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Thames Estuary 2100

This is one of 15 case studies informing the Infrastructure Systems Review.

System: Thames Estuary tidal flood-risk management system.

Systems contribution and value: Shift to adaptive pathways, estuary-wide management and system-level intervention timing. Deferred high-cost interventions, improved maintenance timing, reduced whole-life flood-risk cost and supported co-funding.

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Summary

TEAM2100 (Thames Estuary Asset Management 2100) was a 10-year (2015-25) capital investment and flood-risk management programme run by the Environment Agency. It covered some 350km of flood walls and embankments, and 3,229 fixed-defence assets, most owned by third parties.

This case study shows that, by taking a long-term, whole estuary approach to flood risk and defensive performance, TEAM2100 enabled better investment decisions, resulting in better value for money.

- At estuary-wide level, understanding hydraulic interactions improved strategic choices about the timing and scale of major interventions.
- At asset-system level, whole-life modelling improved decisions about capital intervention, inspection and maintenance.
- Across both levels, moving beyond fragmented asset appraisal delivered measurable whole-life value.

It illustrates these benefits with examples.

The outer estuary is naturally constricted by the Lower Hope Point and North Kent Marshes, influencing mean water levels across the estuary. Their loss would increase defence requirements across multiple asset systems and bring forward extensive defence raising. Sustaining and strengthening the marshes – thereby deferring the defence raising works – was shown to deliver an annualised whole life cost saving of approximately £135 million.

Higher up the estuary, proactive refurbishment was carried out at Ocean Wharf, where an existing gravity wall defence was retained at a cost of approximately £1 million. This contrasts with the £11 million cost of replacing a similar defence at Duke Shore Wharf, where the asset management strategy was to respond on failure. System-wide modelling estimated that each year of deferred maintenance increased whole-life costs by approximately £45 million.

The central lesson is that an approved long-term strategy, sustained delivery capability and integrated leadership enabled TEAM2100 to move beyond fragmented asset decisions, improve system understanding and make better investments. Continued progress depends on using evidence of system contribution and whole-life value to support decisions with third-party asset owners. Opportunities for additional value through integration with environmental, economic and societal systems should be investigated.

350km²
land area protected against flood risk

500,000
properties and nationally significant infrastructure protected

£135M
annualised whole life cost saving

Scope

This case study examines how the TE2100 Plan and TEAM2100 programme applied a systems approach to manage tidal flood risk across the Thames Estuary over the long term. The TE2100 Plan was developed from 2005 and published in 2012. TEAM2100 subsequently ran from 2014 to 2025, translating the strategy into coordinated delivery (figure 1).

The challenge set within the plan was to maintain the required standard of protection under uncertain future conditions while coordinating decisions across a large, diverse and partly third party-owned asset base.

The Thames Estuary tidal flood risk management system extends from Teddington Weir to the outer estuary at Southend and Sheerness. It covers approximately 350km² of floodplain and includes the Thames Barrier, other tidal barriers, raised defences, outfalls and pumping stations. Together, these assets protect more than one million people, over 500,000 properties and nationally significant infrastructure. The system is organised into 23 asset systems, each representing a hydraulically independent flood cell and referred to as a policy unit within the TE2100 Plan (figure 2). These asset systems provide a practical basis for planning and managing risk.[1] [2]

This study examines decision-making at connected levels:

- estuary-wide – understanding hydraulic behaviour and the system-wide role of major assets supports strategic choices about interventions and their timing.
- asset-system level – understanding whole-life performance and condition supports decisions about inspection, operation, maintenance and refurbishment.

It assesses how this two-level approach improved the timing and targeting of investment, operations and maintenance, and the resulting whole-life value. It also considers the constraint created by fragmented ownership, as the Environment Agency owns only around 5% of the raised tidal defences.

1 Environment Agency, Thames Estuary 2100 Flood Risk Management Strategy Appraisal Report, Version 1.4, Scheme Reference RETH000060, Mar. 2010.
2 Environment Agency, Thames Estuary Asset Management 2100 Programme: Asset Management Strategy, Issue 6, Document No. TEA-00-00.00-SG-AM-00-000001, Oct. 2023.

The evidence base for systems change Thames Estuary 2100

Figure 1. TEAM2100 within the long-term TE2100 delivery and adaptation timeline.

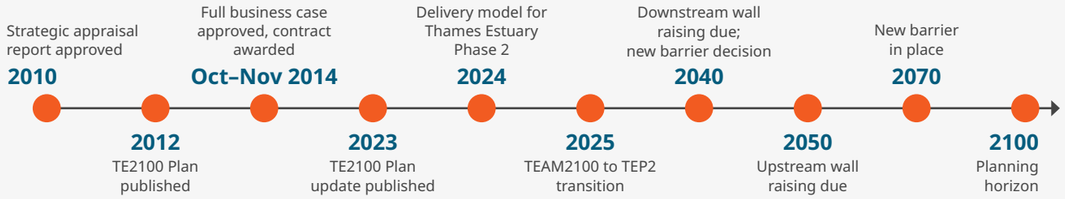


Figure 2. The 23 TE2100 policy units, referred to as asset systems in this case study. Each was originally treated as a hydraulically independent flood cell for planning and appraisal.

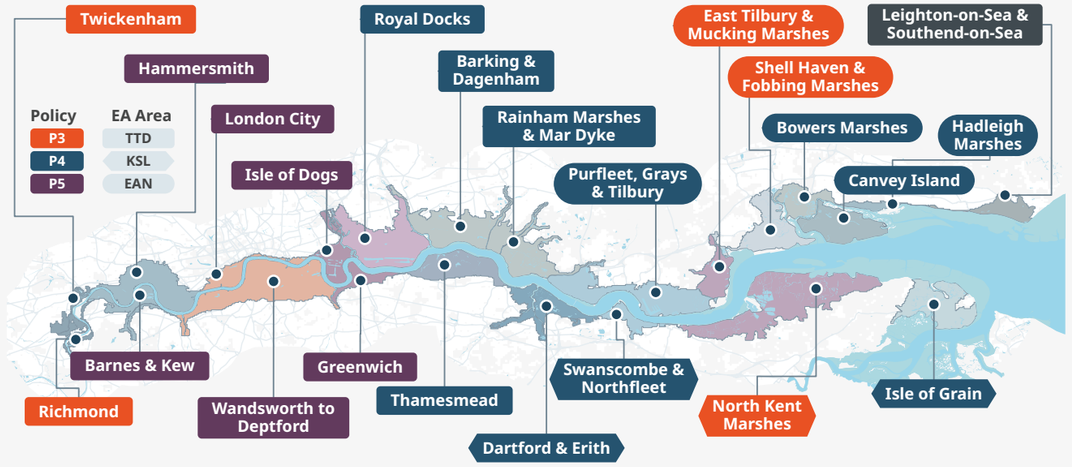
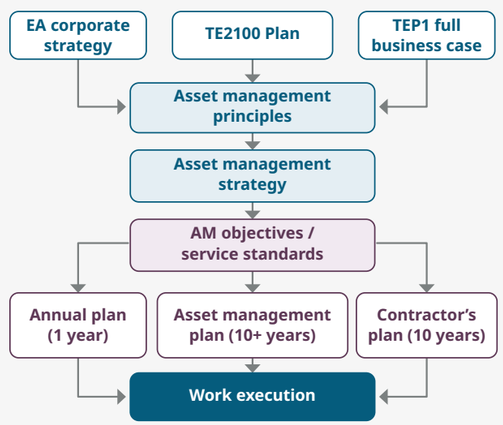


Figure 3. TEAM2100 decision-making process connecting estuary-wide strategy, asset-system evidence and scheme-level delivery.



Key outputs

Estuary-wide system
- Strategic objectives
- Preferred investment approach
- Preferred standard of protection
- Preferred flood risk management policy
- Preferred delivery approach
- Preferred value-adding opportunities

Asset-system level
- Short- and medium-term programme
- Identified local opportunities to add value
- Funding opportunities and constraints
- Design water levels
- Target condition

Asset level
- Asset condition
- Preferred asset intervention option
- Detailed design
- Asset-level opportunities to add value
- Scheme delivery approach

Outcomes

The systems approach improved decision-making at two connected levels within the Thames Estuary tidal flood risk management system: strategic choices affecting the estuary as a whole; and operational and maintenance decisions within asset systems.

At estuary-wide level, the principal change was moving beyond the local value of individual assets to understand how assets and physical processes influence overall system performance. Under a conventional asset-led approach, an intervention may be assessed mainly against the people, property and infrastructure it protects locally. System-level analysis also considers whether an asset affects water levels, barrier operations, defence requirements or the timing of interventions elsewhere in the estuary.

The North Kent Marshes demonstrate the value of this broader perspective. Although they provide relatively limited local benefits, the marshes influence mean water levels across the estuary. Understanding this function showed that their loss would increase defence requirements across multiple asset systems and bring forward extensive defence raising. This changed the basis for decision-making because the assets could be valued according to their contribution to estuary-wide performance, rather than their local benefits alone. The economic assessment quantifies the resulting whole-life value.[3]

At asset-system level, the systems approach improved understanding of asset condition, function, reliability, redundancy and interdependencies. Asset systems provided a practical basis for considering how groups of assets collectively maintain the required standard of protection. Whole-life modelling then enabled decisions about inspection, operation, maintenance and refurbishment to reflect both asset condition and the consequences of deterioration for the wider asset system.

This changed the timing of interventions. Rather than maintaining every asset to the same regime or extending its life until replacement became unavoidable, decisions could be based on the point at which intervention provided the best whole-life outcome. The comparison between Ocean Wharf and Duke Shore Wharf illustrates the consequences. Timely refurbishment at Ocean Wharf retained the existing asset at substantially lower cost, whereas delayed intervention at Duke Shore Wharf resulted in emergency works and major reinstatement. The approach therefore supports earlier intervention where deterioration would create disproportionate future cost. But it also enables deferral of major capital works where systems will continue to perform without increasing unacceptable risk.

Considering asset cohorts within their system context enabled more targeted inspection and maintenance. For example, mapping Victorian masonry defences with shallow foundations against locations vulnerable to erosion can identify where that cohort faces greater deterioration risk. Inspection frequencies can then reflect both asset characteristics and system exposure, strengthening the connection between day-to-day asset management and the long-term strategy.

The flood risk management system operates at two connected levels. Understanding both provides a view of how the system behaves and how changes in one part can affect performance elsewhere.

The principal outcome examined by this case study is improved management of tidal flood risk and whole-life value through better strategic, operational and maintenance decisions, at both estuary-wide and asset-system levels.

Additional benefits were observed where the flood risk management system interacts with wider environmental, economic and societal systems to create further value. These interactions are beyond the scope of this case study and merit further study.

Systems

The Thames Estuary tidal flood risk management system operates at two connected levels. At estuary-wide level, assets and hydraulic processes interact across geographical boundaries. At asset-system level, groups of defences work collectively to provide the required standard of protection. Understanding both levels provides a structured view of how the system behaves and how changes in one part can affect performance elsewhere.

At estuary-wide level, interactions between assets and environmental processes shape hydraulic performance across multiple locations. Operation of the Thames Barrier influences downstream water levels, while features in the outer estuary, including Lower Hope Point and the North Kent Marshes, exert hydraulic control over wider system behaviour. Changes in these locations can affect defence requirements and the timing and scale of interventions elsewhere. These relationships demonstrate that the role of an asset cannot always be understood from its location or local benefits alone.[4]

At asset system level, the approach represented an important progression from appraising individual assets. Each of the 23 asset systems was treated as a hydraulically independent flood cell, within which barriers, walls, embankments and operational assets collectively provide the required standard of protection. With limited exceptions, assets were assumed to contribute only to the protection

3 E. Morris, J. Clarke, D. Matthews and C. Zegers, Rethinking Estuary Appraisal, Document No. TEA-00-00.00-RP-AM-00-000006, unpublished internal TEAM2100 project report, Oct. 2017.
4 Environment Agency, TE2100 High Level Options Pilot Portfolios, Volume 2, Appendices D and E, internal TE2100 technical study, n.d.

The evidence base for systems change Thames Estuary 2100

Figure 4. Location of North Kent Marshes within the estuary and their impact in reducing tidal water levels

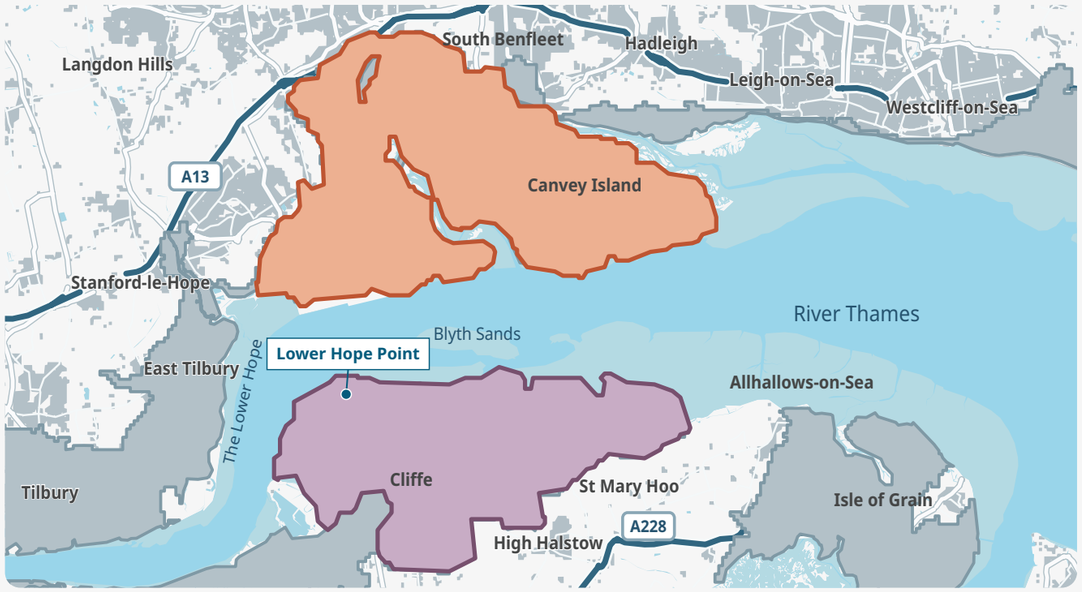
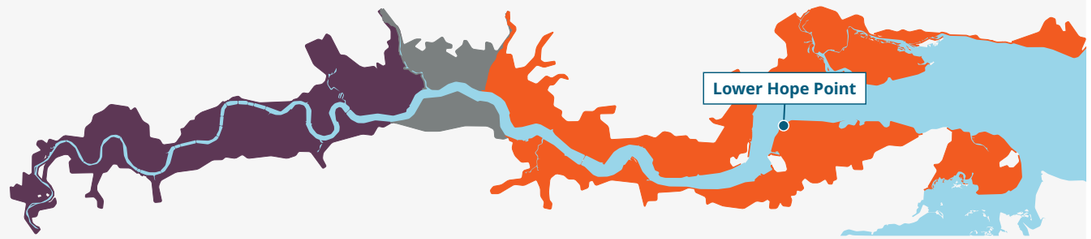


Figure 5. How loss of the Lower Hope Point would accelerate major interventions in the Thames Estuary



Accelerated bank raising

- Twickenham
- Richmond
- Barnes & Kew
- Hammersmith
- Bermondsey
- London City
- Isle of Dogs & Lea Valley
- Greenwich
- Royal Docks

No effect

- Thamesmead
- Barking & Dagenham

Increased defence level

- Rainham Marshes
- Dartford & Erith
- Swanscombe & Northfleet
- Purfleet, Grays & Tilbury
- East Tilbury
- North Kent Marshes
- Shellhaven & Fobbing
- Bowers Marshes
- Canvey Island
- Hadleigh Marshes
- Isle of Grain
- Leigh & Southend

Decision level	System insight	Decision improved	Evidence of value
Estuary-wide	Lower Hope Point and the North Kent Marshes influence water levels and intervention requirements across the estuary	Whether maintaining the hydraulic constriction avoids bringing forward major defence raising and the long-term estuary option	Up to 190km of earlier defence raising avoided; approximately £135 million present-value impact
Asset-system	Whole-life modelling links asset condition and deterioration to the performance required from the asset system	When to inspect, maintain, refurbish or replace assets	Ocean Wharf refurbishment approximately £1 million versus approximately £11 million at Duke Shore Wharf; deferred maintenance approximately £45 million present value per year

of their own asset system. This allowed the function and performance of each asset to be understood in relation to the asset system as a whole, rather than in isolation.

The two levels are connected through an exchange of information. Estuary-wide analysis identifies the influence of major assets, hydraulic processes and alternative intervention pathways across asset-system boundaries. Evidence from asset systems provides a more detailed understanding of asset function, condition and performance. As TEAM2100 moved into delivery, understanding of both the individual asset systems and the estuary-wide system became progressively more developed.

Together, these two levels provide an increasingly refined model of the flood risk management system. This connects the behaviour and performance of assets within individual asset systems to the strategic choices required across the estuary, providing the system understanding that underpins subsequent decisions about capital investment, inspection and maintenance. In addition to the tidal flood risk management benefits evaluated in this case study, opportunities for additional value were identified by integrating flood risk decisions with wider environmental, economic and societal systems (figure 3).

Economic assessment

The systems approach improved whole-life value by changing when, where and at what scale investment was required across the Thames Estuary. At estuary-wide level, value is driven principally by the timing of major interventions. Sea level rise will increase water levels in the estuary and require further investment over time, but understanding how assets and hydraulic processes influence overall system performance allows high cost works to be deferred where the required standard of protection can be maintained without increasing unacceptable risk (Table 1).

Lower Hope Point demonstrates this mechanism because it forms a natural constriction that restricts tidal flow and water levels upstream. Long-term erosion of this feature, followed by tidal inundation of the freshwater North Kent Marshes, would increase the volume of tidal water entering the estuary upstream of this point (figure 4). Although Lower Hope Point provides relatively limited local flood risk benefit, its hydraulic function creates value across the estuary.

TEAM2100 estimated that the loss of this function would increase whole-life costs by approximately £135 million present value, through earlier implementation of up to 190km of defence raising and acceleration of the long-term estuary option (figure 5). An asset-led appraisal based principally on local benefits would not fully recognise this value. The systems approach demonstrates how maintaining a critical hydraulic function can safely defer substantially greater expenditure elsewhere.

At asset-system level, value comes from identifying the optimum point for capital intervention. Strategic deferral is beneficial when performance allows works to be postponed safely. Delay is costly when deterioration increases the scale, complexity or urgency of the eventual intervention. Whole-life modelling distinguishes between these circumstances, relating asset condition and deterioration to the performance required from the system.

Ocean Wharf and Duke Shore Wharf illustrate this distinction. Timely refurbishment at Ocean Wharf retained the existing gravity-wall defence for approximately £1 million. Delayed intervention at Duke Shore Wharf resulted in emergency works and major reinstatement costing approximately £11 million. The comparison demonstrates that extending an asset towards failure is not necessarily economically efficient, particularly where deterioration removes the option for lower-cost refurbishment.

System-based inspection and maintenance planning provides the evidence needed to identify intervention points. Modelling of different regimes across the system indicated that the annualised whole life cost of deferring maintenance came to approximately £45 million (present value) – or £450 million over 10 years.

Understanding asset cohorts within their system context also enables inspection and maintenance to be targeted according to deterioration, exposure and contribution to flood-cell performance.

Long-term visibility of the investment pipeline supported coordinated funding. At the Port of Tilbury, partnership working enabled delivery of a dual-function lock gate and secured £6 million from third-party and local sources, releasing Grant in Aid for investment elsewhere. Across the strategy, aligning whole-life carbon and investment planning is also forecast to reduce carbon emissions by up to 45%, demonstrating the potential to optimise cost and carbon through the same system-level decisions.

The cost associated with collecting the information required to implement this level of systems thinking is particularly interesting. Before TEAM2100, separate engineering inspections and appraisals cost approximately £93,700 per asset in 2026 prices. The business case for TEAM2100 showed that system efficiencies achieved by inspecting assets as cohorts would reduce the cost to approximately £13,390 per assessed asset.

Costs were cut further by bringing together the Environment Agency's then ongoing T98 inspections with georeferenced photography, LiDAR, 3D scanning, GIS and targeted professional input. This enabled consistent and more informed monitoring and analysis across all 3,229 fixed-defence assets. The initial pilot of advanced monitoring for the Isle of Dogs asset system assessed approximately 400 assets for £297,000, equivalent to approximately £363,000 or £910 per asset in 2026 prices.

Applying the Isle of Dogs unit cost across all 3,229 fixed-defence assets gives an indicative cost of approximately £2.9 million. This is slightly below, the £3.1 million estimated for the full business case's targeted programme of 439 engineering inspections and 173 appraisals. The comparison therefore suggests that TEAM2100 could extend analysis across the whole asset base without increasing the direct cost of assessment.

Systemic assessment

The principal lesson from TEAM2100 is that effective systems working required sufficient strategic authority, time and investment certainty to move beyond fragmented asset-level decisions. The TE2100 plan provided the long-term vision and approved strategic direction. TEAM2100 gave a 10 year mandate to deliver that strategy, creating the space to develop system understanding and improve our investment decision making.

This long-term authorising environment was a critical success factor. It enabled TEAM2100 to examine how assets and hydraulic processes contributed to estuary-wide and asset-system performance, improve whole-life modelling and use emerging evidence to refine investment, inspection and maintenance decisions. A piecemeal asset-led approach would have constrained this learning by focusing resources on immediate interventions and local benefits, limiting the programme's ability to identify opportunities for better investment across the system.

Integrated leadership and alignment between strategy, delivery and asset management were also important. The development of a 'one system' delivery model provided a shared basis for decision-making, while progressively improved asset information supported consistent assessment of system contribution, condition and performance.

The principal constraint was fragmented asset ownership. The Environment Agency is responsible for managing flood risk across the estuary but does not own most raised tidal defences. Acting on system-level evidence therefore requires engagement with owners whose responsibilities and priorities may differ, particularly where an intervention creates benefits beyond its immediate location.

The transferable lesson is that technical understanding alone is insufficient. Systems approaches require long-term authorisation, sustained delivery capability and organisational arrangements that allow decisionmakers to learn about the system and act on that evidence. Without these conditions, investment is likely to remain fragmented and opportunities to improve whole-life value may be lost.

Recommendations

1. Enable system-level strategies to guide adaptive delivery
Long-term strategies should define outcomes, performance requirements and adaptive pathways, enabling delivery to refine decisions as system understanding improves. Sustained programme authorisation is essential to provide the time and investment certainty needed to develop this understanding and avoid reverting to fragmented asset-level decisions.

2. Embed adaptive, system-wide decision-making
Value is created through decisions made over time across the system. Decision making should connect estuary-wide strategic choices with asset-system evidence, enabling the timing and form of interventions to be refined as conditions, asset performance and system understanding develop.

3. Align delivery around shared system outcomes
A 'one system' approach should align strategy, delivery and asset management around common objectives. Integrated leadership and a shared evidence base improve coherence and enable decisions to be taken consistently in the interests of overall flood risk management system performance.

4. Enable coordinated investment across organisations
System performance depends partly on assets owned by third parties. Engagement with asset owners should use evidence of system contribution and whole life value to establish a shared basis for intervention decisions. Further work should examine how benefits extending beyond individual assets can support collective business cases and coordinated investment.

5. Build capability and tools for system management
System management requires sustained capability in whole-life modelling, asset information and hydraulic analysis. These tools should support decisions about capital intervention, inspection and maintenance, while allowing system understanding to improve through delivery. Opportunities to create additional value through integration with environmental, economic and societal systems should also be investigated further.

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