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SID 5 Research Project Final Report

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Project identification

1. Defra Project code: FD2622
2. Project title: Understanding the impacts of FCERM on the causes of climate change
3. Contractor organisation(s): Economics for the Environment Consultancy (eftec)
   Enviros Consulting Ltd
   Philip William and Associates (PWA)
4. Total Defra project costs (agreed fixed price): £ 60,100
5. Project: start date .... 23 February 2009
   end date .... 31 March 2010

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Executive Summary

7. The executive summary must not exceed 2 sides in total of A4 and should be understandable to the intelligent non-scientist. It should cover the main objectives, methods and findings of the research, together with any other significant events and options for new work.

Objective

The purpose of this research project is to improve understanding of the climate change impact of flood and coastal erosion risk management (FCERM) policy in England. The research aims of the project are to:

- Provide an evidence base to support the current best estimate of the contribution of FCERM policy to GHG emissions;
- Investigate and evaluate the impact of different FCERM policy options on GHG emissions;
- Identify the FCERM policy areas most likely to present significant threats and opportunities for the release/abatement of GHG emissions and the extent of these impacts in terms of contributing to UK GHG reduction targets; and
- Facilitate understanding of the consequences of current and potential Government intervention in FCERM policy on climate change.

The approach to addressing the research aims is that of a desk-based assessment. No primary data collection has been undertaken; all evidence is collated from secondary sources. The main elements of the assessment are: (i) a conceptual review of the policy context for the project, which informs the scope and subsequent framework for the analysis; and (ii) collation and analysis of currently available data to estimate as best possible the carbon footprint of FCERM policy.

Methods

The term 'carbon footprint' is shorthand for an inventory of the GHG emissions that result from an activity, event, organisation, product or geographical area. Basic principles for developing a carbon footprint are:

- *Establish project boundaries:* In particular determine the scope of activities to be included in the analysis.
- *Determine calculation methodology(ies):* the "first best" approach to calculating emissions is to take primary consumption data and multiply this by a GHG emissions factor.
- *Present results:* it is important that the results are presented in a way that facilitates 'like for like' comparison with existing studies and also highlights any limitations and caveats associated with the results.

The research considers a number of 'scenarios' to assess the GHG emissions implications of current and future policy options. This involves comparison of the carbon footprint of a baseline scenario with the carbon footprints of alternative scenarios that reflect different policy focus:

- Business as usual (BAU): this is the baseline for the assessment that assumes a continuation of the current policy focus and levels of investment.
- Increased investment in river and coastal flooding ('BAU plus'): this assesses the carbon footprint implications of increased expenditure from the BAU case, weighing increased emissions from FCERM activity (i.e. more construction and maintenance schemes) against the decrease in emissions associated with residual flooding damages.
- Addressing surface water flooding ('SWF'): this assesses the implications of increased expenditure on surface water flooding schemes, weighing increases in emissions from asset construction against the decrease in emissions associated with surface water flooding.
- Policy-off: this describes the counterfactual to FCERM intervention and associated net GHG emissions; i.e. the carbon footprint implications of no active FCERM intervention.

Results

Estimated carbon footprints for the BAU, policy-off, BAU-plus and SWF scenarios are presented in Table 1 in terms of annual average tonnes of CO_2e per year. The annual estimate is calculated from the assumed profile of emissions over a 50-year time horizon.

Table 1 Estimate of FCERM carbon footprint for alternative policy scenarios (Mt CO_2e per year)

Scenario	***Emissions arising from:***		***Total***
	FCERM activities	*Flood and coastal erosion damages*	
BAU	0.53	1.89	2.41
Policy-off	n/a	2.89	2.89
BAU plus	0.70	1.67	2.36
SWF	0.55	1.62	2.18

The current 'best' estimate of net emissions from FCERM policy and investments is 2.41 Mt CO_2e per year. The results detailed in Table 1 are subject to several caveats:

- Estimation of FCERM BAU carbon footprint is only possible to the extent allowed by existing information sources. Limited data availability means that not all of the emissions associated with FCERM activities and non-FCERM activities arising due to FCERM can be quantified at present.
- Based on data availability, the estimated carbon footprints include:
  - Emissions associated with FCERM activities - asset construction and maintenance only.
  - Emissions associated with flood and coastal erosion damages - reparations to properties and possessions.
- The analysis does not estimate emissions associated with adaptation measures, development control, mapping and modelling, emergency planning and response, flood storage or managed realignment. In addition emissions from activities dependent on FCERM are not accounted for in the analysis (e.g. agriculture and drainage of land/soils).
- The omitted activities have implications for both emissions and sequestration of GHGs, implying that the net effect on the BAU carbon footprint at present comprises a significant degree of uncertainty.

Overall the resulting carbon footprint estimates should be interpreted with caution, representing indications of order of magnitude rather than precise estimates. Sensitivity testing of component parts of the carbon footprint estimates indicates relatively large ranges based on different sets of assumptions; in general however this is expected given the high-level nature of the analysis.

Conclusions

Overall this project provides a broad view of flood risk management and the science and methods of measuring GHG emissions and carbon sequestration. In practice, many of the component areas of the FCERM footprint could warrant detailed investigation; especially developing the evidence base related to land use management and carbon sequestration, estimating emissions from asset construction and maintenance activities, or estimating emissions associated with flood and coastal erosion damages.

Drawing together the available evidence has permitted a partial estimate of the contribution of FCERM policy to GHG emissions. This suggests that FCERM plays a small role in contributing to national level emissions (estimated to less than 1% of total annual emissions), and that increases and decreases in the level of emissions from FCERM are likely to have relatively minor implications for the attainment of UK GHG reduction targets.

The analysis undertaken also indicates that it is likely that intervention in flood and coastal erosion risk management plays a role in avoiding GHG emissions in the short-term (compared to those that would arise in the absence of active intervention). However key gaps remain, particularly in relation to providing a detailed account of threats and opportunities for the release/abatement of GHG emissions from FCERM policy.

Project Report to Defra

8. As a guide this report should be no longer than 20 sides of A4. This report is to provide Defra with details of the outputs of the research project for internal purposes; to meet the terms of the contract; and to allow Defra to publish details of the outputs to meet Environmental Information Regulation or Freedom of Information obligations. This short report to Defra does not preclude contractors from also seeking to publish a full, formal scientific report/paper in an appropriate scientific or other journal/publication. Indeed, Defra actively encourages such publications as part of the contract terms. The report to Defra should include:

- the scientific objectives as set out in the contract;
- the extent to which the objectives set out in the contract have been met;
- details of methods used and the results obtained, including statistical analysis (if appropriate);
- a discussion of the results and their reliability;
- the main implications of the findings;
- possible future work; and
- any action resulting from the research (e.g. IP, Knowledge Transfer).

1. Introduction

Background

This report provides a summary of the outputs of the research project FD2622 Understanding the Impact of Flood and Coastal Erosion Risk Management on the Causes of Climate Change. Current flood and coastal erosion risk management (FCERM) policy in England recognises the need to address the challenges and pressures from climate change. The majority of effort is focused on adapting to the main impacts of climate change on flood and coastal erosion risk. However, there is also scope for FCERM to contribute to mitigation of climate change by developing policies and strategies that avoid an increase of, or lead to a reduction in, greenhouse gas (GHG) emissions.

Research Objectives

The purpose of the project is to improve understanding of the climate change impact of FCERM policy; in effect, to provide an assessment of its 'carbon footprint'. Establishing how FCERM contributes to emissions of GHGs is critical to facilitating effective policy responses for reducing future emissions. In addition, mitigating the drivers of climate change now can reduce the potential costs of adaptation in the future.

The Terms of Reference (ToR)[1] for the project set out the research aims as to:

- Provide an evidence base to support the current best estimate of the contribution of FCERM policy to GHG emissions;
- Investigate and evaluate the impact of different FCERM policy options on GHG emissions;
- Identify the FCERM policy areas most likely to present significant threats and opportunities for the release/ abatement of GHG emissions and the extent of these impacts in terms of contributing to UK GHG reduction targets; and
- Facilitate understanding of the consequences of current and potential Government intervention in FCERM policy on climate change.

The overall role for the project is to develop as far possible, given the current evidence base, the necessary tool(s) for policy-makers to weigh up and present evidence of the positive and negative effects of FCERM policy on climate change. It also provides an opportunity to identify gaps within the current evidence base and the scope for addressing them.

In addressing the project's research aims, the ToR also identifies a set of specific policy questions to be addressed:

I. What is the current net climate change impact of FCERM activities?

II. What is the best estimate of net GHG emissions from FCERM policy and investments?

III. Which FCERM activities and policies provide significant positive mitigation of net GHG emissions through sequestration of carbon?

IV. What are the FCERM policy areas likely to make the biggest contribution to UK GHG policy under different future scenarios?

V. What are the key opportunities to reduce GHG emissions and/or enhance carbon sequestration in terms of future FCERM policies?

The extent to which the research aim and policy questions have been 'answered' is reviewed subsequently in Section 4.

2. Research Methods

Requirements

Addressing the research aims and policy questions requires an understanding of FCERM policy and investment as well as the science and methods – carbon footprinting - of estimating GHG emissions. Significantly the

[1] Defra (2008) *Understanding the Impact of Flood and Coastal Erosion Risk Management on the causes of Climate Change*, FD2622 Specification.

influence of FCERM policy is not limited to the protection of people and property via construction and maintenance of defences; it also can have considerable influence on land use management and development, which in turn may have significant implications for emissions of GHGs. In addition, the scientific understanding underlying measurement of GHG emissions is complex and still developing, particularly with respect to sequestration of carbon by terrestrial and coastal ecosystems, a key aspect of land use management directly or indirectly influenced by FCERM policy.

Basic principles of a carbon footprint

The term ‘carbon footprint’ is shorthand for an inventory of the GHG emissions that result from an activity, event, organisation, product or geographical area. It typically measures the emissions of each of the basket of six greenhouse gases (CO_2; CH_4; N_2O; PFCs; HFCs; SF_6) expressed in terms of carbon dioxide equivalent (CO_2e) to enable the comparison of emissions of the different gases on a like-for-like basis.

Basic principles for developing a transparent and robust carbon footprint are:

- *Establish project boundaries:* In particular determine the scope of activities to be included in the analysis.

- *Determine calculation methodology(ies):* the “first best” approach to calculating emissions is to take primary consumption data and multiply this by a GHG emissions factor.

- *Present results:* it is important that the results are presented in a way that facilitates ‘like for like’ comparison with existing studies and also highlights any limitations and caveats associated with the results.

In addition the approach to a carbon footprint should facilitate future updating as new or previously unavailable information becomes available.

Approach to research

The approach to the project is that of a desk-based assessment. No primary data collection has been undertaken; all evidence is collated from secondary sources. The main methodological steps of the project are:

1. Establish a framework for analysing the impacts of FCERM policy on climate change

2. Identify and collate available evidence based on data requirements outlined in the framework.

3. Analyse available data to estimate net GHG emissions from FCERM policy

4. Provide high-level assessment of FCERM policy impact on climate change

5. Provide suggestions moving forward and conclusions

While Steps 1 – 4 detail the process for providing a high-level assessment of the GHG implications of the overall FCERM policy circumstances, the research also includes a series of case studies that apply the framework for analysis at an individual FCERM scheme level, attempting to establish the carbon footprint of a selection of recently implemented or appraised coastal and inland flood alleviation projects. Further details are provided in the FD2622 Technical Report.

With respect to 2 and 3 above, the availability of data can represent a significant challenge to carbon footprinting exercises. This is often the case when a subject area is addressed for the first time as is the case for the entirety of FCERM policy.

Framework for analysis

The FCERM policy remit covers all forms of flooding and coastal erosion:

- *River flooding*: from heavy or sustained rainfall exceeding the capacity of rivers and streams.
- *Coastal flooding*: from a combination of high tides and storm conditions flooding coastal and estuary areas.
- *Surface water flooding*: from heavy or sustained rainfall exceeding capacity of drainage systems, particularly in urban areas[2].
- *Groundwater flooding*: from rising groundwater levels particularly in low lying areas.

[2] Note that sewer flooding that occurs as a result of failure of equipment or blockages and results in raw sewage flooding land and properties is outside the FCERM policy remit.

- *Coastal erosion*: loss of land and removal of beach or dune sediments caused by wave action, tidal currents and drainage.

The above risks are managed through the construction and maintenance of defences and other structures, flood forecast and warning services, emergency planning, response to flood events, development control advice, and management of land drainage. These give rise to various activities, investments and outcomes that generate GHG emissions or sequester carbon. The principle sources of emission/sequestration are:

- *Embodied carbon within materials*: GHG emissions associated with the manufacture (and entire life cycle) of a product (or material). With respect to FCERM, embodied carbon is relevant to:
  - Use of materials in asset construction and maintenance activities (i.e. defences and associated infrastructure as well as adaptation, resilience and resistance measures for individual properties), such as concrete and metal; and
  - Use of materials in flood and coastal erosion damage reparations, e.g. repair of building fabric and structures, rebuild of properties, replacement of possessions, etc.

- *Energy use in operations*: FCERM activities give rise to GHG emissions from use of electricity from the national grid and also on-site consumption of fossil fuels, in buildings and facilities (e.g. pumping stations).

- *Energy use in transport*: energy use also includes GHG emissions associated with fuel (petrol, diesel and biofuels). The two main transport emission sources are:
  - Transport of materials (e.g. for asset construction and maintenance); and
  - Transport of people (e.g. for survey, inspection, maintenance, construction, etc).

- *Land use and land use change*: FCERM may influence land use management and consequently GHG emissions from this sector, either directly or indirectly. In the 'direct' case FCERM activities include the creation of floodplain areas designed for flood water storage and managed realignment to accommodate changing coastal processes. These can result in habitat creation, restoration or maintenance, particularly in terms of wetland habitats, which in turn can lead to storage of carbon in floodplain soils or coastal sediment (see also: Thompson, 2008).

  In the 'indirect case', FCERM may be a critical factor to GHG emissions that arise from development of household, commercial and agricultural sectors, particularly if land-use changes as a consequence of FCERM activity; i.e. development is allowed as a result of areas being protected by defences. This may lead to GHG emissions in terms of embodied carbon from construction and energy use (e.g. housing and commercial developments) and also from changes in agricultural land use (and soil use). The principle consideration in relation to indirect land use GHG emissions is 'additionality' and whether in the absence of FCERM the emissions would arise[3].

Broadly, these sources of emissions can be attributed directly to FCERM activities or other activities that are influenced by FCERM:

- *FCERM activities*: actions or interventions that arise as a direct result of FCERM policy that are intended to reduce the risk of flooding or coastal erosion. In general FCERM activities are intended to either reduce the likelihood of flooding or coastal erosion, or reduce the impacts of flooding and coastal erosion.

- *Non-FCERM activities*: actions, interventions or activities that are consequences of FCERM policy, but that are not directly controlled by FCERM. For example repair and rebuilding construction activities in response to flooding damages or agricultural land use protected by flood defences.

Table 1 links the sources of GHG emissions to FCERM and non-FCERM activities as outlined above. This represents. The basic formulation of the FCERM policy carbon footprint which is also set out in Figure 1.

[3] A distinction is drawn between FCERM influencing the location of a particular activity as opposed to its overall economic viability and hence existence. For example, defences may permit development on floodplains, but the counterfactual (i.e. 'no defences') does not imply that properties built on floodplains would not be constructed. Most likely they would be situated in lower risk areas in the absence of defences. However, water level management is critical to the viability agriculture in some areas; e.g. the Fens where the scale of activity and reliance on flood defences is significant and production would not be transferred to other locations in England in the absence of FCERM.

Table 1 FCERM policy and sources of GHG emissions

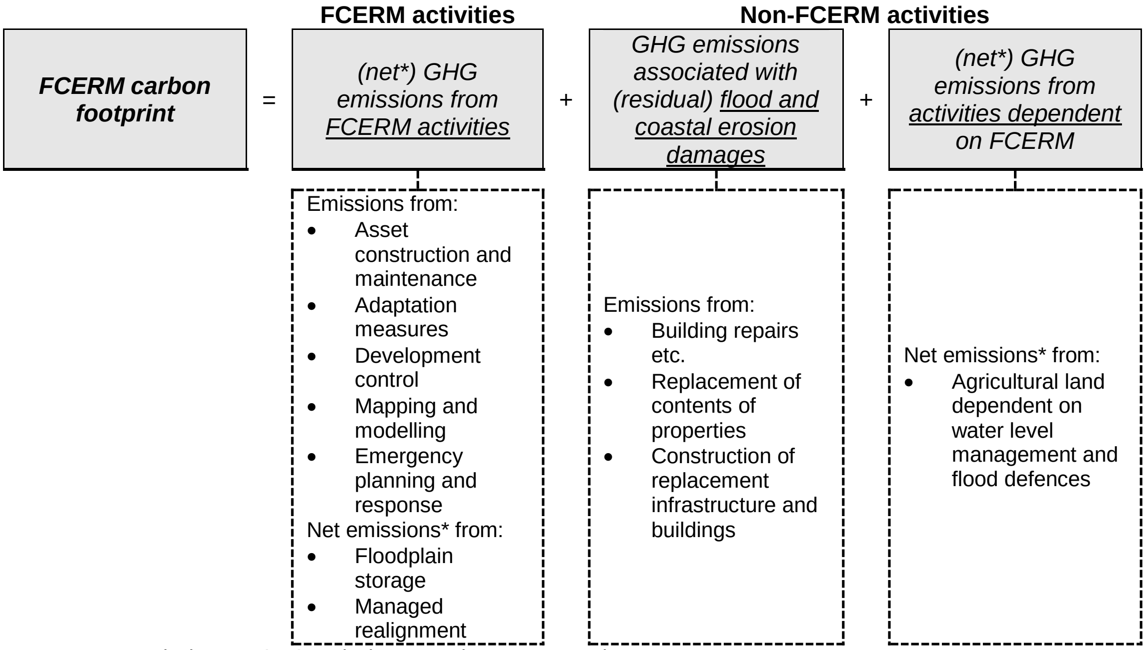
Activity	*Description*	*Sources of emissions/sequestration*				*Notes*
		Embodied carbon	*Energy*	*Transport*	*LUC*[a]	
FCERM activities						
Asset construction	Actions to reduce likelihood of flooding: construction of and improvements to raised defences (e.g. embankments and walls) and structures (e.g. weirs, sluices) to control flow of water and protect multiple properties and/or area of land. Surface water management actions include SUDS[b] (e.g. filter strips, swales, drains, permeable surfaces and infiltration devices, basins and ponds)	✓	✓	✓	✓	GHG emissions associated with works on coastal and inland defences in response to coastal, river and surface water flooding and coastal erosion GHG emissions associated with land-use change are likely to be minor resulting from land take for schemes
Asset operation, maintenance and refurbishment	Actions to reduce likelihood of flooding: pumping, upkeep of raised defences and structures to maintain standard of protection, including inspection, vegetation removal, repairs, renovation and modifications	✓	✓	✓	-	
Adaptation measures	Actions to reduce impacts of flooding at individual property level: ▪ Resilience measures: construction techniques or modifications on standard practice to ensure no permanent damage is caused, structural integrity is maintained and drying and cleaning are facilitated	✓	✓	✓	-	GHG emissions associated with interventions at individual property level in response to coastal, river and surface water flooding
	▪ Resistance measures: construction measures/techniques additional to standard practice to prevent flood water entering properties	✓	-	✓	-	
Floodplain storage	Actions to reduce likelihood of flooding (in populated areas): creation or restoration of flood plain areas adjacent to rivers for flood water storage; typical habitat types include seasonally (or controlled) flooded grassland or pasture, or arable land or amenity land (e.g. sports fields)	-	✓	✓	✓	GHG emissions and sequestration of carbon associated with FCERM land management actions in relation to river flooding GHG emissions associated with energy and transport arise at construction stage and are likely to be minor
Managed realignment	Actions to reduce likelihood of flooding (in populated areas): Creation or restoration of (tidal flooded) wetland habitats in estuarine and coastal areas to accommodate coastal geomorphology processes; typical habitats include saltmarsh and mudflat	-	✓	✓	✓	GHG emissions and sequestration of carbon associated with FCERM coastal land management actions GHG emissions associated with energy and transport arise at construction stage and are likely to be minor

Table 1 FCERM policy and sources of GHG emissions (cont.)

Activity	*Description*	*Sources of emissions/sequestration*				*Notes*
		Embodied carbon	***Energy***	***Transport***	***LUC***[a]	
FCERM activities						
Development control	Actions to reduce likelihood of flooding: inclusion of flood and coastal erosion risk considerations within overall land planning process	-	-	-	✓	Primarily influences land use (residential or commercial) through the planning system and hence GHG emissions associated with development (e.g. house building) including adaptation measures (see above) to address residual flood risk
Flood and erosion mapping and modelling	Actions to inform decision-making: analysis of data and primary survey work (e.g. aerial surveys and LIDAR[c] data collection)	-	-	✓	-	GHG emissions from survey activities in relation to all types of flooding and coastal erosion
Emergency planning and response	Actions to reduce impacts of flooding: analysis of data to identify areas and infrastructure at risk, flood warning systems and actions required in event of flooding	✓[d]	✓	✓	-	GHG emissions from emergency response activities in relation to all types of flooding.
Non-FCERM activities						
Response to flood and coastal erosion property damages	Actions resulting from flood and coastal erosion damages: includes repairs to infrastructure and properties (fabric, fixtures and fittings), replacement of household equipment and goods, use of air blowers and dehumidifiers and also construction of new properties	✓	✓	✓	-	GHG emissions arising from reparation of damages from all types of flooding and coastal erosion
Land use dependent on FCERM	Actions dependent on FCERM activities: agricultural land use made viable due to flood defences and the management of water levels	-	-	-	✓	GHG emissions and sequestration of carbon associated with land uses dependent on FCERM activities

Notes: [a] Land use change; [b] Sustainable drainage systems; [c] Light detection and ranging: airborne Lidar survey measures the height of the ground surface and other features in large areas of landscape; [d] Minimal linked to telemetry equipment and warning signs/systems.

Figure 1 Basic formulation of the FCERM policy carbon footprint



Notes: *Net emissions = GHG emissions – carbon sequestration

The framework for analysis detailed Table 1 and Figure 1 establishes significant data demands. The FD2622 Technical Report sets out both data requirements and current availability, along with key assumptions for the component parts of the FCERM carbon footprint.

3. Results

Policy scenarios

The analysis considers a number of 'scenarios' to assess the GHG emissions implications of current and future FCERM policy options. This involves comparison of the carbon footprint of a baseline scenario with the carbon footprints of alternative scenarios that reflect different policy options. These alternative scenarios may be considered as '*what if*' scenarios. For example, what would the net GHG emissions implications be, if current rates of maintenance, asset construction and residual damages continued?

The baseline and scenarios are:

- Business as usual (BAU): this is the baseline for the assessment that assumes a continuation of the current policy focus and levels of investment. The main emphasis of project's data collection has been to establish the BAU situation; i.e. collate data on existing assets and maintenance and planned infrastructure that reflect the current policy circumstances.

- Policy-off: this scenario describes the counterfactual to FCERM intervention and associated net GHG emissions; i.e. the carbon footprint implications of no active FCERM intervention.

- Increased investment in river and coastal flooding ('BAU plus'): typically expenditure in the 'traditional' FCERM policy areas represent a good return on public investment. EA (2009) reports that benefit cost ratios for river and coastal flooding schemes are around 8:1. This scenario assesses the carbon footprint implications of increased expenditure from the BAU case, weighing increased emissions from FCERM activity (i.e. more construction and maintenance schemes) against the decrease in emissions associated with residual flooding damages.

- Addressing surface water flooding ('SWF'): Surface water management represents a developing policy area under the current draft Flood and Water Management Bill (Defra, 2009b). This scenario assesses the implications of increased expenditure on schemes to control surface water flooding, weighing increases in emissions from asset construction against the decrease in emissions associated with surface water flooding.

Estimated carbon footprints

Estimated carbon footprints for the BAU, policy-off, BAU-plus and SWF scenarios are presented in Table 2 in terms of annual average tonnes of CO_2e per year. The annual estimate is calculated from the assumed profile of emissions over a 50-year time horizon.

Table 2 Estimate of FCERM carbon footprint for alternative policy scenarios (Mt CO_2e per year)

Scenario	*Emissions arising from:*		*Total*
	FCERM activities	*Flood and coastal erosion damages*	
BAU	0.53	1.89	2.41
Policy-off	n/a	2.89	2.89
BAU plus	0.70	1.67	2.36
SWF	0.55	1.62	2.18

The current 'best' estimate of net emissions from FCERM policy and investments is 2.41 Mt CO_2e per year. As detailed in the in FD2622 Technical Report, the greatest contribution to the BAU carbon footprint estimate comes from surface water flooding damages. River and coastal flooding contribute similarly to the overall BAU carbon footprint in terms of FCERM activities (each approximately 10% of the overall estimate). In both cases estimated emissions arising from flood damages outweigh estimated emissions arising from flood alleviation activities. Estimated emissions associated with coastal erosion are relatively minor (0.04 Mt CO_2e per year), representing just under 2% of the total BAU footprint (FCERM activities generate 99% of these emissions).

Key limitations – reliability of results

The results detailed in Table 2 and their implications that are discussed subsequently are subject to several caveats:

- Estimation of FCERM BAU carbon footprint is only possible to the extent allowed by existing information sources. Limited data availability means that not all of the emissions associated with FCERM activities and non-FCERM activities arising due to FCERM can be quantified at present.

- With respect to Table 2 and Figure 1, but based on data availability, the estimated carbon footprints include:
  - Emissions associated with FCERM activities - asset construction and maintenance only.
  - Emissions associated with flood and coastal erosion damages - reparations to properties and possessions.

- The analysis does not estimate emissions associated with adaptation measures, development control, mapping and modelling, emergency planning and response, flood storage or managed realignment. In addition emissions from activities dependent on FCERM are not accounted for in the analysis (e.g. agriculture). Further details as to the limitations of the analysis in regard to these components of the FCERM carbon footprint are provided in the FD2622 Technical Report. Also included is a qualitative assessment of the potentially significant carbon footprint implications of land use management activities.

- The omitted activities have implications for both emissions and sequestration of GHGs, implying that the net effect on the BAU carbon footprint at present comprises a significant degree of uncertainty.

Overall the resulting carbon footprint estimates should be interpreted with caution, representing indications of order of magnitude rather than precise estimates. Sensitivity testing of component parts of the carbon footprint estimates indicates relatively large ranges based on different sets of assumptions; in general however this is expected given the high-level nature of the analysis.

4. Implications of Findings

The implications of the estimated carbon footprints for different policy scenarios are assessed in terms of the specific policy questions I-V set out in Section 1. Overall the research has sought to address all research aims and policy questions set out in the ToR for the project. Current limitations and uncertainty in available data and gaps mean that this project represents a starting point, with the potential for further work to build on the framework and develop the evidence base available. As the evidence base for estimating the carbon footprint develops, the analysis can be refined and improved enabling a fuller account to be made of the current and potential carbon implications of FCERM policy.

I. What is the current net climate change impact of FCERM activities?

The current net climate change impact of FCERM activities can be viewed from two perspectives. First, in relation to the overall level of emissions and on this basis, the net climate change impact is judged to be negative. That is, with respect to the business as usual (BAU) scenario, FCERM activities are a net contributor to GHG emissions. The second perspective considers the impact of FCERM activities in relation to the counterfactual of no FCERM activities (represented by the policy-off scenario). The analysis here suggests that FCERM activities largely represent a net reduction in emissions due to flood alleviation actions which reduce damages from flooding and consequential GHG emissions associated with those damages. In other words, without FCERM activities, net emissions resulting from FCERM policy would likely be greater due to impacts of greater flood damage. This interpretation therefore suggests that, in the short term at least, the net climate change impact of FCERM activities is positive.

The two perspectives highlight the care needed in interpreting results from this research. A key point is the trade-off particularly between flood alleviation and flood damages. Both aspects in isolation contribute to GHG emissions, but the marginal short-term impact of increasing FCERM activities is positive; increased investment in flood alleviation results in reduced damages. This gives net emissions savings in the short term because the emissions savings from the reduced flood damages are greater than the increased emissions from the FCERM activity.

Longer term however the marginal impact of FCERM is more difficult to assess because FCERM policy influences the baseline situation against which changes to emissions are calculated. Therefore, while FCERM avoids emissions resulting from flooding in the shorter term, it may in the long term perpetuate activities (land uses or patterns of development) that have higher carbon emissions, and higher avoided emissions due to avoided flooding, than would otherwise be the case. It has, however, not been possible to account for the more dynamic aspect of FCERM policy in this regard in this analysis. This is primarily limited by the current scope for specifying parameters of alternative policy scenarios.

Overall the resulting carbon footprint estimates should be interpreted with caution, representing indications of order of magnitude rather than precise estimates. Sensitivity testing of component parts of the carbon footprint estimates indicates relatively large ranges based on different sets of assumptions; in general however this is expected given the high-level nature of the analysis (see FD2622 Technical Report for further detail).

II. What is the best estimate of net GHG emissions from FCERM policy and investments?

The current ‘best’ estimate of net emissions from FCERM policy and investments is 2.41 Mt CO_2e per year (see Table 2). As noted in (I) above, the BAU scenario gives rise to lower emissions than the policy-off scenario, suggesting that ‘no active intervention’ in flood and coastal risk management would increase both carbon implications and economic damages. Although the emissions are relatively minor in terms of overall UK GHG emissions (see below), these ‘avoided emissions’ can be viewed as FCERM’s main contribution to UK carbon reduction efforts.

Direct comparison of the estimated BAU and alternative policy scenario carbon footprints with other sectors is difficult. Foremost, no evidence of ‘aggregate’ carbon footprint analysis has been identified for other UK Government policy areas (e.g. the carbon footprint of transport infrastructure, housing development, etc.); reporting that is available focuses on component level (e.g. footprints of carbon efficient homes versus standard construction). In addition, comparison to national UK GHG reporting can only be viewed as ‘indicative’ given the different accounting methods and scope of emissions considered.

Current aggregate UK GHG emissions are in the region of 630 Mt CO_2e per year. The emissions estimate for BAU and other policy scenarios are two orders of magnitude lower and on this basis represent around 0.3 – 0.5% of annual UK emissions. In these overall terms, the magnitude of emissions estimates indicate that FCERM is not hugely significant in contributing to emissions on the national scale, notwithstanding the current omissions from the analysis.

III. Which FCERM activities and policies provide significant positive mitigation of net GHG emissions through sequestration of carbon?

Estimation of the FCERM carbon footprint has not included activities with the potential to sequester carbon due to data limitations. However, supporting qualitative discussion is possible (see FD2622 Technical Report Annex 1 for further detail). With respect to flood storage and managed realignment options, key carbon management conclusions are:

- There is potential to sequester carbon within coastal lowlands through managed realignment, with associated reactivation of geomorphic processes and the creation of accommodation space for accumulation of carbon-bearing sediments.
- Restoration of wetlands in saline environments (saltmarshes and mudflats) has net carbon sequestration potential. Restoration of freshwater and brackish tidal wetlands will sequester carbon (more than saltmarsh and mudflat) but the production of methane will likely offset the carbon sequestration benefits over time (for example a 100 year timeframe). A possible exception is the restoration of seasonally flooded grasslands, which as well as sequestering carbon in soils, if drained through summer months are likely to emit only marginal quantities of methane.
- It may be possible to create managed freshwater wetlands to fill some available accommodation space with organic rich soils while reducing methane emissions and therefore creating net positive carbon sequestration potential, an approach that is being experimentally trialled in the USA.
- Erosion of saltmarsh will release significant quantities of sequestered carbon back in to estuarine circulation with potential for likely conversion to carbon dioxide.
- Drainage of peat soils will release significant quantities of sequestered carbon into the atmosphere.
- From a regional perspective, restoration of saltmarsh will be most effective in carbon sequestration terms in estuaries with high sediment availability, notably the Severn Estuary and Humber Estuary. Restoration of saltmarshes in ‘sandy’ estuaries (e.g. Solway Firth, Morecambe Bay, outer Wash) will sequester less carbon than in relatively ‘muddy’ estuaries. It is anticipated that saltmarshes in the Outer Thames Basin (Essex and North Kent) will continue to be highly sensitive to sea level rise and the erosion will continue to release carbon into circulation. Because of limited sediment availability and high rates of relative sea level rise it is anticipated that saltmarsh restoration will have limited capacity for carbon sequestration in this region.
- Carbon sequestration potential can come at a cost to biological diversity. From an ecological perspective, restoration should include a mix of habitats across the landscape, only some of which will be net sequesters of GHGs in the long term.

IV. What are the FCERM policy areas that are likely to make the biggest contribution to UK GHG policy under different future scenarios?

Results presented in Table 2 and discussed in I - III above broadly establish the policy areas that provide greatest scope for contributing to reductions in GHG emissions. In particular a significant result is the role of flood alleviation activities in reducing potential GHG emissions associated with flood damage. Here a potential policy issue is the extent to which investment should be prioritised between coastal flooding, coastal erosion, fluvial flooding and surface water flooding.

Comparing the ‘effectiveness’ in carbon terms of flood alleviation investment in river and coastal flooding to surface water flooding suggests the latter results in greater gains; i.e. avoided emissions. As detailed above, one extra tonne CO_2e per year emitted as a result of surface water flooding management activities results in a reduction of 10.8 t CO_2e per year from surface water flooding (compared to a reduction of 1.3 t CO_2e per year from river and coastal flooding damages). In contrast the results with respect to coastal erosion suggest that investment in this policy area is not ‘effective’ in carbon terms; one extra tonne of CO_2e per year emitted as a result of investment activities results in a reduction of 0.3 t CO2e per year from coastal erosion damages[4].

Again caution is required in interpreting these results as anything more than indicative, given limitations of the data, but the simple comparison illustrates the GHG emissions trade-offs that can be factored into both strategic level policy decisions and individual project appraisals within specific policy areas. Undoubtedly both levels of policy analysis would benefit from improved data and evidence and more consistent carbon footprint assessments on the basis of the framework set out in Table 1 and Figure 1.

V. What are the key opportunities to reduce GHG emissions and/or enhance carbon sequestration in terms of future FCERM policies?

Drawing together the findings under questions I-IV, the key themes that emerge are:

- Current FCERM *activities* result in net emissions of GHGs but, in general, these emissions are lower than the counterfactual level of GHG emissions that would arise in the short-term in their absence as a result of flood and coastal erosion *damages* (i.e. the policy-off scenario and no active intervention);
- Some sources of emissions and all sources of sequestration are not included in this result. The net effect of their inclusion is not known at present;
- Compared to the net emissions from other sectors, the role of FCERM policies is relatively minor, not withstanding unquantified emissions and data limitations;
- There is potential to enhance sequestration of GHG emissions via land use management (e.g. managed realignment activities and changes in land use in order to be compatible with flood storage). The outcomes

[4] See FD2622 Technical Report for further detail, including the key assumptions that underlie these results.

will be case specific and dependent on a variety of environmental factors and, in general, are unlikely to substantially ‘offset’ GHG emissions that arise in relation to flood alleviation activities and flood damages;

- All analysis and findings are subject to significant assumptions and caveats that reflect the current extent of the evidence base on the carbon footprint of FCERM.

5. Conclusions and Suggestions Moving Forward

Summary

Overall this project provides a broad view of flood risk management and the science and methods of measuring the related GHG emissions and carbon sequestration. In practice, many of the component areas of the FCERM footprint could warrant detailed investigation; especially developing the evidence base related to land use management and carbon sequestration, estimating emissions from asset construction and maintenance activities, or estimating emissions associated with flood and coastal erosion damages.

Drawing together the available evidence has permitted a partial estimate of the contribution of FCERM policy to GHG emissions. This suggests that FCERM plays a small role in contributing to national level emissions (estimated to less than 1% of total annual emissions) and that increases and decreases in the level of emissions are likely to have relatively slight implications for the attainment of UK GHG reduction targets.

The analysis undertaken also indicates that it is likely that intervention in flood and coastal erosion risk management plays a mitigation role in terms of avoided GHG emissions (that would arise in the absence of active intervention). However key gaps remain, particularly in relation to providing a detailed account of threats and opportunities for the release/abatement of GHG emissions from FCERM policy.

Possible future work

The research reveals that relevant evidence has to be drawn from a wide variety of sources, where, in virtually all cases, the intended use of the data is not to facilitate a high level assessment of the FCERM carbon footprint. Proposals arising from the project include:

- It is suggested that the estimate of the FCERM carbon footprint be reviewed and revised as more data becomes available. New data should serve to both increase the coverage of the analysis (by providing an account of currently omitted areas) and permit for a more nuanced approach in terms of the specification of alternative policy scenarios and assessing their carbon implications.

- Work is already taking place within the Environment Agency that will improve the evidence base for estimating the FCERM carbon footprint. This includes assessments of emissions associated with maintenance and operations, and pumping stations. In addition there is a developing evidence base on emissions associated with asset maintenance and construction (via the Construction Carbon Calculator – see FD2622 Technical Report for further detail). However, from the perspective of estimating the FCERM carbon footprint, the EA in particular would benefit from the integration of data already being collated by these on-going but separate initiatives.

- The Environment Agency’s experience in developing approaches to measuring GHG emissions from FCERM activities could usefully inform assessments of the carbon footprints of the other Operating Authorities (Local Authorities and Internal Drainage Boards) activities. In particular the development of surface water management plans is likely to identify the need for significant investment in SUDs and other measures. Here there is an opportunity to ensure GHG emissions and sequestration potential are assessed at the planning stage and accounted for in decision-making. An initiative of calculating carbon from these types of schemes would also improve the evidence base for estimating the overall FCERM footprint, and provide for greater distinction in the specification of alternative policy scenarios; for example in understanding the carbon implications of investment in river and coastal flooding versus surface water management.

- Use of carbon calculators for FCERM (i.e. for EA schemes, LA schemes and surface water flooding) actions should be used more widely, and as their use is extended there should be some review and quality assurance applied to their results. Review should establish typical ranges of emissions for different types of projects, and if results fall outside expected ranges, they should be further scrutinised.

- Appraisal of FCERM projects could routinely calculate carbon savings resulting from reduction of flooding to properties (i.e. avoided emissions that would be generated in response to flooding incidents). At present the approach detailed in the report, primarily via the damage multiplier, but also in term of properties affected as addressed in the case studies, allows for little distinction as to differences in emissions that arise from differences between property types. Hence further work that improves estimates of GHG emissions associated with damages is required, since this would permit greater distinction between alternative options being appraised.

- Establishing the carbon sequestration potential of land use management activities (flood storage and managed realignment), as well as the influence of FCERM on emissions and sequestration from land protected by defences (e.g. agricultural land), in aggregate is a key avenue for further research. The general conclusions presented by this project note that a long term view is required and that understanding local environmental factors is crucial in determining whether carbon sequestration benefits are realised.

Finally it is recommended that further desk-based assessment of secondary data, as undertaken by this study, allows for sufficient time to liaise with relevant organisations for improved data collection. Contacting multiple sources within one organisation – such as the Environment Agency – to ascertain the availability and status of relevant information entails considerable effort, and the task of ensuring coherency of data for the purpose of estimating the carbon footprint for FCERM policy should not be under-estimated.

References to published material

9. This section should be used to record links (hypertext links where possible) or references to other published material generated by, or relating to this project.

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