

# Climate-Resilient River Operations in London by Predictive Digital Twin

Operational Forecasting and Climate Change  
Impact Prediction Simulation Model



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### Smarter UK Ports - Project Introduction

Smarter UK Ports is a series of five use cases for the use of technology in Smarter and Greener ports in the UK, developed and published by the Connected Places Catapult, in association with Royal HaskoningDHV UK.

The use cases are based on real-life challenges within many ports across the UK, co-created with five port authorities to give local context and relevance on how innovative technologies can be implemented to improve their business function, resilience, environmental impact and operational performance.

The five topics were selected together with the partner ports to give context and achievable, nearer-term initiatives that support the delivery of key Maritime 2050 themes. As challenges that exist at ports throughout the UK, these use cases present opportunities for collaboration and knowledge exchange to deploy and scale these potential solutions to realise wider sector impacts.

Meant as a snapshot of relevant challenges to port operators, these studies aim to inspire further discussion and collaboration, with clear next steps to make use of technology that delivers Smarter and Greener Ports

All of the Smart Port Use Cases in this series engage a range of existing or evolving technologies to bring improved digitalisation and business change into the multi-stakeholder environment that UK ports operate within.

We would like to thank our partner port authorities for their contributions and discussions and hope you find the series both enjoyable and informative. We would also welcome you to reach out directly to us with your own challenges and initiatives on our journey to Smarter and Greener UK Ports.

**Henry Tse, Director of New Mobility Technologies, Connected Places Catapult**

Topic	Supporting Port	Maritime 2050 Links
Connected Supply Chain – Virtual Pre-Gate for Ferry Operations	Portsmouth International Port	Trade Technology Environment
Automated Asset Inspection & Shared Port Insight	Shoreham Port	Infrastructure People
Green Energy – Shore Power for Wind-Farm Service Operation Vessels	Port of Tyne Authority	Environment Trade Infrastructure
Climate Resilient River Operations in London by Predictive Level Digital Twin	Port of London Authority	Environment Trade Security & Resilience
Operational Resilience – Monitoring of Marine Assets in Remote Locations	Milford Haven Port Authority	Infrastructure Security & Resilience

# 1

## The Challenge



The River Thames is a critical artery for leisure and freight traffic, with depth and air draft limitations impacted by weather, tide, extraction and flood defences; understanding future behaviour is vital to planners and operators to ensure service resilience is maintained.



The Port of London Authority (PLA) manages the river from sea approaches up to past Teddington Lock (95 miles), supervising all traffic and guiding leisure users on safe passage and practices. The river has 35 bridges along the tidal stretch, with limited air clearance for vessels to pass through.

The PLA issues detailed guidance to mariners for passage planning, draft and air draft clearances for informed consideration of movement along the river; incidents of grounding or bridge-strike are very rare. Additionally, the river is monitored along its length by many flow and water height gauges, by the environment agency and other bodies; much of this data is available on-line and in real-time, for guidance to river users, with detail on current levels against tidal and historical trends.

The river has a large catchment area and is perhaps the most studied and actively managed river in the UK, with the Thames Barrier to manage tidal surges and protect from extreme weather. Government Agencies have numerous static and dynamic models for climate change impact on the river basin and the city.

With growing impact of climate change, rising sea level and incidents of extreme river conditions, both in flood and drought, are more likely and understanding the impact on the river for freight operators, investors and insurers of infrastructure and industry is critical, including the impact on vital services such as extraction of drinking water.

Plentiful data exists, albeit within many complex forms and across multiple owners, to understand historical reactions of river levels along its tidal length resulting from the interplay of weather, tides and human activity. If the investors, insurers, users and managers of the river could have the right level of confidence in predictive forecasts for planning short-term operations, but more importantly, longer-term expectations of river levels in the future, depending on climate scenarios, then this would be a valuable tool. Informed planning for infrastructure and building design, working with nature, will reduce life-cycle cost and improve resilience to flood impacts; operationally, to refine river freight routes and craft.

Guidance for operational passage plans is static, supplemented by real-time data and expert advice on levels, tidal cut/surge, and weather. A PLA and Transport for London study (2016) found that capacity was available to increase passenger and freight river traffic in Central London, but “the system is prone to localised and dramatic increases in vessel traffic which cause bottlenecks limiting capacity in the river as a whole. The Level of Safety was found to be the greatest limitation on the capacity for additional traffic.”

Predictions for climate change are advanced but with different foci, such as flooding. A combined and automatically self-improving model could be mutually valuable to operators

## Fast fact

In London, Port trade increased to 54 million tonne and 4.79 million tonnes of inland freight in 2019.  
Source: PLA

Latest predictions in UKCP18 predict a sea level increase of at least 0.3m and up to 1.15 m in London by 2100 relative to 1981-2000 average.

“The Port of London Authority is working hard to understand and balance future demands on the river Thames, particularly into the coming decades as inevitable pressure from climate change will impact our riverine community in diverse and volatile ways”



Veronica HG Chan, Senior Advisor Climate Change.

## 2

## The Solution



A reliable and self-learning river level prediction tool for operational decisions, absorbing all the river influence data, and then extrapolated into a climate scenario simulation model – a constantly learning digital twin.



The river levels are influenced by several natural and human-driven factors, some of which are regular and predictable tides, for example but many are not. The models are complex, particularly when considering the gradual changes over time of the catchment and spiky impact of human influence, such as treated wastewater discharge, drinking water extraction or the raising of the Thames Barrier.

Historical data exists for most of these influences, and accurate river level data is collected in real-time along the Thames. This creates the feed for an ambitious machine learning model, to correlate river level readings against the many layers of influencing data. The decades of data provides a substantial record of discrete events and combinations to estimate the impact on river levels at key points. It will be challenging to differentiate between coinciding events, such as dry summer weather and water extraction forcing lower levels, or rising sea level, heavy rain in winter and atmospheric pressure conditions driving tidal and catchment surge; however, with over 100 years of data, the relative impact of each should be divisible and measurable in terms of influence on the river.

This tool will require substantial data storage, achievable through a data lake concept, which has links between elements, but also requires human input to guide the exception-handling and learning of the machine to reach useful levels of accuracy; this will involve a wide range of stakeholders and expertise to gather on the mission, best owned by a neutral and transparent body.

The model will create predictive insight by using all the input elements and learning of their relevant impact and convert this to an expected river level output result accordingly. Once tested, this predictive model can be used to provide river users with a short-term forecast on expected river levels, therefore also bridge and under-keel clearances, for approximately 7 days in advance (with suitable margin of variance), which brings operational and passage-planning advantages. This would be presented online to succinctly guide users; importantly to minimise volatile changes from the model inputs, as this would create safety risks and loss of confidence in the advice.

The digital twin remains dynamic, as the model would continue to ingest live data from all the sources, through a series of data interfaces (APIs), to test and refine the learning patterns against the actual readings received from river gauges, thus quickly improving accuracy as exceptions and new events add more subtlety.

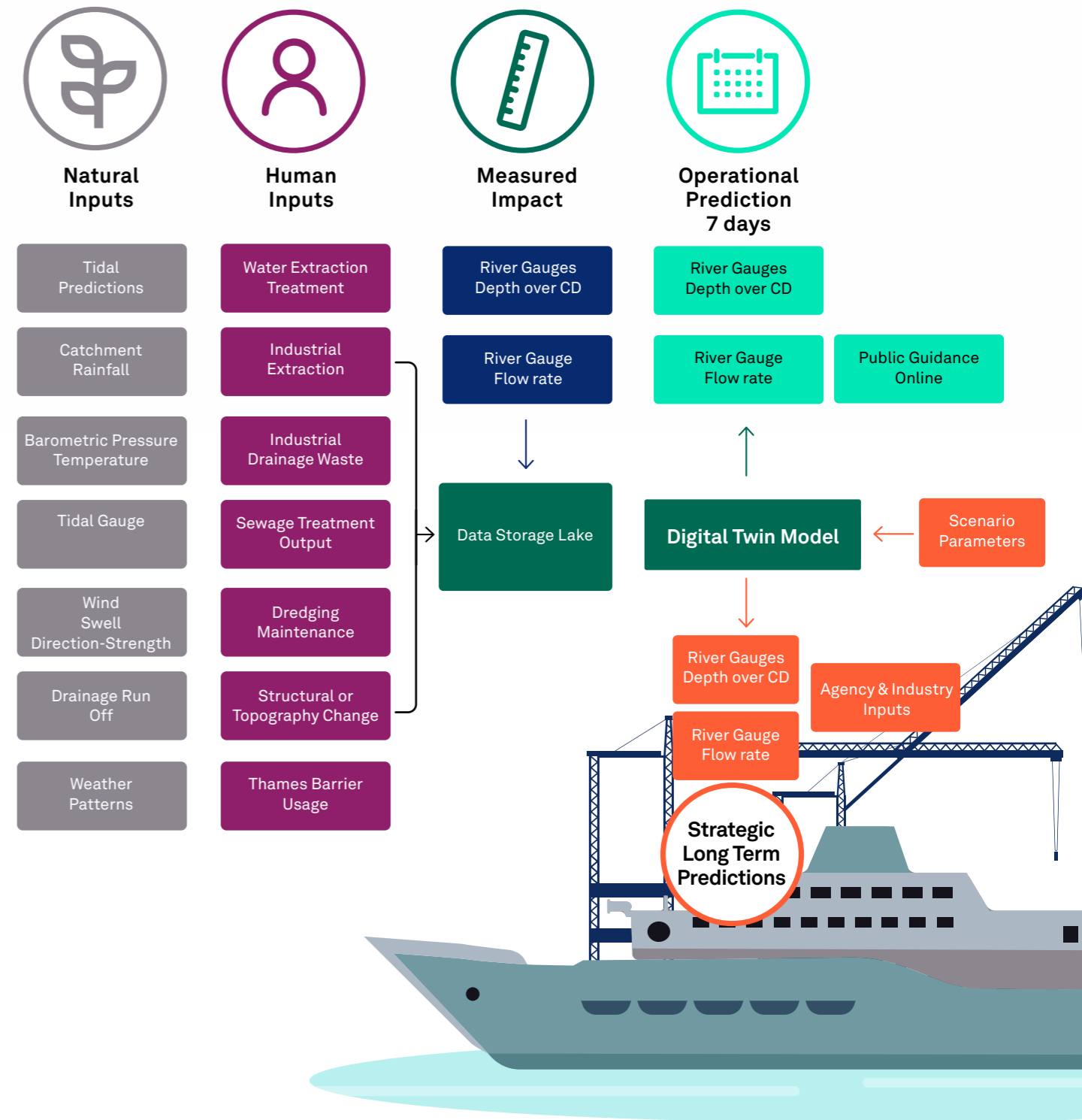
Once sufficiently accurate and reliable in today's working conditions, then specific scenarios can be defined, modelled and tested to simulate more extreme weather and climate change events into the future. This could include sea level rise, water extraction license extensions, storm events or summer droughts. The parameter adjustments will programme the model to show extrapolation into future impacts, providing a valuable prediction for river levels at the key stations. This is important for planning new industrial or residential river-side developments, new waterborne freight routes up-river, investment in flood infrastructure, considerations for water extraction in the growing city and many other strategic needs.

# 3 How it Could Work

Using decades of historical data for many river inputs and outputs, with modern computing power, can create new insights able to predict river levels. This can improve operations and long-term strategic planning for climate change resilience in London.

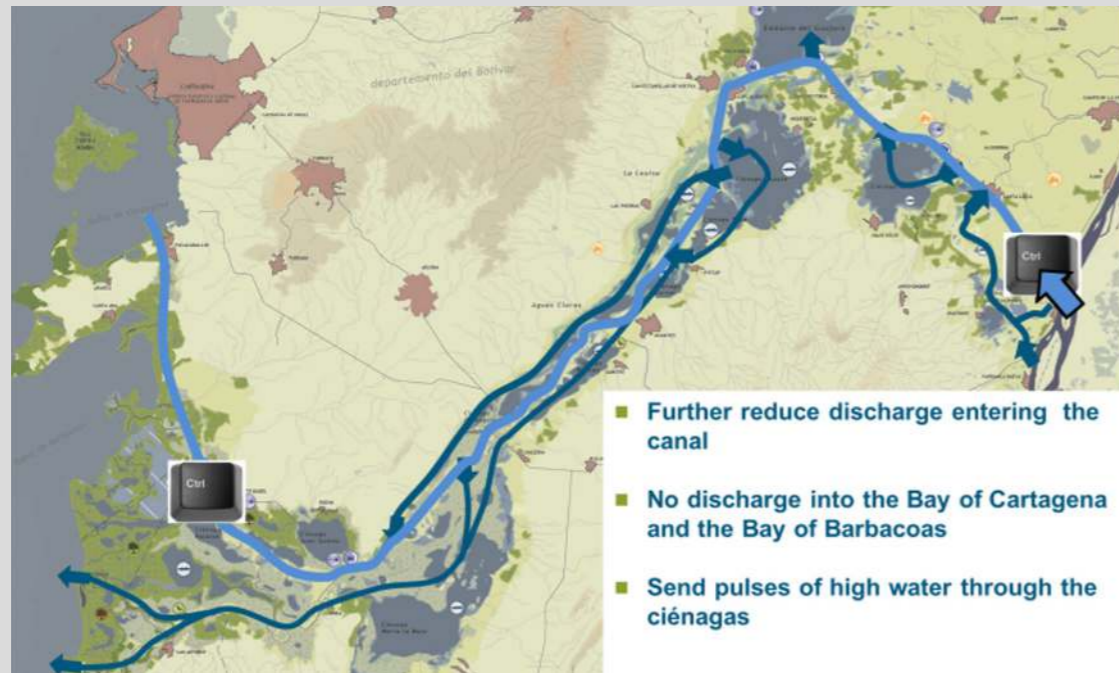


## How this Solution Would Work



**Case study**

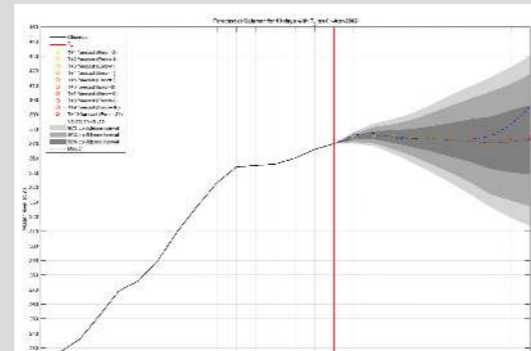
Canal del Dique, Colombia – Flood Management & Prediction



Canal del Dique, Calamar, Colombia.

After major flooding in 2010, a rebuild programme and management strategy was developed to predict and divert water and sediment surges for the canal network linked to Caribbean Sea.

Multiple Linear Regression (MLR) modelling was used for data collected at 10 stations along the Magdalena river basin (over 1,500 km long) for the last 30 years. This data was processed through a regression modelling technique to create a prediction model for a reasonable level of accuracy for 10 days into the future, to guide on expected river levels and flood surges.



10-day river level prediction at Calamar

This allowed authorities to plan for flood gate operations, to divert into relief channels, and also for navigational guidance on the canal, as well as to manage ecological reserves for wildlife. The prediction guided policy making and flood avoidance for this canal system, using robust mathematical modelling techniques.

Source: 37th IAHR World Congress, Royal HaskoningDHV, 2017

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Wider Impacts



Resilience and adaptation to climate change is key to the nation’s river cities, with improved predictions and fluvial understanding vital to investment and strategic decision making; predictive digital twins can support this challenge.





## 5

## Implementation Route

The build of a tidal river digital twin is a data engineering and machine learning challenge, to extract, process and link many data elements, spread across many decades to accurately predict water levels across 95 miles of the Thames.

The Thames is amongst the most complex rivers to model, however, the influences on river levels in the city are broadly similar in many other regions, from the Clyde, Tyne, Mersey and the Humber, Severn and Orwell. The river level prediction digital twin tool would be easily transferable between rivers, and re-learn the local behaviours based on the mass of historical data available for UK river systems. This would extend the value of such a tool and investment to build a multi-city prediction tool for river-related climate change resilience understanding for operational, infrastructure and civilian preparedness.

Similar challenges of river-level prediction and future change are experienced worldwide, with much larger cargo volume ports such as Hamburg working within river environments, and much longer rivers such as the Mississippi using the waterway for freight that is limited by water depth in certain seasons in the inland reaches.

In London, more robust modelling would inform improvements to navigational advice provided by the port authority, refining bridge clearances and river drafts for industrial and leisure users, improving safety generally. The short-term prediction tool would also guide the planning for special loads to move along the river, such as construction equipment, where operational margins and weather windows may be limited.

Improved accuracy and simplified presentation of river data may also encourage more users onto the waterway; this is positive, but with care to be taken that publication of predictive data does not over-ride the awareness and experience needed to navigate on the river safely.

Property and industrial developers along the river may, or not, directly use the river for operations, but the climate-based forecasts for future levels at their proposed locations would inform structural designs, resilience planning and, in some sensitive sites, planned obsolescence or change of land use as climate change advances. Risk assessors and insurance advisers could also use these scenario models to guide policies for river-side property.

This tool can also be integrated with models that have a different focus, such as for flooding impact by the Environment Agency, so an open design and structure should be established to enable easy sharing across the stakeholder community.

Looking ahead, with autonomous and remote-control shipping, particularly for river-crossing ferries and for inland waterway barges, becoming more feasible, then accurate and digitised data on river behaviours and expectations for navigation and manoeuvring become more important, and flow and depth data are key elements for corrections and safety assessment by the automation control systems.



The value of more accurate river level predictions, for now and into the future, is shared by many organisations and users in the community, which creates implementation complexity, so an independent project leader should ensure all the stakeholders are involved in the vision development. These same organisations may also hold the data sources needed for this model; a robust hosting solution and interface design will be needed, ideally at a neutral location, perhaps a university or Government agency.

The business case for this project will arise from the vision development, but it is important to define objectives, metrics and expectations for a range of uses. In the delivery phase, this type of project will have to be an agile development, as unknown obstacles will be discovered, and there will be a greater level of work to improve the granularity of the predictions; the coarse model will be straightforward (tides and weather primarily) but greater accuracy requires much more data ingestion, proportionally more costly therefore.

Once a vision and business case are established, there are key stages to build and deliver such a project -

#### **Data Storage, Structures and Cleaning**

With over 100 years of data, from 20 or more sources, the cleaning and linking is a task that will require thought and build of automated processing to re-structure and import data segments. This storage facility will be the foundation for all influencing data on the model; some may be stored locally, or drawn up and translated from external sources as needed, such as from weather models.

#### **Machine Learning**

Data scientists can identify correlations between the expected outputs (river level) and the many inputs to automatically derive importance of controlling parameters by using mathematics and computer power. This will be guided by a multi-disciplinary team of data scientists, data engineers and river environment expertise, to refine out the errors over time.

#### **Interfacing & Real-time Predictions**

This model will then be able to predict, firstly at a coarse level, then gradually improve, using real-time inputs and the actual river levels to gain accuracy. A series of calls to data interfaces will be used from the first stage to enact real-time links to all the inputs; once tested and results verified for reasonable accuracy, this will then be able to generate user-friendly output for presentation on a web platform or other systems, such as for operational management of freight or passenger vessel traffic.

#### **Scenario Building & Testing**

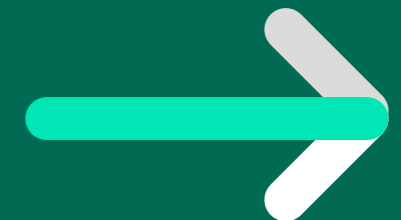
From the original vision stage, the future predictions should be defined; the key parameters to create these scenarios can be adjusted in the model to then simulate the river levels of the future, with extreme storms, droughts, population growth, sea level rise and so forth. This simulation tool will be able to produce output with awareness of accuracy confidence, which will decrease with time range and extremity of input adjustments, as with all such models.

The digital twin of the river will have deliberately limited public exposure, with perhaps only the 7-day level prediction, but many applications are apparent to share within the industrial and governmental agency communities. There may be options to monetise this data for insurance and investment parties, but this should be clarified during the vision and business case stage at the outset.



## Next steps

- Establish a working group of key stakeholders to shape the concept further
- Perform a data audit and review to understand technical feasibility of the project modelling
- Consider the investment case and public value for the river digital twin





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