at the University of Canterbury in New Zealand.

BRITISH GEOLOGICAL SURVEY

Barry Rawlins is a soil scientist with 20 years experience working on soil functions including upland peat systems and carbon cycle biogeochemistry. He recently led the development of the unified peat map of Wales for Welsh Government and used landscape scale data to develop a national scale model of carbon dioxide emissions from fresh waters across England and Wales.

Russell Lawley developed the soil parent material model of the UK and has detailed knowledge of high-resolution (1:10 000 scale) mapping of peatlands throughout Great Britain undertaken by BGS mapping experts. He has more than 15 years experience in the use and application of GIS to issues relating to the surface and sub-surface across the UK and internationally.

Nicole Archer is a soil scientist and hydrologist with experience in the use and application of remotely sensed data across diverse environmental settings, both in the UK, Spain and China. Nicole has more than 15 years experience in the development and application of models to remotely sensed datasets to address a wide range of soil science functions and ecosystem services.

Stephen Grebby is a remote sensing specialist who has led the development of techniques to identify bare peats and drainage ditches across Wales under the Glastir project. He has more extensive experience of the application of lidar and air photo data to landscape issues at national and regional scales.

EARTHY MATTERS ENVIRONMENTAL CONSULTANTS

Florence Renou-Wilson has been working as a research scientist for 16 years in University College Dublin where she is also a lecturer and director of a Masters of Science in Global Change: Ecosystem Science and Policy. She has investigated peatlands in an integrative way

at the crossroads of ecology, forestry, agriculture, climate change and sustainable management. Dr Florence Renou-Wilson was one of three Irish Lead Authors of the Inter-governmental Panel on Climate Change Wetland Supplement (2014). She was involved directly in the derivation of emission factors for rewetted organic soils (chapter 3). She is currently working on a research project investigating both drained and rewetted organic soils and their benefits for climate and biodiversity. Dr Renou-Wilson is a member of the Scientific and Policy Advisory Group to the Peatland Council set up by the government to assist Ireland to respond to the requirements of EU and domestic law relating to the protection of important peatland habitats. She is also a member of the committee of Commission 10 “Climate Change and Peatlands” of the International Peat Society.

David Wilson is an environmental consultant specialising in monitoring and modelling greenhouse gas (GHG) fluxes in peatlands. He received his PhD in 2005 on the subject of “Carbon dioxide, methane and vegetation dynamics in a rewetted cutaway peatland in Ireland” and has since worked on a range of EPA Ireland and industry funded projects investigating GHG fluxes in intact, degraded and restored peatlands in Ireland. He was a Lead Author of Chapter 3 (Rewetted organic soils) in the IPCC 2014 Wetlands supplement where he specifically focussed on developing the methodology for the derivation of emission factors for carbon dioxide. He was also a Reviewer for Chapter 2 (Drained Inland Organic Soils) of the Wetlands supplement. His current research is aimed at progressing Ireland’s inventory reporting of drained organic soils to the Tier 2 level

Table 5. Allocation (in days) of project staff to work packages and tasks. Allocations of staff acting as the lead for each task are highlighted in bold.

Participant	**Institution**	**WP1**					**WP2**	**WP3**		**WP4**			**WP5**	**WP6**	**WP7**	**Manage-ment**
		Task 1.1	*Task 1.2*	*Task 1.3*	*Task 1.4*	*Task 1.5*		*Task 3.1*	*Task 3.2*	*Task 4.1*	*Task 4.2*	*Task 4.3*				
Chris Evans	CEH	**5**	1	2	2	2	6	6	6	1	1	2			4	4
Annette Burden	CEH					**12**		7								5
Heath Malcolm	CEH															**16**
Pete Levy	CEH							2	2	2						
Janet Moxley	CEH	4		**3**	**3**	2	4			3	2	2	7	5	4	2
Amanda Thomson	CEH						2						5	**10**	4	
Gwen Buys	CEH									1	1		**10**	10	4	
Rebekka Artz	JHI	3	1	2	1		2	**10**	**10**						2	1
Steve Chapman	JHI				1					3	3			4		
David Donnelly	JHI									7	6	2				
Jackie Potts	JHI							5	5							
Matt Aitkenhead	JHI									**10**	3	2				
Matt Saunders	JHI							6	5							
Barry Rawlins	BGS									1.5						1
Russell Lawley	BGS									1						
Nicole Archer	BGS									20						
Mary-Ann Smyth	CCC		**3**					5		10	**8**	**3**			2	1
Emily Taylor	CCC									10	10	5				
Dick Birnie	CCC						2	2								
David Wilson	EMES							2	2							
Flo Renou-Wilson	EMES							2	2							

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APPENDIX 1. OPTIONAL WORK PACKAGES

WORK PACKAGE 8: PEATLAND CONDITION MAPPING FOR ENGLAND AND NORTHERN IRELAND

Optional Task 8.1: Assessment of peat condition based on identification of drainage channel intensity using air photos for blanket peats in England

The aim of this work package is to delineate artificial drainage channels in upland peat across all of England and calculate their density (length of ditch per unit area). This information has not previously been systematically mapped across England, but is needed for robust inventory reporting of emissions and removals associated the blanket bog drainage and re-wetting. The method will build upon the work that BGS and CEH are currently undertaking to map drainage channels in upland peat across Wales based on colour (RGB) and colour infra-red (CIR) high resolution air photography, which is also available for England. For Wales, BGS have applied a linear feature extraction algorithm using PCI Geomatica (commercial software) as a semi-automated procedure for delineating drainage channels. There are no licensing costs required for the use of the air photos. We will first define the extent of upland blanket peat using the unified peat map created in WP4. Using the digital photography layers, the algorithm generates vector shapefiles which can be loaded into ArcGIS (ESRI). These then need to be cleaned by a GIS technician to remove extraneous linear features (e.g. some natural drainage channels, roads, regular lineaments in coniferous forests). This process is more efficient than the operator searching all the air photos and delineating artificial drainage channels manually in a GIS package. A GIS operation is then used to compute the drainage intensity per unit area, a standard procedure in geomorphometric analysis.

Cost summary

Redacted

Optional Task 8.2. Assessment of peat condition based on identification of drainage channel intensity using air photos for blanket peats in Northern Ireland

The same procedure as described above for England will be adopted for Northern Ireland, but there is a difference in terms of the data that are available for the drainage channel analysis, and this will mean some development work will be required. First, there are no national scale colour infra-red air photos for Northern Ireland available, so the analysis would be limited to high-resolution colour photos. It will be necessary to test and refine the linear feature extraction procedure using this more limited set of colour information. The peat distribution information will be taken from the existing 1:50 000 scale soil maps of Northern Ireland. There are no licensing costs required for the use of the air photos of Northern Ireland.

Cost summary

Redacted

WORK PACKAGE 9: CONSULTATION MEETING TO ENHANCE KNOWLEDGE OF PEATLAND EXTENT, CONDITION AND LAND-USE ACTIVITY IN THE OVERSEAS TERRITORIES

We recognise the importance of using recent and reasonably accurate information on wetlands and wetland restoration in the Overseas Territories.

We also recognise:

- the practical necessity for island economies to highly value resilience and self sufficiency.
- the probability that some Overseas Territories may prioritise the value of upland farming, soil 'improvements', or tourism development above the value of peatlands, other wetlands or carbon; or may have only recently changed priorities from one to the other.
- that land-use maps, surface geology maps and ecosystem condition maps may not be available for all overseas territories, or may be uncertain. For example, the recent IUCN assessment of peat extent on the Falkland Islands (IUCN, 2011) gave strikingly different estimates of deep peat extent to a previous BGS survey of the islands (Aldiss and Edwards, 1999).
- that several specialists in the UK have good knowledge of those territories, and would helpfully provide indications of whether the maps, data and estimates suggested by this project are sensible, optimistic or pessimistic.

Consulting with leading experts would therefore provide a cost-effective means of ensuring that the best available data are being used to assess and account for emissions from wetlands in the Overseas Territories, as well as ensuring that any emissions estimates produced during the project have been ‘reality checked’ by those with in-depth knowledge of the habitats concerned..

This optional task would comprise two 2 half day round table meetings, one on peatlands and one on coastal wetlands (one be an in-person meeting focused on Falkland peatlands, the other a virtual round table on other wetland areas in the Overseas Territories)

Aims: to discuss availability and accuracy of the maps and data available

- to identify best figures, both on present conditions and on expected future changes (taking into account the regional drive toward tourism development, agriculture, and nature conservation), in order:
- to identify which overseas territories the report needs to focus on for monitoring future changes in GHG emissions from wetland land-use and land-use change
- to identify whether initial estimates provided by this project are realistic
- to include special consideration of the comparatively large peatland area in the Falkland Islands

Cost summary

Redacted