Department for Environment Food & Rural Affairs

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Llywodraeth Cymru Welsh Government

Measuring resilience to flooding and coastal erosion

FCERM Research & Development Programme

Research report

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This report is the result of research commissioned and funded by the Joint Flood and Coastal Erosion Risk Management Research and Development Programme. The Joint Programme is jointly overseen by Defra, the Environment Agency, Natural Resources Wales and Welsh Government on behalf of all risk management authorities in England and Wales: https://www.gov.uk/government/organisations/flood-and-coastal-erosion-risk-management-research-and-development-programme

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Executive summary

The Flood and Coastal Erosion Risk Management (FCERM) Strategy (2020), FCERM policy statement (2020) and the 25 Year Environment Plan (25 YEP) (2018) aim to improve the resilience of the nation to flooding and coastal risks. The FCERM Strategy defines resilience as "the capacity of people and places to plan for, better protect, respond to and recover from flooding and coastal change. This includes making the best land use and development choices, protecting people and places, responding to, and recovering from flooding and coastal change whilst all the time adapting to climate change."

In 2020, Defra completed an evidence review on the concept of flood resilience which made recommendations to set out further detail on how resilience can be measured to monitor changes over time (Defra, FD2716, 2020).

The aim of this research was to determine what measurements could be used to measure changes in resilience over time, and what measurements are most appropriate to use both locally (for example, in communities, towns, rural and coastal areas and catchments) and nationally (England), to indicate changes in resilience to flooding and coastal erosion. The project has been shaped by stakeholder views and consultation through workshops.

The research objectives were to:

1. identify and prioritise what can be measured, in any given place and nationally (England), to best understand flood and coastal resilience, and monitor changes in resilience over time
2. provide evidence to show these measurements are appropriate in a range of scenarios (based on, for example, varied geography, flood sources, socio-economic situations) to ensure they are viable
3. understand what measurements are already being collected and what would be needed operationally (who, how, when) to capture any new measurements

An initial evidence review was used to develop a conceptual framework for the research. This used the Theory of Change (HM Treasury, 2011) to allow outputs (the numbers or type of FCERM activity) to be linked with measurable resilience outcomes across the 5 capitals of social/community, economic, physical, natural and institutional capacities.

Using this framework, existing evidence – including national policies, plans, strategies, guidance and research – was used to identify indicators already used to assess FCERM progress and which could demonstrate changes in resilience. This provided a basis to work with stakeholders to develop indicators that could meet policy and strategy goals and be applied in practice. The approach had 3 stages:

- **'Shape':** Using focus groups to shape our understanding of place-based resilience capacities and how these can be developed, supported or strengthened by resilience actions (July 2021).

- **‘Co-design’:** Working with focus groups to co-design indicators in a real-world context, considering different sources of flooding and coastal erosion risk, geographical and socio-economic characteristics (September 2021). The ‘use cases’ included:
    - multiple sources of flooding – Boston, Lincolnshire
    - coastal erosion and community transitions – North Norfolk
    - inland fluvial flooding and managing residual risk – Salford, Greater Manchester
    - inland surface water flooding in urban areas – Rochdale, Greater Manchester.
- **‘Discuss and prioritise’:** through a national workshop, discuss, decide and prioritise a set of actionable resilience indicators (November 2021).

The project developed a set of 34 resilience indicators to provide a national picture of resilience across the placemaking, better protect, response, recovery and adaptation resilience components. These indicators could support the development of a baseline of resilience, driving change, and having impact across the 5 capitals. The full list of indicators is in section 4.

The project has identified 14 indicators which are ‘**ready now’** and can be measured by data or information that is already available. In some cases, data or information for ‘ready now’ indicators is expected to improve in the coming years. It has also identified 20 indicators that need ‘**further development’** before they can be used. In many cases, while these indicators were considered by stakeholders as worthwhile in measuring resilience, there is currently no way of either quantitatively or qualitatively measuring their progress.

Some of the 34 indicators include ‘component indicators’. Narratives are provided for each indicator, describing what aspect of resilience is being measured and the decisions made when developing the indicator across the co-design process. This research also recommends that social vulnerability of individuals and communities at risk of flooding and coastal erosion needs to be measured to understand the capability and capacity of individuals and communities to have improved resilience.

Applying resilience indicators in practice could help to fill research gaps for indicators needing further development, and provide better evidence on costs and benefits. This could drive science-based policy and practice that justifies and increases the use of a broad range of resilience actions to build a nation resilient to flooding and coastal erosion.

The Environment Agency would not be responsible for collecting data for every indicator. Input from other organisations would also be required to enable reporting. This research identified barriers to collecting data, including unwillingness to collect or share data, lack of resources and lack of support to build capacity and expertise.

The Environment Agency plans to use the research findings to further test and refine the proposed indicators. The research does not represent a final position on which indicators the Environment Agency, Defra or others may adopt. This report does not purport to set out a particular preference, strategy or policy in respect of resilience measures.

1. Introduction

The Flood and Coastal Erosion Risk Management (FCERM) Strategy (2020), FCERM policy statement (2020) and the 25 Year Environment Plan (25 YEP) (2018) aim to improve resilience to flooding and coastal erosion by embracing a broader range of measures beyond more traditional approaches.

The FCERM Strategy defines resilience as "the capacity of people and places to plan for, better protect, respond to and recover from flooding and coastal change. This includes making the best land use and development choices, protecting people and places, responding to, and recovering from flooding and coastal change whilst all the time adapting to climate change."

In 2020, Defra completed an evidence review on the concept of flood resilience which made recommendations to set out further detail on how resilience can be measured to enable levels to be assessed and change monitored over time (Defra, FD2716, 2020). This research builds on these recommendations.

The aim of this research was to determine what measurements could be used, and are most appropriate to use, both locally (for example, in communities, towns, rural or coastal areas and catchments) and nationally (England), to indicate changes in resilience to flooding and coastal erosion, both now and over time. The project has been shaped by stakeholder views and consultation through workshops.

Monitoring trends in resilience over time will enable us to better understand the impact of government policy and demonstrate progress against implementation of the FCERM Strategy.

The objectives of this research were to:

- identify and prioritise what can be measured, in any given place and nationally (England), to best understand flood and coastal resilience, and monitor changes in resilience over time
- provide evidence to show these measurements are appropriate in a range of scenarios (based on, for example, varied geography, flood sources, socio-economic situations) to ensure they are viable
- understand what measurements are already being collected and what would be needed operationally (who, how, when) to capture any new measurements

This research proposes indicators of resilience, the first step in determining a longer-term operational process which can:

- enable levels of resilience to be assessed at different spatial scales
- monitor changes over time to inform action
- determine how activity that will most improve resilience will be identified
- inform FCERM investment and assess the effectiveness of FCERM decisions

This research identifies how to track changes in resilience nationally and locally. Further work is required to explore the realities of collecting data and reporting at different scales, roles and responsibilities and resource requirements.

Context

The Environment Agency commissioned JBA Consulting, working with Rivelin Bridge and Professor Robert Nicholls, University of East Anglia (UEA) and the Tyndall Centre for Climate Change Research, to determine measurements of resilience to flooding and coastal erosion at local and national levels.

The research is intended to help understand how the move from asset-focused flooding and coastal erosion risk management (currently measured as part of the FCERM capital investment programme) to a wider resilience approach is being achieved through a broader range of actions than the historical reliance on conventional, engineered defences. Measuring changes in resilience needs to clearly link back to these actions even if direct attribution is not possible at this stage.

This is the final report for the commission reporting on progress on the ‘co-design’ of resilience indicators, building on 4 interim reports, which are available on request.

The overall project was broken down into the following phases:

Inception and scoping: April to May 2021

- Inception meeting
- Scoping consultations
- Initial data collation and review

Final inception report submitted: 27 May 2021

Evidence gathering: April to June 2021

- Literature review
- Provision of conceptual framework
- Indicator identification/categorisation

Final interim report 1 submitted: 27 May 2021

Shaping the indicators: July to August 2021

- Four focus groups
- Review conceptual framework
- Further indicator analysis

Draft interim report 2 submitted: 3 August 2021

Co-design and data exploration: September/October 2021

- Use case analysis
- Further development of indicators
- Four focus groups

Draft interim report 3 submitted: 21 October 2021

Discuss and refine indicators: November/December 2021

- Use case finalisation
- Further indicator development
- National workshop
- Finalise draft indicators

Draft interim report 4 submitted: December 2021

Reporting: January to March 2022

- Draft indicator e-survey
- Finalise indicators
- RMA route map for implementation

Draft final outputs submitted: 22 March 2022

Final outputs: April 2022

- Final report
- Dissemination webinar

All final outputs submitted: 27 April 2022

Purpose of the report

This report is intended to:

- detail the research approach, including engagement activities, for developing a set of indicators
- provide options for the national set of indicators (a subset of indicators) based on the engagement activities completed throughout the research
- provide options for a set of indicators based on the engagement activities completed throughout the research
- provide an indication of which indicators are ready to measure now and which need further development
- suggest possible next steps for developing the set of indicators

Working definitions

Many of the terms used in the project, including resilience, can be open to interpretation and have different meanings in different contexts. Therefore, we have set out working definitions for various terms used throughout this document to help encourage shared understanding between those working on the project and those engaged in the continued development of the indicators. These have been derived from Theory of Change guidance[1] and the national Flood and Coastal Erosion Risk Management (FCERM) Strategy for England along with our own definitions and interpretations.

Please see Glossary for the working definitions.

Note on using the indicators

The set of indicators developed in this project are research findings only. The research describes what is possible to measure and of potential value, rather than what must be measured. Significant work is needed to further refine and test the indicators and build consensus on the data sources and approaches to data collation and reporting before the indicators can be operationalised (put into practice). The Environment Agency plans to further test and refine the resilience indicators. This research does not represent a final position on indicators which the Environment Agency, Defra or others may use.

While the Theory of Change and other methods used to carry out the research for this report are accepted research practice, we do not provide any guarantees, conditions or warranties that the findings are complete and accurate. We are not liable for any loss or damage resulting from use of the findings in this report.

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[1] Magenta Book Central Government guidance on evaluation

2. Methodology

This section summarises the approach adopted for the research.

Conceptual framework development

The Theory of Change is strongly promoted by HM Treasury's Green and Magenta Books (HM Treasury 2011) and is evident in numerous evaluations that have been carried out in relation to resilience to flooding and coastal erosion. For example, Defra's Flood Resilience Community Pathfinder Scheme Evaluation Report (Twigger-Ross and others, 2015) highlighted the importance of using a Theory of Change approach when developing resilience measures to achieve a clear line of sight and attribution between objectives, activities, outputs, outcomes, and impact.

This approach was used to develop a conceptual framework for this research during the inception stage initially based on the findings from a review of relevant literature (evidence review) and refined by the project team. It provides a clear line of sight between the current context, objectives, activities, and outcomes and impacts, and an organising logic to develop indicators to measure changes in resilience to flooding and coastal erosion.

Indicator development

The conceptual framework guided a co-design approach to develop the resilience indicators. It involved engaging with national and local stakeholders alongside desk-based activities. The project advisory group and the project board oversaw the indicator development process. The main themes were:

- **'Shape':** Using focus groups to shape our understanding of place-based resilience capacities and how these can be developed, supported or strengthened by resilience actions (July 2021).
- **'Co-design':** Working with focus groups to co-design indicators in a real-world context (September 2021).
- **'Discuss and prioritise':** Through a national workshop, discuss, decide and prioritise a range of actionable resilience indicators (November 2021).

Through established Environment Agency channels, contacts across the FCERM sector were invited to attend the focus groups. 102 people from 68 organisations were engaged in the focus groups.

- 68 people from 43 organisations attended the July focus groups (16 on 13 July, 15 on 14 July, 19 on 15 July and 18 on 16 July).
- 68 people from 48 organisations attended the September focus groups (16 on 9 September, 15 on 10 September, 18 on 13 September and 19 on 14 September). 34 people had attended the July focus groups and 34 were new attendees.

- 32 people attended the November national workshop, all of whom had been previously involved.

The organisations involved included the following:

- **27 local authorities:** Arun District Council, Bournemouth, Christchurch and Poole Council, Bristol City Council, Buckinghamshire County Council, Cambridgeshire County Council, Central Bedfordshire Council, City of London Council, Council of the Isles of Scilly, Cumbria County Council, Devon County Council, East Sussex County Council, Gloucestershire County Council, Hampshire County Council, Hertfordshire Council, Hull City Council, North Lincolnshire Council, North Northamptonshire Council, Peak District Council, Plymouth City Council, Salford City Council, Slough Borough Council, South Gloucestershire Council, South Tyneside Council, Southend Borough Council, Teignbridge District Council, Thurrock Borough Council.
- **2 government departments / agencies:** Department for Levelling Up, Housing and Communities (DLUHC), Department for Environment, Food and Rural Affairs (Defra).
- **10 national organisations:** Chartered Institute of Water and Environmental Management (CIWEM), Coastal Group Network, Environment Agency, Flood Re, Forestry Commission, National Flood Forum, National Infrastructure Commission, Natural England, Ordnance Survey, Rural Payments Agency (RPA).
- **2 infrastructure providers:** Network Rail, Yorkshire Water.
- **8 academia/research organisations:** Birmingham City University, Exeter University, Manchester Metropolitan University, National Oceanography Centre, Southampton University, University College London (UCL), University of East Anglia (UEA), University of Exeter.
- **4 flood/coastal groups**: Broughton Flood Group, Carlisle Flood Action Group, Cumbria Local Resilience Forum, Pang Valley Flood Forum.
- **2 Rivers Trusts:** Calder and Colne Rivers Trust; Westcountry Rivers Trust.
- **6 consultancies:** Atkins, HR Wallingford, Jacobs, JBA Consulting, Lumby Consulting, WSP.
- **5 non-profit/charities:** Cumbria Council for Voluntary Service (CVS), Local Trust, Moors for the Future Partnership, Thames21, Wildfowl and Wetlands Trust (WWT).
- **2 Regional flood and Coastal Committees:** Anglian Great Ouse Regional Flood and Coastal Committee, Thames Regional Flood and Coastal Committee.
- **1 other local public sector:** Shire Group of Internal Drainage Boards (IDBs).

The indicator development process was separated into the following activities:

- Development of focus groups' longlist of resilience indicators
- Initial screening of longlist of focus groups' resilience indicators
- Evidence review longlist
- Gap analysis based on evidence review longlist
- Shortlisting against selection criteria

- Refinement based on findings from use case testing, national workshop testing, internal project team reviews and e-survey

Development of focus groups' longlist of resilience indicators

The initial focus group longlist was populated with indicators suggested at the September focus groups, under the headings of placemaking, protect, respond and recover. The list was then prioritised against the categories of must have, should have, could have and would like to have. Indicators were also categorised based on their contribution to institutional, social, economic, natural, and physical resilience.

Initial screening of longlist of focus groups' resilience indicators

This focus group longlist was initially screened to remove duplicates, any indicators not directly relevant to changes in resilience to flooding and coastal erosion, and those that are already an existing requirement such as a number of Strategic Flood Risk Assessments (SFRAs) or local resilience forums (LRFs) with community risk registers.

Evidence review longlist

A longlist of resilience indicators was assembled from a detailed review of 65 documents, including leading national policies, plans, strategies, guidance and research. This longlist of existing and proposed indicators was used to assess FCERM progress or track resilience (see Bibliography). Indicators were clustered to form themed indicator sets and broadly categorised in 2 ways: firstly, to show the type of measure based on conceptual framework components and secondly, based on subject matter.

The type of measure categories included:

- baseline
- output
- outcome
- impact

The subject matter categories included:

- coastal
- community
- development
- economic
- infrastructure
- natural capital
- other
- policy
- property level
- research
- response

- social

Gap analysis based on evidence review longlist

Any relevant indicators from the evidence review, but not in the focus groups, were identified and included in the list. This was achieved by reviewing the focus groups' longlist against the themed indicator sets from the evidence longlist to identify gaps and produce a combined longlist. As the focus of this research was to 'co-design' indicators, the focus groups' longlist was used as the starting point and was subsidised with additional indicators from the evidence review. Further details on the origin of each indicator are provided in section 4: Recommended indicators.

Shortlisting against selection criteria

Nine criteria were proposed using information from the evidence review, which included criteria used in the 25 Year Environment Plan (YEP), the Defra Evidence Review of the Concept of Flood Resilience and the 'Guidelines for development of indicators, indicator systems and provider challenges' report from the emBRACE study (Becker and others, 2015; Defra, 2018; Twigger-Ross and others, 2020). Criteria were amended to meet the specific needs of this project, as several of the criteria were more focused on identifying effective indicators rather than on what really needed to be measured. The final selection criteria were:

- **relevance** – does the indicator meet user needs, focused on ultimate resilience outputs, outcomes, and impact?
- **applicability** – can the indicator be applied to a range of contexts (sources of flooding/coastal erosion, socio-demographic characteristics, urban/rural locations)?
- **scalability** – can this indicator be measured nationally? This aims to target indicators which have data sets with national coverage, but also those that could be collected at a local scale and then aggregated to collate a national picture?
- **trend** – can the indicator demonstrate trends in resilience over time?
- **accessibility** - usability of the measure, available metadata, illustration and accompanying advice
- **data availability** - does the data already exist; if the data does not exist, can it be collected easily by non-specialists; can indicators be selected to reflect differences in context?
- **impact** – does the indicator reflect resilience across the 5 capacities (social, institutional, economic, natural, and physical resilience)

During shortlisting, indicators were screened in or out based on **relevance.** Remaining indicators were then scored against the other 6 criteria. A score of 1,2 or 3 was allocated based on the approach shown in Table 2-1.

Table 2-1 Indicator selection criteria and scoring approach

Criteria	Score = 2	Score = 1	Score = 0
Applicability	Applicable to all sources, and range of characteristics.	Applicable to 2 or more sources and limited range or applicable to one source and a range of characteristics.	Limited to very specific circumstances,
Scalability	Definitely scalable to national level.	Possible scalable to national level.	Definitely not scalable.
Trend	Can definitely show trends on an annual basis.	Should show trends but over a longer time period.	Will not show trends over time.
Accessibility	Indicator is clear and unambiguous, and data requirements are self-evident.	Indicator is clear although there are some queries regarding exact data requirements.	Indicator is ambiguous and requires clarity over the data required.
Data availability	Data readily available - secondary data.	Data can easily be provided, for example, already collected.	Data will need to be collected, for example, through surveys.
Impact	Enhanced resilience of all capacities.	Enhanced resilience of more than one but not all 5 capacities.	Enhanced resilience of one capacity.

Scores were aggregated to inform priority. Weightings were applied to 'trend', 'scalability' and 'data availability' as the project board considered this the most important criteria.

- **Trend** assesses the direct ability of the indicators to show change over time, which is the main aim of the research. This criterion was allocated a weighting of 3.
- **Scalability** considers whether indicators can be populated at local and national levels. This is recognised as an important characteristic for indicators, as flooding and coastal erosion is managed at the local level. Since some indicators may only be measured locally, the ability to scale to the national level is crucial to allow progress to be tracked for England. This criterion was allocated a weighting of 2.
- **Data availability** identifies whether data is currently available, comes from an accessible data source or can be acquired in line with the available budget and time. This criterion was allocated a weighting of 2 to help prioritise which indicators can be implemented in the immediate/short term.

A number of additional indicators or indicator themes were also suggested, or specific indicators/themes highlighted, as being of highest priority during the project advisory group meeting (1 October 2021), coastal erosion meeting (12 October 2021) and project board meeting (13 October 2021). Indicators related to these themes were sourced from the

evidence review where possible, and all additional indicators scored as per the existing method.

Refinement

Use case testing

The next step involved testing the indicators in real-world contexts characterised by different sources of flood and coastal erosion risk, geographical and socio-economic characteristics using use cases. Potential use case candidates were identified specifically via the focus groups. These were appraised in terms of their geographical location and characteristics (inland/coastal, urban/rural), source of risk and issue being addressed and the actions being taken. Four cases were selected following discussions with the project advisory group and project board:

- Multiple sources of flooding – Boston, Lincolnshire
    - developed with representatives from the Environment Agency
- Coastal erosion and community transitions – North Norfolk
    - developed with representatives from North Norfolk District Council and University of East Anglia (UEA)
- Inland fluvial flooding and managing residual risk – Salford, Greater Manchester
    - developed with representatives from Salford City Council, Broughton Flood Group and the Broughton Trust
- Inland surface water flooding in urban areas – Rochdale, Greater Manchester
    - developed with representatives from Rochdale Borough Council, Manchester Metropolitan University (MMU) and the National Flood Forum

While these areas do not fully represent all the potential characteristics facing communities in England, the use cases helped to explore how resilience plays out in different contexts. As this research aimed to design and decide on a framework which is proportionate, credible, simple and meaningful, use cases provided some practically-based applicability and usability.

A desk-based-review identified the challenges, ambitions, actions and any evidence on how changes in resilience were measured within each of the use cases. The indicators that aligned to each use case were investigated and presented at focus groups in September 2021. The proposed indicators were discussed with the use case lead authors to determine how relevant they were to local circumstances, whether they would suggest others, and to discuss data availability. Indicators were refined based on these findings.

Internal project team reviews

The project team further developed the indicators to transform them from output to outcome indicators where possible, and refine the wording to make sure they were measurable indicators. The resulting indicators were then discussed and prioritised in the national workshop.

National workshop testing

A national stakeholder workshop was held on 8 November 2021 with stakeholders involved in the research, including those who attended the focus groups, the coastal erosion workshop and representatives from the use cases. The purpose of the workshop was to gain views on the indicators, including identifying immediate and longer-term priorities; clarifying wording changes to make the indicators more specific or easily understood to anyone; and identifying any potential data related to the indicator. The outcomes of the workshop were used to further refine and prioritise the indicators to develop the draft set of indicators, and within this, a subset of national indicators. The workshop also captured stakeholder feedback on implementing the indicators.

Project advisory group and project board feedback

Five project advisory group and 5 project board meetings were held to review emerging findings and steer research. In December 2021, findings from the national workshop were presented to obtain project advisory group and project board views on:

- how can changes in resilience be tracked considering climate change?
- is there anything obviously missing from the draft national indicators?
- where are definitions/wording clarifications needed?

Indicators with multiple options for measurement were discussed to seek guidance on the suitability of taking each option forward. Project advisory group and project board feedback was used to refine indicators.

E-survey

An e-survey was published via Microsoft Forms on 20 January 2022 and sent to 400 stakeholders, including those involved in the project and Flood and Coastal Resilience Innovation Programme project teams. It closed on 7 February 2022, with 57 responses.

The e-survey was developed based on the revised indicators from the national workshop, project advisory group and project board, and served 2 purposes. It enabled the project to show the revised indicators to the engaged stakeholders, and provided a way of seeking clarification on how to collect data to measure the indicators.

The survey sought to determine available and required data sources to begin measuring proposed indicators. It also sought to identify barriers to data collection and mitigation. Results were sorted by indicator into a list of data sources and barriers. Responses were considered while finalising the recommended set of indicators and the national indicators.

3. Findings

This section describes what was found by applying the method stages. The evidence review was carried out first to inform how to measure resilience, making the best use of existing national and international research. This was applied to create a conceptual framework for developing indicators of resilience for flooding and coastal erosion. The proposed indicators are also described in this section.

Evidence review

The process of developing resilience indicators is complex and approaches vary within the literature. The evidence review found several aspects to be important in developing indicators, including considering:

- the Theory of Change
- multi-dimensional resilience
- applicability criteria
- top-up and bottom-down approaches
- geographical scale
- flood disadvantage

These aspects are further discussed in detail in the following sections.

Theory of Change

The Theory of Change is strongly promoted by HM Government's Green and Magenta Books and is evident in numerous evaluations that have been carried out in relation to resilience to flooding and coastal erosion. For example, Defra's Flood Resilience Community Pathfinder Scheme Evaluation Report highlighted the importance of using a Theory of Change approach when developing resilience measures in order to achieve a clear line of sight and attribution between objectives, activities, outputs, outcomes and impact (Twigger-Ross and others, 2015). By making explicit assumptions, the study found that these could be recognised as hypotheses related to the possibility of alternative outcomes (risks) or the existence of alternative pathways to the same outcomes (opportunities). Using this approach was also found to promote recognition of the multiple factors that influence progress, as well as the potential for change to take difference pathways. By opening up the potential for different outcomes, using this approach also created "space for learning and feedback loops" and facilitated a "movement away from the polarities of 'success' and 'failure'" (Twigger-Ross and others, 2015). The UK Department for International Development's (DFID) research on assessing the impact of International Climate Fund (ICF) programmes on household and community resilience to climate variability and climate change also identifies the need for a clear conceptual

foundation which uses a coherent Theory of Change to allow outputs to be linked with measurable resilience outcomes (Brooks and others, 2014).

Multi-dimensional resilience

A formal definition of resilience still remains ambiguous because it is used to define complex interactions which are often context-specific, scalable and depend on local characteristics or even personal experiences. Therefore, a large proportion of the reviewed literature took the approach of breaking resilience down into fundamental components in order to develop resilience measures which reflect the overarching concept of resilience (Sayers, 2020; Townend and others, 2021). Of the studies reviewed, a variety of different approaches were taken for characterising resilience as a whole by defining its separate dimensions ('fundamental components'). For example:

- The Baseline Resilience Indicators for Communities (BRIC) framework considered 6 types of resilience, including social, economic, housing/infrastructure, institutional, community and environmental resilience (Cutter and others, 2014).
- The Flood Resilience Measurement Tool (FRMT) from the Zurich Flood Resilience Alliance split resilience down into the '5 capitals' of human, social, physical, natural and financial resilience (Keating and others, 2017).
- The Australian Natural Disaster Index (ANDRI) examines 8 themes of coping capacity, including social character; economic capital; infrastructure and planning; emergency services; community capital and information and engagement (Parsons and others, 2017).
- The North Sea Region Interreg C5a programme expands the concept of resilience into an 'overarching context' based on 4 characteristics– resistance, recoverability, adaptation and transformation (Sayers, 2020).
- The Coastal Resilience Model (Townend and others, 2021; University of Southampton and others, (no date)) focused on the pragmatic operationalisation of resilience for coastal areas – a set of objectives to enhance resilience across people, property and nature are defined and quantified using indicators and associated data-driven metrics.
- The Environment Agency's 'Community Resilience and Recovery Metrics Project' (2021a) sets out definitions of social, infrastructure, economic, community and institutional resilience.

Despite these different approaches to characterising multidimensional resilience, common overlaps do exist between the resilience categories (or 'fundamental components'), most notably between economic/financial, social/human and environmental/natural aspects. Due to the complex and often contentious definition of resilience, using component categories (economic, social, environmental) to describe the multidimensional aspects of resilience is a useful and transparent approach to developing comprehensive indicators. We conclude that using a set of resilience components (across the components of resilience - placemaking, better protect, respond and recover) is a transparent and useful way of assessing the present state of resilience and how it might change.

Within the rest of the findings in this report, these resilience categories or fundamental components are referred to as the 5 capitals of social/community, economic, physical, natural and institutional capacity.

For the purposes of the study, the definition of resilience from the FCERM Strategy has been used to frame what is most appropriate to measure to track changes over time and measure strategy progress.

Using applicability criteria

The majority of the studies reviewed used ‘applicability criteria’ (how applicable the indicators are in meeting the desired outcome) to select indicators. However, the process for developing the criteria, as well as the way they were used to select indicators, differed significantly. In a study to assess the impact of International Climate Fund programmes on household and community resilience to climate variability and climate change, the Department for International Development said that it was important to select indicators based on both applicability across a range of contexts and versatility for multiple uses (Brooks and others, 2014). This approach also focused on blending qualitative and quantitative measures to achieve distinct and significant indicators that effectively capture outcomes and impacts, as well as the inclusion of participatory methods which are both comprehensive and practical (Brooks and others, 2014). The importance of the ability to account for and measure unexpected outcomes was also recognised (Brooks and others, 2014).

Criteria were also used in different ways to refine indicator sets. For example, the National Infrastructure Commission (NIC) Performance Measures research described using gateway criteria to filter indicators through a ‘knock-out’ mechanism, whereby any longlist measures which did not meet gateway criteria could not be shortlisted (NIC, 2017). Other studies used scoring techniques to identify which indicators performed best overall against applicability criteria, such as the Defra evidence review of the concept of flood resilience which used a simple ‘(H/green) – Medium (M/amber) – Low (L/red) scale’ to produce indicator rankings (Twigger-Ross and others, 2020). Developing and using applicability criteria is a highly adaptable method that can be moulded to suit the desired context. Applying these criteria during indicator shortlisting is a useful approach for refining indicator sets in a clear and thorough way.

Top-down and bottom-up approaches

The approaches adopted within the reviewed literature were largely based on either top-down or bottom-up assessments. Several frameworks, including the ANDRI, used top-down approaches and were focused on indirectly deriving proxy indicators from existing secondary data such as census data (Parsons and others, 2016). By contrast, bottom-up approaches were also popular within resilience frameworks such as the Flood Resilience Measurement Tool (FRMT), in which directly derived indicators were developed from participatory methods at the local scale, for example, by using stakeholder interviews and community surveys (Keating and others, 2016). The City Resilience Index (CRI),

developed by the Rockefeller Foundation and Arup in 2014, also takes a bottom-up approach focused at the city level, while the BRIC framework is mostly top-down, but does also place emphasis on local communities (Cutter and others, 2014). Determining whether a bottom-up or top-down approach is used is important as it “determines the degree of community involvement in the assessment process, influences the cost and spatial extent of the assessment and the ability to compare across units of analysis using standardised data” (Parsons and others, 2016). As the 2 approaches also have discrete levels of conceptual limitation, understanding the boundaries of each approach is also essential (Parsons and others, 2016).

Geographical scale

A strong understanding of the scale of application emerged as an important aspect within the reviewed approaches for developing resilience indicators, particularly in relation to implications for data and the degree to which qualitative and quantitative approaches can be implemented. Assessments of larger scales are typically achieved through a relatively ‘coarse’ sampling approach, while fine grain assessments are only feasible in terms of practicality and cost at a much smaller scale (Parsons and others, 2016). As such, there is a trade-off which comes into play when considering the spatial extent at which indicators are feasible. For example, Cutter and others (2008) describe the major differences in measuring large-scale global resilience compared to resilience at the community level, recognising that “at the individual or household level, issues of livelihood and entitlements come into play, yet at the national and regional scale the Gross Domestic Product (GDP) is often used as an indicator of resilience.” In addition, the Defra evidence review of the concept of flood resilience identified that indicators could be tailored to geographical area and local variation as an important characteristic for their selection, indicating the importance of ensuring indicator dimensions are compatible with the desired spatial scales for assessment (Twigger-Ross and others, 2019). Since top-down approaches typically sample large spatial extents at a coarse grain, and bottom-up approaches tend to apply at a fine grain to studies with a narrow extent, early consideration should be given to how the choice of approach influences the spatial extent of assessment (Parsons and others, 2019).

Flood disadvantage

There is growing recognition within the literature that the social vulnerability of individuals and communities at risk of flooding greatly affects their capability and capacity to respond, a concept often known as ‘flood disadvantage’. Sayers and others (2017) suggest that better understanding this concept and its relationship with exposure to flood risk is a “prerequisite to delivering a socially just (i.e. fair) approach to prioritising flood risk management efforts.” This is echoed by O’Hare and White (2017), who propose that considering flood disadvantage can add another dimension to flood risk management approaches by accounting for “differing vulnerabilities and sensitivities to flooding and uneven abilities to engage with risk agendas.”

An early approach for measuring baseline social vulnerability was demonstrated by Cutter and others (2003) in their research to assess vulnerability in the United States by using indicators for leading social and economic factors such as housing, wealth, age, ethnicity and economic dependence. This concept is known as the Social Vulnerability Index (SoVI). This is built on in their further work on the disaster resilience of place (DROP) model, in which the first step was focused on measuring inherent resilience, with the aim to "evaluate not only the baseline conditions, but also adverse impacts, and factors that inhibit effective response" (Cutter and others, 2008). Sayers and others (2017) use the Future Flood Explorer to assess social vulnerability to flooding and how this impacts flood disadvantage in the UK. They introduce a Neighbourhood Flood Vulnerability Index (NFVI) to "compare risks between more and less flood vulnerable neighbourhoods" and a Social Flood Risk Index (SFRI) to "identify where vulnerability and exposure coincide to create flood disadvantage." The growing number of approaches that recognise innate inequalities and consider flood disadvantage and social vulnerability when developing resilience indicators suggests that it is useful to consider these elements, particularly to ensure 'respond' and 'recover' aspects of resilience are appropriately considered.

While the text above illustrates that the concept of flood disadvantage is becoming well understood, 'erosion disadvantage' is not a well-developed area. A similar erosion disadvantage in coastal areas subject to erosion can be inferred to exist due to the relative deprivation of coastal areas (Corfe, 2019; House of Lords, 2019). Although this raises many similar distinctions required to better understand 'erosion disadvantage', the different nature of erosion compared to flooding will make the details distinct. It is recognised that those indicators which involve coastal erosion social inequity will require long-term research.

Parallel workstreams

The evidence review also found that a number of parallel work areas were ongoing within the Environment Agency at the time of this study that related to the research, either through benefiting from its findings or providing a potential future opportunity to take forward elements of the research into operational practice. These were:

- the review of the FCERM annual report: The Environment Agency produces this annual report under Section 18 of the Flood and Water Management Act to summarise activities carried out by risk management authorities (RMAs) in England. A review of this reporting framework was underway at the time of this research but was paused to allow the research to complete and inform the review.

- updates to the Defra scorecard for the 2021 to 2027 FCERM capital investment programme: In July 2021, the government announced a suite of key performance indicators that will track delivery of the capital investment programme. This includes outcomes, benefits, expenditure, asset condition and maintenance and programme delivery risks. Overall, 22 measures will be reported quarterly or annually to track the progress and outcomes from the capital investment programme. Some of these measures have been used as indicators in this research, but it is assumed that the

capital investment programme measures would still be used alongside the resilience indicators

- measuring changes in risk: In 2020, the National Audit Office called for the Environment Agency to "update and improve its methodology for calculating the risk reduction achieved from its investment programme and, for each year of the new programme, report publicly on annual progress towards reducing risk by 11%." Work is ongoing to develop a method to report on risk reduction, which is initially focusing on data relating to numbers of properties and estimated annual damages (EAD). It is expected that this work will use the research to develop an EAD method in the future that represents a wider range of flood impacts (damage), and activity to reduce flood likelihood beyond activity funded in the current capital investment programme

- Flood and Coastal Resilience Innovation Programme (FCRIP): The FCRIP is funding 25 projects to implement and evaluate innovative actions to improve resilience to flooding and coastal erosion. These projects will establish new evidence of the costs and benefits of innovative resilience actions and may be able to test indicators developed within this study

Conceptual framework

The conceptual framework provides a logical organising framework for developing indicators for measuring resilience to flooding and coastal erosion and, importantly, informs the narrative or justification for including measures. It follows a Theory of Change approach which fundamentally addresses the following questions:

- What is the current situation or problem that needs to be addressed?
    - Operating environment
- What do we want to achieve in terms of enhancing resilience at the local level?
    - Aim and objectives
- What do we need to do to enhance resilience?
    - Management approaches and range of actions
- How will we know that we are enhancing resilience?
    - Outputs, outcomes, impacts

This framework enables components to be identified where indicators can be developed to measure progress. It also provides the framing for local strategy (local flood risk management strategy, shoreline management plan and contribution to local plans) development. The cyclical nature of the framework is intended to illustrate how the enhancement of resilience is a process of continuous improvement and adjustment as the underlying context and external pressures change over time. Implementing actions and their outputs, outcomes and impact should lead to a change in the underlying context (the resilience of a place or community), which then requires objectives and future actions to be reset. The framework is a way of building adaptation into strategic planning and project level planning. It supports the concept of adaptive pathways, where flexible plans are designed and implemented that can anticipate and effectively respond to uncertain future

changes, with a focus on low and no regrets actions that have the capacity to achieve multiple objectives.

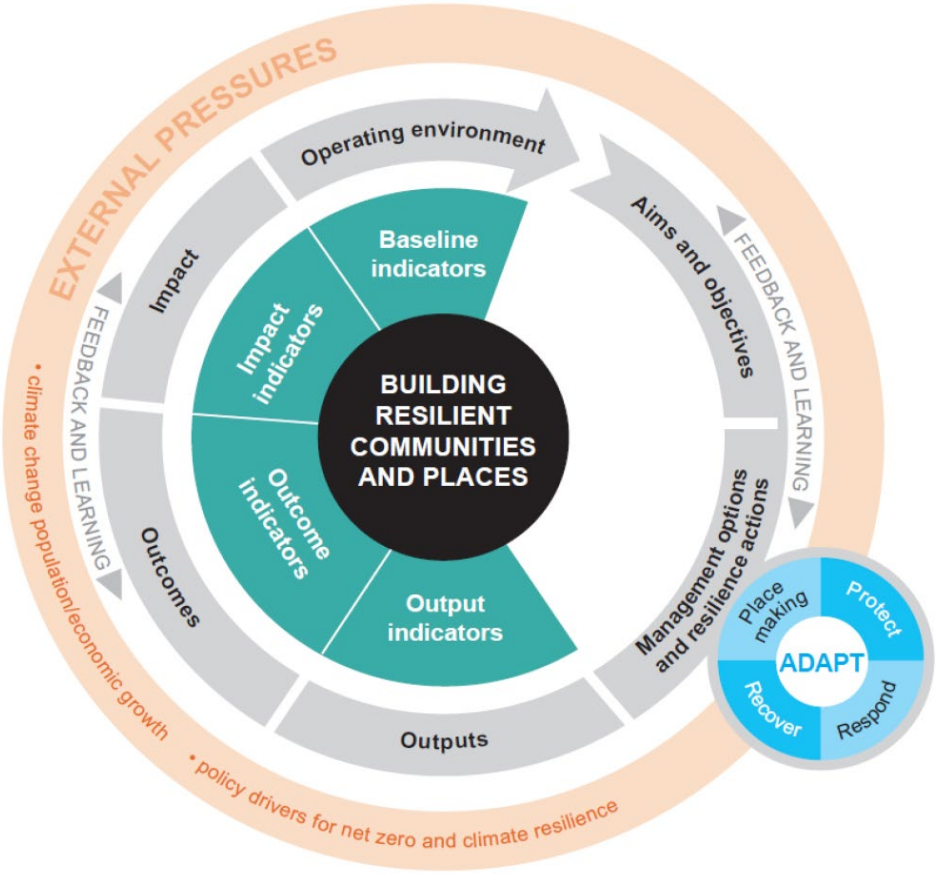

Figure 3.1 Conceptual framework

The components of the conceptual framework (grey arrows in Figure 3.1 above) are explained in more detail below.

Operating environment

The operating environment is the current resilience to flooding and coastal erosion and impact on the 5 capitals: social/community, economic, physical, natural and institutional capacities. This current resilience is highlighted and further challenged with the current FCERM Strategy, FCERM policy statement and 25 Year Environment Plan.

Aims and objectives

The aim of developing indicators is to track changes in resilience and enable us to better understand the impact of government policy. Monitoring trends over time will allow us to drive the implementation of effective resilience actions and enhance the resilience of people and places to flooding and coastal erosion now and in the future, taking account of wider ambitions such as net zero and environmental net gain and contributing to social, economic, physical and natural outcomes.

The objectives are strategic and local actions are framed within the context of local characteristics and the principles of adaptation and transition.

Management options and resilience actions

The proposed revised set of resilience actions, based on the actions promoted in the FCERM Strategy and the Flood and Coastal Resilience Innovation Programme, is set out here with short definitions. Actions in quotation marks have been added or amended in response to discussions at the focus groups.

For the purpose of this research, the actions have been allocated into categories of the 4 components of resilience: placemaking, better protect, respond and recover. However, it should be recognised that some actions do span multiple categories.

The set of resilience actions includes a focus on management options which aim to reduce the consequence, as well as those which reduce the likelihood of flooding and erosion events. This aims to drive the uptake of a broader basket of measures and expand the focus beyond conventional, engineered defences. The long-term ambition is to represent change in resilience as a change in risk (that is, quantified risk reduction due to improved overall resilience, not just increased conventional, engineered defences).

The revised set of resilience actions for placemaking include:

- climate resilient local spatial planning policies – planning policies that contribute towards resilient places and communities now and in the future, taking climate change into account
- avoiding inappropriate development – similar to the above but specifically focused on development not occurring in areas at risk of flooding or coastal erosion or where it could contribute to flooding or coastal erosion elsewhere
- long-term plans for ‘inland’ and coastal community transitions – developing plans to help those in communities that are deemed to be unsustainable in the longer term due to climate change
- uptake of flood resilient building standards – this relates specifically to property flood resilience and standards to ensure effectiveness
- retrofitting sustainable drainage systems (SuDS) – installing sustainable drainage systems in existing developments
- community awareness and education – raising awareness among communities of their level of flood risk and educating them on what this means to them
- catchment and shoreline management and planning – managing land use on a catchment or shoreline basis
- actions that enable communities to capitalise on opportunities, for example, levelling up, net zero, social equity – range of actions that have positive outcomes for other agendas as well as helping to address flooding and coastal erosion

The revised set of resilience actions for better protect include:

- flood and coastal defence – engineered defences to better protect land and communities from flooding and coastal erosion
- asset management and maintenance – management and maintenance of the condition of flood and coastal resilience assets
- integrated water ('flood and coastal') management solutions – the co-ordinated development and management of water, land and related resources, with a focus on water scarcity as well as flooding
- nature-based solutions (NBS) - sustainable management and using nature to tackle socio-environmental challenges
- property flood resilience (PFR) measures - household measures to protect against or withstand flooding
- protection for local community infrastructure – measures in place to protect community buildings
- local monitoring – of assets and water levels to inform action

The revised set of resilience actions for respond include:

- flood forecasting and warning – forecasting flow rates and water levels that are then used to warn those that could be affected
- community response plans (and training) – emergency response plans developed at the local level and training provided to ensure residents, businesses and other stakeholders are aware of the actions to take when a flood or erosion incident occurs
- local emergency response equipment – local equipment that can be used to protect properties during a flood incident
- local warning systems – flood warning systems that operate on a local basis
- flood warning service improvement (and uptake) – ongoing improvement and enhanced uptake
- multi-agency flood plans in place and tested – local plans involving multiple stakeholders that should be enacted during a flood event, plus appropriate training to ensure all parties are aware of their responsibilities

The revised set of resilience actions for recover include:

- utility contingency plans – plans and back up in place should loss of power, water, or information, communications and technology occur
- resilient farming – awareness and development of climate resilient plans to enable farming to respond to and recover from flooding and coastal erosion
- access to affordable insurance for 'householders' – availability of flood insurance and awareness of where and how to access this
- access to affordable insurance for 'businesses' - availability of flood insurance and awareness of where and how to access this
- build back better embedded in flood and coastal erosion repairs – repairs that mean a property is better able to withstand a flood or coastal erosion than in its original condition

There were also resilience actions across the components of resilience which included:

- improving the capacity of all organisations involved in flood and coastal erosion management to reflect the focus on resilience rather than risk. Capacity includes both skills and resources. This may require new legislation or legal obligations

Outputs, outcomes, and impact

Based on the revised set of resilience actions, the intermediate results became outputs. By further refining the co-development process, the outcomes of these resilience actions were identified which increased the 5 capitals of social/community, economic, physical, natural and institutional capacity. The line of sight to resilience is the impact of the actions - ultimately a reduction in flood or erosion risk, or reduction in the consequence of events, which, in turn, enhances the 5 capitals.

Indicator development

Framed within the conceptual framework, the indicator development used the evidence review, focus groups, use cases and the national workshop to move from understanding the operating environment to identifying the outputs, outcomes and impacts. This development can be identified by the characteristics below.

- developing output and outcomes indicators (line of sight)
- contextualising the indicators
- improving clarity and specificity
- enabling measurement
- considering flooding and coastal contexts
- composite indicators
- maturity of subject area (that is, nature-based solutions, mental health impacts)
- data collection
- accessibility of data

Developing output and outcome indicators (line of sight)

The list of indicators identified from the evidence review was categorised to show the type of measure based on conceptual framework components: approximately 50% of indicators were categorised as baseline, 30% as output and the remaining 20% as outcome/impact indicators. As the indicators from the evidence review and focus groups developed the longlist of potential indicators, the conceptual framework was used to test the maturity and grounding of each indicator. Applying the framework to individual indicators allowed the line of sight from resilience action to output, outcome and impact to be tested. This enabled testing to determine if the indicator could successfully track changes in resilience over time, how this could be achieved and to what level of complexity.

The development of indicators focused on resilience capacity, which related to the capacity of a place or community to make the best land use and development choices, protect people and places, prepare and respond to and recover from flooding and coastal erosion, while all the time adapting to climate change. The intention was to develop indicators that can provide a baseline measurement of resilience capacity and can then be used to assess changes in this capacity (outcomes). However, applying the conceptual framework highlighted that, in some instances, developing an output indicator would be more effective in the short term for supporting and enabling a journey towards resilience. In these cases, developing an outcome indicator was challenging due to the maturity of the subject area and/or limited evidence supporting the causal effect from resilience action to outcome. This is explored further by establishing ‘interim’ indicators.

The set of recommended indicators developed through this research is made up primarily of outcome indicators, with some output indicators where limitations exist. The conceptual framework can be used to further explore line of sight and develop indicators into those relating to flooding and coastal erosion impacts. These impacts relate to the ultimate outcomes, such as reduced damages or reduced risk to lives and livelihoods, resulting from enhanced resilience capacity. Future research could further support this development of the line of sight towards impact indicators. Indicators that cover evidence, data, and/or information need (for example, activity under flood modelling, mapping, monitoring) have not been included as this work is a pre-requisite to carry out many of the FCERM actions.

Contextualising the indicators

Draft indicators were developed and tested in use case investigations in order to consider the measurement of resilience within real-world contexts, considering different sources of flood and coastal erosion risk, geographical and socio-economic characteristics. During in-depth use case investigations, the application of potential indicators was explored taking account of local factors. This exercise highlighted the potential challenges in implementing certain indicators and which indicators could potentially be effective at showing changes in resilience over time in the use case context. During the testing, changes were also suggested to further refine specific indicators to improve their clarity and function. The data requirements of draft indicators were also discussed with use case leads to identify indicators where data sets may already exist and where new data would need to be collected.

The main conclusions from the use case studies were as follows:

1. The feedback from the use case studies exercise reinforces the relevance of understanding the local context and baseline in terms of socio-demographic and wider economic capacities.
2. The use cases highlight the importance of local ambitions for framing the understanding of and expectations related to flood and coastal resilience.
3. For each use case it is evident that resilience is a function of the combination of the 4 components: placemaking, protect, respond and recover. It is also evident that

each location is at a different stage of its local journey in understanding and responding to resilience, but has a different priority to the 4 components.

4. Each of the use case groups supported the need to develop outcome indicators at a national level. It was also suggested that locally derived output indicators will have value in supporting and enabling the journey at a local level.
5. All use case groups stressed the importance of realising co-benefits as part of the enabling framework for resilience and developing practices to support this. Use case groups were also conscious of the potential influence of their role in place-making and how this could provide positive impacts in terms of social, economic and environment outcomes to build resilient communities and places.
6. The use case groups also recognised the importance of an enabling environment that fosters action learning organisationally and within communities.

A summary of the main findings for each use case is included below. A full breakdown of the use case testing is presented in Appendix 1.

North Norfolk – Placemaking

This use case highlighted the importance of effective placemaking actions for the resilience of North Norfolk and other coastal communities. It was stressed that long-term, adaptive planning should be prioritised for these areas, since the inconsistent and unpredictable nature of coastal erosion means that forecasting erosion is not possible at present. In particular, an indicator which could track the implementation and effectiveness of plans (for example, shoreline management plans (SMPs)) would potentially be useful to show changes in resilience over time for communities at risk of coastal erosion. Considering whether plans are multi-agency would also help demonstrate whether mechanisms for joint working are in place, for example, between communities and risk management authorities (RMAs). In addition, it was considered that monitoring awareness and understanding of erosion risk within the community would be a good indicator for resilience.

An important message from this use case was that for communities which were forced to abandon properties due to erosion, the ‘recover’ component should relate to the circumstances where members of a community have to relocate. In contexts where physical recovery of a place is not possible, then indicators need to allow for measuring activity which facilitates social and economic recovery of the community. This could be achieved by measuring relocation to suitable accommodation or identifying whether people know where they will live and work if their home becomes uninhabitable.

Boston – Better protect

Testing the indicators in Boston highlighted the contextual nature of resilience and demonstrated the importance of understanding the local setting and baseline in terms of social/demographic, economic and environment capacities. A core message arising from the Boston team was the importance of recognising co-benefits, synergies and dependencies in making the business case for resilience and providing sustainable solutions. This use case also demonstrated the highly interdependent nature of placemaking and protection measures.

Looking ahead, 3 draft indicators stood out as crucial for measuring resilience in Boston. These are ‘public and stakeholder awareness of risks and understanding of risk, and the potential damage and actions that can be taken’; ‘knowledge of service/condition level of existing assets, and changes over time taking account of climate change and asset deterioration’; and ‘knowledge of residual risk in terms of number of properties at risk of flooding or coastal erosion’.

Within the context of the enabling environment for measuring and achieving resilience, the importance of leadership and local champions was evident in the work carried out in Boston, alongside an appetite to ‘do things differently’, embrace best practices and technology, and promote success and lessons. At the core of the team’s resilience thinking is the importance of embedding net zero practices and using the UN Sustainability Development Goals (SDGs) to retrospectively explore co-benefits and realise future opportunities.

Salford – Respond

Testing the indicators within the Salford use case suggested that indicators around awareness and engagement were particularly important for measuring changes in resilience. The main findings from this use case highlighted that using simple output indicators (such as the number of plans in place) would not be as effective at measuring changes in resilience as using outcome indicators (in other words, whether plans were effective and exercised). Similarly, simply measuring the number of flood action groups would not give a useful measure of resilience in Salford, where having a single effective group is more valuable than multiple rival groups. While an indicator focused on flood warnings was considered important, measuring whether action is taken following a warning rather than simply warning sign-up would be preferred, as this would also give a measure of understanding and awareness.

In terms of emergency response, the capacity to respond in terms of available equipment and an appropriate plan was felt to be a better indicator than response times, as response time would need to be measured following an event and would depend on a number of different factors. As a number of the draft indicators rely on measurement post event, it would be valuable to consider if these could be substituted with alternative annual indicators.

Rochdale – Recover

Testing the indicators in Rochdale again highlighted the contextual nature of resilience and the importance of the socio-demographic and economic baseline. The use case also highlighted the importance of local ambitions in framing the understanding of and expectations related to resilience. In this instance, the ambitions include adapting to climate change, achieving environmental net gain by maximising co-benefits, and improving flood literacy and partnership working.

The use case highlights the value of having both output and outcome indicators at the local level. The use case representatives acknowledged that the output indicators may not necessarily reflect resilience, but they are important in signposting the journey people are going on and in achieving longer-term goals and outcomes.

The use case also challenged the concept of ‘recovery’, suggesting that the current definition is too limited and that the recovery needs to be framed as the point in time where members of a community are again able to fully ‘participate in society’. In measuring recovery, it was also recommended that ‘an appreciative inquiry’ approach should be taken; defined as “an approach to organisational change which focused on strengths rather than weaknesses – quite different from many approaches to evaluation which focus on deficits and problems.”

The use case recognised that not all potential indicators can be practically measured today. Where indicators cannot be measured, it was suggested that alternatives are provided in the interim without losing the initial indicators as a goal. This supports the idea of capturing output indicators at a local level and considering other enabling aspects for developing future indicators.

Improving clarity

There was strong feedback from those engaged with the research, the project board and project advisory group that many of the draft indicators would be more useful with improved definition. For example, for indicators which include reference to ‘development’ and/or ‘infrastructure’, a consistent definition should be used (from the National Infrastructure Commission (NIC) or National Planning Policy Framework (NPPF)). Where more subjective words such as ‘effective’, ‘successful’ and ‘benefiting from’ have been used, a clearer definition should be provided so users can understand exactly what the indicator is referring to. Indicators should not include the term ‘resilient’ (for example, proportion of new development that is flood/coastal erosion resilient) as this creates cyclical issues. For indicators which include the phrase ‘at risk’, this would need to be clarified to express whether this includes all risk zones or just those at high risk. In addition, the specific climate change scenarios and timescales would need to be explicitly stated in indicators where these have been referenced.

To address this, indicator commentaries have been provided alongside the recommended set of indicators which include main definitions and provide clarity for users as far as possible. As this is the first stage of research, areas where further guidance or descriptions are required have also been set out within these commentaries. Future research could identify where definitions are lacking or inconsistent and address these gaps.

Enabling measurement

It was also stressed that indicators should be worded to state precisely the proper dimension of what should be measured, such as proportion or number. For example, draft indicators relating to ‘resilient rural land use’, ‘community embedded in decision-making’ and ‘tracking mental health impacts’ were not indicators in their current forms and needed refining to specify the dimensions of precisely what should be measured. It was also identified that actual numbers should be provided where proportions are measured so that overall changes can be seen clearly.

Several indicators were thought to require more research and resources before measurement would be possible. For example, ‘number of properties benefiting from natural flood management (NFM) measures’ would be very difficult to measure since NFM schemes are usually implemented as part of a combination of activities, making apportioning benefits challenging. It was identified that a possible measure for NFM could be in relation to placemaking with respect to the land that was formally allocated to be used for NFM. There is also relatively limited evidence to show the quantifiable measurable flood risk benefits to downstream properties of such schemes.

For some indicators, further clarification is needed to enable consistent measurement. For example, to measure the ‘implementation of sustainable drainage systems (SuDS)’ as there are several types of SuDS (for example, blue, grey, green, urban, rural, above ground), and the user would require clear guidance on which systems would qualify for measurement. This also applied when measuring ‘adaptation plans’ as these exist in many forms, sometimes embedded within other plans or policies. It was therefore recommended that guidance is provided with each indicator to give the user more detail on exactly how the indicator should be measured.

Considering flooding and coastal contexts

Throughout the development of the indicators, those engaged with the research stated that it was hard to comment on the draft indicators for flooding and erosion combined, as measurement would be very different for each context and therefore hard to compare (for example, for ‘residual annual direct property damage’). The workshop findings also highlighted that some draft indicators would be useful to measure resilience for flooding but were not relevant for coastal erosion where there was loss of land, despite including ‘coastal erosion’ within the indicator wording. Since there is no erosion risk warning service for loss of land, erosion cannot be insured against. Also, since erosion happens only once, the number of the respond and recover indicators that could apply to coastal erosion contexts would need to be considered.

Participants suggested that, where indicators do apply to both flooding and coastal erosion, there should be consistency in whether they are included as composites or split into separate indicators. There was limited discussion around indicators for coastal erosion in which there is no loss of land due to current coastal erosion defences, but where failure would lead to significant flooding. As this is currently a possibility in areas such as the south of England, it should be measured alongside coastal erosion where there is loss of land. These current coastal erosion defences have required significant investment, funding and maintenance.

To improve consistency across the indicators, the working definition of flooding includes fluvial, surface water, sewer, groundwater, reservoir and coastal flooding, while coastal erosion remains a separate hazard.

Composite indicators

Feedback from the national workshop and project advisory group suggested that some of the draft indicators were too complex and should be simplified or split to reduce complexity. For example, comments suggested that ‘service/condition level of existing assets and change over time with climate change/asset deterioration’ was difficult to measure and understand as an indicator. Streamlining this to focus on the aspects that would have the most impact on resilience would improve usability and effectiveness.

In addition, project advisory group feedback highlighted that composite indicators should only be included where there is a clear relationship between component parts. For example, it was recommended that the draft composite indicator ‘availability, sign-up and trust in flood warnings’ should be split into 3 separate indicators since the relationship between component parts was not clearly defined and would require detailed research to produce a meaningful composite indicator. Following this feedback, a focus on producing a more accessible and explicit set of indicators was taken forward and composites have only been suggested where there is a clear link.

Data collection

The requirements for data collection were considered throughout this research, with the focus groups, national workshop and e-survey findings highlighting stakeholder concern for how data would be collected for many of the indicators, as well as who would be responsible. This work is intended to be ambitious and develop indicators that will drive change over time and track the outcomes of resilience actions, so it was expected that data may not be available for all the indicators. As such, several themes emerged continuously as priorities for measuring resilience (for example, how engaged communities are and the effectiveness of nature-based solutions (NBS)), but for which data is lacking.

It is important to note that many organisations have roles and responsibilities for implementing the FCERM Strategy (see Annex 2 of the FCERM Strategy). This means that data to measure the indicators will need to come from several sources and a way of reporting on them would need to be determined (whether that is directly by the individual organisations or as a collective process). As such, many stakeholders considered unwillingness of organisations to share or collect data to be a barrier for measurement, particularly where data collection is not currently a legal requirement. The lack of consistent data collection approaches was also considered an important limitation in being able to collect data to measure and report on indicators that need data to be compiled from multiple sources (such as asset condition).

At the focus groups, local authorities raised particular concern about indicators for which they would need to collect or collate data, as there is currently insufficient support to build capacity and expertise to do it. Lack of time, money and resources were specifically noted as challenges for community engagement indicators which would require surveys. Stakeholders noted that indicators that would require frequent or long-term collection

would be particularly resource intensive. For example, annual measurement may be too short a period to reflect changes in resilience for some of the indicators, such as many of the indicators on community engagement, meaning data compilation over longer periods of time would be required. Additionally, some indicators may be more temporally variable and if those indicators are measured yearly, the ‘swings’ in resilience occurring may not be fully representative of flood and coastal resilience.

Challenges around post-event data collection were also noted. It was stressed that these indicators should be tracked against the type and magnitude of the event to allow meaningful comparisons. For example, a draft indicator included the emergency response time. However, for emergency response time following a flooding or coastal erosion event, the response times for an event that impacts 1,000 properties are not comparable with an event that impacts 10 properties. Within the revised set of indicators, draft indicators were further developed insofar as possible that the type and magnitude of the event would not be required to track meaningful comparisons.

Headline indicators have been developed for each of the indicators, allowing them to be categorised in the future into different themes such as administrative, economic, social science, environmental, and others. This categorisation could provide an indication of where the data for these indicators could be derived. For example, development and land use indicators could be categorised as administrative and, therefore, the risk management authorities (RMAs) could provide this data. However, different actors will have access to, hold and will be able to generate the data for the indicators and further development needs to ensure they are aware and able to do this.

Further research will be required to investigate potential data collection methods and sources for many of the indicators recommended from this research. Identifying where efficiencies can be made through existing reporting mechanisms (for example, Section 18 reports) will be crucial in minimising resource requirements.

Maturity of subject area

Participants felt that indicators to show change in levels of engagement and awareness were particularly important, despite being very challenging to define and measure. For example, ‘fear of flooding’ was considered an important aspect of resilience to measure, but participants noted that it would be difficult to separate this from general health and wellbeing. It was also highlighted that fear would be complex to analyse since it could be due to a lack of awareness of risk, a high level of awareness or a lack of confidence in FCERM actions. Similarly, for ‘tracking mental health impacts from flooding/coastal erosion’, it was considered challenging to attribute mental health impacts purely to a flooding or coastal erosion event rather than to a combination of factors. Surveys could be used to obtain data for these measures, but obtaining results that truly represent the mental health impacts experienced in a certain place is likely to be difficult.

Discrepancies between the maturity of evidence available for different indicators were also highlighted, for example, for asset types. When comparing indicators for more

conventional, engineered defences, nature-based solutions (NBS) and sustainable drainage systems (SuDS), stakeholders noted that the standard of evidence required for each indicator varied:

- For conventional, engineered defences (flood walls, embankments), a standard of protection can be assigned, inspections carried out and asset conditions currently reported, meaning an indicator requiring evidence of risk reduction to land use or development is suitable.
- For NBS, evidence of risk reduction is in the early stages. Schemes that offer some quantitative evidence of slowing the flow, storing water or slowing erosion are at the forefront of this, meaning an indicator requiring evidence of this level of maturity is suitable.
- For SuDS, systems should be implemented in line with current industry or government standards, meaning an indicator requiring evidence of this level of maturity is suitable.

These differences in maturity should therefore be considered when designing indicators that can drive change but are achievable in the short term. Where advances in technology and research are anticipated in the future, including aspirational indicators can help drive positive change.

Data sources

Throughout the focus groups and workshops, potential data sources have been identified for the categories and specific indicators. However, an identifiable data source for each indicator was not integral to developing, refining or progressing an indicator to be recommended. This was because this research aimed to identify indicators that best monitored changes in resilience over time, regardless of the barriers to data collection or data sources.

Identifying what measurements are already being collected and what would be needed operationally to capture any new measurements was used to assess the readiness of the indicators to be operationalised now, within 5 years, or whether they required further development (for example, primary data collection such as surveying).

The e-survey focused on identifying potential data sources and barriers to data collection for the draft indicators before they were finalised. The results from the e-survey recognised that participants were not always able to identify data sources that could readily measure an indicator, and further analyses of the data source or supplementary data source would be required.

The data sources suggested included government open data sources across different departments, but also included data sources from private organisations, such as insurance data sets. There were a number of indicators, however, where there were no data sets identified and new data sources would need to be developed. These indicators were often categorised as ‘further development required’. There are also more established data sources for fluvial and tidal flooding than coastal erosion, surface water, groundwater,

sewer and reservoir flooding, so some indicators may be ready to measure for some sources of risk, but not others.

The research and e-survey identified the annual Flood and Coastal Erosion Risk Management report produced by the Environment Agency under Section 18 of the Flood and Water Management Act (FWMA) as an important potential data source and potential way of collecting new data. Although this is an important data source, it currently mostly reports indicators found within the ‘better protect’ resilience component and participants recognised that other and new data sources and mechanisms were required to capture new measurements. It is also recognised that the performance of the shoreline management plan is reported, but it is not a requirement of the FWMA and subject to funding. Consequently, there is a risk that there could be missing data gaps or an inconsistent data set.

The lack of consensus across the data sources required for each indicator identifies that further research into the most appropriate and proportionate data sources is required to effectively operationalise the indicators. Further work would also be required to determine if and how current and new data sources may be used in regard to data resolution, replicability, uncertainty, frequency of collection, geographical variability and quality.

4. Recommended indicators

This section outlines a number of possible indicators which could be applied. It briefly discusses national and socio-demographic indicators. Following this, the main part of section 4 is broken down into 2 sub-sections:

- ‘ready now’ indicators
- ‘further development required’ indicators

‘Ready now’ indicators: where data or information is already available to measure the indicator. In some cases, further data collation and analysis may be needed, but a potential approach to data analysis has already been identified. Some indicators may only be ready for some sources of flooding/coastal risk, or part of the indicator. Where this is the case, components of the indicator that need developing further are highlighted. Many of the ‘ready now’ indicators have scope to evolve and improve as new data and evidence emerge.

‘**Further development required’ indicators**: need further work before they can be used. Data sources are currently unknown or being developed. Further refinement is required to improve definitions and what should be measured. While stakeholders considered these indicators worthwhile in measuring resilience, there is currently no way of quantitatively or qualitatively measuring their progress. Some indicators could be ready within 5 years.

Indicators are presented across the components of resilience, identifying:

- headline indicator: a high-level summary or theme of the indicator(s)
- indicator: a measure of the change of resilience; an overarching indicator if there are component indicators
- indicator type: whether it is an output or outcome indicator; and a national indicator
- components (if applicable): separate indicators providing a more detailed breakdown of the overarching indicator
- justification: why the indicator is important
- development: how the indicator was developed through the research
- weaknesses: any drawbacks to consider when using the indicator
- data: potential data sources for current or future measurement of the indicator
- tracking and evolution: identifying further development required

No targets or standards have been identified for any of the indicators. Where ‘proportion’ has been used as a measure, it is important to note that achieving 100% is not the aim. Instead, the focus should be on monitoring relative change over time (an increasing or decreasing trend) to indicate whether management actions are effectively increasing resilience.

Although indicators measure outcomes of resilience actions where possible, some indicators measure the outputs of actions. This may be due to data availability, a limited evidence base or lack of maturity of the subject area. Due to these challenges,

compromises have been made in some areas to provide a balance between what should be measured to most effectively demonstrate changes in resilience over time, and what is possible to measure. These decisions have been made through extensive discussions between the project team and with stakeholders.

It is acknowledged that some indicators track how well FCERM policy is being met rather than resilience directly, due to the challenges explained above. For these indicators, it is assumed that current policy is enabling improvements in resilience. This allows the indicators to act as an achievable starting point upon which more advanced indicators can be built.

National indicators

The national indicators are a select number of indicators identified from the full set of indicators which could be operationalised at a national level (England). Although individual indicators focus on distinct aspects of flood and coastal resilience, when used together, these indicators could provide a full picture of the changes in resilience to flooding and coastal erosion.

The findings from the national workshop informed the development of criteria for identifying the national indicators, taking into account participants' thoughts on how prioritisation should occur. The following 6 criteria were developed for assessing indicators to include within the national indicators.

- **Related outcomes** – indicators that have the greatest impact across social, economic, institutional, physical and natural capitals.
- **Scalability** – can this indicator be measured nationally? Targeting data sets with national coverage, but could be collected locally and aggregated nationally.
- **Readiness for measuring** – can the indicator be measured now, is it reliant on post-event data collection or surveys?
- **Critical to maintaining/baselining** – to identify if there is a shift of resilience. The national indicator set was chosen to provide a good balance between critical baseline indicators and those driving change.
- **Shift towards FCERM Strategy** – supporting the 3 FCERM Strategy ambitions.
- **Spread across resilience components** – placemaking, protect, respond and recover.

There are 18 indicators within the national indicators, excluding component indicators.

Socio-demographic indicators

The socio-demographic characteristics of communities are essential for understanding the area's resilience to flooding and coastal erosion, and can influence the selection of resilience actions. These socio-demographic characteristics have been considered separately from indicators of flood and coastal resilience. However, the research

highlighted the important and complementary nature of including the socio-demographic indicators alongside the flooding and coastal erosion resilience indicators for context and better understanding the locality of an area.

Consequently, a selection of socio-demographic indicators has been identified to form the overarching national socio-demographic indicators determined by the evidence review, use cases, and workshops and recent research (Environment Agency 2022a). These indicators represent social resilience, economic resilience, and community capital.

- educational equity: % of population with a Level 4 qualification and above
- age: % of population over 65
- transportation access: % of population without a car or van
- community capacity: % of homes with broadband
- language competency: % speaking English as a first language
- special need: % of population with long-term health problem or disability
- housing capital: % of home ownership
- employment: % economic active, % employed
- income and equality: indices of deprivation: % in the top 10% of income deprivation
- single sector employment dependence (reliance for employment on sectors that are at risk of damage or disruption from flooding): % of employment in fishing, farming, forestry or extractive industries
- place attachment: net migration to area of influence over past 5 years
- political engagement: % of voter participation in elections
- broadband coverage: % of households where super and ultra-fast fixed broadband is available

The socio-demographic indicators need to be associated with a local spatial scale. There are many data sets available at local authority scale, but these do not provide the spatial detail needed for a community-scale assessment of resilience. Electoral wards have potential, but the data sets available are limited. Postcode data is widely used in commercial (for example, marketing) contexts but is problematic as this data is expensive to obtain and there can be issues in identifying individual households, data protection and confidentially at such a fine spatial scale of analysis (especially for use by public agencies). For the socio-demographic indicators listed above, the research (Environment Agency 2022a) suggests that many indicators can be derived from the census at output scales. Output scales have the advantage of being the standard community scale used by the Office for National Statistics (ONS) with official and publicly available data sets. They are designed to have similar population sizes and be as socially homogenous as possible, the intention being to enable indices such as Indices of Multiple Deprivation (IMD). A limitation of using census data is the frequency of data release - the last full set of data available is from 2011 (updated census results will be published in full in 2022/2023). A full list of the socio-demographic indicators as listed in the Environment Agency (2022) research is in Appendix 2, including potential data sources.

Summary of indicators

These tables summarise the full set of potential resilience indicators, divided by 'ready now' (Table 4.1) and 'further development required' (Table 4.2).

Table 4.1: 'Ready now' indicators

Resilience component	ID	Headline	Indicator to show changes in resilience over time	Indicator type	Existing data sources	Components needing further development	National indicator?	Source
Place making	A1	Land use at risk	Existing land use at risk of flooding (all sources) or coastal erosion – now (current year) and with climate change.	Outcome	NaFRA; NCERM; National Receptor Database	Climate change (NaFRA2 will improve data from 2024)	Yes	All
Place making	A2	New development against FCERM advice	Proportion (%) of new development for which planning applications were granted against Environment Agency and lead local flood authority (LLFA) flooding and/or coastal erosion advice.	Outcome	Environment Agency Section 18 reports; Gov.uk data	National information on LLFA planning advice not currently available.	Yes	All
Better protect	B2	Annual average damages (modelled damages)	Annual average residual damage (£) of properties (non-residential and residential) and essential infrastructure from flooding.	Outcome	NaFRA	Surface water, groundwater, reservoirs, climate change (NaFRA2 will improve data from 2024)	Yes	Flooding
Better protect	B3	Asset condition	Proportion (%) of flood and coastal assets managed and maintained within and above a specific condition level.	Outcome	Environment Agency FCERM capital investment programme	Data on third party assets not owned by the Environment Agency is not consistently available	Yes	All
Better protect	B5	Nature-based solutions	Number of schemes with NFM/NBS in FCERM programme.	Output	Environment Agency FCERM capital investment programme	See B4 for further future development of this measure	No	All
Better protect	B7	Land use better protected	Proportion (%) of land use better protected by flood/coastal defences.	Outcome	NaFRA;	Data only for impacts of conventional	Yes	All

Resilience component	ID	Headline	Indicator to show changes in resilience over time	Indicator type	Existing data sources	Components needing further development	National indicator?	Source
					National Receptor Database	engineered defences. No information available for temporary defences, NBS and SuDS.		
Better protect	B8	Properties better protected	Proportion (%) of properties at risk better protected through flood/coastal defences.	Outcome	Environment Agency FCERM capital investment programme	Data only for impacts of conventional engineered defences. No information available for temporary defences, NBS and SuDS.	Yes	All
Better protect	B9	National risk reduction	% reduction in national flood and coastal erosion risk (modelled)	Outcome	Environment Agency FCERM capital investment programme	Assessment will be improved by NaFRA2 from 2024	Yes	All
Better protect	B11	PFR proactive installation	Number of properties with PFR installed as part of Environment Agency FCERM capital investment programme.	Output	Environment Agency FCERM capital investment programme	See B10 for further future development of this measure	No	Flooding
Respond	C1	Flood warnings (availability)	Proportion (%) of 'at risk' properties where flood warnings are available and residents are automatically signed up.	Output	Environment Agency Flood Warning Service	Surface water and sewer flooding	Yes	Flooding
Respond	C2	Flood warnings (sign-up)	Proportion (%) of 'at risk' residents proactively signed up to flood warnings (excluding opt-out).	Output	Environment Agency Flood Warning Service	Surface water and sewer flooding	Yes	Flooding
Respond	C7	Community awareness of flood response plans	Proportion (%) of people in areas at risk of flooding who have taken the time to understand how they would respond as a community to flooding in their neighbourhood.	Outcome	Environment Agency Public Flood Survey	Better understanding could be developed via C12	No	Flooding
Recover	D3	Additional PFR post event	Proportion (%) of properties recovered with additional physical PFR resilience measures post event.	Output	Defra PFR recovery grant claims;	Privately-funded PFR installation	No	Flooding

Resilience component	ID	Headline	Indicator to show changes in resilience over time	Indicator type	Existing data sources	Components needing further development	National indicator?	Source
					Flood Re Build Back Better scheme data			
Recover	D5	Flood insurance availability	Availability of flood insurance – proportion (%) of householders with prior flood claims who can receive quotes from 5 or more insurers.	Output	Flood Re data	See D4 for further future development of this measure	No	Flooding

Table 4.2: 'Further development required' indicators

Resilience component	ID	Headline	Indicator to show changes in resilience over time	Indicator type	Further development needed	National indicator?	Source
Place making	A3	Adaptation plans	Proportion (%) of 'at risk' areas with flooding and/or coastal erosion adaptation plans adopted by public bodies.	Outcome	Consistent understanding of what is meant by 'adaptation plans' and data collection still needed	Yes	All
Place making	A4	Building standards	Proportion (%) of local design guides and/or codes which specify building standards for flood and/or coastal erosion resilience.	Output	No current data available	No	All
Place making	A5	SuDS (new development)	Proportion (%) of SuDS in new development that are designed and implemented meeting government or industry technical standards.	Output	Standardised data from LLFAs or LPAs currently not available. Reporting framework needed.	Yes	Flooding
Place making	A6	Rural land use schemes	Proportion (%) of rural land area covered by rural land use schemes or new farming techniques which reduce flood impact.	Output	Definition, measurement and data collection for schemes. Data from future ELMs schemes may help with this measure.	No	Flooding
Place making	A7	Infrastructure service continuity	Proportion (%) of 'at risk' essential infrastructure which do not maintain minimum levels of service during a flood/coastal erosion event.	Outcome	No agreed definition for minimum levels of service. No current way of collecting data and reporting information from utility and infrastructure providers.	No	All
Better protect	B1	Annual economic damages and damages avoided	Total economic damages and damages avoided (£) from flooding/coastal erosion annually.	Outcome	Proactive data collection and quality control needed. No agreed way of assessing actual economic damages.	No	All
Better protect	B4	Nature-based solutions	Proportion (%) of flood or coastal defence schemes that include nature-based solutions (NBS) that offer quantitative	Outcome	Consistently quantifying the benefits of nature-based solutions that slow the flow, store flood	Yes	All

Resilience component	ID	Headline	Indicator to show changes in resilience over time	Indicator type	Further development needed	National indicator?	Source
			evidence it is providing flood/coastal erosion benefits.		waters or offer erosion benefits is not currently possible.		
Better protect	B6	SuDS (retrofit)	Proportion (%) of land use for which sustainable drainage systems (SuDS) were retrofitted in the past year meeting government or industry standards.	Output	There is limited data on SuDs retrofit. A standardised data collection and reporting framework is needed.	Yes	Flooding
Better protect	B10	PFR installation and maintenance	Proportion (%) of property flood resilience (PFR) measures installed which are installed and maintained in alignment with current industry standards.	Output	There is limited data on PFR installation and maintenance. Data on the effectiveness of PFR in improving resilience is also lacking.	Yes	Flooding
Respond	C3	Flood warnings (trust)	Proportion (%) of properties which trust and act on (when appropriate) flood warnings received.	Outcome	Data collection – potential to use post-event surveys or Environment Agency Public Flood Survey	No	Flooding
Respond	C4	Flood emergency plans (non-mandatory)	Proportion (%) of 'at risk' areas covered by non-mandatory emergency plans which include a response to flooding.	Output	Data collection and collation from multiple sources would be needed including from LRFs and LLFAs	Yes	Flooding
Respond	C5	Flood emergency plans (mandatory)	Proportion (%) of 'at risk' community where effective and exercised multi-agency flood emergency plans are in place.	Output	Data collection – potential to use Section 19 reporting. Need to define and get consensus on what is meant by ‘effective’ plans.	No	Flooding
Respond	C6	Coastal erosion awareness	Proportion (%) of people in areas at risk of coastal erosion who are aware of the erosion risks and potential impacts.	Outcome	Data collection – potential to use readiness assessments	Yes	Erosion
Respond	C8	Community participation in incident response	Proportion (%) of 'at risk' areas where community members participate in incident response activities.	Outcome	Data collection – potential to use Environment Agency Public Flood Survey	No	All
Respond	C9	Engagement in schools	Proportion of schools within areas at risk of flooding and coastal erosion with curriculums that include teaching on local impacts and resilience.	Output	Further research; data collection with Department for Education support	No	All
Respond	C10	Community participation in FCERM decision-making	Are there ways for the community to participate in FCERM decision-making?	Output	Data collection – potential to use Environment Agency Public Flood Survey. Difficult to define, quantify and measure community participation.	No	All

Resilience component	ID	Headline	Indicator to show changes in resilience over time	Indicator type	Further development needed	National indicator?	Source
Respond	C11	Future planning (communities)	Proportion (%) of people within 'at risk' areas who know where they will live and work if or when their current home or workplace becomes uninhabitable due to flooding or erosion.	Output	Data collection – potential to use Environment Agency Public Flood Survey	No	All
Recover	D1	Community confidence in future resilience actions	Community confidence in future actions for increasing resilience to flooding and coastal erosion,	Outcome	Data collection – potential to use Environment Agency Public Flood Survey. Need to define and get consensus on what community 'confidence' means.	Yes	All
Recover	D2	Rate of recovery	Average time taken to recover following a flooding or coastal erosion event.	Outcome	Method for measurement needs development; data collection on different aspects of recovery needed.	No	All
Recover	D4	Flood insurance take-up	Proportion (%) of properties in 'at risk' areas without home, business and contents flood insurance coverage.	Outcome	Data collection and accessibility gaps. The insurance sector would need to agree to provide the data transparently.	Yes	Flooding

‘Ready now’ indicators

Placemaking indicators

A1[2]: Land use at risk

Existing land use at risk of flooding (all sources) or coastal erosion – now (current year) and with climate change.

Type: National indicator; Outcome indicator

Components

- A1.1: Proportion (%) of existing land use at risk of flooding (all sources) or coastal erosion – now (current year).
- A1.2: Proportion (%) of existing land use at risk of flooding (all sources) or coastal erosion with climate change. (Potential to be ready within 5 years).

Justification

Tracking land use at risk of flooding or coastal erosion is crucial in understanding whether resilience actions are reducing risk from all sources, and whether this is keeping pace with climate change. This uses National Planning Policy Framework (NPPF) flood risk vulnerability categories. The less vulnerable category includes the majority of non-residential property types, which is important for community and economic impacts (it also includes rural land uses).

Development

Emerged from focus groups as ‘proportion of existing development (split by homes, schools, hospitals and so on) at risk (now and with climate change)'. Indicators within this theme also appeared in the evidence review, for example, ‘total number of properties at risk from flooding’ was identified in the National Infrastructure Commission (NIC) Performance Measures research (NIC, 2017).

Weaknesses

- Lack of definition on climate scenarios, timescales and sources of flooding.
- The term ‘development’ had connotations with ‘new development’, so ‘land use’ is used.

[2] Indicator ID numbers are from the full set of indicators and do not appear in order. They are split into sections for ‘ready now’ and ‘further development required’.

- Groundwater cannot be measured due to lack of data.

Data

Data from the Environment Agency (for example, National Flood Risk Assessment (NaFRA) and National Coastal Erosion Risk Map (NCERM)) is available for reporting on risk from all sources (A1.1). Measurement of land use at risk with climate change (A1.2) will require additional data – likely from NaFRA2 in 2024. Coastal protection survey updates and NCERM 2 (expected to be published in 2023) are also likely to improve data availability for erosion risk.

Tracking and evolution

Tracking land use at risk shows the scale of flooding and coastal erosion impacts now and in the future. A reducing trend in land use at highest risk would indicate increasing resilience. Analysis by land use category shows how resilience is improving with current planning policy. However, risk reduction is only one aspect of FCERM resilience and it is important to consider that places at risk can still be resilient (for example, by implementing respond and recover resilience actions).

A2: New development against FCERM advice

Proportion (%) of new development for which planning applications were granted against Environment Agency and lead local flood authority (LLFA) flooding and/or coastal erosion advice.

Type: National indicator; Outcome indicator

Justification

Tracks whether new development is resilient to flooding and coastal erosion. Measuring the proportion of new developments (built in the last year) granted against advice from statutory planning consultees on flooding or coastal erosion is important for tracking the effectiveness of national spatial planning policy in achieving resilience.

Development

Proposed by focus groups as ‘number of planning applications being granted against flooding/erosion risk advice or declined due to flooding/erosion risk advice’. The Environment Agency records information on outcomes of its planning advice (on flood risk matters where we are a statutory planning consultee). Expanding the indicator to include advice from other statutory planning consultees would help measure progress towards ensuring growth and development is resilient to the future climate.

Weaknesses

- Consistent data is not available for planning advice from other statutory planning consultees – it is likely to exist but will require collation.

- Information on LLFA advice is hampered by the fact there is no formal statutory planning consultee for assessing new development in areas at risk of surface water flooding.

Data

Data is ready now for planning applications granted against Environment Agency advice.

Tracking and evolution

The indicator is important in measuring policy effectiveness in achieving outcomes (for example, a negative trend would indicate planning policies are supporting increased resilience). New development should be broken down into the National Planning Policy Framework's (NPPF) flood risk vulnerability categories to allow the number of homes with planning applications granted against advice to continue to be tracked, but also provide scope to expand this indicator to cover other types of development in the future. The actual number of applications granted against advice in each NPPF category should also be reported to create an aggregated figure for meaningful comparison.

Better protect indicators

B2: Annual average damages (modelled damages)

Annual average residual damage (£) of properties (non-residential and residential) and essential infrastructure from flooding.

Type: National indicator; Outcome indicator

Justification

Measuring changes in anticipated residual annual damages will indicate changes in resilience by showing whether flood defences are providing protection from flood damages. It is a product of both flood likelihood and flood impact (damage), capturing the full range of scenarios, from low impact, frequent flooding through to the impacts of extremely rare catastrophic flooding.

This indicator is based on modelled damages to allow annual data collection which means **comparisons** over time are possible. This can already be measured nationally, unlike actual post event damages (B1).

Development

Originated from the evidence review as 'residual (defended) annual direct property damage (£)'. Residual annual damage was identified for use as an indicator from literature sources, including Environment Agency research, to quantify the benefits of flood risk management actions and advice (Environment Agency, 2015). Residual refers to properties which are currently protected by flood defences.

Weaknesses

- Clarity needed on which sources of flooding/erosion this indicator would cover.
- Annual frequency may not be long enough to reflect changes in resilience.
- Does not apply to coastal erosion as coastal erosion is not repeated and is a one-off loss (calculations for residual damages are not applicable).
- Currently only conventional, engineered protection assets (flood walls and embankments) are included in the calculations. With more data this could be expanded to cover other types of interventions that reduce the probability of flooding.

Data

- Data collected separately to show annual damages for non-residential, residential and essential infrastructure from all sources of flooding.
- Data is ready now for fluvial and tidal flood risk. Other sources of flood risk (surface water, groundwater, reservoirs) and climate impacts are not ready.

Tracking and evolution

As progress is made in increasing resilience across the other 3 components of place-making, responding and recovering, this indicator may need to further evolve or be removed to focus on influencing change beyond conventional, engineered FCERM defences. This could be driven by the Environment Agency's ongoing work to calculate risk reduction.

B3: Asset condition

Proportion (%) of flood and coastal assets managed and maintained within and above a specific condition level.

Type: National indicator; Outcome indicator

Components

- B3.1: Proportion (%) of Environment Agency and third-party flood assets managed and maintained within and above a specific condition level.
- B3.2: Proportion (%) of Environment Agency and third-party coastal assets managed and maintained within and above a specific condition level.
- B3.3 Proportion (%) of flood and coastal assets (all owners for all risk sources) managed and maintained within and above a specific condition level. (Potential to be ready in 5 years).

Justification

This indicator provides a better understanding of whether physical assets are being regularly monitored and maintained to provide the intended levels of protection. The specific condition level target would be the one which is set by government through the FCERM capital investment programme.

Development

Originated from focus groups as ‘service/condition level of existing assets and change over time with climate change/asset deterioration’. Also identified during the evidence review (for example, asset restoration was included as an element of the Climate and Disaster Risk Reduction Prioritisation Framework developed by the Australian Government - Australian Government, Department of Home Affairs, 2019).

The final indicator focuses on the management (maintenance, refurbishment, adaptation) regime of assets, as the standard of protection is expected to change with climate change.

Weaknesses

- Applies to conventional, engineered protection only. Does not include beaches, property flood resilience (PFR), nature-based solutions (NBS) or sustainable drainage systems (SuDS) assets.
- Condition level doesn’t always translate to performance, especially for low-risk assets.

Data

- Data available for Environment Agency assets and some third-party assets (B3.1 and B3.2).
- Data not available for other FCERM assets (B3.3 for all owners and all sources) due to inconsistent reporting and multiple data sets.
- Environment Agency FCERM capital investment programme annual measures could be used in the short term: the measures developed for the 2021/27 Programme, including the headline ‘Reporting Outcomes for Properties and Environmental Outcomes’, will be used to feed into the Defra scorecard. These include Environment Agency and third-party assets at target condition.

Tracking and evolution

Tracking an increase in this indicator would suggest asset management and maintenance actions are supporting a positive change in resilience through protection (and therefore a reduction in risk) over time. This indicator could be developed to enable measurement of system level condition, which is aspirational in the long term.

The indicator could be further developed to report on the resilience of the asset system as a whole, rather than individual assets. There is potential for component B3.3 to be ready in 5 years, but this requires specific knowledge of flood sources and which asset owners this relates to.

B5: Nature-based solutions

Number of schemes with NFM/NBS in FCERM programme.

Type: Output indicator

Justification

This could be used as a partial indicator of resilience, as details on NFM schemes provided through the FCERM capital investment programme currently exist.

Development

The original indicator for NFM/NBS emerging from the focus groups and evidence review was ‘number of NFM measures’.

Weaknesses

This doesn’t measure effectiveness. There is currently no quantifiable and nationally agreed way of measuring the benefits of NFM measures.

Data

Data exists from the FCERM capital investment programme.

Tracking and evolution

See B4 for a more outcome-based way of measuring the effectiveness of different nature based solutions.

B7: Land use better protected

Proportion (%) of land use better protected by flood/coastal defences.

Type: National indicator; Outcome indicator

Components

- B7.1: Proportion (%) of land use better protected by permanent engineered defences.
- B7.2: Proportion (%) of land use better protected by temporary defences (including demountables). (Further development required).
- B7.3 Proportion (%) of land use better protected by property flood resilience (PFR) measures.
- B7.4: Proportion (%) of land use better protected by blue-green infrastructure (including NBS, SuDS). (Further development required).

Justification

This indicator measures whether land use benefiting from conventional, engineered defences is increasing over time. An increase indicates better protection from flood and coastal erosion risk, therefore increasing resilience. It measures the outcome of resilience actions within the protect component, including implementation of permanent and temporary engineered defences, NBS and PFR. Two subcomponents of this indicator are ready now, although they would need further data analysis and assessment for consistency, completeness and quality before they could be used.

Development

This indicator originated from the focus groups and previously related to land use which benefits through any FCERM measure. The indicator only accounts for physical protection measures at this stage, as other FCERM actions are covered as far as possible by other indicators and are often difficult to quantify in terms of land use protected.

Similar indicators were identified in the evidence review, such as 'number of households better protected from flooding' in the 25 YEP (Defra, 2018). This indicator moves beyond properties protected to all land use types. Land use refers to existing development and should be broken down into NPPF flood risk vulnerability categories.

Weaknesses

Double counting may occur within the overarching indicator, as land use may benefit from multiple types of protection measure. Further development is required to establish how the 4 component indicators can be presented as one overarching number and to design a method for effective and meaningful measurement.

Data

- Data from government agencies (see Table 4.1) is available for B7.1 (permanent defences) and B7.3 (PFR).
- Further development of data reporting mechanisms required to enable consistent data collection for B7.2, B7.3 and B7.4.
- Up-to-date registers for PFR, NBS and SuDS are required.

Tracking and evolution

Tracking an increase will suggest actions are improving resilience. Tracking component indicators will demonstrate the progress of different types of protection measures. This indicator could also be checked against socio-demographic indicators to report on land use better protected in socially deprived areas.

B8: Properties better protected

Proportion (%) of properties at risk better protected through flood/coastal defences.

Type: National indicator; Outcome indicator

Justification

This indicator measures the proportion of properties better protected by flood or coastal defences, with an increase indicating an improvement in resilience. Properties better protected is measured as properties move to a lower flood likelihood category. It is an important measure for the FCERM capital investment programme, with the 2021 to 2027 programme being evaluated against progress to better protect over 300,000 properties. FCERM outcome measures 2 and 3 are also about reducing flood/coastal erosion risk to properties.

Development

Identified through the evidence review as ‘number of households better protected from flooding’. Indicator was expanded to all land uses, not just properties. This evolved into indicator B7 – land use better protected.

Weaknesses

- Currently only measures properties.
- Data only for impacts of conventional engineered defences. No information available for temporary defences, NBS and SuDS.

Data

Obtained from FCERM capital investment programme performance measures, specifically data related to outcome measures 2 and 3.

Tracking and evolution

Moving from number of properties (measured for each FCERM capital investment programme) to proportion of properties at risk better protected provides a better indication of the direction of travel.

B9: National risk reduction

Percentage (%) reduction in national flood and coastal erosion risk (modelled).

Type: National indicator; Outcome indicator

Justification

This indicator captures the outcome of a range of resilience actions, including building new defences, maintaining and operating existing defences, flood incident management, and preventing inappropriate development. It has been identified by the National Audit Office (NAO) as an important long-term measure of resilience to flooding and coastal change.

Development

Derived from the focus groups as ‘number of properties at risk of flooding (residential and commercial)’, this was excluded from the original shortlist as it is already measured through current reporting practices. The Environment Agency has added this indicator based on its prominence in measuring the success of the FCERM capital investment programme.

Weaknesses

There is a need to develop methods for measuring and monitoring changes in risk from wider FCERM resilience actions (for example spatial planning).

Data

The indicator already exists – data is available from the Environment Agency.

Tracking and evolution

The Environment Agency has developed a method of measuring this indicator which will input into measures for the 2021 to 2027 FCERM capital investment programme (in response to the NAO recommendation). The assessment of percentage change in risk will be improved by NaFRA2. The method could be extended in future to measure changes in risk from a wider range of resilience actions beyond FCERM capital investment programme schemes.

B11: PFR proactive installation

Number of properties with PFR installed as part of Environment Agency FCERM capital investment programme.

Type: Output indicator

Justification

PFR maintenance is considered a more useful indicator than PFR installation alone. Installation numbers could be used as an interim measure.

Weaknesses

Provides a partial view, not accounting for PFR funded through other routes.

Data

Data is available from the Environment Agency FCERM capital investment programme.

Tracking and evolution

See B10 for a more outcome-based way of measuring PFR installation and maintenance.

Respond indicators

C1: Flood warnings (availability)

Proportion (%) of 'at risk' properties where flood warnings are available and residents are automatically signed up.

Type: National indicator; Output indicator

Justification

Tracking an increase in the proportion of 'at risk' properties where flood warnings are available will reflect an increase in community resilience in terms of enabling their capacity to respond. Tracking this indicator would also allow areas which are at risk but where

warnings are not available to be identified. The ambition is that this would help expand warnings in these areas.

Development

The indicator was originally proposed as ‘availability of, take-up, and trust in warnings and take-up post event’ with the following components:

- availability of flood warnings – output of resilience actions
- take-up of flood warnings – output of resilience actions
- acting on flood warnings – outcome of resilience actions
- trust in flood warnings – outcome of resilience actions

The indicator originated from the focus groups, but was also identified in the evidence review (Becker and others, 2015; Environment Agency 2015; Townend and others, 2021) and from the research finding that ‘receiving a timely, informative and credible flood warning aids response to flooding and recovery’ (Environment Agency 2009).

Stakeholders suggested that there were too many indicators and variation in components (output and outcome) to measure it effectively. They proposed splitting the indicator into 3 separate indicators, as they express different elements of resilience. As a result, the 3 levels of engagement with flood warnings were developed as 3 indicators - availability (C1), proactive sign up (C2), and trust and action (C3).

Weaknesses

The limitation with the indicator is that action is not always taken after receiving a warning. A number of factors affect the response to the flood warning, including the provision of locally relevant, consistent and repeated information, together with the characteristics of the recipient and social context (Blazey and McCarthy 2020).

Data

Data for this indicator should be available via the Environment Agency for collection now.

Tracking and evolution

The indicator could evolve in the future to cover flood warnings for other sources of flooding. Warnings for properties at risk from multiple sources should also be considered. This will rely on appropriate data becoming available and may include secondary LLFA data sets, data from local warning systems for groundwater and surface water, other RMA data sources and/or Met Office rainfall data.

C2: Flood warnings (sign-up)

Proportion (%) of 'at risk' residents proactively signed up to flood warnings (excluding opt-out).

Type: National indicator; Output indicator

Justification

Understanding the level of engagement individuals/households may have with flood warnings. The more engaged individuals are with flood warnings, the more resilient they are in their response to an event.

Development

This indicator excluded ‘opt-out warnings’ to ensure only those individuals/households that proactively signed up are included within the measurement. Although the Environment Agency has run an opt-out service for some time, with individuals in at-risk areas automatically registered, there is still an option to proactively register for flood warnings, which gives individuals a choice of how to receive the warnings. The assumption is that individuals that sign up proactively are more likely to prepare for and respond to flood warnings than those who may not be aware they are signed up.

Weaknesses

May exclude those who are automatically registered and use flood warnings to become more resilient.

Data

Data on those proactively signed up to flood warnings is available now through the Environment Agency.

Tracking and evolution

Tracking an increase in the proportion of 'at risk' residents proactively signed up to flood warnings will reflect an increase in community resilience in terms of their capacity to respond. As with C1, the indicator could be expanded to cover other/multiple flood sources when data becomes available in the future.

C7: Community awareness of flood response plans

Proportion (%) of people in areas at risk of flooding who have taken the time to understand how they would respond as a community to flooding in their neighbourhood.

Type: Outcome indicator

Justification

This tracks the proportion of people who understand how they would respond to flooding, reflecting their levels of flood preparedness. Greater community awareness of flood response plans equates to greater resilience.

Development

Focus groups identified this as a '**must have**' indicator. It was proposed as 'number of flood/coastal action groups in place and meet regularly'. The project team acknowledged that increased participation in these groups is a measure (3.2.4) in the National FCERM Strategy, but the number of meetings could vary based on numerous contextual factors such as level of risk, capacity, capability and population make-up. Therefore, the number of meetings does not necessarily positively correlate with improved resilience.

The indicator was reworded to read 'the proportion of community engaged in flood action groups', but there is no clear line of sight between engagement and quality of response. Stakeholders suggested further reworking to '[we have] taken the time to understand how we would respond as a community to flooding in my neighbourhood', which is currently measured by the Environment Agency Public Flood Survey and may provide a better indication of both formal and informal conversations.

Coastal erosion references are covered in indicator C7.

Weaknesses

The Environment Agency Public Flood Survey has a relatively small sample size and has only recently included the question related to this indicator. Further data collection would be needed.

Data

Some data exists through the Environment Agency Public Flood Survey.

Tracking and evolution

Exploring the links between the proportion of people who understand how they would respond, their level of engagement and how that translates to action is aspirational and could be carried out over the next 5 years.

Recover indicators

D3: Additional property flood resilience (PFR) post-event

Proportion (%) of properties recovered with additional physical PFR resilience measures post event.

Type: Output indicator

Justification

The FCERM Strategy encourages property owners to 'build back better' after a flood and to mainstream property flood resilience measures that reduce flood damages and enable faster recovery (Environment Agency 2020). This will help communities and businesses at risk to adapt and prepare for any future floods and to return to normality quickly as the

flood water recedes. Implementing these measures can also help in the future with accessing more affordable flood insurance. Additional PFR measures being installed post event would demonstrate an increase in resilience. This indicator would measure the proportion of properties (both residential and non-residential) that are recovered, with additional effective PFR measures put in place.

Development

Identified by focus groups as a 'must have' indicator; originally proposed as 'number of homes and businesses recovered with additional resilience measures, for example, raised electrics, installed PFR'. The indicator was refined to provide a comparable measure (proportion of properties) and to make clear that this refers to additional physical PFR measures (preventing flood water from entering a property or allowing water entry in a managed way) installed following an event.

Weaknesses

The current indicator is an output measure and does not give a measure of the effectiveness of the PFR measures installed, only their presence. Further development is needed to establish how data collection would occur post event, but it will likely require primary data collection through surveys which could be included under Section 19 reporting.

Data

There is data on Defra PFR recovery grant claims, which would give a partial indication of additional PFR installation after large flood events. Flood Re has also introduced its Build Back Better scheme[3] and will collect some data on insurance claims for PFR through the scheme, but this will only cover a limited portion of the market. The EA, Flood Re, Defra, and others are currently involved in a pilot project in East Peckham, which is trialling a PFR Compliance Platform to track different types of PFR installed in different properties. This indicator can therefore be measured now, acknowledging that there are data gaps for privately funded PFR installation post event.

Tracking and evolution

Further clarity is required on how additional PFR is improving recoverability. This requires research, such as the pilot program currently underway in East Peckham. There may be potential for existing data to be collated via PFR installation records within LLFAs or through commercial companies performing PFR maintenance visits (subject to their willingness to share). The Flood Compliance Platform currently being trialled is intended to provide a mechanism for ongoing tracking.

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[3] Further information on the Build Back Better scheme is available on the Flood Re website.

D5: Flood insurance availability

Proportion (%) of householders with prior flood claims who can receive quotes from 5 or more insurers.

Type: Output indicator

Justification

A suggested interim measure which focuses on the availability of flood insurance. This could also potentially be used alongside the insurance take-up indicator in the future.

Development

Flood insurance take-up is the recommended indicator relating to insurance, but data is not yet available for this. Access to flood insurance is an important in influencing uptake (as well as affordability and acceptance), so data from this indicator could be used alongside indicator D4.

Weaknesses

This only measures the eligibility of householders to receive insurance quotes that include flood insurance, not actual take-up of insurance (completed policies).

Data

Flood Re currently[4] collects data on the proportion (%) of householders with prior flood claims who can receive quotes from 5, 10 or 15 insurers. This provides a dataset from 2016 until the present, although a methodology change in 2022[5] will create a 'blip' in the results that will need to be acknowledged.

Tracking and evolution

See D4 for a more outcome-based way of measuring the benefits of flood insurance take-up.

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[4] There is no guarantee that this data will be collected and available in the future.

[5] The removal of low- and medium-flood risk properties from the sample, in order to be able to more effectively monitor availability for homes with higher risks (and therefore creating a slight upward jump in average numbers owing to a higher average risk profile).

‘Further development required’ indicators

Placemaking indicators

A3: Adaptation plans

Proportion (%) of 'at risk' areas with flooding and/or coastal erosion adaptation plans adopted by public bodies.

Type: Outcome indicator

Components

- A3.1: Proportion (%) of 'at risk' areas with flood or coastal adaptation plans adopted by public bodies.
- A3.2: Proportion (%) of 'at risk' areas with flood/coastal adaptation policies and plans in place that support long-term adaptation of communities.
- A3.3: Proportion (%) of 'at risk' areas with flooding and/or coastal erosion where recommendations in adopted adaptation plans are embedded in local planning policy.

Justification

Adaptation planning strengthens resilience by enabling communities to proactively prepare for and manage flooding and coastal erosion risk. Examples include shoreline management plans and adaptation pathway plans developed for particular areas such as Thames Estuary TE2100 and Humber Strategy 2100+. Tracking a positive trend in adoption will suggest increasing resilience.

Development

Originated from focus groups as ‘policies in place that support long-term adaptation of communities, economies and environments with buy-in from multiple stakeholders and communities’. Indicators within this theme were also identified in the evidence review, for example, ‘number of people covered by good enough adaptation/resilience policy which results in improved implementation practice as a result of support’ was suggested as a potential indicator for measuring changes in resilience in UK Department for International Development (DFID) research to support the UK’s International Climate Fund (Brooks and others, 2014).

The indicator is split into the following components based on maturity. Component indicator A3.1 is proposed as a starting point due to data collection challenges and will measure the outputs of resilience actions. Broadening this indicator to measure the quality and effectiveness of adaptation plans (A3.2) will move this indicator from output to outcome. Component indicator A3.3 recognises adaptation plans need to be embedded in local policy to provide a statutory driver for implementation (for example local plans, supplementary planning documents and coastal change management areas).

Weaknesses

- No clear consensus on what is meant by adaptation plans – as they exist in many forms.
- The indicator also assumes that specific adaptation policies are identified within plans.
- Lack of local government buy-in and resources may be barriers to collection.

Data

- Collation of data from local government and a number of other sources will be required.
- Requires a consistent approach to reporting (for example, further definition of qualifying plans and policies to enable consistent data collection).

Tracking and evolution

The ambition is to monitor whether these plans effectively support the long-term adaptation of communities (A3.2) and whether they are embedded in local planning policy (A3.3). It is also an aspiration to measure the implementation of adaptation itself (actual change following planning) in the future, but this will require additional in-depth research. This indicator could be used to track the outcome of long-term planning for inland and coastal community transitions as a resilience action.

A4: Building standards

Proportion (%) of local design guides and/or codes which specify building standards for flood and/or coastal erosion resilience.

Type: Output indicator

Justification

Building standards guide developers and designers on resilient construction of new buildings in flood or coastal risk areas. The NPPF allows local planning authorities to develop local design codes or guides to encourage better design and set out design principles for new development in local areas (a new concept introduced in 2021). A positive trend in the proportion of codes and guides that specify building standards for flooding and coastal erosion will indicate increased resilience to flooding and coastal change. This measures the direct output of policy drivers and has emphasis on capturing good practice.

Development

Originated from the advisory group that identified ‘building standards for flooding and coastal resilience’ as a gap in the initial set of indicators. The project team then generated the initial indicator ‘specification of building standards within neighbourhood plans’.

Weaknesses

- Additional guidance will be required to define the qualifying standards.
- Following design guidance for developments at high risk may not necessarily lead to increased resilience. This is especially true for erosion where achieving resilience through building design can be difficult and expensive.
- Does not measure implementation of building standards.

Data

Data from local government would be required to enable monitoring over time. A mechanism for data capture would also need to be developed.

Tracking and evolution

This indicator is a starting point which aims to drive uptake of more resilient design and construction approaches. The aspiration is to expand the indicator to measure implementation of building standards (local construction).

A5: Sustainable drainage systems (new development)

Proportion (%) of SuDS in new development that are designed and implemented meeting government or industry technical standards.

Type: National indicator; Outcome indicator

Justification

Sustainable drainage systems (SuDS) manage and reduce surface water flood risk. Implementing SuDS can control run-off volumes and flow rates, reducing the impact of urbanisation on flooding. SuDS may exist in different forms and can also contribute to wider benefits such as water quality improvements and providing green spaces. This indicator focuses on SuDS in new developments, designed and implemented to meet current standards (at the time of writing this refers to non-statutory technical standards). A greater proportion of SuDS indicates good management of surface water flood risk and increased resilience. SuDS include nature-based solutions, so this indicator is linked to B4 and B5.

Development

Originated from focus groups as ‘implementation and effectiveness of SuDS’. Indicators focused on implementation of SuDS were also identified within the evidence review, for example, ‘uptake of sustainable drainage systems’ within the 25 Year Environment Plan (Defra, 2018). Use case, stakeholder and advisory group comments highlighted that a distinction between SuDS in new development and SuDS in existing development (retrofit SuDS – B6) should be made to enable more consistent measurement.

Weaknesses

- Compliance checks against SuDS standards are not carried out by LLFAs and LPAs unless concerns are raised.
- LPAs and LLFAs may collect data on proposed SuDS for new developments, but applications are typically assessed remotely.
- Resource deficiencies and lack of a consistent reporting framework are barriers to data collection.

Data

A standardised approach to reporting on SuDS would need to be established to allow consistent data collection, along with further discussions on processes, roles and responsibilities.

Tracking and evolution

Scope to include a measure of multi-benefits (for example, biodiversity, water quality, amenity value, mental wellbeing). This could be achieved by focusing on above-ground SuDS, which often include wider benefits alongside flood risk benefits.

New national standards for SuDS could be created if Schedule 3 of the Flood and Water Management Act is enacted, which would help with the development of this indicator.

A6: Rural land use schemes

Proportion (%) of rural land area covered by rural land use schemes or new farming techniques which reduce flood impact.

Type: Outcome indicator

Justification

Rural land use schemes can reduce flood impact and improve resilience. This indicator aims to measure both flood-resilient rural land (including the coast) and the uptake of rural land schemes which reduce flood risk for the downstream catchment. Where there is a larger proportion of rural land that contributes to reducing flood risks, resilience increases.

Development

Focus groups identified resilient rural land use and catchment sensitive farming as important aspects of catchment resilience. This was tested by the North Norfolk use case and considered within the coastal context to measure the available space earmarked for relocation or identified within a roll back zone. Testing supported the ‘resilient rural land use/catchment sensitive farming (CSF)’ category. The category was transformed into an indicator by aligning with criteria in the new Environmental Land Management Schemes (ELMS). This particularly relates to the Local Nature Recovery scheme component, which will fund NBS. The final wording of the indicator was refined from the ‘number of rural land use schemes…’ to ‘proportion (%) of rural land area covered by rural land use schemes…’

to provide a better measure and contextual understanding of rural resilience and contributions to downstream communities. The indicator also links to measurement of NBS (B4, B5 and B7.4).

Weaknesses

It is difficult to identify and define the resilience actions that would be considered within this indicator since there are a wide range involved in CSF. Potential data sources identified from the survey were very limited.

Data

Requires additional data to be collected from Natural England, Forestry Commission, Rural Payments Agency and Countryside Stewardship scheme. New data from the Local Nature Recovery scheme, which is replacing the Countryside Stewardship scheme, could be used to measure this indicator. Until this indicator is further refined, these suggested data sources could provide a baseline or 'starting point' for this indicator.

Tracking and evolution

The farming techniques or schemes (resilience activities) are not currently defined. However, the resilience activities need to definitively show a contribution to reducing flood risk. Further work is required to understand the impacts of future farming techniques on flood resilience. Further research is required to define 'rural land use schemes' or what activities that would include (taking into account CSF) which reduce flood impact, and what the change may be (for example, reducing flood risk to downstream communities or making rural land flood resilient). This indicator could be linked to ELMS in the future to measure the proportion of rural land use at risk of flooding which has schemes in place to reduce flood impact at site and catchment level.

A7: Infrastructure service continuity

Proportion (%) of 'at risk' essential infrastructure that does not maintain minimum levels of service during a flood/coastal erosion event.

Type: Outcome indicator

Justification

Reducing knock-on effects from utility, transport or telecommunications disruption will improve resilience to flooding and coastal erosion. Measuring whether essential infrastructure providers can maintain minimum levels of service during a flood or coastal event will demonstrate whether they are adequately protected or have adequate plans in place to prevent disruption.

Development

Derived by the project team based on findings from the evidence review, originally worded as 'infrastructure investment to improve resilience standards guaranteeing levels of

service (for example, for transport, water, power)' (Environment Agency, 2020). Similar indicators were also suggested at the focus groups, for example, 'ability of key infrastructure to maintain operations through a flood event'. The final indicator was amended to focus on service continuity.

Weaknesses

Further development is required to identify a baseline 'minimum level of service' for infrastructure providers where not already specified.

Data

Requires data from infrastructure providers in the water, utility and transport sectors. Further investigation is required to understand if this information is readily available and how accessible it is.

Tracking and evolution

This indicator measures the outcome of resilience actions which aim to reduce the impacts of flooding and erosion events on essential services. A decreasing trend indicates increasing resilience and that more infrastructure providers can guarantee levels of service during flooding/erosion events. In the future, this indicator could be developed for use in conjunction with economic damages (B1) and used to identify knock-on effects of infrastructure disruption outside of risk zones (for example, power outages).

Better protect indicators

B1: Annual economic damages and damages avoided

Total economic damages and damages avoided (£) from flooding/coastal erosion annually.

Type: Outcome indicator

Components

- B1.1: Total (£) economic damages and damages avoided from flooding annually.
- B1.2: Total (£) economic damages and damages avoided from coastal erosion annually.

Justification

Tracking the actual damages and damages avoided from flooding and coastal erosion will be important for identifying trends in resilience over time. Although some damages are still expected to happen, a decreasing proportion compared to damages avoided will point to increasing resilience. While fluctuations may occur year by year, overall trend will indicate whether protection measures are keeping pace with the increasing frequency and magnitude of events likely to be experienced with climate change. This is different from

indicator B2, based on modelled damages, which is easier to measure and already has established data and methods.

Development

Originated from focus groups as ‘proportion of ‘at risk’ properties that flooded or were affected by coastal erosion in the last year’. Indicators within this theme also featured in the evidence review, for example, ‘proportion of ‘at risk’ properties that flooded in the last year’ is an indicator in the NIC Performance Measures research (NIC, 2017). The indicator was expanded to include direct and indirect impacts to ‘proportion (%) of all development directly and indirectly affected (damaged, relocated) by flooding/coastal erosion annually’. The final wording of this indicator focuses on economic damages and damages avoided, with the intention of being able to better measure flooding/erosion impacts.

Weaknesses

To enable annual measurement, proactive data collection mechanisms would need to be developed, which is likely to be extremely resource intensive.

This indicator would be very difficult to quantify and validate nationally.

Data

For flooding (B1.1), data has been collected before (2013/14 and 2015/16 floods). LLFA Section 19 reports (post flood event) could be used to collect this data. For coastal erosion (B1.2), this data is not currently collected. Further assessment is required to identify data sources and collection methods.

Tracking and evolution

Reporting would involve calculating economic damages for different impact categories (properties, transport, utilities) and would include direct and indirect damages (for example, from power outages) and damages avoided. This figure should also account for homes lost to coastal erosion.

B4: Nature-based solutions

Evidence that flood or coastal defence schemes that include nature-based solutions are providing flood/coastal erosion benefits.

Type: National indicator; Outcome indicator

Components

- B5.1: Proportion (%) of flood or coastal defence schemes that include NBS that offer quantitative evidence it is slowing the flow.
- B5.2: Proportion (%) of flood or coastal defence schemes that include NBS that offer quantitative evidence it is storing water.
- B5.3: Proportion (%) of flood or coastal defence schemes that include NBS that offer quantitative evidence it is slowing erosion.

Justification

This indicator measures the uptake of NBS schemes which effectively contribute to resilience by providing flood/coastal erosion benefits and risk reduction (for example, slowing the flow of water, storing water, slowing erosion). It focuses on flood and coastal erosion benefits only. A positive trend in the proportion of schemes with NBS that demonstrate quantitative evidence of flooding/erosion benefits would indicate increasing resilience.

Development

The indicator ‘uptake of NFM practices’ was proposed in the research to review and update indicators of climate-related risk and actions in England for the Committee on Climate Change (Ffoulkes and others, 2021). This was recognised as a basic output indicator with no measure of effectiveness. The project team adapted this indicator to ‘volume of water stored or slowed by NFM measures’. NFM is often constructed in conjunction with more engineered defences and it can be difficult to disentangle benefits. The final indicator relates to nature-based solutions (NBS) rather than NFM as this can be applied to reduce both flood and coastal erosion risk.

The ambition was to measure ultimate outcomes or benefits to receptors. This could be partly achieved by indicator A6, looking at rural land use schemes which reduce flood impact (many of these are likely to include NBS). However, this is currently unrealistic given the lack of quantitative evidence for the effectiveness of NBS and its relationship with FCERM resilience. Subcomponents B5.1, B5.2 and B5.3 have been developed as a compromise, which will track schemes with NBS that show some ‘quantitative evidence of flood/coastal erosion benefits’. For B5.3, ‘slowing erosion’ was chosen rather than ‘preventing erosion’, as erosion defences only adjust the timing of erosion rather than permanently preventing it.

Weaknesses

There is currently no reliable method or data for quantifying tangible reductions in flood risk from NBS, which is a major barrier to developing this indicator. Measure 1.4.2 in the FCERM Strategy Roadmap, on mainstreaming NBS, is aiming to address this barrier.

Data

- Additional data from government agencies and/or local authorities required.
- Consistent national and local mapping of NBS required (not currently carried out).
- Development of a central database of NBS schemes with flood or erosion risk benefits needed.

Tracking and evolution

Further development is required to establish how the 3 component indicators can be presented as one overarching number and to design a method for effective and meaningful measurement. Quantifying the impact of NBS with certainty and apportioning

the quantitative flood and erosion risk benefits and risk reduction to the NBS elements of hybrid schemes are future challenges for data collection. It is aspirational to move towards a stronger outcome focus for NBS, which could be covered by indicators B7.4 and A6.

B6: Sustainable drainage systems (retrofit)

Proportion (%) of land use for which sustainable drainage systems (SuDS) were implemented (retrofitted) in the past year, meeting government or industry standards.

Type: National indicator; Outcome indicator

Justification

Sustainable drainage systems (SuDS) manage and reduce surface water flood risk. Implementing SuDS can control run-off volumes and flow rates, reducing the impact of urbanisation on flooding. SuDS may exist in different forms and can also contribute to wider benefits such as water quality improvements and providing green spaces. This indicator focuses on SuDS retrofit. Retrofitting SuDS is a significant challenge, with limited existing policy drivers. A greater proportion of SuDS indicates good management of surface water flood risk and increased resilience. SuDS include nature based solutions, so this indicator is linked to B4 and B5.

Development

Originated from focus groups as ‘implementation and effectiveness of SuDS’. Indicators focused on implementing SuDS were also identified within the evidence review, for example, ‘uptake of sustainable drainage systems’ within the 25 YEP. ‘Proportion of land use for which SuDS were implemented’ is used instead of simply the ‘number of SuDS retrofitted’, since a single SuDS scheme may be very large and benefit multiple properties. Land use refers to existing development within the NPPF flood risk vulnerability categories.

Weaknesses

The majority of retrofit SuDS are not captured within planning applications and there is no legal requirement to collect this data. Compliance against industry standards would require verification through on-site inspections which are not currently enforced or resourced.

Data

A standardised approach to reporting on SuDS would need to be established to allow consistent data collection, along with further discussions on processes, roles and responsibilities.

Tracking and evolution

There is scope to include a measure of multi-benefits (for example, biodiversity, water quality, amenity value, mental wellbeing). This could be achieved by focusing on above-ground SuDS which often include wider benefits alongside flood risk benefits.

New national standards for SuDS could be created if Schedule 3 of the Flood and Water Management Act is enacted, which would help with the development of this indicator.

B10: PFR installation and maintenance

Proportion (%) of property flood resilience (PFR) measures installed which are installed and maintained in alignment with current industry standards.

Type: National indicator; Output indicator

Justification

PFR can reduce the vulnerability of people and property to physical and mental impacts of flooding. PFR may be ineffective without appropriate specifications, standards and maintenance. This indicator tracks the proportion of PFR measures installed which are maintained to industry standard. An increase in the proportion of PFR maintained to industry standards would point to increasing resilience.

Development

Originated from focus groups as 'number of commercial and residential properties at high risk of flooding with PFR'. Discussion with use case leads suggested that this was a basic output indicator and should be expanded to include a measurement of PFR effectiveness.

Maintenance of PFR is an area where significant improvements could be made to enhance resilience, especially in areas such as Salford where grants were provided for installation but not maintenance. Many PFR products require regular maintenance to ensure they work correctly and offer the protection for which they are designed. Specific standards could be included in the guidance accompanying the indicator across all areas of PFR (including risk assessments, surveyors, installers, and building materials/products). It would also be possible to use the sector endorsed Code of Practice[6] in the absence of standards.

Weaknesses

As maintenance responsibilities are usually handed over to property owners, the requirements and methods for data collection will be extremely challenging (privacy

[6] The Code of Practice and associated guidance were produced by CIRIA.

issues, unwillingness to share data, lack of reporting framework). Compliance checks by local authorities would require large inputs of time, effort and resources, and access restrictions for privately owned PFR would limit data collection.

Data

Requires data on the total number of PFR installed and proportion maintained to industry standards. Measure 2.4.1 in the FCERM Strategy Roadmap is aiming to address data gaps for PFR.

Tracking and evolution

Further development is required to understand appropriate standards, certification schemes and skills needed in the property resilience industry to provide reassurance that work has been done correctly and to agreed standards. It is aspirational to develop an indicator on PFR effectiveness. This could build on pilot work being carried out by the Environment Agency, Flood Re and others (see indicator D3). This is establishing a scoring methodology to measure the effectiveness of different types of PFR and trialling a PFR Compliance Platform to track PFR installation.

Respond indicators

C3: Flood warnings (trust)

Proportion (%) of properties that trust and act on (when appropriate) flood warnings received.

Type: Outcome indicator

Justification

The more engaged individuals are with flood warnings, the more resilient they will be in their response to an event. This indicator measures the level of appropriate action taken by individuals when they receive a warning.

Development

Indicator C3 originated from the focus groups worded as ‘availability of, take-up and trust in warnings and take-up post event’. A number of factors affect the response to the flood warning, including the provision of locally relevant, consistent and repeated information, together with the characteristics of the recipient and social context (Blazey and McCarthy 2020). It assumes a clear link between levels of trust in warnings provided and the effectiveness of action taken. However, this is yet to be determined. Other links will also need exploring further, such as reasons for not taking action after receiving a flood warning. Further development and research are required to define ‘appropriate levels of action’.

Weaknesses

Data is not currently available and primary data collection would be required, probably through post-event surveys.

Data

Once the evidence links are established and questions framed appropriately, this could potentially be measured via the Environment Agency Public Flood Survey (which already asks questions related to trust in flood warnings).

If data is collected through post-event surveys, questions should be framed appropriately due to the sensitive nature of this information.

Tracking and evolution

The indicator could be expanded to cover other/multiple flood sources when data becomes available in the future.

C4: Flood emergency plans (non-mandatory)

Proportion (%) of 'at risk' areas covered by non-mandatory emergency plans which include a response to flooding

Type: National indicator; Output indicator

Justification

Tracking the preparation of flood emergency plans will demonstrate levels of preparedness which leads to reduced risk to life, damage and financial loss and increased public safety. This reflects increasing individual, community and/or property and infrastructure resilience to a flood event. Proactively producing non-mandatory emergency plans, particularly if they are written by communities, could be considered an indication of resilience. This indicator covers emergency plans which include a response to flooding for communities, local businesses, infrastructure providers and public amenities.

Development

Identified as an output indicator in the evidence review by Becker and others (2015) as ‘existence of local tested community emergency plan’. The project team reworded it to ‘effective and exercised community flood/coastal change emergency plans in place’. Stakeholders acknowledged the difficulties of measuring and testing plan effectiveness (for example, there are a number of flood/emergency plan templates in existence and therefore differences in opinion on what makes them 'effective'). The indicator was split into: flood emergency plans (non-mandatory) (C4) and flood emergency plans (mandatory) (C5), to reflect differences in effectiveness and impact.

Weaknesses

Because the plans are non-mandatory, there is no mechanism or push to report on them. Lead local flood authority (LLFA) data, Environment Agency flood resilience data and local resilience forum (LRF) data sets exist, but the challenges of gaining a nationally consistent picture for all components of the indicator are significant.

Data

Primary data collection/collation of data will be required. This, in turn, may require a regulatory responsibility to report on this data where not already mandated.

Tracking and evolution

A measure of how effective the plans are and how this translates to flood response would be aspirational for the future. Further development is required to establish how to measure different types of non-mandatory plans (for communities, business, infrastructure and public amenities).

C5: Flood emergency plans (mandatory)

Proportion (%) of 'at risk' community where effective and exercised multi-agency flood emergency plans are in place.

Type: Output indicator

Justification

Applies to mandatory flood emergency plans and understanding their efficacy, focusing on capacity to respond and responsibilities under the Civil Contingencies Act. This indicator could identify if there is a minimum standard quality of a flood emergency plan and how its quality or effectiveness increase resilience in responding to flood events. This also captures capacity to successfully deploy temporary defences and emergency flood equipment. Tracking the preparation of mandatory flood emergency plans will demonstrate levels of preparedness, which leads to reduced risk to life, damage and financial loss and increased public safety, reflecting increased resilience.

Development

Identified as an output indicator in the evidence review: ‘emergency response plans’ (Cutter and others, 2008). The project team reworded it to ‘effective and exercised community flood/coastal change emergency plans in place’. As mentioned for indicator C4, there was significant discussion by the project team and stakeholders on the mandatory nature of flood emergency plans as they reflect different levels of resilience. Effectiveness and ability to exercise the plan was considered important, as the presence of a plan may not necessarily improve resilience, for example, if the plan is not operationalised through lack of resources.

Weaknesses

Contingent on defining ‘effective’ levels of service.

Data

LRF data exists. Progress could be tracked through the planned multi-agency flood plan health checks.

Tracking and evolution

Measuring effectiveness and whether plans are exercised will be important to give some indication of quality and a line of sight to resilience, moving this indicator from output to outcome. This is perceived to be achievable in the future for mandatory flood emergency plans through the Section 19 reporting process.

C6: Coastal erosion awareness

Proportion (%) of people in areas at risk of coastal erosion who are aware of the erosion risks and potential impacts.

Type: National indicator; Outcome indicator

Justification

Explores how awareness and understanding of coastal erosion and its impact is changing in 'at risk' communities. Awareness does not always lead to action, but raising awareness and improving understanding of risks is an important first step towards resilience in many coastal communities.

Development

Originated from the focus groups as a ‘must have’ indicator and was originally proposed as ‘improved community awareness and understanding of the flood/coastal change risks they face, potential impacts and proposed plans’. It is also recognised in the flood and natural disaster research (Zurich Flood Resilience Alliance, 2019; Cutter and others, 2008) with indicators such as ‘future flood risk awareness’, ‘governance awareness’ and ‘local understanding of risk’. These alluded to the importance of understanding a community’s awareness that risk may change in the future and their responsibility in preventing, responding and rebuilding. The use case for North Norfolk highlights that since erosion leads to a permanent loss of land, resilience requires a proactive approach that plans, prepares for and understands these changes before they occur.

Weaknesses

Lack of existing data. Measurement of this indicator would require primary data collection via surveys.

Data

Could be measured using ‘readiness assessments’ such as those being carried out as part of the project ‘Working together to adapt to a changing climate: flood and coast’[7], commissioned by the FCERM Joint Research Programme. This is a method to consider the readiness of authorities, communities and other partners to work together on climate adaptation in the context of flooding and coastal erosion. However, this could be challenging to roll out nationally.

Tracking and evolution

Tracking the proportion of people aware of coastal erosion risks and potential impacts will indicate the level of uncertainty/certainty around past, current and future risks; for example, where people are uncertain about how and when erosion will occur and whether there are plans in place to help them prepare. This will ensure mechanisms are implemented/enhanced for managing long-term change, which is crucial for increasing the resilience of coastal communities.

C8: Community participation in incident response

Proportion (%) of 'at risk' areas where community members participate in incident response activities.

Type: Outcome indicator

Justification

This indicator measures the level of community volunteer participation in incident response activities, which reflects community capacity to respond to a flood event. Tracking an increase in the proportion of at-risk areas where community members are engaged in incident response will reflect an increase in community resilience through assumed improved preparedness and capacity to respond. There is potential for this indicator be ready in 5 years.

Development

The indicator originated from the focus groups as a ‘must have’ indicator and was originally proposed as ‘number of flood wardens’. It was also recognised in the evidence review as a measure of resilience through an increase in flood preparedness and the capacity to respond (Twigger Ross and others, 2015). The original indicator was intended to demonstrate the development of relationships between RMAs and local volunteers and therefore their ability to understand the issues and tackle them collectively with the

[7] Final outputs from the project, including the readiness assessment, are due to be published on gov.uk in November 2022.

community. However, the indicator was identified as ‘poor’ during the use case testing based on comments around the definition and role of flood wardens.

The indicator was subsequently changed to ‘proportion (%) of 'at risk' areas where community members participate in incident response activities’. This acknowledges spatially where community members are involved in flood incident response, rather than numbers of volunteers which does not provide clear line of sight to resilience change. Using the term ‘community members’ encompasses multiple types of community volunteers.

Weaknesses

Many wardens and champions are informal, with no consistent resource currently available for identifying and quantifying them. Data quality would be hard to ensure and comparability challenging.

Data

There is potential for this indicator to be measured through the Environment Agency Public Flood Survey. Information could also potentially be obtained from the voluntary sector, who may be involved in response and recovery work with volunteers.

Tracking and evolution

Future development could focus on developing a measure of how effective community engagement is and how that translates to flood response. This could be trialled through the Flood and Coastal Resilience Innovation Programme.

C9: Engagement in schools

Proportion of schools within areas at risk of flooding and coastal erosion with curriculums that include teaching on local impacts and resilience.

Type: Output indicator

Justification

The FCERM Strategy commits to encouraging opportunities for ongoing learning and career development in engineering and environmental sciences. Measuring engagement with children is an opportunity to build up knowledge and understanding of local flooding and coastal erosion impacts to inform local response and recovery actions.

Development

The indicator originated from the focus groups as ‘local schools’ learning packages for learning and hands on experience’ and was reworded to ‘proportion of children engaged through flooding and coastal resilience in school curriculum’. Use case leads identified the importance of engaging young people and children as they often experience the worst mental health impacts. The project team suggested that early engagement with children/young people could influence their willingness to engage in future life amid a

changing climate and may also impact their family's/local community response. However, stakeholders acknowledged the difficulties of measuring whether children are engaged, as well as the fact that the number of children per school varies considerably. They suggested that the number or proportion of schools would be a better measure as levels of personal engagement (especially in children) will be difficult to measure.

Weaknesses

This is a first step indicator for measuring engagement with children in at-risk areas to understand if awareness/engagement in children is improving, but it is not possible to measure the quality of engagement at this stage.

Data

Could be collected through surveys with children and education providers in at-risk areas. Support from the Department for Education may be needed to collect data in schools.

Tracking and evolution

Collecting information for this indicator will require research to identify how engaging with children can improve community resilience over time.

C10: Community participation in FCERM decision-making

Are there ways for the community to participate in FCERM decision-making?

Type: Output indicator

Justification

More collaborative decision-making with communities would encourage an increase in risk awareness, build trust, strengthen community relationships and create buy-in and accountability, leading to an increase in community resilience. This indicator has potential to be ready in 5 years.

Development

Originated in the focus groups as a 'must have' indicator and was originally proposed as 'community embedded in decision-making processes, including understanding of risk and impact fed into modelling and plans'. Use cases suggested measuring community engagement in decision-making would be incredibly difficult. Building the necessary community relationships to develop a communication network capable of collaborating effectively in decision-making can take a long time and factors like level of risk and demographics only add to the complexity. Even strong community links may be restricted to a small group of people and are highly personal. Simply measuring the proportion of the population embedded within decision-making is a poor representation of the resilience benefits afforded in many areas.

The following alternatives were derived, recognising that 'embedded' and 'mechanisms' would need defining:

- community embedded in FCERM decision-making
- mechanisms for embedding community in FCERM decision-making
- proportion (%) of schemes in FCERM capital investment programme targeted at flooding/coastal change actions in the past year which have involved communities in decision-making

The quality of engagement is essential to the line of sight to resilience. However, this indicator would initially assume that all engagement is valuable (for example, a simple yes/no answer providing an output indicator) and eventually look at the extent to which communities are involved in co-production processes and mechanisms (outcome). This indicator could make a significant and positive difference in enabling future collaborative decision-making.

Weaknesses

There is no accepted best approach or trajectory for engaging the community, so defining, quantifying and measuring this process is extremely difficult. This will need significant further development and research.

Data

No existing data mechanism – could potentially make use of the Environment Agency Public Flood Survey.

Tracking and evolution

This indicator could be expanded to understand what mechanisms for community involvement are successful and the level of community participation in making these decisions could be measured. At the local level, this could look at whether developing local flood risk management strategies or plans involves community engagement. An understanding of what more or less-resilient looks like (in terms of community embeddedness) and criteria for measurement need to be developed. Future research is needed to map out where decision-making takes place (schemes, strategies, incident planning and RFCCs). This would determine whether communities are involved in these processes.

C11: Future planning (communities)

Proportion (%) of people within 'at-risk' areas who know where they will live and work if or when their current home or workplace becomes uninhabitable due to flooding or erosion.

Type: Output indicator

Components

- C12.1: Proportion (%) of people within 'at risk' areas who know where they will live if or when their current home becomes uninhabitable due to flooding or erosion.

- C12.2: Proportion (%) of people within 'at risk' areas who know where they will work if or when their current workplace becomes uninhabitable due to flooding or erosion.

Justification

Tracking an increase in the proportion of people who know where they will live and work if their home, workplace or community becomes uninhabitable following a flood or erosion event will reflect an increase in community resilience in terms of their capacity to respond. This indicator has potential to be ready in 5 years.

Development

This indicator originated from the focus groups worded as ‘people know where they will live and work if or when their current home or workplace or community becomes unsustainable’. It was also identified in the evidence review in relation to business and household continuity strategies: whether businesses in the community have contingency plans in place to recover their operations and assets and whether households in the community have a plan for maintaining or recovering their income/livelihoods (Zurich Flood Resilience Alliance, 2019). Therefore, this indicator would be measured as a proxy for community preparedness planning.

To provide a measurement and define ‘unsustainable’ in terms of the timing of response (temporary accommodation while a property is refurbished versus long-term response planning when a property is uninhabitable), the project team refined the indicator as the ‘proportion (%) of people within 'at-risk' areas who know where they will live and work if or when their current home or workplace or community becomes uninhabitable due to flooding or erosion’. Time taken to recover (including temporary accommodation) is included in D2 rate of recovery. The project team also refined the indicator to be more specific regarding inclusion of ‘flooding’ and ‘erosion’.

Weaknesses

Collecting data via surveys may not give a true representation where communities are particularly transient, or residents and business owners move frequently.

Data

Data collection would be in the form of primary survey data. This could potentially take place through questions in the Environment Agency Public Flood Survey, for example, asking people in at-risk areas 'do you know where you would live if your current home becomes uninhabitable due to flooding or erosion?'

Tracking and evolution

Further research is required to establish the links between planning and response to provide a clearer picture of changing trends in resilience and move the indicator from output to outcome. Development is also required to establish if/how the component

indicators can be presented as one overarching number and to design a method for effective and meaningful measurement.

Recover indicators

D1: Community confidence in future resilience actions

Community confidence in future actions for increasing resilience to flooding and coastal erosion.

Type: National indicator; Outcome indicator

Justification

Flooding can have profound effects on people's mental health and wellbeing that may continue over extended periods of time (Stanke and others, 2012). The stress and strain associated with dealing with cleaning up and recovery may also be a problem (Lock and others, 2012). This may influence individual or community confidence to act during a future flooding or coastal erosion event. An increase in confidence would result in reduced anxiety, improved preparedness and therefore a better ability to cope. This will influence capacity to respond and recover, leading to an increase in resilience.

Development

Initially worded as 'tracking mental health impacts caused by flooding and coastal change'. However, there are a number of problems with measuring this, in particular data sensitivity and confidentiality and consequently its availability from health authorities.

It was decided that the indicator would be better represented by tracking 'community confidence in future actions for increasing resilience to flooding and coastal erosion' which will provide an understanding of a community's (scaled up from an individual level) perception of their resilience to recover from future events. This level of confidence can be affected by a multitude of factors such as an understanding of measures being taken to mitigate against flooding and coastal erosion impacts and mental health factors.

Weaknesses

- Data collection would need to be considered and sensitive owing to the personal and subjective nature of the concept, although this is somewhat mitigated by not asking directly about mental health.
- Defining and agreeing what is meant by 'community confidence' at a national level will be very difficult.
- It will be a challenge to gain consistency between communities/spatial areas.

Data

Data does not currently exist. Primary data collection through surveys is potentially the most appropriate method (for example, the Environment Agency Public Flood Survey).

This will require sensitivity regarding framing of the questions, timing (relating to events and experiences) and frequency of surveying.

Tracking and evolution

This is an outcome indicator which relies on our definition of confidence, our understanding of how levels of confidence change and how this affects resilience. Further research is required to refine this indicator, potentially drawing on outcomes from ongoing projects such as the 'Living with Water partnership' across Hull and East Riding.

D2: Rate of recovery

Average time taken to recover following a flooding or coastal erosion event.

Type: Outcome indicator

Components

- D2.1: Average time taken to return to refurbish property following a flooding or coastal erosion event.
- D2.2: Average time taken to relocate to suitable permanent accommodation following a flooding or coastal erosion event.
- D2.3 Average time taken for essential infrastructure to return to full capacity following a flooding or coastal erosion.

Justification

Resilience is defined in part by the time it takes to recover, so the average time taken to recover after a flood/coastal erosion event should be measured. Faster recovery time for properties and essential infrastructure, directly affected by an event, indicates greater resilience.

Development

This indicator originated from the focus groups as a 'must have' indicator worded as 'time taken to recover - get back into property/infrastructure working'. It was also identified in the evidence review, particularly in relation to critical infrastructure and essential service continuity. There is a lack of understanding of how improving the rate of recovery from flood and coastal events can enhance social and economic resilience and how this could be measured on various geographic scales.

The stakeholders identified the need to refine the wording of this indicator to refer to 'fully 'refurbished properties' or 'suitable permanent accommodation' to account for the fact that:

- people may have to return to properties which are not fully recovered (for example, returning to wet properties as they cannot afford to stay elsewhere or do not have insurance)
- following erosion events, time taken to permanently relocate should be measured

There may be scope to expand this indicator to monitor the number of people returning to properties which are more resilient than previously. This presents an opportunity to

understand whether communities are learning from flood events and whether resilience is improved.

Weaknesses

Measurement and comparability of this indicator is complex due to contextual issues. For example, areas experience events of different magnitudes or at different times and this is intrinsic to recovery time. It may also be difficult to track for people relocated due to coastal erosion once they've moved.

Data

The indicator will be dependent on post-event data collection for each of the 3 components and is likely to be difficult to scale due to local factors.

Tracking and evolution

Further development is required to establish if or how the 3 component outcome indicators can be presented as one overarching number and to design a method for effective and meaningful measurement.

D4: Flood insurance take-up

Proportion (%) of properties in at-risk areas without home, business and contents flood insurance coverage.

Type: National indicator; Outcome indicator

Components

- D4.1: Proportion (%) of properties in at-risk areas without home flood insurance coverage.
- D4.2: Proportion (%) of properties in at-risk areas without business flood insurance coverage.
- D4.3: Proportion (%) of properties in at-risk areas without contents flood insurance coverage.

Justification

Flood insurance coverage provides an understanding of the ability of households and businesses to recover economically following a flood event. In the UK, flood insurance is an important part of the portfolio of flood risk management measures, although it can encourage people to continue to occupy risky areas (Penning-Rowsell, 2015). A lack of cover indicates lesser resilience.

Development

The indicator originated from the focus groups as a 'must have' worded as 'home, business and contents insurance uptake'. It was also identified as an outcome indicator in the evidence review: 'flood insurance coverage' (Twigger Ross and others, 2015; Cutter

and others, 2014). There are multiple reasons for variable insurance uptake such as availability, affordability or acceptance. The indicator would be significantly influenced by access to insurance, which is covered by indicator D5.

Stakeholders advised rewording to ‘the proportion of properties in at-risk areas without home, business and contents flood insurance coverage’. This would allow both those who are unable to access insurance (for example, where flood risk is too high) and those who are unable to afford insurance to be included. It would also provide an understanding of insurance uptake coverage and therefore where properties can potentially recover because they have insurance.

Separate indicators for home and contents insurance are recommended to differentiate between those renting (and potentially not having enough contents cover) and landlords who do not have buildings insurance. Properties would be categorised according to the NPPF flood vulnerability classifications. Coastal change was not included in this indicator as there is currently no provision of insurance cover for erosion risk in the UK.

Weaknesses

The indicator would not collect data on those who are 'underinsured' or give information on those with insurance who still may not be able to recover effectively. The indicator does not account for alternatives to business insurance which may be used to finance recovery.

Data

There are several problems with data collection, including:

- insurance data – a big barrier is that insurers are unlikely to provide this, so the indicator would rely on survey data. During flood recovery many people are understandably unwilling to cooperate, so there is likely to be a large degree of inconsistency
- insurance literacy[8] – this would need to be considered as it could affect the accuracy of the data received. People may be under-insured or covered for flooding without realising it. Home insurance includes flood cover as standard (unless a bespoke exclusion is explicitly agreed) so many homeowners answer they do not have ‘flood insurance’ because they haven’t purchased it separately. Only having homeowners examine their policies produces reliable results, and this is too time consuming for most surveys.
- rental status – differentiation for rental properties many be required as responsibilities differ between landlord and tenant. Tenants are often unaware of what their landlord has covered and what they should be covering

[8] How well people understand their type and level of insurance coverage

Some local-level data might be accessible from ongoing projects or from local authorities or LLFAs. Flood Re may hold data on areas that struggle to get (affordable) flood insurance.

Tracking and evolution

Further understanding on how the data would be collected is required, particularly owing to the barriers presented by commercial data provision.

5. Research gaps

Several topics have been identified that are very important for resilience, but it was not possible to develop indicators due to a lack of evidence. These areas have great potential to influence resilience. These topics should be further explored to fill knowledge gaps and understanding. The identified topics recommended for future research are:

- Surface water, groundwater, reservoir and sewer flooding – There is limited data, knowledge and research available for these sources of flooding and consequently it would be a challenge to measure some of the indicators (for example, flood warnings).
- Multiple sources of flooding – Research is needed to identify how many of the indicators could apply in areas at risk from multiple sources of flooding. Exploration of the interdependencies between different sources of flooding could better evidence how resilience indicators could be best applied.
- Coastal defences – Defences such as beaches do not fit neatly into the asset categories used in this research (for example, conventional, engineered defences and nature-based solutions (NBS)). Research should identify how these types of coastal defences could be considered alongside traditional structural defences and understand if some indicators (for example, asset condition) could be expanded to cover these types of assets.
- Mental health – This was an area discussed at length as the mental health impacts of flooding and erosion have a big part to play in resilience. More exploratory work is required to evidence the relationship with resilience before a meaningful indicator can be implemented. There are also difficulties in collecting mental health data (for example, data sensitivity and sharing restrictions). As such, the indicator D1 (community confidence in future resilience actions) has been recommended as a proxy for how well protected people feel. Further research is needed to understand how this can be collected objectively and consistently nationally, regionally and locally.
- Recover indicators – This research recommends only 5 recover indicators. Many of the indicators suggested in this component were removed during the shortlisting process due to a lack of an evidenced link to resilience or because of strong dependencies on post-event data collection and reporting. Further research is needed to enable proactive annual data collection.
- Indicator types – A detailed investigation into indicator types (for example, proxy, composite, process indicators) was out of the scope, but further research into indicator types could inform the future development.
- Line of sight to resilience – Many indicators recommended by this research require further research to provide stronger evidence of their line of sight to resilience (for example, A2 New development in line with FCERM advice; A3 Adaptation plans; B3 Asset condition). Building up a greater knowledge base in these topic areas would allow the relationship between output and outcome indicators and resilience impacts to be defined with greater certainty.

This is not an exhaustive list of the research gaps identified by this work but gives an indication of the main areas for further development.

6. Conclusions

The FCERM Strategy's long-term vision is of a nation ready for, and resilient to, flooding and coastal change – today, tomorrow and to the year 2100. With increased risk of flooding and coastal erosion in the future as a result of climate change, this research aimed to identify indicators that could monitor progress against the strategy vision for boosting resilience, and indicators of resilience in the 25 Year Environment Plan (YEP). Furthermore, it aimed to develop potential indicators representative of the broader range of flood and coastal resilience actions beyond conventional flood and coastal erosion defences, moving towards resilience. These indicators are intended to be a catalyst for wider engagement than has previously been the case for the traditional FCERM actors of the Environment Agency and RMAs, involving wider actors locally, regionally, and nationally, and across government organisations.

This research built on national policies, plans, strategies, guidance and research that identified indicators used to assess FCERM progress, which focused on resilience. The conceptual framework developed based on the Theory of Change defined a coherent conceptual foundation in which the indicators were developed to achieve a clear line of sight and attribution between objectives, activities, outputs, outcomes and impact. It allowed resilience to become multi-dimensional, linking the indicators to improving the 5 capitals – social, economic, physical, natural and institutional. It was clear from the inception of this research that the scale of application for developing and operationalising resilience indicators, particularly in relation to data, would be essential in successfully implementing those indicators. It was important to understand that the indicators developed would need to be tailored to varying scales from individual or household level to national resilience based on the choice of resilience action. Additionally, scale is essential to understanding the capability and capacity to respond to a flood or coastal erosion event. Consequently, social vulnerability of individuals and communities at risk of flooding and coastal erosion needs to be measured alongside resilience actions. This research recommends socio-demographic indicators from recent research (Environment Agency, 2022).

The co-design process of developing the indicators integrated the evidence review and engagement across focus groups, use cases, project advisory group and project board meetings. The use cases were particularly relevant for contextualising the indicators within real-world context, considering different sources of flooding and coastal erosion risk, geographical and socio-economic characteristics.

From this research, 34 potential indicators of resilience have been developed. The project has identified 14 indicators which are 'ready now' and can be measured by data or information that is already available. In some cases, data or information for 'ready now' indicators is expected to improve in the coming years. It has also identified 20 indicators that need 'further development' before they can be used. The variability in stages of readiness is due to factors such as data sources and available collection mechanisms, maturity of the subject area, and lack of consensus about which dimensions of the indicator should be measured. In particular, significant work is needed to better

understand how many of the respond and recover indicators could apply to the coastal erosion context.

18 indicators were identified as national indicators that could provide a national picture of resilience balanced across the components of resilience. These could help to develop a baseline of resilience, driving change, and having impact across the 5 capitals. They would also support the 3 ambitions of the national FCERM strategy. The headline national indicators include:

- land use at risk
- adaptation plans
- annual average damages
- asset condition
- nature-based solutions
- SuDS (retrofit)
- SuDS (new development)
- properties at risk
- national risk reduction
- PFR installation and maintenance
- flood warnings (availability)
- flood warnings (sign-up)
- flood emergency plans (non-mandatory)
- coastal erosion awareness
- community confidence in future resilience actions
- flood insurance take-up

The narrative provided alongside each of the indicators describes the complex nature of the area of resilience the indicator is distilling and the decisions made when developing the indicator from across the co-design process. This narrative should be considered when further refining the indicators in the next steps. The next steps in developing the potential indicators would require further research and engagement to further refine the indicators for use in operational practice, including:

- data collection, sources and owners for each of the indicators
- temporal variability or scale of data collection
- analysis required of data sources
- collation and data mechanisms to be determined
- overlap across existing measures within the FCERM capital investment programme, or others
- direct link to the national FCERM Strategy or the 25 Year Environment Plan
- further testing and refinement of indicators within local and national contexts

The proposed next steps and main recommendations are further identified in the following section.

7. Next steps

The research findings could become the foundation for further developing, embedding and operationalising indicators. It would be beneficial for the co-design process to continue with those already engaged and with others that resilience indicators may impact or influence, particularly those who already collect relevant data.

Testing will be essential to further develop, refine and operationalise the indicators. The use cases provided essential testing within real-world contexts and allowed potential indicators to be applied, taking account of local factors. This exercise highlighted which indicators would be challenging to implement and which could potentially be effective at showing changes in resilience over time. The Flood and Coastal Resilience Innovation Programme (FCRIP) could provide an opportunity to test resilience indicators. The 6-year FCERM capital investment programme could also be used to trial and further refine the indicators, data and processes in place for the next capital investment programme.

Developing approaches for collecting data for the “ready now” indicators would enable an understanding of the nation’s baseline resilience. These approaches would need to be considered carefully within the various roles and responsibilities of the current RMAs and others, and the resources provided to build support to track changes of resilience. If possible, the data sources and collection for each of the indicators should be captured and reported with minimal modifications to internal processes and systems and resources. If there is a significant change required, it should be identified as early as possible. Furthermore, guidance for the approach to collecting and analysing the data for each of the indicators will need to be developed to support organisations in better tracking and achieving resilience.

The Environment Agency is planning to use the research findings to further test and refine the proposed indicators, through a new project. This is likely to be split into design, implementation and evaluation stages:

1. **Design**

- Establishing a reporting and evaluation framework
- Reviewing the national resilience indicators from the research
- Establishing data collection mechanisms to baseline data for each indicator
- Identifying priority areas for indicator development

2. **Implementation**

- Annual measurement of resilience indicators
- Further development of resilience indicators – filling in the evidence gaps
- Piloting and testing through the FCRIP – using the projects on the programme to select and trial certain indicators
- Sourcing opportunities to trial resilience indicators in other contexts

3. **Evaluation**

- Making recommendations for further enhancements and/or changes to the national indicator set and proposals for monitoring and evaluation
- Recommendations for measurement within the next FCERM capital investment programme to support investment in a broader range of resilience actions
- Recommendations for further research and development, including regional and local pilots, and/or cross-sector initiatives and international collaboration

As indicators are operationalised and evidence gaps are filled, a better evidence base of the costs and benefits (including the 5 capitals) of resilience actions can be developed. This evidence base will provide the foundation for science-based policy that justifies and increases the use of a broader range of resilience actions to build a nation resilient to flooding and coastal change.

Glossary

- Action – an intervention which is intended to increase resilience.
- Adapt - taking action to prepare for and adjust to both the current effects of climate change and the predicted impacts in the future, while responding to local place-based needs and ambitions.
- Better protect - reducing the risk of flooding and coastal erosion to enhance the safety of communities and places.
- Capacity – ability or capability.
- Development – new development within the following National Planning Policy Framework (NPPF) flood risk vulnerability categories: essential infrastructure, highly vulnerable development, more vulnerable development, less vulnerable development.
- Economic resilience capacity – the ability of local economies to be able to adapt to, respond to and recover from flooding and coastal erosion. Also concerns the availability of sufficient funding to support adaptation.
- Impact - long-term effects produced as a result of the activity.
- Indicator – evidence of change from the current state/operating environment.
- Institutional resilience capacity – the ability of risk management authorities (RMAs) and other public sector organisations to be able to adapt to, respond to and recover from flooding and coastal erosion.
- Land use – existing development within the following National Planning Policy Framework (NPPF) flood risk vulnerability categories: essential infrastructure, highly vulnerable development, more vulnerable development, less vulnerable development.
- Operating environment – underlying context in terms of current resilience capacities and past and potential future flooding and coastal erosion impacts.
- Operationalise – to take forward a theoretical approach into operational (day to day) practice.
- Outcome – immediate change that occurs as a result of the activity.
- Output – quantitative measure of an activity.
- Natural resilience capacity – the ability of the natural environment to adapt, respond to and recover from flooding and coastal erosion.
- Placemaking – making the best land use and development choices for managing flooding and coastal erosion.
- Physical resilience capacity – the ability of physical assets to adapt, respond to and recover from flooding and coastal erosion.
- Resilience - the capacity of people and places to plan for, better protect, respond to and recover from flooding and coastal erosion, all the time adapting to climate change.
- Recover – the ability of places and people to rebound from flooding and coastal erosion with minimal impacts to property, the natural environment, and health and wellbeing.

- Respond – the ability of places and people to prepare for and react to flooding and coastal erosion in a way that results in minimal impacts to property, the natural environment and health and wellbeing.
- Social capacity - the ability of people to adapt, respond to and recover from flooding and coastal erosion.
- Transition - the process of incremental and/or transformational change, including ‘ways of working’ (practices and behaviours) and/or physical infrastructure.

List of abbreviations

25 YEP	25 Year Environment Plan
ADEPT	Association of Directors of Environment, Economy, Planning & Transport
ANDRI	Australian Natural Disaster Index
BRIC	Baseline Resilience Indicators for Communities
CPA	Coast protection authority
Defra	Department for Environment, Food and Rural Affairs
DFID	Department for International Development
EAD	Estimated annual damages
FCERM	Flood and coastal erosion risk management
FCRIP	Flood and Coastal Resilience Innovation Programme
FRMT	Flood Resilience Measurement Tool
GiA	Grant in aid
ICF	International Climate Fund
IDB	Internal drainage board
LA	Local authority
LLFA	Lead local flood authority
NaFRA	National flood risk assessment
NBS	Nature-based solutions
NCERM	National Coastal Erosion Risk Map
NFM	Natural flood management
NPPF	National Policy Planning Framework
PFR	Property flood resilience
RMA	Risk management authority
SuDS	Sustainable drainage systems
TE2100	Thames Estuary 2100 Plan

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Appendix 1: Use cases

1.1 North Norfolk use case investigation

The purpose of the use case investigations within this research was to consider the measurement of resilience in several real-world contexts that are characterised by different sources of flood and coastal change risk, geographical and socio-economic characteristics. This section relates to the North Norfolk use case and focuses on testing resilience indicators within the coastal erosion context in an area where long-term protection is not feasible and coastal residents need to live with coastal change.

Background and context

The North Norfolk use case focused on the area of coastline between Cromer and Hemsby, which is characterised by soft glacial cliffs and sandy beaches, and has one of the fastest eroding coasts in Europe.

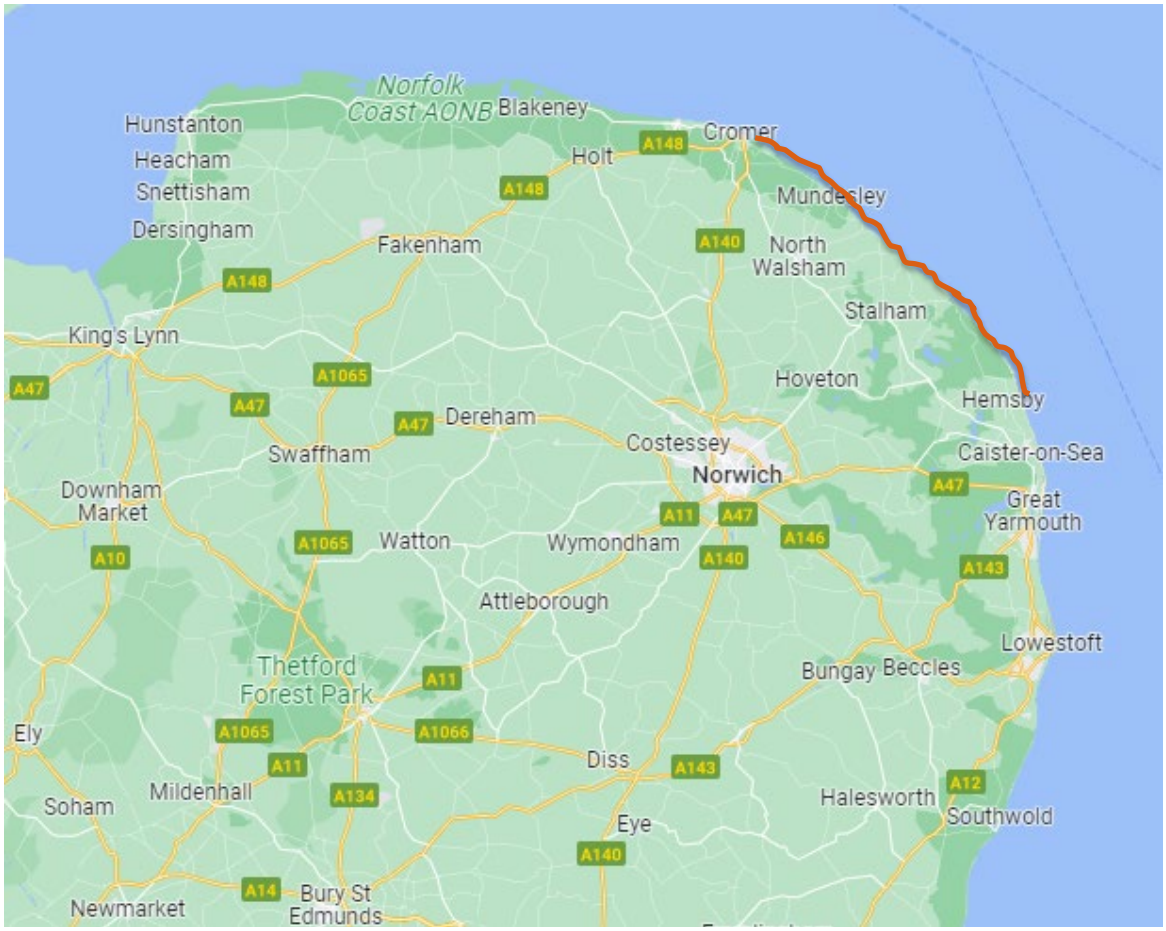

Figure 1. Map showing use case area

North Norfolk is predominantly rural with alternating coastal settlements and farmland. Over the last 50 years, most settlements were protected to slow or stop erosion, but looking to the future, most of these defences will not be renewed and learning to live with

coastal change is essential on much of the frontage. Parts of the coast and surrounding rural landscapes are nationally recognised in the designation of the Norfolk Coast Area of Outstanding Natural Beauty (AONB) and the North Norfolk Heritage Coast. North Norfolk is also important for its biodiversity and areas of nature conservation interest. North Norfolk has areas with high deprivation which have a strong correlation with areas of significant erosion risk. The local economy is dependent on tourism, agriculture and manufacturing, all of which are closely related to the value of the natural environment. North Norfolk is a popular retirement location as well as a popular destination for second homes.

This area is included within the wider Norfolk and Suffolk coast Flood and Coastal Resilience Innovation Programme. Within this wider area it is estimated that around 2,500 homes and business are at risk across the 3 time periods and depending on shoreline management plan (SMP) policy. The medium to long-term SMP policies in North Norfolk are largely managed realignment and no active intervention. At present, there are no mechanisms for managing coastal change, such as the loss of a significant coastal business community and mitigating subsequent impacts on the local economy. The Flood and Coastal Resilience Innovation Programme involves developing a complete package of planning, engagement, technical, financial and policy tools to support coastal transition for local communities subject to coastal change, which could also be applied more widely to the rest of the UK coast. It was also announced in March 2022 that North Norfolk would be part of the Coastal Transition Accelerator Programme, which will trial innovative ways of adapting to coastal erosion.

Figure 2. Images of Happisburgh, December 2013 and April 2021 (Credit: Sophie Day, UEA)

December 2013

Figure 3. Images of Happisburgh, December 2013 (Credit: Sophie Day, UEA)

Resilience ambitions and challenges

The challenge of enhancing resilience for coastal change cannot be underestimated and for this reason, in addition to the use case focusing on coastal erosion, a wider workshop was held with coastal representatives to discuss how this issue should be addressed. The findings from this workshop are included here.

A specific issue raised relates to the importance of managing uncertainty. The following sub-section (credit: Sophie Day, UEA and Rob Goodliffe, North Norfolk District Council) sets out how a community could be resilient to coastal change by better understanding the risks it faces and also having policies and mechanisms in place to enable communities to better prepare for future events. As erosion leads to a permanent loss of land, resilience requires a proactive approach that plans, prepares and works with these changes before they occur.

Coastal change – past and current

a) We are **CERTAIN** that erosion will happen
b) We are **UNCERTAIN** exactly how and when
c) There **IS NO** effective policy or mainstream mechanisms (guidance, options, financing) to help us prepare
d) We are **UNCERTAIN** what the future holds (fear, distrust, reluctance to engage)

Coastal change – future/resilient?

a) We are **CERTAIN that erosion will happen**
b) We are **UNCERTAIN** exactly how and when they have a good indication of trajectory

c) There **ARE** effective policy mechanisms to help us prepare
d) We are reasonably **CERTAIN** what the future holds, how to get there and confident that it will be okay

The above was also discussed at the September focus group on coastal erosion. Having mechanisms in place for managing long-term change, including relocation, was identified as crucial for the resilience of coastal communities.

Recent work by the University of East Anglia (UEA) and North Norfolk District Council with Happisburgh, Bacton, Walcott and Hemsby showed that the following were important characteristics of resilient local communities:

- interim protection
- accessible beach
- safe homes
- economic viability/vitality
- reliable infrastructure
- local public and political willingness to engage
- mental wellbeing/health
- cultural/historic assets and characteristics maintained
- expectation of change

Depending on institutional scale, examples of issues that were also identified as critical for local resilience on eroding frontages from a coastal management authority perspective include:

- resources for local engagement on adaptation
- availability of tested options for adaptation
- financing for implementing adaptation options
- natural service functions of coastal processes

During the September focus group, there was considerable discussion about the challenges of measuring resilience for places that do not have a long-term future. A distinction was made between threatened properties and communities as a whole. Effective placemaking actions were identified as most important for coastal areas. These can be measured via changes in resilience reflected by the effectiveness of policies, mainstreaming mechanisms to create sustainable places and joint working between communities and risk management authorities (RMAs). It was noted that, where communities were forced to abandon individual properties due to erosion, the preparedness and recovery relates to those specific circumstances.

The discussion identified the need to have planning, financial, engagement, policy, legal and technical enablers in place to facilitate resilient placemaking. It was also suggested that there is a need for different language in relation to erosion and coastal change issues, for example, substituting ‘protect’ terminology for ‘manage the hazard’ or ‘buy time’. Plans using adaptive pathways and supported by regular monitoring requirements were also suggested.

However, it was also noted that applying a simple approach and including indicators such as ‘number of plans in place’ would give blunt outputs rather than outcomes, which may not effectively measure resilience to flooding and coastal change over time. For example, with the shoreline management plan (SMP) refresh process, there is a move away from having a plan in place to progress with implementing a plan and using the SMP action plan to track this. These discussions suggested that a potential indicator could relate to plan implementation and effectiveness.

The discussions also highlighted that the resilience of places could include the resilience of the natural function of an environment, for example, how the quality of ecosystem services is affected by sea level rise. It is important that placemaking includes the sustainability of the natural environment, as well as the built environment.

Measuring resilience using draft indicators

Draft indicators were ‘tested’ using the North Norfolk use case in 2 stages:

1. Focus group session on 10 September 2021.
2. Discussion with use case leads on 20 October 2021.

The main findings following these discussions are presented below and were used to influence further indicator development.

September focus group discussions

The focus group held on 10 September focused on coastal erosion, with the North Norfolk use case illustrating the resilience challenges that can be encountered. To facilitate discussion at the workshop, the following potential resilience indicators were suggested for measuring changes in resilience to areas at risk of coastal erosion:

- placemaking – capacity in the local plan to enable the rollback of properties at risk
- protect – interim protection to enable time and space for an adaptation plan to be developed
- respond – effective policy mechanisms in place to enable communities and supporting institutions to respond
- recover – plans in place to enable communities to continue to exist in one way or another on eroding frontages

In general, ‘capacity in the local plan to enable the rollback of properties at risk’ was considered the most important indicator, while the recovery component was considered the least important. Stakeholders suggested that recovery from erosion cannot happen as it involves a permanent loss of land and property.

In addition to these 4 suggested indicators, the group discussion following this highlighted several other recommendations:

- It was stressed that there is a need to measure the understanding of future changes required, the likely impacts that could result from these, and the responses

required. Indicators for enablers could cover financial mechanisms, interim protection, resources for local level engagement and having local plans in place that facilitate rollback.

- The potential to develop indicators for resilient management needs to be considered, but due to the complexity of the circumstances, it is anticipated that additional studies will be required to define and map out the requirement.
- Where places in themselves cannot be resilient (in other words, they are likely to be lost as a result of coastal erosion), activity needs to be measured that facilitates social and economic recovery (for example, relocation).
- The potential to include interim protection was identified to give time and breathing space to develop more adaptive approaches and manage the relocation of a community; short-term protection indicators could be developed linked to such interim measures.
- It was suggested that specific elements of resilience that are within the control of public individuals and groups should be measured in such a way that they can use the information to guide their activities, recognising that civil society can also be an effective agent of bolstering resilience.
- The potential for considering resilience against the UN Strategic Development Goals (SDGs) was also highlighted. For example, under Goal 13 (Climate Acton), this could include the number of coastal management authorities with an adaptation plan; the number of coastal management authorities with resources for engagement on coastal change; the number of local plans with specific policies to enable roll-back of properties.

Discussion with use case leads

The final stage of the use case investigation involved exploring a list of draft indicators in more detail and considering their relevance for the use case area. The North Norfolk use case focused on indicators linked to the placemaking objective. Placemaking is defined as ‘making the best land use and development choices for managing flooding and coastal change’.

The following draft indicators were discussed:

<u>Engagement/community views</u>

- Awareness and understanding of risks, potential damage and plans
- Community embedded in decision-making
- Fear of flooding
- Views on potential impact
- Number of flood/coastal change action groups
- Schools engaged and providing flood/coastal change education

<u>Development</u>

- Proportion of development at risk – now and with climate change
- New development enabled by resilience measures

- Number of planning permissions against RMA advice
- New development that is net zero and flood/coastal change resilient

Plans and policies

- Adaptation policies and plans in place with multi-sector buy-in
- Compliance to British Standard 85500 (Flood Resilient Construction)

Investment

- Partnership funding and innovative finance
- Total value of long-term funding agreements for funding resilience actions
- Increase in jobs created from new investment and/or average incomes from nature of new employment

Wider infrastructure

- Infrastructure investment to achieve resilience standards of service
- Infrastructure investment to protect properties, for example, Network Rail embankment

Land use

- Resilient rural land use

Discussion

Discussions around the suitability and effectiveness of these indicators for use in North Norfolk highlighted the following main issues:

- Clearly defining placemaking, protect, respond and recover is necessary to ensure that they apply to coastal erosion. For example, it should be made clear that 'protect' is not necessarily protecting a place, but protecting people from harm and financial loss.
- An indicator which considers 'creating space' may be useful. This would allow challenges regarding a lack of land available for transition to be considered, for example, in built-up areas or where environmental designations prevent development. This could also be mirrored for areas at flood risk by including an indicator covering the availability of space for flood storage.
- The socio-demographics of coastal communities are well understood and have been documented in Joseph Rowntree Foundation research, CCRA2 and CCRA3, and the recent Chris Witty report on the health of coastal communities. These studies could be applied alongside the indicators developed to ensure local socio-demographics are captured.
- There are challenges with the coastal monitoring programme collecting socio-demographic data, as the funding is directly from Grant in Aid and linked to specific schemes. However, this limitation should be noted and could be changed in future if coastal monitoring was funded through a different mechanism.

- Having a different set of indicators depending on whether an area is implementing a 'hold the line' policy or 'managed realignment/no active Intervention' may be necessary, as very different indicators will be required in these situations.

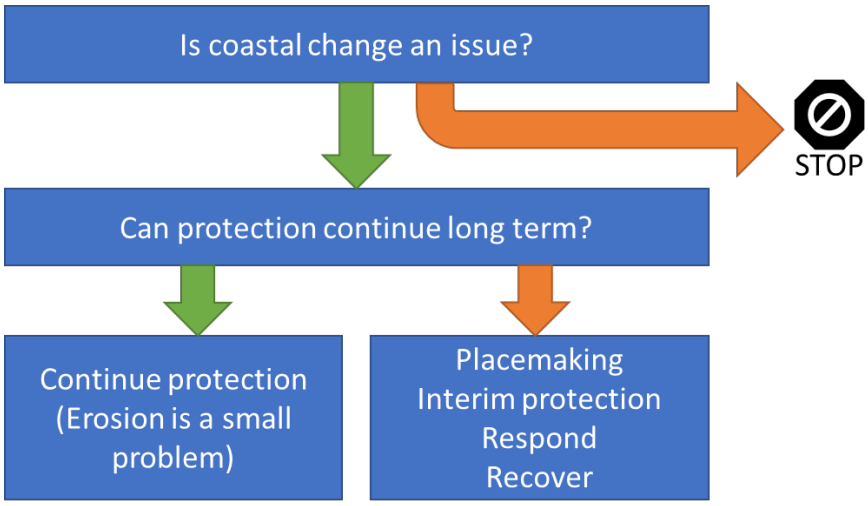

Figure 4. Resilience strategies in the coastal erosion context. Credit: Robert Nicholls, UEA

Further to this, the following suggestions were made regarding the specific indicators discussed.

Engagement/community views

- It is essential to include engagement/awareness/understanding and there is potential to measure this via readiness assessments. Icarus is currently doing work in this area which may be useful.
- The 'fear of flooding' indicator should include coastal change as well.
- Forecasting erosion in the same way as flood events are predicted is not feasible due to its inconsistent and unpredictable nature; even if hypothetically feasible how would such short-term information be used? Therefore, long-term planning needs to be prioritised for coastal erosion.

Plans and policies

- There is potential to include flexibility in planning under this theme, such as moving the boundaries of environmental designations to enable the roll back of coastal communities with the retreating coast. This would need to be considered over time; the Fairbourne relocation in Wales, for example, is a 50-year process.
- Consideration for multi-agency planning is important to ensure integrated not siloed working.
- Including SMPs could be beneficial – making these mandatory would give coastal communities a lot more certainty.
- Measuring compliance to British Standard 85500 (Flood Resilient Construction) does not account for coastal erosion. Could British Standard 8631 (adaptive

pathways) or International Standard 14090 (climate change adaptation) also be measured?
- Having adaptive plans in place is considered more important than policies for North Norfolk and other coastal communities.
- Planning policies around temporary buildings/caravans and vacating these for part of the year could be considered. Mobile accommodation may be beneficial in areas like North Norfolk as relocation is possible if there is an available location.

Investment

- 'Total value of long-term investment funding' is considered especially important.

Wider infrastructure

- It is important to consider co-investment as this can have an impact on local resilience. For example, millions of pounds of private investment was spent floodproofing a local BT asset, but if this had been carried out as a multisector effort, approximately 50 homes could have also benefited for a small additional cost.
- When considering infrastructure investment to protect properties, Network Rail embankments acting as flood defences is not relevant to coastal change.

Land use

- Could available space earmarked for relocation/roll back zone be considered here?
- The co-benefits achieved from coastal change interventions could also be included (for example, creating parkland in roll back and buffer areas).

Coastal erosion workshop

In addition to use case testing, a workshop with a small number of coastal erosion stakeholders was held on 12 October 2021 to discuss wider application of draft indicators to the coastal erosion context. This discussion emphasised the importance of the points above and highlighted the following recommendations:

- Understanding risk, implications and forward plans by all affected parties is important.
- Recognition that relevant indicators for a community or place may change over time (for example, focusing on 'protect' in the short term and 'placemaking' in the longer term).
- It should be made explicit that 'respond' includes 'prepare' in this research.
- Resilience indicators that coastal erosion stakeholders can support included:
    - understanding risk and potential impacts
    - engaging planners via a realistic SMP process
    - adaptive coastal erosion management
- The limitations of current capacity and resources need to be taken account in the route map.

Lessons/recommendations from the use case investigation

Findings from the North Norfolk use case and discussions with the wider coastal erosion community have highlighted the importance of long-term resilience for these areas. It is therefore important to consider how the regularity of measurement will show changes in this long-term resilience over time and to think about the coastal monitoring that will be required and how this could be conducted and funded. As well as work being carried out as part of the Norfolk and Suffolk coast flood and coastal resilience innovation programme, work being undertaken by Coastal Partnership East will also develop important understanding on coastal resilience and this should be incorporated into the development of future indicators.

On an immediate basis, understanding, flexibility and adaptation are the most important approaches to consider in this context. Having the right mechanisms (policy, financial, technical, legal) to actually allow coastal resilience to be enhanced is vital to ensuring resilience gain, and should be considered further in indicator development.

1.2 Boston use case investigation

This section relates to the Boston use case and focuses on testing resilience indicators within the local multiple sources of flooding context.

Background and context

Boston is an historic market town with an important maritime heritage and a long history of flooding. Over the past 200 years the town has experienced 9 major instances of tidal flooding. The most recent flooding in December 2013 affected more than 800 properties across 55 streets.

Boston is also one of the most deprived areas in England (ranked 66th most deprived in 2015) and has one of the lowest average weekly wages. People in Boston cannot afford to suffer the effects of flooding. Post-flooding surveys in 2013 found that 99% of respondents did not have contents insurance.

Prior to the recently completed Boston Barrier, the high flood risk to more than 14,300 homes and businesses (forecast to increase to 20,000 properties over the 100-year design life) and lack of flood resilience meant the town was struggling to attract investment, deprivation issues were likely to continue, and new regeneration schemes were unlikely.

With the barrier completed, Boston now has one of the highest levels of tidal flood protection in the UK outside of London, and is well positioned to achieve enhanced social, economic and environment resilience. The completed scheme recently won the ‘Climate Resilience Project of the Year’ award at the 2021 British Construction Industry Awards.

Figure 5: The impact of the 2013 flood and an image of the recently completed tidal barrier in 2021

Resilience ambitions and challenges

Interviews with the project team and a review of background information on the Boston Barrier investment identified a number of primary challenges related to resilience, namely:

- the Greater Lincolnshire LEP Strategic Economic Plan notes that security from the risk of flooding is an important infrastructure requirement for the area
- the nature of the region means that local authority investment is constrained and struggles to meet all community needs
- the area is one of the most deprived areas in the UK (national deprivation index)
- the level of deprivation makes it difficult for communities to recover from ‘shocks’
- poverty leads to low levels of insurance uptake
- the region is a major source of food production and distribution for the UK
- local public service assets need to be protected, including hospitals and schools
- there are numerous outfalls into the Haven, including those associated with the sewerage network, waste water treatment, flood risks and land drainage functions
- environmental inequality and levels of education

- the ability of local businesses to recover quickly can be severely restricted, resulting in temporary and permanent job losses
- confidence of business to invest for the future
- a massive diversity of stakeholder views and opinions related to resilience to flooding and coastal change

Important local ambitions related to enhancing resilience (through the Boston Barrier investment) include:

- attracting new investment to the local area, enabling regeneration schemes and job creation
- realising wider social and environment benefits such as improvements to the Macmillan Way public footpath, and contribution to the UN Sustainable Development Goals (SDGs)
- realising wider economic benefits through water level management, navigation and tourism

Measuring resilience using draft indicators

Boston was used to test the 19 draft 'protect' indicators and explore the views on the following questions:

- Are the indicators relevant to Boston?
- Would the indicators clearly evidence how resilience is changing in Boston? Can they be used to measure the baseline as well as change?
- What data is required to populate the indicators? Where would this be obtained? If not already available, how challenging would it be to obtain the data? How often should it be updated?
- Should the indicators be recommended for inclusion in the final set?
- Are there other indicators that you consider are also relevant for this use case and resilience dimension?

The draft 'protect' indicators tested as part of Boston use case were as follows:

<u>Engagement/community views</u>

- Awareness and understanding of risks, potential damage and plans
- Community embedded in decision-making
- Fear of flooding
- Views on potential impact
- Number of flood/coastal change action groups
- Number of flood wardens
- Schools engaged and providing flood/coastal change education

<u>Previous events</u>

- River/sewer/flood levels over time vs events and associated damages
- Number of LLFA/CPA flood /coastal change investigations

Residual risk

- Number of ‘at risk’ properties flooded/affected by coastal change
- Number of properties with >1% chance of flooding
- Erosion rates
- Residual annual property damage

Sustainability of defences

- Service/condition level of existing assets and change over time with climate change and asset deterioration
- Properties protected (short term)
- Flood storage in the catchment (number and volume)

Natural flood management

- Number of NFM interventions/green SuDS
- Volume of water stored by NFM measures
- Volume of water slowed by NFM measures

Discussion

In the context of Boston, ’awareness and understanding of risks, potential damage and plans’ was considered a top priority for measurement. Awareness and understanding risk were seen to influence ‘fear of flooding’, but measuring fear was not considered to be meaningful as it is too transitory and difficult to capture a trend.

The second priority was ‘service/condition level of existing assets and change over time with climate change/asset deterioration’. This was considered as core business and a critical baseline for future decision-making and investment.

The third priority was knowledge of residual risk in terms of number of properties at risk of flooding or coastal change. Again, this was considered as core business and a critical baseline for decision-making.

In the context of Boston, indicators related to NFM were considered low priority.

The other indicators were explored, but none stood out as providing clear evidence of changing resilience in Boston.

The project team was keen to highlight the importance of driving net zero as part of a framework for measuring resilience, and the importance of embedding practices to unlock co-benefits. The project team has piloted the use of the UN Sustainable Development Goals (SDGs) to explore the links with placemaking, sustainability and climate resilience, and see this as important to changing mindsets and behaviours at the project level.

Lessons/recommendations from the use case investigation

Main lessons arising from the Boston use case study:

- The importance of making investment decisions based on fully appreciating the local context in terms of social/demographic, economic and environment capacities.
- The importance of recognising co-benefits, synergies and dependencies in building the business case for resilience and implementing sustainable solutions.
- In the context of major investments, addressing multiple sources of flooding, placemaking and protection measures are highly interdependent and work in combination to provide resilience for people and places.
- In the context of protection, 3 indicators stand out as crucial for measuring resilience:
    - Ongoing public and stakeholder awareness of risks and understanding of risk, and the potential damage and actions that can be taken. In the Boston context, it is important that the local community understands its risk is a function of multiple sources of flooding (not just tidal flood risk).
    - Knowledge of service/condition level of existing assets, and changes over time with taking account of climate change and asset deterioration.
    - Knowledge of residual risk in terms of number of properties at risk of flooding or coastal change.
- Two further aspects were recognised as important to driving resilience:
    - Embedding wider climate awareness and climate literacy within school curriculums.
    - Embedding ‘net zero’ practices as ‘a given’ rather than an indicator, and using SDGs to see opportunities and realise co-benefits.

Two final lessons are evident from the Boston use case:

- The importance of leadership and project champions in driving change and resilience outcomes.
- An appetite to ‘do things differently’, embrace emerging best practice and technology, and promote successes and lessons.

1.3 Salford use case Investigation

This section relates to the Salford use case and focuses on testing resilience indicators within the local inland fluvial flooding context.

Background and context

The city of Salford lies on the western side of Greater Manchester, sharing boundaries with Bolton, Bury, Manchester, Trafford, Warrington and Wigan. The city centre, Salford Quays, and some adjoining areas have experienced significant growth and investment in recent years and provide a major concentration of employment, retail, leisure, tourism and cultural opportunities. However, some of the inner neighbourhoods surrounding the city centre are characterised by high levels of deprivation and contribute towards Salford being identified as the 16th most deprived local authority in England. They form part of a much wider concentration of deprivation at the heart of the conurbation which extends into Manchester and Trafford. The River Irwell is a distinctive landscape feature running through this eastern part of the city, but it results in some of the most accessible, economically important and socially deprived areas being at significant risk of flooding.

A large proportion of Salford is located within the flood plain areas of the River Irwell and is at high risk of inland fluvial flooding. There is a high standard of flood mitigation in place, with extensive defences and 2 flood basins protecting around 1,900 homes and businesses. However, taking climate change into account, the risk of flooding in the area is likely to increase. This means challenging decisions are to be made regarding land use. Flood events in Salford have been recorded as far back as 1888, with major events in 1946 (5,300 properties flooded), 1954 (600 properties flooded) and the most recent significant event on Boxing Day, 2015 when 500 residential properties and 196 businesses flooded, with a further 168 properties indirectly affected by knock-on disruption.

Figure 6: Historic flooding in Salford, 1946. Credit: Will Horsfall, Salford City Council

Figure 7: Flooding in Salford, Boxing Day 2015. Credit: Will Horsfall, Salford City Council

In addition to the structural defences, many properties have benefited from grants for property flood resilience (PFR) and have measures in place. Flood warnings are also provided via an LED board in the Lower Broughton area, which also has its own Flood Group and a Community Emergency Plan. The Salford Flood Forum brings together leading partners (Environment Agency, Salford City Council, United Utilities and Broughton Flood Group) and provides an integrated approach to the ongoing management of flooding in the area. Surface water and sewer flooding also present a risk, with recent flooding from these sources on 9 September 2021.

Resilience ambitions and challenges

The high flood risk now and projected for the future presents a specific challenge for the Lower Broughton area of Salford in sustaining a functioning community with the necessary services. Consequently, land use management and planning in this area is particularly difficult. The area is characterised by high levels of deprivation, including low literacy levels which can make it difficult to maximise the uptake of PFR and flood warnings. In relation to the latter, flood alerts and warnings are very frequent, leading to mistrust, but also contributing to high fear of flooding in the community and mental health issues, including PTSD, especially among children.

There have also been issues regarding installation, maintenance requirements and ownership for PFR measures, despite the Department for Levelling Up, Housing and Communities (DLUHC) providing grants for all flooded households following Boxing Day 2015 to install PFR measures. The grants allocated £5,000 per property, with £500 for an initial survey. While 66% of residential and 86% of commercial properties took up the grant, residents in Salford still face challenges with implementing and maintaining effective measures. These challenges include receiving insufficient amounts to cover requirements, difficulty understanding the process due to literacy and language barriers, and trauma due to dealing with flood related matters. In addition, some of the companies that installed these measures have gone into liquidation. Therefore, if repairs are required, these will not

be addressed by the installer, even where warranties are still in place. Salford City Council also encountered challenges of having limited resources to cover the additional work needed (which more generally is an issue in an area at high risk of flooding), receiving minimal guidance on the grant process, not owning the properties (they were owned by registered social landlords or private properties), and the subsequent risk in committing to the works.

Measuring resilience using draft indicators

Draft indicators were ‘tested’ using the Salford use case in 2 stages:

1. Focus group session on 13 September 2021.
2. Discussion with use case leads on 15 October 2021.

The main findings following these discussions are presented below and were used to influence further indicator development.

September focus group discussions

The focus group held on 13 September focused on inland fluvial flooding, with the Salford use case illustrating the resilience challenges that can be encountered. To facilitate discussion at the workshop, the following potential resilience indicators were suggested for measuring changes in resilience to urban areas at high risk of fluvial flooding.

- Placemaking: local plan policies managing development in flood risk areas
- Protect: PFR uptake
- Respond: community perceptions and trust in institutions and information, including flood warnings
- Recover: emergency plan owned and understood by community and stakeholders and home insurance take-up

In addition to these 4 suggested indicators, the group discussion following this highlighted several other recommendations:

- Including a potential indicator related to multi-agency, co-ordinated planning and for having appropriate insurance in place.
- Avoiding standard of protection as an indicator, as this will change over time and is not uniform, making it difficult to identify across an area.
- Rather than measuring the level of sign up to a flood warning indicator, measuring whether people understood the warning and subsequently took appropriate action would give a better measure of preparedness. Including the availability of surface water warnings within this indicator could also be beneficial for many places, including Salford.
- Regeneration in flood risk areas (for example, creating safe development) could be a good indicator for measuring changes in resilience, but in areas where safety is threatened, indicators (and finance) regarding relocation may be required. It was

also suggested that local plans addressing longer term viability issues for communities at highest risk could be included as an indicator.
- Measuring the presence of community action was also suggested. In Salford, the Broughton Flood Group funded an LED light board to advertise warnings, which shows it is becoming resilient as a community. Similarly in Cumbria, there are 30 local flood groups supporting communities at risk.

Discussion with use case leads

The second stage of the use case investigation involved exploring a list of draft indicators in more detail and considering their relevance for the use case area. The Salford use case focused on indicators linked to the 'respond' component. For the purposes of this research, respond is defined as 'the ability of places and people to prepare for and react to flooding and coastal change in a way that results in minimal impacts to property, the natural environment and health and wellbeing'.

The suggested indicators were:

Engagement/community views

- Awareness and understanding of risks, potential damage and plans
- Community embedded in decision-making
- Fear of flooding
- Views on potential impact
- Number of flood/coastal change action groups
- Number of flood wardens
- Schools engaged and providing flood/coastal change education

Flood warnings

- Availability, take-up and trust in warnings, including post-event take-up
- Presence of warnings in multiple languages/targeted at specific groups

Emergency planning

- Effective and exercised community flood/coastal change emergency plans in place
- Capacity of emergency services to respond – response time
- Time required to activate the local response network

Discussion

This sub-section outlines the main discussions resulting from workshops with the use case leads.

Engagement/community views

During the discussion on these draft indicators, the need to understand the socio-demographic and economic characteristics of a place or community was highlighted due to

the contribution these factors make to resilience. Currently, some information on socio-demographics is collected locally and used to influence flood actions. For example, Salford City Council has a list of vulnerable people that are at flood risk, which emergency planners use to inform flood responses. In addition, Greater Manchester County Council regularly conducts a community safety survey, which includes socio-demographic questions, one of which relates to income, which could be used as a proxy for resilience. Local authority functions, such as housing and planning, also have information such as ward profiles. However, areas of transient communities make gaining a full picture of socio-demographics challenging.

It was agreed that indicators around community 'awareness and understanding of risks, potential damage and plans' and 'fear of flooding' are essential for measuring changes in resilience. Regular surveys would need to be carried out to obtain this information, but local authorities currently do not have the resources. There may be some sources which could also be used to input local data, for example, the Broughton Flood Group received lottery funding for a project on increasing flood risk awareness which may have useful outputs. In addition, involving local ward elected members in decision-making was considered an effective way of demonstrating 'community involvement in decision-making'. In Salford, this information is collected through the Greater Manchester community safety survey. It was also considered that measuring 'schools engaged' would be a good indicator of resilience in Salford, as children were particularly affected by the Boxing Day 2015 floods in Salford, and many suffered mental health impacts and PTSD.

Salford representatives agreed that 'number of flood action groups' was not a good resilience indicator, as there could be one very good group (such as Broughton Trust) or multiple rival groups. It was suggested that it would be better to focus on the quality of the group and engagement with the group, for example, the Broughton Flood Group Facebook page has hundreds of followers, which could be a good indicator. Similarly, 'number of flood wardens' was not thought to be a good indicator for Salford, since there is no official flood warden in Lower Broughton, and these are usually only in place where positions have been funded through specific projects. However, the Broughton Flood Group lead fulfils this role within Lower Broughton and has a very positive influence on local resilience. To allow this to be considered, it may be valuable to rephrase this to include 'flood champions'.

Flood warnings

The Environment Agency currently collects data on the take-up of flood warnings, meaning information on take-up goals and methods to promote the service is available now. However, it should be noted that, as flood warnings are now an opt-out rather than opt-in service, high warning take-up does not necessarily represent high engagement within the community, limiting the potential of warning uptake as an indicator for resilience. In addition, flood warnings should be available in the languages that are spoken in a specific area. Having warnings in multiple languages is not useful if they are not the languages understood by local communities.

Emergency planning

In terms of emergency planning, it was considered more important to measure ‘effective and exercised plans’ rather than just the number of plans in place. In Salford, there is a community flood plan for the Lower Broughton area, but not the resources to operationalise this plan. Therefore, just having a plan in place does not necessarily demonstrate resilience. Although flood exercises are regularly carried out in the area, these involve the response network not the community. In terms of emergency response, the capacity to respond based on available equipment was felt to be a better indicator than response times.

Lessons/recommendations from the use case investigation

The Salford use case has highlighted the impact that understanding and awareness in the local community can have on resilience to flooding and coastal change. In Salford, this has been particularly highlighted through the role that an effective flood action group and flood champions can play in enhancing resilience. Engagement with school children and ensuring the community is embedded in decision-making were considered important aspects of resilience in this context. This use case also demonstrated the need to consider whether emergency plans are effectively implemented and exercised, and whether flood warnings are understood and acted on in the local community in order to better measure resilience.

Salford City Council representatives appreciated the benefits of this research, but also stressed that additional resources would be required to collect this type of information, if the lead local flood authority (LLFA) were to be responsible for tracking these indicators. Salford LLFA, like many others, is stretched beyond capacity, with current vacancies being difficult to fill. It would be concerned if additional requirements were placed on the organisation without additional resources.

1.4 Rochdale use case Investigation

This section relates to the Rochdale use case and focuses on testing resilience indicators within the local surface water and residual risk context.

Background and context

Rochdale is a large town within the Greater Manchester county, north-east of Manchester. The town sits along the River Roch (a tributary of the River Irwell), with the river running through the main town. Rochdale has areas with high levels of multiple deprivation which have a strong correlation with areas of significant flood risk.

Rochdale has had a long-term legacy of quite significant fluvial and surface water flood risk. The most significant recent flood event in the area was the Boxing Day flooding in 2015, which affected numerous parts of the borough, with 65 businesses flooded, 320 properties severely damaged and 18,000 properties left without power. There are some fluvial alleviation measures across the river course in place to reduce fluvial risk from the River Roch. The use case leads are particularly interested in residual flood risk and the risk from surface water flooding which remains in the areas of Littleborough and Wardleworth. Littleborough, in the north of the borough, is less deprived; in the latest Index of Multiple Deprivation (IMD) this area was ranked 9,160 out of 32,844 in England, where one was the most deprived and 32,844 the least. Wardleworth, which is closer to Rochdale town centre, scores quite high on the IMD: ranked 1,067 out of 32,844 in England. Wardleworth is a mill neighbourhood with associated mill infrastructure that poses challenges both for the drainage company and in understanding the causes and

sources of flooding.

Figure 8: Flooding in Rochdale, Boxing Day 2015

Roch Valley Neighbourhood Flood and Climate Resilience Programme

The Roch Valley Neighbourhood Flood and Climate Resilience Programme, supported by the Flood and Coastal Resilience Innovation Programme, aims to address residual risk of flooding in the context of climate change and the need to adapt. It involves developing and populating a residual risk framework, piloting and testing community resilience approaches and using these approaches to prepare and implement Neighbourhood Flood and Climate Resilience Plans for Littleborough and Wardleworth. The project plans to target deprived and hard-to-reach communities in the Roch Valley, with high turnover and rented accommodation to achieve a step change in holistic flood resilience across the project communities, increase flood literacy, and embed flood resilience in property and land management, growth and regeneration. The ultimate intention is to better manage residual risk through new, innovative, cross-sectoral approaches by developing adaptive pathways to take account of climate change, development pressures and ageing built environment infrastructure. The programme draws on other work that is being carried out by the local authority, the Environment Agency and other partners in the area, including much broader fluvial alleviation schemes around the River Roch, natural flood management projects, a flood poverty project focused on providing insurance, housing and neighbourhood programmes and follow-on community projects.

Resilience challenges

The main resilience challenges identified by the use case leads are as follows:

- **Fluvial and surface water flooding, often in combination**: Similar to many other areas in England, the Rochdale area is at risk from a combination of fluvial and surface water flooding, including residual risk.
- **Environmental challenges**: There are challenges around the quality of the local environment. Wardleworth, in particular, does not offer many opportunities for nature-based solutions (NBS), even at a small scale. There may be more scope for NBS in the Littleborough area.
- **Local socio-economic challenges**: In Rochdale there are local and discrete and, in some instances, quite severe, social-economic challenges. Wardleworth also has a high percentage of people who are of minority ethnic background who are potentially harder to reach. This poses challenges with engagement and cultural challenges in terms of how people perceive things like flood insurance.
- **Flood poverty**: deprived and hard-to-reach communities. The use case team is particularly interested in flood poverty, especially in relation to flood justice and social justice, when dealing with deprived communities and deprived individuals and families within communities. The team is interested in the financial aspects of resilience, such as the provision of, and access to, flood insurance (for example, how some individuals/families are under insured), those who opt out of the insurance market in various ways, and actual and perceived barriers to insurance take-up (for example, take-up in transient communities).
- **Property condition and maintenance**: This includes challenges with the housing stock, which may not be of the highest standard, and challenges around PFR,

which may not be effective if the condition of a property (or surrounding properties) is poor and/or PFR is not effectively maintained, defective or has passed its operational lifespan. This leads to concerns about effective long-term PFR and protecting important community assets. In contrast, this may offer opportunities to introduce resilience into the urban fabric when properties are upgraded.
- **Tenure and challenges with landlord engagement**: Tenure status of residents poses a challenge in relation to both PFR and flood insurance, as there is a high proportion of social and private rented properties in Rochdale. There is also a significant problem with landlord engagement such as absentee landlords and individual landlords and companies that own several properties on the same street.

Resilience ambitions

The main ambitions of the Roch Valley Neighbourhood Flood and Climate Resilience Programme include:

- reducing the residual risk of flooding in the context of climate change and the need to adapt
- environmental gain through maximising multiple benefits from green and blue infrastructure, including flood resilience, sustainable drainage, biodiversity and water quality, whereby there is more climate resilient housing stock and housing marketing professionals are more engaged with flood resilience and flood resilient behaviours
- improved flood literacy in communities who are more involved in planning and providing flood resilience at an individual and neighbourhood scale
- increased/better insurance take-up by homeowners, landlords and businesses which is affordable, accessible and incentivised
- businesses being more resilient and less likely to experience disruption or significant losses from flood events
- improvement in mental and physical health, improved by greater confidence in flood resilience and reduced anxiety from flood events
- effective partnership working

Measuring resilience using draft indicators

The indicators tested in Rochdale fell under the theme of ‘recovery’. Recovery is defined as ‘the ability of places and people to rebound from flooding and coastal change with minimal impacts to property, the natural environment, and health and wellbeing’.

The list of indicators tested were:

<u>Engagement/community views</u>

- Awareness and understanding of risks, potential damage and plans
- Flooding and coastal mental health impacts
- Community embedded in decision-making

- Fear of flooding
- Views on potential impact
- Number flood/coastal change action groups
- Number of flood wardens
- Schools engaged and providing flood/coastal change education

Recovery planning

- Time taken to recover (get back into property, get infrastructure fully functioning)
- People know where they will live and work if or when their current home or workplace becomes unsustainable
- Effective and exercised recovery plans in place
- Flooding and coastal change mental health impacts

Build back better

- Number of improvements to infrastructure resilience (for example, repaired/raised defences)
- Number of homes and businesses recovered with additional resilience measures

Property flood resilience

- Proportion of ‘at risk’ properties with property flood resilience (PFR) measures installed

Insurance

- Home, business and contents insurance uptake

Discussion

This sub-section outlines the main discussions resulting from workshops with the use case leads.

Flooding and coastal change mental health impacts

Discussions indicated that there are a number of problems with assessing the mental health impacts of flooding as an indicator, although it was identified as a valuable indicator. The sensitivity of the required data limits accessing it from health authorities. Consequently, the data would need to be obtained through surveying. This will pose difficulty due to the intrusive nature of the subject. Quantifying the mental health impacts of flooding via surveying will also be very difficult due to the subjective nature of the concept; for example, self-reported levels of stress are going to vary substantially from person to person, so the accuracy of such approaches is limited. While it would improve the accuracy of such assessments, asking for clinical evidence of mental health conditions would not be feasible due to data sensitivity/confidentiality. It is also very difficult to

separate mental health impacts due to flooding and those conditions which were present prior to the event.

Community embedded in decision-making

Flood action groups consist of a core group that works with the community and professional partners. They work with their community to understand the issues that affect them. They aim to get a common understanding of priorities before working with flood risk management authorities to tackle flood risk. Their leadership helps to bring professional organisations together to tackle issues collectively with the community.

It was suggested that assessing engagement by the proportion of the population embedded within decision-making is not a favourable approach. Engaging the community/building the necessary relationships to develop effective communication can take a long time, and defining, quantifying and measuring what stage this process is at is extremely difficult. Urban communities are also dynamic due to factors such as transience and new development, which further adds to the complexity. The National Flood Forum and Rochdale Borough Council have reasonably strong links into the community, but this is restricted to a small group of people who have been engaged for some time. Simply measuring the proportion of the population embedded within decision-making would therefore be a particularly poor representation of the resilience benefits afforded in Rochdale. Therefore, a different approach is required, recognising there is no one best approach to engaging the community. The process is about developing individual relationships, is difficult to measure in the form of an indicator, and therefore creates issues surrounding comparability from place to place.

Some alternatives to this indicator were discussed, including:

- whether financial support has been obtained to support mechanisms for community engagement?
- presence of local flood ‘champions’

Fear of flooding

The use case leads suggested that the use of ‘fear of flooding’ as an indicator needs to be considered carefully: high fear might not mean low resilience, it could, in fact, mean the opposite. Low fear might be associated with lack of awareness of the risk, a perception of being ‘well protected’ or ‘risk denial’ (where there is actually substantial fear of, for example, costs related to insurance) and therefore poorer resilience. Fear is likely to be higher post flood if the local population did not perceive themselves to be at risk prior to the flood event. There is therefore a need to understand what fear represents in terms of resilience and how this might change over time. If assessing by survey, it must be

understood that some people may not want to admit they are afraid of flooding and this could lead to inaccurate data.

Number of flood/coastal change action groups (meeting regularly)

For this indicator, confounding variables should also be considered. For example, when resilience is high, the number of meetings may decrease as the problem is (perhaps only perceived to be) solved. Therefore, the number of meetings does not necessarily positively correlate with improved resilience. A preferable alternative could be the proportion of those groups which are intended to be set up that are actually established, plus some information on how formal they are and how they are structured.

Number of flood wardens

This was identified as a poor indicator due to the fact that in Rochdale flood wardens are usually lone workers who are not embedded within the community and therefore the number does not reflect community resilience. There is also a broad spectrum of community flood action groups with various responsibilities, from those involved in policy to those involved in direct action/response, and therefore this indicator needs to be more encompassing.

Flood ‘champions’ who work with community groups, for example, churches, and build networks with the community and flood action groups, could potentially be a better measure than the number of flood wardens. However, the number of flood champions will vary from place to place based on numerous contextual factors such as level of risk, capacity and capability. Therefore, it is not necessarily comparable nor a reflection of change in resilience.

It should also be noted that the quality of the response by champions/flood action groups is equally, if not more important, than the quantity of these groups.

Time taken to recover – get back into property/infrastructure fully functioning

This indicator is considered useful due to the temporal nature of the concept. However, many people may be forced to move back into properties which are not fully recovered (for example, still wet) due to the fact that they cannot afford to stay elsewhere and may not have appropriate insurance. Therefore, the indicator perhaps needs to be further specified to include only those people returning to fully refurbished/recovered properties.

There is scope to expand this indicator to monitor the number of people returning to properties which are more resilient than before the flooding event. This presents an opportunity to understand whether communities are learning from flood events. Further

thought was also given as to whether monitoring PFR measures should be incorporated into this indicator.

Number of commercial and residential properties at high risk of flooding with PFR

There is an issue of literacy within the general public when it comes to PFR and the associated level of protection, which may lead to inaccuracies in data collected via survey.

It will also be important to consider the effectiveness of existing PFR measures, not just their presence. Effectiveness is highly specific to the individual household level and various aspects need to be considered. These include whether the PFR measures have been effectively maintained (for example, as a result of wear and tear/usage), the functionality of PFR (which is often only as good as the standard of protection to surrounding properties), and the temporal aspect of climate change.

Home, business and contents insurance uptake

Insurers are unlikely to provide this data and so the indicator would rely on survey data. Unfortunately, during flood recovery many people are understandably unwilling to co-operate with such information requests (they want to be left alone). Therefore, there is likely to be a large degree of inconsistency in the responses provided across a given area, and there might be differences in willingness to participate across different communities. One solution could be to obtain the data from an active focus group that is willing to provide this over time. The National Flood Forum could be useful to consult on this.

Insurance literacy among respondents would need to be considered, should this indicator be assessed through surveying, as this could affect the accuracy of the data received. For example, many people are under insured compared to their perceived level of insurance. Any surveys/questions will need to be differentiated for homeowners and tenants; tenants are often unaware of what their landlord is obliged to cover, what their landlord has covered, and what they should be covering.

Lessons/recommendations from the use case investigation

In general, the use case leads suggested that further thought could be given to the relationship between outputs and outcomes. This process could lead to an array of measures that might not necessarily reflect resilience. In the case of Rochdale, it is about understanding the journey people are going on (consideration given to the journey over time and at fine spatial scales). Attention could be paid to the potential adaptivity of any resilience measures/programmes, the success of these, and the sharing of progress/knowledge. The use case leads also suggested that there is a need to define what a more resilient community might look like – to set a vision and then work back from that. They advised that the term ‘recovery’, and its measurement as a concept, is often misunderstood. Measures of ‘recovery’ need to focus on whether a community has stabilised to the point where its members are again able to fully ‘participate in society’. They proposed that the definition needs to move beyond a currently limited view.

In terms of specific recommendations for actionable indicators, the discussions identified that the timing, type and amount of data collection are crucial. To gain an understanding of vulnerability, it will be important to collect data annually and post flood (as well as having an understanding of the baseline). Discussions around the survey approach indicated that an ‘appreciative inquiry’ approach to surveying several of the more sensitive indicators which capture community views may be effective, possibly alongside or embedded within engagement already being carried out. Appreciative inquiry can be defined as:

‘a model that seeks to engage stakeholders in self-determined change’

and

‘an approach to organisational change which focuses on strengths rather than on weaknesses - quite different to many approaches to evaluation which focus on deficits and problems’

This could involve a minimal sample size, which is considered ideal as certain communities in ‘at-risk’ areas in Rochdale have previously been surveyed heavily. Further surveying needs to avoid potential disengagement in the future due to over engagement.

As previously identified, one solution could be to obtain the data from an active focus group that is willing to provide this data over time. This could allow change to be measured consistently over a period and may provide inroads into their neighbours’ perceptions. The limitations would be the rate of return and objectivity of the respondents. It is important that the users of the indicators understand the context, including how authentic and reliable responses are. Use case leads suggested that this limitation could be reduced/resolved by considering the standard of evidence (robustness) for each indicator in the shortlisting process. They proposed that in instances where concepts are highly subjective (for example, the fear of flooding and mental health impacts of flooding), the objectivity of a given indicator could be graded, alongside aspects such as the available sample size of the data, to help narrow down the feasible indicators for monitoring.

For those indicators that cannot currently be measured, it was suggested that alternatives could be provided in the interim without losing the initial indicator as a goal to be measured in the future. For example, instead of attempting to quantify the mental health impacts of flooding, an alternative could be to quantify the availability of resources/services for supporting mental health and the use of these services.

Appendix 2: Full list of socio-demographic indicators

Resilience variables and data availability (Environment Agency 2022a)

Social resilience

Variable and rationale*	Indicators*	Effect on resilience	Data availability	Unit	Data source
Educational equity: Educational deprivation increases vulnerability.	% of population with a PCT Level 4 qualification and above	Positive	Y	LSOA and above	Census (nomis)
Age: Older people may be more vulnerable.	% of population over 65	Negative	Y	LSOA and above	Census (nomis)
Transportation access: No access to private transport decreases mobility.	% of population without a car or van	Negative	Y	LSOA and above	Census (nomis)
Communication capacity: Access to high-speed internet improves access to warning system.	% of homes with broadband	Positive	Y	Postcode (see below in community capital too)	Ofcom (2013)
Language competency: Communities with a higher proportion of the population having English as a second language are more vulnerable.	% speaking English as a first language	Positive	Y	LSOA and above	Census (nomis)
Special need: Disability and long-term health problems increase vulnerability.	% of population with long-term health problems or disability	Negative	Y	LSOA and above	Census (nomis)

Economic resilience

Variable and rationale*	Indicators*	Effect on resilience	Data availability	Unit	Data source
Housing capital: Home owners are more likely to be able to access economic resources.	% of home ownership	Positive	Y	LSOA and above	Census (nomis)
Employment: employment is usually associated with higher economic resources.	% economic active % employed	Positive	Y	LSOA and above	Census (nomis)
Income and equality: Income deprivation is equivalent to low economic resources.	Indices of deprivation: % in the top 10% of income deprivation	Negative	Y	LSOA and above	Census (nomis)
Single sector employment dependence: Reliance	% employment in fishing, farming, forestry or extractive industries	Negative	Y	Ward and above	Census (nomis)

Variable and rationale*	Indicators*	Effect on resilience	Data availability	Unit	Data source
for employment on sectors that are at risk of damage or disruption from flooding (for example, farming, fishing, forestry) increases likelihood of disruption from flooding.					

Institutional resilience

Variable and rationale*	Indicators*	Effect on resilience	Data availability	Unit	Data source
Flood coverage: Flood insurance reduces financial consequences of flooding.	% of houses covered by insurance for flooding	Positive	N		
Municipal services: Emergency service provision reduces vulnerability.	% of local lead flood authority expenditure for emergency services	Positive	N		
Mitigation (1): Flood preparedness (awareness) reduces vulnerability.	% of population signed up for flood alerts	Positive	Y	Flood warning zones converted into LSOA data	Environment Agency (internal data set)
Mitigation (2): Flood preparedness (existence of flood wardens) increases capacity to respond.	Number of flood wardens in area of influence	Positive	N	Incomplete, inconsistent local data	Environment Agency
Previous disaster experience: Previous flood experience increases resilience (preparedness) but is affected by the amount of flood damage.	Number of previous floods in x years affecting over 100 properties Flood damage per flood	Positive	N	Locally collected data. No national data set	Environment Agency

Infrastructure resilience

Variable and rationale*	Indicators*	Effect on resilience	Data availability	Unit	Data source
Housing style: Temporary and mobile homes are less resilient.	% of housing units that are not bungalows or mobile homes	Positive	N		
Shelter capacity: The availability of temporary accommodation makes it easier to rehouse flooded people.	Units of accommodation available for homeless people	Positive	N		
Recovery: Evacuation centres provide a safe place for people to go.	Number of designated evacuation centres	Positive	N		

Community capital

Variable and rationale*	Indicators*	Effect on resilience	Data availability	Unit	Data source
Place attachment: Migration over short term is associated with reduced sense of belonging.	Net migration to area of influence over past 5 years	Negative	Y	Local authority level	**ONS**
Political engagement: Political engagement increases community's ability to influence decisions and access resources.	% of voter participation in elections	Positive	Y	Constituency level (Ward level turnouts will also be available for local elections)	Electoral Commission
Social capital – civic involvement: Organisations increase the networks of relationships and support.	Number of community/voluntary/ religious organisations in area of influence	Positive	N		
Broadband coverage: Broadband coverage increases community's ability to access information and local online groups.	% of households where super and ultra-fast fixed broadband is available. Ofcom Connected Nations 2018 report	Positive	Y	Available at output area, postcode, and local authority level	Ofcom
Mitigation and social connectivity: Community engagement in flood action groups increases ability to respond to flooding.	Number of flood action groups or community resilience groups in area of influence	Positive	N		

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