Peel Ports Group

Climate Change Adaptation Report

for

Port of Sheerness Ltd

and

Mersey Docks and Harbour Company Ltd

Submitted to DEFRA

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CONTENTS LIST

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EXECUTIVE SUMMARY

This report comprises the Peel Ports Group response to DEFRA's invitation to prepare a voluntary report under the third round of the Climate Change Act 2008 Adaptation Reporting Power. It covers the statutory harbour areas of the Mersey Docks and Harbour Company and the Port of Sheerness Ltd, focussing on the following core Statutory Harbour Authority (SHA) responsibilities:

- Conservancy, pilotage and vessel traffic services for ships and craft using the port
- Maintenance of navigational channels, moorings, lights and buoys, and
- Provision of hydrographic, tidal and other information.

The report was prepared by Peel Ports' Group Marine Department, broadly following relevant steps from the four-stage methodology described in the PIANC guidance 'Climate change adaptation planning for ports and inland waterways' (2020).

Climate change projections for parameters and processes relevant to the above responsibilities were sourced from a variety of publications. Insofar as the data are available, mid-term (30-50 years) and long-term (50-80 years) projections were obtained for each parameter for a range of climate change scenarios. Where possible, English regional data were captured for SE England (for PoSL) and for NW England (for MDHC). A quantified range was developed wherever practicable to reflect the 'most likely' to 'plausible worst case' scenarios, and the adequacy of the available data for the purposes of the risk assessment was assessed.

Following an initial high-level, likelihood-and-consequence review, an internal workshop, led by Group Marine, was held to discuss potential impacts that had been provisionally categorised with a risk rating of 'moderate' or 'high'. This workshop provided an important opportunity to engage with the individuals that have embedded knowledge about current risks and how they are managed, as well as an understanding of the practicality and likely cost-effectiveness of different types of responses to address future risks.

As a result of this process, 22 impacts with a risk rating of moderate or high were confirmed. These impacts were subject to further assessment, including the identification of short term and possible longer-term responses. The following are the main impacts categorised with a 'high' risk rating:

- Uncontrolled opening and **possible structural damage to lock gates** due to sea level rise, extreme high-water levels/water level variation, overtopping, or extreme waves; impacting navigational safety and the loading / movement of products (high confidence)
- **Structural damage to bollards** with vessel alongside due to overtopping, high flow, extreme waves (high confidence)
- **Increased dredging and disposal requirements** if changes in hydrographical conditions affect patterns of sedimentation (low confidence)
- Berthing, quaysides and **operations compromised more frequently** due to overtopping (sea level rise plus extreme wind, wave, storm or surge) (medium confidence)
- **Reduced ability to board and recover pilots** due to more frequent wave height exceedance (or, for Medway, change in fog characteristics) (low confidence)

- **Physical damage to protected habitats** resulting from erosion, deposition, submergence, etc. due to changes in sea level, extreme waves, storminess or high flow rates (high confidence).

Since the 2011 MDHC and PoSL climate change adaptation reports were prepared, awareness of climate change issues and the need to take action has gained considerable momentum within Peel Ports. Workshops have been held; a climate change Steering Group has been established, to consider both mitigation and adaptation issues; and the Group Marine Department took the lead in organising an international ports' climate change adaptation conference in Glasgow during COP26.

Several outstanding uncertainties and shortfalls were nonetheless identified during the preparation of this report:

- Differences in the adequacy of the climate change projections on which the risk assessment is based. These differences are reflected in the level of confidence attributed to the individual risk ratings. We expect this uncertainty to reduce as the climate science advances.
- The need for additional local monitoring and data collection across a range of topics to help improve confidence and inform decision making in the meantime. This will include, where appropriate, local trends in relevant climate parameters or processes; data on the condition and performance of physical assets; and information about the characteristics, costs and consequences of extreme events. Some critical thresholds also remain to be established, where it is both possible and meaningful to do so.
- Potential barriers to adaptation action need to be addressed, including current incentives for the wider sector to adapt, and the challenges in making a robust business case for major investment outside existing capital programmes or maintenance and review schedules. We propose to use an adaptation pathways approach to help deal with these issues, enabling initial action to be taken while work to reduce uncertainty continues.
- As part of ongoing work to identify and assess interdependencies, consideration needs to be given to the potential for cascading failures between interlinked natural and socio-economic systems and sub-systems.

There will also be benefits in continuing to strengthen engagement with staff, build capacity and mainstream climate change considerations across all departments via the internal climate change Steering Group.

1 Introduction

1.1 Background

The Climate Change Act 2008 sets up a framework for the UK to achieve its long-term goals of reducing greenhouse gas emissions and to ensure steps are taken towards adapting to the impact of climate change. The Adaptation Reporting Power introduced under this Act provides for infrastructure operators and public bodies to report to DEFRA on how they are addressing current and future climate impacts.

This report comprises the Peel Ports Group response to the invitation to prepare a voluntary report under the third round of the Climate Change Act Adaptation Reporting Power.

1.2 Peel Ports Group

As the second largest port group in the UK, Peel Ports handles over 70 million tonnes of cargo every year. This climate change adaptation report covers the ports of Liverpool and London Medway, comprising Port of Sheerness and Chatham Docks. These are Peel's two largest English ports, each handling in excess of 10 million tonnes annually. The other English ports are Heysham, Great Yarmouth, and the Manchester Ship Canal.

1.3 Statutory/Competent Harbour Authorities

Peel Ports Group, through the Mersey Docks and Harbour Company (MDHC) and Port of Sheerness Ltd. (PoSL), is the Statutory Harbour Authority (SHA) and the Competent Harbour Authority (CHA) for both harbour areas covered within this report. The CHA responsibilities, under the 1987 Pilotage Act, require MDHC and PoSL to provide pilotage within their areas of jurisdiction. This is mentioned here because pilotage considerations are reviewed in the report but are not necessarily undertaken within the same area of jurisdiction of the SHA.

MHDC's SHA area covers the Port of Liverpool including Liverpool and Birkenhead Docks, the approaches to the Manchester Ship Canal and the Port of Garston. PoSL's SHA limits extend from Allington Lock on the River Medway near Maidstone to a distance approximately five miles offshore into the Thames Estuary. These areas are illustrated on Figures 1 and 2.

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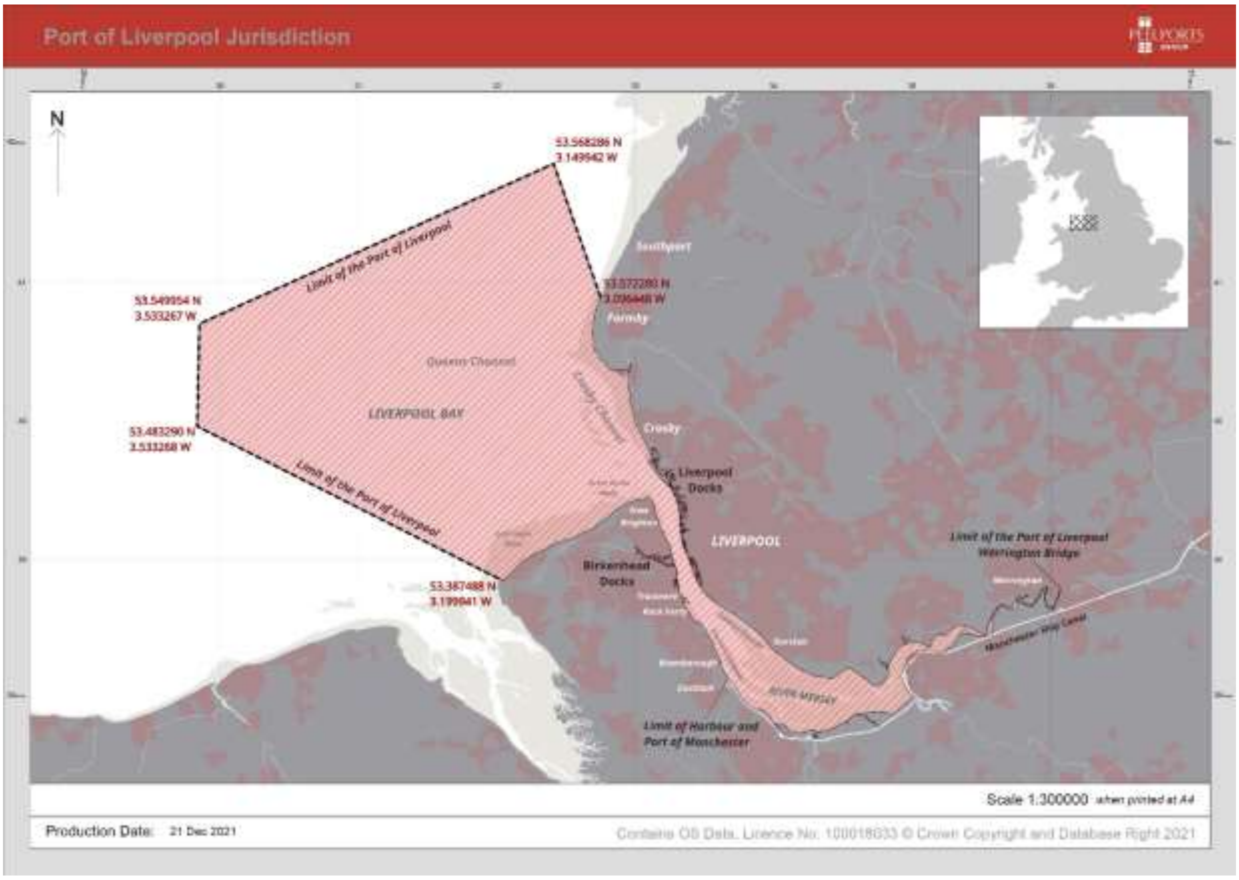

Figure 1. MDHC Statutory Harbour Area

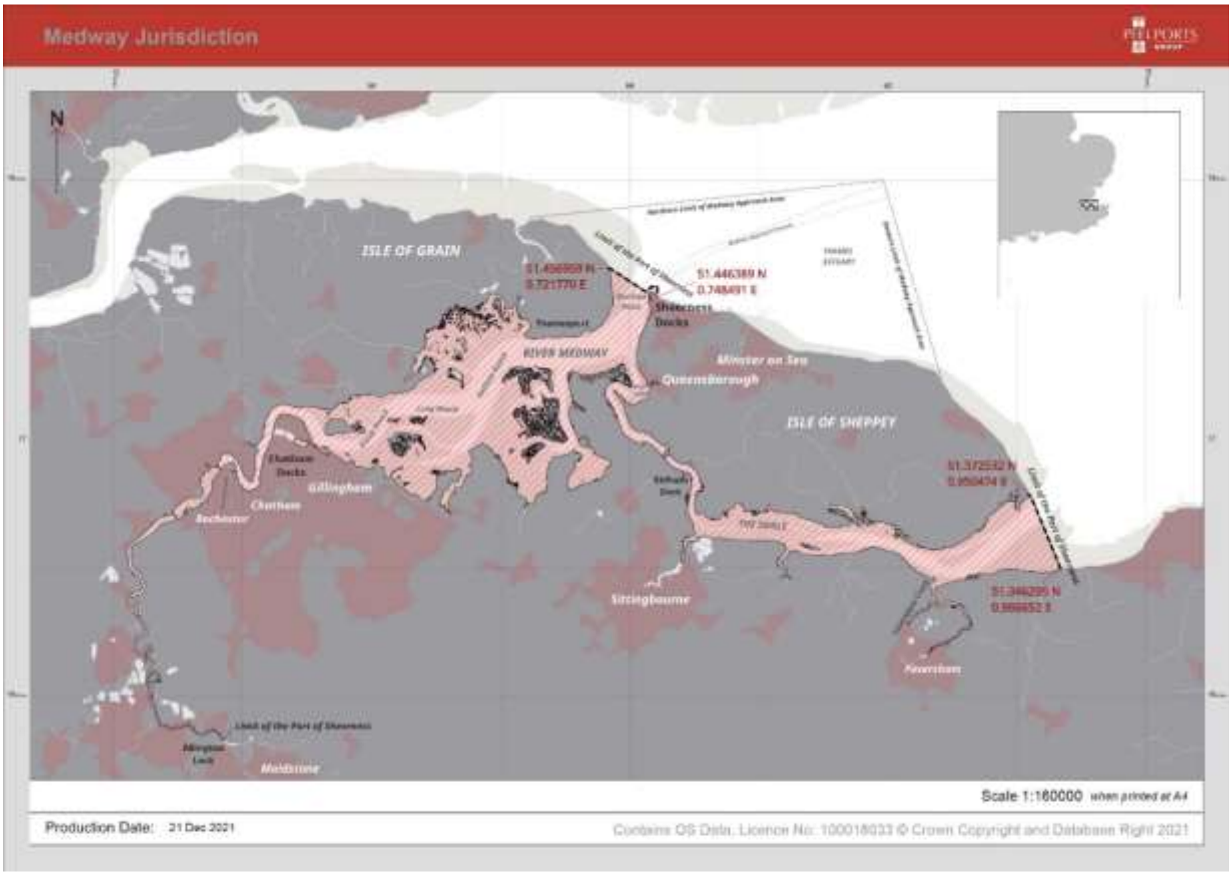

Figure 2. PoSL Statutory Harbour Area

1.4 What's covered?

Peel Ports Group, as SHA, is responsible for the management of navigational safety, the protection of the marine environment, and for all of the Group's marine services, including pilotage, aids to navigation, tugboat operations, hydrographic surveying, dredging and vessel traffic services for ships and craft using the port.

This adaptation report covers the Statutory Harbour Areas of the Mersey Docks and Harbour Company and the Port of Sheerness Ltd. It focuses on the following core responsibilities:

- Conservancy, pilotage and vessel traffic services for ships and craft using the port
- Maintenance of navigational channels, moorings, lights and buoys, and
- Provision of hydrographic, tidal and other information.

1.5 What's not covered?

Work on climate change adaptation planning for other SHA functions is part of an ongoing initiative at Group-level for all Peel's English ports as well as for Clydeport (Scotland). This work is being overseen by a new internal Peel Ports Climate Change Steering Group.

Specifically, as elaborated in Section 9.3, further work is required in relation to interdependencies that could impact on the above core SHA responsibilities. These are situations where the actions of, or impacts on, a third party are likely to affect the port's ability to manage its own climate change risks. Consideration of interdependencies will cover: utilities; local authorities and Highways Agency (e.g., risk of flooding of access roads to Sheerness (Royal Haskoning, 2011(b)) or the single main access route to the Port of Liverpool (Royal Haskoning, 2011(a)); terminal operators and those with storage interests on the port estate; other tenants and organisations on adjacent land holdings. The activities of these organisations all raise issues over which the port has no or only partial control, yet potentially pose some level of risk to Peel's ports operations.

Work on interdependencies will involve sharing relevant information both across the Group and with third parties to inform collaborative assessments where these are needed, and cross-referring where third parties are also being invited to submit adaptation reports.

1.6 Methodology

This report was prepared broadly following relevant steps from the four-stage methodology described in the PIANC guidance 'Climate change adaptation planning for ports and inland waterways' (2020). This methodology includes:

- Stage 1: identify the assets, operations and systems that could be affected by climate change; highlight possible interdependencies; engage with stakeholders
- Stage 2: collate the information needed to explore possible future changes in relevant climate-related parameters and processes; apply climate change scenarios
- Stage 3: assess risks by determining the likelihood and consequence of possible impacts for potentially vulnerable infrastructure assets, operations and systems
- Stage 4: consider how the identified climate risks and hazards might be addressed using an adaptation pathway approach, focusing first on monitoring/data collection to improve understanding of potential impacts, and on 'quick win' and no-regret measures.

The process was informed by the available climate data (see Section 2) and the wider marine teams' working knowledge of the risk baseline (i.e., the current situation, including existing risks and responses such as Standard Operating Procedures and contingency plans that are already in place). Critical operational thresholds were referred to where these are known and appropriate.

Following the initial high-level review, an internal workshop, led by the Group Marine Department was held to further refine the potential impacts provisionally categorised with a risk rating of 'moderate' or 'high'. This provided an important opportunity to engage with colleagues from across the group to discuss how these current and future risks are managed, to establish whether the current processes are sufficient and, if not, to understand the practicality and effectiveness of different types of additional responses.

The workshop confirmed 22 potential impacts on core MDHC or PoSL Competent Harbour Authority responsibilities: these are elaborated in Sections 3 to 8. Possible short-term responses and longer-term options to address each of these impacts were also discussed and agreed at the workshop.

As highlighted in the 2011 adaptation reports (Royal Haskoning, 2011(a) and (b)), increasing temperatures, fewer frost and ice days, and the reduction in the occurrence of fog (Mersey in all seasons; Medway in spring to autumn inclusive) may bring minor benefits to ports operations. However, as no significant opportunities associated with the changing climate have been identified insofar as the above-listed core Competent Harbour Authority responsibilities are concerned, potential climate change benefits are not considered further in this report.

2 Climate change data

2.1 Background

Section 1.2 of the 2011 adaptation reports (Royal Haskoning, 2011(a) and (b)) described the generic effects that changes in climate-related parameters and processes (sea level rise, increased temperatures and heatwaves, rainfall/fluvial flooding, storminess, etc.) can have on port infrastructure and operations. This general discussion is not repeated here. Rather, Table 1 below highlights the climate-related parameters and processes that are considered relevant to the current risk assessment.

2.2 Climate projections

Climate change data for these parameters and processes were sourced from a variety of publications. Insofar as the data were available, mid-term (30-50 years) and long-term (50-80 years) projections were obtained for each parameter for a range of scenarios. Where possible, English regional data were captured for SE England (for PoSL) and for NW England (for MDHC). By way of an example, Figure 3 illustrates how the assumed 'most likely' (RCP 4.5 and 6.0; 50th percentile) and 'plausible worst case' (RCP 8.5 10th or 90th percentile) scenarios were derived using Met Office[1] data for winter mean temperature in NW England and summer precipitation in SE England respectively. Where regional data were not available, in order of preference, England, UK or European-scale projections were used.

[1] https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/land-projection-maps

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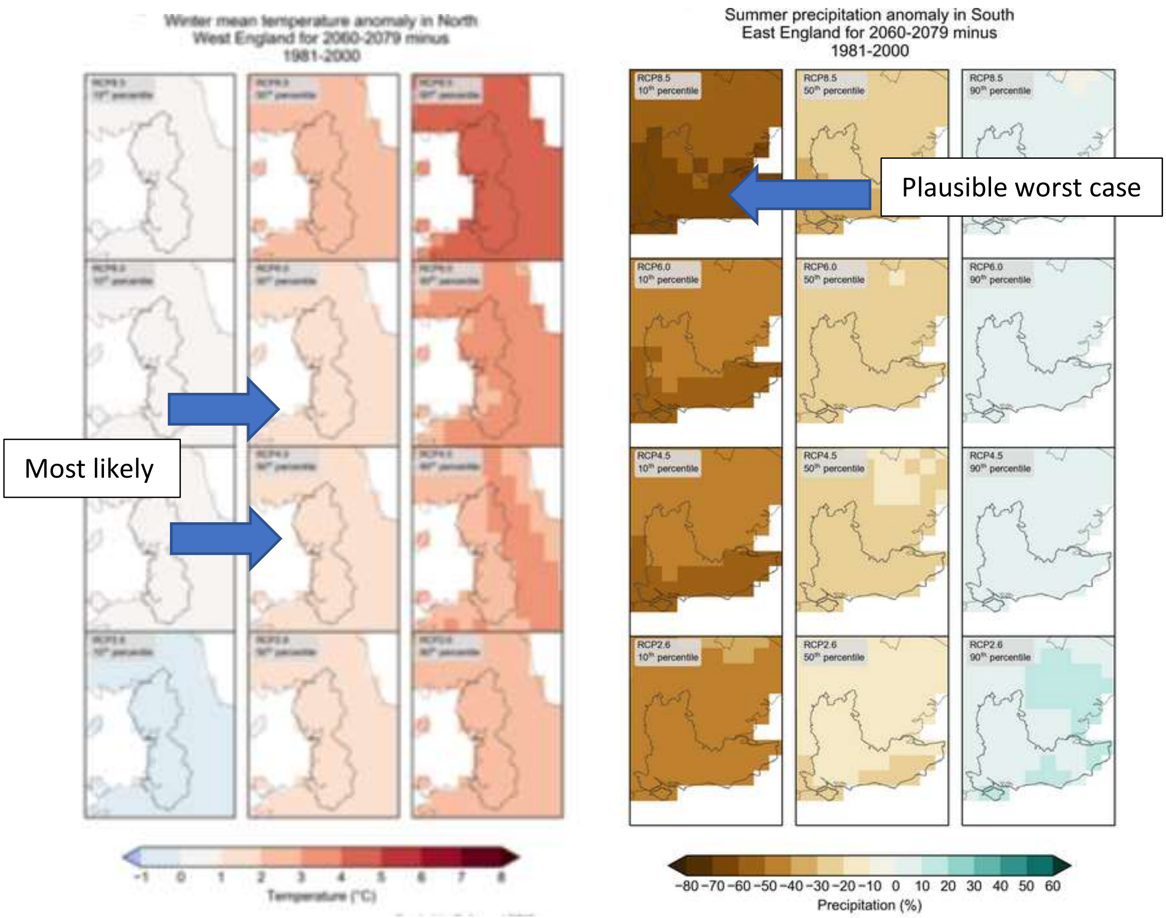

Figure 3. Derivation of 'most likely' and 'plausible worst case' scenarios

For each of the climate-related parameters on which data were sought, Table 1 highlights the main data sources and summarises the projected trends. A quantified range is provided where such information is available: this typically reflects the 'most likely' to 'plausible worst case' scenarios as indicated above. The table then concludes on the adequacy of the available data for the purposes of the risk assessment. In some cases, while information on the anticipated direction and approximate magnitude of change is limited, initial conclusions on the degree of additional risk can nonetheless be drawn. For example, for fog, the direction of change means most risks are likely to reduce rather than increase, and for storm surge the magnitude of projected change is typically small in the context of the sea level rise component. In other cases, however, the information that is available suggests the potential for a significant change, but the current paucity of data means the risk cannot be properly quantified so a precautionary approach is needed (e.g., in relation to sediment dynamics or extreme events).

As mentioned in the 2011 report for the Mersey (Royal Haskoning, 2011(a)) it is of note that the data remains poor for some parameters with the potential to have the greatest impact, particularly in relation to extreme weather events. This remains the case today.

Climate Parameter	Primary Data Source(s)	Key Trends (by mid/end century unless stated)	Data Adequacy
Air temperature	Met Office UKCP18	Noticeably warmer winter days (up to +3°C to +5°C) Significantly hotter summer days (up to +7°C to +15°C) More frequent heatwaves (up to 4/year by 2070) Significantly more humid in summer (up to +16% to +35%)	Good
Sea surface temperature	MCCIP 2020	Warming of +1 to +4 °C Significant year to year variation likely to continue Likely increase in frequency of marine heatwaves	Sufficient
Precipitation	Met Office UKCP18, Environment Agency	Wetter winters (0 to +50%) Significantly drier summers (-10% to -70%) Significant rainfall intensity increase (+10 to +70%) River peak flow increase (+25% to +120%)	Good
Fog	Met Office UKCP09	SE: +7% to +20% winter fog days; summer reduction NW: significant year-round reduction in fog days	Sufficient
Sea level	Environment Agency, Met Office UKCP18	NW: +0.10 to +0.40m by 2060; +0.76 (+1.02m) by 2100 SE: +0.22 to 0.52m by 2060; +0.86 (+1.13m) by 2100	Good
Storm surge	Environment Agency	+2mm/year allowance Future extreme sea levels dominated by MSL change Possible increase in North Atlantic storms by 2100	Sufficient
Offshore wind speed	Environment Agency	5% to 10% allowance but no compelling trends in storminess as determined by maximum gust	Sufficient
Extreme wave height	Environment Agency	5% to 10% allowance; low certainty but for North Atlantic may be increase in most severe wave heights	Poor
Sediment dynamics	MCCIP 2020, HR Wallingford, Defra Marine Strategy	Future storm track or wave direction change as well as changes in river flow will affect sedimentation patterns Relative sea-level rise may reduce nearshore sediment supply from offshore and longshore sources Coastal erosion rates expected to increase in the future; sea level rise may cause stable/accreting coasts to enter an erosion phase	Poor
Extreme events	Met Office 2020, IPCC	Extreme coastal water levels expected to increase: historical 1:100 extreme sea level will become 1:1 year event between 2050 and 2080 Extreme rainfall seasonality changes expected i.e., extension of convective season into autumn; significant increases in autumn hourly rainfall intensity	Poor
Seawater chemistry	Defra Marine Strategy, MCCIP	Seawater pH and salinity expected to decrease, more so in North Sea than Celtic/Irish Seas Dissolved oxygen concentrations to decline globally by 1.5% to 4% by 2090, threatening marine ecosystems	Sufficient

Table 1. Available climate change projection data

3 Risk assessment

3.1 Current risks

Ports are 'at the front line' when many climate change risks are considered. However, their geographical location in the dynamic water's edge environment, together with their various existing Statutory/Competent Harbour Authority responsibilities, means that ports must already be prepared to operate in and cope with storm conditions (including storm surges), high winds, high and low temperature extremes and coastal erosion, etc. Levels of preparedness, including for extreme weather events, are necessarily high.

The adaptation risk assessment therefore needed to:

- focus on the potential for impacts over and above those already experienced or expected*
- consider projected slow onset changes in air and water temperature, sea level rise and changes in seasonal precipitation, as well as increases in the frequency or intensity of extreme hydro-meteorological or oceanographic events.

*Experience of past extreme events has enabled MDHC to identify where and how such events are likely to impact on the port and to manage these risks (Royal Haskoning, 2011(a)). The River Medway does not have a history of being adversely impacted by severe weather. The port is well sheltered from the prevailing winds and to a certain extent is protected from the North Sea by the wider Thames Estuary. Additionally, all but one of the berthing points at Sheerness are on the more sheltered Medway Estuary side; only Berth 10 at Garrison Point is exposed to the Thames Estuary and is therefore more susceptible to high wind and wave conditions. Consequently, the 2011 adaptation report noted that Berth 10 is rarely used (Royal Haskoning, 2011(b)).

3.2 Overview of risk assessment process

Applying the methodology outlined in PIANC (2020) led to the initial identification and high-level 'likelihood-and-consequence' assessment of more than 200 possible climate-related risks. Most were assigned a moderate-low or low risk rating and are not considered further in this report. Rather, the following sections of this report (Sections 4 to 8 inclusive) focus on the 22 potential impacts that were categorised, following discussion at the internal workshop, as having a risk rating of high or moderate.

These impacts are organised under the following headings:

- Risks to operational safety and efficiency (Section 4)
- Risks to navigational safety (Section 5)
- Risk of pollution (Section 6)
- Interdependencies relevant to Competent Harbour Authority functions (Section 7)
- Risk to natural capital (Section 8)

Unless otherwise noted, the risks described in Sections 4 to 8 are operational risks. Most also have potential health and/or safety implications and associated reputational risks. Furthermore, if unmanaged, some of the risks would also have financial and/or environmental consequences.

As anticipated, and as was the case in 2011, the risk assessment did not reveal any risks that could be considered as entirely 'new'. Rather the predicted climatic changes are expected to bring about a change in conditions that the ports are already well used to dealing with, either through an increase or decrease in frequency or extent of a particular climate induced event or condition.

3.3 Presentation of risk assessment outcomes

Each potential impact is summarised on a table. The first column of each table briefly describes the cause(s) and consequence(s) of the impact. The second column indicates the attributed risk rating, and the third column the level of confidence in the risk rating. Confidence is typically a function of the adequacy of the climate change projections used to support the risk assessment (see Table 1) although in some cases it also reflects current known issues. Confidence in impacts that are specifically associated with changes in wave climate or sediment dynamics is therefore generally low. In cases where potentially significant impacts have been identified with low confidence in the projections, monitoring and data collection to improve understanding will be vital. This is picked up in the fourth column, which highlights the responses that are likely to be needed in the short- and longer term. Indeed, the tables show monitoring and additional data collection is needed in relation to many of the potential impacts. This is important because, even where there is high confidence in the climate projections, a decision on when a certain action or intervention is needed will often be informed by information on actual, local rates of change (see Section 9.2).

Also in the fourth column, a distinction is made between responses that should be implemented in the short term (normal font) and – shown in *italics* – those representing options to be considered in due course depending, amongst other things, on monitoring outcomes. Possible responses include not only physical/structural measures but also social/operational or institutional interventions, in line with the recommendations of the IPCC Adaptation Needs and Options report (IPCC, 2014). Some of the responses identified will be delivered via existing or new Standard Operating Procedures (SoPs); others will require supplementary activity, for example additional monitoring. Some represent new actions.

4 Risks to operational safety and efficiency

4.1 Impounded docks and lock gates

Potential Impact(s)	Risk Rating	Confidence	Potential Response(s) *Future Options*
Uncontrolled opening and possible structural damage to lock gates due to sea level rise, surge, extreme high-water levels (critical level = exceeding 10.1m OD for Liverpool), water level variation, overtopping, or extreme waves. Implications for navigational safety and the loading and movement of products	High	High	Monitoring to understand trends in relevant parameters (monitoring to include water chemistry changes) *Develop/enhance warning systems* *Fit flood gates or otherwise modify affected lock gates as business case requires*
Warmer water temperatures leading to increased biofouling of dock or local structures, equipment, ladders, etc. Implications for maintenance activities and costs; also for biodiversity	Moderate	Medium	Monitoring, including baseline conditions and rates of warming Enhanced port-level marine biosecurity Set up alert system Remove debris that may facilitate establishment of invasive non-native species

4.2 Bollards

Potential Impact(s)	Risk Rating	Confidence	Potential response(s) *Future Options*
Structural damage to bollards with vessel alongside due to overtopping, high flow, extreme waves.	High	High	Monitoring to understand trends in relevant parameters Regular condition audits *Contingency planning, including berth management options* *Upgrade bollards* *New infrastructure (e.g. breakwater(s)) to protect against extreme conditions at berth*

4.3 Monitoring and communications systems

Potential Impact(s)	Risk Rating	Confidence	Potential Response(s) *Future Options*
Restricted access for maintenance of monitoring or communications systems due to sea level rise plus overtopping, extreme waves or high flow rates. Implications for maintenance costs due to additional wear and tear.	Moderate	High	Monitoring to understand trends in relevant parameters Review health and safety protocols Regular audits and maintenance Ensure stock of those parts regularly impacted by extreme weather

			Assess options for alternative access or the relocation of equipment *Install alternative or additional equipment to cover downtime and strengthen resilience*
Change in bathymetry compromising equipment configurations; impact on reading of equipment/reliability of data.	Moderate	Low	Monitoring bathymetry including with radar Increased survey frequency *Autonomous/rapid deployment equipment*
Damage to or failure of telemetry, MET, M&E, or physical systems and utilities (marine or terrestrial) due to overtopping or extreme waves.	Moderate	Medium	Monitoring to understand trends in relevant parameters Regular auditing of equipment; maintain central log to report defects *Consider terrestrial assets' relocation* *Invest in multiple systems to increase resilience if critical part is damaged*

5 Risk to navigational safety

5.1 Dredging and disposal

Potential Impact(s)	Risk Rating	Confidence	Potential response(s) *Future Options*
Increased dredging and disposal requirements if changes in hydrographical conditions affect patterns of sedimentation. Potential financial implications	High	Low	Increase frequency of hydrographic survey *Modify dredging and disposal frequency and/or methods (with associated revisions to licensing process)* *Undertake studies to improve confidence in projected local or regional coastal changes* *Explore new beneficial use opportunities*
Reduced operational windows for dredging or disposal due to extreme wave conditions	Moderate	Low	Monitoring to understand trends in relevant parameters *Re-programme dredging campaigns* *Review disposal options or locations*
Disposal options compromised if warming increases presence of invasive non-native species in dredged sediment. Potentially significant financial implications	Moderate	Low	Enhanced port-level marine biosecurity *Additional pre-dredge data collection*

5.2 Tidal berths and slipways

Potential Impact(s)	Risk Rating	Confidence	Potential response(s) *Future Options*
Berthing, quaysides and operations compromised more frequently due to overtopping (sea level rise plus extreme wind, wave, storm or surge).	High	Medium	Monitoring to understand trends in relevant parameters Prioritise maintenance
Berthing and quayside operations compromised more frequently due to extreme wave conditions.	Moderate	Low	Monitoring to understand trends in relevant parameters
Slipway use compromised more frequently due to sea level rise plus extreme wind, wave, storm or surge.	Moderate	Medium	Monitoring to understand trends in relevant parameters Work with third parties to ensure safe practices *Identify safe havens / temporary alternative mooring locations*

5.3 Pilotage

Potential Impact(s)	Risk Rating	Confidence	Potential response(s) *Future Options*
Reduced ability to board and recover pilots due to more frequent wave height exceedance (and/or, for PoSL, change in fog characteristics).	High	Low	*Revision of boarding practices* *Install infrastructure to accommodate autonomous vessels and support remote pilotage*

5.4 Navigation channel and approaches

Potential Impact(s)	Risk Rating	Confidence	Potential response(s) *Future Options*
Reduced operational windows due to extreme wave conditions.	Moderate	Low	Monitoring to understand trends in relevant parameters

6 Risk of pollution

6.1 Fuel station, waste reception facilities

Potential Impact(s)	Risk Rating	Confidence	Potential response(s) *Future Options*
Overtopping causing flooding / damage to fuel station, waste reception facilities. Implications for environment.	Moderate	Medium	Monitoring to understand trends in relevant parameters *Contingency planning* *Bunding around affected areas or relocate facilities*

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7 Interdependencies (relevant to Competent Harbour Authority functions)

7.1 Recreational use

Potential Impact(s)	Risk Rating	Confidence	Potential response(s) *Future Options*
Changes in bathymetry compromising access to marinas, etc.	Moderate	Low	Increase hydrographic survey frequency *Review provision of aids to navigation* *Increased dredging*
Introduction or transfer of invasive non-native species. Implications for environment	Moderate	Medium	Raise awareness via stakeholder workshops Enhanced port-level marine biosecurity
Potential health risks for water users associated with climate change-induced effects on water chemistry or biology e.g., algal blooms, jellyfish. Implications for environment.	Moderate	Low	Enhanced port-level marine biosecurity Raise stakeholder awareness Manage reputational risk

7.2 Road (and rail) infrastructure

Potential Impact(s)	Risk Rating	Confidence	Potential response(s) *Future Options*
Sea level rise plus overtopping, extreme waves or high flow rates causing flooding and possible structural damage affecting road (and rail) infrastructure: restricting access for marine operations team, pilots, etc. with wider implications including navigational safety; operations; health and safety; reputation	Moderate	High	Monitoring to understand trends in relevant parameters *Review contingency plans*

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8 Risk to natural capital

8.1 Protected sites and species, wider biodiversity

Potential Impact(s)	Risk Rating	Confidence	Potential response(s) *Future Options*
Physical damage to protected habitats (erosion, deposition, submergence) due to changes in sea level, extreme waves, storminess or high flow rates.	High	High	Review options for beneficial re-use of dredged material Explore habitat enhancement options Stakeholder engagement Awareness to manage reputational risk
Changes in characteristic biology due to increased temperatures, water chemistry changes (salinity, acidity).	Moderate	Low	*Awareness to manage reputational risk*
Warming waters leading to increased threat to native species from invasive non-native species.	Moderate	Medium	Enhanced port-level marine biosecurity (commercial and recreational users) Awareness to manage reputational risk

9 Addressing shortfalls and uncertainties

9.1 Main shortfalls and uncertainties

As indicated in Sections 2 and 3, significant differences exist in the adequacy of the climate change projections on which the risk assessment is based. These differences are reflected in the level of confidence attributed to the risk ratings in Sections 4 to 8. Over time, as the climate science advances, the level of confidence in the projections should increase. In the meantime, local monitoring and data collection can help improve confidence and inform decision making (see Section 9.2). Locally collected information may also be useful to support: future modelling (e.g., of sediment dynamics); joint probability analysis (e.g., understanding the likely magnitude of extreme events); climate-proofing requirements for new infrastructure; and to otherwise support future climate change risk assessments.

Other uncertainties, potentially acting as barriers to adaptation action, relate to the current incentives for the wider ports' sector to adapt (regulatory, commercial, reputational); and meeting the costs of adaptation (including the challenges that can be associated with making a robust business case for major investment outside existing capital programmes or maintenance and review schedules).

The development of climate change adaptation responses using an adaptation pathways approach can help deal with some of these uncertainties, enabling initial action to be taken while work to reduce uncertainty is ongoing. Adaptation pathways describe sequences of actions that can be implemented progressively, depending on how the future unfolds and how knowledge improves. These pathways can include the implementation of appropriate short-term, interim or temporary interventions while longer-term (and sometimes more complex and/or costly) responses are developed.

9.2 Data collection, monitoring and adaptive management

Many of the potential responses identified in Sections 4 to 8 identify 'monitoring to understand trends in relevant parameters' as a short-term action.

PIANC (2022, forthcoming) highlights a number of situations in which site-specific information is essential to generate local understanding, identify trends and inform decisions, including:

- Knowledge about the condition and performance of physical assets, including records of the effects of extreme events or changes in natural conditions, can help determine <u>when</u> adaptation responses need to be implemented
- Local hydro-meteorological or oceanographic data can help to understand local trends and assess whether these are in line with projected national rates of change, informing location-specific adaptive management decisions and allowing optimal selection of design criteria
- Post-event data from large weather events, such as the extent and duration of inundation from storm tides and flooding, can be used to validate predictions about likely impact zones and to validate models around future conditions
- A record of the costs and other consequences of damage, disruption or downtime associated with extreme events can facilitate an informed assessment of the financial and economic benefits of adaptation vs. the consequences of inaction, in turn supporting the business case for measures

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- Knowledge about the effectiveness or performance of already-implemented adaptation and resilience responses or measures helps inform decisions on future modifications or measures.

For some potential impacts identified in Sections 4 to 8, the critical threshold above which an impact would be expected is already known. In others, this type of threshold has yet to be defined (e.g., in relation to certain water levels, wind speeds, wave heights, temperatures and so on). In these cases, if it is both possible and meaningful to define such critical thresholds, this work needs to be undertaken as a matter of urgency.

In parallel to establishing critical thresholds, a review of current monitoring activity against the bullet point list above will help to understand where additional monitoring may be needed to ensure an adequate understanding of local trends in relevant climate parameters or processes. The review should also consider whether additional data on the condition and performance of physical assets is needed, and whether existing internal processes for recording the characteristics, costs and consequences of extreme events are sufficient. Together, this additional information and improved understanding will enable adaptive management responses and proportionate adaptation pathways to be developed.

9.3 Potential for cascading failures

As part of the ongoing and future work to identify and assess interdependencies mentioned in Section 1.5, consideration needs to be given to the potential for cascading failures between interlinked natural and socio-economic systems and sub-systems. Inadequately accounting for such complexities can lead to blind spots in adaptation planning (Lawrence et al., 2020). Assessments therefore need not only to identify where port activities and operations depend on third parties (utilities, transport links, etc.) but also to recognise the potential for one failure to cause another, as was observed in the first months of the COVID-19 pandemic. In climate change terms, a period of prolonged and widespread severe weather damaging homes and affecting the transport network, may impact on the availability of and access for port personnel and lorry drivers, compromising vessel loading and unloading efficiency, and creating a backlog that ultimately affects the wider supply chain.

9.4 Other challenges and opportunities

Since the first climate change adaptation reports were prepared (Royal Haskoning, 2011 (a); (b)), the visibility of climate change issues has gained momentum across Peel Ports Group. Awareness raising workshops have been held; a climate change Steering Group has been set up to consider both mitigation and adaptation issues; and Group Marine organised an international Ports climate change adaptation conference in Glasgow during COP26 (see https://www.maritimeuk.org/imh-2021/imh-events/practical-climate-change-adaptation-challenges-and-good-practice-solutions-ports/).

Notwithstanding this progress, work continues to embed climate change thinking within the organisation. The following key areas are being developed:

- Climate change risk assessment processes to be extended to other ports in the Group
- Continuation of the inclusive programme to strengthen engagement with staff, build capacity and mainstream climate change considerations, including via the climate change Steering Group
- Ensuring climate-proofing of new and replacement infrastructure, assets, equipment and operations
- Greater engagement with key stakeholders, including in identifying and assessing interdependencies

- Ensuring that climate change issues are properly reflected in the development of future Port Masterplans.

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