ONR Research

Literature Review of Recent NERC-Funded Studies of Relevance to ONR's External Hazards Discipline

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EXECUTIVE SUMMARY

This literature review report is intended to contribute to the development of ONR's knowledge in the area of recent NERC-funded research projects relevant to the External Hazards discipline. It presents a summary of progress of this research into topics of interest to external hazards inspectors and provides links to further information about these topics. Based on my literature review, I conclude that the Natural Environment Research Council (NERC) is funding interesting research that is relevant to the Office for Nuclear Regulation's (ONR's) external hazards inspectors, and ONR should keep a watching brief on the progress of this research.

LIST OF ABBREVIATIONS

CREDIBLE	Consortium on Risk in the Environment: Diagnostics, Integration, Benchmarking, Learning, and Elicitation
CURE	CREDIBLE project - Uncertainty and Robustness Estimation
EA	Environment Agency
EDF	Electricité de France
EISCAT	European Incoherent Scatter Scientific Association
FAAM	Facility for Airborne Atmospheric Measurements
FFIR	Flooding from Intense Rainfall
HVAC	Heating, Ventilation and Air Conditioning
MEMORY	Multi-Event Modelling Of Risk & recoverY
NCAS	National Centre for Atmospheric Science
NEDF	Nuclear Engineering Directors Forum
NERC	Natural Environment Research Council
ONR	Office for Nuclear Regulation
PSHA	Probabilistic Seismic Hazard Analysis
PURE	Probability Uncertainty and Risk in the Environment
RACER	Robust Assessment and Communication of Environmental Risk
SAFE	Sensitivity Analysis for Everybody
TAG	Technical Assessment Guide
UKRI	United Kingdom Research Institutes

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1 INTRODUCTION

1. The Natural Environment Research Council (NERC) funds research on a variety of aspects of natural environmental hazards and also facilitates research through collaboration with industry, government and the academic community. The hazards that NERC is interested in are relevant not only to the nuclear industry but also to wider UK major infrastructure sectors. ONR has participated in a number of NERC funded projects in the last couple of years and NERC has fairly recently (August 2016) completed a major five year project on Probability Uncertainty and Risk in the Environment (PURE).

2. The purpose of this paper is to summarise the findings from the literature review of recently-completed NERC funded research to a) establish its relevance to the nuclear industry and b) consider how/if it can/should be translated into regulatory guidance and Relevant Good Practice. This will help maintain ONR's external hazards discipline's awareness of ongoing environmental research relevant to the nuclear sector.

3. The alignment with ONR Strategy [1] is: Inspire climate of stakeholder respect, trust and confidence. This will enable ONR to interact with other UK infrastructure organisations that have an interest in environmental hazards. Engaging with the broader scientific and research community will help improve ONR's knowledge and understanding of known natural hazards to nuclear licensed sites.

2 METHODOLOGY

4. In order to find relevant research projects for inclusion in the report, I undertook the following:

   - Searches on the UKRI (UK Research Institute) Portal [2] for relevant keywords
   - Review of the PURE project outcome report [3]
   - Discussion with the Environment Agency (EA)
   - Consultation with ONR's Meteorological and Flooding Hazards Expert Panel

5. I limited my search to recent research which I defined as research projects completed within the past five years. I considered the aims, objectives and outcomes of each research project and included those most directly relevant to the work of the external hazards team in this report.

3 RESEARCH PROJECT SUMMARIES

6. Using the methodology described above, I identified the following NERC-funded research projects of interest to ONR. The first three projects listed fall under the umbrella of the Consortium on Risk in the Environment: Diagnostics, Integration, Benchmarking, Learning, and Elicitation (CREDIBLE). The first seven (including the CREDIBLE projects) are part of the Probability, Uncertainty and Risk in the Environment (PURE) research programme. Both PURE and CREDIBLE are described in [3].

3.1 Project Name – CREDIBLE project - Using weather forecasts to optimally issue severe weather warnings

3.1.1 Description

7. A weather warning system is a tool by which imperfect forecasts about the future are combined with potential consequences to produce a warning in a way that is deemed optimal. The project team produced a tool that combines predictions of future weather with user attitude towards false alarms and missed events to produce bespoke warnings that are optimal for each user.

3.1.2 Relevance to External Hazards

8. Nuclear plant managers need to make decisions about triggering operator actions to ensure plant safety when an extreme weather event is forecast. The forecasting and notification system the manager relies on should take into account the need to balance the minimisation of false alarms with the potential nuclear safety implications of missed events (i.e. events that occur without having been forecast).

3.1.3 Forward Actions

- Maintain a watching brief on research in this area
- Information to be used to inform discussions with licensees with regards to their weather warning systems
- Consider for inclusion in future Technical Assessment Guide (TAG) 13 [4] updates

3.1.4 Further information:

9. Theo Economou et al, University of Exeter and UK Met Office

10. https://www.credible.bris.ac.uk/2016/08/18/case-study-3-using-weather-forecasts-to-optimally-issue-severe-weather-warnings/

3.2 Project Name – CREDIBLE project - Sensitivity Analysis for Everybody (SAFE)

3.2.1 Description

11. The goal of this project was to provide a suite of tools and methods to support uncertainty and risk assessment in natural hazards in order to improve the transparency and defensibility of risk management decisions. The SAFE tool was developed to allow those who use and develop models to identify those parameters that most influence model accuracy. It enables the user to identify the major sources of model uncertainty and thus to prioritise efforts for uncertainty reduction.

3.2.2 Relevance to External Hazards

12. There is significant uncertainty inherent in the analysis of natural hazards that is required as part of the nuclear safety case. It is important that licensees understand the sources of that uncertainty in order to prioritise their efforts at increasing the accuracy of their analysis, and to ensure that decisions on protection requirements take the level of uncertainty into account.

3.2.3 Forward Actions

- Maintain a watching brief on research in this area
- Information to be used to inform discussions with licensees on their understanding of the sources of uncertainty in their analysis of natural hazard risk
- Consider for inclusion in future TAG13 updates

3.2.4 Further information:

13. Francesca Pianosi et al, University of Bristol

14. https://www.safetoolbox.info/

3.3 Project Name – CREDIBLE project - Uncertainty and Robustness Estimation toolbox (CURE)

3.3.1 Description

15. Assumptions regarding the nature of epistemic uncertainties and how they are taken account of should be recorded and communicated to stakeholders. Good practice in this respect is still developing. This project aims to represent good practice in applying uncertainty estimation methods as well as in being explicit about modelling choices and assumptions. The toolbox provides a range of different uncertainty estimation methods that users can apply that are demonstrated using various environmental model applications.

3.3.2 Relevance to External Hazards

16. Licensees need to make choices on the ways that uncertainty is taken into account in natural hazards modelling. The CURE toolbox could provide them with a way of recording these decisions and assumptions to ensure they are captured.

3.3.3 Forward Actions

- Maintain a watching brief on research in this area
- Information to be used to inform discussions with licensees on uncertainty estimations.
- Consider for inclusion in future TAG13 updates

3.3.4 Further information:

17. Trevor Page et al, Lancaster University and University of Bristol

18. https://www.credible.bris.ac.uk/2016/08/18/case-study-9-credible-project-uncertainty-and-robustness-estimation-toolbox-cure/

3.4 Project Name – Probability and uncertainty in earthquake risk estimation

3.4.1 Description

19. Estimating hazard from a low seismicity area such as the UK is difficult for a number of reasons, mainly associated with the small number of events on which to base the estimates. This project advanced the development of long and consistent earthquake observations by combining different types of observations, including pre-digital proxy data. The results can be used to determine a recalibrated catalogue for the UK that accounts for various sources of uncertainty.

3.4.2 Relevance to External Hazards

20. Due to the very long return periods involved in the analysis of earthquake risk at nuclear sites, licensees need to take into account the largest possible data set in order for their calculations to be statistically valid. This recalibrated catalogue for the UK that this project has produced will be invaluable in this regard. Also of note is the fact that one of ONR's seismic expert panel members was a lead investigator on this project (Ian Main).

3.4.3 Forward Actions

- Maintain a watching brief on research in this area
- Information to be used to inform discussions with licensees on the selection of data for their probabilistic seismic hazard analysis (PSHA).
- Consider for inclusion in future TAG13 updates

3.4.4 Further information:

21. Ian Main, Roger Musson et al, University of Edinburgh and BGS Edinburgh

22. https://nerc.ukri.org/research/funded/programmes/pure/pure-brochure/

3.5 Project Name – Quantification of uncertainties in tsunami modelling

3.5.1 Description

23. To understand tsunami risk at any location, complex computer simulations are used. These simulations are subject to large uncertainties – for example, tsunamis result from deformation of the sea bed, but the precise characteristics of seabed deformation cannot be known in advance. Therefore it is necessary to explore the range of possible deformations as well as uncertainties in other factors such as bathymetry. The project addressed this by using dimension reduction techniques designed to reduce the size of the problem without compromising the ability to evaluate tsunami wave impacts at the coast. The project also developed visualization tools to examine possible variations in tsunami flows in detail.

3.5.2 Relevance to External Hazards

24. There is uncertainty in the analysis of Storegga slide-type tsunamis and their potential effects on the UK. The techniques developed including the visualization tools may help licensees to understand the risk of these types of tsunamis affecting their sites.

3.5.3 Forward Actions

- Maintain a watching brief on research in this area
- Information to be used to inform discussions with those licensees whose sites have the potential to be impacted by Storegga slide-type tsunamis.
- Consider for inclusion in future TAG13 updates

3.5.4 Further information:

25. Serge Guillas et al, University College London

26. https://nerc.ukri.org/research/funded/programmes/pure/pure-brochure/

3.6 Project Name – Robust Assessment and Communication of Environmental Risk (RACER) Visualisation and communication

3.6.1 Description

27. Currently, weather forecasts do not explicitly show uncertainty information. Studies show that decision makers infer their own level of uncertainty with considerable individual differences. This project demonstrated that users' decisions are sensitive to the manner in which uncertainty is presented. The project then turned to investigating how users respond to and interpret natural hazard forecasts where information is shown explicitly. Initial findings suggest that when users are given a median line on a graph showing uncertainty, their eyes are drawn to the median line and they are less aware of extreme values. When no median line is shown, they are more aware of extreme values. The researchers have collated key points and guidelines into a leaflet, *Presenting data and uncertainty*.

3.6.2 Relevance to External Hazards

28. Plant operators need to make decisions based on weather forecasts (for example decisions on whether to suspend certain operations such as fuel movements in case a

storm is forecast). These decisions need to take into account the associated uncertainty. The outcomes from this project could be used to ensure that licensees make use of information on uncertainty more effectively.

29. More widely, the results from this project could be used to help licensees ensure uncertainty information in external hazards safety cases is displayed and communicated effectively.

3.6.3 Forward Actions

- Maintain a watching brief on research in this area
- Information to be used to inform discussions with licensees on:
  - The way they consider uncertainties associated with weather forecasts
  - The way they display and communicate uncertainty in external hazards safety cases
- Consider for inclusion in future TAG13 updates

3.6.4 Further information:

30. Mulder et al, University of Reading

31. https://connect.innovateuk.org/web/pure/quick-guide

3.7 Project Name – Quantifying the uncertainty in volcanic ash forecasts

3.7.1 Description

32. The goal of the project was to develop a way to understand the limitations of current ash forecasting models and to account for the resulting uncertainties. This has enabled researchers to identify the most effective options for reducing the uncertainty inherent in these models. Future research in these areas will enable the UK to be more resilient to volcanic ash events in the future.

3.7.2 Relevance to External Hazards

33. Volcanic ash poses a hazard not only to aircraft (as cited in the project description) but also to nuclear power plants – for example by clogging intake filters and preventing Heating, Ventilation and Air Conditioning (HVAC) systems from operating effectively.

3.7.3 Forward Actions

- Maintain a watching brief on research in this area
- Information to be used to inform discussions with licensees on their response to volcanic eruptions
- Consider for inclusion in future TAG13 updates

3.7.4 Further information:

34. Helen Dacre et al, University of Reading, University of Durham, and the UK Met Office

35. https://nerc.ukri.org/research/funded/programmes/pure/pure-brochure/

3.8 Project Name – Flood MEMORY: Multi-Event Modelling Of Risk & recoverY

3.8.1 Description

36. FloodMEMORY investigated the effects of temporal clustering of flood events on natural, built and socio-economic systems in order to identify critical vulnerabilities, better allocate resources for protection and recovery, and improve flood resilience.

- Floods do not occur at regular intervals – they cluster in time
- The vulnerability of receptors and performance of pathways both have memory
- If repeated shocks occur within the memory period then increased damage may occur

37. This project sought to:

- Identify and quantify this under-estimated risk
- Increase resilience by pre- and post-event actions

By better identifying critical vulnerabilities, those responsible for flood risk mitigation can better allocate resources for protection and recovery, and improve flood resilience.

3.8.2 Relevance to External Hazards

38. Generally, flood risk analysis is performed for a single event but the effects of a flood can be compounded if multiple events occur in quick succession, either at a site or in the surrounding area. Licensees will be able to use the project's outputs to stress-test or adapt their strategies accounting for multiple flood events.

3.8.3 Forward Actions

- Maintain a watching brief on research in this area
- Information to be used to inform discussions with licensees on the risks from multiple flood events occurring together.
- Consider for inclusion in future TAG13 updates

3.8.4 Further information:

39. Chris Kilsby et al, Newcastle University, National Oceanography Centre, Environment Agency, and others

40. https://research.ncl.ac.uk/floodmemory/

3.9 Project Name – Adaptation and resilience of coastal energy supply

3.9.1 Description

41. The project aimed to identify the challenges facing the future security of the UK nuclear energy sector and coastal energy supply as a result of changing patterns of temperature and rainfall, sea-level rise and storms. In particular, it examined the threats posed to future energy generation and the distribution network by flooding and erosion, changing patterns of coastal sedimentation, water temperature and the distribution of plants and animals in the coastal zone.

3.9.2 Relevance to External Hazards

42. This project is directly relevant to external hazards as it examined the effects of climate change on the resilience of nuclear sites in UK. The decision-making tool developed by the project could be used by licensees and regulators to examine the future vulnerability of nuclear sites to flooding from sea-level rise and storm surges.

3.9.3 Forward Actions

- Maintain a watching brief on research in this area
- Information to be used to inform discussions with licensees on the risk of flooding at their sites
- Consider for inclusion in TAG13 updates

3.9.4 Further information:

43. Andy Plater et al, University of Liverpool, BGS, EDF, NOC, others

44. https://gtr.ukri.org/projects?ref=EP%2FI035390%2F1

3.10 Project Name – Physical and biological dynamic coastal processes and their role in coastal recovery (BLUE-coast)

3.10.1 Description

45. This project intends to deliver improved predictions for coastal erosion in different coastal habitats, along with modelling tools to better understand coastal recovery and to understand the implications of climate change for coastal systems. It will provide evidence-based advice for different options for coastal protection and management. BLUE-coast will explicitly address uncertainties in the prediction of medium-term (years) and long-term (decadal and longer) regional sediment budgets and better understand morphological change and how the coast recovers after sequences of events.

3.10.2 Relevance to External Hazards

46. This project will enable licensees to understand the extent of the erosion that may occur at their sites in the medium and longer term. This will help them to plan for the adaptation measures that may be required to ensure their sites are adequately protected from coastal flooding.

3.10.3 Forward Actions

- Maintain a watching brief on research in this area
- Information to be used to inform discussions with licensees on predictions for coastal erosion at their sites and the mitigation measures that may be required
- Consider for inclusion in future TAG13 updates

3.10.4 Further information:

47. Alejandro Jose Souza, Laurent Olivier Amoudry et al, National Oceanography Centre, Met Office and others

48. https://gtr.ukri.org/projects?ref=NE%2FN015894%2F1

3.11 Project Name – European Incoherent Scatter Scientific Association (EISCAT) 3D - Europe's next-generation radar for space weather and whole atmosphere research

3.11.1 Description

49. EISCAT 3D is an international collaboration that will deliver a new world-leading radar in Europe to monitor and improve understanding of the atmosphere and space weather. It will also provide essential validation for models of the whole atmosphere and for forecasting space weather, which are currently under development. Space weather is the term used to describe natural changes in the upper atmosphere and near-space environment driven by energy from the Sun. As technology advances and science, industry, and society rely more and more on satellite technology, so our vulnerability to space weather increases.

50. Extreme space weather, which features on the UK Government's 2015 National Risk Register [5], can cause serious damage to satellites and their associated services, as well as to other critical infrastructures such as power grids and aviation. Long-term

trends in space weather also affect the strategies and policies required to protect satellites from the hazards of collision with space debris. However, space weather cannot yet be reliably forecast. To do so requires scientific research to improve understanding and develop improved forecasting models, and better data to inform the research and validate the models.

51. EISCAT 3D will be an international research infrastructure, using radar observations and the incoherent scatter technique for studies of the atmosphere and near-Earth space environment as well as for support of the solar system and radio astronomy sciences. The radar system will be suitable for a wide range of scientific targets including space weather forecasts.

3.11.2 Relevance to External Hazards

52. Space weather is an area of emerging interest to nuclear operators as space weather has the potential to disrupt the functioning of Control and Instrumentation (C&I) and electrical equipment at nuclear sites. Research in this area is developing rapidly, and an enhanced capability to predict extreme space weather events will allow nuclear operators to take any actions needed to ensure the safety of their facilities prior to an event occurring.

3.11.3 Forward Actions

- Maintain a watching brief on research in this area
- Information to be used to inform discussions with licensees on their preparations for extreme space weather events
- Consider for inclusion in future TAG13 updates

3.11.4 Further information:

53. Craig James Heinselman, EISCAT Scientific Association

54. https://gtr.ukri.org/projects?ref=NE%2FR015848%2F1

3.12 Project Name – Forecasting Rainfall exploiting new data Assimilation techniques and Novel observations of Convection (FRANC)

3.12.1 Description

55. Brief periods of intense rainfall can lead to flash flooding with the potential to cause millions of pounds of damage to property, and to threaten lives. Accurate flood warnings even just a few hours ahead can allow preparations to be made to minimize damage. In order to improve the prediction of these events, more accurate forecasts of heavy rainfall are needed, which can then be used to inform flood prediction and warning systems. Initial conditions for numerical weather prediction are usually estimated using a sophisticated mathematical technique known as data assimilation that blends observations with model information, taking account of the uncertainties in the data.

56. This project has developed a new technique for diagnosing time-varying observation error correlations from data assimilation output statistics (observation minus background and observation minus analysis). Numerical studies in a simplified model framework have demonstrated the efficacy of the technique and now studies with the operational system are ongoing.

3.12.2 Relevance to External Hazards

57. Flash flooding events on nuclear sites can affect vulnerable systems, structures and components and therefore have a negative impact on nuclear safety. The ability to

forecast these events more accurately will mean that operators have more time to prepare for these events, taking actions such as clearing debris that could block drains and ensuring portable protection equipment such as dam boards are put in place.

3.12.3 Forward Actions

- Maintain a watching brief on research in this area
- Information to be used to inform discussions with licensees on forecasting intense rainfall events
- Consider for inclusion in future TAG13 updates

3.12.4 Further information:

58. Sarah Louise Dance et al, University of Reading, UK Met Office and others

59. https://gtr.ukri.org/projects?ref=NE%2FK008900%2F1

3.13 Project Name – Susceptibility of catchments to INTense RAinfall and flooding (SINATRA)

3.13.1 Description

60. The goal of this project is to advance scientific understanding of the processes determining the probability, incidence and impacts of flooding from intense rainfall (FFIR). The impact from these extreme rainfall events can be affected by a wide range factors (or processes) such as the location and intensity of the rainfall, the shape and steepness of the catchment it falls on, how much sediment is moved by the water and the vulnerability of the communities in the flood's path. Furthermore, FFIR are by their nature rapid, making it very difficult for researchers to 'capture' measurements during events. The complexity, speed and lack of field measurements on FFIR make it difficult to create computer models to predict flooding and often there is uncertainty as to their accuracy.

61. To address these issues, NERC launched the FFIR research programme. It aims to reduce the risks from surface water and flash floods by improving our identification and prediction of the meteorological (weather), hydrological (flooding) and hydro-morphological (sediment and debris moved by floods) processes that lead to FFIR. A major requirement of the programme is identifying how particular catchments may be vulnerable to FFIR, due to factors such as catchment area, shape, geology and soil type as well as land-use.

62. The three stages of project SINATRA are to: (1) increase scientific understanding of what factors cause FFIR and gather new, high resolution measurements of FFIR; (2) use this new understanding and data to improve models of FFIR to enhance predictions of where they may happen - nationwide (3) use these new findings and predictions to provide the Environment Agency and other professionals with information and software they can use to manage FFIR, reducing their damage and impact to communities.

3.13.2 Relevance to External Hazards

63. As stated above - flash flooding events on nuclear sites can affect vulnerable systems, structures and components and therefore have a negative impact on nuclear safety. The ability to forecast these events more accurately will mean that operators have more time to prepare for these events, taking actions such as clearing debris that could block drains and ensuring portable protection equipment such as dam boards are put in place.

3.13.3 Forward Actions

- Maintain a watching brief
- Information to be used to inform discussions with licensees on forecasting intense rainfall events
- Consider for inclusion in future TAG13 updates

3.13.4 Further information:

64. Hannah Louise Cloke et al, University of Reading, UK Met Office, and others

65. https://gtr.ukri.org/projects?ref=NE%2FK00896X%2F1

3.14 Project Name – The North Atlantic Climate System Integrated Study (ACSIS)

3.14.1 Description

66. Major changes are occurring across the North Atlantic climate system: in ocean and atmosphere temperatures and circulation, in sea ice thickness and extent, and in key atmospheric constituents such as ozone, methane and particles known as aerosols. Many observed changes are unprecedented in instrumental records. Changes in the North Atlantic directly affect the UK's climate, weather and air quality, with major economic impacts on agriculture, fisheries, water, energy, transport and health.

67. ACSIS is a 5 year strategic research programme (2016 – 2021) whose goal is to enhance the UK's capability to detect, attribute (i.e. explain the causes of) and predict changes in the North Atlantic Climate System. ACSIS will deliver new understanding of the North Atlantic climate system by integrating new and old observations of atmospheric physics and chemistry, of the ocean state and of Arctic Ice. The observations will be complemented by detailed data analysis and numerical simulations. Observations will come from existing networks, from NERC's own observational sites in the North Atlantic, and from space. Seasonal surveys using the National Centre for Atmospheric Science (NCAS) Facility for Airborne Atmospheric Measurements (FAAM) aeroplane will further enhance observational strategies. A key dimension of the observational opportunity is that data records of sufficient length, for multiple variables, are becoming available for the first time. The modelling component will involve core numerical simulations with cutting-edge atmosphere, ocean, sea ice, chemistry and aerosol models using the latest parameterizations and unprecedented spatial detail, as well as bespoke experiments to investigate specific time periods or to explore and explain particular observations.

68. ACSIS will provide advances in understanding and predicting changes in the North Atlantic climate system that can be exploited to assess the impact of these changes on the UK and other countries - for example in terms of the consequences for hazardous weather risk, the environment and businesses. ACSIS outputs will also inform policy on climate change adaptation and air quality.

3.14.2 Relevance to External Hazards

69. Licensees are required to take climate change into account in their analysis of natural hazards such as meteorological and flooding hazards. The implications of changes to the North Atlantic climate system need to be included in their considerations.

3.14.3 Forward Actions

- Maintain a watching brief on research in this area
- Discuss as part of the meteorological and flood hazards expert panel meetings
- Consider for inclusion in future TAG13 updates

3.14.4 Further information:

70. Bablu Sinha et al, National Oceanography Centre

71. https://gtr.ukri.org/projects?ref=NE%2FN018044%2F1

3.15 Project Name – BIG data methods for improving windstorm FOOTprint prediction (BigFoot)

3.15.1 Description

72. Windstorms can cause great damage to property and infrastructure. The windstorm footprint (a map of maximum wind gust speed over 3 days) is an important summary of the hazard of great relevance to the insurance industry and to infrastructure providers. Windstorm footprints are conventionally estimated from meteorological data and numerical weather model analyses. However there are several interesting less structured data sources that could contribute to the estimation of the windstorm footprints, and more importantly will raise the spatial resolution of these estimates. This is important as there are important small-scale meteorological phenomena, such as sting jets, that are currently not well resolved by the current methods. This project proposes to exploit additional sources of data.

3.15.2 Relevance to External Hazards

73. Licensees use maximum wind speed gusts to analyse potential damage to their facilities from extreme winds. Reducing uncertainty and increasing special resolution of these estimates would enable more accurate estimates of the potential damage that extreme winds could cause.

3.15.3 Forward Actions

- Maintain a watching brief on research in this area
- Information to be used to inform discussions with licensees on wind gust estimates
- Consider for inclusion in the TAG13 update

3.15.4 Further information:

74. Peter Challenor, University of Exeter

75. https://gtr.ukri.org/projects?ref=NE%2FP017436%2F1

4 DISCUSSION AND CONCLUSIONS

76. It is clear that NERC funds a wide range of research projects of relevance to ONR's external hazards disciplines. This literature review provided a useful way of raising awareness of these projects within ONR.

77. In addition to this review, ONR external hazards inspectors maintain their awareness of relevant research projects in other ways, including:

- Liaising with the Environment Agency via regular meetings, including EA participation in ONR's Flooding and Meteorological Hazards Expert Panel.
- Discussions and presentations from ONR's Flooding and Meteorological Hazards Expert Panel on research items of interest to the discipline.
- Participation in national and international conferences and workshops to gain insights into ongoing research and make and maintain contacts with relevant stakeholders

- Knowledge sharing on relevant research with licensees (for example, joint ONR/EDF knowledge sharing workshops)

78. The literature review of NERC-funded research provided a useful addition to these existing methods of maintaining awareness of relevant research.

5 NEXT STEPS

79. The following next steps are proposed to allow ONR to maintain up to date knowledge of NERC-funded research:

- Update the list of relevant NERC funded projections and descriptions annually via UKRI portal searches – this could take the form of a research note or an appendix to this report
- Consider how to gain additional knowledge of research ongoing internationally
- Disseminate relevant research findings to the nuclear industry via publishing this literature review on ONR's research register website [6], and potentially future updates to ONR's TAG13 and via the Nuclear Engineering Directors Forum (NEDF)
- Meet with NERC contacts to review project list and findings (suggested frequency – every two years approximately). The External Hazards research lead will then report back on relevant research to both the Professional Lead for Civil Engineering and External Hazards and the ONR Regulatory Research Manager. This will also meet the intention of the "watching brief" for the projects included in this literature review, and will also allow ONR to receive information on other newer projects in a timely manner..

6 REFERENCES

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[3] PURE, "Transforming the quantification and communication of natural hazard risk," 2016.

[4] ONR, "Nuclear Safety Technical Assessment Guide – External Hazards, NS-TAST-GD-013 Revision 7," 2018.

[5] UK Government, "National Risk Register of Civil Emergencies," 2017.

[6] ONR, "Research Register Web Site," [Online]. Available: http://www.onr.org.uk/research/index.htm.