DESIGNING SUSTAINABLE SEA DEFENCES: DEVELOPING PRINCIPLES FOR PROCEDURES, PROCESSES AND PRACTICE

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INTRODUCTION

Two stages of The Portsmouth Elephant Cage, an international design research programme, were held over 2016-2017 with the purpose of advancing study into more sustainable, effective, efficient and better future spatial design responses to climate change induced rises in sea level in urban locations; through an archetypical investigation of Portsmouth, UK (Figure 1).

In the first stage, launched through an open Anglo-Dutch design contest procedure, eighteen emergent young design professionals from architecture, landscape architecture, engineering and planning were selected. They were coalesced into three balanced competitive teams, mentored by six international coastal design experts from across the disciplines, and supported by sixteen masters of architecture students along with five promoters from Project Compass CIC, Architectuur Lokaal and the Portsmouth School of Architecture. This stage over two and a half days included eight seminars, generated collaborative design outputs from the three teams and included in a final public consultation key authority stakeholders.
Prior to the programme’s commencement outline engineering proposals for Portsmouth’s southern sea front defences had been published. These raised significant questions regarding potentially adverse impacts on the city’s sustainability and its tourist economy. The three teams therefore developed alternative design polemics capable of addressing sea level rises along this frontage and were encouraged to innovate.

The programme’s ostensive aim was to evaluate, hypothesise, consult and shift the understanding of potential design opportunities for coastal defences and their resilience\(^1\). It also aimed to further inform design practice, advance professional knowledge, expertise and understanding to build capacity for achieving better and more sustainable global solutions for urban and regional resilience in comparable coastal cities. This co-creation process was founded on collaborative cross-disciplinary professional working practices, consultation and the opportunity these offer for contributing to the advancement of knowledge, its exchange, networks of expertise along with public understanding and expectations.

This paper outlines the context, objectives, process, adopted procedure and collaborations underpinning the programme with initial reporting and reflections on the principles emerging from the first stage, along with preliminary outputs.

This design research was supported by Project Compass CIC (UK), Architectuur Lokaal (NL), and the Stimerings Fonds Creatieve Industrie (NL), was hosted within the Portsmouth School of Architecture in collaboration with the Eastern Solent Coastal Partnership and extends the author’s ongoing design research inquiry on sustainability and resilience in Portsmouth and the Solent region\(^2\).

**CONTEXT**

Climate change induced rises in sea level pose significant recognised risks for sustainable development in urban agglomerations globally\(^3\). A known problem arises therefore as to how best to address these risks efficiently, appropriately and sustainably; along with how investment on mitigation might be most effectively allocated, prioritised and designed to maximise resilience and cost benefits\(^4\).

At a conservative estimate 147 to 216 million people globally live on land at risk of being submerged below sea level, or at regular flood levels, by the end of this century assuming emissions of heat-trapping gases continue on their current trend, but the figure may be as large as 650 million. The largest populations by numbers of those most exposed are in countries in Asia; China, Vietnam, Japan and India, with the UK and four other European countries also making the list (Figure. 2)\(^5\).
Coastal cities of twenty-seven European Union states exposed to the risk of inundation, up until 2100 from 100 year event storm surges, indicates a high preponderance are located around the North Sea, the English Channel and the Atlantic. States such as the Netherlands and UK are particularly exposed (Figure 3).
With a long highly indented coastline the UK’s coastal exposure is also high. The UK’s coastline at around 12,429km is high for a land mass of 243,610 km² and has a coast/area ratio of 51.4 m/km², whilst relative to the length of its coastline the UK has a low population at 5.2 people/m². However Ordnance survey calculates UK’s main island at 17,820 km² and when the larger islands are added, this rises to 31,368 km from which may be derived an upper coast/area ratio of 129.6 m/km².

This illustrates the significant and unique challenges the UK faces with a coastline that is proportionately high relative to its land area and with a comparatively low density of people relative to coastal length. UK therefore needs to ensure its coastal management and mitigation strategies for sea level change deliver optimum cost benefit, so that investment, which is currently prioritised to protecting life and property, may also be more critically considered in areas of higher population densities in terms of whole life and social value sustainability, for overall efficiency and effectiveness.

Whilst the analysis of empirical data relating to climate change induced flood management and wider strategic responses has developed rapidly, direction on the necessary detailed design resolutions particularly in urban coastal areas remains more skeletal. In responsive design ongoing questions arise as to how urban agglomerations and their societies may best react to the risk, so that the most appropriate and sustainable solutions achieving best value and environmental quality are delivered. An intent of this research programme has been to explore and expand this knowledge.

**England**

In England and Wales the Environment Agency estimated that “around 10m people, in 5.5m properties, live in flood risk areas, with 2.6m of those properties at direct risk of flooding from rivers or sea” and that there is “a recurring theme is of inadequate consultation, co-operation and unity between public authorities”.

A probable scenario of a 2m rise in sea levels would threaten significant UK population concentrations, with regionally the highest anticipated numbers, 111,356 located in South East England (Figure 4).

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* Compared to the lengths of the Dutch coastline 451km, Italy 7,600km, Spain 4,964km, or France 3,427km, compared to the coast/area ratio of Netherlands 13.3 m/km², Italy 25.8 m/km², Spain 9.95 m/km², Ireland 21.0 m/km² and France 7.58 m/km² and Compared to the ratio of population to length of coastline for The Netherlands 37.78 p/m, Italy 8.00 p/m, Spain 9.36 p/m, and France 19.46 p/m
In February 2017 nearly £6 billion of investment was consented for England for both coastal and fluvial projects to address flooding issues,\(^{11}\) (or roughly 11% of High Speed Rail 2).

**Portsmouth**

South Hampshire is the largest built up region at risk in the South East, with Portsmouth in the low lying East Solent coastal area having a population density of 5,100 people/km\(^2\), which exceeds that of London, being pre-eminent. Portsmouth is one of only two island cities in Europe and like Venice also has an imperial maritime history, with its open spaces provided largely by the sea or along the seafront.

The Portsmouth Southsea southern frontage is particularly vulnerable to rises in sea level. There are 8,077 residential properties within this areas primary food cell, with 4,114 residential properties and 704 commercial properties at direct risk of inundation\(^ {12}\). This popular southern frontage, has extensive beaches, promenades and leisure activities; is rich in historic assets, with five scheduled monuments and thirty four listed buildings; and has a range of other unique functions such as the world’s only commercial hovercraft service, the large annual Victorious Festival and the grandstanding for yacht racing events which occur immediately off this coast. The city derives a significant 12% of income from tourism.

In 2015 the Eastern Solent Coastal Partnership (ESCP) a local authority consortium with a remit to manage the regions coastline, sought to consult the public on their approx. £62m proposals to improve sea defences to the Portsmouth Southsea frontage\(^ {13}\). Existing defences have, in places, passed the end of their life expectancy so replacement is urgently required. The ESCP proposals based on a policy of ‘holding the line’ entailed constructing a terraced concrete sea defence structure on the beach and raised a number of challenges, including whether or not better value might be achievable, and what future lessons might be learnt\(^ {14}\).
Summary review of existing Coastal Management Strategy

There are three strategic options commonly adopted when evaluating coastal management: attack, defend or retreat. In an attack strategy the usable land/space is extended into, on or over the sea (example: the Dutch Polders). Defend seeks to secure existing waterfront lines (example: a sea wall), while a retreat strategy accepts the invasion of the sea as part of the natural processes, which may also be used to help dissipating the sea’s energy (example: salt marshes).

In areas having a high population density coastlines are most commonly defended and typically two forms of approaches may be adopted; hard or soft engineered defences. Hard engineered solutions cover for example sea walls, groynes and rock armour; while soft engineering may cover beach nourishment, replenishment and managed coastal realignment.

A range of developed coastal defence typologies may then be deployed according to factors such as; the sectional profile of the coast/sea front, the character and level of coastal exposure, alignment and configuration of the coast, the angle of wave energy and the strength and direction of longshore drift. Additionally the anticipated extent of climate change induced rises in sea level, the base evaluation data and the designed scenarios, the risk factors applied to tidal, surge and overtopping episodes; the cost of interventions, along with social, cultural and environmental factors and impacts for the specific location, may then be evaluated.

Notably the sectional profile significantly affects how rapidly wave energy and overtopping maybe deflected or dissipated on impact; with a more vertiginous and severe hard engineered coastal perimeter taking greater energy impacting on its smaller surface area.

In the UK the risk factors adopted are typically established to withstand a 1:200 year flood event. This may be lower than the Netherlands for example, where designs might provide for above a 1:4000 year event, and are therefore more robust and offer greater long term resilience and sustainability.

RESEARCH OBJECTIVES, METHOD AND ANALYSIS

Objectives

A unique research proposal was instigated to further interrogate the issues along the Portsmouth Southsea frontage (Figure 6). Key objectives included exploring, unencumbered, options to enhance the potential for more creative and better quality design solutions and guidance, and developing this through collaborative practice engaging expertise across the disciplines of architecture, landscape architecture and coastal engineering.
The intentions were also to develop wider professional knowledge and practices in the field of coastal management design, along with their dissemination and seek to influence commissioning authorities and stakeholders, in urban coastal areas most at risk, by developing contributions to effectiveness and efficiency that inform better design quality and value in future outputs.

**Process, procedures, organisation and implementation.**

As both countries share a high exposure to risks from rising sea levels, an Anglo-Dutch international collaborative framework was instigated to advance the programme, through the agencies of an architectural procurement intelligence service, Project Compass CIC with Dutch collaborators Architectuur Lokaal, an Architecture Foundation. A purpose being to ‘highlight the many advantages and flexibilities some alternative approaches to procurement can offer to increase understanding of the potential’.

The Dutch ‘Stimulerings Fonds Creative Industrie’ provided funding enabling its implementation. To elicit wide ranging options, collaborative cross-disciplinary design research, expertise from suitable design professionals and mentors, a unique innovative process was developed and structured, aligned with recommendations for collaborative ‘parallel commissioning’ within Project Compass’s Design Contest Guidance, and to Architectuur Lokaal’s experiences of four previous Elephant Cage competitive exercises. The name encompasses varied procedures for collaborative design practice, having a competitive selection stage, which puts ‘big young beasts together with mentors’. Inspired by the writings of the Architectural critic Geert Bekaert, it has similarities with a design charrette but access is open and a collaborative inter-generational and inter-disciplinary co-creation process is engaged. The process, programme and participatory composition was then uniquely constructed for the research enquiry remit.

In September 2016 open competitive calls for Anglo-Dutch participants (of forty years of age or under) were issued with a Competition Brief, Project Brief and terms and conditions. Following their submission deadline UK participants were selected by an architectural jury (b) and notified on 3 November 2016.

Over 23th - 25th November 2016, the Elephant Cage then brought together seventeen young Dutch and British experts in Architecture, Landscape, Engineering and Planning in Portsmouth to work together on this design research collaboration supported by Masters students from Portsmouth School.

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b Russell Curtis (RCKa architects), Sasha Bhavan (Knox Bhavan Architects), Merlin Fulcher (The Architects Journal) and Walter Menteth (Project Compass)
Living and Sustainability: An Environmental Critique of Design and Building Practices, Locally and Globally

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of Architecture. Mentoring was provided by seven experts from the various design disciplines and hosted in the Portsmouth School of Architecture.

For full analysis a site visit, provision of the outline design drawings along with seven seminar presentations delivered by the internationally eminent mentors and organisers(c), further briefing(d) and models of the current proposals, prepared specially and emphasising some impacts at human scale were provided. Participants were formed into three professionally balanced teams and over two and a half days, prepared three design strategies that responded to the climate change and coastal defence brief; exploring propositions for both local and global application. The teams were encouraged to consider divergent theoretical design viewpoints based on their synergies.
This first stage of the Elephant Cage concluded with a public presentation and debate of the three proposed schemes, at which key stakeholders and the public were present.

Analysis
The analysis contributed a valuable context for the design research and the following critiques were raised.

Figure 5. 1:1 scale model (with inset sections) of existing ESCP proposals showing the height of the proposed sea defences in 5 locations indicating the impact on existing landside views and access towards the sea along the Portsmouth Southsea frontage. (© Russell Gould & Walter Menteth)

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(c) Martin Knuijt (Director OKRA, Landscape Architects), Matthijs Bouw (Director One Architecture), Nick Clarke (Director Ramboll), Sophie Thompson (Director LDA, Landscape Architects), Julia Barfield (Director Marks Barfield Architects), Indira van t’Klooster (Architectucur Lokaal) and Walter Menteth with Anna Berkman. Frank de Graaf and Alexander Lee (Royal Haskoning DHV) provided additional mentoring

(d) Including a presentation covering the public authorities existing engineering led proposal, by Zane Gunton (Eastern Solent Coastal Partnership) the participating representative of the commissioner’s
The separation of the promenade, beach and sea from Southsea common and the city to the north were considered detrimental. In most parts a wall, with limited access over it, would be apparent from the landside severing the city from connecting fluidly with the coast. This wall was found to rise up to a height of 3.8m, was not well integrated to the landscape character or urban context on its landside and blocked views of the sea (Figure 5).

Various implications arise from the extensive use of concrete hard-wall engineering solutions. As opposed to alternative coastal defence typologies concrete constructions using terraced sea walls, may incur higher CO2 emissions and whole life costs, whilst delivering a coastal frontage that can be less hospitable and poorly accessible for all, especially children and the elderly. To maintain them they can require extensive water jet and biocide cleaning.

Small listed structures such as wind shelters, seats and monuments despite their relative ease of relocation were being treated as fixed edifices establishing immovable points of reference in the proposed plans. Similarly roads running parallel and immediately adjacent to the coast line and serving the beach were impacting the available sea defence options because it appeared they were also being addressed as unchangeable elements.

Rather than giving consideration to any more nuanced contextual approaches including coastal realignment, the ESCP design was pre-determined by an early policy decision to ‘hold the line’, which notably was impacting the strategic designs, the sustainability and whole life cycle costing.

The outline proposals were prepared within strict Governments budgetary constraints, with little extension of the scope of works through leverage, and had advanced to HM Treasury Green Book stage two (The Outline Business case). In part these funding limitations, the remit, its outputs and programme could also be seen to have had an impact.

Southsea common is 0.5km wide between the sea front and the city and is a unique area of largely open land which when considered conjunctively with the sea defences appeared to offer further and better opportunities.

Given the extensive investment to be committed there appeared opportunity and capacity for leveraging more enhancement from the proposals including the potential for improving the waterfront environment, amenity and promenade by better integrating landside architectural and landscape projects with the proposed engineering requirements.

**INITIAL OUTPUTS**

In responding to the programme the three teams entitled ‘Awake, Asleep and Dreaming’, ‘The New Common’ and ‘Dancing Coastline’ prepared their outputs which reflected their distinct approaches. Their detailed presentations are as described in summary below."
'Awake, Asleep and Dreaming'
Rather than having a single line of defence, three separate lines of defence are proposed, referred to as Awake, asleep & dreaming, and reflecting their degree of active protection. Unique scenarios develop in adaptive relationships in the interplay and spaces between these three lines of defence as their relative positions vary along the coast (Figure 7).

The asleep line comprises the outer most defence line, locating off shore elements in the form of reefs and barriers designed to absorb and dissipate the most severe wave energy. Over time this is sustained by natural processes of deposition, strengthening and enlargement (Figure 8).

The second ‘awake’ line of defence comprises interventions creating inhabited barriers and functional infrastructure sustaining economic activity on the sea front; which might for example include beach huts, lidos, kiosks, stadia seating on levees, water capture cisterns and tunnels.

The third defence line ‘dreaming’ proposes linear landscaped berms and levees as the final defence line so that this may enhance wider social and community activity; which might for example include performance bowls, skate board parks and undulations providing amenity landscape offering increased environmental value.
'The New Common'
In their sea front character assessment and analysis of the coastal conditions this team identified three varied conditions along the frontage and responded with three strategic approaches one for each of the identified conditions (Figure 9).
At Southsea common it was proposed to raise the common upwards to create an undulating naturalised coastal landscape; creating opportunity to re-profile the coast so that a usable beach front would, once again, be achieved. Easy access to the beach is provided over a re-landscaped common now located at a higher level; with additional amenity both above and below it and potentially rich environmental benefits. The space beneath this ‘new common’ offered opportunity for a wide range of black box activities, conference centres, cinema, leisure, service circulation and parking functions delivering economic sustainability and contributing towards the city’s regeneration. The successful scheme at Katwijk in the Netherlands recently completed by OKRA Landscape architects, provided a reference for this design, landscape and economic modelling (Figure 10). This new defence line then continued with a hard engineered levy around Southsea Castle.
To suitably enhance the existing Eastney beach to the east, beach replenishment and enlargement was...
proposed, extending the shoreline outwards. Shingle dredge excavated to keep the existing ports mouth navigation channel clear for shipping was found suitable; but this is currently transported overland for beach replenishment to the UK east coast (at great expense and environmental costs). In the ESCP designs rock armour was proposed, for example for new groynes, and this was to be quarried and imported from Norway. This replenishment strategy, while significantly contributing towards defence and sustaining the potential ecological, social amenity and economic benefits, might also develop a more efficient circular economy.

'Dancing Coastline'
This team perceived it to be crucial to develop realistic expectations from coastal management over the long term in response to the inevitability of change. Their proposition for appropriate and incremental interventions, postulated a dynamic ‘dancing’ coastline which would change over time, requiring delivery of salient ‘precision work’, utilising multiple modes and approaches, involving stakeholders and engaging with both defend and retreat strategies. A landscape scenario for a 100 years hence was proposed, embodying for example the identification of protected and higher ground, based on enhancing the uniqueness of places and character over the projected timescale along with the principles of re-flooding (Figure 11).

In proposing that land could be lost to the sea, whether over 100 years or during particular storm events, it was considered that public education, expectations and landscape management might be better unlocked; on the premise that a defence strategy demarking a singular line of public safety offered reduced flexibility, and that greater benefit might derive from some permanent or temporary loss of land. Those areas would then over time contribute more effectively to mitigating storm and surge energy. It was considered that two such proposals that might deliver more appropriate and effective solutions were allowing flooding into Canoe Lake and also parts of Southsea common. These illustrated how circulation and amenity might then be addressed across the public realm in this retreat strategy (Figure 12).
Interim findings
This research has identified initial sea defence design and policy parameters having potential application both for guiding wider city coastal resilience and sustainability globally, whilst informing improvement in Portsmouth. From the first stage the following summarises some parameters for coastal design strategies in urbanised locations that lead beyond simple hydrological and engineering led solutions.

Strategic design parameters for coastal strategies
Instigating more contextually specific investigations by wide ranging early inter-disciplinary collaborative practice to reframe progressive discourse can permit conceptual innovation and co-creation that better informs sustainable design, practice and implementation.

The character and context of the sea should be well understood and evaluated from all available data and projections. For example this should include wave energy, predicted sea level changes, longshore drift, surge probabilities, sediment availability, coastal dynamics, alignments and processes, ecology, maritime traffic, geology and movements, seasons, temperature and salinity, and anticipate the long term energies and changes impacting coastal locations. Hinterland analysis of the wider landside character and topography, and its environmental, social and economic context is necessary to fully optimise coastal response strategies allowing interventions to be better tailored to their context (not simply along a narrow sea front margin). In dense urban areas particularly it must be recognised that waterfronts provide multiple social benefits for all ages for example for amenity, health, well-being and leisure, sustaining considerable economic benefits. These should be valued both qualitatively and quantitatively.

CO2 emissions are evidently impacting sea levels rises and should be given greater consideration in coastal design strategies. CO2 production, mitigation, and whole life embodied energy should be particular considerations when designing coastal defence structures accounting for all factors...
including: materials, the supply chain and ecological values. Designs creating lower CO2 emissions and having lower embodied energy should be better valued.

To ensure designs are robust in the long term when evaluating risks in urbanised areas it is advisable to allow for sufficient contingencies based on a broader range in the progressing trends of data forecasts underpinning anticipated sea level rises. Some forecasts now being applied might be considered conservative, particularly in the UK. Reviewing these upwards in areas of high population could be advisable.

In the management and expectations of sea level change it is possible to implement more appropriate and more incremental interventions through improved governance, education, consultation, engagement and programming for having, over time, more resilient and adaptive coastlines. Frontage margins that may permit re-profiling the coastline section or allow some partial or full future inundation, should be considered and where-ever possible sufficient margins should be allowed and/or planned. When dissipated over a wider surface area the sea’s energy maybe reduced proportionally and more sustainable benefit may also derive.

Rather than adopting a single line of defence thought should be given to staggered defence lines, considering the opportunities and benefits which might accrue in the intervening spaces and/or sacrificial areas, and the possibilities that the lower heights of defence structures can offer more complimentary alternate functions. When building a reef, levee or wall fully consider what further opportunities may arise. For example can energy be productively captured and used, and what additional benefit may derive above, within or beside the element.

Raising and lowering land levels, and extending sea fronts might be considered, with more nuanced deployment of all potential attack, defend and retreat strategies in synergy. When well designed, raising land levels in dense urban areas can provide significant opportunities with areas below grade suited to ‘black box’ functions.

Existing environmental, social and cultural assets should be reviewed holistically over the whole life of an anticipated project, with substance given to adaptive repurposing of such assets within sea defence strategies. Adaptive repurposing of the existing foreshore topography might also be considered.

Existing infrastructure might be better reviewed with greater flexibility and consideration given to their mobility and/or relocation. Fixing coastal defence lines for the next 100 plus years on the basis of existing roads, promenades or small civic monuments clearly may not be most effective. Coastal access, circulation and its porosity should therefore be considered and reviewed holistically. For example vehicular circulation organised radially to the line of the coast may offer more sustainable future solutions than roadways aligned parallel and in close proximity to the coast, because radial routes can then be foreshortened.

Coastal pedestrian, bicycle and service routes need not be conjunctive or adjacent, and segregation may benefit landscape, ecological, environmental, health and safety concerns. Access to the waterfront should seek to offer maximum landside connectivity with safe, unencumbered and step free access for all ages, wherever possible. However where safe alternative routes can also be provided during times of inundation coastal promenades do not always need to be above high water level. This might be considered similar for example to the way people can choose to freely walk anywhere on a beach.
Proposed coastal strategies should be economically modelled over their whole life cycle and where investment is more widely integrated in a sustainably contextual long term spatial design strategy, sea defences infrastructure may deliver broader benefits. With public investment better value resolutions may be sustained where there is opportunity for leveraging forward additional private funds. For example when building a wall, levee or reef - for providing additional benefit make it attractive for forward investment.

CONCLUSION
The Portsmouth Elephant Cage scope, process, programme, design briefing and seminars significantly contributed to enhancing knowledge exchange, skills transfer, the development of cross disciplinary professional expertise and co-creation. The collaborating professionals, mentoring and support by masters students, brought forward a wide range of creative propositions providing valuable new insights having global and local relevance, with the international engagement expected to extend capacity and the reach of the programmes outputs.

The first stage outputs having been reviewed and continue to be disseminated alongside the web resource that has been developed, to inform better design practice elsewhere. These may also contribute to enhancing the opportunities for a strategic design vision for Portsmouth's frontage.

By considering a wider conceptual field within a competitive co-creation process engaging multi-disciplinary teams and drawing upon best practice and exemplars, provided fresh and enriching insights. Through embodying innovations that better inform social, environmental and economically contextual resolution, the outputs underlined the infrastructure's potential, extended research inquiry and informs practice. By pursuing polemically different strategic propositions creatively the three alternatives have highlighted more resilient and sustainable designs principles.

The divergent but complimentary outputs generated at the Elephant Cage, while offering hypothetical shifts, can be seen as having a wider strategic relevance extending beyond application to a specific context. Yet the individual lack of specificity was a contextually pragmatic weakness. With the participants having more time and immersion to consolidate their outputs a more direct Portsmouth specific practical applications might have been delivered on programme completion.

Comparative studies of two different recent coastal management scheme designs at Katwijk and Schreveningen (NL) and blue-green strategies within Rotterdam along with further seminars delivered by local experts and stakeholders were undertaken in the second programmed stage. The stagings might have been better reversed but for functional necessities. Finally the process and outputs were further appraised against real and theoretical situations and feedback.

Nonetheless key principles derived from The Elephant Cage’s strategic outputs have subsequently informed an alternative more detailed sea defence alternative design proposition on Portsmouth’s Southsea front, radically different to that of ESCP. Launched in June 2017, this was publically presented and exhibition in July 2017 at the Portsmouth Grassroots Festival and is reported separately. After publication interest from the community, the public authorities and their representatives, in response, had generated a paradigm shift in the perception of opportunities and benefits that may be derived from Portsmouth’s sea defences. To inform Portsmouth’s design practices it would also clearly have been better for the clients to have resourced and have had...
implement this Elephant Cage process of ‘parallel commissioning’ at commencement of their own design investigations.

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