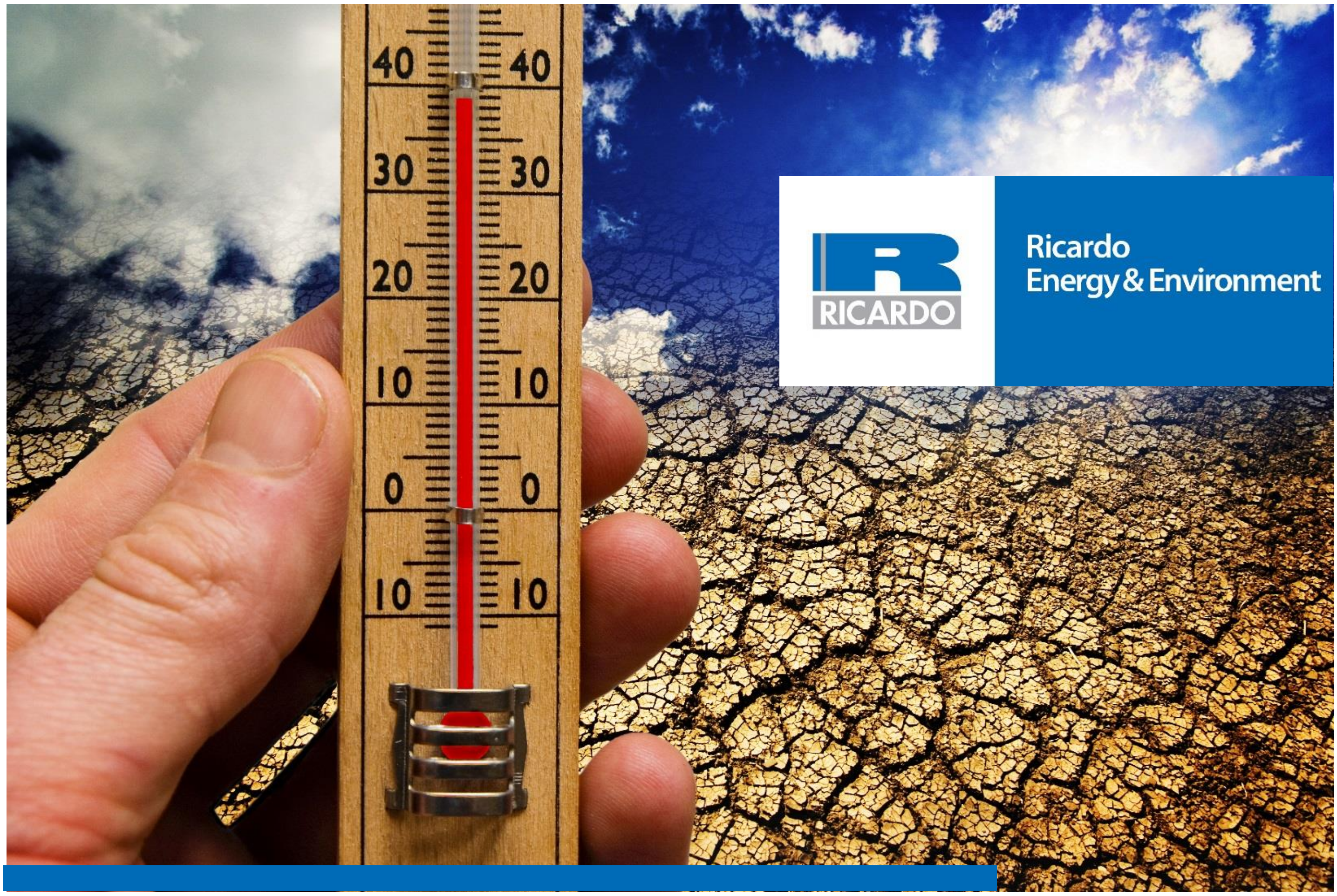

Output 2: Critical Climate Impacts Report

Assessing the magnitude of select impacts in the UK and Russia

Report for Foreign and Commonwealth Office

Federal State Budgetary Institution «Institute of Global Climate and Ecology of Federal Service for Hydrometeorology and Environmental Monitoring and Russian Academy of Sciences». (FSBI "IGCE")

Federal State Budgetary Institution
"State Hydrological Institute" (SHI)

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Customer:

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Bilateral Project: Assessing and Communicating Country Level Climate Impacts in Russia and the UK

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Executive summary

This is the final report for the UK Foreign and Commonwealth Office (FCO) funded Russia-UK project "Assessing and communicating country level climate impacts in Russia and the UK". This project is a collaborative effort between the Institute of Global Climate and Ecology of Roshydromet and RAS (FSBI "IGCE") in Russia and the UK-based environmental consultancy Ricardo Energy & Environment. The State Hydrological Institute (Roshydromet) has also contributed to the Russian part of the assessment. The purpose of the project is to develop and apply approaches for the assessment and synthesis of climate impacts at a national level in both countries to enable more consistent and transparent communication of key impacts and raise awareness of these among national and international stakeholders. For this project, Russia has focussed on assessing the magnitude of climate impacts on terrestrial permafrost. The UK has focussed on assessing the impacts of climate change on flooding.

Russian Assessment of Climate Change Impacts on Permafrost

The influence of climate change on natural systems, socio-economic sectors and human health is gradually becoming a topic of high interest in Russia, despite a certain degree of climate scepticism in society and in some parts of the Russian business community. In the last decades, the non-scientific community has begun to realise the possible threats from climate change and has thus started to interact with scientists to develop effective assessments of the consequences of climate change for further planning.

This project has focused on assessing the magnitude of climate impacts on terrestrial permafrost. Permafrost covers about 65% of the total area of Russia including several cities and industrial facilities. Warming of the permafrost in this area leads to negative environmental and socio-economic consequences. The high vulnerability of Arctic regions to climate warming is reported in many scientific papers and is a topic of great concern all over the Arctic region, not only in Russia.

The table below provides an overview of the observed impacts of climate change on the permafrost zone in Russia. The assessment of the projected impacts of climate change on permafrost is provided in the main report.

Observed climate impacts on the permafrost zone

Sector	Observed climate impacts	National impact rating	Confidence rating	Data quality rating	Time period	Metadata identifier(s)*
Coastal systems and low-lying areas	Intensification of coastal erosion along the Arctic coast	High	Medium	High	1979-2012	1.1
	Intensification of landslides and thermokarst processes in the permafrost zone	Low	Medium	Medium	1970-2013	1.2
Human settlements, industry, and infrastructure	Destruction of transport infrastructure in the permafrost zone	High	High	Medium	1970-2010	1.3
	Destruction of oil and gas pipelines in the permafrost zone	Medium	Medium	--	1990-2010	1.4
	Destruction of buildings in the permafrost zone	High	Medium	Medium	1970-2000	1.5

* The metadata identifier is used to direct the reader to the information sources used for the assessment. The metadata for this assessment are presented in Appendix 1 of this report.

It was found that in general the methodology for assessing the magnitude recommended in CLICC suits the Russian data on the permafrost zone, but it should be improved taking into consideration the national features of Russia. More models and projections need to be developed to obtain more robust magnitude assessments for projected climate impacts. An increase in accessibility of data and improvement of data validation is needed.

The UK Assessment of Climate Change Impacts on Flooding

The main source of information used to complete the assessment of the impacts of climate change on flooding in the UK was the 2016 report 'UK Climate Change Risk Assessment Evidence Report.' This evidence report was produced to inform the 2017 UK Climate Change Risk Assessment (CCRA). The Adaptation Sub-Committee (ASC) of the Committee on Climate Change worked with a range of experts to review published data and produce the independent evidence report of the risks and opportunities to the UK from climate change.

The table below provides an overview of the observed impacts of climate change on flooding in the UK. The assessment of the projected impacts of climate change on flooding is provided in the main report.

Observed climate impacts							
Sector	**Observed climate impacts**	**Global impact rating** (High / Medium / Low)	**National impact rating** (High / Medium / Low)	**Confidence rating** (Very low / Low / Medium / High)	**Data quality rating** (Low / Medium / High)	**Time period**	**Metadata identifier(s)***
Terrestrial and inland water systems	• Observed increase in the frequency and magnitude of flooding • Some evidence suggests that UK extreme weather events (such as flooding) can be attributed to climate change	**High**	**High**	**Mostly: Medium**	**Medium**	**Baseline 1960- 1990 observed till 2014**	**Time period 1.2** **Otherwise: 1.1**

*The metadata identifier is used to direct the reader to the information sources used for the assessment. The metadata for this assessment are presented in Appendix 2 of this report.

Flood risk is one of the more advanced sectors for climate risk assessments in the UK, with a well-developed, sophisticated modelling base. However, the complexity of assessing current and future flood risk using models comes with its own uncertainties and limitations, including key uncertainties related to modelling flood extent and uncertainty regarding the quantification of the impacts of flooding.

Conclusions

This project has provided an excellent opportunity for researchers in Russia and the UK to compare their respective countries' methodologies for assessing national level climate impacts and discuss the challenges of conducting such assessments. As anticipated, the two issues selected (thawing permafrost in Russia and flooding in the UK) presented very similar challenges for high-level review and synthesis of their impacts across sectors at a national level. The project team has found that the CLICC methodology and template, as developed during the CLICC pilot phase, provided a useful and concise format for communicating these assessments in a consistent way for simple yet meaningful presentation to a wide range of audiences, including policy and decision-makers. Although Russia and the UK conducted their assessments in two different ways, completing the template and providing supporting metadata was feasible for both countries.

This project has also highlighted the challenges of bringing together scientists and policy-makers to discuss and understand the impacts of climate change. The project team recognises the importance of communicating climate impacts in such a way that it is accessible and relevant to a variety of audiences, including scientists, business, the public, policy-makers, and the international community. The project outputs are designed to provide useful summaries to all of these audiences including technical reports, templates, executive summaries, articles and press releases. In particular, the assessments from this project have been conducted according to the draft CLICC methodology, providing summaries of climate impacts in Russia and the UK in consistent, standardised formats which could be compared with those from other countries.

The following conclusions have been highlighted throughout the course of the project:

- The project team recognises the importance of continuing to share experiences and work together to develop consistent and transparent methodologies for assessing and communicating national level climate impacts. This collaboration between British and Russian scientists has provided useful insight to the methodologies used to assess climate impacts in both countries and will provide lessons learned to the ongoing CLICC initiative.
- Further research is needed in both countries to assess the magnitude of climate impacts on additional sectors. The impacts of climate change on the health sector proves to be a challenging topic in both countries where there are still a number of knowledge gaps and uncertainties.
- In Russia, further research is needed to develop climate projections and expand the body of work on understanding future climate impacts. Although progress has been made in recent years on evaluating climate models in permafrost zones, confidence ratings of projected climate impacts in this area remain low due to the need for further modelling work and projections.
- The use of conclusions from assessment reports by policy-makers in Russia remains challenging due to specific technical language of the reports. This project has highlighted the importance of making outputs accessible to policy-makers through the use of simplified policy-relevant formulations and has worked to produce summaries of the project research which are useful to policy-makers.
- This project has begun the process of making information on climate change more accessible to the public in Russia, but there is further work to do. Future projects should build on this and continue to provide clear, robust information which can be communicated to the public in an appealing and engaging way.

Next Steps

The project culminated in a **final project workshop**, which was held on the 1st March at the British Ambassador's Residence in Moscow. This event brought together scientists, policy-makers, and representatives from private sector organisations who are interested in climate impacts on permafrost. Workshop participants highlighted the following recommendations and suggestions for future work on climate impact assessments in Russia:

- Greater focus on social impact assessment which take into account the social vulnerability of the population of Russia to climate change;
- Make an assessment on regional and local scale as well as national scale;
- Take into consideration different scenarios of climate change (including alternative scenarios of cooling);
- Improve the presentation of assessments of climate impacts by considering accessibility, not only for decision-makers but also for the general public and the business community;
- On the basis of the obtained results and future work, develop proposals for the development of new regulations for changing climatic conditions on the territory of Russia;
- Make the project results available to the organisations developing the Russian national adaptation plan;

- Inform the mass-media about the project results and improve the overall cooperation with mass-media in the future work.

Following the completion of this project, the project team also hopes to continue to **develop national level assessments of climate impacts through additional bilateral projects** between the UK and Russia. The project team members have built an excellent working relationship and hope to continue to expand this area of collaboration and research through future projects. In particular, future work could address key gaps in knowledge and assessment systems, such as climate change - human health interactions and presenting information on climate impacts on human health and associated risks in a standardised format. Such work would facilitate engagement between Roshydromet and the agencies responsible for developing adaptation measures and plans in the human health sector in order to more effectively exchange information for better preparedness to cope with the consequences of climate change.

And finally, the project outputs and lessons learned are important to **feed back into the ongoing CLICC initiative** as they will:

- assist the CLICC initiative to regain momentum since the transition from UK Government to UNEP
- feed into the second round of CLICC country pilots that are planned for 2017
- be available to other countries and international bodies via the UNEP CLICC website
- demonstrate that Russia and the UK continue to engage with the CLICC initiative and to play a leading role in developing a standard format for communicating the country level impacts of climate change.

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Appendices

1 Introduction

This is the final report for the UK Foreign and Commonwealth Office (FCO) funded Russia-UK project “Assessing and communicating country level climate impacts in Russia and the UK”. This project is a collaborative effort between the Institute of Global Climate and Ecology of Roshydromet and RAS (FSBI “IGCE”) in Russia and the UK-based environmental consultancy Ricardo Energy & Environment. The purpose of the project is to develop and apply approaches for the assessment and synthesis of climate impacts at a national level in both countries to enable more consistent and transparent communication of key impacts and raise awareness of these among national and international stakeholders.

The following sections provide an overview of the assessments from both Russia and the UK. For this project, Russia has focussed on assessing the magnitude of climate impacts on terrestrial permafrost. The UK has focussed on assessing the impacts of climate change on flooding. These topic areas were selected because Russian permafrost regions have exhibited one of the highest rates of climate change in the past decades; understanding the socio-economic and environmental consequences of these changes is a critical topic for Russia. Similarly, risks from flooding and coastal change were recently identified as one of six immediate priority areas in the UK’s Climate Change Risk Assessment Evidence Report (ASC, 2016) and thus remains a critical topic for the UK.

The results from this project will feed into the overarching initiative “Country Level Impacts of Climate Change (CLICC)” initially funded by UK government and now being taken forward by the United Nations Environment Programme (UNEP).

1.1 Country-level Impacts of Climate Change (CLICC)

The Country Level Impacts of Climate Change (CLICC) project was initiated to improve global understanding of national level impacts to support action on climate change. The project approached this challenge by facilitating the development of a common process to enable countries to present their climate change impacts in a harmonised way. CLICC seeks to establish a long-term process, supported and coordinated at the international level.

CLICC’s core aims are to:

- Facilitate global understanding of country-level climate impacts to support action on climate change, by informing national mitigation and adaptation planning, and international dialogue
- Promote good practice and collective learning in assessing climate impacts.

The initial phases of the CLICC initiative developed a common process for countries to present the impacts of climate change at the national level, drawing on existing national assessments and other research material.[1] Ricardo Energy & Environment on behalf of UNEP and the UK Department of Energy and Climate Change coordinated the pilot phase of the CLICC project, including consensus building on the core aims, principals and approach of CLICC, confirming the scope of each pilot, organising workshops and meetings, brokering collaborative working and exchange of experience.

IGCE and Ricardo Energy & Environment played an important role by undertaking the CLICC pilots for Russia and the UK respectively in 2015-2016. Four more countries also developed CLICC pilots: China, Vietnam, Ghana and Fiji.

There were five stages, or tasks, undertaken to produce the CLICC Pilots:

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[1] Further information is available at http://www.unep.org/provia/CLICCPROJECT

1. Inception – covered the briefing and consultation with participating countries to agree the scope and objectives for each pilot, and to confirm the approach that each country would take.
2. Application – the agreed scope and approach was then put into practice. The countries collated and synthesised their information into a pilot template, supported by Ricardo, the UK Government, and UNEP.
3. Learning exchange – ran throughout the pilot phase to facilitate participating countries in sharing their experiences, tackling similar challenges together and then identifying lessons learned.
4. Quality assurance – to ensure that the pilots were of a consistent quality.
5. Reporting – publication of pilot outputs, lessons learned and recommendations on the outcomes for UNEP and future CLICC activities.

By the completion of the CLICC Pilots, the project succeeded in:

- Developing and testing a common approach for rating and communicating country-level impacts of climate change.
- Establishing systems and protocols for collaborative working and collective learning.
- Creating a “community of practice”.
- Generating an international profile and a future for CLICC.

The CLICC pilots also helped to build relationships between countries that might not normally work together on climate change impacts. In particular, the UK and Russia have been able to continue work on the assessment of national level impacts through this FCO study, thereby continuing the work begun during the CLICC pilots.

1.2 CLICC methodology

One of the main outputs from the pilot phase was a CLICC Template and accompanying set of CLICC Technical Guidelines. The CLICC Template is intended for use by countries in communicating their climate change impacts internationally in a harmonised way. It comprises high-level summary tables for observed and projected climate impacts, with supporting metadata tables for provision of information about the underlying data.

One of the central principles of CLICC is that it enables all countries to participate and complete the template in a harmonised way regardless of the level of information available on national level climate impacts or that they wish to communicate. Thus, the CLICC Template identifies headings and core content, and the CLICC Technical Guidelines provide instructions for completing the template and outline technical parameters and definitions of key terms.

This study for the FCO has followed the CLICC approach, using the CLICC Template to complete the assessment of the impacts of climate change on permafrost in Russia and flooding in the UK. The CLICC approach proved a useful way of structuring, summarising and assessing the magnitude of the impacts. Lessons learned from this study will also be fed back into future CLICC developments in order to continue to shape and amend the CLICC Template and Technical Guidelines. The sections below provide an overview of the UK and Russia’s assessments, with the detailed metadata tables provided in the Appendices.

2 Russian assessment: national level impacts of climate change on permafrost

2.1 Russian efforts in climate change impacts and risk assessments

Russian scientists have been involved in major international climate assessment initiatives. In 2008 Roshydromet published the first Assessment Report on Climate Change and its Consequences in Russian Federation (2008). The first volume of this report was devoted to the analysis of the observed and projected changes in physical parameters of the climate system, while the second one was focused on the climate change impacts on natural systems, economic sectors, and human health. Soon after the release of this report, Roshydromet prepared the Climate Doctrine. The document was officially endorsed by the Prime Minister of Russia in December 2009. It was the first-ever document presenting Russia’s vision of climate change problems and a way to develop response measures. Since that time, climate scientists have made progress in assessing climate change and its consequences, which resulted in the publication of the Second Roshydromet Assessment Report on Climate Change and its Consequences in Russian Federation (2014). Some new approaches were applied and new results were obtained.

Climate change influence on different natural systems, socio-economic sectors and human health is gradually becoming a topic of high interest in Russia, despite the climate scepticism existing in society, in particular, in some parts of the Russian business community. In the last decades, the climate change problem became a matter of concern not only for climate scientists, but also for some private companies and policymakers. The non-scientific community has realised the possible threats from climate change for the environment, socio-economic facilities, and human health. Stakeholders have started to interact with scientists to develop the effective assessments of climate change consequences for further planning. A good example of such collaboration is the collaboration between climate scientists and transport and energy companies in the North of Russian.

An example of involving policymakers in climate initiatives is the signing of the United Nations Framework Convention on Climate Change (1992), the Kyoto protocol (1997), and, recently, the Paris Climate agreement (2015).

For this project, we focused on assessing the magnitude of climate impacts on terrestrial permafrost. Permafrost covers about 65% of the total area of Russia with a lot of cities and industrial facilities. Warming of the permafrost in this area leads to negative environmental and socio-economic consequences. The high vulnerability of Arctic regions to climate warming is reported in many scientific papers and is a topic of great concern all over the Arctic region, not only in Russia.

The purpose of this study is to synthesise results and key findings regarding climate change impacts in the Russian permafrost zone from the scientific papers, national and international assessment reports and present the magnitude of these impacts in the format developed in the CLICC project. Methodologies for assessing the magnitude of impacts are presented in the next section.

2.2 Methodologies of assessing climate change impacts in the permafrost zone of Russia

Impact rating

The magnitude of climate change impacts in the Russian permafrost zone was assessed using the CLICC approach. An impact magnitude is characterised with three categories: high, medium and low.

Impacts of climate change on the environment in the permafrost zone of Russia mainly relate to the intensification of geocryological processes, such as landslides, thermokarst, thermoerosion, and, partially, coastal erosion. According to the methodology proposed in the CLICC project (see Section 1.2), a magnitude of the environmental impacts can be assessed quantitatively by the area (in km^2) affected or lost due to these processes. For the coastal erosion, about 30 km^2 per year was lost during the last 30 years (Anisimov, 2010). Thus, it meets the criterion of 'high' according to the 'global' categories for impact rating proposed in the CLICC guidance. This amounts to about 900 km^2 for the last 30 years, which is substantial even for Russia with its rather large territory. Unfortunately, such estimates in regard to thermokarst and landslides processes were not found in scientific literature. Therefore, a magnitude of this impact was rated as 'low'.

Magnitude of a *social impact* can be quantified by the number of people affected by damaged buildings and transport infrastructure. In the assessment made in (Anisimov, Streletskiy, 2015), the total number of people in Russian arctic cities affected by the deformation of infrastructure objects was estimated at about 1,335,000. The amount of people living in the settlements affected by reduction in the ice-road operation period is about 987 000 (Hatleberg, 2012). In both cases, the values mean 'high' magnitude of impact according to the CLICC methodology.

Economic impacts can be quantified by the cost of damage or disruption. There are several assessments of the costs of damage to the pipelines (see metadata in the Appendix), which yields a 'high' rate according to the CLICC methodology. However, due to insufficient evidence of direct climate impacts on the pipelines' destruction, the rating 'medium' was applied. Information about the degree of the damage (%) for construction (e.g., roads, railways, buildings) or reduction in the bearing capacity was also taken into consideration. Since in the majority of cases the effect exceeded 20%, the impact can be rated as 'high'.

If an impact of climate change leads simultaneously to social, economic and environmental consequences, its magnitude was assessed as highest.

Regional differences. In this study, impacts are not considered by regions or administrative territorial units of the Russian Federation. The rating characterises the Russian territory as a whole. See the discussion on this matter in Section 1.4.

A list of impacts with their magnitudes is presented in Tables 2.1 and 2.2.

Confidence rating

Confidence of magnitudes of both observed and projected climate impacts was assessed using CLICC recommendations:

'High' confidence rating was applied, if there was a large amount of evidence/observations/modelling calculations for different regions of Russia based on reliable data and methods, and with widespread agreement between studies and experts.

'Medium' confidence rating was applied, if there were several evidences/observations/modelling calculations in some regions/cities of Russia based on reliable data and methods.

'Low' confidence rating was applied, if there were a few evidences/observations/modelling calculations in a specific region/city of Russia either with or without quality assessment.

Data quality rating

Data quality of observed climate impacts presented in the report was also assessed using the CLICC table:

Data quality assessment		
Dataset:		
Data Quality Criteria	Levels	Score
1. Transparency and auditability	1. Data unavailable to public	
	2. Limited summary data available	2
	3. Full raw/primary data set and metadata available	
2. Verification	1. Unverified data	
	2. Limited verification checks in place	
	3. Detailed verification in place and documented	3
3. Frequency of updates	1. Sporadic	
	2. Every 3-5 years	
	3. Annual or biennial	3
4. Security	1. Future data collection discontinued	
	2. Future data collection uncertain	
	3. Future data collection secure	3
5. Spatial coverage	1. Partial national coverage	
	2. National coverage, some bias	2
	3. Full national coverage, including adjacent marine areas, if and where appropriate	
TOTAL		**13**
Total scores should be rated as follows: 5 to 8 (Low); 9 to 12 (Medium); 13 to 15 (High)		**High**

Data quality regarding projected climate impacts presented in the report was not assessed; see discussion in Section 1.4.

Time period

The time period for observed impacts indicated in the template is characterised by the initial and final years of observations/modeling results. Some years within the period may not be covered by observational data. A time period indicated for projected climate impacts is the time period (or even a single year) for which the projection was made.

2.3 Assessing climate change impacts in the permafrost zone – CLICC template

The methodological tools presented above were applied to produce the following CLICC template. The template is made on the basis of the Summary report (Output 1 for this project, DOI: 10.13140/RG.2.2.27434.41920) "Impacts of Changing Climate in Permafrost Regions: The Russian Perspective", prepared by the State Hydrological Institute of Roshydromet. This report contains the main scientific results about climate impacts in the permafrost zone which were obtained for the last decades in Russia. The observed and projected climate impacts in the permafrost zone are related to the corresponding sectors: "Coastal systems and low-lying areas" and, "Human settlements, industry, and infrastructure". The metadata for the template are presented in Appendix 1. The discussion is presented in the next section.

Table 2.1. Observed climate impacts

Sector	Observed climate impacts	Global impact rating	National impact rating	Confidence rating	Data quality rating	Time period	Metadata identifier(s) *(Please see Annex 1)*
Coastal systems and low-lying areas	• Intensification of coastal erosion along the Arctic coast • Intensification of landslides and thermokarst		High Low	Medium Medium	High Medium	1979-2012 1970-2013	1.1 1.2
Human settlements, industry, and infrastructure	• Destruction of transport infrastructure in the permafrost zone • Destruction of oil and gas pipelines in the permafrost zone • Destruction of buildings in the permafrost zone		High Medium High	High Medium Medium	Medium -- Medium	1970-2010 1990-2010 1970-2000	1.3 1.4 1.5

Table 2.2. Projected climate impacts

Sector	Projected climate impacts	Impact rating	Confidence rating	Data quality rating	Time period	Metadata identifier(s) *(Please see Annex 1)*
Coastal systems and low-lying areas	• Intensification of coastal erosion along the Arctic coast	Low	Low	--	2020-2050	2.1
Human settlements, industry, and infrastructure	• Destruction of transport infrastructure in the permafrost zone • Destruction of buildings in the permafrost zone	High High	Low Low	-- --	2050 2045-2055	2.2, 2.4 2.3, 2.4

2.4 Discussion: challenges and knowledge gaps

Available information on observed climate impacts in the permafrost zone

There is plenty of information on climate impacts in the permafrost zone. This allows the conclusion that it is one of the most vulnerable parts of Russia in relation to climate change. Most of the outcomes from climate warming are negative, except one positive impact, namely, decrease in energy consumption for heating. The latter one has not been considered in this work due to substantial differences in the experts' judgements. From the perspective of assessing the magnitude of climate change impacts, all available data about *observed* impacts can be divided into three categories:

1) Observations of impacts/consequences of thawing permafrost with a few quantitative or just qualitative characterisations, with the indication of the process direction (e.g., increase/decrease in the amount of thermokarst lakes); this can relate to a long period and to a large area.
2) Quantitative assessments of consequences of climate change characterising the extent of damage for certain regions/cities/accidents.
3) Evidences/assessments of the overall damage and number of people affected without information about drivers (can be of non-climatic nature).

Assessing magnitude of observed impacts according to CLICC methodology using all three categories is rather challenging.

Available information about the projected climate impacts in permafrost region

The information about projected impacts of climate change is based on climate, permafrost, and engineering models' calculations. However, for each impact only one or two modelling-based assessments of projected impacts exist. This is not sufficient the robust conclusions about magnitude of the impacts. Thus, more projections should be developed in order to get more certain evaluation of climate change impacts. Some progress has been recently made in the evaluation of climate models for the permafrost zone (Anisimov and Kokorev, 2013, 2016) and permafrost projections (Anisimov and Sherstukov, 2016).

Magnitude of climate impacts

The methodology described in Section 2.2 was partially applied to evaluate the magnitude of observed and projected climate impacts in the permafrost zone of Russia. It was found that in general the methodology for assessing the magnitude recommended in CLICC suits the Russian data on the permafrost zone. However, it should be improved taking into consideration the national features of Russia, which can be expressed as follows:

- The proposed methodologies assume the existence of appropriate quantitative information (e.g., area of exposure, cost of damage, number of people affected) which is actually nonexistent for Russia in the majority of cases;
- The proposed critical thresholds recommended for 'global rating' do not completely suit the national rating for Russia; economic development, distribution of the population and national features should be taken into consideration;
- The proposed methodologies are developed to present the assessment on average across the country; in such a big country as Russia specific regions have their own features; this should be taken into account;

Thus, to properly assess climate change impacts in the permafrost zone of Russia one needs to:

- Have the appropriate data (quantitative and related specifically to the impacts);
- Develop the national critical thresholds for rating the magnitude of environmental, social and economic impacts taking into consideration the regional features;

Substantial progress in relation to the second of the above-mentioned gaps was made by O.A. Anisimov (Anisimov, Reneva, 2006; Anisimov, Streletskiy, 2015). The proposed special hazard index for assessing climate change impacts in the permafrost zone on ecosystems and infrastructure allows assessing magnitudes of the impacts (a detailed example is presented in metadata Table 2.4 in the Appendix).

The main reason for the above-mentioned knowledge gaps is probably insufficient cooperation between scientists from different fields (e.g. climatology, economics and social science). More close interactions between stakeholders, policymakers and other information users are also needed. One of the purposes of this project is to improve such cooperation and interactions.

Confidence rating

The confidence rating of observed climate impacts presented in this report is mostly medium. This means that one can partially trust in these judgements regarding magnitudes. This means that the overall rating assessment relied on just a few sources of evidence. Therefore, additional research is needed in different regions.

The confidence rating of projected climate impacts is low for all three impacts presented in this report. Thus, more models and projections need to be developed to obtain more robust magnitude assessments.

Data quality rating

The data quality rating of observed climate impacts is mostly medium. Looking at the data quality tables provided in the metadata in the Appendix for each dataset, one can conclude that for most of the data the access is limited or limited information is available. In addition, the verification of the datasets used is in most of cases is uncertain or limited. Thus, an increase in accessibility and improvement of data validation is needed. This will increase the overall data quality and reliability of the impact assessment.

3 British assessment: national level impacts of climate change on flooding

3.1 UK Climate Change Risk Assessment

The main source of information used to complete the assessment of the impacts of climate change on flooding in the UK is the 2016 report ‘UK Climate Change Risk Assessment Evidence Report.’ (ASC, 2016). Every five years the UK Government must carry out an assessment of the current and future risks to the country from climate change. The Department for Environment Food, and Rural Affairs (Defra) published the first Climate Change Risk Assessment (CCRA) in January 2012.

To inform the 2017 risk assessment, the Adaptation Sub-Committee (ASC) of the Committee on Climate Change worked with a range of experts to review published data and publish an independent evidence report of the risks and opportunities to the UK from climate change. Defra used the ASC’s evidence report as the basis of a Government report, which was laid before Parliament in January 2017.

The ASC’s independent report to Government, ‘UK Climate Change Risk Assessment Evidence Report’ sets out the most urgent risks and opportunities arising for the UK from climate change. (Committee on Climate Change, 2016). In compiling the Evidence Report, the UK Government asked the ASC to answer the following question:

> “Based on the latest understanding of current, and future, climate risks/opportunities, vulnerability and adaptation, what should the priorities be for the next UK National Adaptation Programme and adaptation programmes of the devolved administrations?” (ASC, 2016)

To achieve this aim, the ASC worked with hundreds of academics and other experts to assess nearly sixty individual risks and opportunities in three steps:

- **Step 1:** Understand present-day vulnerability and assess current climate-related risks, opportunities and levels of adaptation.
- **Step 2:** Understand future vulnerability and adaptation, and assess how climate and socio-economic change may alter climate-related risks and opportunities in the 2020s, 2050s and 2080s.
- **Step 3**: Prioritise risks and opportunities for which additional action is needed in the next five years to manage the risk or take advantage of the opportunity.

The Evidence Report uses the concept of urgency to summarise the findings of the analysis. One of four 'urgency categories' has been assigned by the ASC to each risk and opportunity: more action needed, research priority, sustain current action, or watching brief. (ASC, 2016)

3.2 Methodology

The Evidence Report includes eight technical chapters, developed by nine independent lead contributors, 60 contributing authors and the ASC Secretariat. The technical chapters are as follows:

1. Introduction
2. Approach and context
3. Natural environment and natural assets
4. Infrastructure
5. People and the built environment
6. Business and industry
7. International dimensions
8. Cross-cutting issues.

In addition to the main report, four research projects were commissioned by the ASC in order to fill specific knowledge gaps that were identified. In particular, one project considered projections of future flood risk for the UK. The analysis undertaken in this research takes account of four sources of flooding: coastal, fluvial, surface water and groundwater. It projects future flood risks for the 2020s, 2050s and 2080s. It finds that significant additional investment and adaptation action will be needed to counter the increase in UK flood risk projected under a 2°C rise in global mean temperatures. It also finds that even the most ambitious adaptation scenarios will not be able to avoid the large increase in UK flood risk implied by a 4°C rise in global temperatures. Long stretches of current coastal flood defence structures in England will become highly vulnerable to failure as sea levels rise, making it increasingly more difficult and costly to manage the risk of widespread coastal inundation. (Sayers, 2015)

Given the CCRA Evidence Report is the most up to-date-document produced in the UK for presenting current and projected climate risks and impacts, this project for the FCO uses the analysis in the report to provide all the relevant information for completing the CLICC template. The analysis presented by the respective experts in the CCRA Evidence Report chapters has been summarised into Metadata tables in Appendix 2.

The primary source for Table 3-1 was the 'UK Climate Change Risk Assessment 2017: Evidence Report. Synthesis Report Appendix: Urgency scoring tables'. Two other chapters from the report were also used for detailed information:

- Warren, R., Watkiss, P., Wilby, RL., Humphrey, K., Ranger, N., Betts, R., Lowe, J., and Watts, G. (2016) UK Climate Change Risk Assessment Evidence Report: Chapter 2, Approach and Context. Report prepared for the Adaptation Sub-Committee of the Committee on Climate Change, London.

- ASC (2016) UK Climate Change Risk Assessment 2017 Synthesis Report: priorities for the next five years. Adaptation Sub-Committee of the Committee on Climate Change, London.

Climate impacts and impact ratings

The observed and projected climate impacts were identified from the above resources focusing on impacts to communities, businesses and infrastructure. Metadata Table 1.1 in Appendix 2 presents the quantified data from the CCRA Evidence Report which clearly indicate the magnitude of climate impacts. The CLICC impact rating approach used for categorising impacts to high, medium and low was used to assess the magnitude of impacts.

Confidence ratings

The CCRA Evidence Report highlights confidence rating for the quantified impacts. It is based on the overall quality of the evidence base that has been used to identify the urgency. Metadata Table 1.1 in Appendix 2 presents more information on the confidence categories defined in the CCRA Evidence Report.

Data quality rating

Data quality of observed and projected climate impacts in the CCRA Evidence Report has a medium rating, particularly due to lack of clarity on factors such as frequency of updates, security and special coverage which were used in the CLICC template for the data quality assessment.

It is worth noting that Sayers et al. 2015 highlights ‘’the data upon which this assessment is based are the best publically available sources, often obtained from years of data acquisition and research and development programmes. The UK is well served by flood risk analysis in the public and private domains. Thus, whilst inevitably imperfect the information upon which this assessment is based is considered fit-for-purpose’’.

Metadata Table 1.2 in Appendix 2 has been completed using Sayers, et al. 2015.

3.3 Assessment of the impacts of climate change on flooding in the UK

The information obtained in the CCRA Evidence Report is summarised in Tables 3.1 and 3.2; the format of these tables is the template developed in the CLICC project. The metadata information for this template is presented in Tables 1.1 and 1.2 in Appendix 2.

Table 3-1: Observed impacts of climate change on flooding

Observed impacts of climate change on flooding							
Sector	**Observed climate impacts**	**Global impact rating** (High / Medium / Low)	**National impact rating** (High / Medium / Low)	**Confidence rating** (Very low / Low / Medium / High)	**Data quality rating** (Low / Medium / High)	**Time period**	**Metadata identifier(s)**
Terrestrial and inland water systems	- Observed increase in the frequency and magnitude of flooding - Some evidence suggests that UK extreme weather events (such as flooding) can be attributed to climate change	**High**	**High**	**Mostly: Medium**	**Medium**	**Baseline 1960- 1990 observed till 2014**	**Time period 1.2** **Otherwise: 1.1**

Table 3-2: Projected impacts of climate change on flooding

Projected climate impacts						
Sector	**Projected climate impacts**	**Impact rating**	**Confidence rating**	**Data quality rating**	**Time period**	**Metadata identifier(s)**
Coastal systems and low-lying areas	1. Projected reduction in land availability and capability due to flooding	**High**	**Medium**	**Medium**	**2020s, 2050s and 2080**	**1.1 and 1.2**
Health	2. Projected increase in health and social care delivery affected by flooding	**Medium**	**Low**	**Medium**	**2020s, 2050s and 2080**	**1.1 and 1.2**
Human settlements, industry, and infrastructure	3. Projected increase in infrastructure services affected by flooding	**High**	**Medium**	**Medium**	**2020s, 2050s and 2080**	**1.1 and 1.2**
	4. Projected increase in people, communities and buildings exposed to flooding	**High**	**Medium**	**Medium**	**2020s, 2050s and 2080**	**1.1 and 1.2**
	5. Projected increase in direct and indirect losses and damages to businesses from flooding	**High**	**Medium**	**Medium**	**2020s, 2050s and 2080**	**1.1 and 1.2**

3.4 Discussion: Challenges and knowledge gaps

Despite the UK's extensive scientific information on climate impacts, there are still areas of uncertainty and limitations to the risk assessment approach.

The CCRA Evidence Report concluded there were a number of limitations (Warren, 2016) to the approach which are summarised below:

- Available resources: the CCRA approach relied on adaptation experts providing their time free of charge/much less than their normal day rates.
- Urgency scores: based on expert judgement by the ASC, in turn informed by evidence presented in the chapters – leaves opportunity for expert judgement to hide certain value judgement or biases. To address transparency and any unintended biases, urgency scores have been widely reviewed and critiqued by a wide range of stakeholders.
- Approach to literature review: does not allow for direct comparison of the magnitude between risks. A standardisation of magnitude was completed for selected risks by the degree of global temperature increase.
- Approach to literature review: does not allow for any new analysis to be undertaken to address existing evidence gaps, aside from a few exceptions
- The wide network of reviewers required a considerable amount of resources to ensure the approach and outputs were present and interpreted in a consistent manner.
- Time constraints: limited time meant a systematic review was not feasible. The approach relied heavily on expert knowledge from authors/reviewers and information provided through a public call for evidence to ensure main sources were incorporated.

Flood risk is one of the more advanced sectors for climate risk assessments in the UK, with a well-developed, sophisticated modelling base. However, the complexity of assessing current and future flood risk using models comes with its own uncertainties and limitations (Kovats, 2016), for instance:

- The data and methods used to assess current flood risk in each country of the UK (England, Scotland, Wales and Northern Ireland) vary. The approach used in the CCRA to assess future flood risk combined these different methods into a consistent framework.
- There are key uncertainties related to modelling flood extent. This relies on detailed information on return period flows and local topography. Only limited work has been undertaken to validate the model used for England using observed flood data, which makes it difficult to understand the range of uncertainty.
- There is also considerable uncertainty regarding the quantification of the impacts of flooding (annualised damage costs) which are primarily estimated from insured losses. Evidence from peer-reviewed studies demonstrates that these uncertainties may be significant. Current methodologies focus on the number of flooded properties in order to gauge immediate financial cost arising from damage. The wider economic and social costs are not included. The impacts on health (direct and indirect health costs) are also not included in current estimates.

4 Discussion: Russian and British approaches

This project has provided an excellent opportunity for researchers in Russia and the UK to compare their respective countries' methodologies for assessing national level climate impacts and discuss the challenges of conducting such assessments. As anticipated, the two issues selected (thawing permafrost in Russia and flooding in the UK) presented very similar challenges for high-level review and synthesis of their impacts across sectors at a national level. The project team has found that the CLICC methodology and template, as developed during the CLICC pilot phase, provide a useful and concise format for communicating these assessments in a consistent way for simple yet meaningful presentation to a wide range of audiences, including policy and decision-makers. Although Russia and the UK conducted their assessments in two different ways, completing the template and providing supporting metadata was feasible for both countries.

In order to complete the assessment of flooding, the UK approach has been to translate sectoral climate risk assessments and the supporting evidence into the CLICC template which focuses on impacts and the magnitude of those impacts. The Russian approach to completing the assessment has been to first consolidate information on climate change impacts in permafrost zones, and then use the evidence in order to assess the magnitude of the impacts.

Although the CLICC methodology provides a useful way for communicating national level impacts in a consistent way, there are still a number of challenges to completing such assessments and then communicating them with relevant stakeholders. The bilateral discussions between the UK and Russia have illustrated that, not surprisingly, both countries struggle to overcome knowledge gaps, understand uncertainty in the assessments, and engage with decision-makers and the public. Some of the challenges to this process are summarised below.

Obtaining and assessing scientific information on impacts and risks

The first challenge to assessing national level climate impacts is of course to obtain robust scientific information to understand the impacts and risks. The UK and Russia, and indeed all the other countries that were involved in the CLICC pilots, have worked hard to assemble and understand the scientific information available on observed and projected climate impacts which pose a risk to their respective countries.

The UK has a wealth of information on national level impacts, including UK climate projections, extensive academic research, and the CCRA process which assesses the uncertainty and magnitude of the climate risks. However, there are still limitations to conducting the assessment in this way, as discussed in Section 3.4. For example, in the assessment of different climate risks there are still knowledge gaps which are often filled by expert assessment and consultation with key stakeholders. However, many of these knowledge gaps persist because they involve issues that cut across different funding bodies, require integrated models, or need data and tools that are difficult to obtain. In many instances the evidence required for the CCRA would best be delivered by a more coordinated approach to modelling climate risks at a national scale. Climate risk analysis inevitably requires modelling, because it deals with future scenarios of climatic and socio-economic changes. High spatial resolution is required for all of the UK, because climate risks depend on local conditions, but interact over a range of scales.

Russia has plenty of information about climate change and its observed and projected impacts in the permafrost zone, but few assessments of the particular magnitude and urgency. This gap is a serious problem for presenting the climate information to the policy-makers and stakeholders and can be filled via collaborative work of scientists, private sector specialists and stakeholders. This project has provided a good opportunity to collaborate with relevant specialists, identify knowledge gaps, and provide an overall assessment of the magnitude of impacts in the permafrost zone.

The projections of climate impacts in Russia need to be further improved in order to have more robust information for decision-making.

Engaging with policy-makers

Once the assessment of national level impacts is complete (or at least partially complete), there is the challenge of engaging with policy-makers in order to prompt action to address impacts and encourage adaptation planning.

In the UK, there is a set process whereby the UK CCRA Evidence Report is delivered to the UK Government so that it can then be used to inform the update to the National Adaptation Programme. Although this provides a clear legal link between the scientific community and the policy-makers, the process of establishing how this communication is best achieved is evolving over time. For example, the first CCRA in 2012 provided evidence on the magnitude and confidence for different risks and opportunities, but policy makers then found it difficult to understand what actions were needed as a result, as current adaptation efforts had not been taken into account. For CCRA2, a more directive product was created that took current adaptation into account and described each risk or opportunity by the urgency with which further action was needed, as well as the type of response required (more action needed, research priority, sustain current action or watching brief).

For the recent CCRA2 Evidence Report, a series of products that were tailored to different audiences were produced to inform the UK Government and help make the information in the report more understandable to non-technical audiences. The table below illustrates those products for the CCRA2 Evidence Report.

Table 4-1: CCRA2 Evidence Report products (Committee on Climate Change, 2016)

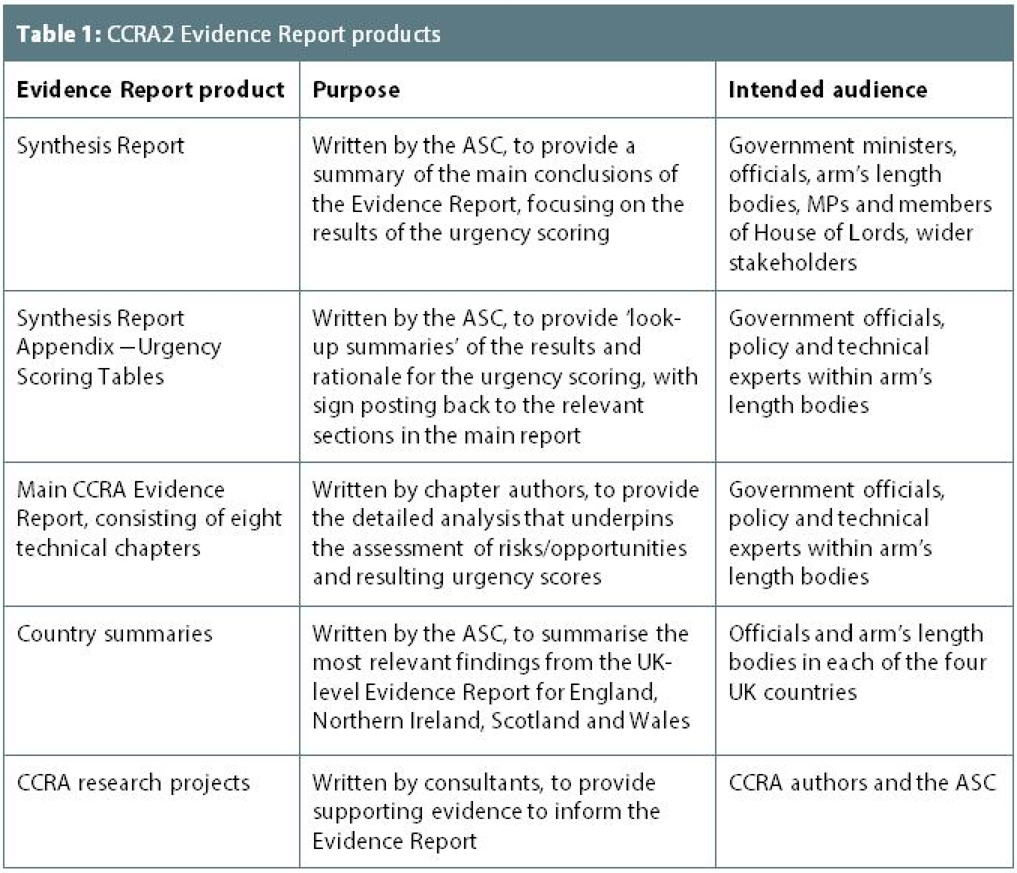

Table 1: CCRA2 Evidence Report products

Evidence Report product	Purpose	Intended audience
Synthesis Report	Written by the ASC, to provide a summary of the main conclusions of the Evidence Report, focusing on the results of the urgency scoring	Government ministers, officials, arm's length bodies, MPs and members of House of Lords, wider stakeholders
Synthesis Report Appendix – Urgency Scoring Tables	Written by the ASC, to provide 'look-up summaries' of the results and rationale for the urgency scoring, with sign posting back to the relevant sections in the main report	Government officials, policy and technical experts within arm's length bodies
Main CCRA Evidence Report, consisting of eight technical chapters	Written by chapter authors, to provide the detailed analysis that underpins the assessment of risks/opportunities and resulting urgency scores	Government officials, policy and technical experts within arm's length bodies
Country summaries	Written by the ASC, to summarise the most relevant findings from the UK-level Evidence Report for England, Northern Ireland, Scotland and Wales	Officials and arm's length bodies in each of the four UK countries
CCRA research projects	Written by consultants, to provide supporting evidence to inform the Evidence Report	CCRA authors and the ASC

Russian national assessment reports are disseminated amongst advisors to the governmental officials, members of relevant divisions of the Russian Academy of Sciences, and regional authorities. It is a main source for consultancy in the field of climate change and its impacts. The first

"Assessment Report on Climate Change and Its Consequences in the Russian Federation" (2008) served as a basis for the development of the Climatic Doctrine of the Russian Federation. The "Second Roshydromet Assessment Report on Climate Change and Its Consequences in the Russian Federation" (2014) will serve as a source of information for the development of national adaptation strategy in accordance to the Paris Agreement. Both documents are widely used for the production of other climate related national documents, for example the National Communications to the Conference of the Parties to the United Nations Framework Convention on Climate Change (submitted to the UNFCCC Secretariat every four years).

Adaptation planning

And finally, once researchers have information on climate impacts and have buy-in from the policy-makers, there is the challenge of ensuring this information feeds into adaptation planning. There is also the question of how to engage with businesses and the public in order to encourage behaviour change.

In the UK, the CCRA 2017 approach and its outputs were designed to provide evidence to inform the development of the UK Government's national adaptation programme (UK NAP) and the programmes of the devolved administrations. In particular, this was highlighted through the use of urgency categories to present the results.

The CCRA2 provides consistent evidence across sectors and regions in a format that enables the UK Government and devolved administrations to respond more easily. It should be emphasised that the CCRA2 does not extend to identifying specific adaptation options, rather it aims to indicate where action is needed most urgently over the next five-year period (i.e. the next policy cycle) of the next round of national adaptation programmes (2018 - 2022). The approach supports adaptation decision-making in the near term in addition to long term risks by highlighting where early interventions are needed to address risks that will have impacts over different timescales - the short, medium and long term. The approach uses a mix of different types of adaptation actions for different timescales, across three types of measures (as described by Ranger et al., 2010; Watkiss and Hunt, 2011; Fankhauser et al., 2013).

The Second Roshydromet Assessment Report on Climate Change and its Consequences in the Russian Federation provides recommendations on adaptation planning for many sectors in many regions, including those in the permafrost zone. The process and link between these recommendations from scientists to the adaptation actions is still to be developed.

4.1 Conclusions and Next Steps

This project has provided an excellent opportunity for the UK and Russia to build on the work begun during the CLICC pilot phase and continue to develop their national level assessments of climate impacts. In particular, this work has provided useful insight on the national level impacts of climate change on permafrost zones in Russia, a topic which has critical importance for a number of sectors and regions of Russia.

This project has also highlighted the challenges of bringing together scientists and policy-makers to discuss and understand the impacts of climate change. The project team recognises the importance of communicating climate impacts in such a way that it is accessible and relevant to a variety of audiences, including scientists, business, the public, policy-makers, and the international community. The project outputs are designed to provide useful summaries to all of these audiences including technical reports, templates, executive summaries, articles and press releases.. In particular, the assessments from this project have been conducted according to the CLICC methodology, providing summaries of climate impacts in Russia and the UK in harmonised formats which could be compared with those from other countries.

The following conclusions have been highlighted throughout the course of the project:

- The project team recognises the importance of continuing to share experiences and work together to develop consistent and transparent methodologies for assessing and communicating national level climate impacts. This collaboration between British and Russian scientists has provided useful insight to the methodologies used to assess climate impacts in both countries and will provide lessons learned to the ongoing CLICC initiative.
- Further research is needed in both countries to assess the magnitude of climate impacts in additional sectors. The impacts of climate change on the health sector proves to be a challenging topic in both countries where there are still a number of knowledge gaps and uncertainties.
- In Russia, further research is needed to develop climate projections and expand the body of work on understanding future climate impacts. Although progress has been made in recent years on evaluating climate models in permafrost zones, confidence ratings of projected climate impacts in this area remain low due to the need for further modelling work and projections.
- The use of conclusions from assessment reports by policy-makers in Russia remains challenging due to the technical language of the reports. This project has highlighted the importance of making outputs accessible to policy-makers through the use of simplified policy-relevant formulations and has worked to produce summaries of the project research which are useful to policy-makers.
- This project has begun the process of making information on climate change more accessible to the public in Russia, but there is further work to do. Future projects should build on this and continue to provide clear, robust information which can be communicated to the public in an appealing and engaging way.

Next Steps

The project culminated in a **final project workshop**, which was held on the 1st March at the British Ambassador's Residence in Moscow. This event brought together scientists, policy-makers, and representatives from private sector organisations who are interested in climate impacts on permafrost.

Figure 4-1: Final Project Workshop participants

Workshop participants highlighted the following recommendations and suggestions for future work on climate impact assessments in Russia:

- Greater focus on social impact assessment which take into account the social vulnerability of the population of Russia to climate change;
- Make an assessment on regional and local scale as well as national scale;
- Take into consideration different scenarios of climate change (including alternative scenarios of cooling);
- Improve the presentation of assessments of climate impacts by considering accessibility, not only for decision-makers but also for the general public and the business community;
- On the basis of the obtained results and future work, develop proposals for the development of new regulations for changing climatic conditions on the territory of Russia;
- Make the project results available to the organisations developing the Russian national adaptation plan;
- Inform the mass-media about the project results and improve the overall cooperation with mass-media in the future work.

Following the completion of this project, the project team hopes to continue to **develop national level assessments of climate impacts through additional bilateral projects** between the UK and Russia. The project team members have built an excellent working relationship and hope to continue to expand this area of collaboration and research through future projects. In particular, future work could address key gaps in knowledge and assessment systems, such as climate change - human health interactions and presenting information on climate impacts on human health and associated risks in a standardised format. Such work would facilitate engagement between Roshydromet and the agencies responsible for developing adaptation measures and plans in the human health sector in order to more effectively exchange information for better preparedness to cope with the consequences of climate change.

And finally, the project outputs and lessons learned are important to **feed back into the ongoing CLICC initiative** as they will:

- assist the CLICC initiative to regain momentum since the transition from UK Government to UNEP
- feed into the second round of CLICC country pilots that are planned for 2017
- be available to other countries and international bodies via the UNEP CLICC website
- demonstrate that Russia and the UK continue to engage with the CLICC initiative and to play a leading role in developing a standard format for communicating the country level impacts of climate change.

References

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Hatleberg, E.B. (2012). Human-Environmental Change in the Russian Arctic: An Integrative Perspective. Ms. Thesis, The Faculty of Columbian College of Arts and Sciences of the George Washington University, Washington DC, USA. 85 pp.

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Second Roshydromet Assessment Report on Climate Changes and Its Consequences in Russian Federation, General Summary (2014). Moscow, Roshydromet. 55 pp.

Appendices

Appendix 1: Metadata and data quality assessment tables to the CLICC template for terrestrial permafrost in Russian Federation

Appendix 2: Metadata and data quality assessment tables to the CLICC template for flooding in the United Kingdom

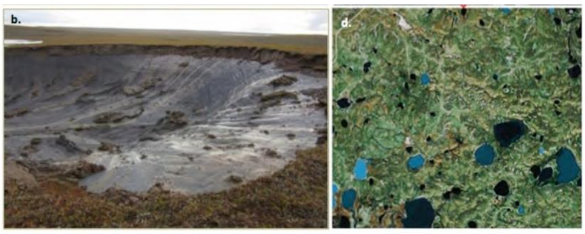
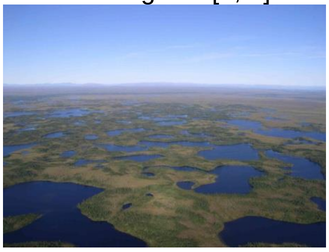
Appendix 1 - **Metadata and data quality assessment tables to the CLICC template for terrestrial permafrost in Russian Federation.**

Metadata	
Metadata identifier	**1.1**
Impact	Intensification of coastal erosion along the Arctic coast due to increase in sea water temperature and wave action and decrease in sea ice extent
Explanation for *Impact* rating (The impact rating is based on expert judgement, in the right column the examples for specific years and periods are presented)	**<u>High</u>:** • Every year about 30 km^2 of land along the Russian Arctic coast are flashed to the water due to erosion [1]. Thus, for 30 years about 900 km^2. The rate of coastal erosion in Russia is higher than in Greenland, Canada and Alaska [2]. • Coastal erosion is already affecting the settlements, geodesic and navigational infrastructure, such as the fuel tanks and light houses [1]. Particular concerns are associated with the damage and loss of isotopic thermo-electric elements that are used to power the light houses. Several such units have been flashed to the sea due to coastal erosion [1].
Explanation for *Confidence* rating (Explanation of the confidence rating given and how it relates to the specific information in question)	**<u>Medium:</u>** Multiple sources of high-quality independent observations of coastal retreat in different regions of Russian Arctic based on reliable analysis of long-term rows, with widespread agreement between studies and experts; some evidences of coastal retreat influence on the infrastructure.
Climate projections, emissions scenarios, or models used (if relevant)	N/A
Source(s) (e.g., document, study, report, etc.)	1. Anisimov OA (ed.), 2010. Environmental and socio-economical impacts of climate change in permafrost regions: predictive assessment based on synthesis of observations and modeling, Greenpeace, Moscow, p. 39. 2. Lantuit, H., Overduin, P.P., Couture, N., Wetterich, S., Are´, F., Atkinson, D., Brown, J.,Cherkashov, G., Drozdov, D., Forbes, D.L., 2012. The Arctic Coastal Dynamics database: A new classification scheme and statistics on Arctic permafrost coastlines. Estuaries Coasts 35 (2), 383-400.
Datasets (if applicable)	Satellite data and field monitoring of the rate of coastal

	retreat
Additional assumptions (if applicable and not covered by common ratings approach)	N/A
Additional limitations (if applicable and not covered by common ratings approach)	Besides climatic, permafrost, and sea ice changes, coastal erosion is governed by anthropogenic and technogenic factors, e.g., industrial activity [1].

Data quality assessment		
Data quality assessment		
Dataset:	**Satellite data and field monitoring of the rate of coastal retreat**	
Data Quality Criteria	**Levels**	**Score**
1. Transparency and auditability	**1. Data unavailable to public**	
	2. Limited summary data available	**2**
	3. Full raw/primary data set and metadata available	
2. Verification	**1. Unverified data**	
	2. Limited verification checks in place	
	3. Detailed verification in place and documented	**3**
3. Frequency of updates	**1. Sporadic**	
	2. Every 3-5 years	
	3. Annual or biennial	**3**
4. Security	**1. Future data collection discontinued**	
	2. Future data collection uncertain	
	3. Future data collection secure	**3**
5. Spatial coverage	**1. Partial national coverage**	
	2. National coverage, some bias	**2**
	3. Full national coverage, including adjacent marine areas, if and where appropriate	
	TOTAL	**13**
Total scores should be rated as follows: 5 to 8 (Low); 9 to 12 (Medium); 13 to 15 (High)		**High**

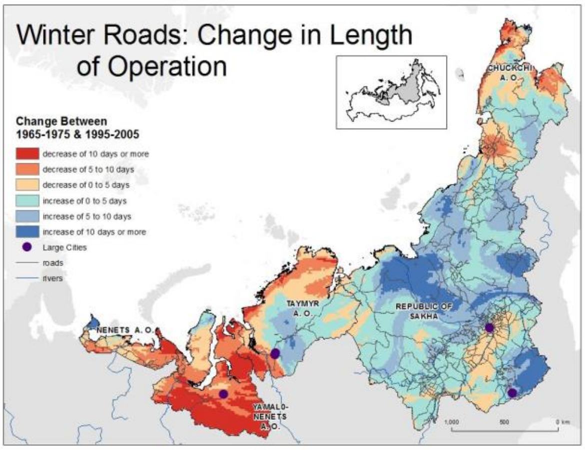
Metadata	
Metadata identifier	**1.2**
Impact	Intensification of landslides and thermokarst processes in the permafrost zone

Explanation for *Impact* rating (The impact rating is based on expert judgement, in the right column the examples for specific years and periods are presented)	**<u>Low</u>:** • The activation of landslides is controlled by increasing atmospheric precipitation and by changes in summer air temperature. The landslides create highly dissected landscapes typical of the central Yamal region (Fig. 1) and present hazards to gas development and other land uses in this region [1].  *Figure 1. Landslides of the Central Yamal Peninsula* • The landslide processes have major ecosystem consequences. These processes cause desalinisation of the underlying marine sediments, which enriches the active layer with salts and triggers unique vegetation successional processes, eventually leading to colonisation of landslide surfaces by extensive willow plant communities, which present additional obstacles for reindeer moving through the landscapes [1]. • Thermokarst lake dynamics (fig. 2) is an indicator of climate change in the Arctic. Satellite data indicates that such processes are currently taking place in Russian permafrost regions [2, 3].  *Figure 2. Thermokarst lake, Yamal Peninsula.* • Increases and decreases in lake area as a response to climate change are of a regional character [4] and are linked to environmental and local climate controls. In general, there is an increase in the number and area of thermokarst lakes in continuous permafrost zone and a reduction in the number and area of lakes in discontinuous and sporadic permafrost zones.
Explanation for *Confidence* rating (Explanation of the confidence rating given and how it relates to the specific information in question)	**<u>Medium:</u>** Several sources of independent observations of landslides and thermokarst dynamics in some regions of Russian permafrost zone

Climate projections, emissions scenarios, or models used (if relevant)	N/A
Source(s) (e.g., document, study, report, etc.)	1. Walker, D. A., J.L. Peirce (eds.), 2015. Rapid Arctic Transitions due to Infrastructure and Climate (RATIC): A contribution to ICARP III. Alaska Geobotany Center Publication AGC 15-02. University of Alaska Fairbanks, Fairbanks, Alaska, 58 pp. 2. Biskaborn, B.K., U. Herzschuh, D.Y. Bolshiyanov, G. Schwamborn and B. Diekmann, 2013. Thermokarst Processes and Depositional Events in a Tundra Lake, Northeastern Siberia. Permafrost and Periglacial Processes, 24: 160–174. doi:10.1002/ppp.1769. 3. Bryksina, N.A. and Kirpotin S.N., 2012. Landscape-space analysis of change of thermokarst lakes areas and number in the permafrost zone of West Siberia [in Russian]. Tomsk State University Journal of Biology, 4: 185-194. 4. Kravtsova, V.I. and A.G. Bystrova, 2009. Changes in thermokarst lake size in different regions of Russia for the last 30 years [in Russian]. Earth Cryosphere, XIII, 2: 16-26.
Datasets (if applicable)	Landslides and thermokarst processes observations
Additional assumptions (if applicable and not covered by common ratings approach)	N/A
Additional limitations (if applicable and not covered by common ratings approach)	N/A

Data quality assessment		
	Data quality assessment	
Dataset:	**Landslides and thermokarst processes observations**	
Data Quality Criteria	**Levels**	**Score**
1. Transparency and auditability	**1. Data unavailable to public**	
	2. Limited summary data available	**2**
	3. Full raw/primary data set and metadata available	
2. Verification	**1. Unverified data**	
	2. Limited verification checks in place	**2**
	3. Detailed verification in place and documented	
3. Frequency of updates	**1. Sporadic**	
	2. Every 3-5 years	
	3. Annual or biennial	**3**
4. Security	**1. Future data collection discontinued**	
	2. Future data collection uncertain	
	3. Future data collection secure	**3**

5. Spatial coverage	**1. Partial national coverage**	
	2. National coverage, some bias	**2**
	3. Full national coverage, including adjacent marine areas, if and where appropriate	
	TOTAL	**12**
Total scores should be rated as follows: 5 to 8 (Low); 9 to 12 (Medium); 13 to 15 (High)		**Medium**

Metadata	
Metadata identifier	**1.3**
Impact	Destruction of transport infrastructure in the permafrost zone
Explanation for *Impact* rating (The impact rating is based on expert judgement, in the right column the examples for specific years and periods are presented)	**High**: *Ice-roads* In the absence of a well-developed network of all-season roads, winter ice roads are particularly important in permafrost regions to keep connections with the mainland. The duration of the winter road operational period depends on winter temperature and snow fall, which have changed significantly and unevenly in the Russian North since the 1960s [1]. While in Yakutia and selected regions in Central Siberia the operational period of the winter roads has increased on average by several days [1], in most 13 industrialised areas of West Siberia, including the oil and gas extracting provinces on Yamal, it has dropped by more than 10 days (fig. 3). Unlike the case with Alaska and Northern Canada, Russia does not have a developed network of local airlines effectively serving routes in the High North.  *Figure 3. Changes in the duration of the winter road operational period between 1970s and 2000s [1].* The social consequences of the changes in the duration of the winter road operational period could be evaluated by the number of settlements and people in the affected

	regions. Of the total settlements, 47% experienced some degree of decrease in days of winter road operability. However, these settlements accounted for 987,600 people, or 74% of the total population of Russian permafrost regions [2]. The largest decreases in potential length of winter road operability occurred in northern Chuckchi AO, southern Yamalo-Nenets AO, and eastern Nenets AO where some settlements saw winter road operability decrease by 4%, equating to decreases between 10 and 15 days from the 1970 time period to the 2000 time period. *<u>Roads and railways</u>* The investigation of the 19 km auto roads (fig. 4) and 15 km of railways in Norilsk region shown that every 3 km they have deformations that are dangerous for traffic safety [3].  *Figure 4. Deformation in the road Norilsk-Talnah, 2010 [3].* The investigation of 54 km of Ulak-Elga railway section (Amur region-Yakutia) shown the significant deformations due to thawing permafrost, which led to the emergency conditions of the railway [4].  *Figure 5. Wave-like deformations of the Ulak-Elga railway section [4].* The total length of the ground subsidence sections of railways in permafrost region is about 800 km. Among them 75% - at Far Eastern Railway, 13% - at East Siberian Railway, 6% - Northern Railway, 4% - Trans-Baikal Railway, 1% - Sverdlovsk Railway [5]. In 1998 about 48% of the Baikal-Amur Mainline Railway embankment was exposed by deformations due to thawing [6].
Explanation for *Confidence*	**<u>High:</u>** large amount of evidence based on observations of the transport infrastructure state in different parts of

rating (Explanation of the confidence rating given and how it relates to the specific information in question)	Russian permafrost zone with widespread agreement between studies and experts
Climate projections, emissions scenarios, or models used (if relevant)	N/A
Source(s) (e.g., document, study, report, etc.)	1. Anisimov O.A., Streletskiy D.A., 2015. Geotechnical risks from thawing permafrost. Arctic 21st century: 60-74. 2. Hatleberg, E.B., 2012. Human-Environmental Change in the Russian Arctic: An Integrative Perspective. Ms. Thesis, The Faculty of Columbian College of Arts and Sciences of the George Washington University, Washington DC, USA. 85 p. 3. V.I. Grebenets, V.A. Isakov, 2016. Deformations of roads and railways within the Norilsk-Talnakh transportation corridor and the stabilisation methods. Earth Cryosphere. Vol. XX, № 2, p. 69-77. 4. Isakov V.A., Naumov M.S., Telkov F.S., 2013. Obsledovanie gruntov osnovanija na napravlenii Ulak–Jel'ga [Investigation of railway Ulak-Jel'ga ground basement], Put' i putevoe hozjajstvo, no 4, pp. 28–31 (in Russian). 5. Resources and Risks of Permafrost Areas in a Changing World, volume 5. Proceedings of the Tenth International Conference on Permafrost Salekhard, Yamal-Nenets Autonomous District, Russia, June 25–29, 2012. «Pechatnik», Tyumen, 2012 (Extended Abstracts in Russian). 6. Second assessment report on climate change and its consequences in Russian Federation / Bedritsky A.I. et al. Moscow, Roshydromet, 2014.
Datasets (if applicable)	Transport infrastructure in permafrost zone
Additional assumptions (if applicable and not covered by common ratings approach)	N/A
Additional limitations (if applicable and not covered by common ratings approach)	N/A

Data quality assessment		
Data quality assessment		
Dataset:	Transport infrastructure in permafrost zone	
Data Quality Criteria	Levels	Score
1. Transparency and auditability	1. Data unavailable to public	1
	2. Limited summary data available	
	3. Full raw/primary data set and metadata available	
2. Verification	1. Unverified data	
	2. Limited verification checks in place	2
	3. Detailed verification in place and documented	
3. Frequency of updates	1. Sporadic	
	2. Every 3-5 years	
	3. Annual or biennial	3
4. Security	1. Future data collection discontinued	
	2. Future data collection uncertain	
	3. Future data collection secure	3
5. Spatial coverage	1. Partial national coverage	
	2. National coverage, some bias	2
	3. Full national coverage, including adjacent marine areas, if and where appropriate	
	TOTAL	11
Total scores should be rated as follows: 5 to 8 (Low); 9 to 12 (Medium); 13 to 15 (High)		Medium

Metadata	
Metadata identifier	**1.4**
Impact	Destruction of oil and gas pipelines in the permafrost zone
Explanation for *Impact* rating (The impact rating is based on expert judgement, in the right column the examples for specific years and periods are presented)	**<u>Medium</u>:** - Russia has an extensive network of pipelines with a total length of about 350000 kilometers, of which more than 71000 kilometers traverse permafrost regions. Thawing permafrost leads to the deformation and damage of pipelines, exacerbates the problems of pipeline maintenance, and increases operational costs [1]. According to the survey conducted by the Earth Cryosphere Institute in Tumen, 23% of the total number of accidents in the geotechnical systems serving the needs of the extracting and transportation industries are attributed to changes of permafrost. About 55 billion rubles are spent annually to fix the mechanical deformations resulting from uneven settlement of the thawing permafrost [1]. - It is very likely that thermokarst settlements of the ground were one of the causes of the accident on the Vosey - Head Facilities (Golovnye soorugenia) Pipeline located in the Komi Republic in 1994 [2]. This was the heaviest onshore pipeline accident in the world. As a result of up to 6 pipe bursts, more than 160,000 tons of oil containing liquid spilled out. Monitoring studies of an experimental non-operational 45 km long overground pipeline performed by the PechorNIPIneft Institute have shown that even seasonal thermokarst settlement of the ground causes multiple emergency situations. - According to [3] only 3% of all the accidents with pipelines can be associated with cryogenic processes, thus with thawing permafrost.
Explanation for *Confidence* rating (Explanation of the confidence rating given and how it relates to the specific information in question)	**<u>Medium:</u>** Several sources of independent observations of the permafrost degradation effect on the pipelines destruction in Russian permafrost zone
Climate projections, emissions scenarios, or models used (if relevant)	N/A
Source(s) (e.g., document, study, report, etc.)	1. Anisimov OA (ed.), 2010. Environmental and Socio-economical impacts of climate change in permafrost regions: predictive assessment based on synthesis of observations and modeling, Greenpeace, Moscow, p. 39. 2. Oberman N.G., 2007. Global warming and changes in the permafrost zone of the Pechora-Urals region Razvedka i Ohrana Nedr, 4: 63-68 (in Russian).

	3. N.V. Chuhareva, S.A. Mironov, T.V. Tikhonova, 2012. Prediction of accidents and damage to gas pipelines in Far North conditions. Neftegazovoe delo, № 3, p. 99-107 (in Russian).
Datasets (if applicable)	N/A
Additional assumptions (if applicable and not covered by common ratings approach)	N/A
Additional limitations (if applicable and not covered by common ratings approach)	N/A

Metadata	
Metadata identifier	**1.5**
Impact	Destruction of buildings in Russian the permafrost zone
Explanation for *Impact* rating (The impact rating is based on expert judgement, in the right column the examples for specific years and periods are presented)	<u>**High**</u>: - Most of the buildings in Russian permafrost zone were built in the 1960s and 1970s, and the effect of climate change had not been incorporated into their design [1]. According to expert estimates, about a quarter of deformations of buildings (see fig. 7) and constructions in permafrost zone of Russia may be due to the fact that climate change has exceeded the stability limits calculated during the construction. Buildings frequently become problematic after 6-10 years of operation, despite a stated lifetime of 50 years [1]. - According to a survey of structures were affected by deformations due to thawing permafrost about 10 % of buildings in Norilsk, 22 % in Tiksi, 55 % in Dudinka, 35 % in Dikson, 50 % in Pevek and Amderma, 60 % in Chita, and 80 % in Vorkuta [2]. - The mean percent change in bearing capacity between the 1970 and 2000 time periods across the Russian permafrost regions has decreased slightly, by 7% [3]. The greatest decreases in bearing capacity occurred in southern Yamalo-Nenets AO and north and east Chuckchi AO [3] (fig. 6). - The social impact of buildings destruction can be assessed by the amount of population of these cities (see table 1) [4]. The moderate category, defined as decreases between 5% and 10%, contained the most settlements, 33 settlements, and the largest population, at 653100 people. Combined, the most troubling categories, catastrophic and severe, accounted for 28 settlements and 375400 people. The stable classification accounted for 22 settlements, which accounted for the smallest amount of people, 90300.

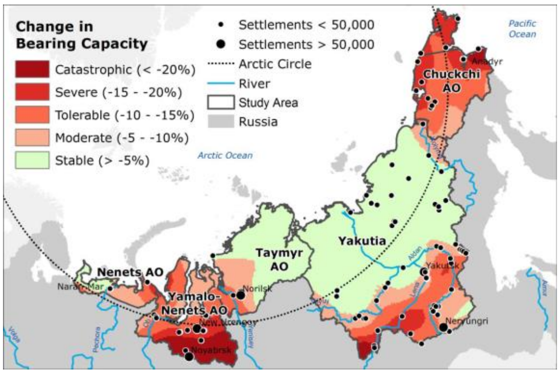
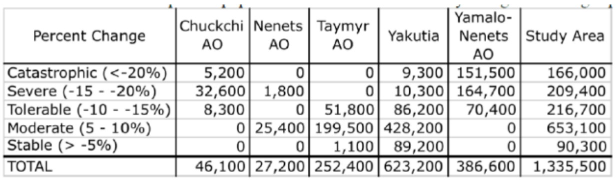


Figure 6. Changes in permafrost bearing capacity between the 1970s and 2000s [3].

Table 1. Distribution of present population for urban settlements by change in bearing capacity.



Percent Change	Chuckchi AO	Nenets AO	Taymyr AO	Yakutia	Yamalo-Nenets AO	Study Area
Catastrophic (<-20%)	5,200	0	0	9,300	151,500	166,000
Severe (-15 - -20%)	32,600	1,800	0	10,300	164,700	209,400
Tolerable (-10 - -15%)	8,300	0	51,800	86,200	70,400	216,700
Moderate (5 - 10%)	0	25,400	199,500	428,200	0	653,100
Stable (> -5%)	0	0	1,100	89,200	0	90,300
TOTAL	46,100	27,200	252,400	623,200	386,600	1,335,500


a) b)

Figure 7. Deformation of buildings in permafrost zone: a) Yakutsk, 1999[1, 5]; b) Chersky village [1].

Explanation for *Confidence* rating (Explanation of the confidence rating given and how it relates to the specific information in question)	**<u>Medium:</u>** A lot of observations of buildings' destructions in different regions of Russian permafrost zone but a few evidences of the influence of warming permafrost
Climate projections, emissions scenarios, or models used (if relevant)	N/A
Source(s) (e.g., document, study, report, etc.)	1. Anisimov O.A. (ed.), 2010. Environmental and Socio-economical impacts of climate change in permafrost regions: predictive assessment based on synthesis of observations and modeling, Greenpeace, Moscow. 2. Streletskiy, D.A., Shiklomanov, N.I., Grebenetz V.A., 2012. Climate Warming-induced Changes in Bearing

	Capacity of Permafrost in the North of West Siberia, Earth Cryosphere, XVI (1): 22-32 (in Russian). 3. Streletskiy, D.A., Shiklomanov, N.I., Hatleberg E., 2012. Infrastructure and a Changing Climate in the Russian Arctic: A geographic Impact Assessment, Proceedings of the 10th International Conference on Permafrost, K.M. Hinkel Editor, The Northern Publisher, Salekhard, Russia, Vol. 1, 407-414. 4. Anisimov OA, Streletskiy DA, 2015. Geotechnical risks from thawing permafrost. Arctic 21st century: 60-74. 5. Alekseeva O.I., V.T. Balobaev, M.N. Grigoryev, V.N. Makarov, R.V. Chzhan, M.M. Shats, V.V. Shepelev, 2007. On issues around construction in the permafrost zone (with the example of Yakutsk)' Kriosfera Zemli 2: 76-83 (in Russian).
Datasets (if applicable)	Buildings in the permafrost zone
Additional assumptions (if applicable and not covered by common ratings approach)	N/A
Additional limitations (if applicable and not covered by common ratings approach)	Anthropogenic and technogenic activity can cause destructive processes resulting in damages to constructions built on permafrost independently of a changing climate. However, the influence of these processes is strengthened by climate change [1] A lot of non-climatic factors, including errors in design of basements, the salting and mineralisation of soils due to effluent leaks, and lack of shower canalisation network cause degradation of the frozen basements and foundations of buildings and constructions, while climatic warming is merely intensifying these processes [1].

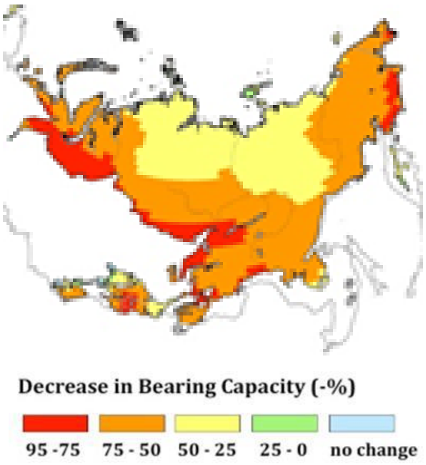
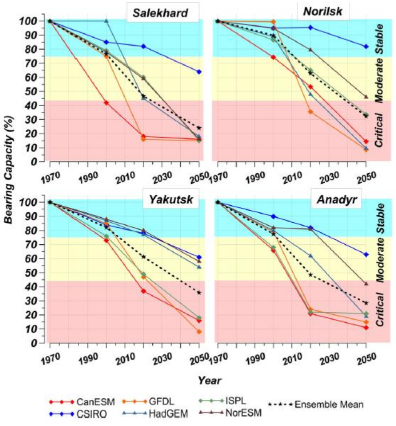
Data quality assessment		
Data quality assessment		
Dataset:	**Buildings in the Russian permafrost zone**	
Data Quality Criteria	**Levels**	**Score**
1. Transparency and auditability	**1. Data unavailable to public**	
	2. Limited summary data available	**2**
	3. Full raw/primary data set and metadata available	
2. Verification	**1. Unverified data**	
	2. Limited verification checks in place	**2**
	3. Detailed verification in place and documented	
3. Frequency of updates	**1. Sporadic**	
	2. Every 3-5 years	

	3. Annual or biennial	**3**
4. Security	**1. Future data collection discontinued**	
	2. Future data collection uncertain	
	3. Future data collection secure	**3**
5. Spatial coverage	**1. Partial national coverage**	
	2. National coverage, some bias	**2**
	3. Full national coverage, including adjacent marine areas, if and where appropriate	
	TOTAL	**12**
Total scores should be rated as follows: 5 to 8 (Low); 9 to 12 (Medium); 13 to 15 (High)		**Medium**

Metadata	
Metadata identifier	**2.1**
Impact	Intensification of coastal erosion along the Arctic coast
Explanation for *Impact* rating (The impact rating is based on expert judgement, in the right column the examples for specific years and periods are presented)	**Low**: It is expected that the warming climate and decrease in ice area observed in the Arctic regions will lead to more stormy conditions and an acceleration of coastal retreat [1] The rate of coastal retreat on the Western Yamal coast will not change until the end of XXI century. The maximum rate will be at about 2040th up to 15 m/year [2].
Explanation for *Confidence* rating (Explanation of the confidence rating given and how it relates to the specific information in question)	**Low:** Several sources of modeling results in some regions of Russian Arctic coast
Climate projections, emissions scenarios, or models used (if relevant)	-
Source(s) (e.g., document, study, report, etc.)	1. Anisimov O.A. (ed.), 2010. Environmental and Socio-economical impacts of climate change in permafrost regions: predictive assessment based on synthesis of observations and modeling, Greenpeace, Moscow. 2. Second assessment report on climate change and its consequences in Russian Federation / Bedritsky A.I. et al. Moscow, Roshydromet, 2014.
Datasets (if applicable)	N/A
Additional assumptions (if applicable and not covered by common ratings approach)	N/A
Additional limitations (if applicable and not covered by common ratings approach)	N/A

Metadata	
Metadata identifier	**2.2**
Impact	Destruction of transport infrastructure in the permafrost zone
Explanation for *Impact* rating (The impact rating is based on expert judgement, in the right column the examples for specific years and periods are presented)	**High:** *Ice-roads* By the mid-21st century the accessibility of remote settlements currently served by winter roads will fall on average by 13 percent, and the area, where winter road operations remain economically feasible, will reduce by 1 million km^2 [1] (about 6% of total area of Russian Federation).
Explanation for *Confidence* rating (Explanation of the confidence rating given and how it relates to the specific information in question)	**Low:** A few sources of modeling results in some regions of Russian permafrost zone
Climate projections, emissions scenarios, or models used (if relevant)	The Arctic Transport Accessibility Model [1]
Source(s) (e.g., document, study, report, etc.)	1. Stephenson SR, Smith LC, Agnew JA, 2011. Divergent long-term trajectories of human access to the Arctic. Nature Climate Change 1:156-160.
Datasets (if applicable)	N/A
Additional assumptions (if applicable and not covered by common ratings approach)	N/A
Additional limitations (if applicable and not covered by common ratings approach)	N/A

Metadata	
Metadata identifier	**2.3**
Impact	Destruction of buildings in the permafrost zone
Explanation for *Impact* rating (The impact rating is based on expert judgement, in the right column the examples for specific years and periods are presented)	**High:** The model-based projection of the permafrost bearing capacity under the changing climatic conditions for the mid-21st century is presented on figure 8. It is shown that by mid-21st century bearing capacity will decrease by 50%-95% in the southernmost permafrost zone and by 25%-50% elsewhere in Russian permafrost regions [1].

	 *Figure 8. Mean changes in bearing capacity of the frozen ground for the Russian permafrost region from the 1965-1975 reference period for 2045-2055 years [1].* The decrease in bearing capacity for the main Russian Arctic cities is presented on figure 9. On average, the fastest changes are projected for Salekhard and Anadyr. There the bearing capacity has potential to reach critical levels by mid 2020s. In Yakutsk and Norilsk the projected climate-induced decrease in bearing capacity will exceed 55% around the 2040s [1].  *Figure 9. Bearing capacity of standard pile foundation in percentages relative to 1965-1975 reference period estimated using climates, produced by six GCMs for the model grid cells containing for Russian Cities: Salekhard, Norilsk, Yakutsk, and Anadyr. Years on Y axis represent decadal periods used for calculations. [1]*
Explanation for *Confidence* rating (Explanation of the confidence rating given and how it relates to the specific information in question)	**Low:** A few modeling calculations of reduction of the bearing capacity of buildings in Russian permafrost zone

Climate projections, emissions scenarios, or models used (if relevant)	Six CMIP5 GCM models [2]
Source(s) (e.g., document, study, report, etc.)	1. N. I. Shiklomanov, D. A. Streletskiy, T. B. Swales, V. A. Kokorev, 2016. Climate change and stability of urban infrastructure in Russian permafrost regions: prognostic assessment based on GCM climate projections, Geographical Review, 2016, 106, 1–18, doi: 10.1111/gere.12214. 2. Anisimov OA, Kokorev VA, 2013. Constructing optimal climate ensemble for evaluation of the climate change impacts on the cryosphere. Ice and Snow 121:83-92.
Datasets (if applicable)	N/A
Additional assumptions (if applicable and not covered by common ratings approach)	N/A
Additional limitations (if applicable and not covered by common ratings approach)	N/A

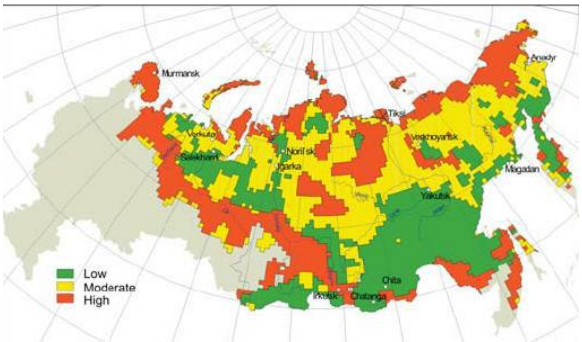
Metadata	
Metadata identifier	**2.4**
Impact	Intensification of all geocryological processes which will lead to infrastructure deformations in the permafrost zone
Explanation for *Impact* rating (The impact rating is based on expert judgement, in the right column the examples for specific years and periods are presented)	**<u>Low-High (depending on the region):</u>** The influence of climate change on the infrastructure of the permafrost zone can be assessed using a geocryological hazard index I_G [1, 2, 3], which is the combination of the projected change in active-layer thickness, ΔZ_{al}, expressed in relative units with respect to modern norm, and the volumetric ground ice content, V_{ice} [1]: $I_G = \Delta Z_{al} \cdot V_{ice}$ 

	Figure 10. Predictive permafrost hazard map for Russia. The map was constructed using the GFDL climatic scenario for 2050 [1]. Figure 10 illustrates the regional distribution of the permafrost hazard index calculated using CMIP5 climate projection for mid-21st century [1]. The southern zone of high hazard potential extends continuously from the southwestern limit of permafrost on the Kola Peninsula through Komi Republic and Tumen region to Lake Baikal. The southeastern part of the high hazard potential is near the cities of Chita, Blagoves'chensk, Komsomolsk-na-Amure, over most of the Japan seacoast, and at selected locations on Sakhalin and Kamchatka [1]. Here, high potential threats are associated with the projected thawing of sporadic permafrost, most of which may disappear in the near-surface layer by the middle of the century. Such changes are particularly detrimental to the roads, pipelines, and rail tracks traversing the permafrost islands. Uneven ground settlement due to thermokarst and soil erosion may lead to distortions of landscape and affect the engineered structures. The northern zone of high hazard potential includes the Russian Arctic coast from the Kara Sea on the west to the Chukchi Sea on the east. River terminals in Salekhard, Igarka, Dudinka, and Tiksi fall within this zone. Most of the central part of the Russian permafrost zone is the zone of moderate hazard potential, whereas large areas in southern Yakutia and in central Siberia between the Ob and Yenisey Rivers will have low susceptibility to climate-induced permafrost hazards [1].
Explanation for *Confidence* rating (Explanation of the confidence rating given and how it relates to the specific information in question)	**Low:** Modelling calculations of only two versions of hazard indexes using several climate models
Climate projections, emissions scenarios, or models used (if relevant)	‘‘median’’ GFDL climatic scenario for 2050 [1] 5 CMIP5 climate models [1]
Source(s) (e.g., document, study, report, etc.)	1. Anisimov OA, Reneva SA, 2006. Permafrost and changing climate: the Russian perspective. Ambio 35:169-175. 2. Anisimov OA, Streletskiy DA, 2015. Geotechnical risks from thawing permafrost. Arctic 21st century: 60-74. 3. Anisimov O.A. (ed.), 2010. Environmental and Socio-economical impacts of climate change in permafrost regions: predictive assessment based on synthesis of observations and modeling, Greenpeace, Moscow.
Datasets (if applicable)	N/A
Additional assumptions (if applicable and not covered by common ratings approach)	N/A

Additional limitations (if applicable and not covered by common ratings approach)	N/A

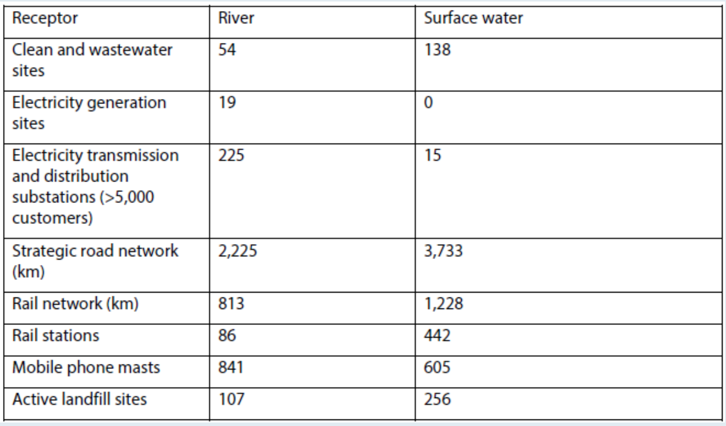
Appendix 2 - **Metadata and data quality assessment tables to the CLICC template for flooding in the United Kingdom.**

<table>
<tr><th colspan="2">Metadata</th></tr>
<tr><td>Metadata identifier</td><td>1.1</td></tr>
<tr><td>Source(s) (e.g., document, study, report, etc.)</td><td>Primary Source: UK Climate Change Risk Assessment 2017: Evidence Report. Synthesis Report Appendix: Urgency scoring tables

Other Sources:
<i>1. Warren, R., Watkiss, P., Wilby, RL., Humphrey, K., Ranger, N., Betts, R., Lowe, J., and Watts, G. (2016) UK Climate Change Risk Assessment Evidence Report: Chapter 2, Approach and Context. Report prepared for the Adaptation Sub-Committee of the Committee on Climate Change, London.</i>

2. ASC (2016) UK Climate Change Risk Assessment 2017 Synthesis Report: priorities for the next five years. Adaptation Sub-Committee of the Committee on Climate Change, London.</td></tr>
<tr><td>Explanation for <i>Impact</i> rating (Explanation of the impact rating given and how it relates to the specific information in question)</td><td>
<table>
<tr><th>Impact</th><th>Information used to determine impact rating</th></tr>
<tr><td>Observed increase in the frequency and magnitude of flooding</td><td><u>Impacts on land availability and capability due to flooding</u>
From page 23:
Over 40,000 hectares of agricultural land were inundated during the 2007 floods in England, causing an estimated £50 million of damage. The floods and storm surge in 2013/14 caused an estimated £19 million of damage to agriculture.
(Medium magnitude/medium confidence)
<u>Impacts on infrastructure services from flooding</u>
From page 52-53:
• Flooding was directly responsible for approximately 340,000 passenger delay minutes on the rail network between 2006 and 2013 (5% of all delays).
• Around 163,000 delay minutes were caused by flooding on the strategic road network between 2006 and 2014 (7% of all delays).
• The number of customer minutes lost from the high voltage electricity network from flooding between 1995 and 2011 was nearly 14,000 (1% of total).</td></tr>
</table>
</td></tr>
</table>

- Number/length of infrastructure assets and networks in the UK located in areas exposed to a 1:75 or greater annual chance of <u>flooding from rivers and/or surface water</u> (present day)

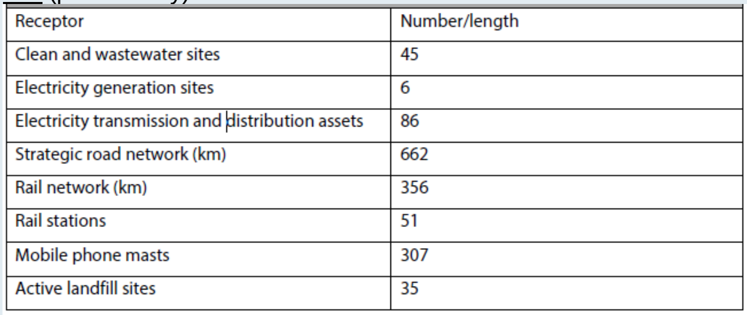


Receptor	River	Surface water
Clean and wastewater sites	54	138
Electricity generation sites	19	0
Electricity transmission and distribution substations (>5,000 customers)	225	15
Strategic road network (km)	2,225	3,733
Rail network (km)	813	1,228
Rail stations	86	442
Mobile phone masts	841	605
Active landfill sites	107	256

(High magnitude/medium confidence)

From page 56

Number/length of infrastructure assets and networks in the UK located in areas at 1:75 or greater annual chance of <u>flooding from the sea</u> (present day)



Receptor	Number/length
Clean and wastewater sites	45
Electricity generation sites	6
Electricity transmission and distribution assets	86
Strategic road network (km)	662
Rail network (km)	356
Rail stations	51
Mobile phone masts	307
Active landfill sites	35

(Medium magnitude/high confidence)

<u>Impacts on people, communities and buildings from flooding</u>

From page 95-96

England

- There are 2.3 million residential properties located in areas at any degree of risk of flooding across England, of which 690,000 (3%) are at 1:75 or greater risk. This equates to 1.4 million people at 1:75 or greater risk.
- There are 4.25 million people living in areas at any degree of risk from flooding
- The direct Expected Annual Damages (EAD) alone from flooding to residential properties is £270 million for England (high magnitude, medium confidence).

Wales:

- There are 160,000 residential properties at any degree of risk from flooding across Wales, of which 51,000 (4%) are at 1:75 or greater risk.
- This equates to 95,000 people at 1:75 or greater risk.
- Current expected annual damage to residential properties is estimated to be £22 million

(Medium magnitude, medium confidence).

Scotland:

- There are 180,000 residential properties at any degree of risk from flooding across Scotland, of which 97,000 (4%) are at 1:75 or greater risk.
- This equates to 200,000 people at 1:75 or greater risk (medium magnitude, medium confidence).
- Current expected annual damage to residential properties is estimated to be £42 million (medium magnitude, medium confidence). SEPA estimate that there are 134,000 residential properties located in areas at any degree of flood risk.

(Medium magnitude, medium confidence).

Northern Ireland:

- There are 56,000 residential properties at any degree of risk from flooding across Northern Ireland, of which 23,000 (2%) are at 1:75 or greater risk.
- This equates to 56,000 people at 1:75 or greater risk (low magnitude, medium confidence).
- Current expected annual damage to residential properties is estimated to be £8.1 million (low magnitude, medium confidence).

(Medium magnitude, medium confidence).

Impacts to health and social care delivery from floods

From page 105:

- Damage to healthcare infrastructure has been reported in recent flood events (e.g. the loss of regional blood centre in Southwest England in 2007).
- There have been incidents of hospital flooding in the 2015/16 winter floods, with impacts on non-urgent care.
- In England, there are currently 166 hospitals and 1,163 care homes that are located in areas at a 1-in-200 or greater chance of flooding in any given year (low magnitude, low confidence).
- In Wales, there are currently 10 hospitals and 45 care homes that are located in areas at a 1-in-200 chance of flooding or greater in any given year (low magnitude, low confidence).
- In Northern Ireland, no hospitals are currently located in areas at 1:200 or higher risk of flooding. There are 19 emergency service stations, 37 GP surgeries and 16 care homes that are located in areas at a 1-in-200 chance of flooding or greater in any given year (low magnitude, low confidence).
- In Scotland, between 0 -2 hospitals are located in areas at 1:200 or higher risk of flooding, and there are 84 emergency service stations, 10 GP surgeries and 53 care homes located in areas at a 1-in-200 chance of flooding or greater in any given year (low magnitude, low confidence).

Losses and damages to businesses from flooding

From page 121

- Recent analysis found the number of non-residential properties at risk of flooding (1:1000 year or less) is approximately 1.1 million.
- Of these the number at risk of significant flooding, which is defined as flooding more frequent than 1:75 (a 1 in 75 or greater chance of flooding in any given year) is 420,000.
- Based only on the direct impacts of flooding, expected annual damages to non-residential properties are £800 million

From page 128-129

<table>
<tr><td></td><td></td><td></td><td>

Coastal flooding is estimated to contribute 30% of total expected annual damages to the England, including both residential and non-residential properties.
Coastal flooding is estimated to contribute 8% of total expected annual damages to the Northern Ireland, including both residential and non-residential properties.
Coastal flooding is estimated to contribute 16% or 21% of total expected annual damages to the Scotland, including both residential and non-residential properties.
Coastal flooding is estimated to contribute to 34% of total expected annual damages from flooding to Wales for the present day, including both residential and non-residential properties.

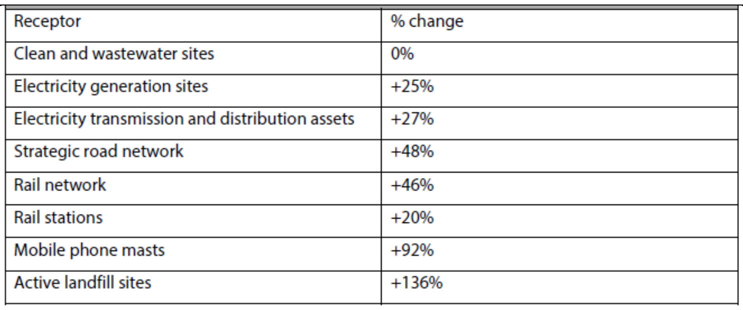
</td><td></td></tr>
<tr><td></td><td></td><td>Observation of impacts related to climate change</td><td>
Source: ASC (2016) UK Climate Change Risk Assessment 2017 Synthesis Report: priorities for the next five years. Adaptation Sub-Committee of the Committee on Climate Change, London.

Studies suggest flood events like in autumn 2000 (Pall et al., 2011), and extremely wet winters like the winter of 2013/14 (Shaller et al., 2016), have become more likely. This is consistent with the increasing moisture levels that a warmer atmosphere can hold. There is some evidence that heavily moisture-laden air currents (atmospheric rivers), linked with the flooding in England in November 2009 and December 2015, are more likely to form and can hold more moisture with climate change (Lavers et al., 2013).

</td><td></td></tr>
<tr><td></td><td></td><td>Projected reduction in land availability and capability due to flooding.</td><td>
From page 23:
Using an indicative 1 in 75 year average risk level, flooding from fluvial, coastal and pluvial sources is projected to increase from 570,000 hectares (present day) to

750,000 hectares in the context of a 2°C rise in global mean temperatures by the 2080s; and
940,000 hectares in the context of a 4°C rise

(High magnitude/medium confidence)
</td><td></td></tr>
<tr><td></td><td></td><td>Projected increase in infrastructure services affected by flooding</td><td>
From page 53
Projected change in number/length of infrastructure assets and networks in the UK located in areas exposed to a 1:75 or greater annual chance of <u>flooding from rivers and/or surface water</u> under a trajectory of a 4ºC rise in global mean temperature by the end of the century.
<table>
<tr><th>Receptor</th><th>River</th><th>Surface water</th></tr>
<tr><td>Clean and wastewater sites</td><td>+21%</td><td>+49%</td></tr>
<tr><td>Electricity generation sites</td><td>0%</td><td>0%</td></tr>
<tr><td>Electricity transmission and distribution substations (>5,000 customers)</td><td>+9%</td><td>+4%</td></tr>
<tr><td>Strategic road network</td><td>+57%</td><td>+54%</td></tr>
<tr><td>Rail network</td><td>+56%</td><td>+50%</td></tr>
<tr><td>Rail stations</td><td>+37%</td><td>+22%</td></tr>
<tr><td>Mobile phone masts</td><td>+59%</td><td>+25%</td></tr>
<tr><td>Active landfill sites</td><td>+2%</td><td>+4%</td></tr>
</table>
(High magnitude/medium confidence)
From page 57
Projected change in number/length of infrastructure assets and networks in the UK located in areas exposed to a 1:75 or greater annual chance of <u>flooding from the sea</u> under a trajectory of a 4ºC rise in global mean temperature by the end of the century.
</td><td></td></tr>
</table>



Receptor	% change
Clean and wastewater sites	0%
Electricity generation sites	+25%
Electricity transmission and distribution assets	+27%
Strategic road network	+48%
Rail network	+46%
Rail stations	+20%
Mobile phone masts	+92%
Active landfill sites	+136%

(High magnitude/medium confidence)

Projected increase in people, communities and buildings exposed to flooding

Page 96

England:

- By the 2050s the projected number of people at 1:75 or greater risk rises to around 1.7 million under a 2 degree scenario and 2.2 million for a 4 degree scenario.
- For the 2080s, the projections suggest 2 million people under a 2 degree scenario and 2.9 million people under a 4 degree scenario.
- Expected annual damage to residential properties is projected to rise by between 22 – 78% in the 2050s and 47 – 160% in the 2080s depending on climate scenario.

(High magnitude, medium confidence).

Wales:

- By the 2050s the projected number of people at 1:75 or greater risk rises to around 119,000 under a 2 degree scenario and 166,000 for a 4 degree scenario.
- For the 2080s, the projections suggest 142,000 people under a 2 degree scenario and 209,000 people under a 4 degree scenario
- Expected annual damage to residential properties is projected to rise by between 35 – 110% in the 2050s and 59 - 220% in the 2080s depending on climate scenario

(medium magnitude, medium confidence).

Scotland:

- By the 2050s the projected number of people at 1:75 or greater risk rises to around 220,000 under a 2 degree scenario and 242,000 for a 4 degree scenario.
- For the 2080s, the projections suggest 236,000 people under a 2 degree scenario and 286,000 people under a 4 degree scenario
- Expected annual damage to residential properties is projected to rise by between 43 - 99% in the 2050s and 73 - 190% in the 2080s depending on climate scenario

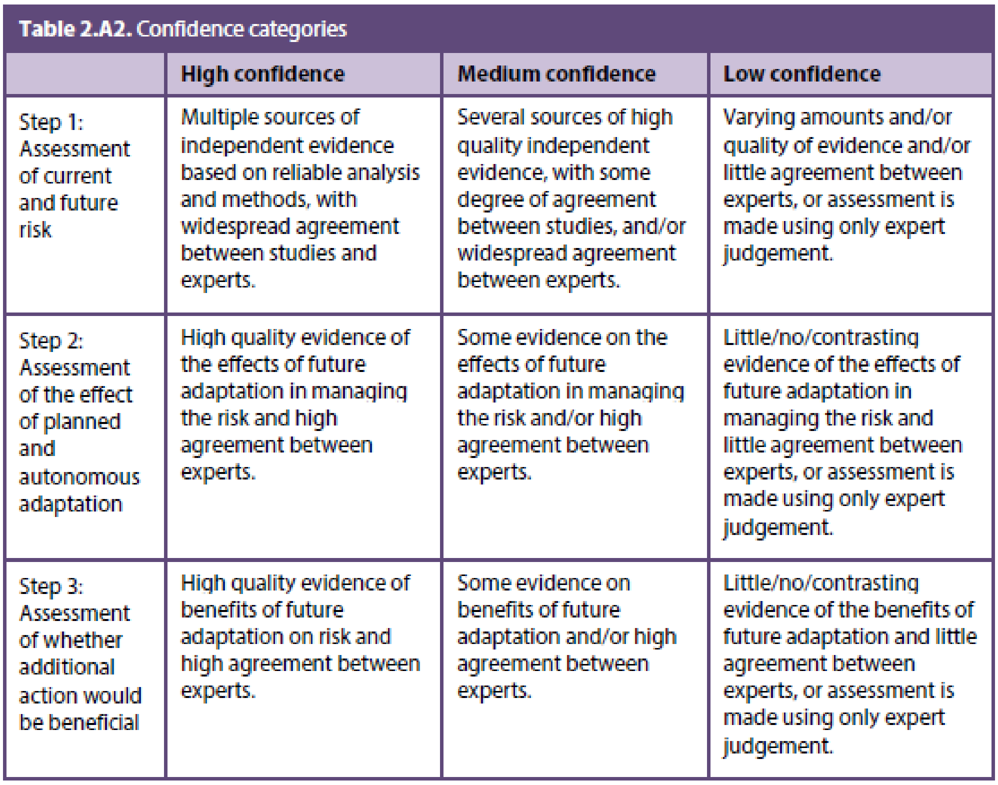
(medium magnitude, medium confidence).

Northern Ireland:

- By the 2050s the projected number of people at 1:75 or greater risk rises to around 67,000 under a 2 degree scenario and 76,000 for a 4 degree scenario.
- For the 2080s, the projections suggest 73,000 people under a 2 degree scenario and 98,000 people under a 4 degree scenario (low magnitude, medium confidence).
- Expected annual damage to residential properties is projected to rise by between 33 - 62% in the 2050s and 60 - 150% in the 2080s depending on climate scenario (medium magnitude, medium confidence).

Assumption: Assuming no population growth and a continuation of current levels of adaptation (i.e. the standard of protection provided

			by flood defences reduces in areas where the benefit cost case is weakest, but is maintained in areas with the highest standards today	
		Projected increase in health and social care delivery affected from flooding	**From page 107** Future projections indicate an increase in number of GP surgeries, care homes, emergency service stations and hospitals in the flood risk zone, with the largest change in risk generally shown for care homes (medium magnitude, low confidence). • By the 2050s under a 4 degree scenario, the number of hospitals in **England** located in areas at 1 in 200 annual chance of flooding or greater increases to 187 - 200 and the number of care homes increases to between 1,338 – 1,454. • Under a 4-degree scenario in the 2050s, the number of assets in **Northern Ireland** located in areas at 1 in 200 annual chance of flooding or greater increases to 23 - 24 for emergency service stations, 40 for GP surgeries and 18 - 19 for care homes, with no hospitals at risk. • By the 2050s under a 4 degree scenario, the numbers of hospitals in **Wales** located in areas at a 1-in-200 annual chance or greater increases to 13 - 14 and the number of care homes increases to 62 – 64. • Under a 4 degree scenario by 2050, the numbers of **Scottish** assets located in areas at 1-in-200 annual chance of flooding or greater increases to 105-107 for emergency service stations, 12-13 for GP surgeries and 64-66 for care homes.	
		Projected increase in direct and indirect losses and damages to businesses from flooding	**From page 121** By the 2050s, the number of non-residential properties in the UK at risk of significant flooding is projected to increase between 16% and 42%. Expected annual damages are projected to increase between 26% and 69%, equivalent to a £200 million to £550 million increase. [Scenario: 2°C or 4°C , not including population growth and assuming the continuation of current levels of adaptation] [High- Medium Magnitude, Medium Confidence] **Page 128-129** **England** In the future, damages from coastal flooding in England could increase by around 175% by the 2080s from a baseline of £260 million present day. [Scenario: 4°C, not including population growth and assuming a continuation of current levels of adaptation]. (High Magnitude, Low Confidence). **Northern Ireland**: In the future, damages from coastal flooding in Northern Ireland could increase by around 60% by the 2080s from a baseline of £2.2 million present day. [Scenario: 4°C, not including population growth and assuming a continuation of current levels of adaptation] (High Magnitude, Low Confidence). **Scotland** In the future, damages from coastal flooding in Scotland could increase by around 450% by the 2080s from a baseline of £26 million present day. [Scenario: 4°C, not including population growth and assuming a continuation of current levels of adaptation] (High Magnitude, Low Confidence). **Wales:** In the future, damages from coastal flooding in Wales could increase by around 300% by the 2080s from a baseline of £28 million present day. [Scenario: 4°C, not including population growth and assuming a continuation of current levels of adaptation] (High Magnitude, Low Confidence). Estimates suggest that, in the short-term (0 to 20yrs), no non-residential properties in Wales are at risk of coastal erosion. This is estimated to increase to 52 in the medium-term (20 to 50 years	

<table>
<tr><td></td><td><table><tr><td></td><td>ahead) and 182 in the long-term (50 to 100 years ahead). This represents less than 0.1% of all non-residential properties in Wales. (Medium Magnitude, Low Confidence)</td></tr></table></td></tr>
<tr><td>Explanation for <i>Confidence</i> rating (Explanation of the confidence rating given and how it relates to the specific information in question)</td><td>
<p>The magnitude and confidence of individual projected impacts is noted in <i>Red Italics</i> in the respective rows above.</p>
<p>The approach used:
[Source: <i>Warren, R., Watkiss, P., Wilby, RL., Humphrey, K., Ranger, N., Betts, R., Lowe, J., and Watts, G. (2016) UK Climate Change Risk Assessment Evidence Report: Chapter 2, Approach and Context. Report prepared for the Adaptation Sub-Committee of the Committee on Climate Change, London.]</i></p>
<p>The confidence scores outlined in the CCRA 2017 Evidence Report present the overall quality of the evidence base that has been used to arrive at the decision on urgency. The table below provides criteria to be used to assign a confidence score to each risk and opportunity assessed.</p>

<p>Table 2.A2. Confidence categories</p>
<table>
<tr><th></th><th>High confidence</th><th>Medium confidence</th><th>Low confidence</th></tr>
<tr><td>Step 1: Assessment of current and future risk</td><td>Multiple sources of independent evidence based on reliable analysis and methods, with widespread agreement between studies and experts.</td><td>Several sources of high quality independent evidence, with some degree of agreement between studies, and/or widespread agreement between experts.</td><td>Varying amounts and/or quality of evidence and/or little agreement between experts, or assessment is made using only expert judgement.</td></tr>
<tr><td>Step 2: Assessment of the effect of planned and autonomous adaptation</td><td>High quality evidence of the effects of future adaptation in managing the risk and high agreement between experts.</td><td>Some evidence on the effects of future adaptation in managing the risk and/or high agreement between experts.</td><td>Little/no/contrasting evidence of the effects of future adaptation in managing the risk and little agreement between experts, or assessment is made using only expert judgement.</td></tr>
<tr><td>Step 3: Assessment of whether additional action would be beneficial</td><td>High quality evidence of benefits of future adaptation on risk and high agreement between experts.</td><td>Some evidence on benefits of future adaptation and/or high agreement between experts.</td><td>Little/no/contrasting evidence of the benefits of future adaptation and little agreement between experts, or assessment is made using only expert judgement.</td></tr>
</table>
</td></tr>
<tr><td>Climate projections, emissions scenarios, or models used (if relevant)</td><td>
<p>From page 17- [Source: <i>Warren, R., Watkiss, P., Wilby, RL., Humphrey, K., Ranger, N., Betts, R., Lowe, J., and Watts, G. (2016) UK Climate Change Risk Assessment Evidence Report: Chapter 2, Approach and Context. Report prepared for the Adaptation Sub-Committee of the Committee on Climate Change, London.]</i></p>
<p>The method for this CCRA has expanded on the response function approach through using a wider range of evidence from a literature review. Some sources of evidence use response functions, while others take a different approach. This means that assumptions about potential future levels of climate change will already be built into much of the evidence. In general this takes the form of scenario analysis where a wide range of scenarios has been used. Common sets of scenarios are UKCP09, RCP and SRES scenarios (see below), and direct CMIP5 modelling output.</p>
</td></tr>
<tr><td>Datasets (if applicable)</td><td>The analysis for this Evidence Report has been conducted through a literature review of the available evidence. In addition to this, four research projects were commissioned specifically to provide further data and information on key aspects of the evidence base for the UK, and these have been published separately. The projects were funded with the support of the Natural Environment Research Council and the Environment Agency.</td></tr>
</table>

	1. Sayers and Partners et al. (2015) for the ASC: Future projections of UK flood risk.(See **Metadata identifier 1.2)** 2. HR Wallingford et al. (2015) for the ASC: Updated projections of water availability in the UK. 3. AECOM et al. (2015) for the ASC: Aggregate assessment of climate change impacts on the goods and services provided by the UK's natural assets. 4. Met Office et al. (2015) for the ASC: Developing H++ climate change scenarios
Additional assumptions (if applicable and not covered by common ratings approach)	The relevant assumptions are presented in *Green Italics.* **From page 21-** [Source: *Warren, R., Watkiss, P., Wilby, RL., Humphrey, K., Ranger, N., Betts, R., Lowe, J., and Watts, G. (2016)* ***UK Climate Change Risk Assessment Evidence Report: Chapter 2, Approach and Context****. Report prepared for the Adaptation Sub-Committee of the Committee on Climate Change, London.]* As a consequence of the issues in the first CCRA, the CCRA 2017 attempt to assess the effects of current and planned policies as well as their potential influence on risk reduction and adaptation needs according to three distinct categories of action, where it is possible to do so: • **Current level of adaptation**. This assumption applies where no additional action is undertaken to reduce risks or to take advantage of opportunities compared to today and where there is no additional autonomous action. In some cases, this would mean that no action is taken at all, while in some areas such as water resources planning and flood defense maintenance it may mean that levels of action would continue at a defined level in line with the level of effort taking place today. Much of the published literature that provides future estimates of risks assumes no adaptation, either autonomous or planned. This scenario is applied in step 1 of the urgency scoring framework. • **Current objectives.** This assumption applies where specific actions or targets that are currently planned or announced in Government policies and programmes are implemented, and/or that in the future, some autonomous adaptation occurs, for example, the Government's six-year spending plan on flood defenses in England. High-level government aspirations (rather than specific actions) are not included in this scenario. This scenario is applied in step 2 of the urgency scoring framework. • **Current objectives+.** This assumption is applied in some of the supporting research (Sayers and partners for the ASC, 2015; HR Wallingford et al. for the ASC, 2015). It goes beyond current policy objectives and assesses how much action could feasibly be taken. This could include all cost-beneficial adaptation or go further and consider transformational change. It is worth noting that although anticipated it these categories were not applied to most of evidence. However where possible the analysis included the descriptors in the urgency tables (e.g. 'assuming a continuation of current level of adaptation, x y z happens')
Additional limitations (if applicable and not covered by common ratings approach)	**From page 27-** [Source: *Warren, R., Watkiss, P., Wilby, RL., Humphrey, K., Ranger, N., Betts, R., Lowe, J., and Watts, G. (2016)* ***UK Climate Change Risk Assessment Evidence Report: Chapter 2, Approach and Context****. Report prepared for the Adaptation Sub-Committee of the Committee on Climate Change, London.]* • The urgency scores for this CCRA are based on the expert judgement of the ASC, which in turn has been informed by the evidence presented in the chapters. There is always a risk that expert judgement can hide certain value judgements or biases. The authors of the report and ASC have attempted to make this assessment as transparent as possible to ensure that the reader can judge the results for themselves. To correct for any unintentional biases, the urgency scores have also been widely reviewed and critiqued by the report's authors, peer reviewers, stakeholders and external reviewers, so this does not necessarily represent a limitation. • The literature review approach does not allow for a direct comparison of magnitude between the risks. Some standardisation of magnitude for selected risks by degree of global temperature increase has been undertaken and is presented in the Synthesis Report. • Following a literature review approach has also not allowed new analysis to be undertaken where there are evidence gaps, apart from a few exceptions. • Following a process with many authors required considerable resource to ensure that the approach and outputs were consistently presented and interpreted. • Time constraints did not allow for a systematic literature review. Instead, the process relied on a call for evidence, author and reviewer knowledge to ensure that the main sources of evidence

	were incorporated

Data quality assessment		
Dataset: *(List the dataset assessed)*		
Data Quality Criteria	**Levels**	**Score**
1. Transparency and auditability	1. Data unavailable to public	
	2. Limited summary data available	
	3. Full raw/primary data set and metadata available	3
2. Verification	1. Unverified data	
	2. Limited verification checks in place	
	3. Detailed verification in place and documented	3
3. Frequency of updates	1. Sporadic	
	2. Every 3-5 years	2
	3. Annual or biennial	
4. Security	1. Future data collection discontinued	
	2. Future data collection uncertain	2
	3. Future data collection secure	
5. Spatial coverage	1. Partial national coverage	
	2. National coverage, some bias	2
	3. Full national coverage, including adjacent marine areas, if and where appropriate	
	TOTAL	12
Total scores should be rated as follows: 5 to 8 (Low); 9 to 12 (Medium); 13 to 15 (High) **RATING**		Medium

<table>
<tr><th colspan="2">Metadata</th></tr>
<tr><td>**Metadata identifier**</td><td>1.2</td></tr>
<tr><td>**Source(s)** (e.g., document, study, report, etc.)</td><td>Climate Change Risk Assessment 2017: Projections of future flood risk in the UK, Project A: Report prepared for the Committee on Climate Change, UK

Sayers, P.B; Horritt, M; Penning-Rowsell, E; McKenzie, A. (2015) Climate Change Risk Assessment 2017: Projections of future flood risk in the UK. Research undertaken by Sayers and Partners on behalf of the Committee on Climate Change. Published by Committee on Climate Change, London.</td></tr>
<tr><td>**Explanation for *Impact* rating**
(Explanation of the impact rating given and how it relates to the specific information in question)</td><td>
<table>
<tr><th>Impact</th><th>Information used to determine impact rating</th></tr>
<tr><td>Projected reduction in land availability and capability due to flooding.</td><td>From page vii:
• The area of **Special Protection Areas, Special Areas of Conservation and Ramsar sites** exposed to flooding more frequently than 1:75 (on average) increases by 25% and 44% for 2°C and 4oC respectively by the 2080s.
• The area of **Best and Most Versatile (BMV) agricultural land** at risk from flooding increases by 32% and 65% under these climate projections.</td></tr>
<tr><td>Projected increase in risks to infrastructure services from flooding</td><td>From page viii:
Change in risk to national infrastructure
• Infrastructure assets will be subject to significant increases in risk; with the number of sites exposed to the highest chance of flooding (i.e. more frequently that 1:75 years on average) increasing by 30% (under 2oC climate change projection) and 200% (4oC climate change projection) by the 2080s.
• Local actions currently being taken to protect infrastructure assets (e.g. for electricity substations) to a 1:200 year return period standard are effective in reducing risk for the 2020s and 2050s; but protection to an even higher standard would be required to cope with climate changes anticipated for the 2080s.
Effects of climate change on transport infrastructure are also significant; the length of railway line located in areas exposed to flooding more frequently than 1:75 years (on average) increases in the 2080s by 53% and 160%; the length of major roads by 41% and 120%; the number of railway stations by 10% and 28% for 2°C and 4oC respectively.</td></tr>
<tr><td>Projected increase in risks to communities, people, health and buildings from flooding</td><td>From page vii:
The number of residential properties exposed to flooding more frequently than 1:75 years (on average) increases significantly in all futures; increasing from **860,000 today** to 1.2 million (a 40% increase) by the 2080s under a 2°C increase in GMT, and to 1.7 million (a 93% increase) under 4oC.</td></tr>
</table>
</td></tr>
</table>

		Both of these estimates assume no population growth and adaptation continuing at current levels. From page vii: The most significant source of flooding today (based analysis of the underlying data provided by the lead authorities in each country) is fluvial (river), contributing £560m (40%) of total UK EAD. Coastal flooding contributes £320m (24%), surface water £260m (20%) and groundwater £210m (16%). In the future all of these sources are projected to increase risk. From pager vii: • The increases in Expected Annual Damages are greater than increases in numbers of properties in areas mostly likely to be flooded. Present day Expected Annual Damages (based analysis of the underlying data provided by the lead authorities in each country) are estimated to be £1.1bn (for the UK as a whole, excluding groundwater); by the 2080s, these are projected to increase to £1.7bn (under 2°C climate change projection) and £2.8bn (under 4°C climate change projection), *assuming no population growth and continuing adaptation at current levels.* • *Under the high growth population projection*, these figures increase to £1.8bn and £2.9bn for 2°C and 4°C respectively. • The number of social infrastructure homes located in the highest flood probability category by the 2080s will be increased for 2°C and 4ºC respectively, *(assuming current levels of adaptation and no population growth)*: ○ care homes located by 48% and 140%; ○ schools by 32% and 95%; ○ emergency services sites by 36% and 100%; ○ hospitals by 23% and 68%; and ○ GPs surgeries by 46% and 140% **Change to risks on people** • The total number of people living in properties exposed to flooding more frequently than 1:75 years (on average) increases from 1.8milllion in the present day to 2.5million (an increase of 41%) under 2°C climate change projection and 3.5million (an increase of 98%) under 4°C climate change projection by the 2080s, *assuming current levels of adaptation are continued and no population growth.* • People living in properties located within the

	UK's most deprived communities face even higher increases in risk. The number of people in these areas exposed to flooding more frequently than 1:75 years (on average) increases by 48% and 110% under 2°C and 4°C respectively.
Explanation for *Confidence* rating (Explanation of the confidence rating given and how it relates to the specific information in question)	
Climate projections, emissions scenarios, or models used (if relevant)	From page vi: - The analysis undertaken (as part of the second CCRA) provides a broader assessment of future flood risks across the whole of the UK and takes account of four sources of flooding (coastal, fluvial, surface water and groundwater). - Two climate change projections (based upon a 2oC and 4oC change in Global Mean Temperature (GMT) by the 2080s from the 1990s baseline), a more severe H++ scenario and three population growth projections (low, high and no growth) are considered together with six Adaptation Scenarios (including assumed enhanced and reduced adaptation levels when compared to present day). - Each Adaptation Scenario reflects a range of individual Adaptation Measures to manage the probability of flooding, manage exposure to floods and reduce the vulnerability of those exposed. - Future flood risks are projected for the 2020s, 2050s and 2080s. - The UK Future Flood Explorer (FFE) is used to complete the analysis. The UK FFE uses nationally recognised source, pathway and receptor data from across the UK to construct an emulation of the present day flood risk system and to explore the future change in flood risk (taking account of climate change, population growth and adaptation).
Datasets (if applicable)	n/a
Additional assumptions (if applicable and not covered by common ratings approach)	From page 26: Base Date October 2014: The base date for the analysis is October 2014. The assumptions made in reconciling the analysis to this date are: • All data provided on present day risks are representative of the flood risk system as of October 2014: All of the datasets provided for use in the analysis are all considered to represent the state of the flood risk system as of October 2014 (despite the individual data within these datasets being derived at various times). • Climate change only influences estimates from October 2014 onwards: To determine a future climate (for example sea levels or rainfall in the 2050s) it is assumed that any climate change that has occurred between the base date of the climate analysis (for example from 1960-1990 baseline that underpins UKCP09) to 2014 has already been observed and is included within the data provided on the present day flood risk system.
Additional limitations (if applicable and not covered by common ratings approach)	

Data quality assessment	
Dataset: *(List the dataset assessed)*	Appendix A Supporting data sets

Data Quality Criteria	**Levels**	**Score**
1. Transparency and auditability	1. Data unavailable to public	
	2. Limited summary data available	
	3. Full raw/primary data set and metadata available	3
2. Verification	1. Unverified data	
	2. Limited verification checks in place	
	3. Detailed verification in place and documented	3
3. Frequency of updates	1. Sporadic	
	2. Every 3-5 years	2
	3. Annual or biennial	
4. Security	1. Future data collection discontinued	
	2. Future data collection uncertain	2
	3. Future data collection secure	
5. Spatial coverage	1. Partial national coverage	
	2. National coverage, some bias	2
	3. Full national coverage, including adjacent marine areas, if and where appropriate	
	TOTAL	12
Total scores should be rated as follows: 5 to 8 (Low); 9 to 12 (Medium); 13 to 15 (High) **RATING**		Medium

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