CASE STUDY

USARIS: Uncertainty Quantification and Sensitivity Analysis for resilient Infrastructure Systems

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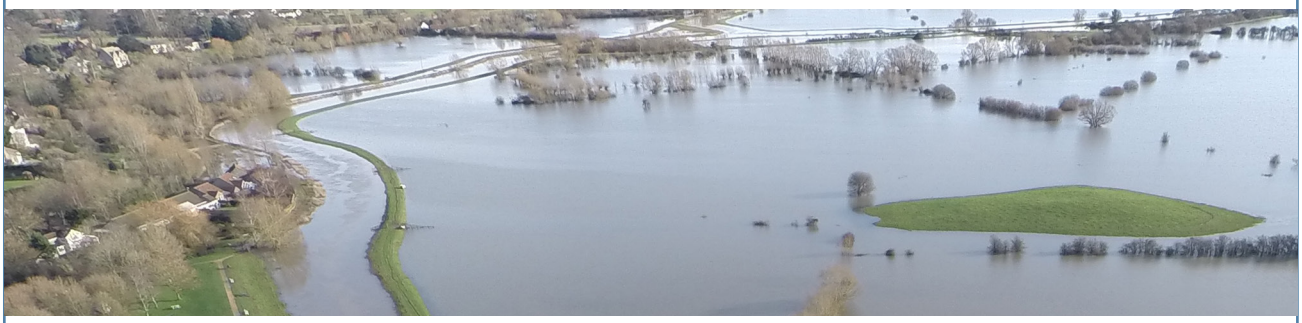
Introduction

Mathematical modelling is increasingly used to inform decisions in a variety of sectors, from flood risk management to energy planning, and from UK government decisions to EU policy level.
The USARIS project has developed a toolkit to allow researchers and analysts to improve understanding of uncertainty in infrastructure models. Government and industry in the infrastructure sector can use this toolkit to put model results into context and to use model predictions in a more appropriate and responsible way.



What would you identify as the main impact of this work?

Infrastructure projects cost billions of pounds and take years or even decades to plan and build. USARIS work will help to ensure that infrastructure systems are better suited to future demands and needs by identifying key uncertainties present in scenario building.

Key challenges that USARIS aims to solve

Model outputs are conditional on many uncertain assumptions, due to our incomplete or imperfect knowledge of the external drivers and internal properties of the systems being modelled, data gaps and errors, and simplified assumptions.

Overconfidence in model results and insufficient consideration of the breadth of possible futures is a key obstacle to infrastructure resilience. If models are used to inform large investment decisions, they must be trustworthy and defensible.

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What was the key aim of the project?

The USARIS project set out the foundations for integrating functionalities for Uncertainty Quantification and Sensitivity Analysis (UQ&SA) into the DAFNI platform. We developed a range of pilot applications of UQ&SA for infrastructure models, and produced training materials to inform and educate industry, policymakers and early career researchers about the importance of uncertainty and sensitivity analysis, and how to apply it in practice.

What did DAFNI allow you to do that you couldn't have achieved otherwise?

DAFNI allowed the team to access models from a variety of infrastructure sectors to develop the pilot applications and to investigate differences across them.

This will result in a journal paper on assessing the relative importance of different sources of uncertainty in models in the energy and water sector. The paper proposes a generic conceptualisation that can be applied across sectors but also highlights differences found in the two applications - for example, the team found that uncertainty about future climate is very important in the water resource application but less important than previously thought in the wind power application.

What outputs from the project have you put onto the DAFNI platform?

Three pilot applications have been developed, and the models are available on DAFNI together with a workflow example of how to run these models against different, equally plausible combinations of uncertain input parameters:

Hydrological rainfall runoff model – this simulates river flows from rainfall and temperature data. The model can be used to determine maximum flood magnitude and to design flood defences.

Water resource system model – this simulates movement of water across reservoirs and treatment works for given inflows and water demand. The model can be used to estimate water availability changes due to climate change population increase, and the cost and benefit of adding new water resources.

Wind power model – this simulates the power potential of a wind turbine from wind speed data and depending on the turbine characteristics, such as the hub height and power curve. The model can be used to inform sizing and location of new windfarms, or to feed into multi-source energy systems stress testing.

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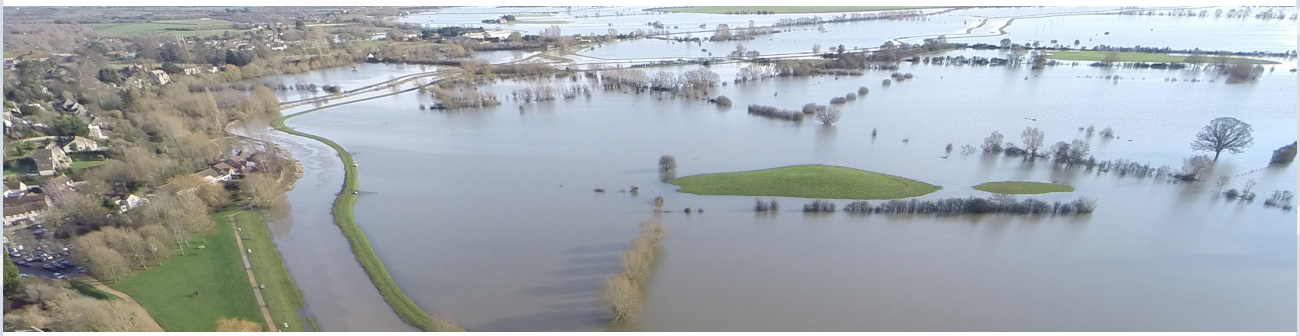
The workflows available on DAFNI are complemented by a set of open-access Jupyter Notebooks for visualising the simulation data generated on DAFNI and for assessing outputs in uncertainty and sensitivity. These Notebooks are available at: https://github.com/SAFEtoolbox/SAFE-on-DAFNI

The set of applications gives a concrete demonstration of the value of uncertainty and sensitivity analysis and provides other researchers with a blueprint of how they could conduct these kinds of analyses, as the code can be adjusted by users to allow them to tailor it to their own scenarios.



How do you anticipate other researchers, policymakers and stakeholders using this work?

Information about model sensitivities helps modellers to understand where they should invest their efforts to prioritise the reduction of uncertainty. Uncertainty and sensitivity information helps model users to grow confidence and understanding of when model predictions can be used, when they are valid, and which are the critical assumptions that underpin them.

An important aspect of the USARIS project has been working with industry and regulators who use model outputs to inform decisions. The team has been using dialogue and education to further the debate around the best way to quantify and communicate uncertainties, with stakeholders including the Water Industry Modelling Advisory Group (MAG) and the Environment Agency. In June 2025, Hannah and Francesca will meet with the Department of Energy Security and NetZero (DESNZ) to share insight from the BRINES and USARIS projects. In July 2025, Francesca will speak at the PRIMaRE conference at the University of Bristol, focused on research and development for Marine Renewable Energy.

The USARIS team has also been developing and delivering training for early career researchers on uncertainty in modelling, including a DAFNI webinar, training for research students in the CDT Resilient Future Floods, and online training on reproducibility in hydrological research for the Flood and Drought Research Infrastructure project.

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How could this work benefit society as a whole?

Although the pilot applications developed in the USARIS project have been very much UK-focused, the methodology is completely generic and applicable everywhere.

In April 2025, Francesca gave a keynote talk on the project and global sensitivity analysis at the 11th International Conference on Sensitivity Analysis of Model Output (SAMO) in France, sponsored by the European Commission Joint Research Centre and Centre for Competence in Modelling.

Any utility, government or private contractor engaged in infrastructure maintenance and build should incorporate uncertainty and sensitivity analysis into their scenario building.

Next steps

Work with two other DAFNI projects will continue: with Dr Hannah Bloomfield on BRINES: Building Risk-Informed redundancy for Net-zero Energy Systems, and with Dr Anna Murgatroyd on the water resources simulation system, Pywr-WREW: Water Resources model for England and Wales built in Python.

With Pywr-WREW, the next step will be to look beyond regional scale and investigate uncertainties in the national-scale model, used to appraise different investment scenarios, that the government is considering for increasing water resilience at national scale.

With BRINES, the next step will be to extend the uncertainty and sensitivity analysis to bigger energy systems, including not only wind power but also solar and other technologies.

The USARIS team are preparing journal papers which will be submitted in summer 2025.

One focuses on comparisons between model uncertainty in the energy and water sector. The second concentrates on a detailed wind power application.

Since the rise of renewable energy, the energy landscape has become more complex, with generation levels now more uncertain as they are so deeply connected to the environment and climate. Uncertainty analysis is essential in the current landscape where energy production is no longer a closed manmade system.

Who's involved?

The USARIS project is led by Dr Francesca Pianosi, Associate Professor in Water and Environmental Engineering, and Saskia Salwey, Research Associate, both in the School of Civil, Aerospace and Design Engineering at the University of Bristol. *Saskia is now a postdoctoral researcher at Utrecht University

When did the project start and finish?

The project ran from October 2023 to September 2025.