

Tidal Flooding on the Clyde Options Analysis and Scoping of Adaptation Pathways

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1 Executive summary

1.1 Aims and approach

Adaptation pathways is a decision-making tool employed to adapt to climate change and the inherent uncertainties of future risk. This research sets-out to explore the evidence base to help design and apply adaptation (investment) pathways to the tidal reach of the Clyde drawing on international practice and UK guidance. This research is a first for Scotland providing:

- information to help frame actions and decisions at a local, regional and national level around future flood resilience and long-term adaptation on the Clyde;
- practical insights into the application of adaptation pathways practice to the Clyde; and
- a starting point for the co-design and development of a route map and future actions.

This research takes a system-wide perspective covering the tidal reach of the Clyde from the tidal weir in Glasgow to the outer estuary at Gourrock.

At a national level this report will support the delivery of the Second Climate Change Adaptation Programme (SCCAP) by **informing development of a credible climate adaptation plan for the tidal reach of the river Clyde**, and provide practical insights that can be shared with other regions. At a regional and local level, the findings are designed to support the Clyde Mission, which is working across public and private sectors to ensure the Clyde is adaptable and resilient to the effects of climate change; and achieve the grand challenge **“to make the Clyde an engine of sustainable and inclusive growth”**.

This research builds on previous ClimateXChange research to address the following research aims:

1. Review knowledge, insight and expertise;
2. Assess current and future flood risk scenarios;
3. Consider the environmental, economic and social implications of adaptation;

4. Recommend measures that would be most appropriate to pursue further to inform the development of a plan guided by an adaptation pathways approach;
5. Identify potential financing options for these measures;
6. Consider synergies and trade-offs with the wider work of Clyde Mission and other relevant policies and plans;
7. Share the learning and explore the resources needed to make progress.

The approach and methodology draw on best practice and are structured around the steps set out in BS861:2021 “*Adaptation to climate change – Using adaptation pathways for decision making – Guide*”.

1.2 Making use of adaptation pathways for the Clyde

Over the last 200 years the Clyde has experienced significant adaptation and transformation. As the region looks ahead, this continued transformation will be essential to addressing future climate shocks and stresses (including tidal flood risk), alongside socio-economic and environmental ambitions; to meet the needs and aspirations of both current and future generations.

Building on this history of adaptation, stakeholders have expressed a desire to re-imagine the current relationship between the river, people and place; to create a vibrant connected river corridor and waterfront, and make the river “*an asset to be proud of*”. The approach to adaptation for the Clyde will therefore need to be transformation-orientated, with place making and resilience at the heart of investment decision making and future pathway design.

The following conclusions arising from this research will be important to understanding the necessary transformation and framing adaptation pathways practices for the Clyde.

Sea Level Rise. The climate evidence shows that it is plausible for mean sea levels in the Clyde to rise by 1.5m to 2.5m over the next 120 years, and higher still in the future. The consequence, if adaptation measures are not taken, is areas that are currently exposed to occasional flooding from coastal storms and tidal surges will become inter-tidal or permanently under water. Within the context of traditional planning timeframes, which are typically 5-25 years, sea level rise may appear to be “*non-urgent*” to decision makers. However, considering today’s investments will shape the infrastructure and land-use well into the next century, then planning for sea level rise and tidal flood risk becomes “*important*” in the short-term.

Decision making framework. The practice of adaptation pathways is flexible enough to be used as an investment decision making framework and/or as a project planning tool. For the Clyde, the practice has most to offer, in the short-term, as a decision-making framework. This will enable the approach to work alongside established governance arrangements and delivery routes (public and private), to embed resilience and adaptation within existing and near-term plans; and inform shared ambitions and plausible investment pathways.

Investment options and pathways. The scoping described in this report has identified a number of strategic approaches to option development for the Clyde, described as: Business as Usual, Strategic Wins, Blue-Green Units, Blue-Belt and Blue-belt + Barrage. These strategic approaches have been combined to illustrate five plausible long-term investment pathways for adaptation on the Clyde. The five investment pathways are:

- Reactive
- Delayed Adaptation
- Managed Transformation

- Mission-based (no Barrage)
- Mission-based (with Barrage)

Investment practice shift. Adaptation to tidal flood risk on the Clyde is unlikely to satisfy stakeholder ambitions unless it is supported by a shift in appraisal and investment practice that unlocks wider sources of funding and finance. The shift will need to drive public and private investment, and sustain a working portfolio of projects that collectively realise multiple (societal, economic and environmental) benefits to enhance the resilience of the Clyde today and in the future.

Resource commitment. Adaptation pathway approaches will assist decision making and development of solutions for the “*non-urgent but important*” impacts of sea level rise and tidal flood risk. Existing flood risk management investment practices and mindsets will however be insufficient to foster the public-private collaboration and innovation to deliver transformation-orientated adaptation. For adaptation to succeed, it will be necessary to embrace new ways of working and build multidisciplinary team(s) supported by dedicated resources and early investment.

1.3 Recommendations for future route-map development

1.3.1 Priority recommendations

Looking forward it is important “*not to rush to solutions*”, but instead focus on creating ‘a shared vision’, a collaborative decision-making environment and a system-wide understanding of adaptation and resilience. These are key foundations for enabling an adaptation pathways approach to be implemented for the Clyde.

Recommended first steps for adaptation on the Clyde include:

- R1.1 agree a *framework* for the application of adaptation pathways for the Clyde that fosters systems-thinking and a process for place-based decision making;
- R1.2 agree what “a resilient Clyde” means, to inform *design principles* for investment and pathway development, and shape indicators for monitoring and evaluation;
- R1.3 establish a ‘*resilience zone*’, a geographic boundary for decision-making;
- R1.4 build an action plan (*Mission Map*) for the first five years of investment; and
- R1.5 scope and develop a knowledge portal to support innovation, collaboration and long-term monitoring and evaluation.

These recommendations are demanding and will require stakeholders to think in new ways and commit time and energy to the process. The potential reward, in terms addressing tidal flood risk and achieving the grand challenge ‘*to make the Clyde an engine of sustainable and inclusive growth*’ is locally, regionally and nationally compelling. This report includes a recommended *framework* and *resilience zone*, and indicative *design principles* and *Mission Map*; providing a starting point for future stakeholder co-design and action.

1.3.2 Secondary recommendations

Based on importance to understanding of the system behaviour and interdependencies, informing adaptation pathway choices (in terms of benefits and trade-offs), and exploring potential investment triggers, this report also recommends:

- R2.1 exploring the strategic investment case for a multi-functional tidal barrage within the inner and middle reaches of the Clyde;
- R2.2 exploring the strategic investment case for creation of new tidal wetlands in the vicinity of the Clyde, White Cart and Black Cart Rivers; and
- R2.3 exploring the risks to critical road and rail infrastructure in the outer reach of the Clyde, and options to sustain future infrastructure services.

Two further enabling activities are also recommended, namely:

- R2.4 explore and develop operational spatial units to support integrated decision making at system, reach and neighbourhood scales; and
- R2.5 explore and develop Clyde specific design and appraisal guidance to support spatial planning, and embed co-benefits within investment decision making and pathway design.

1.3.3 Additional recommendations

A core aspect of this research and the dialogue undertaken with stakeholders has related to the availability of existing data and evidence. Looking forward it is recommended that regional and national investments to enhance access to data and make evidence more accessible to a wider range of audiences are continued.

Furthermore, it is recommended that future investments are expanded to:

- strengthen incentives for public and private bodies to share data and information;
- support non-specialist users to access, use and interpret available datasets; and
- share and promote learning from adaptation as new data and evidence emerges.

More important than enhancing data and information management, is the need to enhance awareness of resilience and adaptation practices to support collaboration and planning for climate change. It is recommended that guidance is enhanced and developed to support:

- understanding of system-thinking, resilience and adaptation pathway practices;
- uptake of a broader portfolio of adaptation measures including grey, green and soft infrastructure;
- appraisal of adaptation investments, and greater consideration of co-benefits, value-creation, and funding and finance within business cases; and
- monitoring and evaluation of adaptation to strengthen impact analysis, pathway design, and learning related to the costs and benefits of adaptation.

Glossary

Adaptation – The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustments to expected climate and its effects. (Source: *Intergovernmental Panel on Climate Change 2014*¹)

Incremental adaptation: Adaptation actions where the central aim is to maintain the essence and integrity of a system or process at a given scale.

Transformational adaptation: Adaptation that changes the fundamental attributes of a system in response to climate and its effects.

Adaptive management - process of iteratively planning, implementing and modifying strategies for managing resources in the face of uncertainty. Note – Adaptive management involves adjusting approaches in response to observations of their effects and changes in the system brought on by resulting feedback effects and other variables. (Source: *BS8631:2021*²)

Adaptation Pathways (APs) – series of adaptation choices involving trade-offs between short-term and long-term goals and values (Note: These are processes of deliberation to identify solutions that are meaningful to people in the context of their daily lives and to avoid maladaptation). (Source: *BS8631:2021*)

Mission – a concrete target, achievable step towards a grand challenge that contextualises projects. (Source *Mazzucato, M and Dibb, G. (2019). Missions: A beginner's guide. UCL Institute for Innovation and Public Purpose, Policy Brief series (IIPP PB 09)*³)

Resilience – The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganising in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning and transformation. (Source: *Intergovernmental Panel on Climate Change 2014*)

System – A set of elements or parts that is coherently organised and interconnected in a pattern or structure that produces a characteristic set of behaviours, often classified as its “function” or “purpose” (Source: *Donella H. Meadows, “Thinking in Systems” 2008, Sustainability Institute*)

Systems thinking – is a set of synergistic analytic skills used to improve the capability of identifying and understanding systems, predicting their behaviours, and devising modifications to them in order to produce desired affects. These skills work together as a system. (Source: *Ross D. Arnold, Jon P. Wade, 2015*⁴)

¹ https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-TS_FINAL.pdf

² <https://standardsdevelopment.bsigroup.com/projects/2019-00219#/section>

³ https://www.ucl.ac.uk/bartlett/public-purpose/sites/public-purpose/files/iipp_policy_brief_09_missions_a_beginners_guide.pdf

⁴ <https://doi.org/10.1016/j.procs.2015.03.050>

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2 Introduction

2.1 Purpose of the report

This research sets-out to explore the evidence base and application of adaptation pathways practices for the tidal reach of the Clyde to support plans and actions similar to those underway in other river and coastal areas in the UK and internationally. This research and scoping exercise is a first for Scotland, providing:

- information to help frame actions and decisions at a local, regional and national level around future flood resilience and long-term adaptation on the Clyde;
- practical insights into the use of adaptation pathways practice on the Clyde; and
- a starting point for co-design and development of a future route map and actions.

The research takes a system-wide perspective covering the tidal reach of the Clyde from the tidal weir in Glasgow to Gourock. The tidal reach is show on *Figure 1* below.

Figure 1: Tidal reach of the Clyde



Image credits: @2021 Microsoft Corporation Earthstar Geographics SIO

At a national level the findings of this report will support delivery of the Second Climate Change Adaptation Programme (SCCAP) 2019-2024⁵ vision: *“We live in a Scotland where our built and natural places, supporting infrastructure, economy and societies are climate ready, adaptable and resilient to climate change”*.

At a regional level the findings will directly support the Clyde Mission’s vision driven approach backed by evidence and facts; and at a local level the findings will support actions to deliver community resilience and secure strategic assets.

This research draws upon Climate Ready Clyde’s ‘Glasgow City Region Climate Adaptation Strategy and Action Plan’⁶ and the associated reports on adaptation and transformation. This research also builds upon recent ClimateXChange reports on flood risk management investment⁷, and managed adaptive pathways approaches⁸.

⁵ <https://www.gov.scot/publications/scottish-climate-change-adaptation-programme-progress-report-2021/>

⁶ <http://climatereadyclyde.org.uk/adaptation-strategy-and-action-plan/>

⁷ <https://www.climateexchange.org.uk/research/projects/international-practice-on-assessing-investment-needs-and-securing-investment-to-adapt/>

⁸ <https://www.climateexchange.org.uk/research/projects/taking-a-managed-adaptive-approach-to-flood-risk-management-planning-in-scotland/>

2.2 Research aims and objectives

The objective of this research and scoping exercise is to support the SCCAP by **informing development of a credible climate adaptation plan for the tidal reach of the river Clyde** and provide practical insights that can be shared with other coastal regions in Scotland and beyond. The seven research aims are summarised in *Table 1*.

The outputs of this research will be used to guide wider activity under the Clyde Mission⁹ which is a national, place-based economic development initiative that seeks to achieve a Grand Challenge: **“to make the Clyde an engine of sustainable and inclusive growth, for the city, the region and for Scotland”**. The geography of interest to Clyde Mission is the river and the riverside, up to 500 metres from the river itself.

Table 1: Summary of the research aims

| # | Research aim |
|---|--|
| 1 | Review knowledge, insight and expertise from existing data sets and reports relating to flooding, wave overtopping and coastal erosion on the Clyde, and international case studies from coastal regions with adaptation pathways. |
| 2 | Assess current and future flood risk scenarios under projected sea-level rise, including different climate (including high end scenarios) and socio-economic projections, and consider uncertainty through to 2100 and beyond ¹⁰ . |
| 3 | Consider the environmental, economic and social costs and benefits of a range of adaptation measures which could be taken in response to these scenarios, linked to Just Transition principles ¹¹ in the short, medium and longer term. This should include consideration of the implications for the management and operation of the sewer network and wastewater treatment works along the tidal River Clyde. |
| 4 | Recommend which of the measures above it would be most appropriate to pursue further to inform the development of a climate adaptation plan guided by an adaptation pathway approach, giving priority to the use of nature-based solutions, though it is recognised that a pathway is likely to involve a mix of green and grey infrastructure and consider wider land-use planning. |
| 5 | Identify potential financing options for these measures. |
| 6 | Consider synergies and trade-offs with the wider work of Clyde Mission (for example, the net zero masterplan for the Clyde) and other relevant policies and plans (e.g. the indicative and emerging Regional Spatial Strategy and fourth National Planning Framework), considering the principles of a well-being economy and wider place making. |
| 7 | Share the learning amongst stakeholders in the Glasgow City Region and across Scotland and explore the resources needed to progress on an adaptation pathways approach. |

⁹ Clyde Mission is a cross-sector collective of those with the knowledge, resource and levers that can help to achieve the Grand Challenge. It comprises five interlinked Missions, that seek to deliver benefits for the environment, businesses and communities. Those five Missions are: Create new, good and green jobs and a workforce with the skills to secure those jobs; Use vacant and derelict land for the benefit of the economy, the environment and communities; Adapt to climate risks, especially flooding; Accelerate Scotland’s progress to net zero; and Use the river to create better places for people and communities.

¹⁰ A 2300 high emissions scenario is currently specified for all Coastal Map updates.

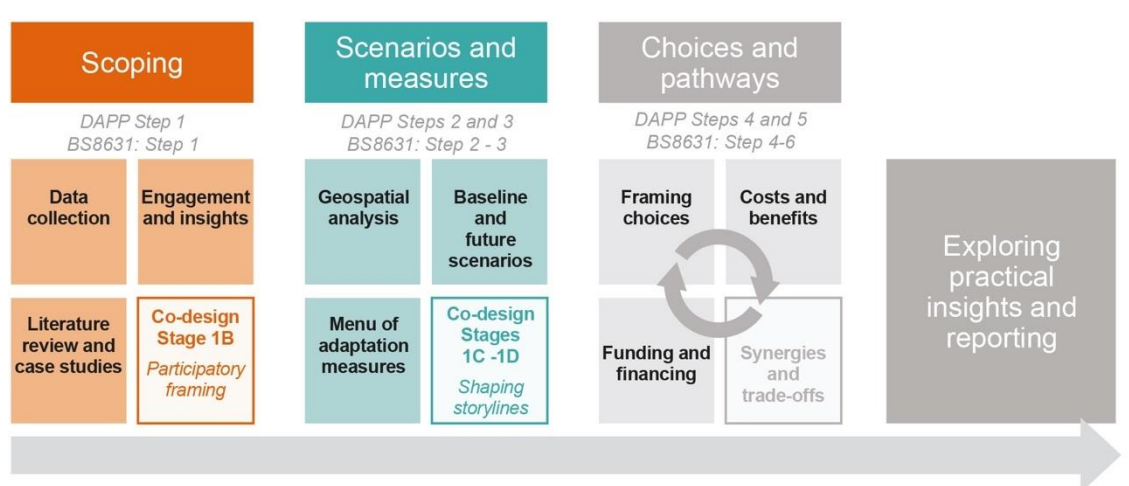
¹¹ <https://www.gov.scot/groups/just-transition-commission/>

2.3 Summary of approach

To best achieve the research aims and support learning amongst stakeholders, the research method was structured around Steps 1-6 of BS8631:2021 'Adaptation to climate change – Using adaptation pathways for decision making – Guide'¹². The methodology is summarised in *Figure 2* below and set-out in more detail in *Section 3.0*.

The methodology also aligns with Steps 1-5 of the internationally recognised Dynamic Adaptive Policy Pathways (DAPP) methodology by Haasnoot et al., 2019¹³; designed to support decision making under deep uncertainty.

Figure 2: Summary of the research phases and alignment with BS8631 :2021 steps



2.4 Structure of the report

This report is set out to align with the research methodology and research aims. *Section 3.0* describes the research methodology and the approach to the outputs. *Section 4.0* describes the international literature review and lessons of potential value to the Clyde (research aim 1). *Section 5.0* then sets-out scoping stage insights (research aim 1), and ambitions and aspirations for the tidal river Clyde. This section concludes with the framing of design principles for design of future adaptation (investment) pathways.

Section 6.0 provides an overview of flood mechanisms relevant to the Clyde, sets-out baseline and future flood risk scenarios and provides an approach to designing for uncertainty and considering high-end scenarios for the Clyde (research aim 2).

Sections 7.0 describes adaptation measures and choices of most relevance to the tidal River Clyde. *Section 8.0* then explores the application of adaptation pathways on the Clyde and considers: costs and benefits, funding and finance, synergies and trade-offs, and priorities (research aims 3-6).

Sections 9.0 and *10.0* set out practical insights and conclusions to inform future pathway development and sharing of lessons (research aim 7). Finally, *Section 11.0* summarises recommendations for taking forward the application of adaptation pathways practices on the Clyde (research aims 4 and 7).

¹² <https://shop.bsigroup.com/products/adaptation-to-climate-change-using-adaptation-pathways-for-decision-making-guide/standard>

¹³ https://doi.org/10.1007/978-3-030-05252-2_4

3 Methodology

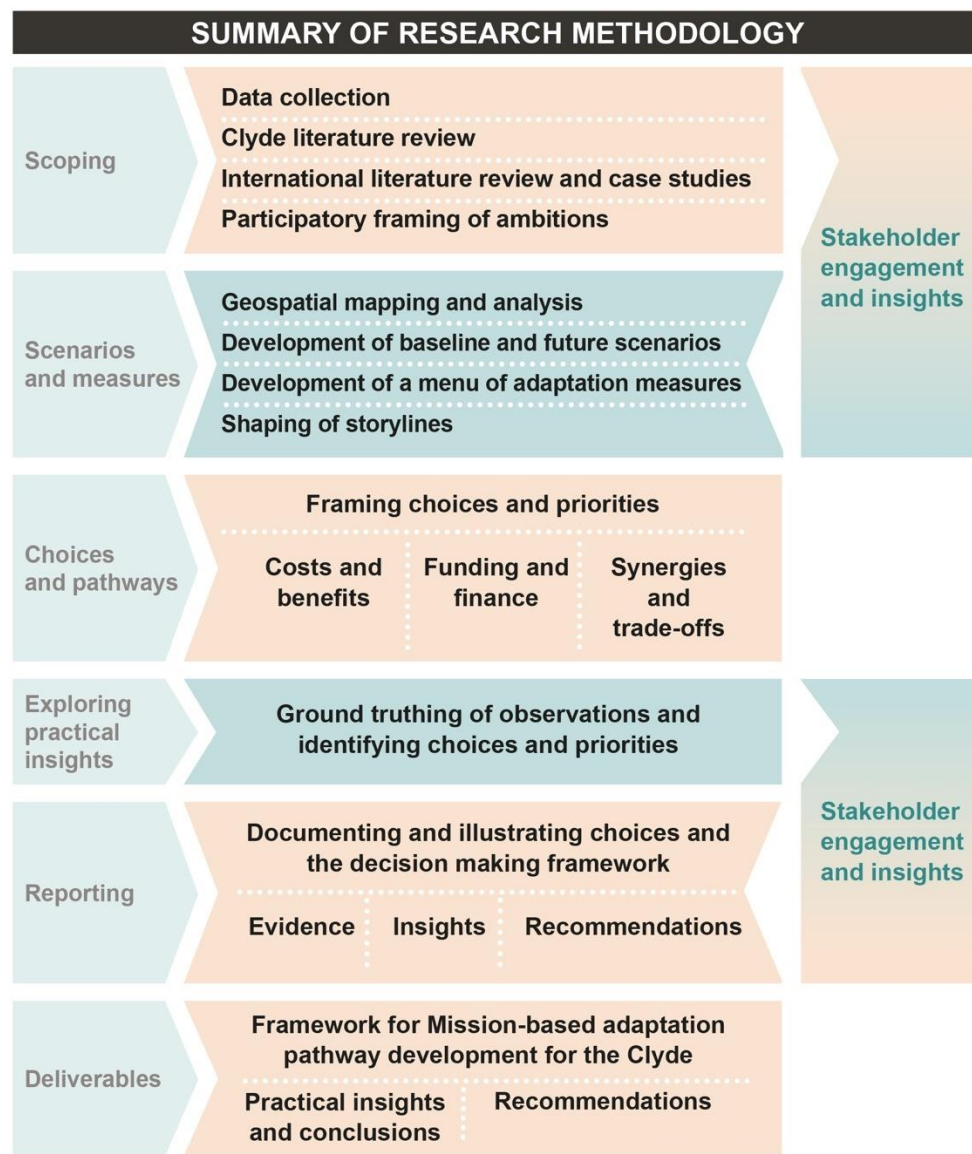
3.1 Approach and methodology

This research and scoping study are informed by best practice in adaptation pathways and builds on previous ClimateXChange research¹⁴. The approach and methodology are designed around the Steps set out in BS861:2021 and includes:

- a review and analysis of existing evidence (climate change, adaptation, local policies and plans) and engagement with local stakeholders;
- a multi-disciplinary scoping of potential adaptation responses and choices; and
- reporting of practical insights, conclusions and recommendations.

Figure 3 summarises the methodology and workflow. More detail on the approach to the international and local literature reviews is provided in *Sections 4.1* and *5.1*.

Figure 3: Description of the research approach and methodology



¹⁴ <https://www.climatechange.org.uk/research/projects/international-practice-on-assessing-investment-needs-and-securing-investment-to-adapt/>

3.2 Outputs and deliverables

The outputs of this research and scoping study have been designed to provide:

- a baseline of evidence to support future plans and decision making;
- practical insights into the potential use and application of adaptation (investment) pathways for the tidal river Clyde; and
- recommendations for future co-design and development of plans and actions.

Anticipated primary users of this research include:

- The Scottish and UK Government
- Local Authorities and SEPA
- Clyde Mission
- Climate Ready Clyde
- Metropolitan Glasgow Strategic Drainage Partnership

3.3 Research limitations

A key characteristic of adaptation pathway practices and adaptative management approaches is stakeholder (public and private) collaboration and co-design of objectives, actions and outcomes. Co-design of this work with stakeholders and decision makers was beyond the scope, resource commitment and timeframe of this work.

To mitigate this limitation, engagement has taken place with the project Steering Group, the Clyde Mission Adaptation Sub-Group and interested local parties to inform our understanding of local ambitions, challenges and opportunities; and ground-truthing of insights was undertaken. This is however not a substitute for co-design, and as such the research outputs and deliverables have been shaped to support future development and stakeholder collaboration and community engagement.

4 International practice and lessons

4.1 Approach to international case studies

A review of international case studies created an evidence base to inform approaches and identify practical insights that can be applied to the Clyde in developing adaptation pathways.

Four case studies were selected from a long list of international locations undertaking coastal adaptation pathways approach in a similar coastal or tidal context. The long-list drew on the jurisdictions included in previous ClimateXChange research 'International practice on assessing investment needs and securing investment to adapt (2021)'.¹⁵

To select the final case studies, they were assessed against their relevance to:

- Transformational approaches
- Consideration of nature-based solutions
- Delivering wider economic benefits
- Mission driven
- Contributing to net zero agenda

The final case studies selected for review were Copenhagen, New York, San Francisco Bay and STAR2CS Interreg Project¹⁶. For more information, *Appendix A* provides a full list and summary of all the documents reviewed.

Table 2: Overview of the selected international case studies

| Case Study | Description |
|---|---|
| Copenhagen ¹⁷ | Rising sea levels threaten the low-lying city of Copenhagen whilst increasing urban development at the water edge increases vulnerability. As a result, Denmark is taking an approach to mainstream adaptation into long-term development. |
| New York ¹⁸ | New York is highly exposed to sea level rise and extreme weather events. As the most densely populated city in the United States it has a high vulnerability. Following extensive damage and inundation from Hurricane Sandy in 2012, the city has been pro-active in developing plans and policies to increase resilience. |
| San Francisco Bay ¹⁹ | A densely populated urban area, San Francisco sits in a sheltered estuary with complex interactions requiring coordinated adaptation solutions to adapt to rising sea levels. |
| Star2CS (Interreg Project) ²⁰ | Star2CS is an Interreg funded project working across 8 pilot areas in Europe with the objective to overcome the |

¹⁵ <https://www.climateexchange.org.uk/research/projects/international-practice-on-assessing-investment-needs-and-securing-investment-to-adapt/>

¹⁶ Short Term Adaptation for Long Term Resilience to Climate Change (STAR2C) is not a specific location, but a cross-border collaboration between eight European locations to embed adaptation into their decision-making and planning processes.

¹⁷ https://en.klimatilpasning.dk/media/568851/copenhagen_adaption_plan.pdf

¹⁸ <https://www1.nyc.gov/assets/planning/download/pdf/planning-level/waterfront/wrp/revisions-2017/policy-62-guidance-document-nov2018.pdf>

¹⁹

https://www.sfei.org/sites/default/files/toolbox/SFEI%20SF%20Bay%20Shoreline%20Adaptation%20Atlas%20April%202019_highres.pdf

²⁰ <https://star2cs.com/pilot-projects/decision-making-processes/>

'implementation gap' currently faced in delivering local action to build adaptation capacity.

The documents were reviewed against the following research questions:

1. What is the framing of the adaptation pathway approach?
 - 1.1. What are the drivers for adopting adaptation pathways?
 - 1.2. What are the objectives and ambitions of the adaptation pathway case study?
 - 1.3. What principles underly the adaptation pathways approach?
2. What adaptation measures have been explored or adopted?
 - 2.1. How have adaptation measures been selected?
 - 2.2. What range of adaptation measures have been selected or explored?
 - 2.3. How have measures been assessed and synergies/trade-offs been assessed?
3. What is the approach taken to pathways design?
 - 3.1. How have triggers and thresholds been identified?
 - 3.2. How are/will triggers and thresholds be monitored?
4. How does the case study visualise pathways and route maps?
5. Are there any other lessons that have been learnt/identified applicable to the Clyde?

4.2 Research insights

4.2.1 What is the framing of adaptive pathways?

All the case studies reviewed are considering adaptation within the wider challenges and complexities that they face and not in isolation. New York, in particular, takes a highly integrated and strategic approach with adaptation part of the wider socio-economic transformation of the city. Adaptation pathways then sit within the context of a strategic plan for adaptation. Whilst there is intent to undertake an adaptation pathways approach and the tools and evidence base is being developed, it is not fully developed in any of the case studies.

4.2.2 What adaptation measures have been explored or adopted?

San Francisco Bay Shoreline Adaptation Atlas takes a strategic approach to identifying adaptation options for the Bay area with an emphasis on identifying nature-based approaches. Their approach acknowledges the importance of the interconnected system and local diversity by defining Operational Landscape Units (OLUs), typologies and opportunity mapping.

The Atlas describes OLU as *"...a practical way to manage the physical and jurisdictional complexity of the Bay shoreline. Home to beaches, wetlands, marinas, ports, landfills, lifeline infrastructure, residential neighbourhoods and more, San Francisco Bay's 650-kilometer (400-mile) shoreline is diverse, which means there is no one-size-fits-all solution to rising sea levels. The OLU framework divides the Bay shoreline into 30 distinct OLU, geographic areas that share common physical characteristics. OLU cross traditional jurisdictional boundaries of cities and counties but adhere to the boundaries of natural processes like tides, waves, and sediment movement"*.

In New York City, the 'NYC Urban Waterfront Adaptive Strategies' is provided for planners and policy makers to identify and evaluate strategies for adaptation pathways. The guide identifies a range of potential adaptation strategies including interventions for a set of coastal area typologies representative of the range of conditions found in New York. Strategies are assessed for the applicability, costs and benefits and impacts. An

evaluation framework to monitor – assess - evaluate – develop pathways for communities is provided to identify and develop adaptation strategies providing the best cost benefit for their area.

This strategic approach to identifying suitable adaptation measures to be developed into adaptation pathways at the local level is a similar approach proposed for the Clyde. The need for locally appropriate measures and acknowledgement of the locally diverse character and needs of the system is highlighted in these case studies. Therefore, the use of typologies, character zones and operational landscape units could also be applied within the Clyde to support opportunity mapping and portfolio development.

4.2.3 What is the approach taken to pathways design?

In San Francisco Bay, an identified portfolio of measures appropriate to each area, are used as a toolkit of solutions to strategically inform choices, pathway design and phasing of implementation. Whilst this does not constitute an adaptation pathway plan itself, the approach supports the adaptation planning processes by targeting investment choices and supporting pilots, monitoring and evaluation to continually enhance evidence for future adaptation choices and investment.

New York is the only case study that has established monitoring and indicators for informing their adaptation pathways approach. The NPCC1 (New York Panel on Climate Change) report provides a useful framework for identifying indicators, criteria for selection and indicator categories that could be developed within the Clyde context. They also aim to not just measure changes in climate but also in impacts, adaptations and socio-ecological factors. The concept of “locally appropriate yet regionally co-ordinated” is valuable to the Clyde and wider implementation of adaptation pathways across Scotland.

A key aspect of the New York monitoring is the interaction between scientists and decision-makers in the creation of an ongoing assessment of current climate trends and a set of hyper-local projections by the NPCC. This has led to the development of the New York City Climate Change Resilience Indicators and Monitoring System (NYCLIM). NYCLIM is co-generated by scientists and communities to determine which indicators should be tracked over time to provide the most useful information for planning and preparing for climate change in New York City. This process by which climate risk information is co-generated by practitioners, policy makers and scientists is especially transferable.

4.2.4 How does the case study visualise pathways and route maps?

None of the case studies have a fully developed adaptation pathway plan with route maps visualised. San Francisco proposed a conceptual pathways map triggered by sea level rise but not tied to specific timeframes.

Reference in the New York case study was made to developing climate action plans that are scenario neutral with decisions that do not require information about the likelihood of different future scenarios. However, Rosenzweig and Solecki (2014) state that whilst New York have developed downscaled scenarios, these may not characterise the likelihood of future changes completely and could potentially lead to maladaptation.

The Star2C propose a pathways visualisation with tipping points at the point of changing ecological conditions i.e. ‘bottlenecks’ for Natura2000 sites. They visualised pathways for both the preferred climate adaptation route and preferred Natura2000 adaptation route to help identify synergies between the approaches. This approach also highlights

the importance of additionally considering adaptation for habitat resilience and not maintaining a singular focus on adaptation for human or economic assets.

4.2.5 Are there any other lessons that are applicable to the Clyde?

The Copenhagen Urban Lab and Rebuild by Design are examples of design-led tools for engagement at the local level (rather than the system). These approaches could be adapted and employed to develop and inform future recommendations within the Clyde Mission, stimulate public-private partnerships for innovative solutions and generate interest, enthusiasm and acceptance for a transforming area.

4.3 Lessons from Copenhagen

4.3.1 Copenhagen Lab

Copenhagen Urban Lab was a design challenge to develop a tool to assist coastal communities in the challenges of adapting to sea level rise and storm surges. Through the Urban Lab the Copenhagen Lens was developed as a stakeholder engagement tool to develop a co-created vision for coastal adaptation. The Lens provides a visualisation to explore overlap and interdependencies between values across environmental, social and economic principles. It aims to increase awareness and collaboration to identify synergies and create multi-functional approaches to coastal adaptation (Ramboll, 2018).

4.4 Lessons from New York

4.4.1 Identifying Indicators

New York has assembled a suite of indicators to monitor climate change and adaptation to inform their decision making. This includes the creation of criteria to select indicators and defined categories. As adaptation decisions are informed by more than just physical climate, indicators should not just be based solely on climate data but should also consider social-economic changes such as demographic data and land-use, and advancements in research and evidence of whether adaptation is taking place and where. Indicators should therefore be identified across the following areas:

Table 3: Indicator categories and examples in New York informed [by NPCC1 \(2010\) report, Chapter 7: Indicators and Monitoring](#)²¹

| Indicator category | Description | Indicators examples |
|--|--|--|
| Physical climate change variables | Monitoring the physical climate for climate change trends relative to forecast values. | Temperature, precipitation and sea level rise. |
| Risk exposure vulnerability and impacts | Information tracking potential impacts of hazards as well as socio-economic changes indicating change in vulnerability to hazards. | Electrical outages, combined sewer overflows, salt-water intrusion. |
| Adaptation measures | To monitor the implementation of adaptation strategies and their effectiveness. | The number of buildings in coastal flood zones, insurance index of infrastructure coping capacity to climate change, |

²¹ <https://nyaspubs.onlinelibrary.wiley.com/doi/full/10.1111/j.1749-6632.2009.05321.x>

| | | |
|---------------------|---|---|
| | | number of days with major telecoms outages. |
| New research | Monitor advances in knowledge and scientific progress related to climate change theory, impacts, adaptation strategies and their effectiveness. | Tracking new climate change research findings that may alter future projections and uncertainties and affect adaptation strategies. |

Lessons from New York NPCC1 (2010) report suggest appropriate indicators should additionally fulfil the following criteria as far as possible:

Table 4: Extract from [NPCC1 \(2010\) Report Indicators and Monitoring](#)²²

| | |
|-----------------------------|--|
| Policy relevance | <ul style="list-style-type: none"> • Provide a representative picture of climate conditions. • Measure stakeholder-relevant climate change hazards and society's responses. • Be simple, easy to interpret, and able to show trends over time. • Be responsive to changes in climate and related human activities. • Provide a basis for intra- and intercity comparisons. • Have a scope applicable to critical regional climate change issues. • Have a baseline, threshold, or reference value or range of values against which to compare, so that users can assess the significance of the values associated with it through time. |
| Analytical soundness | <ul style="list-style-type: none"> • Be theoretically well founded in technical and scientific terms. • Based on local, national, or international standards with consensus about its validity. • Readily linked to economic models, scenario projections, and information systems. |
| Measurability | <ul style="list-style-type: none"> • Based on readily available data or data available at a reasonable cost–benefit ratio. • Be adequately documented and of known quality. • Updated at regular intervals, in accordance with reliable procedures. • Of sufficient length in time and numbers to allow a quantitative statistical evaluation of the uncertainties associated with the data. |

4.4.2 Monitoring Indicators

New York has developed a collaborative cross-sector monitoring system to track indicators over time to inform decision making for climate change named NYCLIM (New York City Climate Change Resilience Indicators and Monitoring System). Four types of indicators are monitored: climate, risks, vulnerability and resilience; across scientific institutes, practitioners and local communities. Close collaboration and participatory decision making across stakeholders with a central data repository is central to the operation of the system.

²² <https://nyaspubs.onlinelibrary.wiley.com/doi/full/10.1111/j.1749-6632.2009.05321.x>

4.5 Lessons from San Francisco Bay

4.5.1 Policy Units

The [San Francisco Bay Shoreline Adaptation Atlas](#)²³ takes a strategic approach to identifying adaptive options for the Bay area with an emphasis on nature-based approaches. It acknowledges the importance of the interconnected system but with locally diverse characteristics by taking an approach to define Operational Landscape Units to provide a planning framework to prioritise nature-based solutions. The boundaries for the units were established by physical and ecological processes that are large enough to consider adaptation strategies but small enough to manage and organise effectively. Each unit was then characterised by a range of factors including natural, physical and ecological gradients to patterns within the built environment to create a typology. The typology creates an understanding of how stretches of shoreline that are similar in character and have similar problems, may support similar types of adaptive measures.

4.5.2 San Francisco Design Guidance

'[Guidance for incorporating sea level rise into capital planning](#)'²⁴ presents a framework to consider sea level rise within the capital planning process. The guidance requires projects to evaluate their vulnerability through an assessment process based on an asset vulnerability as a combination of 1. Exposure, 2. Sensitivity and 3. Adaptive capacity. A low score is associated with limited exposure, minimal sensitivity and high adaptive capacity resulting in an overall low vulnerability rating. In contrast, a high score and therefore highly vulnerable asset is significantly exposed, highly sensitive or limited adaptive capacity to sea level rise. Rating thresholds are identified based on different asset types and their tolerance for inundation.

4.5.3 San Francisco Rebuild by Design

Rebuild by Design is a design competition replicating the success of Hurricane Sandy competition in San Francisco. The challenge was to tackle long-term sea level rise to meet the question: 'can the Bay Area come together to shift its course and build a more resilient region before a big disaster hits and can we address other regional challenges along the way?'. This design competition format assists collaboration between private and public sectors together to tackle a system wide problem, create a sense of opportunity and promote the aspirations of the area.

4.6 Lessons from STAR2C

A key learning from the STAR2C work is there can be multiple preferred pathways depending on the framing of investment priorities. In the case of the Natura2000 example, preferred pathways were illustrated for climate-orientated adaptation and nature-oriented adaptation. The mapping of these pathways considered three types of tipping points: nature based, technical and climate change to design future pathways.

²³

https://www.sfei.org/sites/default/files/toolbox/SFEI%20SF%20Bay%20Shoreline%20Adaptation%20Atlas%20April%202019_highres.pdf

²⁴ https://onesanfrancisco.org/sites/default/files/inline-files/San_Francisco%20SLR_Guidance%20SLRTC%20REV%20TO%20CPC%20Jan%202020.pdf

5 Scoping

5.1 Policy review

5.1.1 A place-based policy review

To support this research a place-based policy review gathered contextual information for the project. This desk-based review performs two functions in this study: the analysis of relevant objectives captured in place-based policy documents in and around the Clyde region; and the identification of the policy challenges and opportunities that could support the development of the adaptation pathways approach for managing future flood risk from the Clyde.

The purpose of the review was to:

- capture an overview of the document, highlighting relevance to this study;
- determine the temporal scale of the objectives (short, medium, long term);
- identify key objectives relating to adaptation and climate change;
- record the partners involved in the development of the document, for future reference; and
- provide a brief commentary on the potential value and adaptation pathway approach to the objectives set-out in the individual documents, or how the documents objectives may support development of adaptation pathways for the Clyde.

Readily available policy documents relevant to flood risk, adaptation and climate change were investigated to create the descriptive baseline. The study team, through the Steering Group and through the local knowledge acquired from working in the Scottish flood risk management sector, reviewed pertinent documents thought to be most relevant to the development of the adaptation pathways. The study team identified several key reports from the Clyde area which provide some contextual background on early development of adaptation plans in and around the Clyde, and can be used to develop an understanding of the policies and their objectives.

The following reports were reviewed, a complete summary of the review for each document is provided in *Appendix B*.

- Glasgow City Region Indicative Regional Spatial Strategy (iRSS)²⁵
- Clyde Mission Position Paper, Better Places for Communities (unpublished)
- Clyde Mission Position Paper, Climate Adaptation (unpublished)
- Glasgow City Region Economic Strategy 2017 – 2035²⁶
- National Transport Strategy 2²⁷
- Climate Ready Clyde Theory of Change²⁸
- Draft NPF4²⁹
- Clyde Regional Marine Plan Pre-Consultant Draft³⁰

²⁵

<https://glasgow.gov.uk/councillorsandcommittees/viewSelectedDocument.asp?c=P62AFQDNDXT181NT81>

²⁶ <https://www.northlanarkshire.gov.uk/sites/default/files/2020-10/Glasgow%20Region%20-%20Economic%20Strategy%202017%20-%202035.pdf>

²⁷ <https://www.transport.gov.scot/publication/national-transport-strategy-2/>

²⁸ <http://climatereadyclyde.org.uk/our-vision-theory-of-change/>

²⁹ <https://www.transformingplanning.scot/national-planning-framework/draft-npf4/>

³⁰ <https://www.clydemarineplan.scot/wp-content/uploads/2019/06/Pre-consultation-draft-Clyde-Regional-Marine-Plan-18-March-2019.pdf>

- The Environment Strategy for Scotland³¹
- ClydePlan Strategic Development Plan³²
- Glasgow City Region Climate Adaptation Strategy and Action Plan³³
- MGSDP Surface Water Management Masterplan³⁴
- River Clyde 2050 Strategic Development Framework³⁵
- A Green Network Strategy for Glasgow City Region³⁶

5.1.2 Review of findings

A key finding from the place-based literature review is the importance of people and place in the Clyde region. Across the active partners, there is the long-term ambition to improve resilience to the impacts of climate change across the region, whilst focusing on reconnecting the spatial zones within the region that have historically been divided by natural features, infrastructure, or socio-economic divides. Through committing to connectivity, the Clyde region is thus improving the quality of life with increased work, social and leisure opportunities. The ambition and driver to deliver all this, whilst remaining committed to building on the cultural heritage that makes the Clyde region what it is today.

The review found the linkages between the timings of the various plans challenging to structure. In the bigger picture, the Indicative Regional Spatial Strategy the Clyde Mission and Climate Ready Clyde documents focus on the long-term outlook for the Clyde. This presents opportunity for the adaptation pathways approach to influence the shaping of the delivery of increased resilience to flood risk, through working with long term planning and investment across the region.

Longer term planning. The development of the Fourth National Planning Framework (NPF4) outlines planning objectives to 2045, underpinning the wider driver for a longer-term vision. Draft NPF4 focuses on the objectives of climate change, resilience, health and wellbeing, Net Zero and greener space, linking together the partner organisations across the Clyde region and their ambitions. There may be opportunity to work with NPF4 to capture the longer-term vision of an adaptation pathway approach and facilitate this vision through working with the shorter-term actions delivered through Clyde focused plans and strategies, as outlined further here.

The Green Network paper highlights the importance of connectivity in the Clyde region. Each document reviewed, irrelevant of timescale, discusses connectivity and working together to improve connectivity between people and places. There may be opportunity for the Green Network strategy, drawn closer by adaptation pathways, to work with the wider NPF4 and vision, and the plans with flexibility in short to medium term planning, to increase connectivity whilst delivering on all other objectives.

Short to medium term planning in the Clyde Region. In the short to medium term (20-50 years), plans such as the Glasgow City Region Climate Adaptation Strategy, the Glasgow City Region Economic Strategy and the Clyde Regional Marine Plan present

³¹ <https://www.gov.scot/publications/environment-strategy-scotland-vision-outcomes/documents/>

³² <https://www.clydeplan-sdpa.gov.uk/strategic-development-plan/current-plan/current-strategic-development-plan-july-2017>

³³ <http://climatereadyclyde.org.uk/adaptation-strategy-and-action-plan/>

³⁴ <https://www.mgsdp.org/index.aspx?articleid=21091>

³⁵

<https://www.glasgowconsult.co.uk/UploadedFiles/River%20Corridor%20Strategic%20Development%20Framework%20-%20Draft%20November%202018.pdf>

³⁶ <https://www.gcvgreennetwork.gov.uk/green-network-strategy>

the opportunity to facilitate change through short term actions and medium-term planning.

The Glasgow City Region Climate Adaptation Strategy has a 2025 action plan, 2030 strategy and 2050 vision. This approach could support and help build on adaptation pathways through the short-term delivery of actions, a strategy that guides actions and enables action review in the medium term and the long-term vision which enables goals to be delivered, through flexible partnership working.

The Glasgow City Region Economic Strategy (2017) builds on the City Deal and existing projects to develop an outlook to 2035, accompanied by a 3-year action plan, prioritising actions to be delivered that will lead to greater collaboration and joint working to boost the working economy. Building on the Glasgow City Deal, the economic strategy, could also be a mechanism to gradually introduce and implement adaptation pathways, potentially through the provision of the short-term economic mechanisms that could help facilitate the delivery of adaptation pathways as the pathways progress. An update of the Economic Strategy was published in December 2021³⁷.

The Clyde Marine Plan sets out a vision for the next 20 years. This shorter-term vision presents an opportunity to support the development of a longer-term strategy for planning and investment in the marine environment with the application the flood risk adaptation pathways. Working with the land-based Clyde partners to meet the objectives could lead to a more integrated management approach between the Marine and Land based activities, offering further economic, social and environmental value to the Clyde region. There are further potential links with the Marine Plan and the River Clyde 2050 Strategic Development Plan, which has a greater focus on connectivity, river corridors, working alongside the social, economic and environmental measures in the region.

Furthermore, adaptation pathways for the Clyde could again link together the objectives of the land-based organisations with the Marine environment by linking together the MGSDP Surface Water Management Masterplan. Presently, this plan has no specific mention about the Clyde as a waterbody. Adaptation pathways could help to develop a way of working between the surface water management and the coastal waters, for the overall betterment of water quality, linking once again to the Clyde Marine Plan.

Summary of findings. All these papers included in this place-based review, guided by the new NPF4 and Climate Adaptation Strategy, could be enhanced by capturing adaptation pathway initiatives to help manage the increasing risk of flooding across the Clyde region, whilst working with partners to deliver these core objectives and vision of both the pathways, and the longer-term planning ideals.

Adaptation pathways would lead to greater opportunity in the Clyde region to bring together these various visions from a range of organisations who are all looking to achieve similar outcomes. The vision of the pathways, guided by the place-based literature review, and the needs of dealing with the anticipated impacts of climate change, can facilitate further integration of social, economic, and environmental objectives. Adaptation pathways will support and build on the importance of the Clyde for the region, geographically and culturally; Glasgow made the Clyde, the Clyde made Glasgow. Adaptation Pathways can ensure that this healthy, positive relationship between water and people continues.

³⁷ <https://glasgowcityregion.co.uk/wp-content/uploads/2021/12/GCR-EconomicStrategy-Final.pdf>

5.2 Stakeholder workshop

To inform this research and the evidence base for long-term adaptation pathways for the Clyde, a stakeholder workshop was held online in October 2021. The aims and objectives on the workshop were to:

- introduce potential future users (Clyde Mission, SEPA and MGSDP) to the research project and our emerging approach to explore and evaluate the use and design of adaptation pathways for the River Clyde;
- explore / test a framework for adaptation pathways choices and co-benefits for the River Clyde; and
- inform refinement of the framework for developing choices and adaptation pathways. This includes refinement of the narrative/language, and tailoring choices to the River Clyde.

In total 18 stakeholders participated from: SEPA, Scottish Government, Scottish Canals, West Dunbartonshire Council, Glasgow City Council, Scottish Futures Trust, Scottish Enterprise, and the University of Strathclyde. The workshop was structured around:

- What does good look and feel like for the Clyde?
- What co-benefits should solutions target?
- What are the key challenges to realising this choice of pathways?
- How can an adaptation pathways approach help to overcome these challenges?
- What are the quick wins?

Figure 4 below provides a snapshot of participants perspectives on ‘what good looks and feels like for the Clyde?’. A core theme running through these responses is ‘a vibrant connected river’ and the concept of making the river **‘an asset to be proud of’**.

Figure 4: Stakeholder responses to what does good look and feel like?



With respect to wider aspirations from future investments in adaptation, a diverse range of co-benefits were identified covering the following 10 themes:

- Greater connectivity with the river
- Blue-green infrastructure and associated amenity and water quality benefits
- Natural environment and biodiversity
- Health and well being
- Community resilience and civic pride
- Reduced inequalities and education

- Liveable neighbourhoods and affordable housing
- Jobs and investment
- Net Zero and sustainable development
- Green energy creation

Perceived key challenges to realising the above aspirations were:

- Making the business case and assigning value and benefits
- Land ownership
- Working across different tiers and localities of governance
- Bringing business together with the public sector
- Common agreement on goals and targets
- Working within existing plans and strategies and avoiding duplication
- Establishing an approach that has long term political support
- Resource capacity: people, skills and expertise

Looking forwards, the key areas where stakeholders perceive the process of adaptation pathways can add-value and support decision making included:

- supporting development of a clear vision, leadership and long-term strategy;
- enabling priorities to be set; and a programme of activities to be agreed;
- establish a flexible systems-based approach that can keep options open for the future;
- address different needs – ‘what trumps what?’;
- support development of the right tools to deliver including policy, regulation, data management;
- empowering participation, collaboration and resource commitment;
- establishment of a framework for measuring impacts and outcomes; and
- creating an adaptation framework that can be followed or picked up by multiple actors with the knowledge that they are all moving in the right direction.

Finally, perceived quick wins for adaptation were identified:

- involving local artists and writers in visual and textual narratives of the Clyde futures to support engagement and co-design;
- identify and address data gaps, including understanding the worst case for sea level rise to know where adaptation is not necessary;
- advancing thinking on the possibility of a tidal barrage to assess whether or not such a solution is viable or necessary;
- development of a masterplan that embraces adaptive design and links together existing initiatives (such as Climate Ready Clyde);
- pilot temporary solutions and land-uses to test ideas;
- use the remediation of vacant and derelict land to enable related uses and adaptation, with Govan Graving Dock highlighted specifically; and
- education and knowledge exchange related to climate resilience and adaptation practices.

Overall, a common message from the stakeholders was to ensure that adaptation on the Clyde is viewed as an opportunity, and that adaptation is used to see and create positives. This aligns with the Mission-based approach to adaptation explored in this report and local plans and strategies, and the international approaches seen in Copenhagen, New York, and San Francisco

5.3 Geospatial analysis

Freely available GIS datasets were analysed, in accordance with industry data standards, to provide an initial system-wide understanding of the Clyde, and the associated vulnerabilities to flood risk.

Selected GIS outputs are shown on the following pages:

- *Figure 5* provides an overview of the areas vulnerable to tidal flood risk. Areas shaded red represent the highest vulnerability and areas shaded dark green the lowest (based on the SEPA combined NFRA Scores)
- *Figure 6* shows the relationship between the areas at risk of flooding (shaded blue) and areas of social deprivation (shaded red), and
- *Figure 7* shows the relationship between the areas at risk of flooding (shaded blue) and the current growth area zones.

Section 6 of this report describes the baseline and future flood risk scenarios in more detail.

Figure 5: Combined NFRA Scores

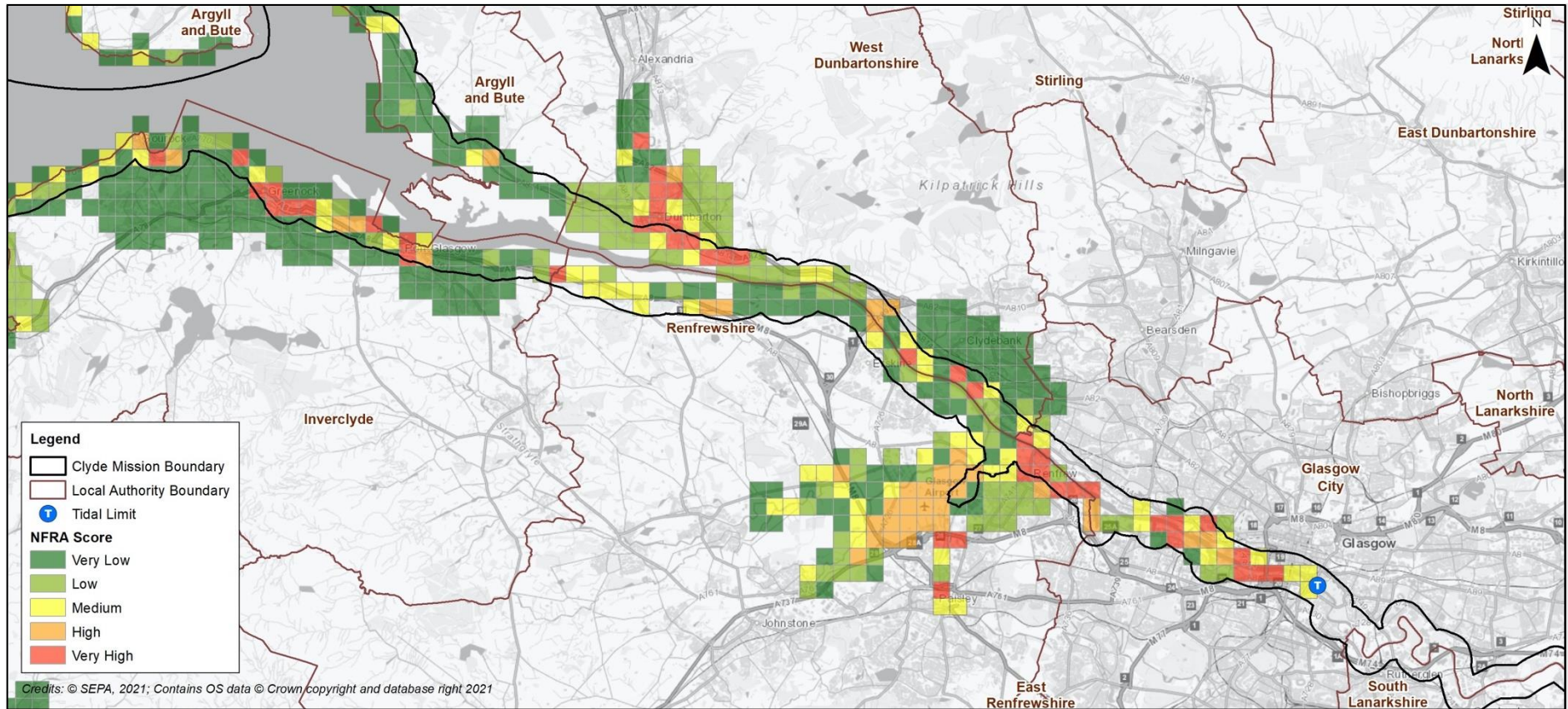


Image Credits: @SEPA, 2021: Contains OS data @ Crown copyright database right 2021

Figure 6: Flood risk and social deprivation

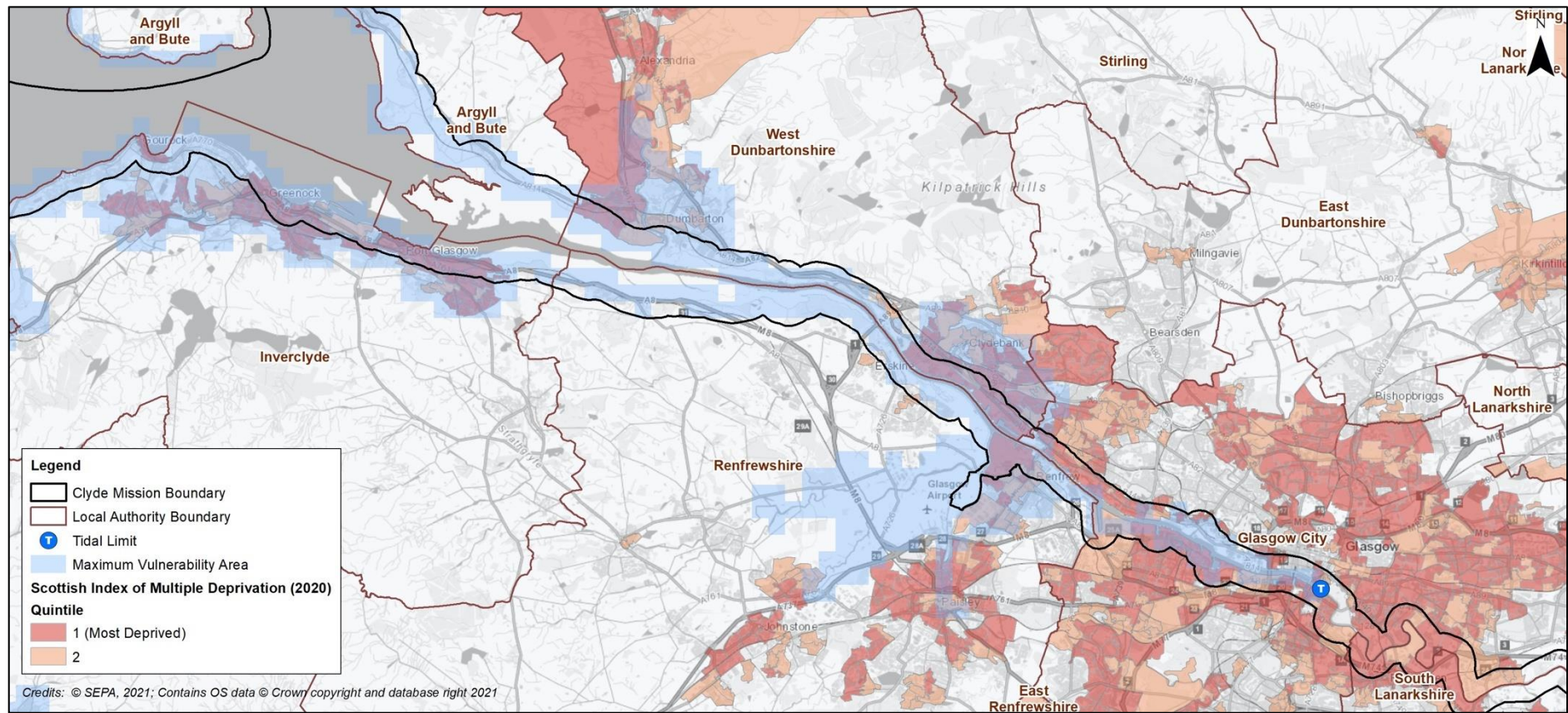


Image Credits: @SEPA, 2021: Contains OS data @ Crown copyright database right 2021

Figure 7: Flood risk and growth areas

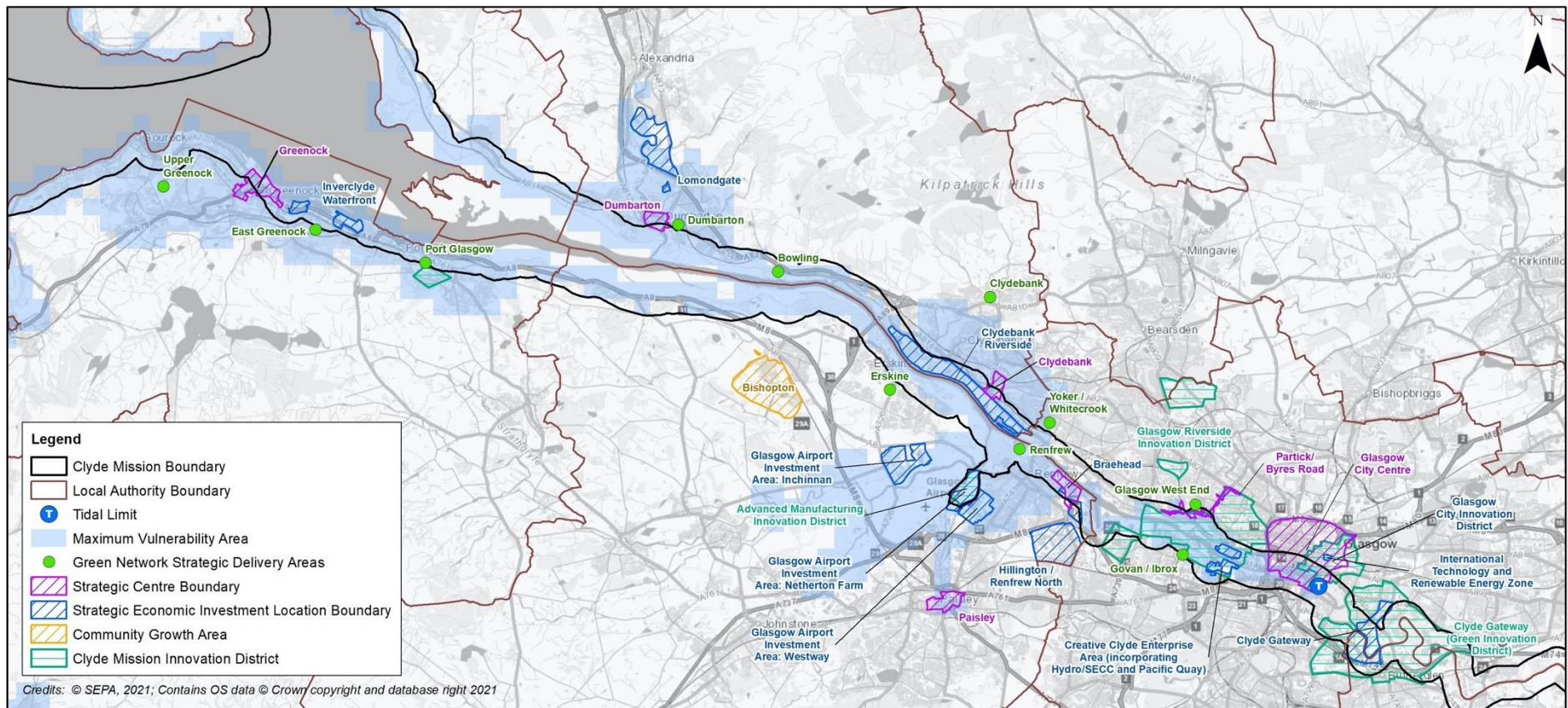


Image Credits: @SEPA, 2021: Contains OS data @ Crown copyright database right 2022

5.4 Ground-truthing

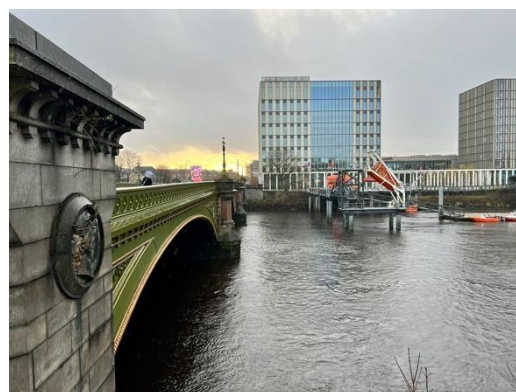
To further inform the project teams understanding of the opportunities and constraints to adaptation on the Clyde, site visits were undertaken over a period of 5-days during November 2021, alongside face-to-face meetings with interested stakeholders. These visits were supported by local stakeholders from Glasgow University, NatureScot, Clyde Mission, and Seawater Solutions.

The visits and meetings supported ground-truthing and validation of emerging insights from the research and scoping. *Figure 8* sets out key insights and observations arising from the site visits and potential triggers for future adaptation investments.

Figure 8 Summary of insights from ground-truthing

Public safety and security: A major consideration for future adaptation measures is the implications for public safety and public-realm design under normal conditions, during extreme events, and under conditions that exceed defence capacity. Future implications for emergency response and navigation will be important. The images below show a high tide inundating a public walkway; and the Clyde lifeboat facilities.

Implications for public safety and security are a potential trigger for future investment.



Asset life and condition. The water's edge is heavily engineered and managed throughout the system and the condition of defences and quay walls varies considerably. The images below show quay wall deterioration at Govan, and the tidal weir adjacent to Glasgow Green.

Knowledge of the form, ownership and condition of the assets and defences throughout the system will be important to adaptation decision making. Asset life and/or asset failure are potential triggers for future investment.



Major development: Throughout the corridor there is substantial development activity taking place. This development is not always shown within existing datasets and mapping information, demonstrating the importance of ground truthing. The images below show new development at Clydebank and a new bridge crossing (and associated development around Glasgow airport) on the Black Cart.

Development activity represents a potential trigger adaptation.



Critical infrastructure and utilities: Within the at-risk areas there is significant critical infrastructure which presents significant economic and social risks. The images below show the low-lying nature of rail infrastructure at Gourrock and the M8.

Risk to critical infrastructure represent a potential trigger for adaptation.



Navigation and marine activity: Economic activity on the Clyde is significant and maintaining navigation security will be important. The images below show activity at Greenock and a tug using the river at Clydebank.

Climate risk and opportunities from a marine / navigational perspective represent potential triggers for adaptation on the Clyde.



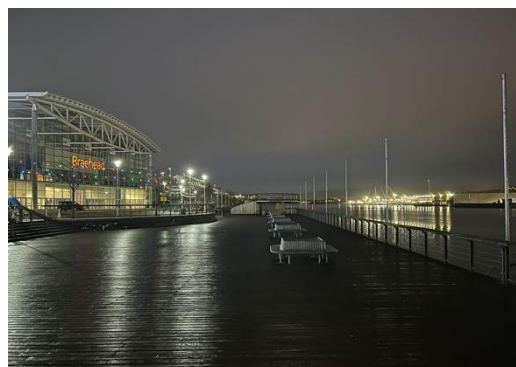
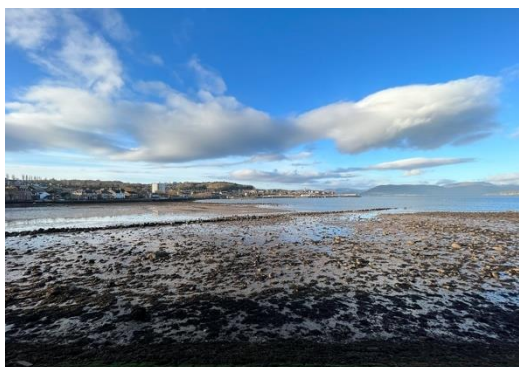
Environmental and heritage assets: The river corridor also includes widespread areas with environment designation and valuable heritage assets at risk of coastal squeeze and flood risk. The images below show the Ramsar and SPA designated area in the vicinity of the Erskine Bridge and heritage/navigation assets at Bowling.

Climate risks to environment and heritage assets represent potential triggers for adaptation on the Clyde.



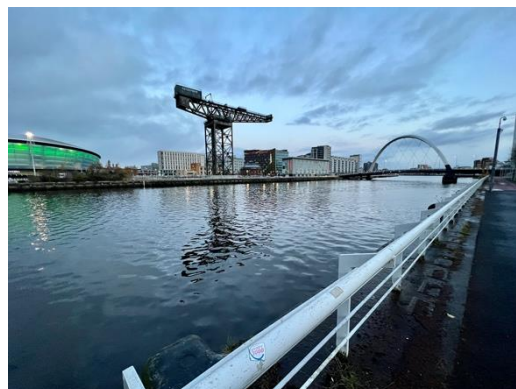
Residential and commercial property: The river corridor includes substantial residential, commercial and retail property that is vulnerable to flooding and future sea level rise. The images below show the low-lying nature of property at Gourock, and the Braehead commercial development in Renfrew.

Projected flood damages and/or single extreme events represent potential triggers for adaptation on the Clyde.



Mixed-use development in the central Glasgow: The centre of Glasgow includes substantial areas of water's edge development that are of regional and national importance, illustrated below.

Projected flood damages and/or single extreme events represent potential triggers.



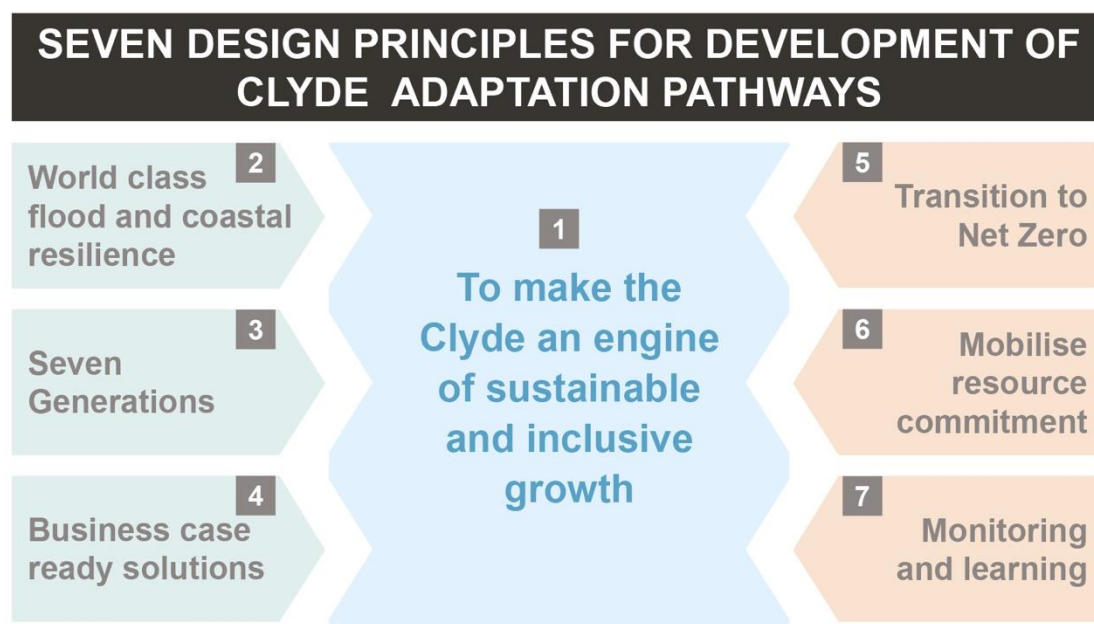
5.5 Framing of design principles for Clyde Adaptation Pathways

Building on the review of existing policies and plans, the stakeholder insights, the GIS work and the ground-truthing activities, working design principles have been established by the research team to frame adaptation ambitions for the Clyde. The design principles provide a basis for undertaking research aims 2-7 and exploring Clyde specific insights and recommendations. The seven design principles are:

1. To make the Clyde an engine of sustainable and inclusive growth;
2. To foster world-class place-based adaptation solutions for flood and coastal resilience, actively responding to:
 - Long-term sea level rise
 - Current and future extreme tides and coastal storms
 - Current and future fluvial and surface water flood risks³⁸
3. To take an outlook that responds to current societal needs and the interests of next 7 generations;
4. To support business case ready solutions that can secure public and private funding and finance, and realise long-term value for money and co-benefits;
5. To support the transition to Net Zero;
6. To mobilise resources and commitments to drive innovation and deliver initial adaptation measures and priorities; and
7. To provide a framework for monitoring and learning.

The design principles are summarised in *Figure 9* below. An outlook of seven generations has been adopted to reflect the central importance of intergenerational equity and long-term resilience to the consideration of adaptation investment pathways. Seven generations correlates to a horizon of 2200.

Figure 9: Seven design principles for development of Clyde adaptation pathways



³⁸ Analysis of fluvial and pluvial risk was outside the scope of this research.

6 Baseline and future scenarios

6.1 Introduction

This section summarises our understanding of both current (*Section 6.3*) and future (*Section 6.4*) flood risk for the Clyde. It draws on the work of a variety of sources such as the SEPA NFRA dataset, UKCP 09 and 18, Dynamic Coasts and the recently completed (2021) Tidal Modelling undertaken by Fairhurst consulting engineers.

To support investment decision making, this section uses the evidence to scope and describe the window of plausible uncertainty to be considered in future adaptation pathway design. This section does not set out to establish or predetermine appropriate standards of protections or acceptable levels of risk.

Section 6.5 recommends methods to help consider this knowledge in future decision making to enable responsible and sustainable development within the Clyde system.

6.2 Understanding flood mechanisms

To fully understand the flood risk on the Clyde we need to consider the different flooding mechanisms which occur. Each mechanism has a different cause, presents different challenges, and can be addressed by different solutions. Some will present a more immediate problem than others, but all need to be considered when planning the future of the Clyde.

The *Table 5* below describes the different mechanisms which occur on the Clyde and gives examples of the types of solutions which address this type of flooding. These lists are not exhaustive.

Table 5 – Description of different types of flood mechanisms

| Flood source / mechanism | Description | What can we do? |
|-------------------------------|--|---|
| Sea Level Rise | <p>Permanent raising of the sea level across the globe due to climate change.</p> <p>When designing with sea level it is common to either use the projections and design for a future date or to allow for a defined height of sea level rise.</p> | <p>Possible solutions include</p> <ul style="list-style-type: none"> - Permanent flood walls, - A tidal barrage - Relocation of assets to higher ground - Floating infrastructure <p>Flood storage will not be applicable as the volume of water is too vast.</p> |
| Tidal Flooding - Surge Events | <p>Sea water is pushed by storms and areas of high pressure and squeezed against the coast resulting in localised short term high-water levels. These surge events often last a day or two before they dissipate.</p> | <p>Possible solutions include</p> <ul style="list-style-type: none"> - A tidal barrier - Tidal flood plains / storage - Demountable defences - Resilient infrastructure (raised buildings, designing areas to be able to flood without damage) |

| Flood source / mechanism | Description | What can we do? |
|--------------------------|--|--|
| Wave Overtopping | In areas of open water such as estuaries and coastline wave overtopping can result in flooding. Here the volumes are less than with tidal surge events and have a more localised effect. This is likely to be more significant in the outer estuary. | Possible solutions to reduce wave overtopping volumes are: <ul style="list-style-type: none"> - Wave walls - Foreshore measures to dissipate energy (salt marsh, rock structures, dunes, beaches) |
| Fluvial Flooding | This is flooding from the water coming down from river catchments. High rainfall events can overwhelm river systems and result in breaching of defences. Like tidal flooding this is often modelled and described with a return period (such as 2% AEP ³⁹). | Possible solutions for fluvial flooding are: <ul style="list-style-type: none"> - Flood walls - Flood storage reservoirs - Natural flood management - Making room for the water, setting back from the river edge |
| Pluvial Flooding | High rainfall events can often overwhelm existing surface water drainage systems resulting in surface water flooding. This is typically a problem in built up areas where hard surfaces prevent water from being absorbed naturally into the soil. | The following solutions may help address pluvial flooding: <ul style="list-style-type: none"> - Sustainable urban drainage - Improved conveyance (e.g. sewer network), - Attenuation (storage for peak times) |
| Coastal Erosion | Although not directly a flood risk coastal erosion is strongly linked with tidal flooding, wave overtopping and sea level rise. Wave action and currents over time can erode soft foreshores, this can result in a retreat of the water's edge threatening property and infrastructure. | Solutions which calm the wave environment reduce erosion, these include: <ul style="list-style-type: none"> - Salt marsh - Rock structures - Dunes - Beaches <p>Similarly hard defences such as walls stop the process of erosion.</p> |

Some events may result in more than flood source, and it is inevitable that all will occur in conjunction with sea level rise in time.

6.3 Current flood risk

The Scottish Environmental Protection Agency (SEPA) publish a National Flood Risk Assessment (NFRA) approximately every 6 years, with the latest published in 2018. The NFRA dataset scores areas based on the receptors at risk to identify areas where flooding has a greater impact. This scoring has been plotted graphically *Figure 7*. This

³⁹ AEP stands for Annual Exceedance Probability which is the chance or probability of a natural event (usually rainfall or flood event) occurring annually and is usually expressed as a percentage.

shows there are several vulnerable hot spots currently along the Clyde, notably Greenock, Dumbarton, Renfrew, Govan and Glasgow City.

This NFRA dataset is used to define Potentially Vulnerable Areas (PVAs), which align with these hotspots. The Clyde and Loch Lomond Local Plan District considers the PVAs within the study area. The most recent version of this Flood Risk Management Plan for the area was published in December 2021.⁴⁰

The flooding anticipated is defined as from 3 flood sources in the Local Plan: coastal flooding (which in this context is understood to be tidal flooding), river flooding (fluvial) and surface water flooding. The previous 2016 Clyde and Loch Lomond Local Plan published a breakdown of the Average Annual Damages for the PVAs, shown in *Table 6*, which provides insight to the relative impact of different sources of flooding. The table shows that coastal/tidal flood risk is significant across the whole area but is not always the dominant source of risk. This distribution does not consider the long-term impacts of climate change.

Table 6 – Relative distribution of Average Annual Damages by source

| PVA | Distribution of Average Annual Damages by source | | |
|--|--|-----------------|---------------|
| | Coastal / Tidal | River / Fluvial | Surface water |
| Loch Lomond and Vale of Leven | 67% | 22% | 11% |
| Helensburgh to Loch Long | 79% | 11% | 10% |
| Yoker Catchment - Clyde (Clydebank to Partick) | 39% | 23% | 38% |
| Greenock to Gourrock | 20% | 30% | 50% |
| Clyde South - Port Glasgow to Inchinnan | 17% | 1% | 82% |
| White Cart Water Catchment | 14% | 51% | 35% |
| Glasgow City Centre | 32% | 0% | 68% |

Sea level rise is a process which has already been observed. The Met Office provided evidence to the UK parliament inquiry on Coastal Flooding and Adaptation to Climate Change⁴¹ in 2019 stating that since the start of the 20th century approximately a 20cm rise in global mean sea level has been observed, which relates to a 16cm relative sea level rise to the UK. That this rate is increasing has also been documented and current rates for global mean sea level rise are around 5mm per year according to the World Meteorological Organisation⁴². Whilst historically sea level rise has not been obvious to the public it is projected to become increasingly more so.

⁴⁰ <https://www2.sepa.org.uk/frmplans/documents/lpd11-clyde-and-loch-lomond-frmp-2021.pdf>

⁴¹ Coastal Flooding and Adaptation to Climate Change - Met Office Written Evidence, Nov 2019, The Environment, Food and Rural Affairs Committee. <http://data.parliament.uk/WrittenEvidence/CommitteeEvidence.svc/EvidenceDocument/Environment,%20Food%20and%20Rural%20Affairs/Coastal%20flooding%20and%20adaptation%20to%20climate%20change/written/101326.html>

⁴² Global Climate in 2015-2019: Climate Change Accelerates, September 2019, World Meteorological Organisation. <https://public.wmo.int/en/media/press-release/global-climate-2015-2019-climate-change-accelerates>

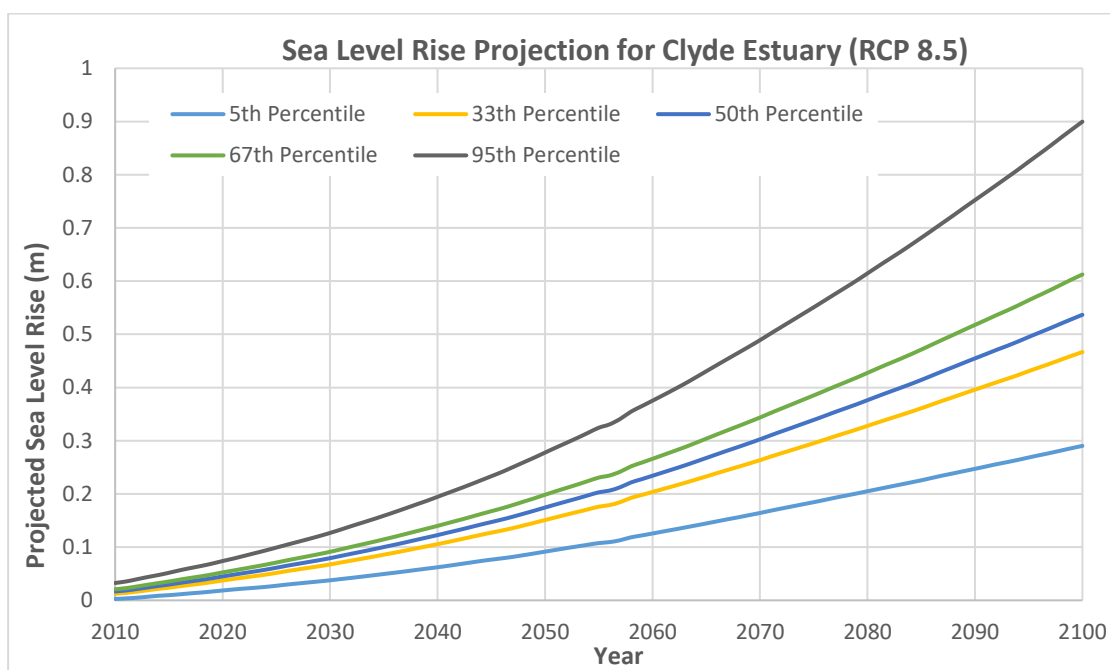
6.4 Future flood risks

UKCP18 publishes projections of the effects of climate change, including sea level rise around the UK. This data is based on reviews of the global mean sea level projections and adapted to consider local effects (e.g. vertical land displacement). The graph in *Figure 10* shows the sea level rise projection for the Clyde estuary from 2007 up to 2100. The different percentiles shown represent the uncertainty in the data.

RCP 8.5 is used in this report to illustrate the window of plausible uncertainty that should be considered in adaptation pathways. Current adaptation planning considers a range of RCP scenarios, and the Climate Change Committee recommends planning for 2C temperature increase, but assessing the risk of 4C rise⁴³.

The UKCP18 data does not fully consider the potential impacts from the ice caps, and the projections are a warning that significant additional sea level increase may be observed because of warming global temperatures.

Figure 10 - Sea level rise projections for Clyde estuary 2010 to 2100⁴⁴



Note 1: RCP stands for Representative Concentration Pathways. UKCIP guidance defines RCPs as “a method for capturing assumptions [economic, social and physical changes to our environment] within a set of scenarios. The conditions of each scenario are used in the process of modelling possible futures”⁴⁵.

Note 2: Percentile is the probability level associated with the projected sea level rise.

Note 3: The UKCP18 Science Overview Report provides an overview the most recent climate projects and tools to access climate data.⁴⁶

⁴³ <https://www.theccc.org.uk/publication/is-scotland-climate-ready-2022-report-to-scottish-parliament/>

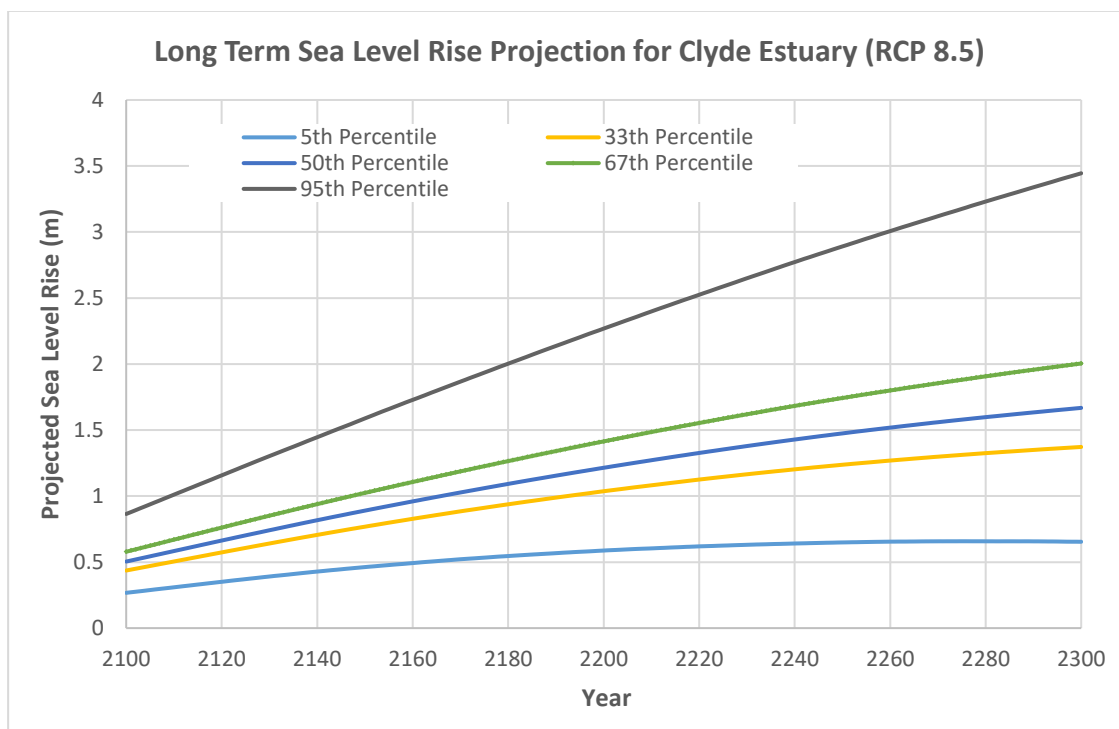
⁴⁴ UKCP18 Data for RCP 8.5 Scenario (Area 55.94 – 4.92) 21st Century Projections, 2018, Met Office

⁴⁵ <https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/research/ukcp/ukcp18-guidance---representative-concentration-pathways.pdf>

⁴⁶ <https://www.metoffice.gov.uk/pub/data/weather/uk/ukcp18/science-reports/UKCP18-Overview-report.pdf>

Sea level rise can be seen to accelerate from the current situation and the degree of uncertainty also increases further into the future. *Figure 11* shows the longer-term projections between 2100 and 2300. These projections show the continuing trend and growing uncertainty which exists with the climate projections.

Figure 11 - Sea level rise projections for the Clyde 2100-2300⁴⁷



The UKCP18 projections presented in *Figures 11* and *12* do not account for all possible contributions of sea level rise, for example the effects of ice sheet flows and the potential for rapid deglaciation of the ice caps. To account for this an additional high impact low probability scenario was developed, referred to as H++. H++ was described in UKCP09, the predecessor to the current UKCP18. The values in UKCP09 are still recommended for use in decision making.

The maps presented in *Figures 12* to *17* show the comparison between a sea level rise of 2-4m and the current areas identified by the NFRA data⁴⁸ as at medium risk for tidal flooding. The map on the left highlights areas which would become intertidal (flooded on each tide) or permanently inundated in the event of 2m+ sea level rise. The map on the right shows areas that are currently expected to be flooded in a 0.5% AEP (Annual Exceedance Probability) tidal event. The areas highlighted on both maps for each of the six figures are similar.

What is not projected on these maps, due to the uncertainty in the future impact on storm events, is what the flood risk area would look like for a 0.5% AEP event with 2m+ of sea level rise. We can expect this area to be significantly greater.

Sea level rise, whilst currently in motion is unlikely to have a significant impact on the Clyde in the short term. It will gradually undermine the ability for the system to withstand tidal extremes and lower the effective standard of protection to all areas. This process will be steady over the next 30 – 50+ years, and then likely to accelerate.

⁴⁷ UKCP18 Data for RCP 8.5 Scenario (Area 55.94 – 4.92) Extended Projections, 2018, Met Office

⁴⁸ National Flood Risk Assessment, 2018, SEPA

Figure 12 - Greenock sea level rise comparison with extreme flooding

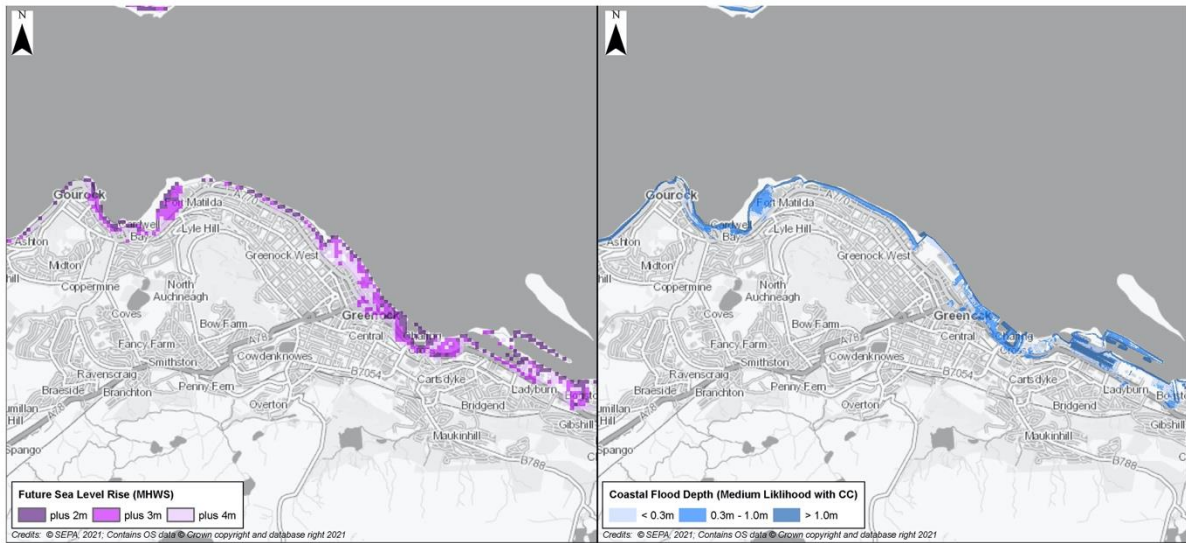


Figure 13 - Port Glasgow sea level rise comparison with extreme flooding

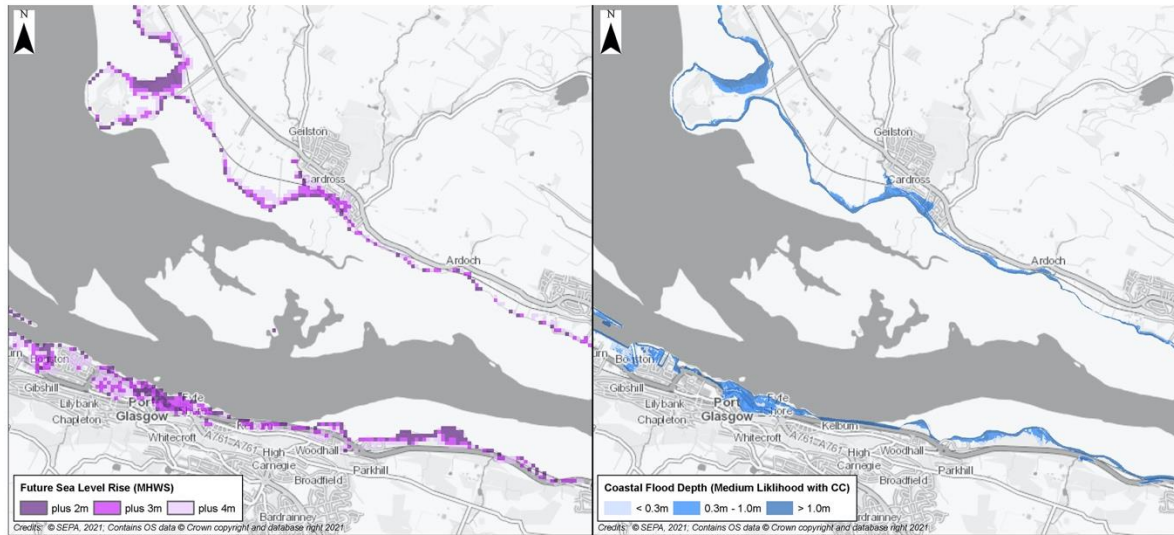


Figure 14 - Dumbarton sea level rise comparison with extreme flooding

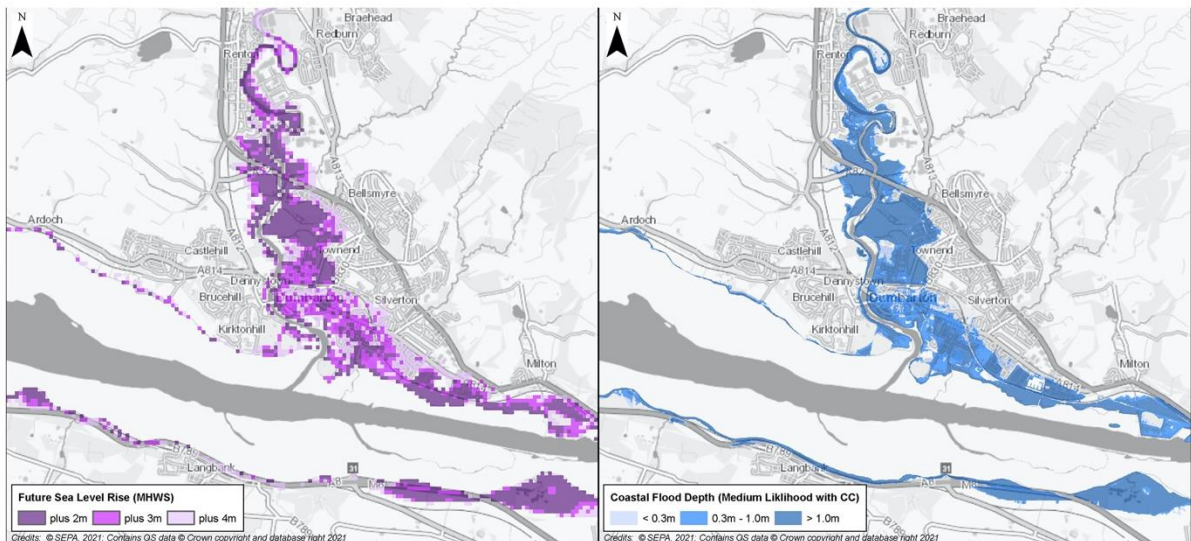


Figure 11 - Clydebank sea level rise comparison with extreme flooding

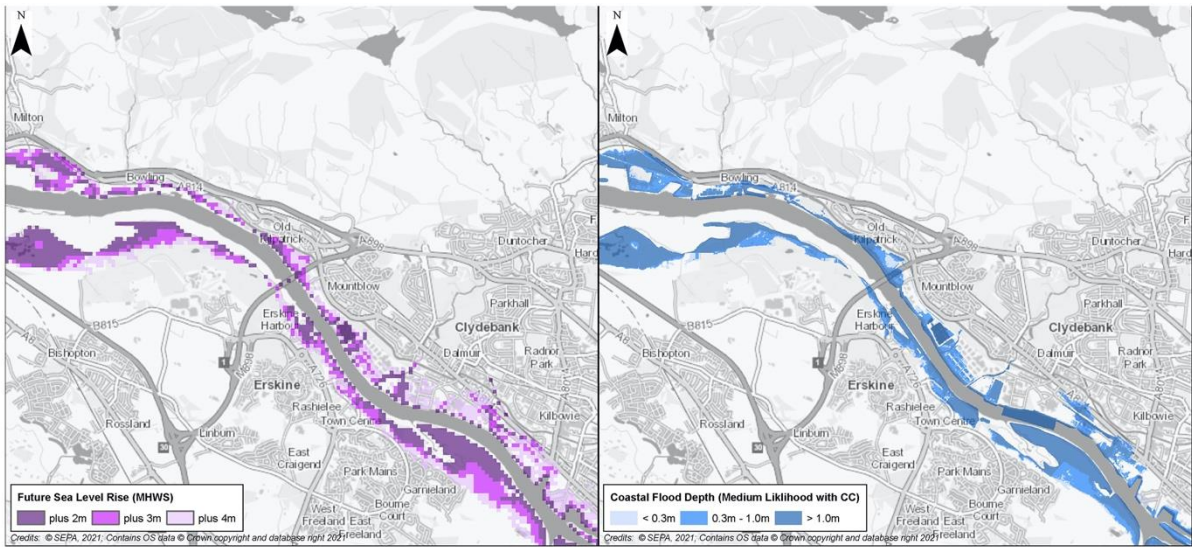


Figure 12 – Glasgow airport level rise comparison with extreme flooding

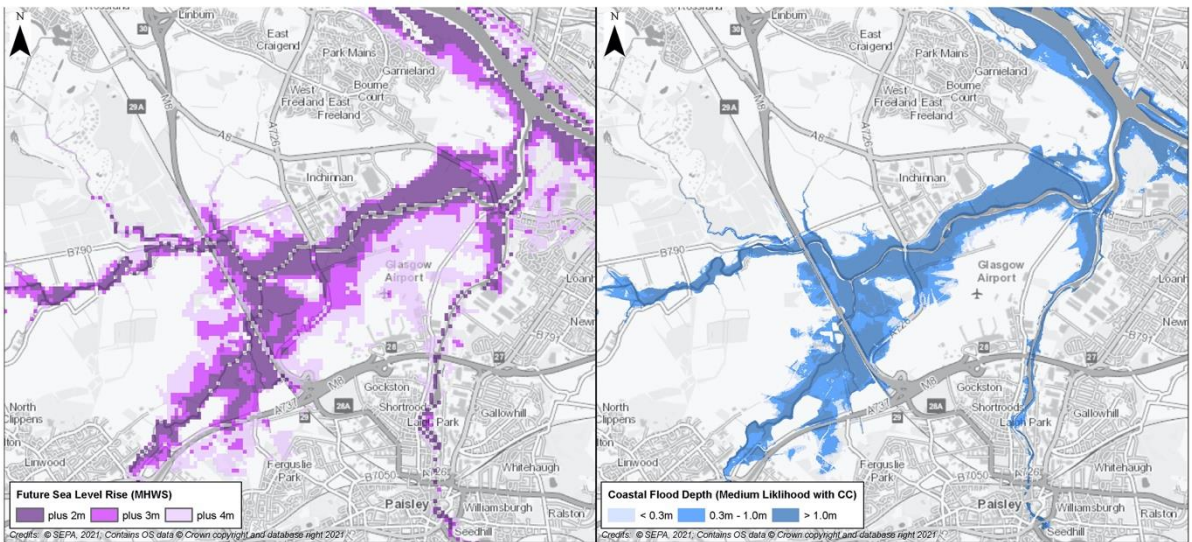
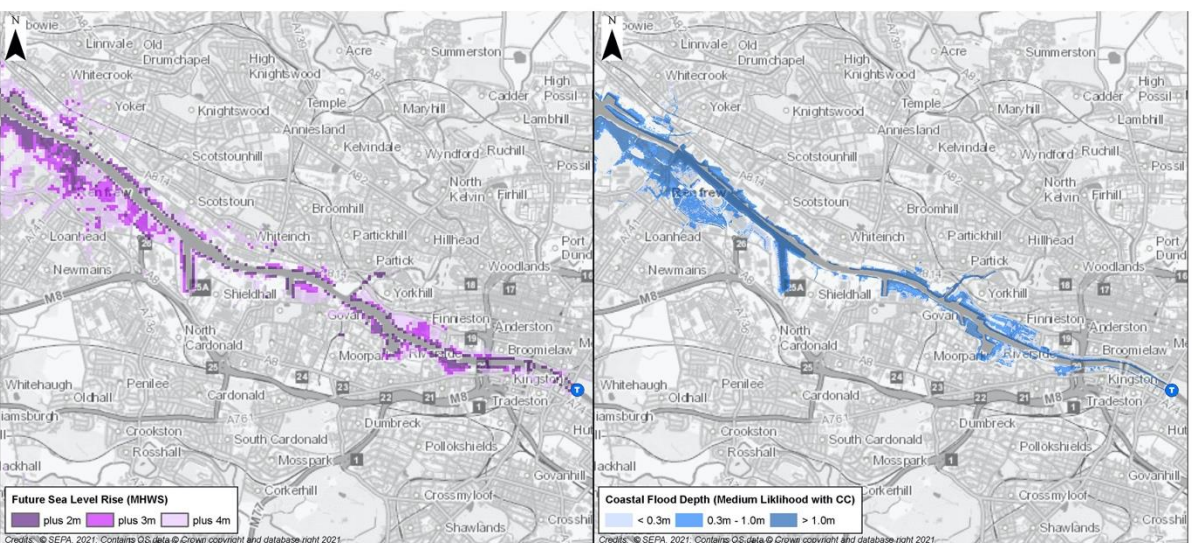


Figure 13 – Renfrew-Glasgow City sea level rise comparison with extreme flooding



When looking further into the future and considering investment in longer term infrastructure, sea level rise will have a significant effect and whilst rising sea levels is not urgent today, it is an important consideration for today's decision making.

The Third UK Climate Change Risk Assessment (CCRA3) Future Flood Risk Report⁴⁹ assesses the impact that sea level rise has on the standard of flood protection (SoP) afforded by existing defences for extreme events. In Scotland it estimates that a 0.35m rise would turn areas currently protected to a 1 in 50-year SoP (2% AEP) into a 1 in 14-year SoP (7.1% AEP), and a 1 in 100-year SoP (1% AEP) into a 1 in 28-year SoP (3.6% AEP).

UKCP18 anticipates that the rising mean sea level will be the primary driver in increased future tidal flood risk rather than an increase in storminess. So although tidal surges themselves may not change significantly in level relative to the mean sea level at the time, the increased mean sea level will result in higher surge levels.

The River Clyde hydrodynamic model was updated in 2021 by Fairhurst. This models the extreme tidal flood levels along the River Clyde.

With rising seas, the wave environment is likely to be altered affecting both overtopping and erosion rates.

As well as sea level, rainfall has shown an upward trend in Scotland since the 1970s and this trend is predicted to continue. Scotland between 2008–2017 has been on average 11% wetter than between 1961–1990 and 4% wetter than between 1981–2010⁵⁰. An increase in rainfall is likely to impact on both fluvial and pluvial flooding increase flood frequency. In the immediate term pluvial and fluvial flooding present a more widespread problem for the Clyde region.

6.5 Designing for uncertainty

The impact of future flood risk is likely to be heightened by socio-economic trends. The population is growing and with the trend for smaller sized households, the need for significantly more housing and improvements in capacity of infrastructure will continue.

To allow the necessary improvements for Glasgow and the Clyde region to continue as an economic powerhouse for Scotland and improve the existing social deprivation in the area, careful planning and design must be undertaken. Exact future flood levels remain uncertain, but that sea level will rise and flood risk will increase is not. It is possible to construct guidance to enable development within the uncertainty, avoiding poor long term investment decisions.

Methods for designing for tidal extremes are well defined and modelled. Planning authorities, developers and governments are familiar with the process and language around this. What is less well developed is how we design for future sea level rise scenarios and what levels we should be using where. Designing with both in combination is essential to meet the mission on the Clyde.

⁴⁹ Third Climate Change Risk Assessment Main Report Final Report prepared for the Committee on Climate Change UK, July 2020, Sayers, P.B, Horritt, M.S, Carr, S, Kay, A, Mauz, J, Lamb, R and Penning-Rowsell, E

⁵⁰ UKCP18 Overview Summary, 2019, The Met Office

6.5.1 Designing for Sea Level Rise - 9 Box Design Guidance

John Englander developed the Englander 9 Box Design Guidance⁵¹ which has been adopted by the Institute of Mechanical Engineers in their Rising Seas: The Engineering Challenge⁵² publication. This guidance provides sea level recommendations based on asset sensitivity to flood risk and asset design life. This approach has value to decision making on the Clyde and supporting non-climate specialists with sensitivity analysis.

Following the Englander 9 Box Design concept, a River Clyde version has been developed and presented in *Table 7* based on locally projected levels. The proposed table replaces the 100-year asset life proposed by Englander with 120 years to reflect the typical design life for highways assets and key infrastructure. The purpose of this table is to support investment decision making, for adaptation and infrastructure development, by provide a window of plausible uncertainty to be consider as part of the risk management and adaptation pathways process.

Table 7 – Sea level rise values to support decision making sensitivity for the Clyde

| | | Horizon / Asset Life | | |
|-------------|--------|----------------------|----------------|-----------------|
| | | 2052 (30 year) | 2072 (50 year) | 2142 (120 year) |
| | | Sea level rise (m) | | |
| Sensitivity | Low | 0.2 | 0.4 | 1.5 |
| | Medium | 0.3 | 0.6 | 2 |
| | High | 0.4 | 0.8 | 2.5 |

The values proposed in *Table 7* are based on the local sea level rise projections drawing on UKCP09 and 18 and SEPA Guidance⁵³. The range⁵⁴ of values reflect the uncertainty in the response of the ice caps and the extent that their loss will accelerate sea level rise. The values in *Table 7* have been combined with the most recent tidal model results for the Clyde to establish a set of future MHSW levels covering Gorouck and Greenock, Port of Glasgow to Erskine and Erskine to City Centre. These levels are presented in *Table 8*⁵⁵. These numbers should be reviewed as new studies are published.

Key to implementing this approach is a common understanding of the sensitivity definitions. Englander and the IMechE do not elaborate on a definition, other than suggesting comparison between a football pitch (low sensitivity) and nuclear power station (high sensitivity). *Table 9* has been developed to provide a more detailed framing of low, medium and high sensitivity for the Clyde.

⁵¹ Englander 9 Box Matrix, John Englander and The Rising Seas Institute.

<https://risingseasinstitute.org/englander9boxmatrix/>

⁵² Rising Seas: The Engineering Challenge, November 2019, The Institute of Mechanical Engineers (IMechE)

⁵³ https://www.sepa.org.uk/media/426913/lups_cc1.pdf

⁵⁴ The values proposed by Englander are significantly higher than the values in Table 7.

⁵⁵ The values in Table 8 include for a 0.5%AEP tidal surge.

To aid the interpretation of these sensitivity definitions *Table 10* provides examples of assets which would fall in each category for each typical asset life. The examples given here are for illustrative purposes only. Each development should be assessed based on its individual risks. It may be that different assets within a development, or parts of a development may be treated differently, dependant on the asset sensitivities and the management approach.

Table 8 – MHWS levels to support sensitivity assessment for the Clyde

| | | Horizon / Asset Life | | |
|-----------------------------------|--------|--------------------------|----------|-----------|
| | | 30 Years | 50 Years | 120 Years |
| Gourock and Greenock | | Level mAOD ⁵⁶ | | |
| Risk / Sensitivity | Low | 4.1 | 4.3 | 5.4 |
| | Medium | 4.2 | 4.5 | 5.9 |
| | High | 4.3 | 4.7 | 6.4 |
| Port of Glasgow to Erskine | | Level mAOD | | |
| Risk / Sensitivity | Low | 4.6 | 4.8 | 5.9 |
| | Medium | 4.7 | 5.0 | 6.4 |
| | High | 4.8 | 5.2 | 6.9 |
| Erskine to City Centre | | Level mAOD | | |
| Risk / Sensitivity | Low | 5.1 | 5.3 | 6.4 |
| | Medium | 5.2 | 5.5 | 6.9 |
| | High | 5.3 | 5.7 | 7.4 |

Table 9 – Description of sensitivity

| Low | Medium | High |
|---|--|--|
| Assets have a self-contained footprint Easily repaired or retrofitted at relatively low cost with low complexity No or low risk to life Limited wider economic, social or environmental disruption | Neighbourhood scale asset and footprint Disruptive repair, modification and replacement Risk to life Significant neighbourhood economic, social or environmental disruption | Critical infrastructure High costs and complexity (time and resources) of repair, modification or replacement Significant risk to life Significant system-wide economic, social or environment disruption |

⁵⁶ mAOD (meters Above Ordnance Datum). The figures provide the actual elevation referenced to the mean sea level at the UK Ordnance datum at Newlyn, Cornwall. All elevations in the UK are derived from this datum.

Table 10 – Examples of assets by sensitivity and typical asset life

| Sensitivity | Horizon (Asset Life) | | |
|-------------|---|--|---|
| | 2052 (30 year) | 2072 (50 year) | 2142 (120 year) |
| Low | Localised port infrastructure upgrade | New public waterfront park | New tidal wetlands |
| Medium | Retail development, Floating structures, Retrofit of existing utilities | Minor river crossing such as footbridges | New neighbourhood scale mixed use riverside development |
| High | District heating plant New industrial facilities | A new waste water treatment facility, hospital, school | Major new bridge crossing, tidal barrier, evacuation routes |

The following illustrate how the tables could be applied to different asset classes:

- A major new road bridge would consider 2.5m of sea level rise to determine the height of the bridge and approach roads. In doing this it ensures that vessels can still pass under the bridge through its life and vehicles will still be able to access the bridge.
- A new waste water facility with a 50-year design life would allow for 0.8m of sea level rise when assessing flood risk and build defences or make provision for the future raising of defences to meet this value. Equally outfall heights would consider the sea level rise to ensure that should this occur, the plant can still discharge water as required.
- A major new mixed-use development would consider the impacts of 2m of sea level rise during the design. Key elements like utilities may be fully protected whereby less critical elements may be designed to be resilient rather than resist the flooding. Defences where used may not be built to the full height or built at all to begin with but allowance for them or their raising would be made in the design and budget.

6.6 Clyde Resilience Zone

Based on the significant future tidal flood risks on the Clyde, it is recommended that a Resilience Zone is established to provide an operational area for systems-thinking and investment decision making. The creation of a Resilience Zone would provide:

- a clear framing of the Clyde system for future adaptation decision making, collaboration and data sharing; and
- a flexible boundary for the application of adaptation pathway practices.

Within the Resilience Zone the recommended approach would be to consider adaptation investments and impacts at a system-wide scale. Outside the Resilience Zone adaptation investment decisions would be considered at the local or neighbourhood scale.

Figure 19 provides a recommended boundary for a Clyde Resilience Zone. This boundary takes account of the climate projections and uncertainties set out in Section 6.4. The zone has been defined by the tidal area and a 2.5m rise in mean sea level.

Figure 19 Clyde Resilience Zone

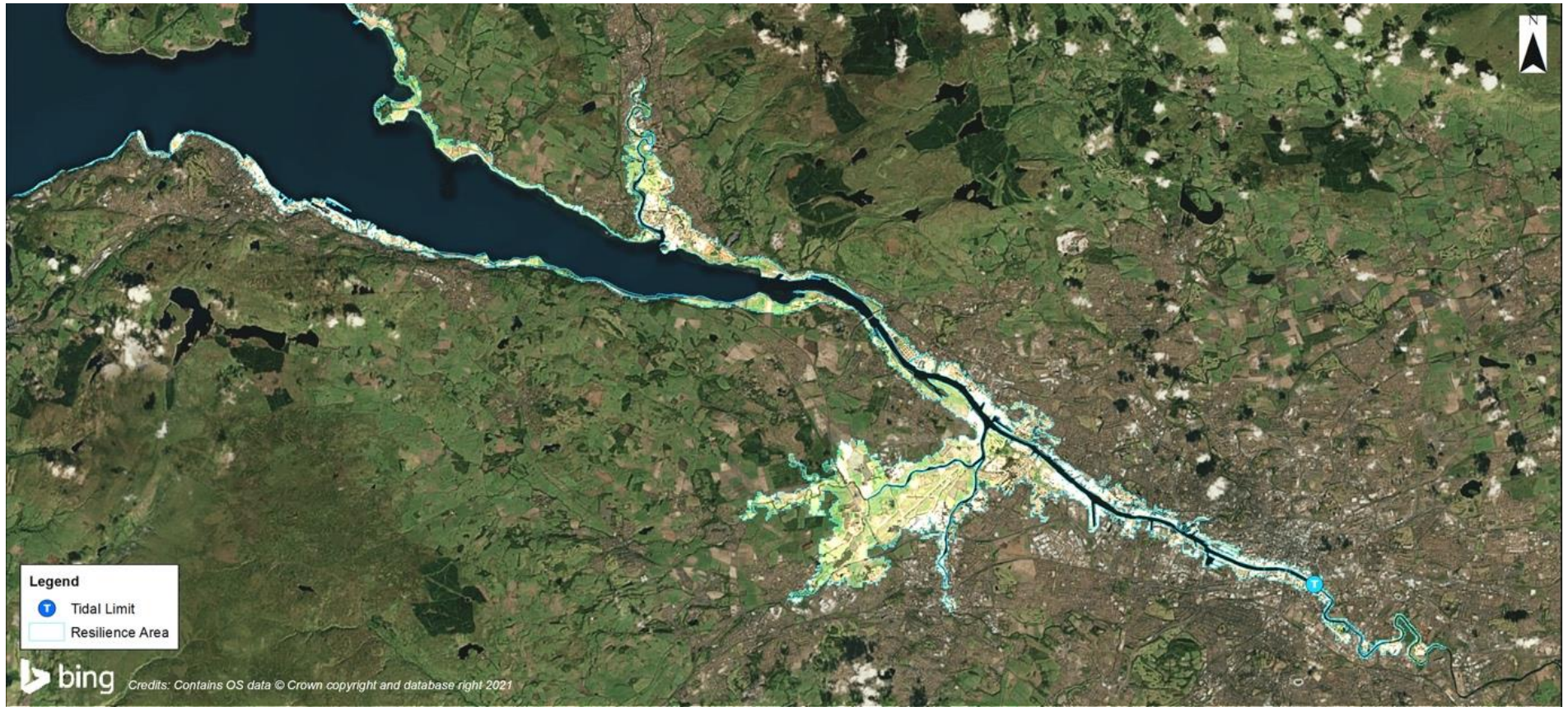


Image Credits: Contains OS data @Crown copyright and database right 2021

7 Strategic options adaptation measures

7.1 Introduction

This section explores the options and measures available for adaptation to tidal flood risk on the Clyde. The intention is not to screen out options and choices, but to present possibilities, and sign-post responses and adaptation measures that can shape future pathways and drive resilient outcomes for the Clyde; taking account of stakeholder aspirations and the working design principles described in *Section 5.5*.

Section 7.2 provides an overview of tidal adaptation measures and responses. *Section 7.3* then explores the adaptation responses with significant system-wide potential to shape pathway design and support adaptation in the long-term. *Section 7.4* then looks at the inner estuary (tidal weir to Govan), middle estuary (Govan to Erskine Bridge) and outer estuary reaches (Erskine Bridge to Gourrock) of the Clyde to identify the adaptation measures and choices with most potential to explore in the short-term. The delineation of the reaches is not fixed, and the segmentation it is not intended to suggest these reaches should be managed individually.

7.2 Adaptation portfolio

7.2.1 System-wide measures for the tidal River Clyde

Adaptation measures are specific interventions to manage the shoreline from flooding and sea level rise. They can be combined or implemented over time in a planned sequence or pathway (see *Section 8*) that is appropriate to the risks and characteristics of the location. Over time they help to manage and reduce coastal risks including erosion, fluvial flooding, the impacts of sea level rise, and combined risks such as tidal surges and surface water risk.

This sub-section describes a number of adaptation measures that are considered appropriate to the Clyde estuary to address sea level rise and manage tidal flood risk. These are not exhaustive and have been selected to illustrate the range of opportunities that are available and can be meaningfully explored for the Clyde Estuary today and into the future under different scenarios. The intention is to combine a range of measures to develop a portfolio of strategic interventions for a resilient system.

7.2.2 Key aspects of resilience and type of adaptation measures

To capture the range of possible adaptation actions required to deliver and maintain future resilience on the Clyde, measures are considered across the aspects of resilience as described by the National Infrastructure Commission⁵⁷. These aspects support the capacity to deal with short term shocks and stresses (such a tidal surge or coastal storm), and the capacity to adapt and transform to longer terms stresses (such as sea level rise), risks and opportunities. *Table 11* describes these aspects of resilience.

Table 11 Key aspects of resilience

⁵⁷ <https://nic.org.uk/app/uploads/Anticipate-React-Recover-28-May-2020.pdf>

| | |
|----------------------------|---|
| Anticipate | These include actions to prepare in advance to respond to shocks and stresses. |
| Resist and Absorb | These include actions taken in advance to help withstand or endure shocks or stresses to prevent an impact on infrastructure services as well as actions that, accepting there will be or has been an impact on infrastructure services, aim to lessen that impact. |
| Respond and Recover | Actions that help quickly restore expected levels of service following an event. |
| Adapt and Transform | Actions that modify the system to enable it to continue to deliver services in the face of changes and actions that regenerate and improve systems for the future. |

This report also considers three types of adaptation measures as described in Table 12.

Table 12 Classification of soft, green and grey adaptation measures

| | |
|-----------------------|---|
| Soft measures | These measures include the non-structural, policy, regulatory and financial measures that enable other structural measures or influence future land use and the built environment to manage risk. |
| Green measures | These include natural and nature-based solutions (NbS) to provide coastal protection and other ecosystem services. As defined by Engineering with Nature, “NbS focus on conserving, restoring and engineering natural systems for the benefit of people and ecosystems we inhabit”. ⁵⁸ |
| Grey measures | These are physical, human-made engineered structures to provide tidal and coastal protection usually made with relatively hard materials to a specified standard of protection. |

7.2.3 Grey measures

Engineered structures have traditionally been the main stay of tidal and coastal protection. They can provide an effective solution to a specific problem with a designed standard of protection. Generally, the costs and benefits are more easily calculated and modelled to create a business case for funding than for green and soft measures. They also have a clear asset life, depreciation and return on investment for management. On the other hand, grey measures do not always provide the additional co-benefits that other green measures create, and grey measures can have significant ecological and carbon impacts.

With a growing uncertainty in future climate change impacts, the protection that grey infrastructure provides also becomes more uncertain. Often the presence of a hard engineered structure can create a false sense of security for the communities that

⁵⁸ https://ewn.erdcdren.mil/?page_id=4351

benefit so if a structure fails in the future under extreme events, they are less prepared and able to respond. It can also result in other assets or buildings being built in vulnerable areas behind engineered structures.

7.2.4 Green measures

Green measures or nature-based solutions work with natural processes to provide protection for ecosystems and the urban environment whilst providing a range of ecosystem services including coastal protection and flood risk reduction. As well as coastal risk reduction, they inherently provide multiple benefits such as critical habitat, biodiversity, carbon sequestration, recreation and leisure. They often have lower whole-life costs and are more adaptable over time than traditional engineered approaches. However, knowledge about and confidence in their performance varies and is largely dependent on the local context and conditions which may change over time.

It is more complex to calculate the benefits of green infrastructure and therefore make a financial case, however, as they offer so many benefits, nature-based solutions should be considered in the Clyde Estuary and be piloted and monitored to understand their performance, design and implementation. Additionally, they should be considered in combination with grey engineered approaches where nature-based solutions alone cannot be relied upon to provide the full standard of protection. Such hybrid approaches have the benefit of providing the confidence of engineering with the added value of co-benefits and adaptability over time. Information on the conceptualisation, planning, design and construction of nature-based solutions for coastal adaptation is available in the International Guidelines for Nature Based Solutions for Flood Risk Management by Engineering with Nature⁵⁹.

7.2.5 Soft measures

These non-structural measures work with and support the structural green and grey measures to build the adaptive capacity of communities. They tend to be focused on human behaviour and include measures to enable the continued use of vulnerable areas through planning, regulation and design standards; and improve the ability to respond to risk by increasing community resilience. They are generally more cost effective than structural adaptations but their effectiveness is often complicated by social challenges and human behaviour.

7.2.6 Portfolio of measures

These aspects and measures provide a portfolio of opportunities for the Clyde. To deliver long-term resilience it is important that future investments adopt a portfolio of measures that address both physical interventions and wider interventions to deal with emergency response and transformation. This approach can deliver both coping capacity and adaptive capacity. *Figure 20* sets out a portfolio of opportunities and measures that can be used to address sea level rise and tidal on the Clyde.

Figure 20 System-wide adaptation opportunities and measures for the Clyde

⁵⁹ https://ewn.erdcdren.mil/?page_id=4351

System-wide adaptation opportunities and measures for the Tidal River Clyde

| | Anticipate | Resist and Absorb | Respond and Recover | Adapt and Transform |
|----------------|---|--|--|--|
| Soft Measures | <ul style="list-style-type: none"> • Clear place-based ambitions • Governance and collaboration • System-wide • Knowledge sharing • Resilience indicators and monitoring • Research and development | <ul style="list-style-type: none"> • System-wide Policy Units / zones • Design and appraisal guidance • Design standards | <ul style="list-style-type: none"> • Communication plans • Flood warning systems • Emergency plans including evacuation and signage • Continuity planning • Insurance | <ul style="list-style-type: none"> • System-wide adaptation framework • Education and awareness • Legal framework • Funding and finance • Knowledge of costs and benefits |
| Green Measures | <ul style="list-style-type: none"> • Policy • Land-water zoning • Buffer-zones for roll-back • Design guidance and standards • Pilots and trials | <ul style="list-style-type: none"> • New tidal wetlands • Urban waterfront parks • Sustainable Urban Drainage • Landscaping • Artificial reefs | <ul style="list-style-type: none"> • Communication plans • Neighbourhood recovery plans • Build-back green • Asset decommissioning | <ul style="list-style-type: none"> • Land-use change • Asset relocation • Blue-Green corridor |
| Grey Measures | <ul style="list-style-type: none"> • Relocation of critical infrastructure • Relocation of community infrastructure and property • Design guidance and standards • Asset management and retrofit | <ul style="list-style-type: none"> • Flood walls and Embankments • Quay wall and land raising • Underground flood storage • Elevation of buildings, infrastructure and utilities • Floating and amphibious structures | <ul style="list-style-type: none"> • Incident plans • Temporary defences • Property flood resilience • Pumping stations • Build back better | <ul style="list-style-type: none"> • Tidal barrier and barrage systems • Terraced waterfront development and quay wall replacement/repair |

7.3 Adaptation responses

7.3.1 Overview

Drawing on the portfolio of measures set out in *Figure 20*, the following sub-sections elaborate on measures that have system-wide potential to support adaptation to sea level rise and tidal flood risk, and contribute to the long-term social, economic and environmental resilience of the Clyde.

7.3.2 Tidal Barrage

A tidal barrage is an operational structure which artificially controls water movement and water levels through the day-to-day operation of gates and sluices. These structures can be multi-functional and include energy generation, locks for navigation and be integrated with river crossings for transport and pedestrian use.

For the Clyde, a multi-functional barrage within the inner reach of the estuary could deliver benefits in the long-term by protecting areas from sea level rise and extreme tides. The ability to regulate water levels may also provide pluvial and fluvial flood management benefits by allowing flood waters to pass through during high rainfall events and avoid risk of flooding upstream. Managed water levels in the inner reach may also provide economic benefits to the area with opportunities for safe amenity and recreational use of the river. Navigation could be maintained through the inclusion of a lock, and a barrage could provide an opportunity for energy generation.

Alternative locations in the middle reach of the estuary could also be considered for a tidal barrage and consideration given to combining a barrage with a river crossing. A barrage in this reach would be a more significant undertaking in terms of scale and complexity, but would also provide flood protection to an increased stretch of river. Managed water levels in this reach may provide new development opportunities in areas such as Princes Docks and Govan Docks. A barrage in the middle reach would have a greater impact on navigation, and more significantly change the existing tidal and river flows, and the ecological function of the river.

In both reaches, trade-offs would need to be considered, and the benefits weighed against the significant capital, operational and maintenance costs. The implications for surface water management and wastewater management would also need to be assessed.

From an investment case perspective, it should be noted that the economic benefits of flood risk reduction associate with sea level rise and tidal flood risk, would only materialise in the long-term. For a successful investment case to be made for a tidal barrage in the short to medium term, the investment would need to be integrated with wider local regeneration and development objectives. *Box-outs 1* and *2* provide examples of barrages constructed in the UK.

This report has not considered a tidal barrage within the outer estuary as the current distribution of assets at risk of flooding in the Clyde do not necessitate an outer barrage solution over and above other combinations of grey, green and soft measures.

Depending on the success of adaptation response over the next 10-50 years, the rate and magnitude of future increases in mean sea level and the amount of sensitive new development within the proposed Resilience Zone, an outer tidal barrage may need to be re-considered in the long-term. Short-term consideration is however unwarranted and

would potentially risk maladaptation by overshadowing and drawing finite resources away from other measures described in this report.

Box-out 1 : Tees Barrage, Stockton and Tawe Barrage, Swansea

The **Tees Barrage** was built in 1995 to reduce tidal flooding in the River Tees by controlling the flow of water and managing water levels with four large flood gates. As well as the river barrage, the construction included a road bridge, footbridge and fish pass. The maintenance of river levels upstream of the barrage, has created a thriving leisure and sports community. Additionally, a white-water centre was created alongside the barrage to provide a white-water slalom and artificial 'surf wave' attracting thousands of visitors every year. The inclusion of Archimedes Screws provides power generation that is sold back to the national grid. As a result, the barrage has significantly contributed to the regeneration of the area converting it into an economically thriving location⁶⁰.



The **Tawe Barrage** built in 1992 is a partial inclusion barrage meaning it is overtopped by 70% of tides to maintain brackish water for migratory fish north of the river. The barrage includes a boat lock, spillway, fish pass and a generator turbine. The turbine generates power but was also used to pump water back into the Tawe River. The objective of the barrage was to create static water levels and improve leisure and marine activities within an area of the town requiring significant regeneration. This included a 200-berth marina with access via the barrage's lock with the result of significant economic improvement to the area.



7.3.3 Tidal Barrier

The terms tidal barrage and tidal barrier tend to be used interchangeable, however the function of each is different in terms of their contribution to flood risk management and their ability to address increases in mean sea level. A tidal barrage, as described in the previous section, maintains and manages water levels on a daily basis, and could provide an effective measure for addressing permanent long-term changes in mean sea level in the Clyde.

A tidal barrier, on the other hand, only operates during extreme tidal surges and storms to avoid inundation due to temporary (1-2 days) increased in water elevation. The Thames Barrier⁶¹, see *Box-out 2*, is such as structure.

⁶⁰ <https://tbiwwc.com/activities/make-more-of-your-visit/engineering-innovation>

⁶¹ <https://www.gov.uk/guidance/the-thames-barrier>

In the long-term, the projected permanent increases in mean sea level in the Clyde will necessitate a barrage solution if this type of grey adaptation measure was adopted. A tidal barrier could provide a transitional solution as part of a pathway to a barrage solution, but to address sea level rise a tidal barrier will not suffice in the long-term. For that reason, short-term consideration of a tidal barrier does not aid the process of identifying long-term adaptation pathways choices for the Clyde and has not been recommended for further consideration in this report.

Box-out 2 Thames Barrier, London

The **Thames Barrier** spans 520m of the River Thames and protects 125 square kilometres of central London from flooding caused by tidal surges. It has 10 steel gates that can be raised into position. Since the barrier became operational in 1982 and has been closed 205 times during its life (as of Feb 2022). Of these closures 114 were to protect against tidal flooding and 91 were to protect against a combination of tidal/fluvial flooding.



7.3.4 Creation of new tidal wetlands and managed realignment

The creation of new tidal wetlands or saltmarsh through the deliberate flooding of agricultural land provides potential to enhance defence against extreme tides and tidal locking in the future i.e. from the combination of extreme high tides causing high fluvial flows to back up and exacerbate fluvial flooding in the catchment. The area along the Black Cart, White Cart and the confluence with the Clyde provides such a strategic opportunity to make space for water, provide a buffer zone to future proof the system and implement large-scale nature-based solutions. Due to the sheltered situation of the estuary, dissipation of wave energy by wetlands is not a significant benefit and due to the spatial extent of the area available for these approaches, it is unlikely to reduce tidal levels up the estuary. It does, however, provide co-benefits in habitat creation, carbon sequestration and potential recreation and leisure benefits.

Tidal wetlands can be created and raised to keep pace with sea level rise through direct placement of fine dredged sediment on lower mudflats and shallow subtidal areas. Dredging provides an important socio-economic role in maintaining navigation in the Estuary. Typically dredged materials are disposed of offshore resulting in a loss of sediments from the system. A currently underused alternative is to beneficially use dredged materials to protect and restore declining habitats and creation of new habitats such as saltmarshes and mudflats. This could be effective at supplying local mudflats with sediments whilst simultaneously making use of dredgings elsewhere in the estuary. There are a number of financial, technical and regulatory challenges to be considered, such as the characteristics of the receiving environment, the local planning and policy context and licences and permissions requiring strategic planning and integrated management. The [Environment Agency's Restoring Estuarine and Coastal Habitats with Dredged Sediments Handbook](#)⁶² has been created to help practitioners to

⁶² https://catchmentbasedapproach.org/wp-content/uploads/2021/10/Restoring-Coastal-Habitats_V8.pdf

overcome these challenges and establish future projects. *Box-out 3* provides an example of a project creating new salt marsh.

Box-out 3 : Creation of new salt marsh

Dredged sediments in the Port of Delfzijl are being used to create **new salt marshes** in the Eems-Dollard estuary in the northeast of Netherlands. This site is being used as a test site by EcoShape to develop improved methods to restore salt marshes by reusing sediment, testing different combinations of fine sediments on salt marsh establishment. The new salt marshes will improve water quality, ecology, provide coastal protection and improve the attractiveness of the coast. In addition, salt marsh captures carbon dioxide forming a long-term carbon sink. Current results are positive with vegetation colonising rapidly and reduction in wave heights passing through the marsh reduced by 60%.⁶³



As the Clyde estuary is a designated Ramsar site, Special Protection Area and Site of Scientific Interest with internationally important wetland habitats, adaptation should also consider minimising the loss of these valuable habitats in the face of sea level rise. The Scottish Natural Heritage Commissioned Report (no. 891, 2017) reviewed and identified locations suitable for managed realignment in the Clyde Estuary for adaptation⁶⁴. In some locations, saltmarsh fronts critical transport infrastructure so providing benefit in foreshore energy dissipation but due to space constraints, there is very limited opportunity to enable roll back. Long-term thinking could therefore consider creative strategies such as hybrid approaches to structurally engineer saltmarshes, land-use zoning, purchasing land and realignment of infrastructure to plan for managed realignment and avoid reliance on short-term thinking/quick fix grey infrastructure interventions that would negatively impact on habitats.

7.3.5 Raised tidal defences

In locations where a 'hold the line' policy is required, tidal defences can be incrementally raised over time. A variety of design options can improve the public-realm alongside flood defence improvements including measures such as:

- setting-back defences from the original line and including access barriers and landscaping;
- raising defences at the water's edge; and
- terracing the defence line and building out into the river to provide protection while also creating a connection between the river and the urban space.

The multi-functionality and ecological value of hard coastal defences can also be improved with the integration of green elements into grey infrastructure.

⁶³ <https://www.ecoshape.org/en/pilots/saltmarsh-development-marconi-delfzijl-9/>

⁶⁴ <https://www.nature.scot/doc/naturescot-commissioned-report-891-impacts-sea-level-rise-and-storm-surges-due-climate-change-firth>

Figure 21 provides an illustration of various forms of raised tidal defences. Images 1 to 3 show examples of raised defences on the water's edge. Images 4 to 6 show examples of incorporating public realm within raised tidal defences. Images 7 to 9 provide examples of vegetation used in conjunction with grey infrastructure.

Figure 21 Examples of raised tidal defence



Images are by permission of :
 images 1 to 3 and 9 – JT Mackley ; images 4 to 6 – LDA Design ; and images 7 and 8 Larissa Naylor

Any future investment in raising of defences is likely to require enhancement to the surface water management and drainage systems.

With rising sea levels, additional enhancements are likely to be required for existing surface water management and drainage systems to avoid tidal locking i.e. where surface water is unable to discharge into the river due to high water levels resulting in flooding upstream.

7.3.6 Elevation of quay walls, moorings and marine facilities

Incremental raising of port and marine facilities such as quay walls can continue to provide flood defence and maintain the commercial value of sites over time. Due to the sheltered nature of the estuary and good connectivity, the marine and port facilities are well situated to be able to gain potential competitive advantage over other UK ports and take larger vessels in the future.

7.3.7 Critical road and rail infrastructure

Critical road and rail infrastructure can be moved out of the sea level rise zone by raising their elevation on an embankment, causeway or bridge, moving to a new location or rerouting via other existing transport routes.

Due to the low energy environment in the estuary, coastal protection in the form of foreshore treatment such as rock revetment, may be suitable in the medium-term to stabilise the shoreline and prevent erosion. In the long-term, elevation or realignment may be required at critical locations to maintain transport links during extreme high tide events. As relocation of transport infrastructure is complex requiring permitting, land acquisition and associated costs, long-term planning is prudent to identify opportunities to upgrade within wider infrastructure projects.

Elevating transportation structures could improve habitat corridors and create additional room for saltmarsh migration and transition zone restoration. Additionally, there may be opportunities to implement nature-based measures within major projects to increase adaptability and upgrade existing infrastructure to improve water quality in the estuary.

Living shorelines is a concept originating from the US that uses vegetation, sand/soil and limited hard structures at the shoreline edge for bank stabilisation. The key feature is the inclusion of ecological function. For example, the foreshore may include natural elements such as tidal flats, seagrass beds and intertidal marshes. In higher energy or exposed environments, wooden or rock sills may be used parallel to the shoreline or hybrid designs that include hard engineered structure combined with natural elements. Where space constraints do not allow for full restoration, Living Shorelines can be created on a previously hardened shoreline to create a more natural edge.

7.4 Reach level adaptation choices

The potential of adaptation responses varies across the estuary, driven by the different characteristics, land-use and economic value of the area. This sub-section provides a summary of the key measures and responses of greatest potential for exploration within the Inner, Middle and Outer reaches of the estuary.

7.4.1 Inner Estuary

The Inner Estuary consists of mixed-use urban development with an existing hard shoreline. The strategy here is likely to take a defensive hold-the-line approach and potential consideration of a long-term engineering intervention with a tidal barrage. The opportunity for nature-based solutions becomes more limited in this reach but could be considered through 'greening the grey' hybrid approaches.



7.4.2 Middle Estuary

The middle estuary offers the most potential for nature-based solutions and local realignment and wetland creation. This also opens opportunities for creative thinking in multi-functional use of water adapted initiatives. Incremental raising of walls and defences may still be required in key areas of economic importance to maintain standards of protection.




7.4.3 Outer Estuary

This reach is a mixture of residential, open space, protected environmental areas and industrial/commercial use. The strategic approach in this reach will be mainly driven by the land-use type with the maintenance and raising of defences for key industrial and commercial facilities with land-use zoning, realignment and greening the shoreline in non-urban areas to allow existing valuable habitats to adapt. Critical transport infrastructure along the coastal zone also forms an important strategic consideration.



Figure 22 summaries the potential of the described adaptation choices and measures for the inner, middle and outer reaches of the Clyde. This provides a useful starting point for prioritising investigations and exploring the design of future adaptation pathways. *Figure 22* it is not intended to screen-out consideration of other grey, green or soft adaptation measures in this report. However, based on the framing and design principles established in this report, the summary reflects the research teams assessment of potential and alignment with stakeholder ambitions.

Figure 22 – Reach level adaptation choices



| Adaptation Measures | Inner Clyde | Middle Clyde | Outer Clyde |
|---|----------------------|--------------|-------------|
| | Adaptation potential | | |
| Tidal Barrage | ◆ ◆ | ◆ | ○ |
| Raised tidal defences | ◆ | ◆ | ◆ |
| Elevation of quay walls and marine facilities | ○ | ◆ | ◆ |
| Creation of tidal wetlands | ○ | ◆ ◆ | ◆ |
| Critical road and rail Infrastructure | ○ | ◆ | ◆ ◆ |
| Greening the grey | ◆ ◆ | ◆ ◆ | ◆ |
| Managed realignment | ○ | ◆ ◆ | ◆ |

◆ ◆ High potential ◆ Some potential ○ Low or no potential

8 Future adaptation pathways

8.1 Investment pathway design

The international literature review for San Francisco, New York City, and Copenhagen showed that these localities are all considering their adaptation investments within the context of the wider place-based challenges and complexities they face, rather than in isolation. This approach similarly reflects the transformational and system-wide aspirations of Clyde stakeholders engaged during this study, and Clyde Mission's ambition to 'make the Clyde an engine of sustainable and inclusive growth' captured in the design brief set-out in *Section 5.5*.

To satisfy this brief, *Section 6.0* demonstrates the importance of taking a long-term perspective to pathway design. This recognises that new infrastructure investments, due to their long asset life and the potential cost and complexity of replacement, need to be designed for uncertainties; and consider long-term sea-level rise implications on business case decisions. *Section 7* of this report has described the system-wide adaptation opportunities and measures for addressing sea level rise and tidal flood risk; and identified tactical choices of particular relevance to the inner, middle and outer Clyde. These choices form a starting point for investigating adaptation options.

This section examines the strategic design of pathways at a system-wide level with a decision-making horizon of 2200. Before examining the available choices and alternative future pathways, it is important to recognise where adaptation pathways sit within the overall hierarchy and framework for adaptation investment. *Figure 23* provides a framework that has been used in other tidal areas⁶⁵ to foster a shared understanding of adaptation pathways and their supporting role in: enabling action, driving desired invest portfolios and outcomes, and delivering impactful resilience for people and places.

Figure 23 – Framework for adaptation investment

| FRAMEWORK FOR ADAPTATION INVESTMENT | |
|-------------------------------------|---|
| RESILIENCE | People, places and systems Values and ambitions + shocks and stresses (local metrics: social, environmental and economic) |
| INVESTMENT PORTFOLIOS | Value capture (value at risk and value potential) Current and future generations (horizon/systems thinking) |
| ENABLING ACTIVITIES | A. Shaping investment ambitions and assessing needs B. Making choices and securing investment |
| TOOLS | Guidance and best practice, MCDA, Adaptive Pathways, CBA |
| PRINCIPLES | 3P's: Partnership working + Public Sector Leverage (funding and finance) + Public Value for Money |

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⁶⁵ Tidal River Nene Study and Lincolnshire Coastal Adaptation Planning - Environment Agency 2021.

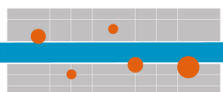
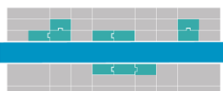



8.2 Strategic investment choices and pathways

From a strategic perspective there are five key approaches to optioneering, business case development and investment decision making that could be adopted for the Clyde:

- **Business as Usual** investment at the neighbourhood scale
- **Strategic Wins** investment in system-level
- **Blue-Green Units** driven investment at the neighbourhood/ reach scale
- **Blue-belt** driven system-wide investment
- **Blue-belt + Barrage** driven system-wide investment

These approaches are described in the table below, alongside the scale of the benefits/impacts within the Clyde and examples.

Table 13 – Strategic Investment Choices for the Clyde

| Strategic Choice | Description |
|---|---|
| <p>Business as Usual</p>  | <p>Continue decision making based on national prioritisation of hot-spots and risk within a rolling 6-year investment programme.</p> <p>Impacts: Reach and/or neighbourhood scale.</p> <p>Example: The Clyde and Loch Lomond Local (action) Plan.</p> |
| <p>Strategic Wins</p>  | <p>In combination with Business as Usual, invest in options that deliver system-wide adaptation benefits, maximise future choices and/or actively shape and inform pathway design.</p> <p>Impacts: System-wide and/or reach.</p> <p>Examples: Creation of new tidal wetlands, and adaptation of critical road and rail infrastructure.</p> |
| <p>Blue-Green Units</p>  | <p>Establish Blue-Green Spatial Units that enable development choices and implementation at the reach/neighbourhood whilst fostering system-wide integration.</p> <p>Impacts: System-wide, reach and neighbourhood scale.</p> <p>Examples: Shoreline Management Plans, San Francisco Bay Shoreline Adaptation Atlas (Operational Landscape Units)</p> |
| <p>Blue-belt</p>  | <p>In combination with Blue-Green Spatial Units invest actively in an accessible and resilient waterfront along the length of the Clyde.</p> <p>Impacts: System-wide, reach and neighbourhood scale.</p> <p>Examples: The Big-U New York City⁶⁶</p> |
| <p>Blue-belt + Barrage</p>  | <p>In combination with Blue-Belt invest in a multi-functional inner Clyde barrage.</p> <p>Impacts: System-wide, reach and neighbourhood scale.</p> <p>Examples: Tees Barrage and Tawe Barrage.</p> |

⁶⁶ <https://www.youtube.com/watch?v=GEmVETFPR3c>

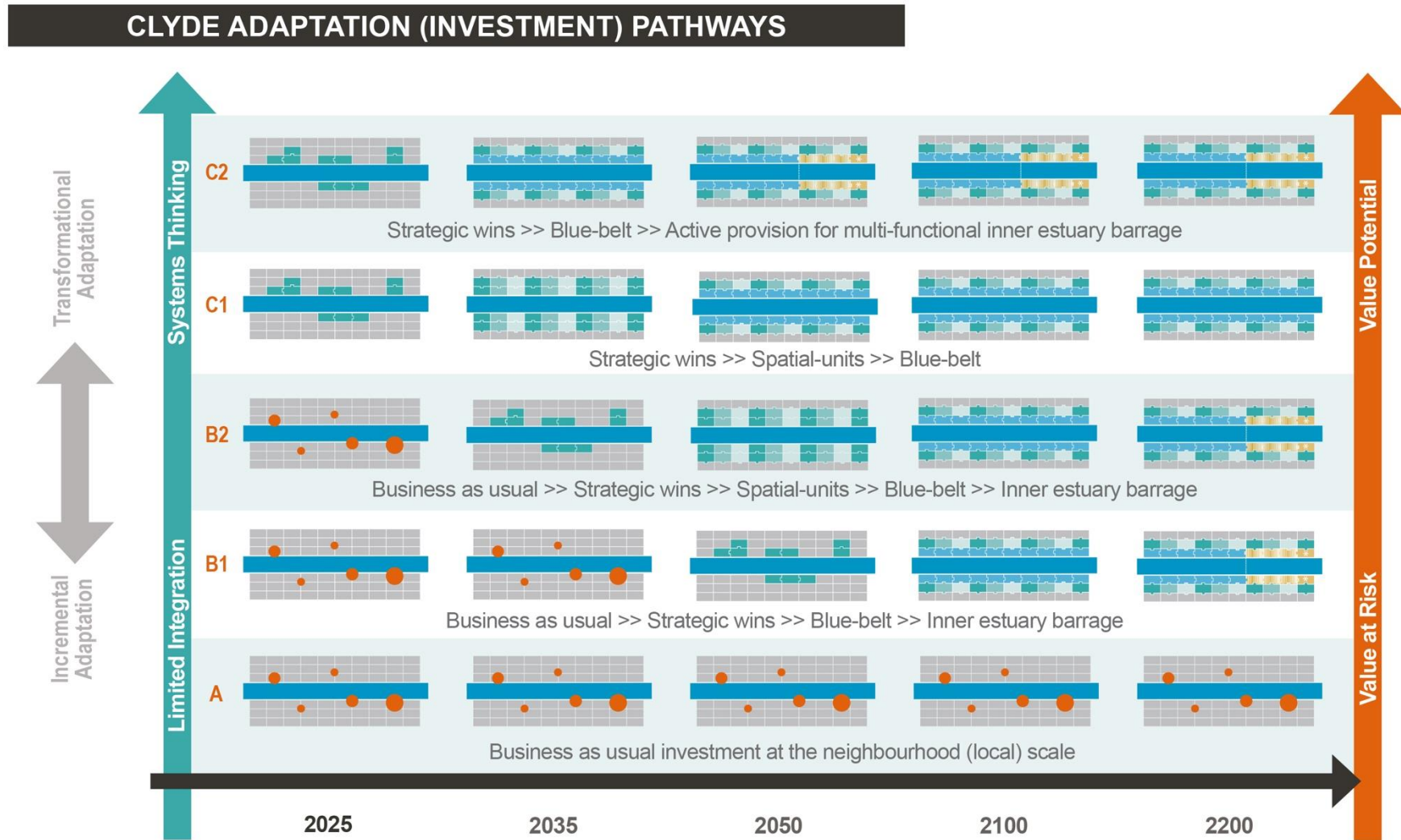
Building on these strategic choices we have developed five plausible adaptation investment pathways for the Clyde. These pathways are described in *Table 14* below.

Table 14 – Five plausible adaptation investment pathways for the Clyde

| ID | Pathway Name | Description of the investment journey | Main driver for the Business Case |
|----|------------------------|--|-----------------------------------|
| A | Reactive | Rolling programme of Business-as-Usual flood risk management investments at the reach and/or neighbourhood scale. | Value at Risk |
| B1 | Delayed Adaptation | Business as Usual in the near future, followed by a managed transition of strategic wins and blue-belt development, followed by development of a multi-functional barrage in the next century. | Value at Risk |
| B2 | Managed Transformation | A managed transition applying the strategic choices as adaptation steps: Business as Usual, Strategic Wins, Blue-Green Unit and Blue-Belt this century, backed-up with the planned possibility for a Clyde Barrage in the next century. | Value at Risk |
| C1 | Mission-based One | System wide development of an accessible and resilient waterfront based on no physical restriction to tidal movement and river flows; starting with strategic wins in the short-term, Blue-Green Unit development within the next two decades, and incremental development of a system-wide masterplan accommodating flexible land use policies. | Value Potential |
| C2 | Mission-based Two | System wide development of an accessible and resilient waterfront including an inner Clyde multi-functional barrier; starting with strategic wins in the short-term, Blue-Green Unit development within the next two decades, and multi-functional barrage implementation mid-century onwards. | Value Potential |

Figure 23 on the next page provides an illustration of the investment journey against the five plausible adaptation pathways. The horizon taken for the pathways is 2200. The timings should be taken as indicative rather than absolute.

Figure 24 – Five plausible adaptation pathway choices for the Clyde



Each of the pathways will deliver different benefit streams and satisfy the pathway design principles to different extents. *Table 15* describes how well the pathways meet the design principles. The table illustrates that pathways A and B1 do not readily satisfy the design principles, whereas B2, C1 and C2 have the potential to satisfy the design principles. The principle 'Transition to Net Zero' is flagged as amber for 4 out of the 5 choices as the Net Zero contribution is intrinsically linked to the adopted measures rather than the overall pathway, and is therefore difficult to judge from a strategic perspective.

Table 15 – Satisfaction of the design brief

| Clyde Pathway Design Principles | A Reactive | B1 Delayed Adaptation | B2 Managed Transition | C1 Mission base One | C2 Mission based Two |
|---|--|-----------------------------|-----------------------------|---------------------------|----------------------------|
| | R-A-G assessment: satisfaction of design brief | | | | |
| To make the Clyde an engine of sustainable and inclusive growth | Red | Red | Amber | Green | Green |
| World class flood and coastal resilience | Red | Red | Green | Green | Green |
| Seven generations | Red | Amber | Green | Green | Green |
| Business case ready solutions | Red | Amber | Green | Green | Green |
| Transition to Net Zero | Red | Amber | Amber | Amber | Amber |
| Mobilise resources and commitment | Red | Amber | Green | Green | Green |
| Monitoring and learning | Red | Green | Green | Green | Green |

Clearly all the pathway choices are complex and will necessitate a portfolio-based approach and co-design of the investment strategy and delivery. Front-end investment (time, money and resources) will be important to successful mobilisation of adaptation on the Clyde. Key challenges will include those in *Table 16* below, which is drawn from the Infrastructure and Projects Authority Project Routemap.⁶⁷

Table 16 – Key challenge and risks

| | | | |
|--|--|--|---|
| Requirements Delivering strategic project outcomes and realising the benefits. | Systems Integration Making multiple systems work as one. | Procurement Understanding how the project will buy goods and services. | Asset Management Balancing costs and risks to maximize whole life benefits. |
| Governance Establishing clear accountability and empowering effective decision-making. | Organisational Design & Development Organising the project team to deliver successfully. | Risk Management Managing uncertainties and opportunities. | Delivery Planning Readying the project for transition into delivery. |

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https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1000747/Routemap_Flyer.pdf

8.3 Funding and finance

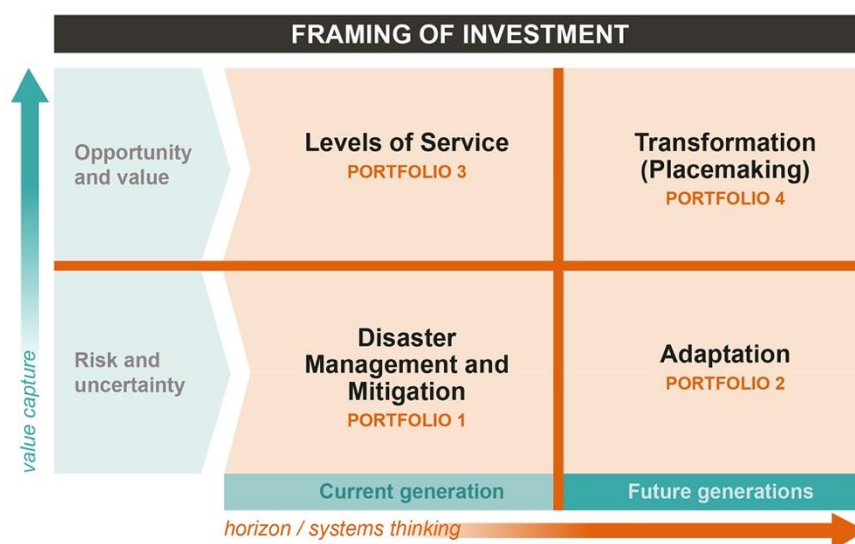
To identify potential funding and financing for future pathways we have drawn on the findings from the ClimateXChange research “International practice on assessing investment needs and securing invest to adapt to climate change”. The findings of this research identified a framing of investment ambitions and investment portfolios that aligns well with the Climate Ready Clyde Finance Typology and can be used to map the pathways identified in *Section 8.2* against types of investment portfolio.

The framing is based on two key dimensions that influence investment ambitions and balances choices between:

- ‘risk and uncertainty’ and ‘opportunity and value’
- ‘current generations’ and ‘future generations’.

The two dimensions lead to four types of investment portfolio shown in Figure 25 and described below.

Figure 25 – International framing of investment ambitions



Portfolio 1: Disaster management and mitigation. Within this portfolio investment decisions tend to be driven by the management of risk and uncertainty with a focus on the current generation and immediate needs. Investment tends to be driven by public sector funding with a significant focus on the security of people and property achieved through reactive investment in disaster assistance and upfront investments in mitigation. Asset management is a key aspect of this portfolio. Typical investments include: flood warning and preparedness, recovery assistance and compensation, flood defence, coast protection, and property-level protection.

Portfolio 2: Adaptation. Within this portfolio investment decision-making looks more to the long-term and considers the implications on future generations. Although still driven largely by the management of risk and uncertainty, decision making tends to focus on the wider system and place, not just people and property. Investments in this portfolio still tend to be driven by public sector funding but this portfolio presents greater opportunities for co-investment in wider longer-term social and environmental benefits. Investments in the portfolio include: managed realignment, nature-based solutions and system-wide solutions rather than individual assets.

Portfolio 3: Levels of service. This portfolio focuses very much on the current generation, but rather than just considering risk, investment decision making tends to consider the wider economic value to society and concepts such as willingness to pay. Investment in this portfolio tend to be more of a blend of public and private finance. Investments in resilient economic infrastructure are a key aspect of this portfolio. Investments include: utilities and infrastructure resilience (transport, ports and water).

Portfolio 4: Transformation and place-making. This portfolio is future focused with investment decisions driven by value creation and societal opportunity. Investments in this portfolio tend to be a blend of public and private finance. Like adaptation these investments bring changes to place and unlock social, environmental and economic benefits. Investments in the portfolio include: development, regeneration and green growth.

The connection between these portfolios and the potential sources of funding and financing is illustrated in *Figure 26*. The alignment of these portfolios to the typology for adaptation financing development by Climate Ready Clyde is described in *Table 17*.

Figure 26 – Sources of potential funding and finance by investment portfolio

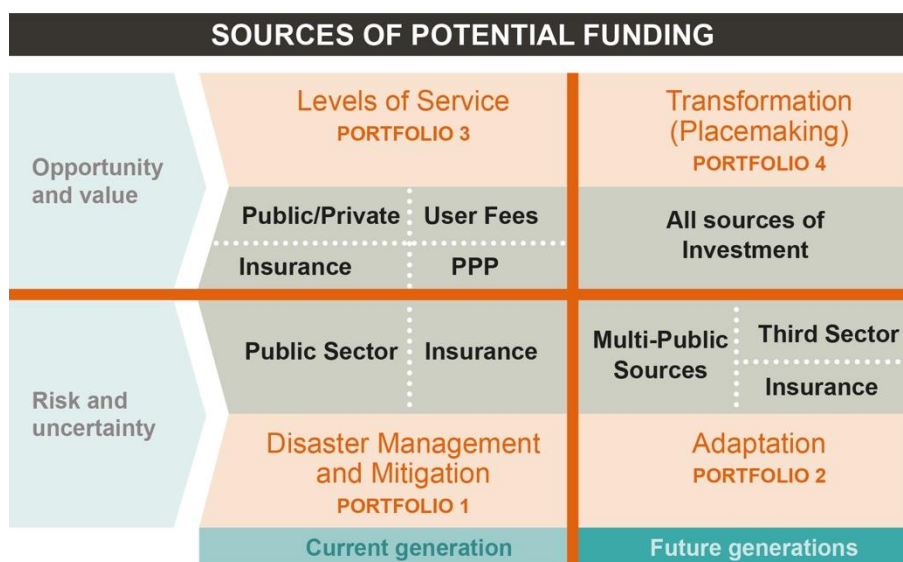


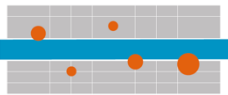
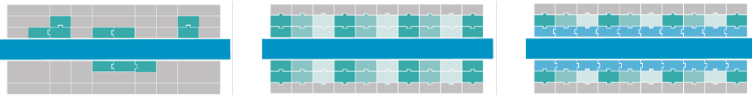
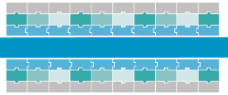
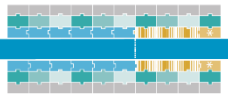
Table 17: Portfolio alignment with the Climate Ready Clyde Finance Typology

| Portfolio | Climate Ready Clyde finance typology | | |
|--|--------------------------------------|------------------------|---|
| | Type of Adaptation | Type of Finance | |
| Portfolio 1 Disaster management and mitigation | Incremental adaptation | Conventional finance | Public sector funds using grants, i.e. business as usual. |
| Portfolio 2 Adaptation | Transformational adaptation | Conventional finance | Public sector funds for new innovative adaptation or delivering at scale. |
| Portfolio 3 Levels of service | Incremental adaptation | Transformative finance | New instruments of financing models to scale-up adaptation. |
| Portfolio 4 Transformation (placemaking) | Transformational adaptation | Transformative finance | New instruments/ financing models for innovative systemic adaptation. |

Applying this framing to the strategic investment choices for the Clyde it is possible to map the likely funding and finance choices and how these will vary over time.

Table 18 maps the strategic investment portfolios (1-4) against the strategic investment choices for the Clyde. Figure 27 then maps these investment portfolios against the indicative Clyde Adaptation (investment) pathways to show the likely change in funding and finance needs and opportunities over time.

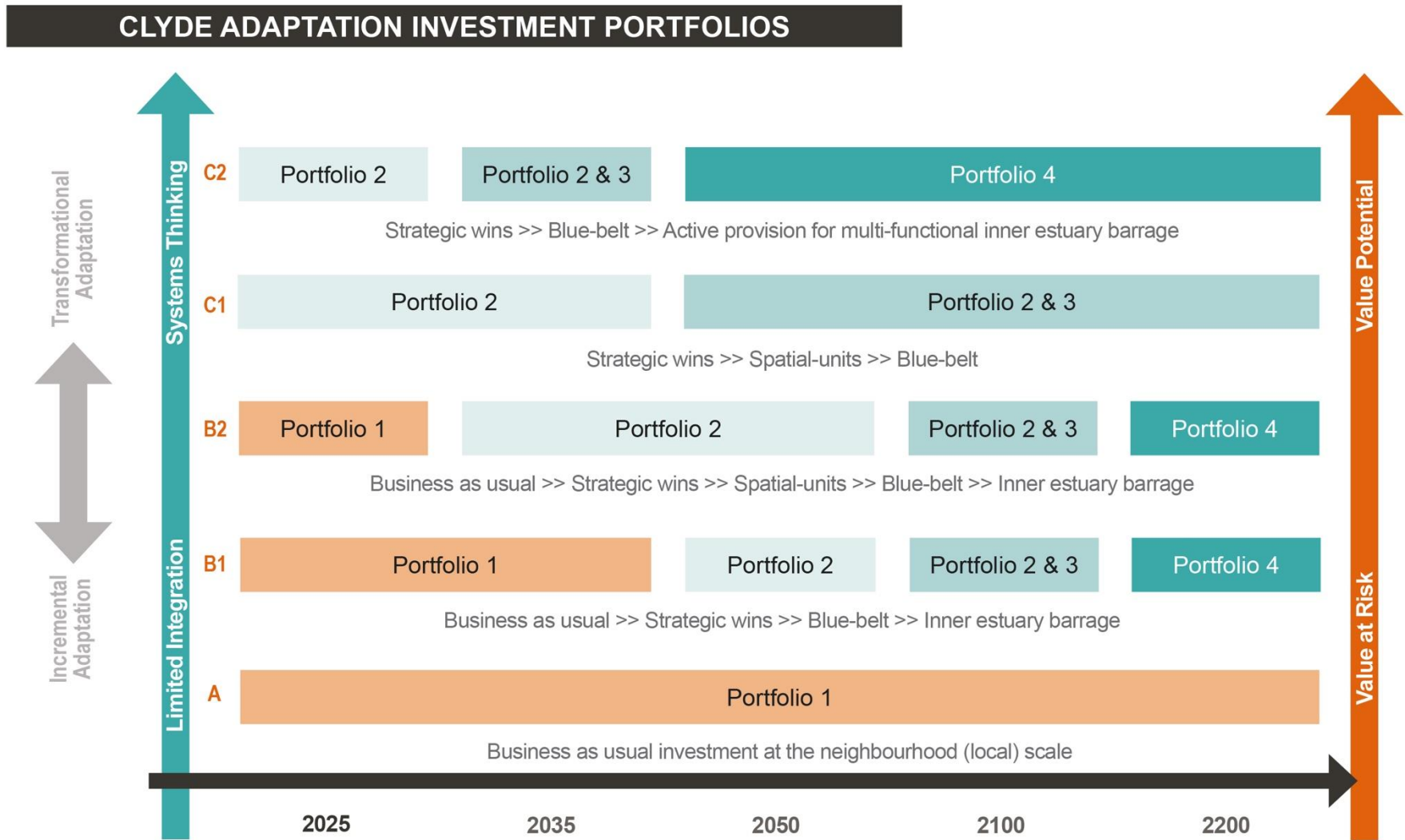
8.3.1.1 Table 18: Alignment between the Portfolios and investment choices for the Clyde

| Portfolio | Types of funding and finance | Applicability to the strategic investment choices for the Clyde |
|--|--|---|
| Portfolio 1 Disaster management and mitigation | Public Sector Insurance |  |
| Portfolio 2 Adaptation | Multi-public sector Third Sector Insurance |  |
| Portfolio 3 Levels of service | Public/private User Fees Insurance PPP |  |
| Portfolio 4 Transformation (placemaking) | All Sources of Investment |  |

What Figure 26 illustrates is that moving beyond reactive investment and incremental adaptation, the funding and financing needs will change over time; and depending on the chosen pathway(s), will move at different rates in terms of the pathway need for transformative financing and innovation.

Recognising that the lead time for delivering transformational solutions is likely to be 20+ years indicates that near-term funding and financing innovation is required if solutions are to be realised on the ground from 2040 onwards. To realise higher levels of transformational adaptation will also require solutions and investment cases to focus more on value potential (value creation) and greater systems thinking. This is explored in more detail in the next section.

Figure 27 – The potential investment journey based on Portfolios



8.4 Shaping future investments on the Clyde

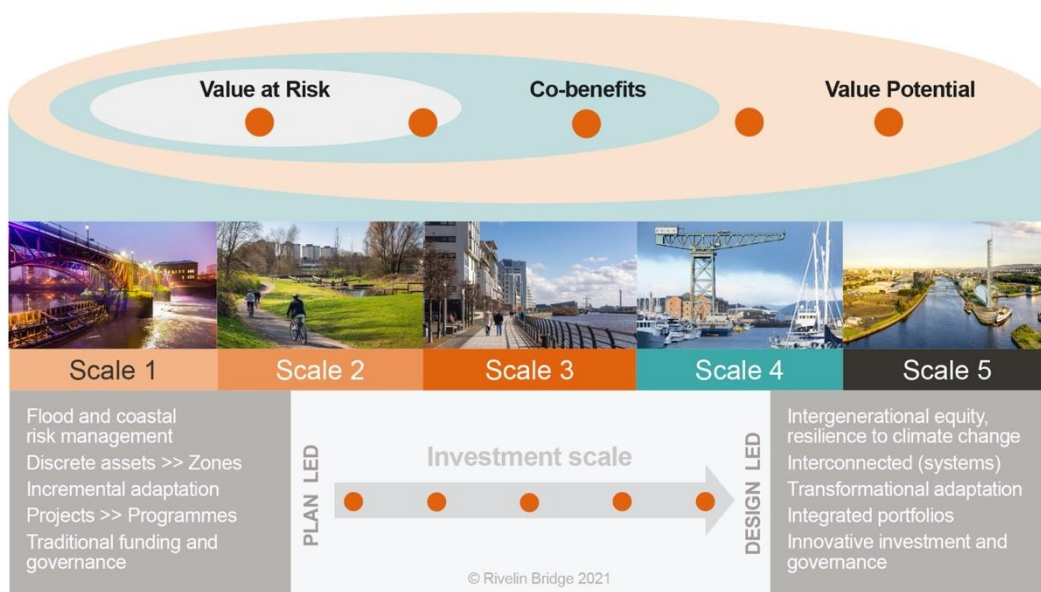
Looking forward, it is clear that moving straight to the development of a single pathway for the Clyde is unwarranted and in the absence of the right enabling environment, an explicit adaptation pathways plan will become a blocker to collaboration and system-wide decision making.

A more valuable first step to embedding adaptation pathway practices for the Clyde, is to agree an overall working framework and process for co-design and development of investment pathways. This process can then be used to facilitate and co-ordinate an investment shift towards greater public-private investment in system-level outcomes, and portfolios of projects that collectively realise multiple benefits; and enhance the resilience of current and future generations.

Figure 28 below illustrates the necessary investment practice shift (Scale 1 to 5) to support adaptation (investment) pathways. The left-hand side of the image (Scale 1) reflects the traditional approach to plan led investment based on discrete assets, incremental adaptation, and traditional funding tied to avoiding flood damages (Value at Risk). The right-hand side of the image (Scale 5) reflects an idealised investment approach that take a design led approach to investment based on intergenerational equity, transformational adaptation and innovative funding designed to support co-benefits and value creation.

A practical starting point for making this shift would be to pilot the concept of ‘value at risk’ and ‘value potential’ within business cases for flood and coastal risk management with the Clyde. This concept is described in the ClimateXChange report *“International practice on assessing investment needs and securing investment to adapt”*⁶⁸ (2021). The approach is currently (2022-2027) being piloted in England to support business case development for the £200m flood and coastal resilience innovation programme.

Figure 28: Investment practice shift to support adaptation pathways for the Clyde

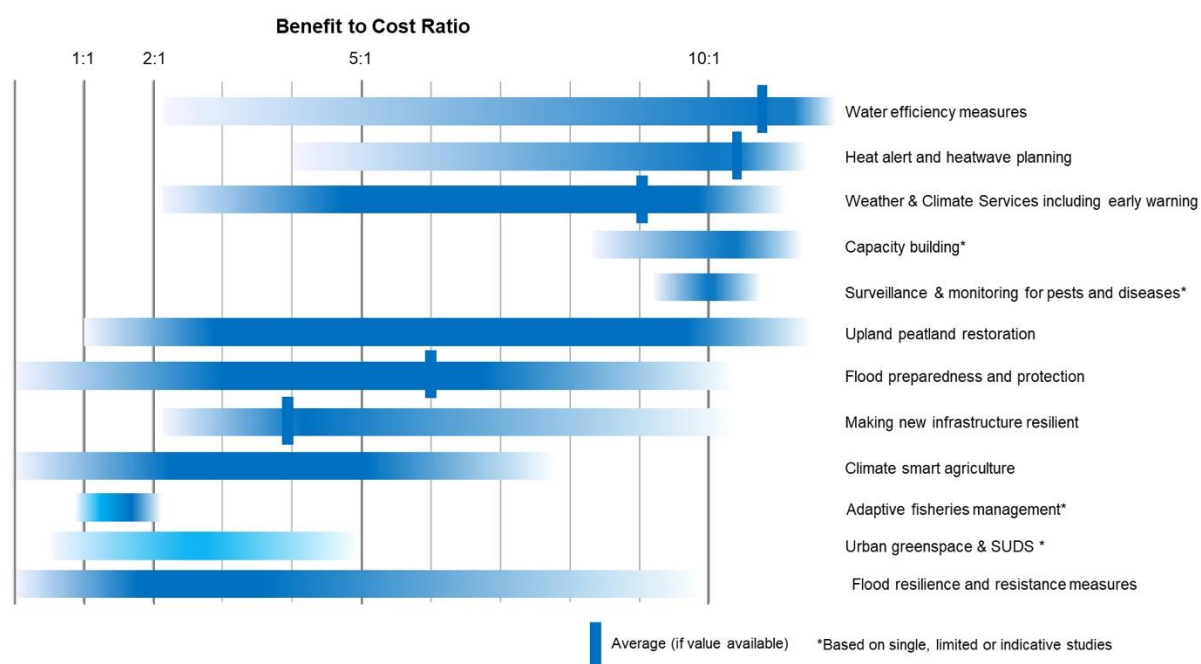


⁶⁸ <https://www.climateexchange.org.uk/research/projects/international-practice-on-assessing-investment-needs-and-securing-investment-to-adapt/>

A key part of the developing future business cases for adaptation pathways will be dependent on providing the supporting evidence for costs and benefits to support a full range of soft, green and grey measures. The evidence base for the costs and benefits of grey measures is accepted and embedded within existing appraisal guidance and methodologies. The evidence base for soft and green measures is less mature but developing.

A useful starting point for strategic consideration of costs and benefits is the work of Watkiss et al., (2020) illustrated in Figure 29. “The figure shows the indicative benefit-to-cost ratios and ranges for a number of adaptation measures. It is based on the evidence review undertaken in the CCRA3 Value Study, which was co-funded by the EU’s Horizon 2020 RTD COACCH project (Co-designing the Assessment of Climate Change costs). Vertical bars show where an average BCR is available, either from multiple studies or reviews. It is stressed that the BCRs of adaptation measures are highly site- and context-specific and there is future uncertainty about the scale of climate change; actual BCRs will depend in these factors”.

Figure 29: Benefit-cost ratios of climate change adaptation measures



Source : Paul Watkiss, Paul Watkiss Associates (2022)

To support future business cases and associated funding and finance it will be beneficial to capture future learning on costs and benefits as pathways evolve. This learning will be an important part of the necessary monitoring and evaluation for adaptation pathways.

9 Practical insights

9.1 Mission-based approach

One of the challenges to future decision making and investment on the Clyde is how best to align and co-ordinate the application of adaptation pathway practices within the landscape of initiatives, strategies and plans that already exist (*Section 5.1*). Important to this integration is the question: do adaptation pathways practices align with the transformational, Mission-based, approach to investment being led by the Clyde Mission; and can transformation and adaptation investments to tidal flood risk work together?

UCL's Institute for Innovation and Public Purpose has led on putting missions at the heart of innovation and growth policy globally. UCL published "Missions: A Beginner's Guide"⁶⁹ in 2019 that describes mission practices and four key working principles: co-creating markets, picking the willing, welcoming uncertainty, and tilting towards a direction. The UCL guide also sets out criteria for the development of missions, namely:

1. Be bold, inspirational with wide societal relevance;
2. Set a clear direction – targeted, measurable and time-bound;
3. Be ambitious and realistic;
4. Encourage cross-disciplinary, cross-sectoral and cross-actor innovation; and
5. Involve multiple, bottom-up solutions.

These working principles and design criteria align well with the working practices and desired outcomes of adaptation pathways (*Section 5.5*) and central attributes of the adaptation process described in BS8631:2021:

- To incorporate a long-term vision and objectives into short-term decisions;
- To develop flexible long-term responses to climate risks and opportunities in the face of uncertainty; and
- To identify interested parties to be engaged to achieve effective outcomes.

The conclusion of this report is that **a Mission-based approach to adaptation pathways, and investment will be essential** for the Clyde to:

- be responsive to socio-economic needs and physical/environmental challenges,
- provide a compelling and actionable narrative for investing in future generations and slow onset sea level rise, and
- support business case development to successfully secure funding & financing.

A Mission-based approach to the Clyde will provide a strong operational framework to drive ambitions, action and investment in the immediate future, and a platform for creating the enabling environment to deliver system-wide resilience and meet the needs of future generations. A mission-based approach will also foster co-creation and engagement, and the translation of adaptation pathways theory into tangible actions, initiatives and investment.

⁶⁹ https://www.ucl.ac.uk/bartlett/public-purpose/sites/public-purpose/files/iipp_policy_brief_09_missions_a_beginners_guide.pdf

Five practical benefits of a Mission-based approach to tidal adaptation on the Clyde are described in *Table 19* below. These benefits are conditional on the future operational environment embracing the concept of ‘designing for uncertainty’ (*Section 6.5*) and considering investment in terms of the impact on the next 7 generations.

Table 19: Practical benefits of a Mission-based approach to adaptation on the Clyde

| # | Description of benefit |
|---|--|
| 1 | A Mission-based approach provides a catalyst for addressing the urgent and important socio-economic issues on the Clyde, alongside the non-urgent and important physical and environmental issues associated with slow-onset sea level rise. The concept of non-urgent and important draws from Stephen Covey’s framework for prioritising actions aimed at delivering long-term goals. ⁷⁰ |
| 2 | A Mission-based approach provides a tangible and credible entry-point for adaptation engagement with public and private sector stakeholders that can be responsive to short-term interests, whilst facilitating dialogue (awareness and education) about the long-term needs and choices. |
| 3 | A mission-based approach can enable a more ‘design-led’ and creative approach to framing of investments that can support co-design of investments and innovation between the public, private and third sectors . A more design centred approach is also likely to enable more cross-sectoral solutions, realise multiple-benefit initiatives and more business-case ready solutions. |
| 4 | A mission-based approach can support adaptation pathways decision making and investment by recognising socio-economic triggers and opportunities alongside climate and asset related triggers. This will enable future plans and decisions to be responsive to ambitions and opportunities as well as climate shocks and stresses. |
| 5 | A mission-based approach on the Clyde can also address co-ordination gaps and foster governance arrangements to support system-wide investment . |

A key aspect of Mission-based approaches is stakeholder collaboration in the co-design of mission maps, narratives, visualisation and SMART goals aligned to opportunities for cross-sectoral innovation, and a clear and actionable portfolio of projects to enable bottom-up action and experimentation. These aspects and a good overview of the application of the approach can be seen in Camden Councils recently published report ‘Developing renewal missions in Camden’⁷¹ (2021) which explores issues and root causes, actors and tools, and opportunity area; and provides a clear narrative and route-map for taking the missions forward.

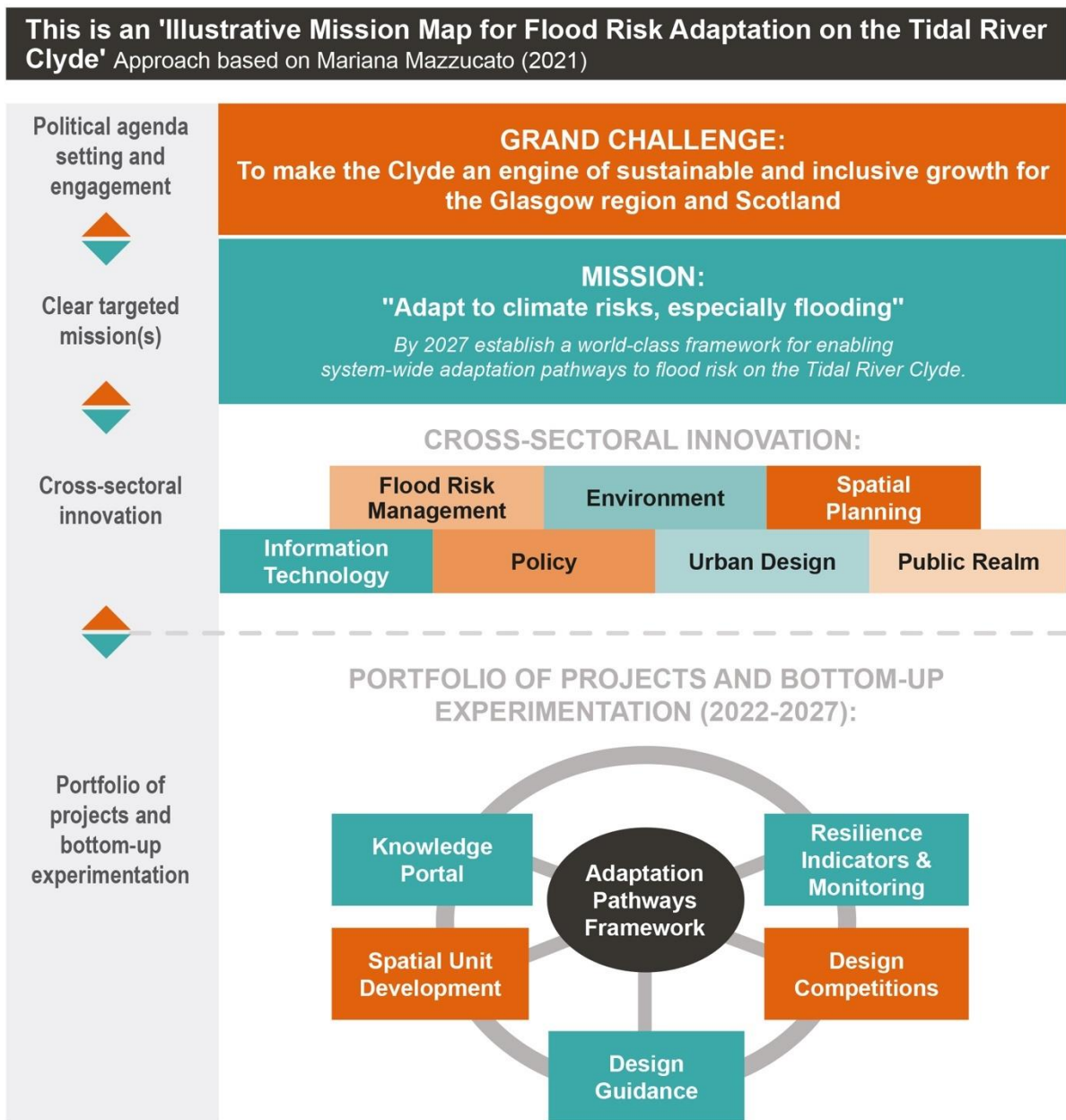
It is not the place of this research to prescribe a Mission Map. However, to provide a starting point for exploration, *Figure 30* provides an illustration of what this could look like for the Tidal River Clyde based on the approach of Marianna Mazzucato⁷² (2021).

⁷⁰ Stephen Covey, A. Roger Merrill, and Rebecca R. Merrill, *First Things First*. New York: Simon and Schuster, 1994.

⁷¹ https://camdenrenewal.com/wp-content/uploads/2021/12/Developing-renewal-missions-in-Camden_Renewal-Commission-Report-2021.pdf

⁷² *Mission Economy: A Moonshot Guide to Changing Capitalism*, Penguin Random House UK, 2021

Figure 30: Illustration of a Mission Map for adaptation



Project Descriptions:

Adaptation Pathways Framework. Establish process and governance for driving adaptation and learning on the River Clyde

Knowledge Portal. Develop and promote an accessible knowledge portal to support cross-sector collaboration, adaptation engagement and capacity building.

Spatial Unit Development. Develop operational spatial units to support integrated decision making between system, reach and neighbourhood scales.

Design Guidance: Co-create design and investment guidance for a future Blue-belt on the Clyde (for built environment and infrastructure investments).

Design Competitions. Collaborative design competitions to explore strategic opportunities and enable or pilot new solutions.

Resilience Indicators & Monitoring: Develop place-based indicators to monitoring changes in resilience accounting for climate change and adaptation investments.

9.2 A framework for adaptation pathways design for the Clyde

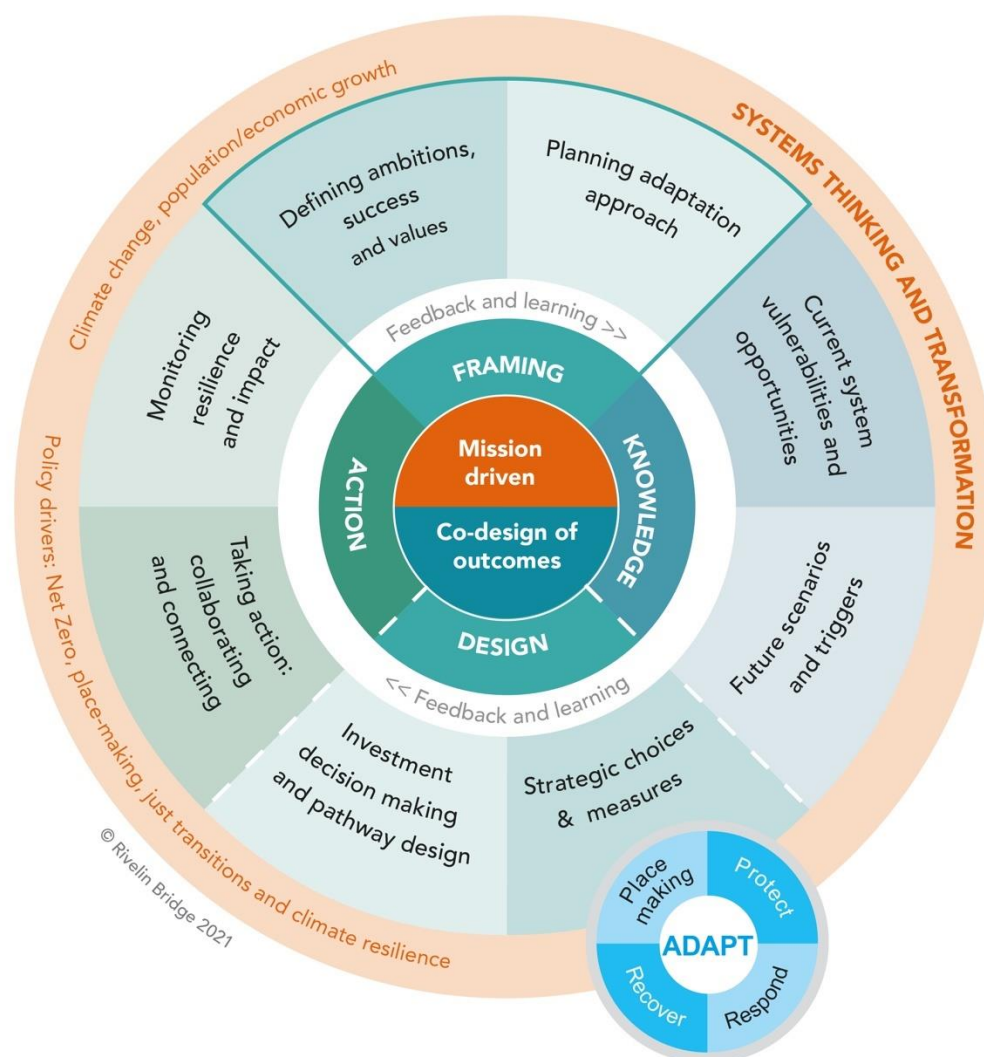
The emerging practice of adaptation pathways is not universally understood by professionals and stakeholders. The practice tends to be considered interchangeable with the broader concepts of climate adaptation and adaptive management; which although are related concepts do not directly link 'designing for uncertainty' (Section 6.5) and 'business case development' (Section 8.4).

Moving forward with investment decision making on the Clyde, this research indicates it will be important to agree a working framework, definitions and process for co-design and development of adaptation (investment) pathways. The process will need to support a Mission-based approach (Section 9.1) and systems-thinking, the necessary investment practice shift (Section 8.4), and foster innovation and learning. Co-design with stakeholders and local communities should be at the heart of the process.

Building on the practices explored in this report, Figure 31 illustrates a starting point for a Clyde specific framework for adaptation pathways design, framed around:

- 2 principles: systems thinking and transformation
- 2 core aspects to the process: mission-based and co-design of outcomes
- 4 core inter-dependent pillars: framing, knowledge, design and action, and
- 8 procedural steps connected by feedback and learning.

Figure 31: A framework for adaptation pathways design for the Clyde



The framework is a development of the best practice used to design the research methodology, namely: BS8631:2021 ‘Adaptation to climate change – Using adaptation pathways for decision making – Guide’⁷³, and The Dynamic Adaptive Policy Pathways (DAPP) methodology by Haasnoot et al., 2019⁷⁴. The overall workflow is clockwise through the 8 steps, but the framework supports interaction between the steps and parallel development of activities subject to sufficient definition of the initial Framing.

Building on this research and scoping, the framework is designed to support a transformation-orientated approach, placing more emphasis on “defining ambitions, success and values”, before stakeholder planning of the adaptation approach. The framework is not intended as finished product, but as a starting point for stakeholder design. *Table 20* sets out key aspects for stakeholder development and design.

Table 20: Key aspect of the framework requiring stakeholder development

| Step | Key aspects for stakeholder development |
|--|---|
| Framing | |
| Defining ambitions, success and values | <ul style="list-style-type: none"> ○ Ambitions should be co-designed with stakeholders and include a Clyde definition of resilience (now and in the future). |
| Planning adaptation approach | <ul style="list-style-type: none"> ○ A process (framework) should be co-designed with Stakeholders to inform governance, engagement activities, phasing of actions and priorities, and monitoring and evaluation. |
| Knowledge | |
| Current system vulnerabilities and opportunities | <ul style="list-style-type: none"> ○ A boundary should be agreed to the spatial extent of the system taking a resilience zone approach. |
| Future scenarios and triggers | <ul style="list-style-type: none"> ○ Early agreement on future scenarios will be important to collaboration and engagement. ○ Trigger design should include socio-economic triggers, physical trigger such as asset conditions, and climate change. |
| Design | |
| Strategic choices and measures | <ul style="list-style-type: none"> ○ A menu approach should be taken to the design on choices and measures taking account of investments in place-making, protect, respond, recover and adapt. |
| Investment decision making and pathway design | <ul style="list-style-type: none"> ○ A portfolio approach to investments should be taken, rather than a single over-arching plan. ○ Investment decision making should include benefits associated with ‘value at risk’ and ‘value potential’. |
| Action | |
| Taking action: collaborating and connecting | <ul style="list-style-type: none"> ○ It will be important to include pilot programmes to build trust and credibility with stakeholders and decision makers. |
| Monitoring resilience and impact | <ul style="list-style-type: none"> ○ Early agreement on the framework for monitoring and evaluation (linked to the Clyde definition of resilience) will be valuable to tracking progress, successes and achievements. |

⁷³ <https://shop.bsigroup.com/products/adaptation-to-climate-change-using-adaptation-pathways-for-decision-making-guide/standard>

⁷⁴ https://doi.org/10.1007/978-3-030-05252-2_4

9.3 Priorities

Building on the mission map described in *Section 9.1*, and the proposed framework for mission-based adaptation pathways set-out in *Section 9.2*, *Table 21* outlines priority actions for progressing adaptation pathway practices and design for the Clyde. Priority should be given to actions 1, 2, 3 and 4 (Framing activities) but once these are sufficiently defined other actions can run in parallel.

Table 21: Priorities for progressing Clyde adaptation practices and pathway design

| Action | Description of recommended action |
|--|---|
| Defining ambitions, success and value | |
| 1 | Co-design a Mission Map for system-wide adaptation. |
| 2 | Co-design resilience indicators and metrics for the system |
| Planning adaptation approach | |
| 3 | Formalise a framework for Mission-based adaptation on the Clyde. |
| 4 | Develop operational spatial units to support system-wide decision-making |
| Current system vulnerabilities and opportunities | |
| 5 | Scope the development of a knowledge portal for the Clyde |
| Future scenarios and triggers | |
| 6 | Develop Clyde specific guidance for designing for uncertainty. |
| 7 | Evaluate the combination of long-term tidal and fluvial risk |
| Strategic choices and measures | |
| 8 | Investigate strategic-wins (tidal barrage, creation of new wetlands, protection of critical road and rail infrastructure, managed realignment). |
| Investment decision making and pathway design | |
| 9 | Develop guidance for blue-green infrastructure and water sensitive design and appraisal (value at risk and value potential). |
| Taking action – collaborating and connecting | |
| 10 | Establish communications and engagement strategy (including opportunities for co-design and design competitions). |
| Monitoring resilience and impact | |
| 11 | Establish a route-map for monitoring resilience and learning. |

9.4 Building adaptation capacities and competence

Central to tackling the adaptation challenge for the Clyde is building and sustaining adaptation capacities and competence over the next decade to successfully foster systems thinking, collaboration and co-design of outcomes and solutions. Creating and realising the potential for adaptation pathways will not be achieved through traditional flood and coastal risk management practice, competencies and resourcing. A more

design-led approach is called for that can flexibly respond to both risks and opportunities.

The recently published Design Council research report “*Beyond Net Zero: A systemic design approach*”⁷⁵ provides a useful starting point for building the competencies and designing working practices to support adaptation on the Clyde. The report is relevant as it explores how design can best play a role in delivering: Net Zero, climate mitigation and climate adaptation, and sustainability.

Two key insights from the Design Council research that are relevant to the Clyde are:

1. The importance of fulfilling four key design roles within the process, and
2. Four overarching working practices that designers should adopt.

The four key design roles, competencies, are summarised in *Table 22*, and are underpinned by the four working practices of:

- **divergent and convergent thinking** – which dedicates time to understand the context before rushing to solutions;
- **disrupting and remaking** – by understanding root-causing and what can be made to disrupt the problem and create necessary change;
- **zooming in and out** – switching focus between system, reach and neighbour scales, and between the present to the future; and
- **resourcing ‘invisible’ activity** – to build connections, relationships, leadership and storytelling to enable delivery.

Table 22: Key design roles / competencies (Source Design Council 2021)

| Four key design roles / competencies | |
|--------------------------------------|--|
| Systems thinker | Someone who has the ability to see how everything is interconnected in a bigger picture and zoom between the micro and macro and across silos. |
| Leader and storyteller | Someone who can tell a great story about what might be possible and why it is important, get buy-in from all levels and have the tenacity to see the work through. |
| Designer and maker | Someone who understands the power of design and innovation tools, has the technical and creative skills to make things happen, and put these to work early in the process. |
| Connector and convenor | Someone who has good relationships, can create spaces where people from different background come together, and joins the dots to create a bigger movement. |

Building competencies and embedding new ways of working over the next decade will require significant resource commitment in both time and money.

9.5 Designing for uncertainty

A core principle of adaptation pathways (BS8631:2021) is *planning for multiple futures, not just “most likely” or single predicted future*; and the associated engineering concept of designing for uncertainty (*Section 6.5*). To support collaboration between planners, engineers and investment decision makers (public and private) it will be important to

⁷⁵ <https://www.designcouncil.org.uk/resources/guide/beyond-net-zero-systemic-design-approach>

agree a common approach to scenario development and sensitivity analysis on the Clyde, particularly with respect to future sea level rise scenarios. This research concludes that a practical approach for scenario development is to adopt the Englander 9-Box matrix embraced by the Institution of Mechanical Engineer's in their publication "Rising Seas: The Engineering Challenge" (2019)⁷⁶.

Table 23 summarises how this approach can be applied to agree a consistent set of sea level rise scenarios for the Clyde. More detail is provided in Section 6.5. For the purpose of adaptation pathway development, the absolute increase in sea level is less important than ensuring investment choices and decisions consider a wide range of future scenarios.

Table 23: Proposed approach to determining sea level rise scenarios for Clyde

| | | Horizon for scenarios / expected asset life | | |
|--------------------------|--------|--|--|-----------|
| | | 30 Years | 50 years | 120 years |
| | | Basis for calculating the future increase in sea level | | |
| Asset Risk / Sensitivity | Low | Base level on SEPA Guidance (2019) ⁷⁷ (new guidance is expected Spring 2022) | | |
| | Medium | Base level on SEPA guidance multiplied by 1.5 to provide a margin of safety | Base level on UKCP09 ⁷⁸ lower H++ scenario for 2100, plus SEPA Guidance of 0.15m/decade after 2100. | |
| | High | Base level on SEPA guidance multiplied by 2.0 to provide a margin of safety | Base level on UKCP09 upper H++ for 2100 plus SEPA Guidance of 0.15m/decade after 2100. | |

Although this research has focused on tidal flood risk and future sea level scenarios, it is important that future design and investment decisions also take account of the interaction with future fluvial and pluvial flood risk scenarios. This was beyond the scope of this research. However, as the fluvial hydraulic model for the Clyde catchment has recently been updated (2021), this provides a basis for building on this research, to explore the future interaction of tidal and fluvial risk. This will be particularly important to the future exploration of adaptation measures and choices on the inner and middle reaches of the tidal Clyde (the tidal weir to Erskine Bridge).

9.6 System-level investigations

Section 7 of this report has described the portfolio of interventions available for adaptation to tidal flood risk on the Clyde, structured around:

- aspects of resilience: anticipate, resist, absorb, respond, recovery, and adapt/transform, and

⁷⁶ <https://www.imeche.org/policy-and-press/reports/detail/rising-seas-the-engineering-challenge>

⁷⁷ https://www.sepa.org.uk/media/426913/lups_cc1.pdf

⁷⁸ <https://www.metoffice.gov.uk/research/approach/collaboration/ukcp>

- three types of measures: soft, green and grey.

At a system-level there are three interventions that should be investigated in the short-term to improve understanding of the system behaviour and interdependencies, inform adaptation pathway choices (in terms of benefits and trade-offs), and explore potential investment triggers and phasing of strategic choices. The three investigations are outlined in *Table 24* below.

These investigations will also inform understanding of potential no-regret investments and help avoid potential maladaptation. The three investigations are not intended to limit the investment choices or future consideration of a full range of grey, green and soft infrastructure measures and options.

Table 24: Investigations to inform adaptation pathway choices

| Intervention | Estuary location | Summary description of short-term investment |
|---------------------------------------|------------------|---|
| Tidal barrage | Inner and Middle | Explore: the strategic case for a multi-functional barrage; taking account of all sources of flood risk, water quality and geomorphology; social, economic and environmental benefits / costs; and potential adaptation pathways, phasing and logistics. |
| Creation of new tidal wetlands | Middle | Explore: the strategic case for creation of new tidal wetlands (including integration of saline tolerant agriculture) in the vicinity of the Clyde, White Cart and Black Cart Rivers, to adapt to the combined influences of sea level rise, tidal flood risk and fluvial flood risk in the long-term; and the potential to enhance the Clyde's natural capital and biodiversity. |
| Critical road and rail infrastructure | Outer | Explore: the long-term risks to critical road and rail infrastructure from sea level rise, extreme tides and coastal erosion; the socio-economic impacts; investment options and potential adaptation pathways, phasing and logistics. |

In addition to the above, there are two further investments, described in *Table 25*, that should be explored in the short-term due to their influence on adaptation pathway design at a system-level, reach and neighbourhood scale, and their importance to fostering co-design of outcomes between stakeholders and 'defining ambitions, success and values'.

Table 25: Enabling activities to support co-design and frame successful outcomes

| Enabling activities | Estuary location | Summary description of short-term investment |
|-------------------------------|------------------|--|
| Spatial Unit Design | System-wide | Explore and develop spatial units to support decision making at system, reach and neighbourhood scales. This should include establishing a Resilience Zone (described in <i>Section 6.5.2</i>) to provide a clear spatial boundary for spatial unit design and decision making. |
| Design and appraisal guidance | System-wide | Explore and develop Clyde specific design and appraisal guidance to support spatial planning, and embed innovation in blue-green infrastructure within investment decisions on the waters-edge. |

9.7 Capacity building for adaptation pathways

To address the challenges and opportunities described in this report, and stimulate cross-sectoral innovation for adaptation on the Clyde, there are a number of priority areas for upskilling of existing professionals and wider capacity building (knowledge, skills and services). These priority areas are set-out in *Table 26* against the adaptation framework themes (*Figure 29*). A key success factor in building capacities for adaptation will include fostering **life-long learning** of existing professionals recognising this is a fast-moving, cross-cutting and emergent area of practice.

Table 26: Priority areas for upskilling and capacity building

| # | Description of capacity building areas |
|---|--|
| Theme: Framing | |
| C1 | Training and development of existing professionals to enhance capacities for co-creation and application of adaptation pathway practices . |
| C2 | Training and development of existing professionals to enhance capacities for systems-thinking, innovation and resilience . |
| Theme: Knowledge | |
| C4 | Expansion and development of new tools and services to support systems thinking and resilience . |
| Theme: Design (and investment decision making) | |
| C5 | Enhancement of existing standards, design guidance and tools to embed place-making practices, and accelerate and scale the uptake of blue-green infrastructure practices within the spatial planning and civil/environmental engineering professions. |
| C6 | Enhance professional capacities for co-design of solutions (including cross-sectoral working) and business case preparation for adaptation. Expanding |

| # | Description of capacity building areas |
|---------------------------------|--|
| | the number of 'T-shaped' professionals ⁷⁹ will be key to this, meaning professionals that are broad in their thinking, able to work across silos, and deeply knowledgeable and up to date in their core professional expertise. |
| Theme: Action (delivery) | |
| C7 | Continue to enhance education and capacity building to address the deficit in engineering skills , including flood risk management and coastal engineering, recognised by the Royal Academy of Engineering ⁸⁰ , the Chartered Institute of Water and Environmental Management ⁸¹ , the soon to be published " <i>Jobs and skills for adaptation and resilience in the Clyde Corridor</i> " by Dr Leslie Mabon, School of Engineering and Innovation, the Open University. |
| C8 | Enhance existing tools, products and services related to monitoring and communicating climate hazards, resilience and adaptation . |

In addition to technical development of existing professionals, it will be important for public, private and third sector collaboration to continue building the adaptation culture, networks and capabilities of organisations present in the Clyde region.

The Adaptation Scotland 'Capability Framework'⁸² provides a well-established framework for assessing organisational capabilities and planning future improvements. The framework is centred around 4 pillars:

- Organisational culture and resources
- Understanding the challenge
- Planning and implementation, and
- Working together.

In addition to the capability framework there are a number of emerging British Standards that can support learning and capacity building for the Clyde, these include:

- Adaptation to climate change – Principles, requirements and guidelines (ISO 14090:2019)⁸³
- Adaptation to climate change – Requirements and guidance on adaptation planning for local governments and communities (ISO 14092:2020)⁸⁴
- Adaptation to climate change – Guidelines on vulnerability, impacts and risk assessment (ISO 14091:2021)⁸⁵, and
- Adaptation to climate change – Using adaptation pathways for decision making – Guide (BS 8631:2021)⁸⁶

⁷⁹ doi: 10.2166/wp.2013.011

⁸⁰ <https://www.raeng.org.uk/publications/reports/engineering-skills-for-the-future>

⁸¹ <https://www.newcivilengineer.com/latest/london-centre-launched-to-tackle-flooding-skills-gap-25-04-2018/>

⁸² <https://www.adaptationscotland.org.uk/how-adapt/your-sector/public-sector/framework>

⁸³ <https://shop.bsigroup.com/products/adaptation-to-climate-change-principles-requirements-and-guidelines/standard>

⁸⁴ <https://shop.bsigroup.com/products/adaptation-to-climate-change-requirements-and-guidance-on-adaptation-planning-for-local-governments-and-communities/standard>

⁸⁵ <https://shop.bsigroup.com/products/adaptation-to-climate-change-guidelines-on-vulnerability-impacts-and-risk-assessment/standard>

⁸⁶ <https://shop.bsigroup.com/products/adaptation-to-climate-change-using-adaptation-pathways-for-decision-making-guide/standard>

10 Summary of options

This research has explored a wide range of strategic options and choices for the application of adaptation pathways for the Clyde, and tactical options for starting the process and route-map development and actions. It is not the intention of this report to screen out choices. The future choices will be dependent on the chosen framing of adaptation ambitions. It is important that the ambitions and associated objectives and outcomes are co-designed with stakeholders right from the start.

Table 27 summarises the strategic and tactical options explored in this report and the recommended starting points for further development. The options in the table are hierarchical meaning the options will inform the options and choices below them. i.e. the adaptation approach selected will inform the strategic investment choices and strategic pathways and so on.

Table 27: Summary of options and choices

| Options | Recommended approach or starting point |
|---|--|
| Strategic assessment of options | |
| Adaptation approach (Sections 5.5 and 9.1) | <p>Recommended that a <i>Mission-based</i> approach is taken to drive transformational adaptation at a system-level; and that <i>Design Principles</i> for Adaptation Pathways are agreed.</p> <p>Seven Design Principles:</p> <ol style="list-style-type: none"> 1. To make the Clyde an engine of sustainable and inclusive growth; 2. To foster world-class place-based adaptation solutions for flood and coastal resilience, actively responding to: <ul style="list-style-type: none"> • Long-term sea level rise • Current and future extreme tides and coastal storms • Current and future fluvial and surface water flood risks 3. To take an outlook that responds to current societal needs and the interests of next 7 generations; 4. To support business case ready solutions that can secure public and private funding and finance, and realise long-term value for money and co-benefits; 5. To support the transition to Net Zero; 6. To mobilise resources and commitments to drive innovation and deliver initial adaptation measures and priorities; and 7. To provide a framework for monitoring and learning. |
| Strategic investment choices (Section 8.2) | <p>Five strategic investment choices are identified as a starting point for examining strategic investment choices:</p> <ul style="list-style-type: none"> ○ Business as Usual ○ Strategic Wins ○ Blue-Green Units ○ Blue-belt ○ Blue-belt + Barrage <p>○ Business as Usual: Continue decision making based on national prioritisation of hot-spots and risk within a rolling 6-year investment programme.</p> |

| Options | Recommended approach or starting point |
|---|---|
| | <ul style="list-style-type: none"> ○ Strategic Wins: In combination with Business as Usual, invest in options that deliver system-wide adaptation benefits, maximise future choices and/or actively shape and inform pathway design. ○ Blue-Green Units: Establish Blue-Green Spatial Units that enable development choices and implementation at the reach/neighbourhood whilst fostering system-wide integration. ○ Blue-belt: In combination with Blue-Green Spatial Units invest actively in an accessible and resilient waterfront along the length of the Clyde. ○ Blue-belt + Barrage: In combination with Blue-Belt invest in a multi-functional inner Clyde barrage. |
| <p>Strategic pathways (Section 8.2)</p> | <p>Five plausible adaptation pathways are identified as a starting point for pathway design and development:</p> <ul style="list-style-type: none"> ○ reactive ○ delayed adaptation ○ managed transformation ○ mission-based one ○ mission-based two <p>Plausible pathways:</p> <ul style="list-style-type: none"> ○ Reactive: Rolling programme of Business as Usual flood risk management investments at the reach and/or neighbourhood scale ○ Delayed Adaptation: Business as Usual in the near future, followed by a managed transition of strategic wins and blue-belt development, followed by development of a multi-functional barrage in the next century. ○ Managed Transformation: A managed transition applying the strategic choices as adaptation steps: Business as Usual, Strategic Wins, Blue-Green Unit and Blue-Belt this century, backed-up with the planned possibility for a Clyde Barrage in the next century. ○ Mission-based One: System wide development of an accessible and resilient waterfront based on no physical restriction to tidal movement and river flows; starting with strategic wins in the short-term, Blue-Green Unit development within the next two decades, and incremental development of a system-wide masterplan accommodating flexible land use policies. ○ Mission-based Two: System wide development of an accessible and resilient waterfront including an inner Clyde multi-functional barrier; starting with strategic wins in the short-term, Blue-Green Unit development within the next two decades, and multi-functional barrage implementation mid-century onwards. |
| <p>System wide opportunities and measures (Section 7.2)</p> | <p>A portfolio approach is recommended to identify measures and develop solutions with the portfolio based on:</p> <ul style="list-style-type: none"> ○ Anticipate, Resist and Absorb, Respond and Recovery, Adapt and Transform ○ Soft, Green and Grey Measures |

| Options | Recommended approach or starting point |
|--|--|
| | <p>Key Aspects of resilience:</p> <ul style="list-style-type: none"> ○ Anticipate: These include actions to prepare in advance to respond to shocks and stresses. ○ Resist and Absorb: These include actions taken in advance to help withstand or endure shocks or stresses to prevent an impact on infrastructure services as well as actions that, accepting there will be or has been an impact on infrastructure services, aim to lessen that impact. ○ Respond and Recovery: Actions that help quickly restore expected levels of service following an event. ○ Adapt and Transform: Actions that modify the system to enable it to continue to deliver services in the face of changes and actions that regenerate and improve systems for the future. <p>Types of measures:</p> <ul style="list-style-type: none"> ○ Soft measures: These measures include the non-structural, policy, regulatory and financial measures that enable other structural measures or influence future land use and the built environment to manage risk. ○ Green measures: These include natural and nature-based solutions (NbS) to provide coastal protection and other ecosystem services. As defined by Engineering with Nature, “NbS focus on conserving, restoring and engineering natural systems for the benefit of people and ecosystems we inhabit”. ○ Grey Measures: These are physical, human-made engineered structures to provide coastal protection usually made with relatively hard materials to a specified standard of protection. |
| Reach level adaptation choices (Section 7.4) | <p>Seven key choices identified at the reach level providing a starting point for investigations:</p> <ul style="list-style-type: none"> ○ Tidal barrage ○ Raised tidal defences ○ Elevation of quay walls and marine facilities ○ Critical road and rail infrastructure ○ Greening the Grey ○ Manage Realignment |
| Tactical assessment of next steps | |
| Process (Section 9.2) | <p>It is recommended that:</p> <ul style="list-style-type: none"> ○ An adaptation framework is developed for the application of adaptation pathways for the Clyde; and that the practice is adopted as a decision-making framework in the first instance. |
| Investigations (Section 9.6) | <p>Three investigations are recommended for:</p> <ul style="list-style-type: none"> ○ Tidal barrage ○ Creation of new tidal wetlands ○ Critical road and rail infrastructure |
| Enabling activities (Section 9.6) | <p>Two enabling activities are recommended:</p> <ul style="list-style-type: none"> ○ Spatial Units developed. ○ Design and appraisal guidance developed. |

11 Scoping conclusions and lessons

Over the last 200 years the Clyde has experienced significant adaptation and transformation. As the region looks ahead, this continued transformation will be essential to addressing future climate shocks and stresses (including tidal flood risk), alongside socio-economic and environmental ambitions; to meet the needs and aspirations of both current and future generations.

Building on this history of adaptation, stakeholders have expressed a desire to re-imagine the current relationship between the river, people and place; to create a vibrant connected river corridor and waterfront, and make the river “*an asset to be proud of*”. The approach to adaptation for the Clyde will therefore need to be transformation-orientated, with place-making and resilience at the heart of investment decision making and future pathway design.

The following conclusions arising from this research are important to understanding the necessary transformation and framing adaptation pathways practices for the Clyde.

Sea Level Rise. The climate evidence shows that it is plausible for mean sea levels in the Clyde to rise by 1.5m to 2.5m over the next 120 years, and higher still in the future. The consequence, if adaptation measures are not taken, is areas that are currently exposed to occasional flooding from coastal storms and tidal surges will become inter-tidal or permanently under water. Within the context of traditional planning timeframes which are 5-25 years, sea level rise may appear to be “*non-urgent*” to decision makers. However, considering today’s investments will shape the infrastructure and land-use well into the next century, then planning for sea level rise and tidal flood risk becomes “*important*” in the short-term.

Decision making framework. The practice of adaptation pathways is flexible enough to be used as an investment decision making framework and/or as a project planning tool. For the Clyde, the practice has most to offer as a decision-making framework. This will enable the approach to work alongside established governance arrangements and delivery routes (public and private), to embed resilience and adaptation within existing and near-term plans; and inform shared ambitions and plausible investment pathways.

Investment options and pathways. The scoping described in this report has identified a number of strategic approaches to option development for the Clyde, described as: Business as Usual, Strategic Wins, Blue-Green Units, Blue-Belt and Blue-belt + Barrage. These strategic approaches have been combined to illustrate five plausible long-term investment pathways for adaptation on the Clyde. The five investment pathways are:

- Reactive
- Delayed Adaptation
- Managed Transformation
- Mission-based (no Barrage)
- Mission-based (with Barrage)

Investment practice shift. Adaptation to tidal flood risk on the Clyde is unlikely to satisfy stakeholder ambitions unless it is supported by a shift in appraisal and investment practice that unlocks wider sources of funding and finance. The shift will need to drive public and private investment, and sustain a working portfolio of projects that collectively realise multiple (societal, economic and environmental) benefits to enhance the resilience of the Clyde today and in the future.

Resource commitment. Adaptation pathway approaches will assist decision making and development of solutions for the “*non-urgent but important*” impacts of sea level rise and tidal flood risk. Existing flood risk management investment practices and mindsets will however be insufficient to foster the public-private collaboration and innovation to deliver transformation-orientated adaptation. For adaptation to succeed, it will be necessary to embrace new ways of working and build multidisciplinary team(s) supported by dedicated resources and early investment.

Further lessons emerging from this research and scoping are outline in *Table 28*.

Table 28: Lessons for the scoping of adaptation pathways.

| # | Description of benefit |
|----------------------------------|--|
| BS8631:2021 | BS8631:2021 provides a good starting point for scoping of adaptation pathways. It is important to recognize that the approach can be tailored to suit the investment situation and applied as a strategic process to support co-design and collaboration and/or as a detailed tool for mapping investments and implementation. Applied knowledge of adaptation practices to secure investment and implement solutions on the ground is not extensive, and for that reason there is value in a literature review (and interviews with practitioners) as part of scoping to capture emerging insights and lessons from other projects. |
| Multi-disciplinary team | A multi-disciplinary team is necessary for scoping adaptation pathways. Aside from adaptation expertise it is important to include expertise related to: policy and spatial planning, engagement and co-design, GIS and data management, climate resilience, coastal management and engineering, benefits analysis and business cases. It is also crucial to include local knowledge and networks. |
| Framing ambitions and objectives | Involvement of project partners and stakeholders in the framing of adaptation ambitions and objectives is key to situational awareness, and prioritising scoping activities, data sources and project outputs. |
| Systems and futures thinking | Systems and futures thinking are challenging, and it is easy to revert to local scale thinking and insights based on historic trends and lived experience. Scoping stage governance therefore needs to provide assurance that sufficient weighting is given to credible future scenarios. |
| Data collection programme | Data collection, obtaining data licenses and validation of information is time consuming and needs to be adequately resourced and programmed to commence at the start of any scoping exercise. |
| Site validation | Data and GIS are no substitute for a site walk-over and inspection to provide a sense of place and validate insights. |
| Sign-posting case studies | Adaptation is cross-sectoral in nature. For findings and insights to be credible across disciplines and with stakeholders, it is important to sign-post existing practice, case studies and examples. |
| Monitoring and evaluation | Understanding of monitoring and evaluation, and the identification of signals, thresholds and triggers is key. This can include environmental and climate triggers, physical changes such as asset condition, as well as wider socio-economic changes. It is therefore important for the team to have a good appreciation of indicator design, tools and evaluation. |

12 Recommendations

12.1 Priority recommendations

Progressing the practice of adaptation pathways for the Clyde, it is important “*not to rush to solutions*”, but instead focus time, money and resources on: creating a shared vision of desirable futures and framing ambitions; establishing working practices for collaborative decision-making, innovation and learning; and developing a system-wide understanding of resilience and adaptation choices at a strategic level.

These are core foundations for enabling an adaptation pathways approach to be implemented for the Clyde, providing the ‘framing’ for future: knowledge, design and action stages. Recommended first steps for adaptation on the Clyde include:

- R1.1 agree a *framework* for the application of adaptation pathways for the Clyde that fosters systems-thinking and a process for place-based decision making;
- R1.2 agree what “a resilient Clyde” means, to inform *design principles* for investment and pathway development, and shape indicators for monitoring and evaluation;
- R1.3 establish a ‘*resilience zone*’, a geographic boundary for decision-making;
- R1.4 build an action plan (*Mission Map*) for the first five years of investment; and
- R1.5 scope and develop a knowledge portal to support innovation, collaboration and long-term monitoring and evaluation.

These recommendations are demanding and will require stakeholders to think in new ways and commit time and energy to the process. The potential reward, in terms addressing tidal flood risk and achieving the grand challenge ‘*to make the Clyde an engine of sustainable and inclusive growth*’ is locally, regionally and nationally compelling. This report includes a recommended *framework* and *resilience zone*, and indicative *design principles* and *Mission Map*, providing a starting point for future stakeholder co-design and action.

12.2 Secondary recommendations

To inform the understanding of adaptation pathways and choices for the Clyde, it is also recommended that the following investigations are undertaken to:

- R2.1 explore the strategic investment case for a multi-functional tidal barrage within the inner and middle reaches of the Clyde;
- R2.2 explore the strategic investment case for creation of new tidal wetlands in the vicinity of the Clyde, White Cart and Black Cart Rivers; and
- R2.3 explore the risks to critical road and rail infrastructure in the outer reach of the Clyde, and options to sustain future infrastructure services.

The above investigations are recommended because they will inform the technical understanding of how the system works, and the understanding of potential investment triggers, plausible pathways and the phasing of strategic choices. The investigations will also inform understanding of potential no-regret investments and help avoid potential maladaptation. These investigations are not intended to restrain future consideration of grey, green and soft infrastructure measures and options.

To support systems-thinking and future investment two further enabling activities are also recommended, namely:

- R2.4 explore and develop operational spatial units to support integrated decision making between system, reach and neighbourhood scales; and
- R2.5 explore and develop Clyde specific design and appraisal guidance to support spatial planning, and embed co-benefits within investment decision making and pathway design.

12.3 Additional recommendations

A core aspect of this research and the dialogue undertaken with stakeholders is related to the availability of existing data and evidence. Looking forward it is recommended that regional and national investments to enhance access to data and make evidence more accessible to a wider range of audiences are continued.

Furthermore, it is recommended that future investments are expanded to:

- strengthen incentives for public and private bodies to share data and information;
- support non-specialist users to access, use and interpret available datasets; and
- share and promote learning from adaptation as new data and evidence emerges.

More important than enhancing data and information management is the need to enhance awareness of resilience and adaptation practices to support collaboration and planning for climate change. It is recommended that guidance is enhanced and developed to support:

- understanding of system-thinking, resilience and adaptation pathway practices;
- uptake of a broader portfolio of adaptation measures including grey, green and soft infrastructure;
- appraisal of adaptation investments, and greater consideration of co-benefits, value-creation, and funding and finance within business cases;
- monitoring and evaluation of adaptation to strengthen impact analysis, pathway design, and learning related to the costs and benefits of adaptation.

13 Appendix A International literature review document summaries

| Case study location | Document Title | Summary of document |
|---------------------|--|---|
| Copenhagen | Climate Adaptation Plan | The Climate Adaptation Plan sets out the intent and vision to combat the impacts of climate on the city of Copenhagen. They have an ambition to be climate neutral by 2025 and seek to tackle the climate adaptation by promoting 'integrated planning of the city and its infrastructure to the benefit of the population and environment'. As well as tackling the challenges of increased and heavier downpours and higher sea levels, this plan also considers higher temperatures, urban heat islands, climate change groundwater and indirect consequences. |
| | Copenhagen Urban Lab | Copenhagen Urban Lab was a design challenge to develop a tool to assist coastal communities in the challenges of sea level rise and storm surges. Through the Urban Lab the Copenhagen Lens was developed as a stakeholder engagement tool that provides a pathway for municipalities to develop a guiding vision for coastal adaptation. |
| | Climate Change Adaptation in Delta Cities: Good Practice Guide | This Good Practice Guide identifies the key elements required to successfully deliver climate change adaptation in delta cities. Copenhagen is included for developing a Climate Adaptation Plan complemented by the Cloudburst Management plan to deal with sea level rise, and heavier rain events. |
| New York | Urban Waterfront Adaptive Strategies | This guide for planners and policy makers to identify and evaluate strategies for increasing the resilience of waterfront neighbourhoods to coastal storms and sea level rise includes an inventory of adaptive strategies and how to assess them for adaptive pathways. |
| | NYC Panel on Climate Change: Monitoring and indicators (2010, 2015 and 2019 reports) | The NPCC1 (2010) Indicators and Monitoring chapter addressed the need for assembling a suite of indicators to monitor climate change and adaptation to inform climate change decision making. It outlined criteria for selection of indicators (policy relevance, analytic soundness, measurability), defined categories of indicators |

| Case study location | Document Title | Summary of document |
|---|---|---|
| | | (physical climate change; risk exposure, vulnerability, and impacts; adaptation; new research), and provided examples of specific indicators. |
| | | NPCC2 (2015) focused on how New York City's climate measurement, monitoring, and assessment activities may be better coordinated and enhanced to guide the city in becoming more responsive to ongoing climate change. |
| | | NYCC 2019 introduced the proposed NYCLIM – New York City Climate Change Resilience Indicators and Monitoring System which tracks four types of indicators from data collection agencies, processing centres, urban decision makers, and policies, projects and programmes |
| | Hurricane Sandy and adaptation pathways in New York: Lessons from a first-responder city | This paper evaluates how New York City has embraced adaptation pathways, with Hurricane Sandy as a major decision point. |
| A Liveable Climate | A Liveable Climate - is a sub-document (7 of 9) of NYC2050 Strategy. Initiatives include: achieve carbon neutrality and 100% clean electricity - strengthen communities, buildings, infrastructure and the waterfront to be more resilient - create economic opportunities for all New Yorkers through climate action - fight for climate accountability and justice. New York City is making changes to its physical environment to promote resiliency and mitigate the most dangerous and destructive climate impacts. This includes hardening stormwater, wastewater, and other critical infrastructure to withstand climate impacts, and advancing nature-based solutions, such as wetland and forest restoration, to stabilize shorelines, reduce erosion, act as carbon sinks, and mitigate urban heat island effects. The city is also working with federal partners and making significant investments to mitigate neighbourhood coastal flood risks, with a series of projects. | |
| OneNYC2050 -Building a Strong and Fair City: The Strategy | 'A liveable climate' part of the vision is to prepare the city for the impacts of climate change and no longer rely on fossil fuels. Initiatives include: achieve carbon neutrality and 100% clean electricity - strengthen communities, buildings, | |

| Case study location | Document Title | Summary of document |
|---------------------|--|---|
| | | infrastructure and the waterfront to be more resilient - create economic opportunities for all New Yorkers through climate action - fight for climate accountability and justice. |
| | The New York City Waterfront Revitalization Program - Climate Change Adaptation Guidance | <p>The New York City Waterfront Revitalization Program (WRP) is the City's principal Coastal Zone Management tool. It establishes the City's policies for development and use of the waterfront and coastal areas.</p> <p>This policy requires the consideration of climate change projections for coastal flooding and sea level rise into the design and review of projects – at the asset level. Also, potential vulnerabilities need to be assessed to and consequences of sea level rise and coastal flooding over their lifespan and to identify and incorporate design techniques to address these risks.</p> |
| | Resilient Infrastructure for New York State - Rebuild by Design | <p>Rebuild By Design is a region-wide competition for special resiliency projects sponsored by the Executive Branch of the US Federal Government - a programme contributing to adaptive transformation.</p> |
| San Francisco Bay | San Francisco Bay Shoreline Adaptation Atlas | <p>Takes a strategic approach to identifying adaptive options for the San Fran Bay area with an emphasis on identifying where nature-based approaches, such as beaches, marshes, and subtidal reefs, can help create a resilient shoreline with multiple benefits. It acknowledges the importance of the interconnected system but also locally diverse. They take an approach by defining Operational Landscape Units (OLU) to provide a critical planning framework for prioritising NbS that work together in synergy, avoid unintended impacts and ensure future adaptation actions are sustainable and cost effective.</p> |
| | Guidance for incorporating sea level rise into capital planning | <p>This Guidance presents a framework for considering sea level rise within the capital planning process for the City and County of San Francisco (CCSF). The Guidance also outlines some key issues related to sea level rise adaptation planning; however, specific adaptation strategies and approaches are not provided.</p> |

| Case study location | Document Title | Summary of document |
|---------------------|---|---|
| | San Francisco ReBuild by Design | <p>Rebuild by Design is a design competition replicating the success of Hurricane Sandy competition to San Francisco. The challenge was to tackle long-term sea level rise to meet the question: 'can the Bay Area come together to shift its course and build a more resilient region before a big disaster hits and can we address other regional challenges along the way?'</p> <p>This design competition format could be applicable to Clyde bringing private and public sectors together to tackle a system wide problem and creating a sense of opportunity and promoting the aspirations of the area.</p> |
| | Embarcadero Seawall Program | The Port of San Francisco is leading the Embarcadero Seawall Program, a citywide effort to create a more sustainable and resilient waterfront. There are three elements to the Program—Strengthen, Adapt and Envision—which allow the Port to respond to risks and conditions |
| | California Adaptation Planning Guide - Appendix B | This Guide sets out general information on what adaptation planning is and an overview of an adaptive pathways approach. |
| Star2CS | Adaptation Catalyst E-Tool | The Adaptation Catalyst E-Tool has been developed to visualise and test the effectiveness of different adaptation measures over time under different scenarios with the ability to test measures under different scenarios and assess the costs, benefits, impact/protection and adaptation capacity |
| | Natura2000 Implementation pathways | A methodology to develop adaptation pathways to balance the objectives of Natura2000 sites and climate change adaptation |

14 Appendix B Place-based literature review document summaries

| Title / Org. / Pub. | Summary | Outlook / Key Objectives | Partners |
|---|---|---|--|
| <p>Glasgow City Region Indicative Regional Spatial Strategy⁸⁷⁸⁸</p> <p>Clydeplan / Glasgow City Region</p> <p>2nd June 2020</p> | <p>The IRSS has been developed to support the preparation of the NPF4. The iRSS sets out nationally important, regional and spatial priorities within a geographical area. Glasgow City Region captures the River Clyde catchment. The aim of the iRSS is to support the effective operation of the region, alongside supporting recovery from the Covid-19 pandemic. Many of the areas within the iRSS capture the 4 priorities (climate, people, work, place). Ayrshire & Arran also includes the priority of connectivity, recognising the importance of the relationships between the mainland and islands in the area.</p> | <p>Outlook</p> <ul style="list-style-type: none"> • Long term <p>Objectives</p> <ul style="list-style-type: none"> • to improve the health and well-being of its people by delivering an inclusive, net zero and climate resilient economy <p>Supporting Scotland's priorities on:</p> <ul style="list-style-type: none"> • climate – responding to the climate emergency • people – planning can support wellbeing ensuring communities have access to services and facilities • work - effective and efficient planning can support inclusive growth • place - planning can maintain and enhance the unique character and identity of our natural and built environment | <ul style="list-style-type: none"> • East Dunbartonshire Council • East Renfrewshire Council • Glasgow Council • Inverclyde Council • North Lanarkshire Council • Renfrewshire Council • South Lanarkshire Council • West Dunbartonshire Council |
| <p>Clyde Mission Position Paper, Better Places</p> | <p>A paper that provides advice to the Mission leads on the Clyde Mission to help inform decisions to create better places for people and communities.</p> | <p>Outlook</p> <ul style="list-style-type: none"> • Long term <p>Objectives (Objectives of the Mission as a whole)</p> | <ul style="list-style-type: none"> • SEPA • Glasgow City Region & constituent local authorities on the Clyde |

⁸⁷ [viewSelectedDocument.asp \(glasgow.gov.uk\)](#)

⁸⁸ [npf4-irss-submissions-summaries-nov-2020.pdf \(transformingplanning.scot\)](#)

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| <p>for Communities⁸⁹</p> <p>Clyde Mission</p> | <p>Suggestions that could be considered are through:</p> <ul style="list-style-type: none"> • Understanding assets, needs and opportunities • Creating opportunities to build on assets and meet community needs • Consider how to maximise benefits from other projects and initiatives • Considering how to reflect the Clyde’s maritime heritage in the development of assets that will support community benefits <p>The paper presents key papers that support the approach and evidence on economic inactivity, incapacity, unemployment, housing and procurement that support the need to improve places for people and provide targets to deliver those improvements.</p> | <ul style="list-style-type: none"> • Create a globally competitive, entrepreneurial, inclusive and sustainable economy • To tackle poverty by sharing opportunities, wealth and power more equally • To value, enjoy, protect and enhance our environment • live in communities that are inclusive, empowered, resilient and safe • To have thriving and innovative businesses, with quality jobs and fair work for everyone <p>(Objectives of this specific paper)</p> <ul style="list-style-type: none"> • To help inform decisions on the direction of Missions by the Mission Leads to help create better places for people and communities. | <ul style="list-style-type: none"> • Metropolitan Glasgow Strategic Drainage Partnership • Clydeplan • Climate Ready Clyde • Sustainable Glasgow • Scottish Government • Flood Risk Management Leads (Environment and Forestry) • Directorate for Energy and Climate Change • University of Strathclyde • Clyde Climate Forest / Glasgow and Clyde Valley Green Network • Clyde Gateway • Scottish Enterprise • Highlands and Islands Enterprise • NatureScot • Scottish Water • Scottish Canals • Marine Scotland • Adaptation Scotland • Scottish Futures Trust • Infrastructure Commission for Scotland • Dynamic Coast |
| <p>Clyde Mission Position Paper, Climate Adaptation⁹⁰</p> <p>Clyde Mission</p> | <p>A paper that focuses on providing advice to the Mission leads on the Clyde Mission recommended approach to adapt to climate risks, especially flooding.</p> <p>This paper guides the Mission leads to share and explore appropriate avenues for the work to create a review of risk, strategies, actions and areas for exploration with the Clyde region. Note, there are 4 other Mission Papers to be considered (jobs & skills, Net</p> | <p>Outlook</p> <ul style="list-style-type: none"> • Long term <p>Objectives (Objectives of the Mission as a whole)</p> <ul style="list-style-type: none"> • Create a globally competitive, entrepreneurial, inclusive and sustainable economy • To tackle poverty by sharing opportunities, wealth and power more equally | <ul style="list-style-type: none"> • Metropolitan Glasgow Strategic Drainage Partnership • Clydeplan • Climate Ready Clyde • Sustainable Glasgow • Scottish Government • Flood Risk Management Leads (Environment and Forestry) • Directorate for Energy and Climate Change • University of Strathclyde • Clyde Climate Forest / Glasgow and Clyde Valley Green Network • Clyde Gateway • Scottish Enterprise • Highlands and Islands Enterprise • NatureScot • Scottish Water • Scottish Canals • Marine Scotland • Adaptation Scotland • Scottish Futures Trust • Infrastructure Commission for Scotland • Dynamic Coast |

⁸⁹ Draft paper received 16 August 2021

⁹⁰ Draft paper received 16 August 2021.

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|---|--|--|--|
| | Zero, vacant and derelict land, better places for communities). | <ul style="list-style-type: none"> To value, enjoy, protect and enhance our environment live in communities that are inclusive, empowered, resilient and safe To have thriving and innovative businesses, with quality jobs and fair work for everyone <p>(Objectives of this specific paper)</p> <ul style="list-style-type: none"> To help inform decisions on the direction of Missions by the Mission Leads to develop approaches to adapt to climate change risks. | |
| <p>Glasgow City Region Economic Strategy 2017 – 2035⁹¹</p> <p>Glasgow City Region</p> <p>December 2016</p> | <p>14.1.1.1 The economic strategy builds on the City Deal and existing projects to develop an outlook to 2035, accompanied by a 3-year action plan.</p> <p>The strategy identifies 11 objectives that support the aim of ‘sustained and inclusive economic growth through significantly improving productivity, boosting incomes; strengthening and growing the diverse business base to create more and better jobs; and increasing the working age population by supporting more people into work and attracting and retaining talent to the Glasgow City Region’.</p> <p>The 3-year action plan prioritises actions to be delivered that will lead to</p> | <p>Outlook</p> <ul style="list-style-type: none"> 2035 <p>2035 Vision</p> <ul style="list-style-type: none"> A strong, inclusive, competitive and outward-looking economy, sustaining growth and prosperity with every person and business reaching their full potential <p>11 Objectives</p> <ul style="list-style-type: none"> Attract and retain talent and enterprises relocating to GCR Improve economic outcomes for all through addressing long standing barriers in the labour market such as skills and health, both for those who are currently out of work and those on low incomes | <ul style="list-style-type: none"> East Dunbartonshire Council East Renfrewshire Council Glasgow Council Inverclyde Council North Lanarkshire Council Renfrewshire Council South Lanarkshire Council West Dunbartonshire Council |

⁹¹ [Ben Lucas Metro Dynamics \(glasgowcityregion.co.uk\)](http://glasgowcityregion.co.uk)

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| | <p>greater collaboration and joint working to boost the working economy.</p> | <ul style="list-style-type: none"> • Create a skills and employment system that meets the current and future needs of GCR businesses and supports our residents to access jobs and progression opportunities • Grow the presence of Scotland's Growth Sectors in the city region so that we increase the total number of GCR's businesses and employees who work in these sectors • Significantly improve the productivity of GCR's diverse business base through increased investment, innovation and exporting • Increase the number of sustainable and high growth start-ups surviving beyond five years • Grow GCR supply chain activity whose growth underpins the success of GCR sectors • Building on the City Deal bring forward in parallel strategic programmes, projects, and associated investment that maximise the value of the Deal • Maximise the potential of the key GCR economic assets • Actively promote GCR globally, with a focus on international investment opportunities • Increase in the number of housing and commercial completions and decrease the amount of derelict and vacant land | |
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| <p>National Transport Strategy 2⁹² Transport Scotland</p> <p>Feb 2020</p> | <p>14.1.1.2 Creating a vision for transport for the whole of Scotland and for the entire transport system across the country.</p> <p>The paper presents the NTS 2 visions, priorities and 3 outcomes associated with each priority. These form the basis for decision making and evaluation of the success of the NTS 2. The paper further presents the challenges associated with each priority, which has helped shape the priorities and support the delivery of the intended outcomes.</p> | <p>Outlook</p> <ul style="list-style-type: none"> • 20 years <p>Vision</p> <ul style="list-style-type: none"> • We will have a sustainable, inclusive, safe and accessible transport system, helping deliver a healthier, fairer and more prosperous Scotland for communities, businesses and visitors <p>Objectives (4 priorities)</p> <ul style="list-style-type: none"> • Reduce inequalities - Everyone in Scotland will share in the benefits of a modern and accessible transport system • Takes climate action - People will be able to make travel choices that minimise the long-term impacts on our climate and the wellbeing of future generations • Helps deliver inclusive economic growth - Scotland will have a transport system that will help deliver sustainable and inclusive economic growth enabling the whole country to flourish • Improves our health and wellbeing - Scotland's transport system will be safe and enable a healthy, active and fit nation | <ul style="list-style-type: none"> • Transport Scotland |
|--|--|--|--|

⁹² [national-transport-strategy.pdf](#)

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| <p>National Transport Strategy: Takes Climate Action⁹³</p> <p>Transport Scotland</p> <p>Feb 2020</p> | <p>One of the four priorities of NTS2. People will be able to make travel choices that minimise the long-term impacts on our climate and the wellbeing of future generations. We face a global climate emergency. Scotland must transition to a net-zero emissions economy for the benefit of our environment, our people and our future prosperity.</p> | <p>Outlook</p> <ul style="list-style-type: none"> • 2045 <p>Objectives</p> <p>Takes Climate Action:</p> <ul style="list-style-type: none"> • Will help deliver our net-zero target • Will adapt to the effects of climate change • Will enable greener, cleaner choices <p>Further priorities:</p> <ul style="list-style-type: none"> • Reduces inequalities • Helps our economy prosper • Improves our health and wellbeing | <ul style="list-style-type: none"> • Transport Scotland |
| <p>Climate Ready Clyde Theory of Change (Vision)⁹⁴</p> <p>Climate Ready Clyde</p> | <p>14.1.1.3 Climate Ready Clyde has developed a Theory of Change that sets out a long-term vision for a climate ready Glasgow City Region. The Theory of Change informs adaptation actions in the Glasgow region. It highlights the impacts, interventions and outcomes that support the goal to achieve the vision and guiding principles for how they should be achieved.</p> | <p>Outlook</p> <ul style="list-style-type: none"> • Long term <p>Objective</p> <ul style="list-style-type: none"> • Glasgow City Region that flourishes in the future climate | <ul style="list-style-type: none"> • NLC • East Renfrewshire Council • University of Glasgow • SLC • NHS Glasgow and Clyde • SPT • University of Strathclyde • Glasgow City Council • Scot Gov • WDC • EDC • SEPA • SGN • Inverclyde Council • Renfrewshire Council • NatureScot |

⁹³ [National Transport Strategy: Takes Climate Action](#)

⁹⁴ [Our vision \(climatereadyclyde.org.uk\)](http://climatereadyclyde.org.uk)

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| <p>Fourth National Planning Framework: position statement⁹⁵</p> <p>Scot Gov</p> <p>26 Nov 2020</p> | <p>The fourth National Planning Framework (NPF4) will consider what Scotland should look like in 2050, set out national planning policies and guide where future development should take place.</p> | <p>Outlook</p> <ul style="list-style-type: none"> • Up to 2050 <p>Objectives</p> <ul style="list-style-type: none"> • The long-term strategy will be driven by the overarching goal of addressing climate change. <p>NPF4 will focus on achieving four key outcomes:</p> <ul style="list-style-type: none"> • Net-Zero Emissions • A Wellbeing Economy • Resilient Communities • Better, Greener Places | |
| <p>Clyde Regional Marine Plan Pre-Consultant Draft⁹⁶</p> <p>Clyde Marine Planning Partnership</p> <p>18 March 2019</p> | <p>The Clyde Regional Marine Plan, once adopted, will provide a statutory policy framework to support effective decision-making and appropriate investment, enabling delivery of the Plan's vision and aims. The Plan interprets and supports Scotland's National Marine Plan in a regional context.</p> | <p>Outlook</p> <ul style="list-style-type: none"> • 20-year vision <p>Objectives</p> <ul style="list-style-type: none"> • The marine and coastal environment of the Clyde Marine Region is clean, healthy, safe, productive, biologically diverse and accessible for all. • The marine and coastal environment of the Clyde Marine Region is managed sustainably to support productive and thriving coastal communities and to allow nature to flourish. | <ul style="list-style-type: none"> • Argyll & Bute Council • British Marine Scotland • Caledonian Maritime Assets Limited • CalMac Ferries Ltd • Clydeplan • Clydeport Operations Ltd., Statutory Harbour Authority • Community of Arran Seabed Trust (COAST) • Field Studies Council Millport • Individual – Simon Macdonald, representing the West Coast Regional Inshore Fisheries Group • Individual – Elaine Whyte, representing the |

⁹⁵ [Fourth National Planning Framework: position statement - gov.scot \(www.gov.scot\)](https://www.gov.scot/publications/fourth-national-planning-framework/position-statement/pages/1-to-10.aspx)

⁹⁶ [Pre-consultation-draft-Clyde-Regional-Marine-Plan-18-March-2019.pdf \(clydemarineplan.scot\)](https://www.clydemarineplan.scot/pre-consultation-draft-clyde-regional-marine-plan-18-march-2019.pdf)

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| | | | <p>Clyde Fishermen’s Association</p> <ul style="list-style-type: none"> • Individual – Anthony Gallagher – Chairperson • Loch Lomond & The Trossachs National Park • North Ayrshire Council • Royal Society for the Protection of Birds • Royal Yachting Association Scotland • Scottish Canals • Scottish Environment LINK • Scottish Natural Heritage • Scottish Sea Anglers Conservation Network • Scottish Environment Protection Agency • South Ayrshire Council • The Crown Estate • The Scottish Salmon Company • Visit Scotland |
| <p>The Environment Strategy for Scotland: vision and outcomes⁹⁷</p> <p>Scot Gov</p> <p>25 Feb 2020</p> | <p>Scotland's Environment Strategy provides a framework to bring strategies and plans together and identify new strategic priorities and opportunities. It will help guide to protect and restore Scotland's natural environment. In delivering the above, the goal is to support the wellbeing of</p> | <p>Outlook</p> <ul style="list-style-type: none"> • 2045 <p>Objectives</p> <ul style="list-style-type: none"> • By 2045: By restoring nature and ending Scotland's contribution to climate change, our country is transformed for the better - helping to | |

⁹⁷ [The Environment Strategy for Scotland: vision and outcomes - gov.scot \(www.gov.scot\)](http://www.gov.scot)

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| | people in Scotland and strengthen the economy. | secure the wellbeing of our people and planet for generations to come. | |
| Clydeplan Strategic Development Plan ⁹⁸ Clydeplan July 2017 | The current SDP is based around the four planning outcomes in the existing NPF3: <ul style="list-style-type: none"> • A successful and sustainable place • A low carbon place • A natural resilient place • A connected place <p><i>Note NPF4 is due for publication in Autumn 2021.</i></p> | Outlook <ul style="list-style-type: none"> • 2036 Objectives Vision: <ul style="list-style-type: none"> • ‘By 2036 Glasgow and the Clyde Valley will be a resilient, sustainable compact city region attracting and retaining investment and improving the quality of life for people and reducing inequalities through the creation of a place which maximises its economic, social and environmental assets ensuring it fulfils its potential as Scotland’s foremost city region.’ | <ul style="list-style-type: none"> • EDC • East Renfrewshire Council • Inverclyde Council • NLC • Glasgow City Council • Renfrewshire Council • SLC • WDC |
| Glasgow City Region Climate Adaptation Strategy ⁹⁹ Climate Ready Clyde June 2021 | Glasgow’s first Adaptation Strategy and Action Plan. A statement for the future in which the city flourishes in the future climate. The Strategy outlines the processes and interventions needed to manage climate risks, provides a strategic framework for adaptation in the GCR, sets out how to develop collaboration and how climate resilience will be monitored, evaluated and learnt from. | Outlook <ul style="list-style-type: none"> • A vision to 2050. • A strategy to 2030. • An action plan to 2025. Objectives <ul style="list-style-type: none"> • Systems focused. • Inclusive. • Collaborative. • New governance. • New funding. | <ul style="list-style-type: none"> • NLC • East Renfrewshire Council • University of Glasgow • SLC • NHS Glasgow and Clyde • SPT • University of Strathclyde • Glasgow City Council • Scot Gov • WDC • EDC |

⁹⁸ [ApprovedPlanHighRes.pdf \(clydeplan-sdpa.gov.uk\)](#)

⁹⁹ [01 Adaptation Strategy and Action Plan Summary \(adobe.com\)](#)

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| | The accompanying Action Plan describes the actions taking place between 2020 and 2025 to move towards the vision. | <ul style="list-style-type: none"> • Innovative and transformative. | <ul style="list-style-type: none"> • SEPA • SGN • Inverclyde Council • Renfrewshire Council • NatureScot |
| <p>MGSDP Surface Water Management Masterplan¹⁰⁰</p> <p>Metropolitan Glasgow Strategic Drainage Partnership (MGSDP)</p> <p>Sept 2016</p> | The primary purpose of the MGSDP Surface Water Management Masterplan is to summarise the 24 identified actions to address the main surface water related challenges, working in partnership with all agencies involved in delivering different aspects of the system to manage rainfall and flooding | <p>Outlook</p> <ul style="list-style-type: none"> • 50 years (2066?) <p>Objectives</p> <p>The MGSDP has five over-arching objectives:</p> <ul style="list-style-type: none"> • Flood risk reduction. • River water quality improvement. • Enabling economic development. • Habitat improvement. • Integrated investment planning. | <ul style="list-style-type: none"> • Glasgow City Council • Scottish Water • SEPA • Clyde Gateway • SLC • Scottish Canals • Clydeplan • Scot Gov • Scottish Enterprise • EDC • NLC • Renfrewshire Council |
| <p>River Clyde 2050 Strategic Development Plan¹⁰¹</p> <p>Glasgow City Council</p> <p>Nov 2018</p> | The SDF provides a route map towards the 'River Clyde 2050' capturing a combination of the City Development Plan objectives and a range of specific Placemaking Strategies defined as 'River Rooms'. It also identifies the critical need to continue to understand the impact of current and future climate change. The SDF identifies that to deliver this scale of coordinated placemaking, a multi-agency governance group will be critical. | <p>Outlook</p> <ul style="list-style-type: none"> • 2050 <p>Objectives</p> <ul style="list-style-type: none"> • Creating and growing the activation of the water and vibrancy of the River Corridor at different locations, scales and timeframes. • Repairing and creating strong movement connections and access to, along and on to the river; • Enhancing and reinforcing the distinctive character of the River | Unknown |

¹⁰⁰ [Microsoft Word - MGSDP - SWM Masterplan - Summary and Actions - v1.0.docx](#)

¹⁰¹ [River Corridor Strategic Development Framework - Draft November 2018.pdf \(glasgowconsult.co.uk\)](#)

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| | | <p>Corridor and its role through a framework of landscape, cultural heritage, play, art, landmarks, lighting and smart technology initiatives;</p> <ul style="list-style-type: none"> • Repairing the urban and landscape fabric along the River Corridor to help unlock the economic, environmental and social potential of the City Centre and riverside neighbourhoods’. • e. Enhancing, growing, and safeguarding the biodiversity value and environmental quality of River Corridor, including the water environment. | |
| <p>A Green Network Strategy for the Glasgow City Region¹⁰²</p> <p>Glasgow and Clyde Valley Green Network Partnership</p> <p>Sept 2017</p> | <p>A green network strategy developed in the Glasgow City Region recognising that improving the environment of the region would support economic growth, health and wellbeing and link rural and urban areas.</p> | <p>Outlook</p> <ul style="list-style-type: none"> • 2050 <p>Objectives</p> <ul style="list-style-type: none"> • To ensure that no one is going to be more than 5mins walk from a green space, connected to the Green Network. • Delivered through planned development, infrastructure improvements, public sector activities and major projects. | <ul style="list-style-type: none"> • Clydeplan • MGSDP • Climate Ready Clyde. • NLC • WDC • GCC • SLC • Nature Scot • Glasgow Centre for Population Health. • Renfrewshire Council. • ERC • Inverclyde Council • Scottish Forestry • Scottish Enterprise • EDC • SEPA • Public Health Scotland |

¹⁰² [Green Network Strategy - GCV Green Network](#)

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