EAST BOSTON BUFFER: A TRANSFERABLE URBAN FRAMEWORK FOR ADAPTING TO SEA RISE

by Carolyn Jenkins

B.S., Architecture (2007)
University of Virginia

Submitted to the Department of Architecture in partial fulfillment of the requirements for the degree of MASTER OF ARCHITECTURE at the MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

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Signature of Author:..
Department of Architecture
January 17, 2013

Certified by: ....
Andrew Scott
Associate Professor of Architecture
Thesis Supervisor

Certified by:...
Takehiko Nagakura
Associate Professor of Design and Computation
Chair of the Department Committee on Graduate Students

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THESIS COMMITTEE

Andrew Scott, BArch
Associate Professor of Architecture
Thesis Supervisor

James Wescoat, PhD
Aga Khan Professor

John Fernandez, MArch
Associate Professor of Architecture and Building Technology and Engineering Systems

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ABSTRACT

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Urban vulnerability to climate change is constantly increasing. Many coastal cities will need to begin sea rise mitigation efforts soon, and now is a critical time for architects to intervene in this process with good design that takes on the issue of sea rise in the city, not just as a problem but as an opportunity and catalyst for change.

Data published in August 2012 revealed that the US East Coast is experiencing a rate of sea rise that is four times the global average. The city of Boston in particular has a high percentage of flood-prone areas due to the city's dramatic history of landmaking. Of all the neighborhoods comprising Boston, the often-overlooked neighborhood of East Boston is the most flood-prone. The project is site-specific in that it is sited in the context of East Boston, but the design methodology and synthesis of technologies serve as a prototype to be applied to any urban waterfront.

This thesis project address the issue of sea rise in an urban context as a unique condition related to the construction a sustainable environment. In order to meet seemingly contradictory need for sea rise defense and capacity for future urban growth, the project reconsiders waterfront architecture as a new hybrid of architecture plus infrastructure as a means of building resilience and addressing scientific uncertainty.

The project establishes a systematic approach to a layered buffer zone that mediates between the sea and the vulnerable urban fabric of East Boston. The buffer is conceived of as a framework for future development that balances energy collection, environmental enhancement, and social enrichment through the allocation of productive, inhabitable, and recreational spaces within a defensive landscape. Through careful orchestration and layering of multi-disciplinary sea rise mitigation tools, the designed framework projects a new future for the urban waterfront – one that promotes social as well as physical resilience and adaptability in an ever-changing coastal environment.

Thesis Supervisor: Andrew Scott
Title: Associate Professor of Architecture

ACKNOWLEDGEMENTS

Thank you to my advisory committee for helping me navigate this immense topic. Andrew, thank you for encouraging me to keep track of the bigger picture and maintain clarity on an already complex topic. Thank you Jim for helping me keep my threads of reasoning relatively untangled. Thank you John, for your encouragement and insight despite the distance.

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Thank you Mom and Dad for your unfaltering support.

To Joe, thank you for everything.

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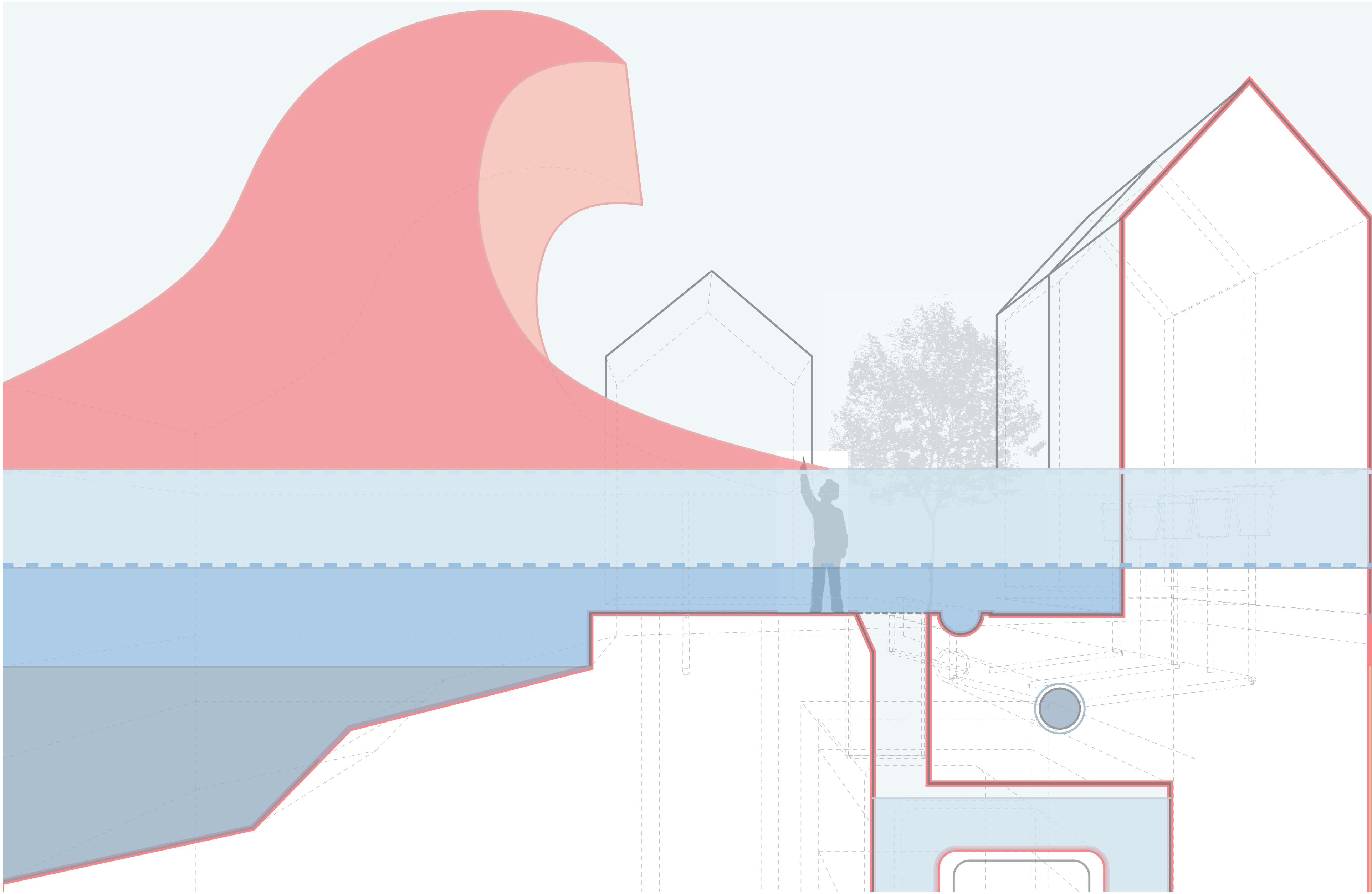


EAST BOSTON BUFFER:

A TRANSFERABLE URBAN FRAMEWORK FOR ADAPTING TO SEA RISE

WITHOUT THE INVESTMENT OF SEA RISE MITIGATION INFRASTRUCTURES, CITIES WILL FIND THEMSELVES REPEATEDLY PAYING FOR DISASTER CLEANUP.[1]

1. Hunter, Marnie and Hetter, Katia, *Transit systems struggling to restart.* CNN. Updated 12:55 PM EDT, October 30, 2012. Accessed online November 5, 2012. http://www.cnn.com/2012/10/28/travel/tropical-weather-transportation/index.html

1.0 - INTRODUCTION

> **DEFINITIONS:**
>
> **Hazard:** a natural possible source of danger.
>
> **Disaster:** an occurrence causing widespread destruction and distress including total failures and misfortunes of human actions[1]. Disaster is the introduction of humans into a hazard situation.
>
> **Risk:** likelihood of a disaster based on vulnerability probability based on exposure to hazards.
>
> **Sea Rise:** This project includes both thermal expansion and ice cap melting to arrive at 2 Meters (M) by 2100. The latest IPCC (2007) predicted a 0.6 M-1.4 M sea rise by 2100 and only considered thermal expansion.
>
> 1. Inam, Aseem. *Planning for the Unplanned: Recovering from Crises in Megacities*. New York: Routledge, 2005. Print.

PROJECT APPROACH & SCOPE

As much as two meters of sea rise is expected by 2100. Such a gradual rise over the course of a century may not seem like a big deal, but when coupled with urban population growth and increase of severe storms, coastal cities - especially on the U.S. east coast - are sitting at a critical time where decisions need to be made about how to develop their waterfront. The conflation of these issues makes for a complex context for an architectural project. This project has been cognisant of these tangential issues, but explicitly not taken them on in a detailed way. The focus of the project is strictly how to manage sea rise urbanistically and architecturally by creating a performative and adaptive environment for inundation that creates physical framework for buildings and spatially provides places for social activation and participation.

CROSSING DISCIPLINARY BOUNDARIES

The design of an effective infrastructure is inherently complex and multi-disciplinary. This thesis argues that ultimately the effectiveness of such infrastructure in a city is tied to it's experience as part of the urban environment. As an architecture student, I do not endeavor to become expert at the myriad specialties that would be required to weigh in on such a project in the 'real world'. To keep the project in the realm of architecture, the approach of this thesis was to begin with a research phase (refer to sections 2, 6.1 and 6.4 for work from this process) for developing a sufficient understanding these disciplinary tools to incorporate them in a strategic urban plan.

This complex problem of how to manage sea rise in an urban context has challenged experts as well. So far, the myriad of proposed solutions in cities and countries around the world have yielded disparate results. Generally, these projects are approached as single discipline endeavors. One such case which displays the inadequacy of such an approach is currently underway in the Maldives. The Maldivian government is implementing two concurrent and very different initiatives. The following section looks at the single disciplinary approaches being employed in greater detail and draws lessons from them - resulting in the argument for the layered strategies this thesis promotes.

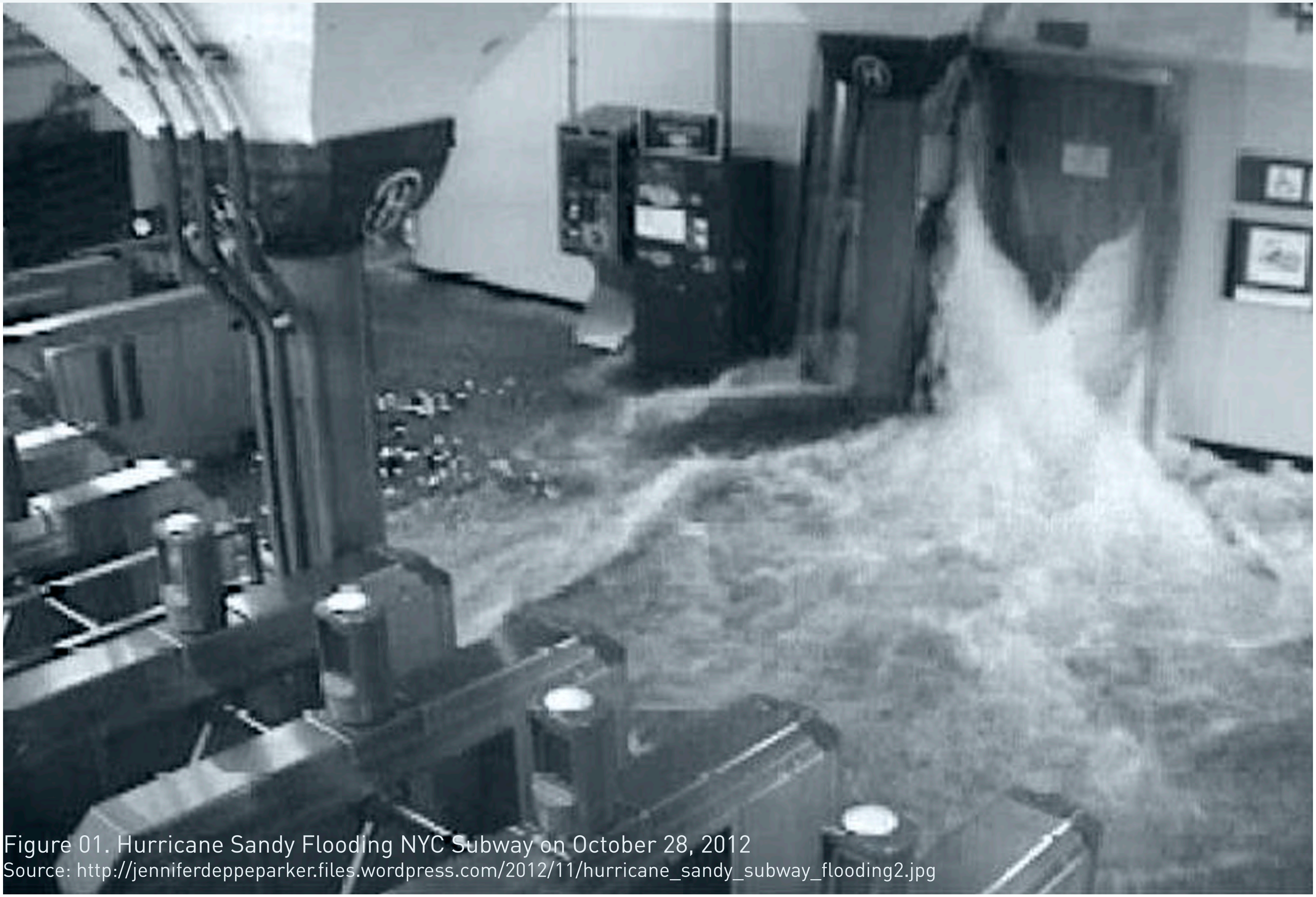


Figure 01. Hurricane Sandy Flooding NYC Subway on October 28, 2012
Source: http://jenniferdeppeparker.files.wordpress.com/2012/11/hurricane_sandy_subway_flooding2.jpg

MALDIVES CASE STUDY

The Maldives have been on the forefront of sea rise and climate change in the media as well as design and related industries trying to tackle the problem of sea rise. The country has become a testing ground for methods to adapt an existing urban condition to sea rise. So far there have been two sea rise mitigation strategies implemented by the Maldivian government, both of which are currently on-going.

The first is the Safer Island Development Program' (SIDP) which identified 10 of the Maldives islands as more valuable (more urban) and sets them as safe havens for the population[1]. These islands are receiving hard infrastructures such as sea walls and desalination plants. SIDP has already led to severe destruction of existing natural capital. Dredging to create sandbars and erect seawalls is unintentionally weakening coral reefs and soil stability - natural shields against storm swells and surges.

In response to these issues, the Mali government has initiated a second program, 'Integrating Climate Change Risks into Resilient Island Planning' (ICCR). ICCR is a bottom-up approach of building capacity among local policy makers and communities to implement soft infrastructure projects.[2] These projects include: replenishing natural ridges, afforestation, enhancing the island drainage system, restore vegetation along the shoreline, repair breaches in coral sea wall, planting mangroves and beach nourishment. These are all what I define as landscape tools.

Neither approach has a promising future, urbanistically speaking. The former removes buildings from the waterfront, separating the city and the sea. The latter doesn't facilitate buildings at all. It is a retreat, which cedes more and more property to the sea over time. Most cities around the world cannot afford to take either approach.

1. Adaptation Learning Mechanism. *Integration of Climate Change Risks into the Maldives Safer Island Development Programme,* http://www.dev.adaptationlearning.net/project/integration-climate-change-risks-maldives-safer-island-development-programme. Accessed December 2, 2012.

2. Sovacool, B.K. "Hard and Soft Paths for Climate Change Adaptation." Climate Policy. 11.4 (2011): 1179. Print.

URBAN POPULATION GROWTH

Coastal areas are the most developed in the nation. This narrow fringe– only 2% of the nation's land–is home to more than 17% of the US population. Coastal population is increasing by 3,600 people per day, a projected total increase of 27 million people between now and 2015.[1] The region's projected growth from 2010-50 is 35.2% (18.4 million people).[2]

Sources: 1. http://state_of_coast.noaa.gov/bulletins/html/pop_01/pop.html, 2. http://www.america2050.org/northeast.html

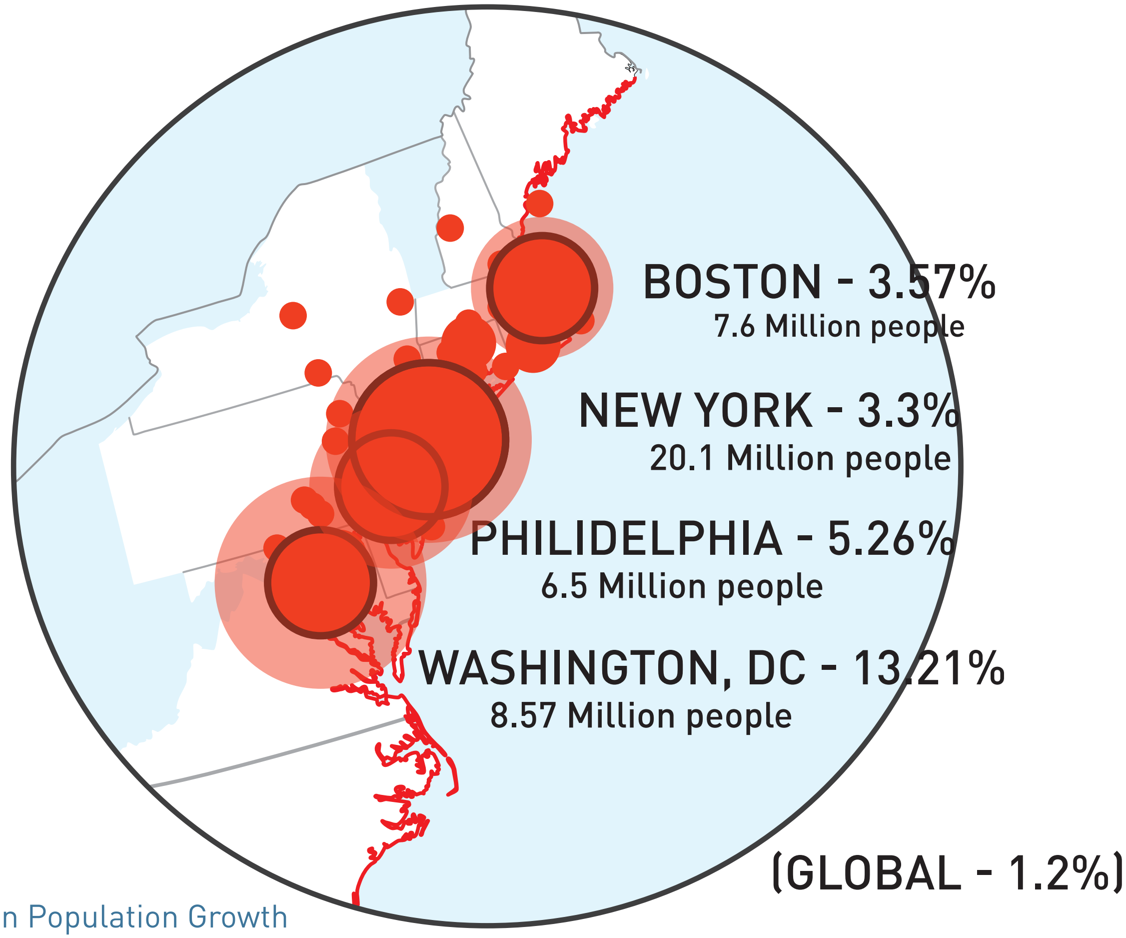


Figure 02. Northeast Megapolis Urban Population Growth

COASTAL DESIGN NEEDS A NEW TYPOLOGY

URBAN SEA RISE VULNERABILITY

The stakes are too high for trial and error sea rise mitigation tactics. Coastal cities need a framework for long-term resilience that provides some continuity between the city and the sea. The public right to waterfront access as well as safety is long-valued and too precious to throw away in the face of climate change. In the book *Disasters by Design*, Dennis Mileti argues that we need to move beyond current dichotomous measures for mitigation, like those used in the Maldives, which have a pattern of (1) staggering monetary losses from disasters still increasing, (2) simply postponing losses that will be more catastrophic when they do occur and (3) result in even short term or cumulative environmental degradation and ecological imbalance, which, besides being detrimental to society, also contributes to the occurrence and severity of the next disaster.[3]

There are three main reasons why urban areas are particularly vulnerable to sea rise. First, historic development has led to large ares of low lying ground (Figure 05). Second, the dependence of buried and centralized infrastructures - the hazards of which were recently seen in New York City when Hurricane Sandy hit (Figure 01). Third, the lack of a physical buffer or capacity for flooding. There is no where for the water to go, so when a flood occurs, it is never welcome.

On the US East Coast, urban vulnerability is partly due to coastal cities development history. The US 'Northeast Megapolis' (refer to Figure 02 - the cities of Boston, New York, Philadelphia and Washington, DC) has a dramatic history of transformation along the waterfront: construction, demolition, and reconstruction – destroying natural flood buffers for the sake of physical and ultimately economic growth. In Boston, for example, the land-making process has completely transformed the coast- wharfing out by 300% - from 16mi^2 to 48mi^2 (Figure 03).[4] The areas of land that have been added

> BOSTON'S POPULATION IS EXPECTED TO INCREASE **120% BY 2100.**[1] MEANWHILE, EUSTATIC RISE (SEA RISE) COULD REVERT THE CITY TO IT'S **1880 SIZE!**[2]
>
> Sources: 1. Kirshen, Knee, and Ruth, *Climate Change and Coastal Flooding in Metro Boston*, 2008, p. 453.
> 2. *Mapping Boston* / edited by Alex Krieger and David Cobb, with Amy Turner, 1999,

3. Mileti, Dennis S., *Disaster By Design: A reassessment of Natural Hazards in the United States*. P. 24.
4. Seasholes, Nancy. *Gaining Ground: A history of land-making in Boston*. Cambridge: MIT Press, 2003.

BOSTON SEA RISE = 4 x GLOBAL AVERAGE

Data published in August, 2012 revealed that the US East coast is showing faster than average and faster than previously anticipated sea rise. This has led to city planners in Boston finally declaring that sea rise was a 'Near Term Risk' in August, 2012.[1]

Source: 1. http://www.npr.org/2012/08/21/159551828/boston-plans-for-near-term-risk-of-rising-tides

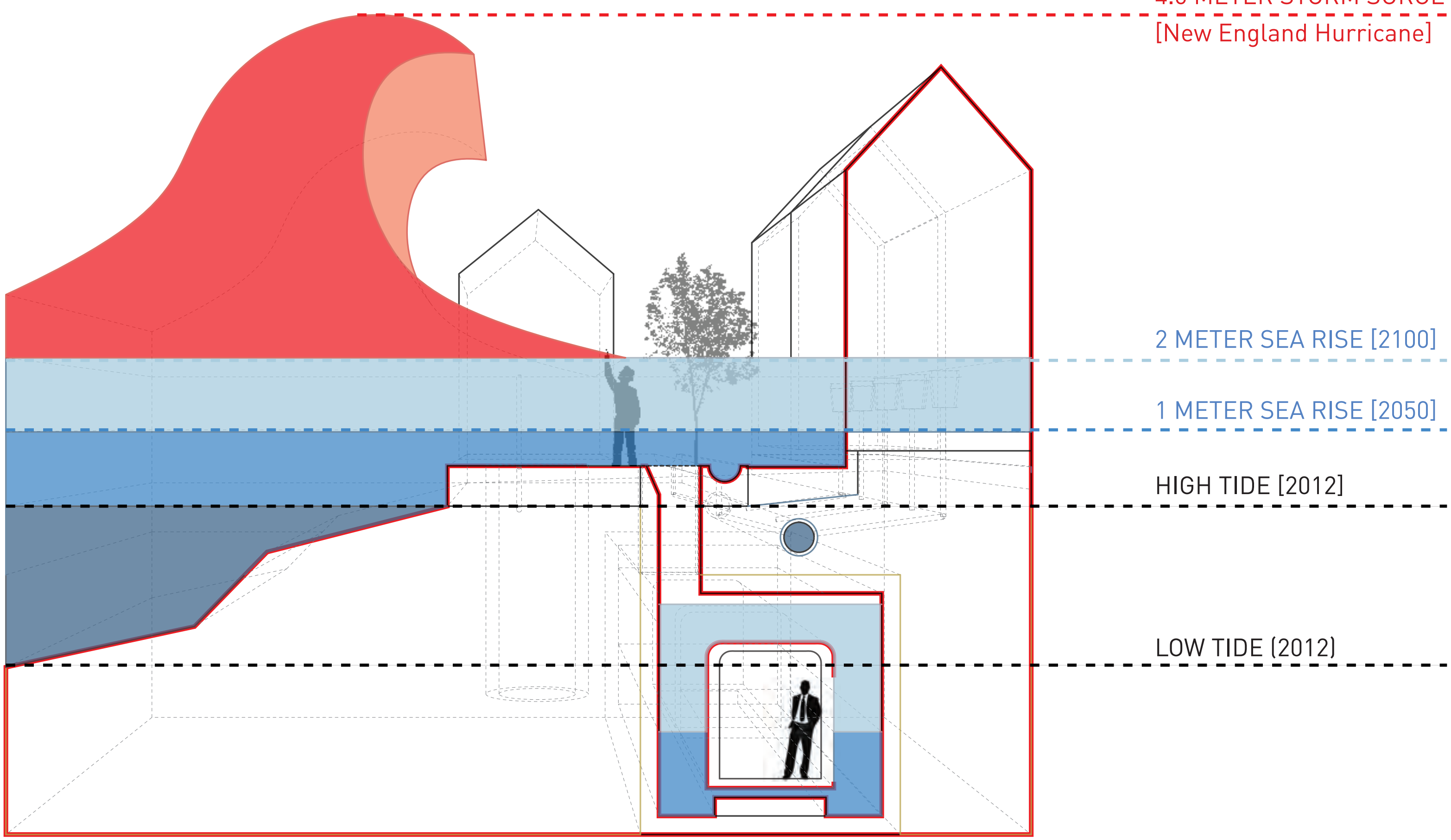


Figure 03. Urban Sea Rise Hazards

PROGRAMMED TO WORK WITH FLOODING

are just above sea level. Given that sea rise due to climate change is expected to reach as much as 0.6 meters by 2050 and over 2.0 meters by 2100, the city as a whole could revert to it's 1880 size (Figure 05).[5] More than 30% of the neighborhood of East Boston would be submerged at high tide (not to mention storm surge).

Historical waterfront projects not only represent areas of risk for cities, but also demonstrate a capacity for large-scale transformation of the water's edge. If designed thoughtfully, sea rise preparation has the potential to be the next phase of their waterfront development lineage. The urban waterfront territory has historically been and can continue to play a critical role in the coastal city's economy and identity.[6]

PHYSICAL & SOCIAL VULNERABILITY

Especially within these low-lying territories, mitigation strategies need to address the ramifications of hazards including land loss, disrupted linkages in transportation networks, and increasing threat of storms to private and public property due to climate change. As seen in NYC during Hurricane Sandy on October 28, 2012, underground public infrastructure systems like subway become very vulnerable to flooding and dependent on effective local scale flood defense strategies. Without the investment of sea rise mitigation infrastructures, cities will find themselves repeatedly paying for disaster cleanup.[7]

Similar to complex infrastructure networks, interwoven economic and social ties make cities more vulnerable to sea rise than less densely populated areas. The success of cities is measured by economic growth. Agglomeration benefits due to proximity of activities to one another in a city create a complex web of interrelationships that extends

5. Eaton, Sam. *Sea Levels May Rise Faster than Expected*, Public Radio International, December 6, 2011. http://www.theworld.org/2011/12/sea-levels-may-rise-faster-than-expected/. Accessed November 9, 2012.

6. Desfor, Laidley, Stevens and Schubert. *Transforming Urban Waterfronts: Fixity and Flow*. 2011, Routledge, New York, NY.

7. *Transit systems struggling to restart.* Marnie Hunter and Katia Hetter, CNN. Updated 12:55 PM EDT, Tue October 30, 2012. Accessed online November 5, 2012. http://www.cnn.com/2012/10/28/travel/tropical-weather-transportation/index.html

CLIMATE CHANGE AND STORMS

It is essential to understand the landmaking history of Boston and have a sense of the timescale at hand to inform future decisions. It also shows how short-term planning needs to be part of a wholistic plan that takes into consideration future risks. This thesis project will focus on the main sea rise prediction benchmarks of 2050 and 2100 for planning projections.
Source: http://state_of_coast.noaa.gov/bulletins/html/pop_01/pop.html

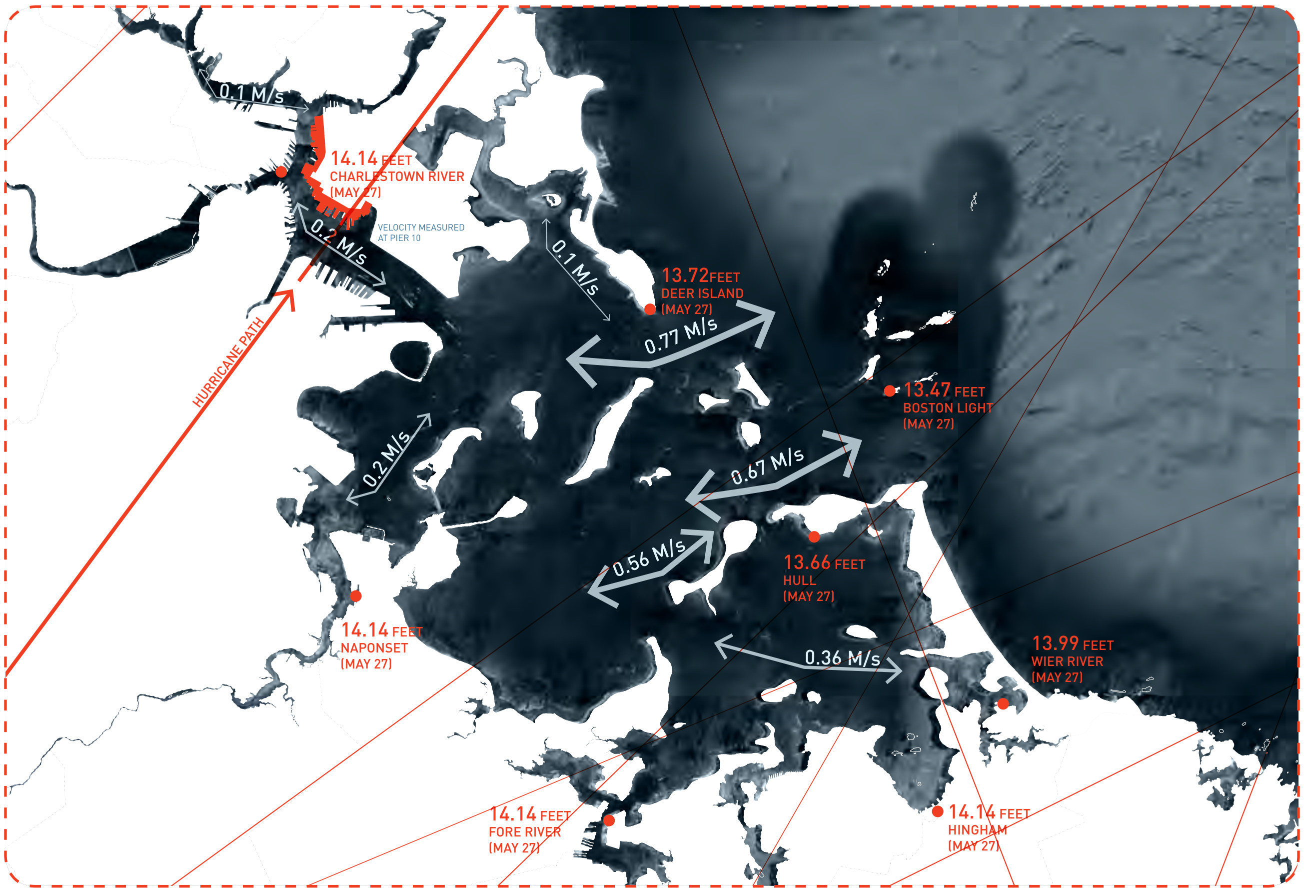


Figure 04. Boston Harbor Risks (Water Depth, Velocity and Storm Paths)

& ADDRESS LOCAL NEEDS FOR RESILIENCE

into current and future flood-prone areas. If unaddressed, sea rise could result in productivity decline and negative economic repercussions of land use shift (refer to section 3.0 for land tenure mapping studies).[8] In addition to high economic cost, urban population growth is anticipated to continue and put pressure on cities to continue to allow development in vulnerable waterfront areas. The influx of people need a place to live and work and it is in the city's financial interest to grow. This pressure could exacerbate the aforementioned social vulnerabilities.

The slow-onset of sea rise due to climate change makes it less prominent in media and less of a priority to citizens than other more visible safety concerns. Chronic effects of sea rise can lead to greater vulnerability because they are more readily dismissed than catastrophic effects of storm surges from hurricanes. The media coverage of recent coastal storms like Sandy, Katrina, and Ike has begun to raise public awareness to the hazard of coastal living. There has been increasing momentum to taking defensive action along the East Coast at a government level. The sooner action is taken, the better, and more likely that the solution will be able to adjust to climate change in a way that dovetails with the urban context (unlike what has been done in the Maldives).

CONCLUSION

We can see that the sum of sea rise vulnerability in the city is a combination of physical and social layers of vulnerability. Such a layered issue inherently demands a layered response. This thesis posits that within the emerging sea rise resilience discourse, what is missing in city context is a means of simultaneously address the needs for resiliency and development capacity. In the urban context, the question is not whether to develop the waterfront, but how. Productive coastal defense will require the hybridization of mitigation tools to create a multi-layered framework for physical sea rise resilience. Social resilience is enhanced by accommodating future development. In this way, the anticipation of climate change can become a catalyst for innovation. This outcome will not happen by chance. Individuals, communities and institutions must choose to make this happen and take action soon.

> HISTORIC STORMS HAVE DELIVERED SURGES AS HIGH AS **4.6 METERS** TO THE BOSTON COASTLINE (FIGURES 3, 5,6)![2]

8. Ghosh, S. N. *Flood Control and Drainage Engineering*. 2nd ed. Rotterdam ; Brookfield, VT: A.A. Balkema, 1997.

BOSTON LANDMAKING & WATERFRONT HISTORY

It is essential to understand the landmaking history of Boston and have a sense of the timescale at hand to inform future decisions. It also shows how short-term planning needs to be part of a wholistic plan that takes into consideration future risks. This thesis project will focus on the main sea rise prediction benchmarks of 2050 and 2100 for planning projections.
source: http://state_of_coast.noaa.gov/bulletins/html/pop_01/pop.html

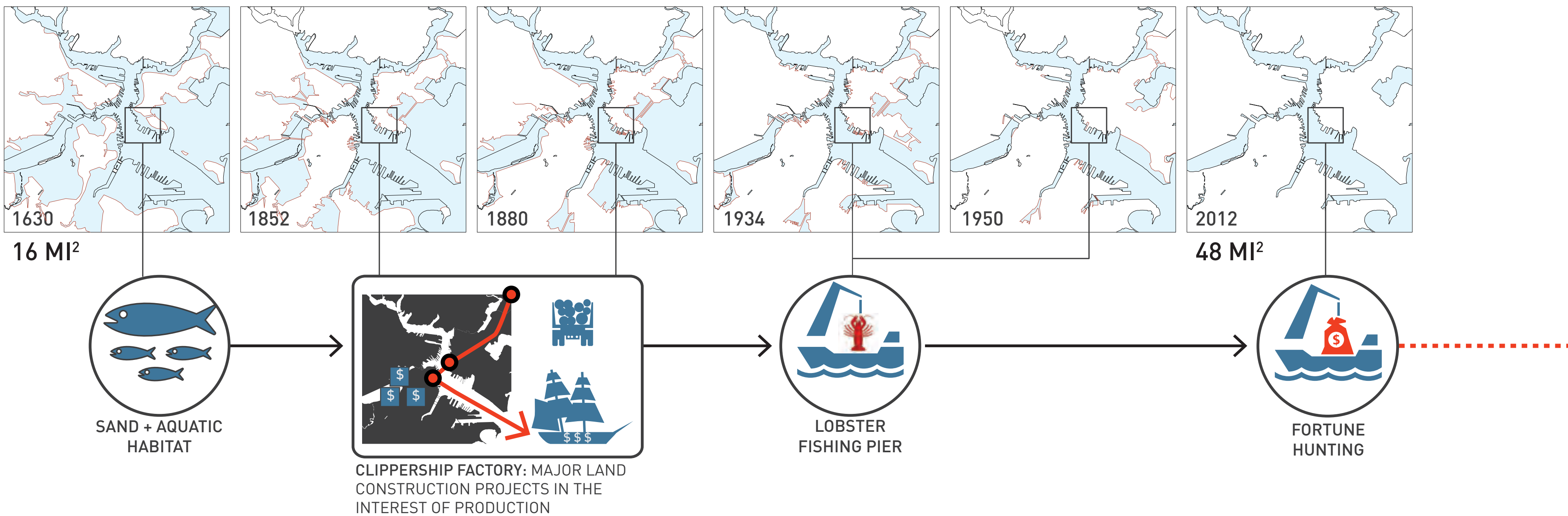
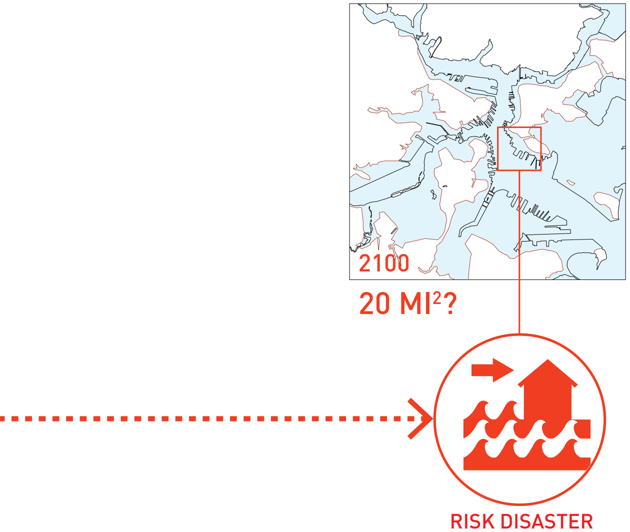


Figure 05. Boston Landmaking History

1.2 - INTRODUCTION



The following chapters of this book build a methodical framework for selecting and evaluating combinations of sea rise mitigation strategies that can be applied to work with urban waterfront development in a productive and urban lifestyle enhancing way. Section 1.3 will look at the regulatory framework that helps understand the areas of vulnerability in the city. Chapter two builds an understanding of what it means to be resilient and adaptable as goals for urban sea rise mitigation systems. Chapter three takes on the specific urban context of Boston and the neighborhood of East Boston to observe layers of urban vulnerability and develops parameters for building resilience. In chapter four these criteria are applied to proposed hybrid methods of mitigation and speculates the resultant performance of hybrids of two or more of these approaches. Through the design of these hybrid typologies, Chapter five reflects on how well this thesis answers the question of how to make architecture in a performative environment for climate change.

THESIS QUESTION:

HOW TO MAKE ARCHITECTURE IN A PERFORMATIVE URBAN ENVIRONMENT FOR SEA RISE?

Sea rise mitigation action will soon be taken in coastal cities and NOW is a critical time for architects to intervene in this process with good design that takes on the issue of sea rise in the city, opportunistically as a catalyst to create a dynamic interface between city and sea.

1.3 - INTRODUCTION

EXISTING REGULATORY FRAMEWORK

There are guidelines in place at multiple scales that restrict development in flood-prone areas. On any given building site there are federal, regional, and local acts dictating the physical construction that can occur. Insurance costs in flood areas are also a very influential driver of coastal development. In that way, it building restrictions are partly governed by statistics and historic storm events. Building codes and legislation acts have been passed down through generations and are a form of collective memory and intelligence. They can be used to gain insight to some effective physical flood prevention measures that are already in place as well as the important role that policy will play in the urban resilience-building process. The main challenge of these regulations into future and their applicability to sea rise scenarios is their ability to accommodate uncertainty.

The Flood Control act of 1936 was the first federal regulation of floodplain. It established criteria for a project within a floodplain stating that the benefits 'must exceed the cost to whomsoever they accrue'. This was aimed at preventing the constructions that manipulate waterflow in ways that put other's property at risk. Prior to the act, local construction of dams had resulted in the flooding of other people's land. This law can be extrapolated to sea rise mitigation measures duty today to be considerate of the full impact such to ensure that local actions don't put others at risk either at present or in the foreseeable future (or has overcapacity for flood to accommodate uncertain future needs).

Today, a national level, The Federal Emergency Management Agency (FEMA) offers guidelines for construction in flood prone areas as part of the National Flood Insurance Program (NFIP). In order to receive flood insurance, structures must comply with their construction guidelines. NFIP 'Wet Floodplain Requirements Technical Bulletin 7-93' sets requirements for building within flood prone areas through their 'Wet Construction Guidelines'. Wet Floodplain Construction is a method of constructing structures that plan for the entry and exit of water into the construction (from foundations, floors, walls, finishes, and electrical). Aside from a few variances, such as seafood processing and other farming activities, the programmed space must be above floodwaters and <u>the wet areas</u> are reserved for parking and some storage.[1] However, they identify

1. Wet Floodproofing Requirements for Structures Located in Special flood Hazard Areas in

CONTEXTUAL TIMELINE - HISTORICAL

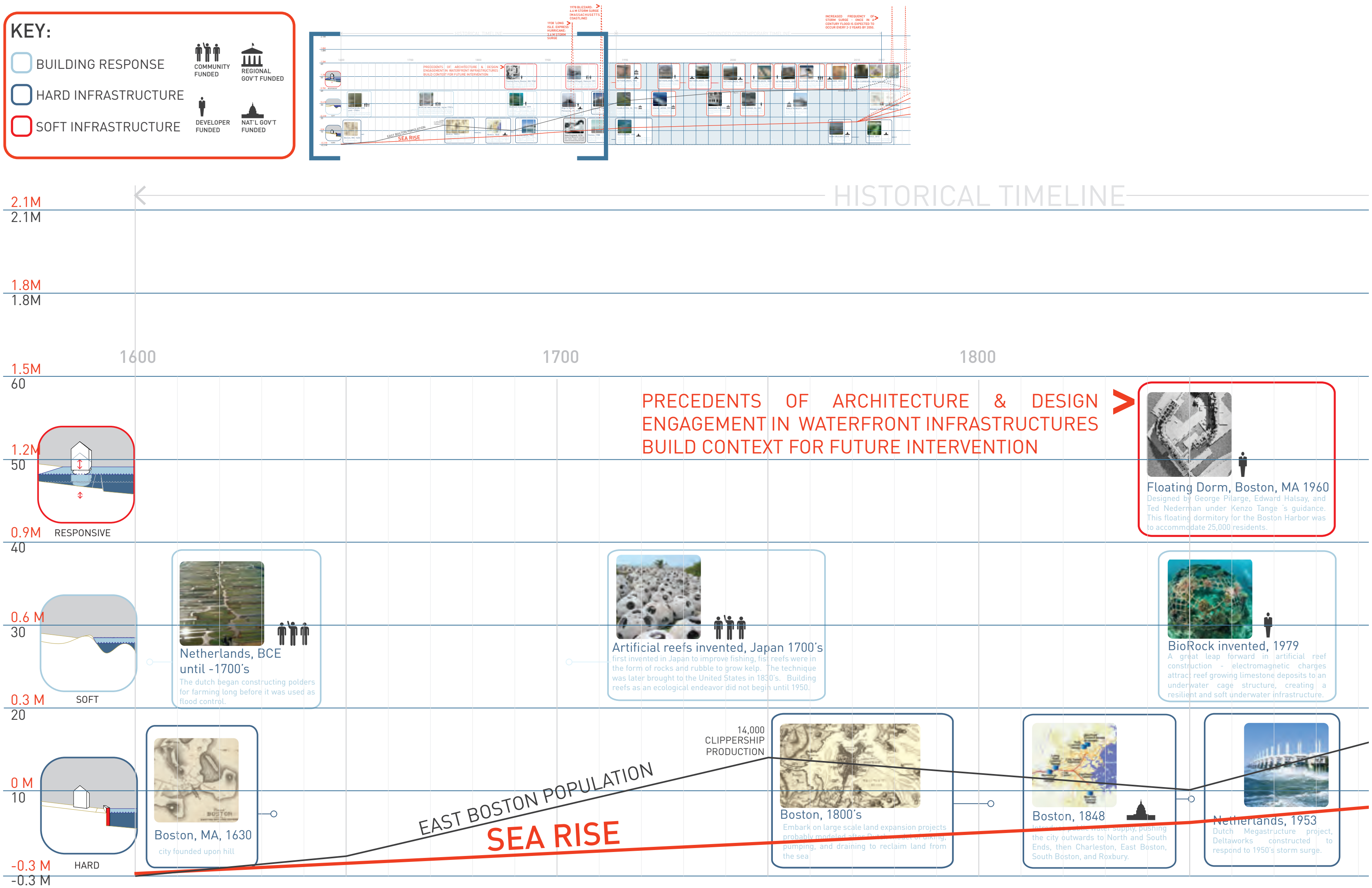
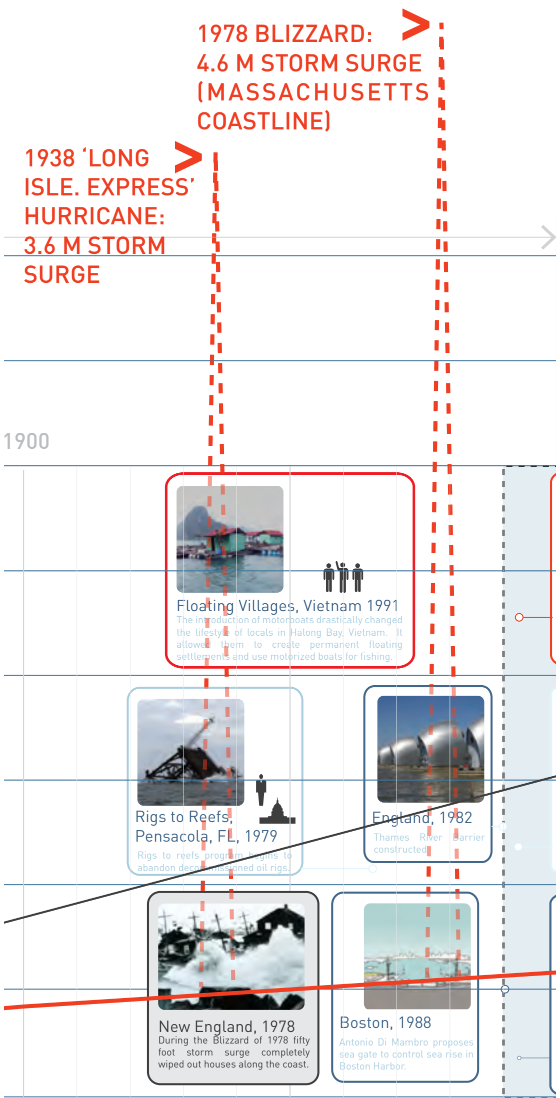


Figure 06. Historical Sea Rise Timeline

1.3 - INTRODUCTION



several exceptions where working within these guidelines do not suffice. For example, if the rate of rise of water is too fast for people to escape the site, the building must be relocated. This could be prevented if other measures are taken like using natural buffers such as wetland or planted areas to slow the inundation of floodwaters.

At a state level, building codes become an authority. Sections of the International Building Code (IBC) has been adapted by states to address flooding issues. For example, in Massachusetts, IBC codes 104.10.1 'Areas Prone to Flooding', 107.2.5 'Site Plan' and 110.3.3 'Lowest Floor Elevation', have all been altered to create more stringent restriction on development within flood prone areas.[2] Still, these codes will not suffice as flooding and storms increase in waterfront zones. Will need to amend these laws to anticipate increased frequency to build resilience and adaptability.

More locally along the Boston waterfront, the Massachusetts Public Waterfront Act, Chapter 91, takes precedent. The Act was adopted in 1866 and restricts waterfront developments with the aim to protect the Commonwealth of Massachusetts water bodies from environmental degradation and to preserve them as a publicly accessible asset.[3] By preserving public access, Chapter 91 encourages the public stewardship of these water's edge zones, thereby increasing collective sea rise and flood resilience. It also minimizes the variability of the waterfront zone and therefore the possibility that someone can develop the waterfront in a way that will adversely impact those around them.

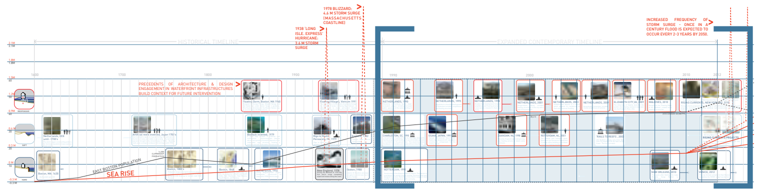
The aforementioned codes and restrictions were written with seasonal flooding and the occasional storm in mind. Preparations for sea rise differ from contending with tidal and seasonal changes in the level of sea at the land/ sea interface because they introduce the challenge of uncertainty. The existing regulatory framework attempts to build resilience in the built environment to minimize flood risks, but falls short in terms of addressing future uncertainty and only narrowing in on single disciplines. These

accordance with the National Flood Insurance Program. FEMA Technical Bulletin 7-93.

2. Massachusetts Building Code. 8th Edition Base Code. Accessed online: http://www.mass.gov/eopss/consumer-prot-and-bus-lic/license-type/csl/8th-edition-base-code.html. Accessed November 5, 2012.

3. Chapter 91: The Massachusetts Public Waterfront Act. Massachusetts Department of Environmental Protection. September 2003.

CONTEXTUAL TIMELINE - CONTEMPORARY



INCREASED FREQUENCY OF STORM SURGE - ONCE IN A CENTURY FLOOD IS EXPECTED TO OCCUR EVERY 2-3 YEARS BY 2050.

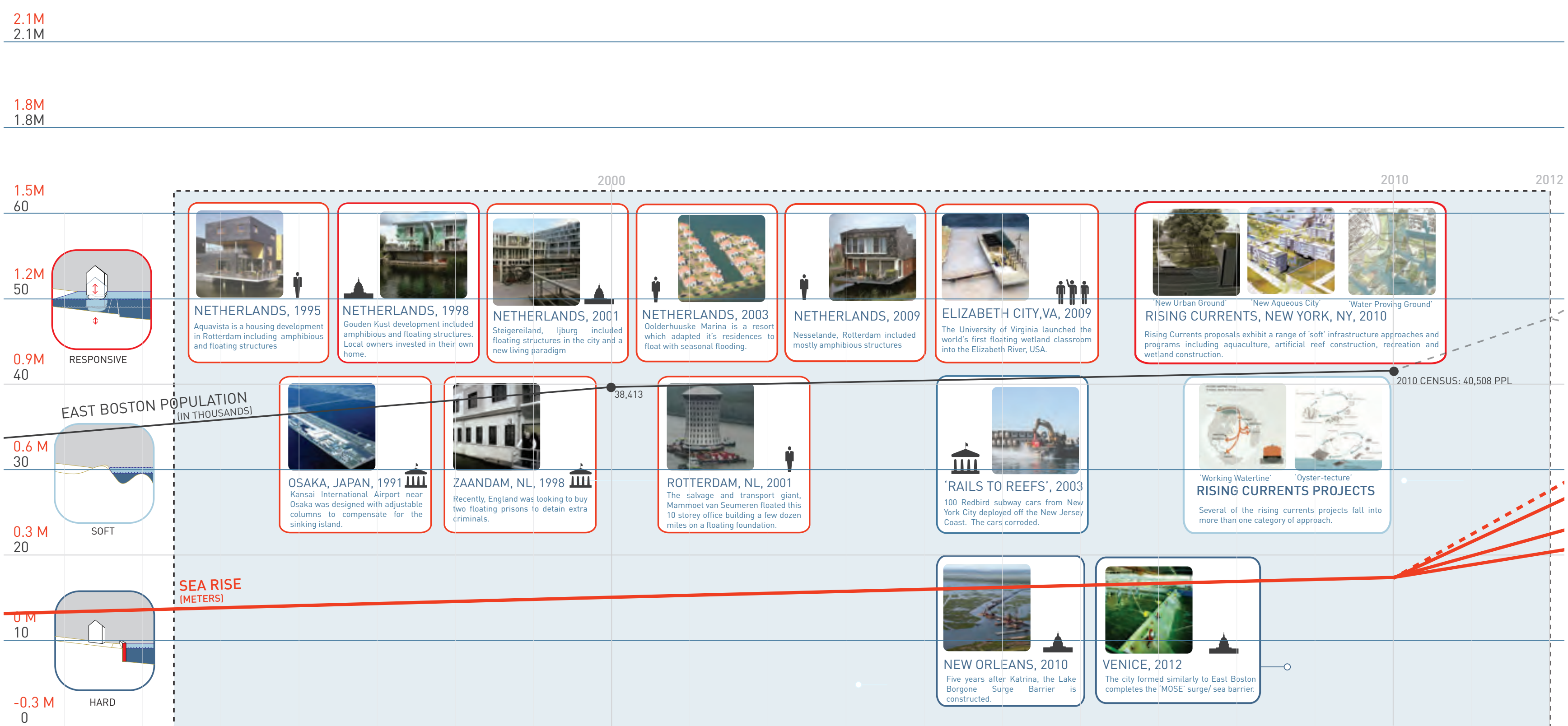
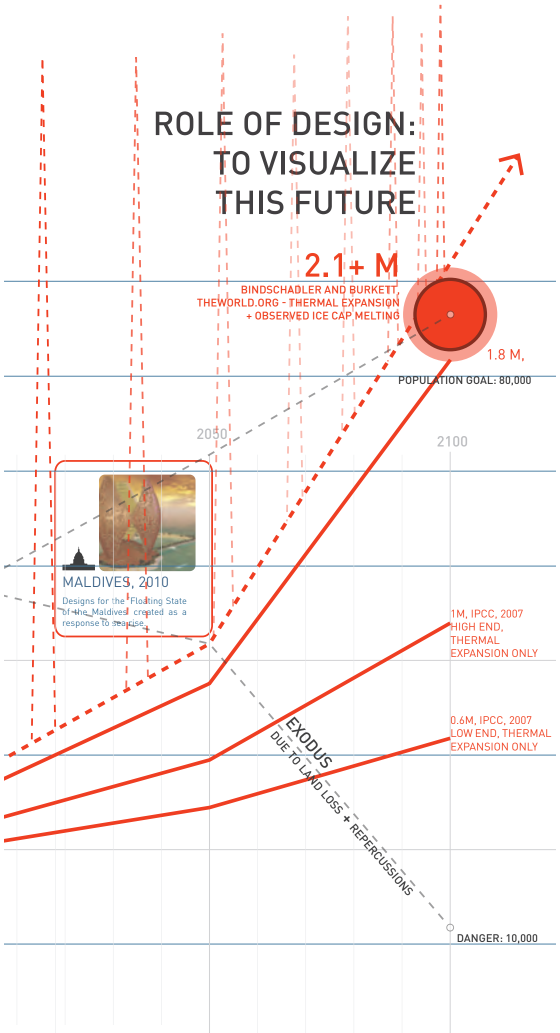


Figure 07. Contemporary Sea Rise Timeline



regulations are further illustration of the lack of coordination between architecture and other flood mitigation strategies. What is needed is a coordinated interdisciplinary approach for coastal development. FEMA provides construction guidelines for building in the flood zones, Chapter 91 acknowledges the broader impact of development in these areas, and local building codes attempt to restrict development, but what is lacking is a way of bringing various protective measures together to form a holistic, sustainable waterfront sea rise strategy.

CONCLUSION

Combining this knowledge of contemporary precedents, the issues of urban vulnerability, and current regulatory framework in place, this thesis seeks to contributes two things to the field of urban sea rise mitigation; (1) it identifies the need for layered approach to address layered problem of urban sea rise and (2) proposes a preliminary qualitative method of anticipating or predicting how layers of such a mitigation strategy will perform together.

Thesis also makes a contribution by addressing some of the shortcomings of the precedents shown on this timeline (Figures 06-07) which: treated architecture and infrastructure separately, did not take advantage of the dynamic nature of ocean and had no apparent anticipation of action of time on the projects. To better integrate these layers, the project takes on multiple scales from the urban edge to building. The urban plan that has helped to locate a project site and in turn, the architecture project has then given a better understanding of the conditions created by the urban intervention.

RESEARCH METHODOLOGY

2.1 - RESEARCH

CRITERIA FOR RESILIENCE & ADAPTABILITY

There are multiple and contending definitions of what resilience and adaptability are in the context of sea rise and climate change. This chapter will define these terms as gradients of performance with regards to climate change (gradual sea rise) and storms (sudden inundation). The assumption is made that existing sea rise mitigation tools, like those used in the Maldives, Chapter 1.1, are all striving to achieve resilience and adaptability, and that they can be characterized as achieving some level of each. In Appendix 6.1, the following definitions of 'Low', 'Medium', and 'High Resilience' and 'Low', 'Medium', and 'High Adaptability' are applied to the full range of mitigation tools, thus allowing for qualitative comparison of these tools as well as inference into how they would perform as hybrids.

The hypothesis of this thesis is that when these usually independently employed mitigation techniques are used together to create a sectionally layered approach, the resulting performance is greater than the sum of parts. By partnering with other sea rise mitigation measures; architecture can contribute to sea rise adaptability and resilience by addressing the need for development and infrastructure stewardship by occupying waterfront zones.

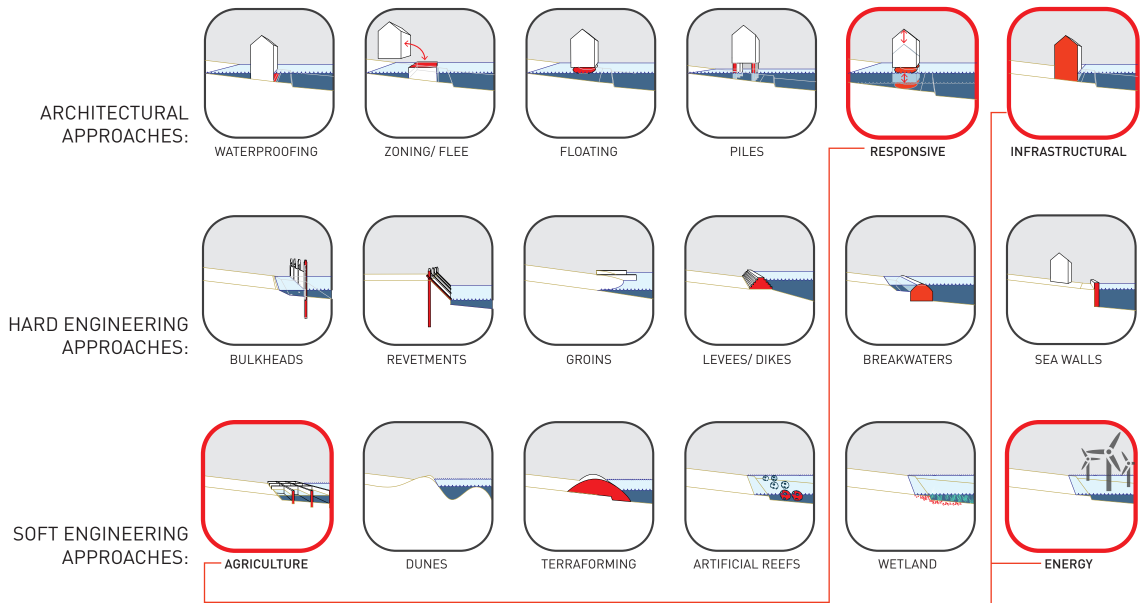
URBAN RESILIENCE

Resilience is the ability of a system to maintain it's structure, identity, feedback and function when subject to disruptive forces.[1] A few synonyms of the word 'resilient' are: bouncy, buoyant, effervescent, elastic, hardy, plastic, pliable, rebounding, springy, stretchy, strong, supple, and tough. Definition of successful urban sea rise resilience as 'bouncing back' does not accurately reflect the realities of post-disaster scenario. After a disaster has taken place, a hurricane, Nor'easter, etc., the affected community rebuilding activities undertaken present community members with a new reality that differs in several fundamental ways from that prevailing pre-disaster.[2]

For the purposes of this paper, the term 'resilience' is used to describe those charac-

1. Walker, B., et al. "Resilience, Adaptability and Transformability in Social--Ecological Systems." Ecology and society 9.2 (2004): 5
2. Paton, Douglas and Johnson, David. *Disaster Resilience: An Integrated Approach*. Charles C Thomas Publisher, Ltd. Springfield, Illinois 2006.

TOOLS OF SEA RISE MITIGATION



< Unlike hard or soft solutions, responsive architecture works in the event of successive storms.

< Hard barriers leave the area at risk of sudden and unforeseen infrastructure failure or ‘levee effect’

< Soft approaches alone take up too much buildable space - not suitable for expanding urban environments.

THE ROLE OF ARCHITECTURE...

to cross disciplinary boundaries to marry sea rise mitigation tools to achieve a productive, urbanistically viable result.

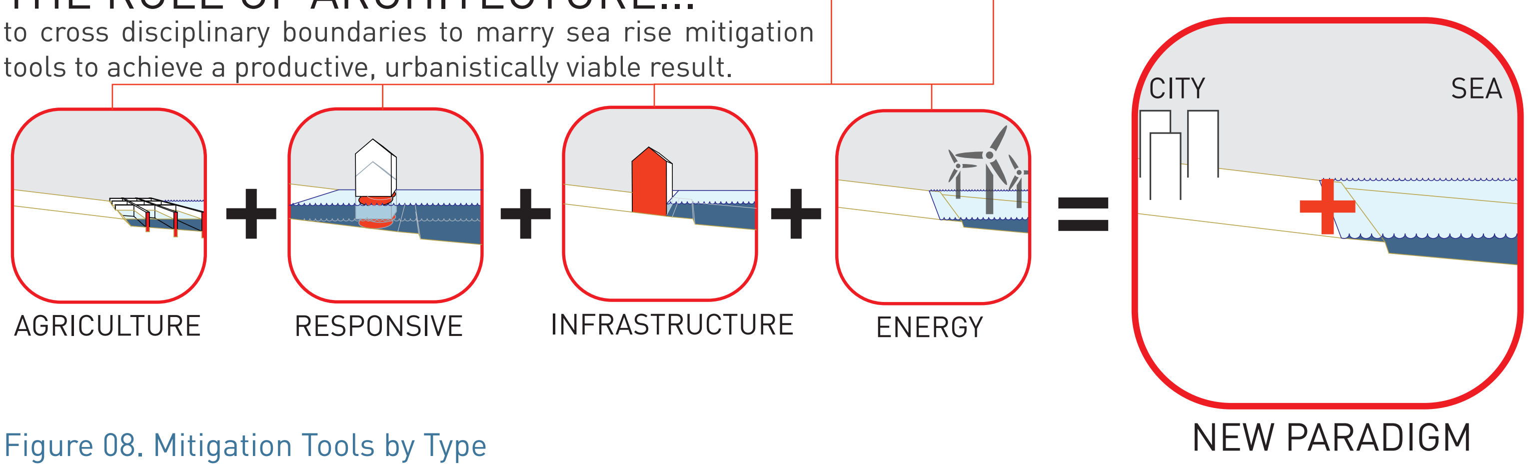


Figure 08. Mitigation Tools by Type

teristics that can be cultivated in a mitigation strategy to better withstand a disaster as well as recover quickly from it. In contrast with 'risk management' and reactionary or recovery approaches, resilience identifies and enhances positive attributes of an ecosystem. In Risk Society, Urlich Beck argues that we have become paralyzed by efforts to manage risk, inhibiting our ability as a society to respond to hazards in resilient ways.[3] An important part of building resilience is social awareness and education to avoid this paralysis.

This thesis uses the six traits that characterize resilience as defined by Wildavsky.[4] First is the 'Homeostasis' principle, which holds that the system is maintained by feedback loops between it's components(Figure 09). These feedback loops signal changes and enable learning. Second is the 'Omnivory' principle, which holds that external shocks are mitigated by the diversification by which resources are delivered (Figure 12). Thus, the more diverse the resources, the less likely the supply of vital systems will falter. For example, the incorporation of decentralized energy systems can increase resilience by providing alternative energy modes if the centralized urban energy distribution is impaired by fallen branches in a storm. Third is the 'High Flux' principle, which holds that the faster resources move through a system, the more likely they are to be available at any given time (Figure 11). An example of this in sea rise tools is an efficiently designed wetland where water filters through it so quickly that it increases the resilience of that land in a flood or storm scenario. Fourth is the 'Flatness' principle, which proposes that the reduction of hierarchy in a system (Figure 10) makes the whole system more resilient. A direct application of this principle might be in the structural system for a surge breaker. Tetrapods, a type of breakwater, make resilient surge breakers because each unit is able to take on as much as the next. This allows the whole to gradually shift and adapt to tidal and storm forces. The fifth principle is the 'Buffering' principle, which refers to the surplus or slackness in a system (Figure 13). A tidal basin, which has overcapacity to satisfy some tributary area, is an example of this principle. The sixth and final principle is the 'Redundancy' principle, by which interchangeable parts allow vital functions to continue while formerly redundant elements take on new functions (Figure 14). Piggybacking on the previous example, if

> REFER TO **APPENDIX 6.1** FOR A COMPREHENSIVE CATALOG OF SINGLE MEANS MITIGATION TOOLS BY DISCIPLINE & THEIR ADAPTABILITY / RESILIENCE RATING .

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3. Beck, Ulrich. *Risk Society: Towards a New Modernity*. London: Sage Publications, 1992.
4. Barnett, Jon. "Adapting to Climate Change in Pacific Island Countries: The Problem of Uncertainty." World Development 29.6 (2001): 977-93.

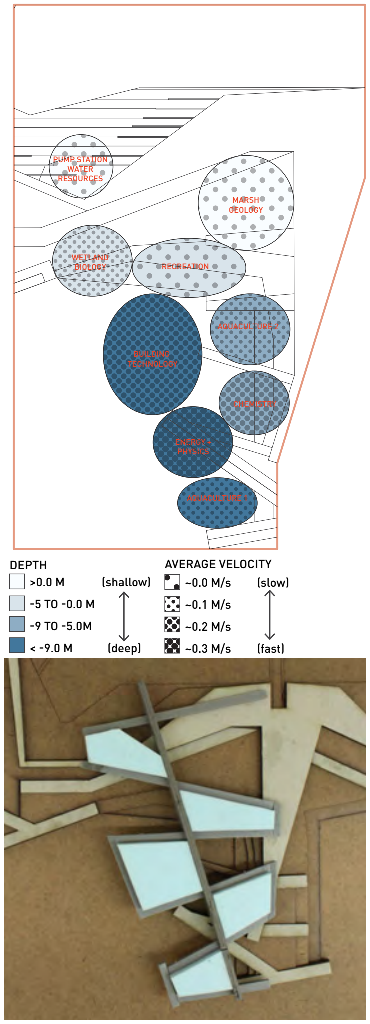

Figure 09. Homeostasis Principle
System is lens for unique site conditions for educational study - creating dynamic homeostasis.

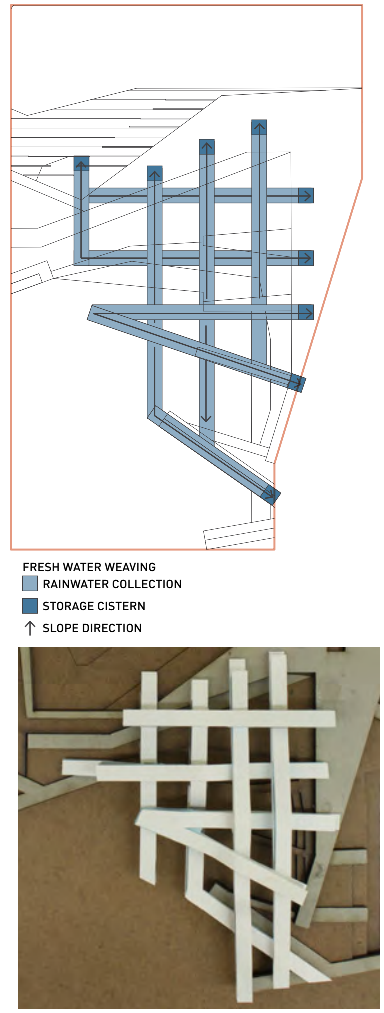

Figure 10. Flatness Principle
Rainwater uniformly collected, distributed and stored through non-heriarchical grid.

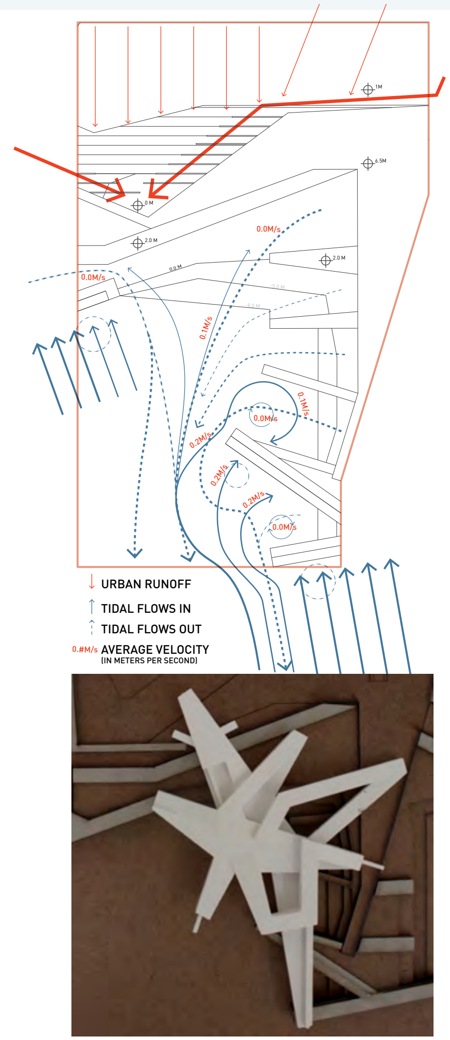

Figure 11 High Flux Principle
Urban runoff water and inundation rapidly conveyed, readily absorbed and filtered through loop system.

there are multiple tidal basins to serve one tributary area, some of those basins may serve alternate functions when not required to contain water, but area available in the event that the primary basin is full of impaired.

APPLICATION OF URBAN RESILIENCE CONCEPT

Based on the six resilience principles, mitigation tools are evaluated as low, medium or high. If a tool exhibits only one of these characteristics, it is rated 'low resilience'. If it displays two to three it is 'medium resilience', and four or more, 'high resilience'. For example, in Appendix 6.1, tool 4.1– breakwater is considered 'low resilience' because it displays only principle 4, flatness. There is little hierarchy in a breakwater system.

ADAPTABILITY

If resilience is the presence of means to respond to flooding or surges, adaptability or adaptive capacity in the sea rise discourse is the extent to which tools are able to adjust to accommodate uncertain future changes. In the climate change context, UNDP and the Global Environmental Facility define adaptation and adaptive capacity as "a process by which strategies to moderate, cope with and take advantage of the consequences of climatic events are enhanced, developed and implemented" and "the property of a system to adjust it's characteristics or behavior, in order to expand it's coping range under existing climate variability, or future climate conditions".[5] The desire here is to pre-program a system with a wide range of operation modes.

In the disaster resilience context, there is a similar definition of social adaptability. Brian Walker defines social adaptability as the 'actors' capacity to manage system and avoid crossing into an undesirable regime. The agility with which actors are able change course is a measure of adaptable social system. So too with mitigation tools, transformability and flexibility are desirable characteristics. The IPCC (International Panel on Climate Change) expanded that definition to include the ability to take advantage of climate change.[6] Appendix 6.1 ranks currently used mitigation tools as having Low,

---

5. Burton, Ian, Bo Lim, Erika Spanger-Siegfried, Elizabeth L. Malone, and Saleemul Huq. *Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies, and Measures*. Cambridge, UK: Cambridge University Press, 2005. Print.
6. Niang-Diop, I., et al. "Formulating an Adaptation Strategy." Adaptation Policy Frameworks for Climate Change: Developing Strategies, Policies and Measures (2004): 183-204.

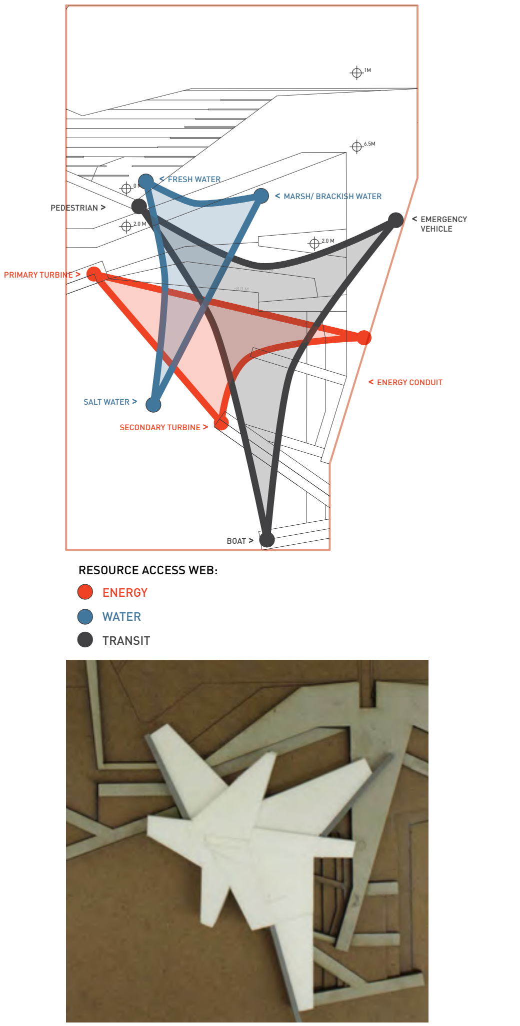

Figure 12. Omnivory Principle
Resources are obtained from multiple, triangulated sources to prevent system disruption.

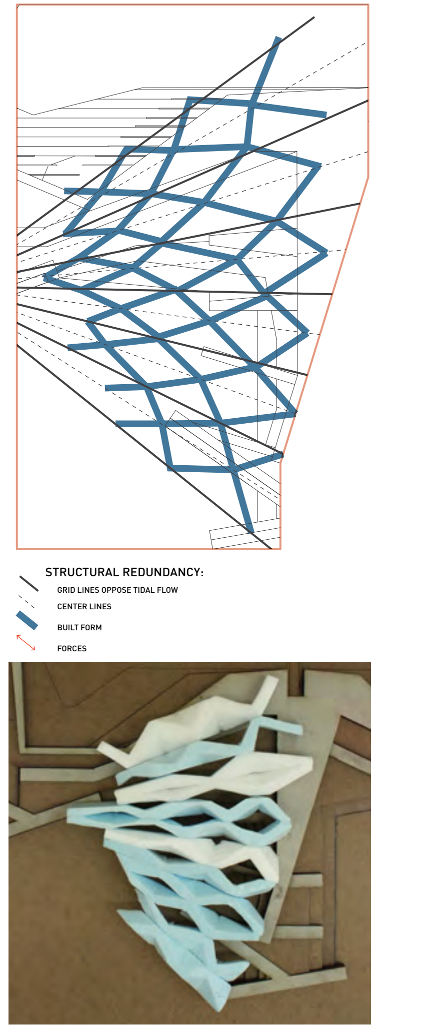

Figure 13. Buffering Principle
Structural redundancy create through weaving grid that responds to tidal directions.

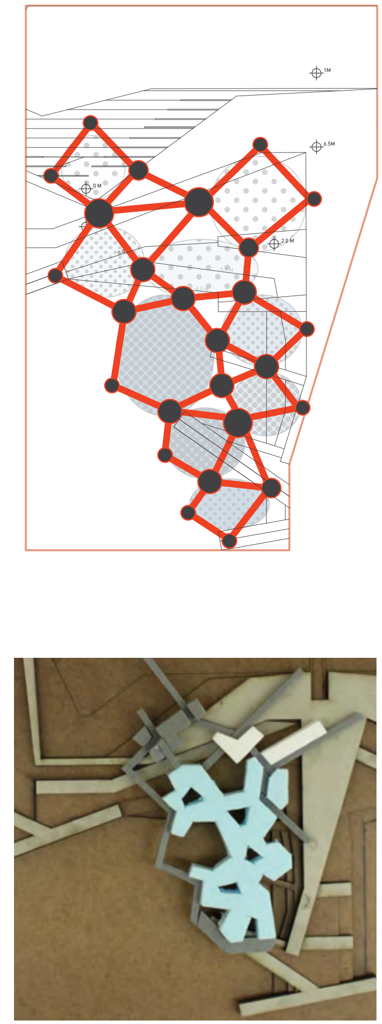

Figure 14. Redundancy Principle
Nodes and connectors create decentralized networked system for circulation and structure.

Medium, and High Adaptability based on their relative degrees of flexibility.

With few exceptions, there is a correlation with what are commonly considered 'soft' and 'hard' infrastructures as being High and Low Adaptability, respectively. There are two main paths toward adaptability and they can be understood through the lens of 'soft' and 'hard' energy paths coined by Amory Lovins in the 1970's. Hard infrastructure are characteristically complex, expensive, and large and can last hundreds of years, resulting in 'lock in' patterns of development and growth around them.[7] The term refers to engineering infrastructures such as sea gate or walls that are only adaptable as far as they can be added to or operable. For example, the MOSE tidal gates in Venice (listed on Figure 06) can be tuned to respond to a set range of flooding scenarios. Once sea rise or surges exceed that range, the gates are obsolete. Hard infrastructures are undesirable as a first resort because the trajectory of sea rise cannot be predicted that far out. Once the performance demand of flooding or storms exceeds the system's designed range, it is very economically (and environmentally) costly to adapt.

In contrast, soft mitigation measures prioritize natural capital, community control, simplicity, and regional appropriateness.[8] Soft sea rise infrastructures include low-impact technologies like artificial reefs, beach nourishment, and barrier island construction. For example, park and wetlands plant species and slopes can be planned to enable the absorptive wetland buffer to track with flooding over time. (Figure 16).

MULTI-SCALAR URBAN APPLICATION OF ADAPTABILITY

Part of the challenge that this design project takes on is how apply these definitions of resilience and adaptability 'on the ground' in the urban context. This transition between abstract ideas and practice is a difficult one to make and articulate and is often neglected in literature. The diagram and sketch models in Figures 09- 14 make this transition from abstract concept to physical form. This patterning exercise is a useful way of finding the intersection between abstract principles of sea rise resilience and the physical tools of mitigation.

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7. Hassler, U. 2009, 'Long-term building stock survival and inter-generational management: the role of institutional regimes', Building Research & Information 37(5), p.552-568.
8. Sovacool, B.K. "Hard and Soft Paths for Climate Change Adaptation." Climate Policy. 11.4 (2011): 1177-1183. Print.

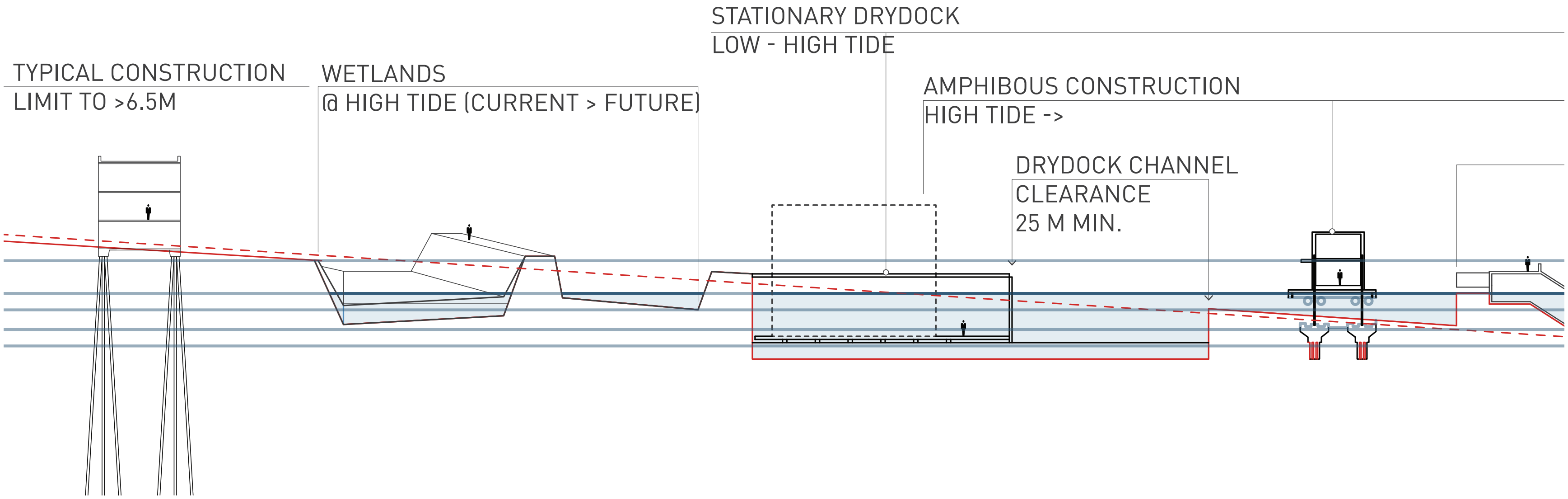
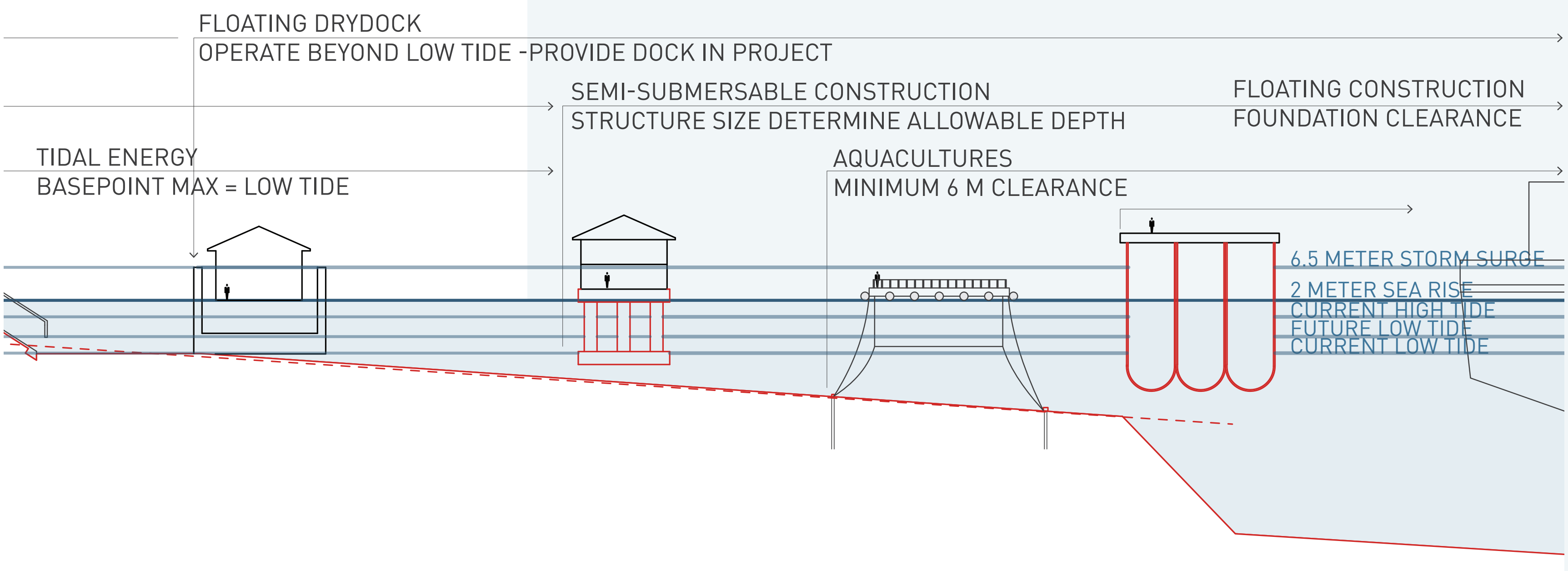


Figure 15. Various sea rise mitigation constructions & respective depths.

2.2 - RESEARCH

INTERDISCIPLINARY TOOLS FOR SEA RISE MITIGATION

One way of classifying climate change mitigation strategies is by the number of means use and the number of objectives that the strategy or tool aims to meet. I will begin by evaluating 'single means, single objective' tools. Most flood mitigation strategies are implemented discretely by discipline; architecture, engineering, etc. This thesis argues for an erosion of these disciplinary boundaries as a means to build a new, broader set of tools for sea rise resilience. In the process of breaking down disciplinary boundaries, I begin by developing an understanding of the parameters associated with each of the sea rise mitigation tools (Figure 15) and grouping them by the primary discipline that employs them (Appendix 6.1). Finally the single means, single discipline measures are recombined across disciplines through design to explore areas for innovation.



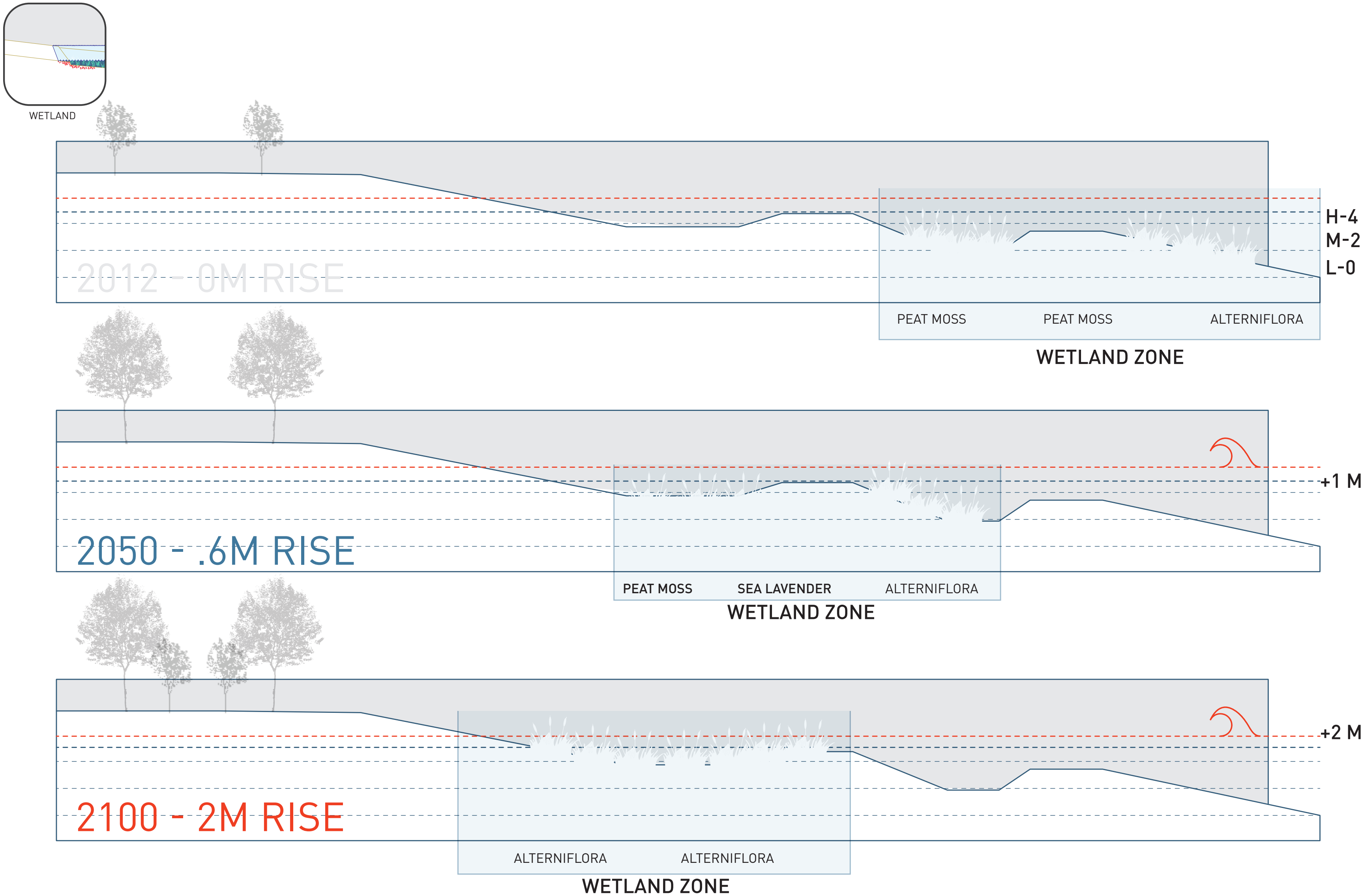


Figure 16. Planned wetland response to sea rise rise over time.

Embodied Energy

Eliminate future construction waste: flexible, floating buildings are easy to move if no longer required

Environment

Improve water quality by stimulating aquaculture diversity. Floating constructions provide protection, localized lower water temperatures aids diversity and the undersurface is hanging mussel cultivation.

Reduced Energy Use

Reduce building energy consumption: sustainable cooling through convection of ocean air or water.

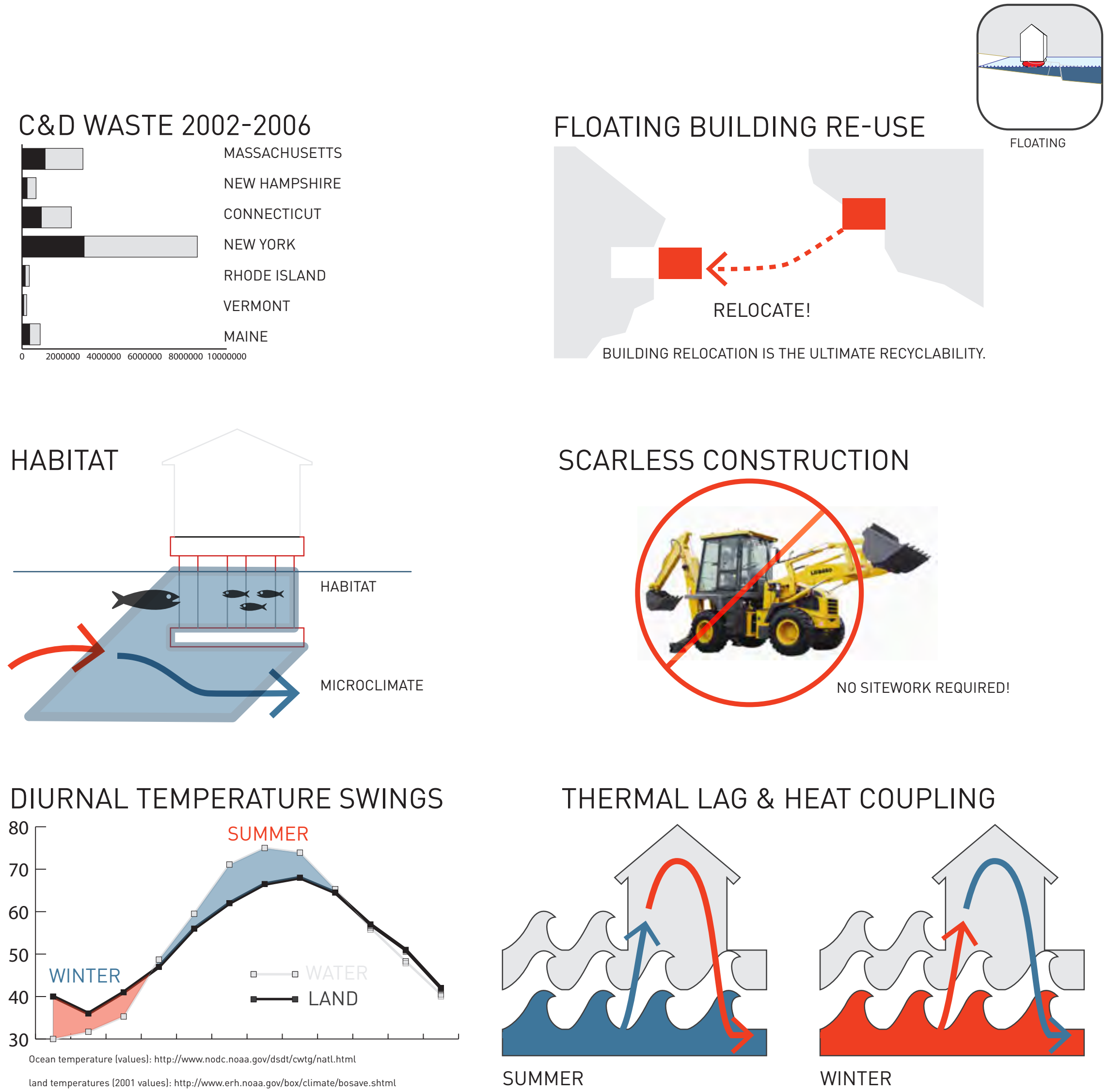


Figure 17. Adaptability of Floating Constructions.

Figure 04. Boston Harbor Risks (Water Depth, Velocity and Storm Paths)

3.1 - SITE

BOSTON SEA RISE CONTEXT & PROJECT SCOPE

Boston makes an ideal site for this case study project due to it's dramatic landmaking history. Upon taking a closer look at the city, it is not surprising that those ares with the most man-made land are the most vulnerable.

In addition to low lying land, Boston is vulnerable due to the probability of storms causing a storm surge and the high tidal fluctuations that seasonally occur. Figure 4 shows the paths of historic hurricanes which have crisscrossed the city, as well as the magnitude and direction of tidal flows in the Boston Harbor[1]. The magnitude varies throughout the year, the level shown is the peak spring tide recorded at respective monitoring locations.[2]

This thesis addresses three site scales for intervention within the Boston context:

3.1 - CITY SCALE
The Boston Harbor is considered for the design of the mitigation system. The transferability of the layered system and the range of performance are based on the range of urban edge conditions present in the harbor.

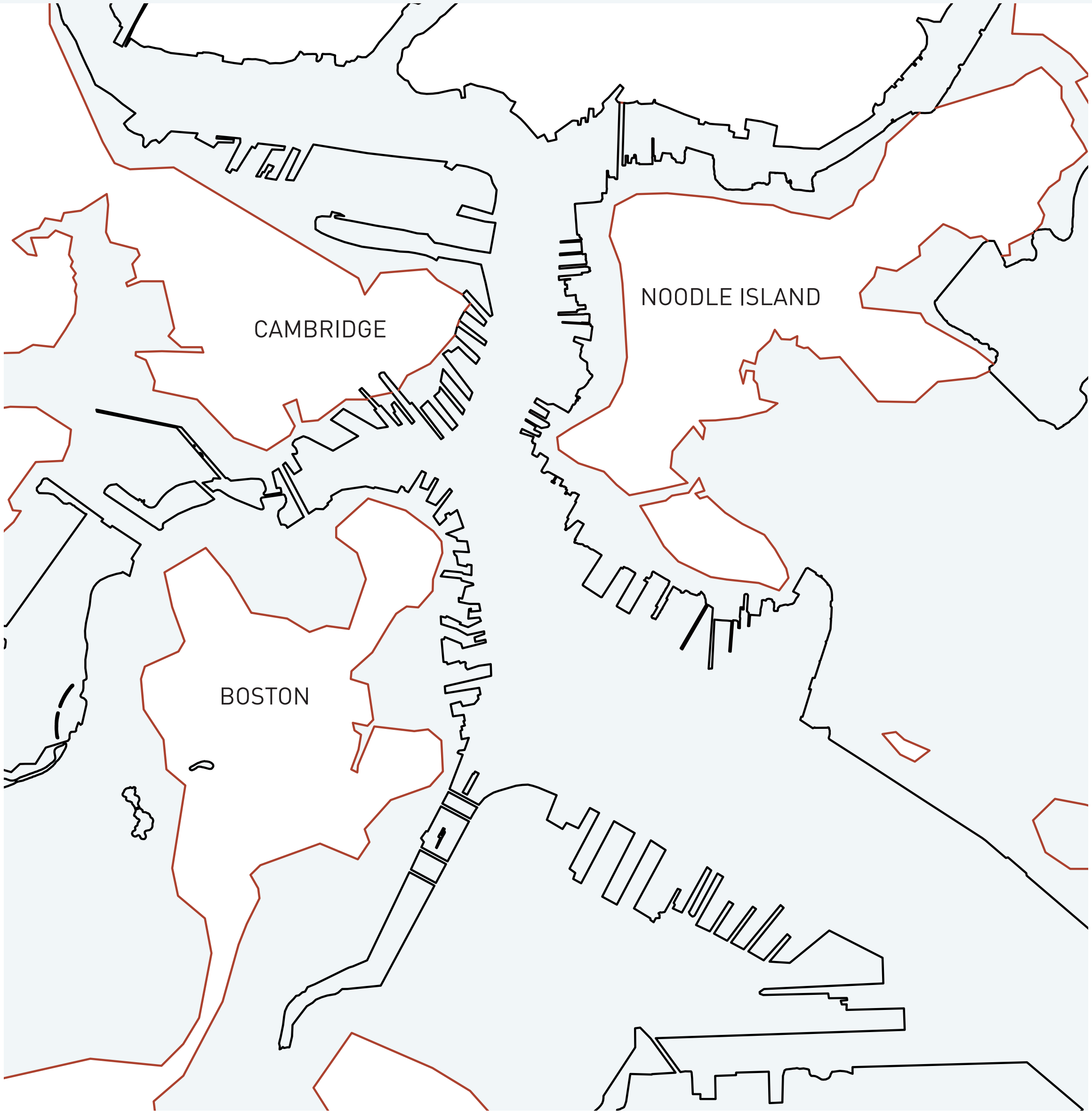
3.2 - NEIGHBORHOOD SCALE
The neighborhood of East Boston is used for a specific edge design.

3.3 - LOCAL SCALE
Specific building design responds to and forms symbiotic relationships with the neighborhood's edge landscape infrastructure.

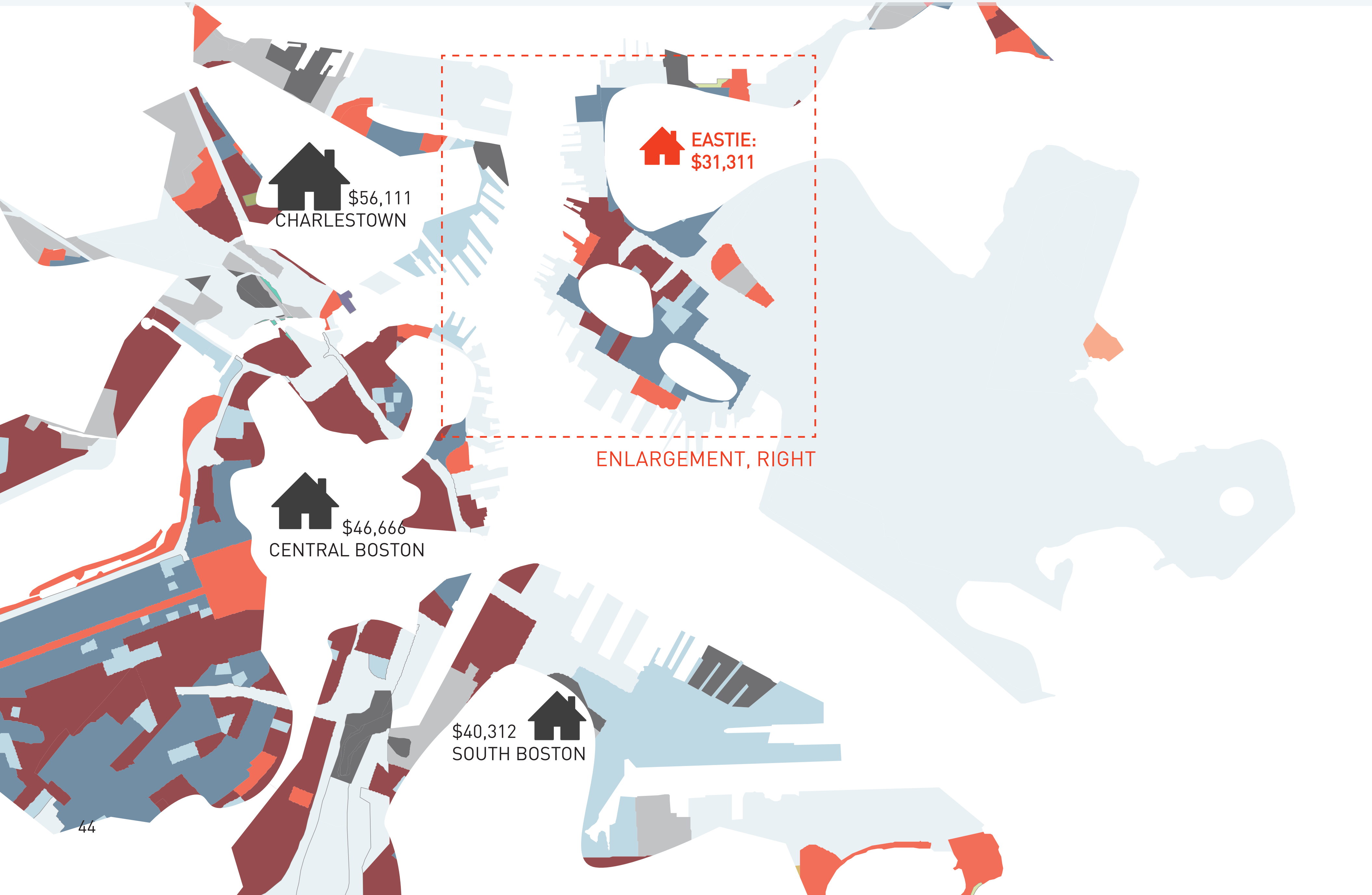
> OF THE BOSTON NEIGHBORHOODS, **EAST BOSTON** LOOSES THE GREATEST PERCENTAGE OF IT'S LAND WITH SEA RISE.

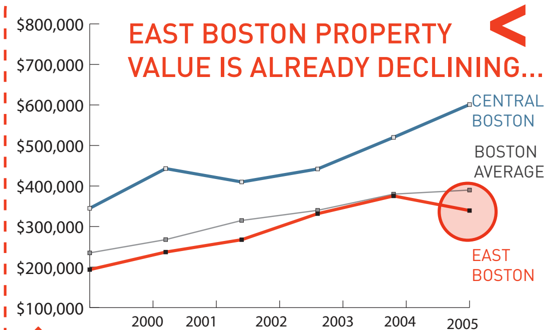
1. Water speed data: http://tidesandcurrents.noaa.gov/currents09/tab2ac2.html#12
2. Tide data source: http://www.boatma.com/tides/Boston-Harbor.html,


EAST BOSTON
CHARLESTOWN
CAMBRIDGE
CENTRAL BOSTON
SOUTH BOSTON
BOSTON HARBOR



> WITH JUST **2 METERS** OF SEA RISE, BOSTON LOOKS LIKE IT DID IN **1880**!


EASTIE:
$31,311
$56,111
CHARLESTOWN
ENLARGEMENT, RIGHT
$46,666
CENTRAL BOSTON
$40,312
SOUTH BOSTON



MEDIAN RESIDENTIAL PRICE

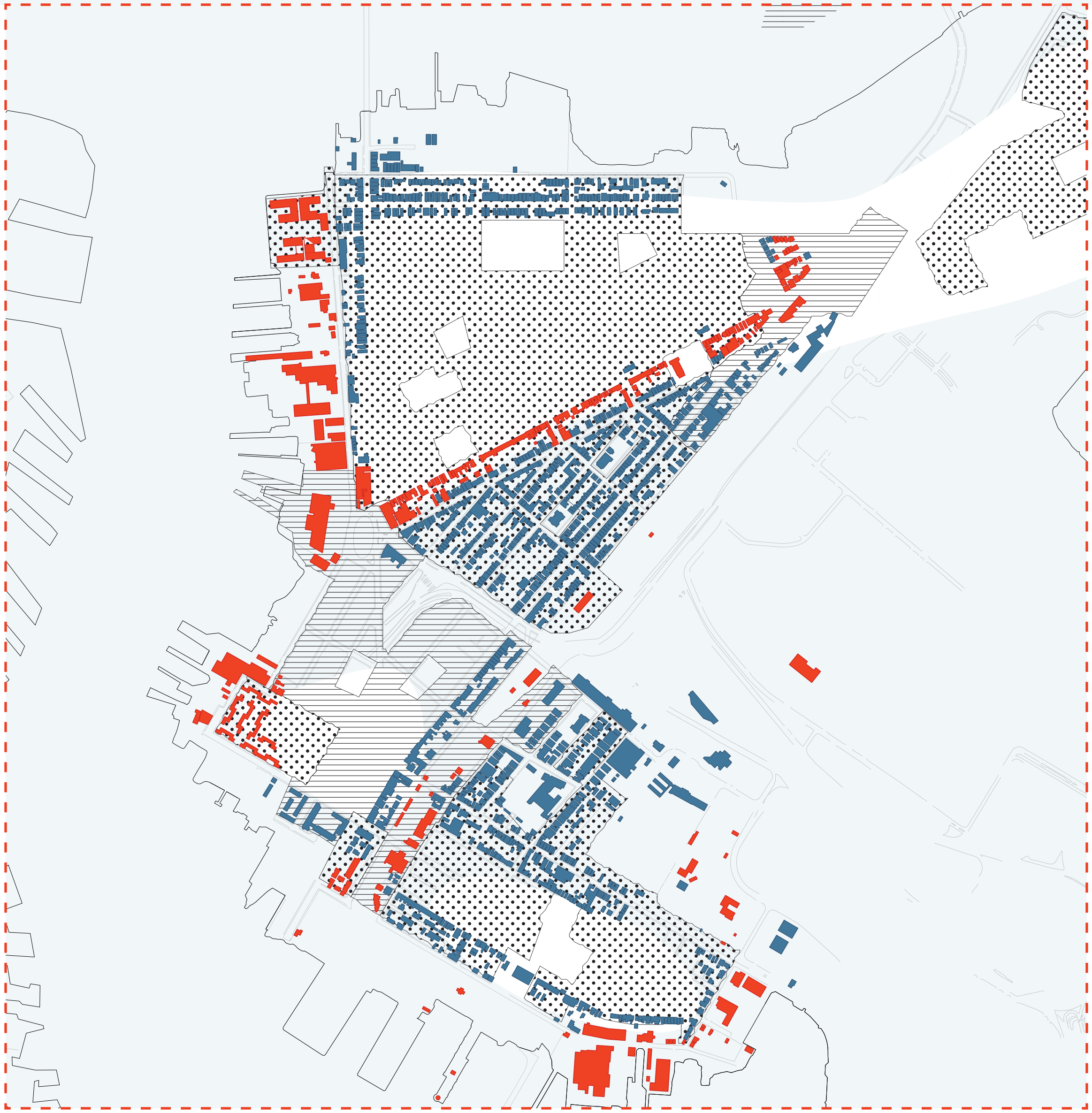
Central Boston includes the North End/Waterfront, Downtown, West End, Chinatown and Bay Village

BUILDING LOSSES

YEAR: 2050, 2100

TYPE: RESIDENTIAL, COMMERCIAL

2050 - 222 STRUCTURES, >200,000 M^2
2100 - 1,148 STRUCTURES, >420,000 M^2



"WATER PROMISES TO BE TO THE 21ST CENTURY WHAT OIL WAS TO THE 20TH CENTURY. THE PRECIOUS COMMODITY THAT DETERMINES THE WEALTH OF NATIONS. HOW A COUNTRY HANDLES IT'S WATER PROBLEM COULD SPELL THE DIFFERENCE BETWEEN GREATNESS AND DECLINE."

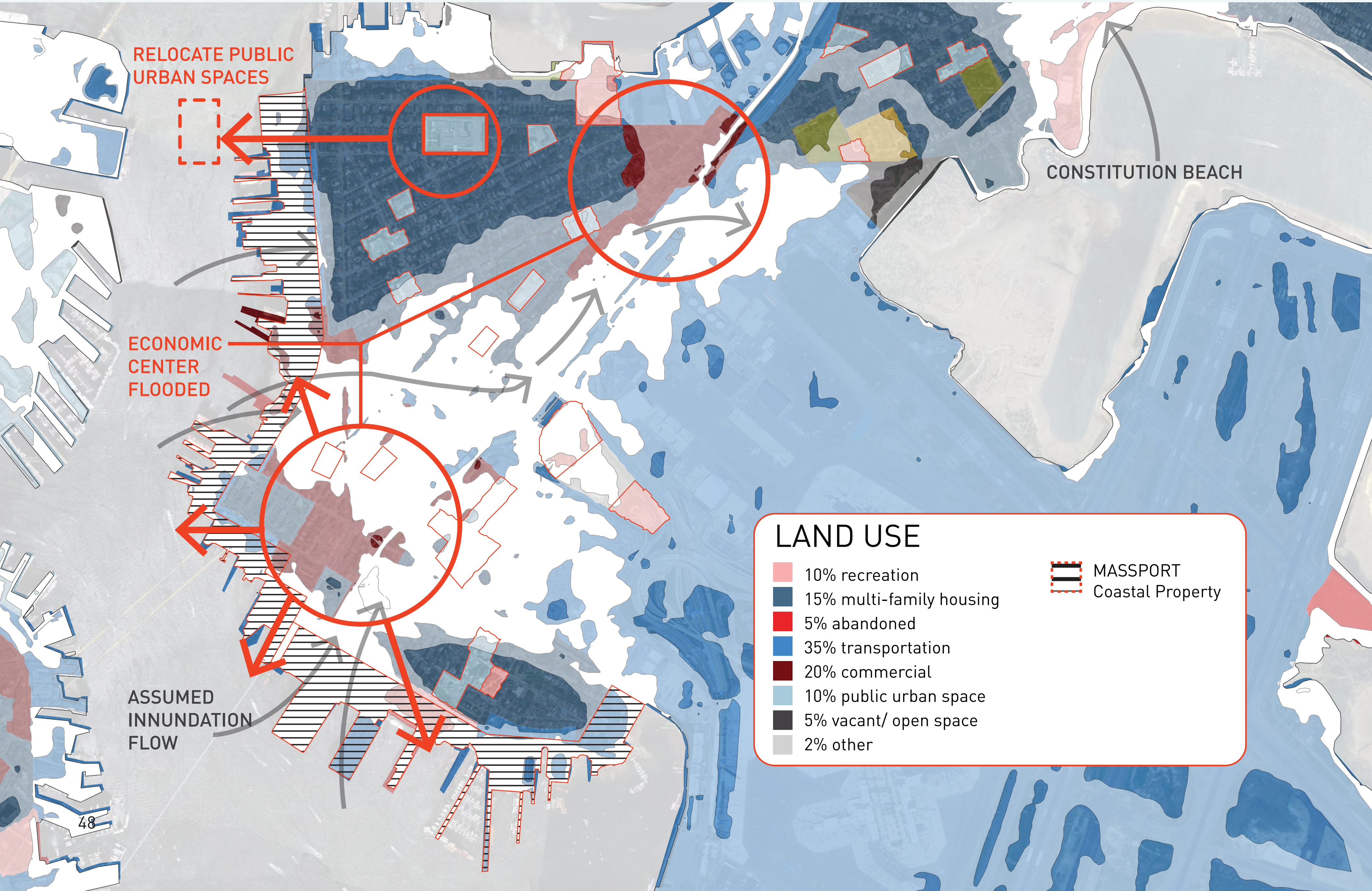
-Tully, Shawn. 'Water, water everywhere', Fortune Magazine, 15 May, 2000.

3.2 - SITE

EAST BOSTON VULNERABILITY MAPPING

Within the city of Boston, East Boston is the perfect place to start mitigation efforts. The East Boston waterfront is currently in a transition period and the entire inner harbor property facing central Boston is slated to be developed just as discussions of sea rise are gaining ground. A study titled Climate Impact on Metro Boston (CLIMB) completed in 2004 proposed that the sea wall be built along the length of this site.[1] Just like the Maldives example, the City of Boston needs to develop a capability to sustain societal processes through the proactive development of adaptive and resilient capacity. In the book, *Disaster Resilience: An Integrated Approach*, Douglas Paton and David Johnson argue that cities need to 'develop a capacity for continued functioning, normal routines...'.[2] This paper argues that cities should aim to improve upon normal functioning by considering what qualities are currently missing in waterfront projects to make them sustainable in the face of sea rise.

1. Kirshen, Paul H. Infrastructure Systems, Services and Climate Change: Integrated Impacts and Response Strategies for the Boston Metropolitan Area. S.l: s.n., 2004. Print.
2. Paton, Douglas and Johnson, David. Disaster Resilience: An Integrated Approach. Charles C Thomas Publisher, Ltd. Springfield, Illinois 2006.


RELOCATE PUBLIC URBAN SPACES
CONSTITUTION BEACH
ECONOMIC CENTER FLOODED
ASSUMED INUNDATION FLOW
LAND USE
10% recreation
15% multi-family housing
5% abandoned
35% transportation
20% commercial
10% public urban space
5% vacant/ open space
2% other
MASSPORT Coastal Property

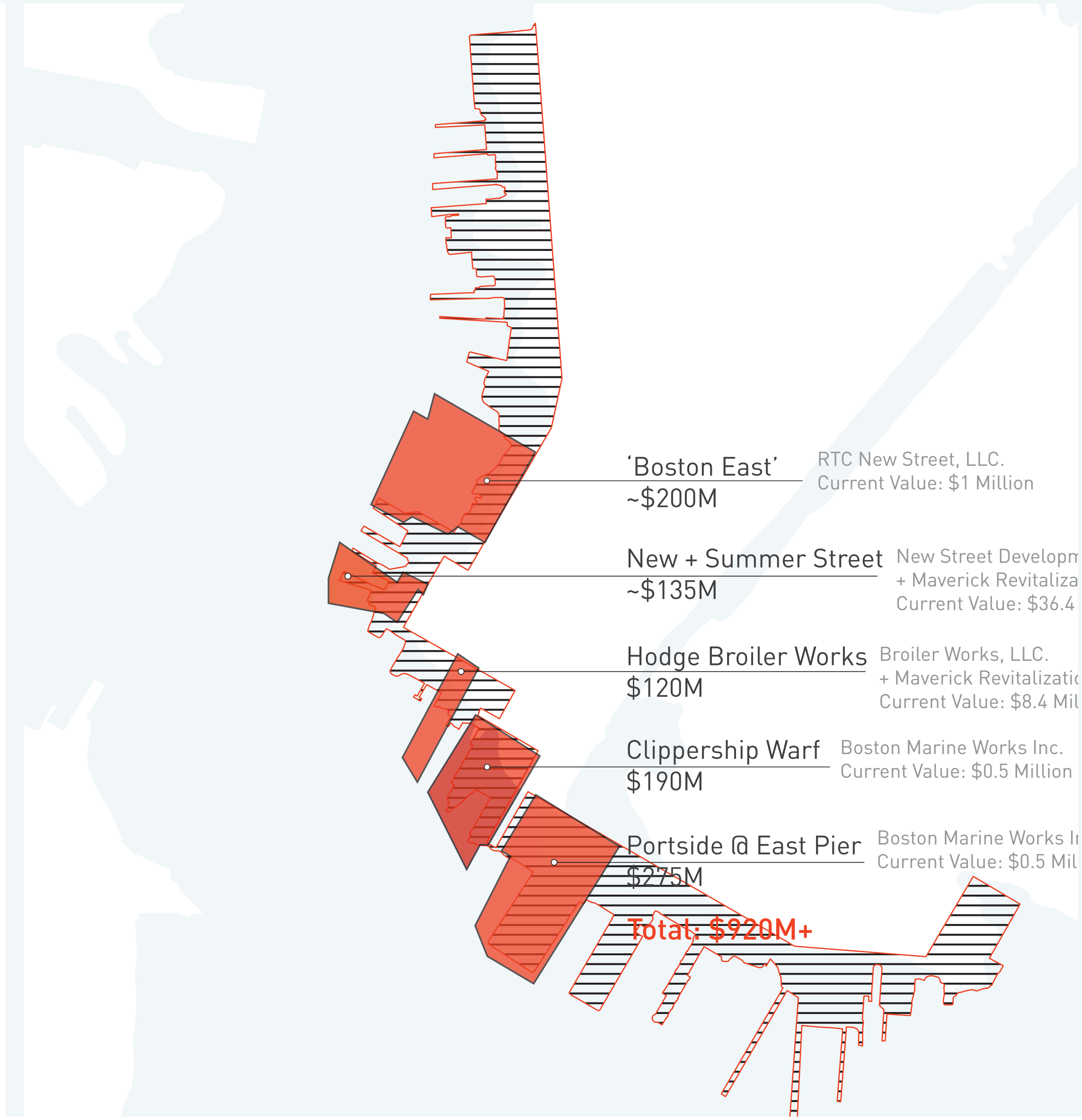
CURRENTLY PROPOSED WATERFRONT DEVELOPMENTS

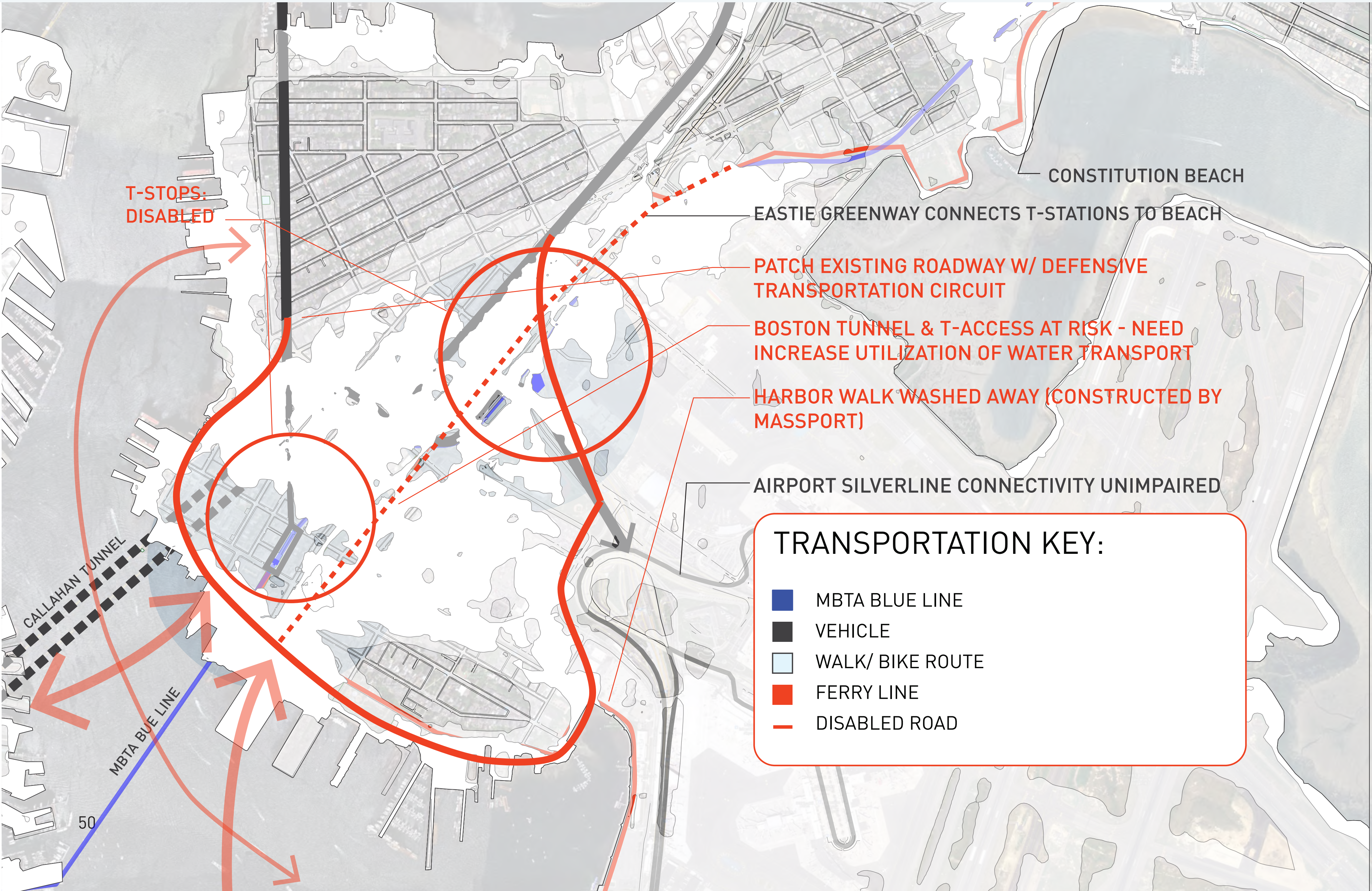
Figure 18. Rendering of proposed 'Boston East' Development

> PROGRAM STRATEGIES

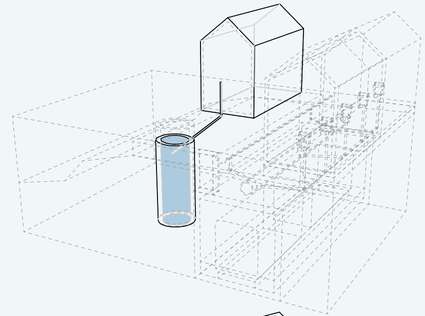
01. Redistribute public spaces to the perimeter / waterfront zone.

02. Redistribute commercial activity by creating new adaptable and self-sufficient economic driver programs on the coastline.



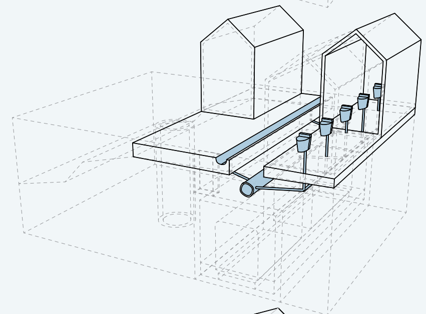

T-STOPS:
DISABLED
CONSTITUTION BEACH
EASTIE GREENWAY CONNECTS T-STATIONS TO BEACH
PATCH EXISTING ROADWAY W/ DEFENSIVE TRANSPORTATION CIRCUIT
BOSTON TUNNEL & T-ACCESS AT RISK - NEED INCREASE UTILIZATION OF WATER TRANSPORT
HARBOR WALK WASHED AWAY (CONSTRUCTED BY MASSPORT)
AIRPORT SILVERLINE CONNECTIVITY UNIMPAIRED
CALLAHAN TUNNEL
MBTA BLUE LINE
TRANSPORTATION KEY:
MBTA BLUE LINE
VEHICLE
WALK/ BIKE ROUTE
FERRY LINE
DISABLED ROAD

IMPACTED LAYERS



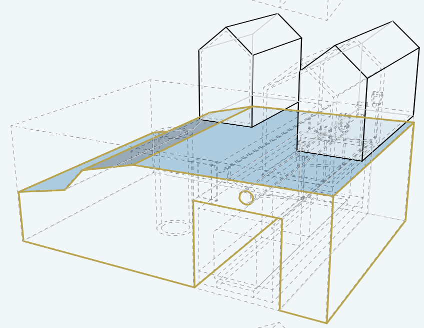
WATER SCARCITY

In the event of any flood, runoff collects contaminants and renders well water undrinkable for days. [1] The city of Boston still relies heavily on well water and is at risk of increased freshwater scarcity.



SANITATION

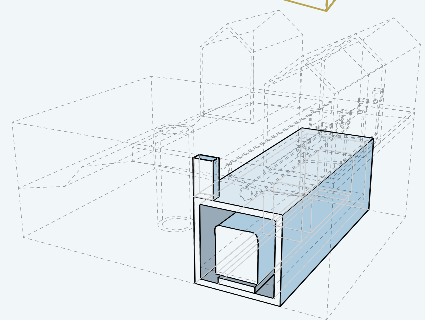
Currently Boston has a partially mixed stormwater and sewer system. When flooding or heavy water innundation occurs, sewer is impacted. [2]



LAND + BUILDING

If preventative measures are not taken, repeated flooding due to sea rise will required repeated repair ($$$). In other parts of the east coast, sea rise has already resulted in the complete loss of property. [3]

Based on Massachusetts property rights, land consumed by the ocean is forfeit. This can have major reprecussions of zoning and adjacent land value.



TRANSPORTATION

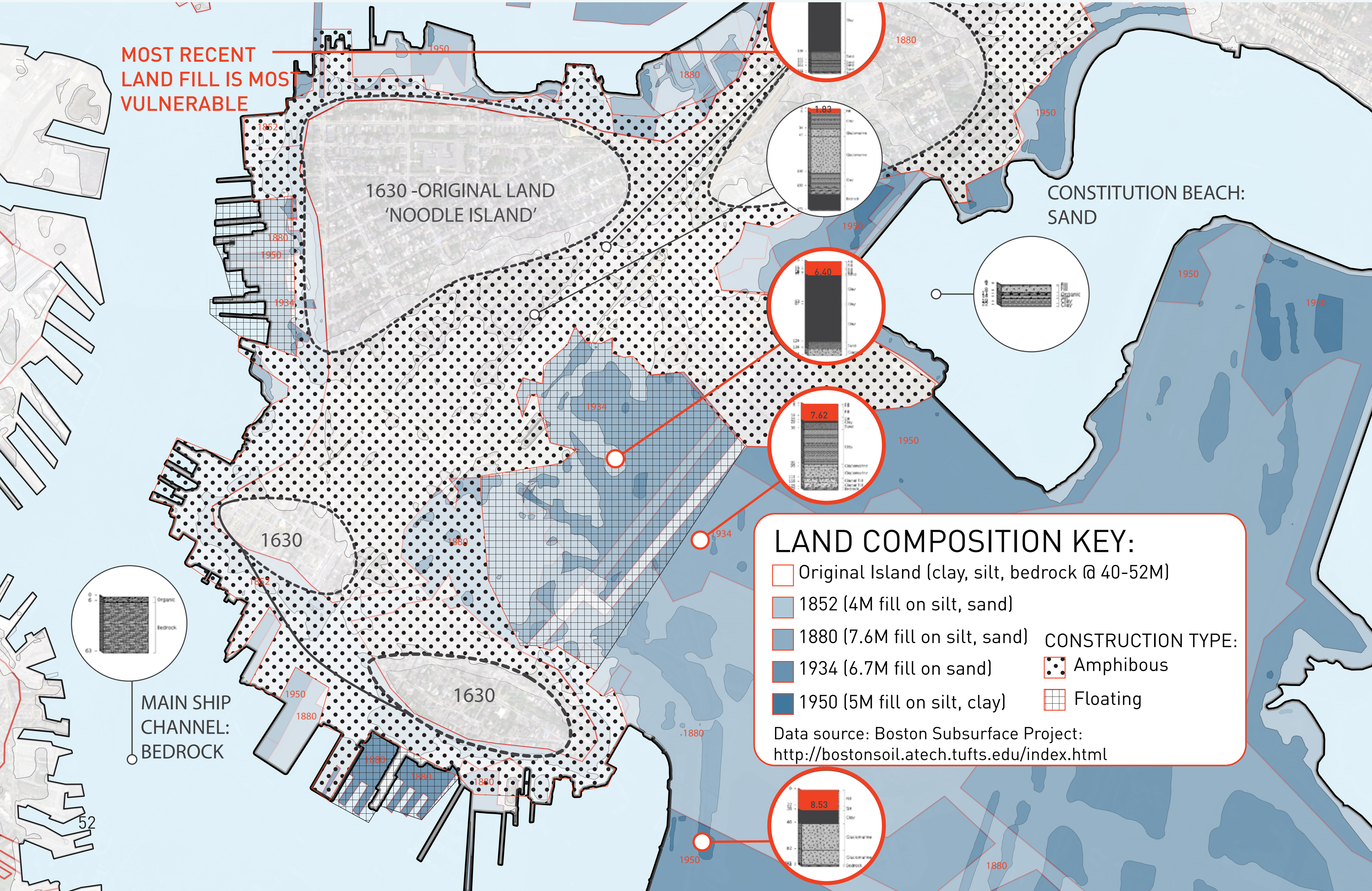
The first major impact of sea rise will be low lying city infra-structure. Flooded transportation infrastructure impairs mobility and costs billions to repair. [4]

Figure 18. 1910 Paris Flood

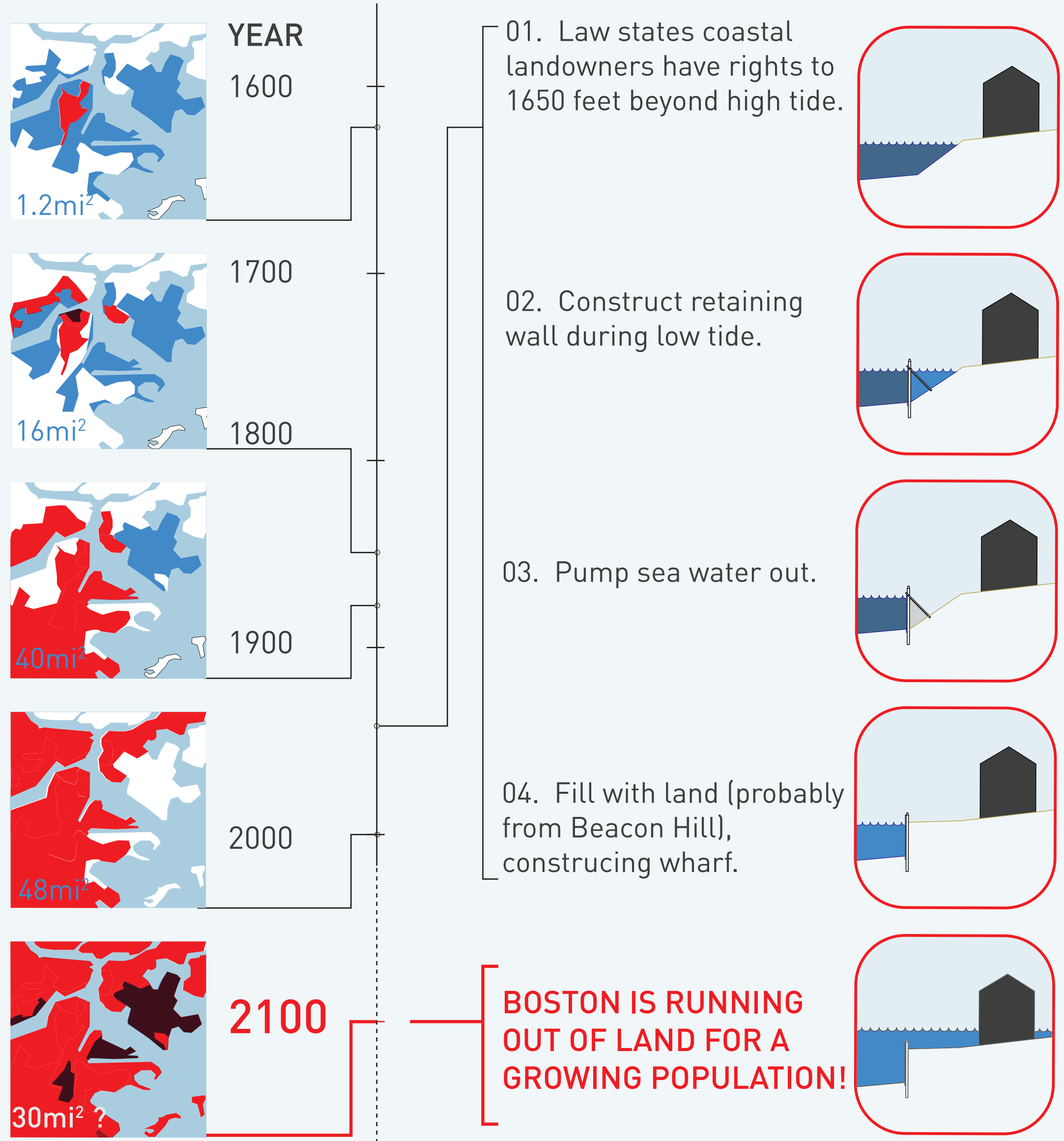
> INFRASTRUCTURE STRATEGIES

01. Redistribute public spaces to the perimeter / waterfront zone.

02. Redistribute commercial activity by creating new adaptable and self-sufficient economic driver programs on the coastline.


MOST RECENT
LAND FILL IS MOST
VULNERABLE
1630 -ORIGINAL LAND
'NOODLE ISLAND'
CONSTITUTION BEACH:
SAND
1630
1630
MAIN SHIP
CHANNEL:
BEDROCK
1852
1880
1934
1950
LAND COMPOSITION KEY:
Original Island (clay, silt, bedrock @ 40-52M)
1852 (4M fill on silt, sand)
1880 (7.6M fill on silt, sand)
1934 (6.7M fill on sand)
1950 (5M fill on silt, clay)
CONSTRUCTION TYPE:
Amphibous
Floating
Data source: Boston Subsurface Project:
http://bostonsoil.atech.tufts.edu/index.html
1.83
6.40
7.62
8.53

3.2 - SITE WHARFING OUT



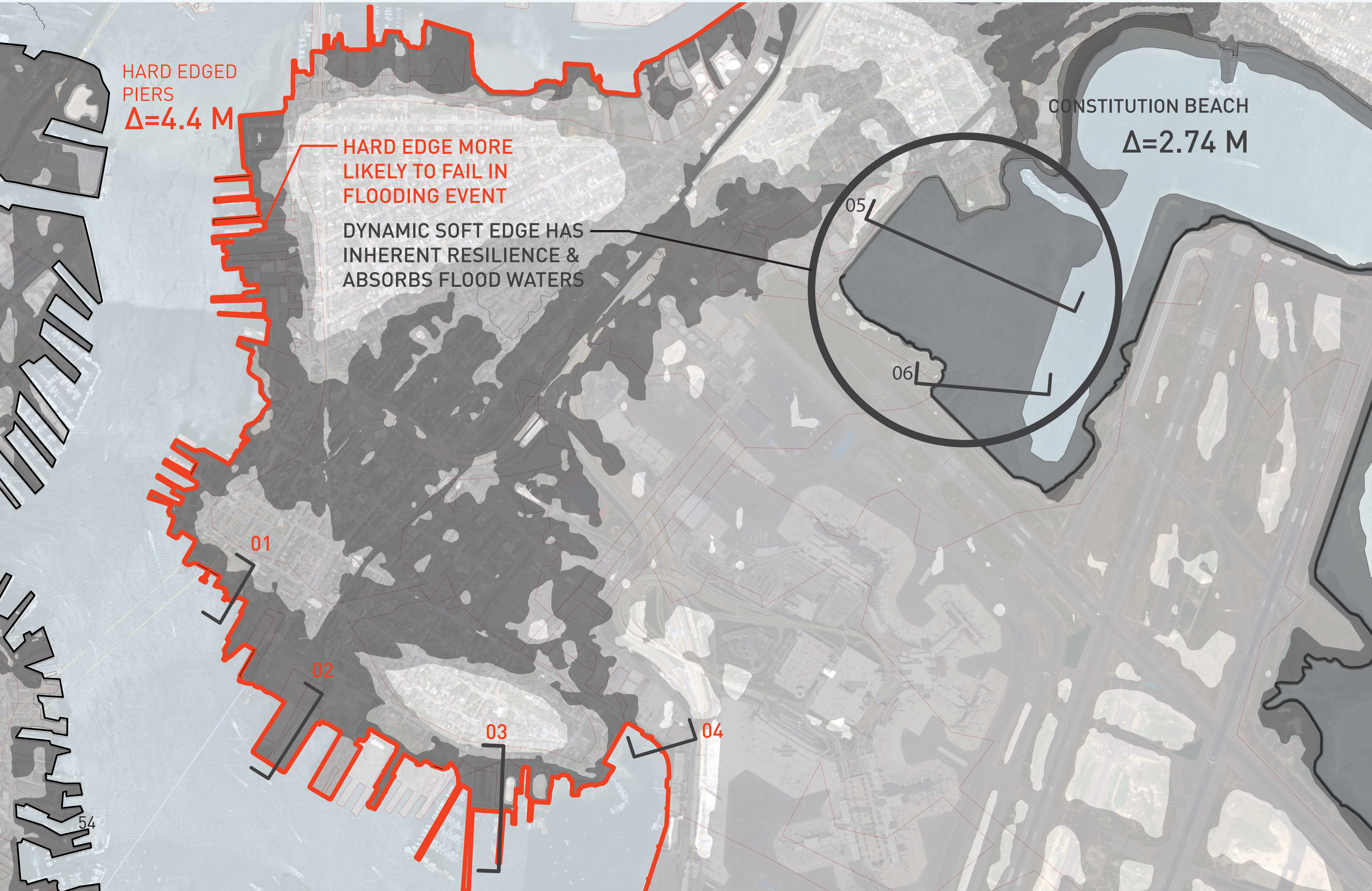
> Light soils erode more readily than compact ones, like **CLAY**.

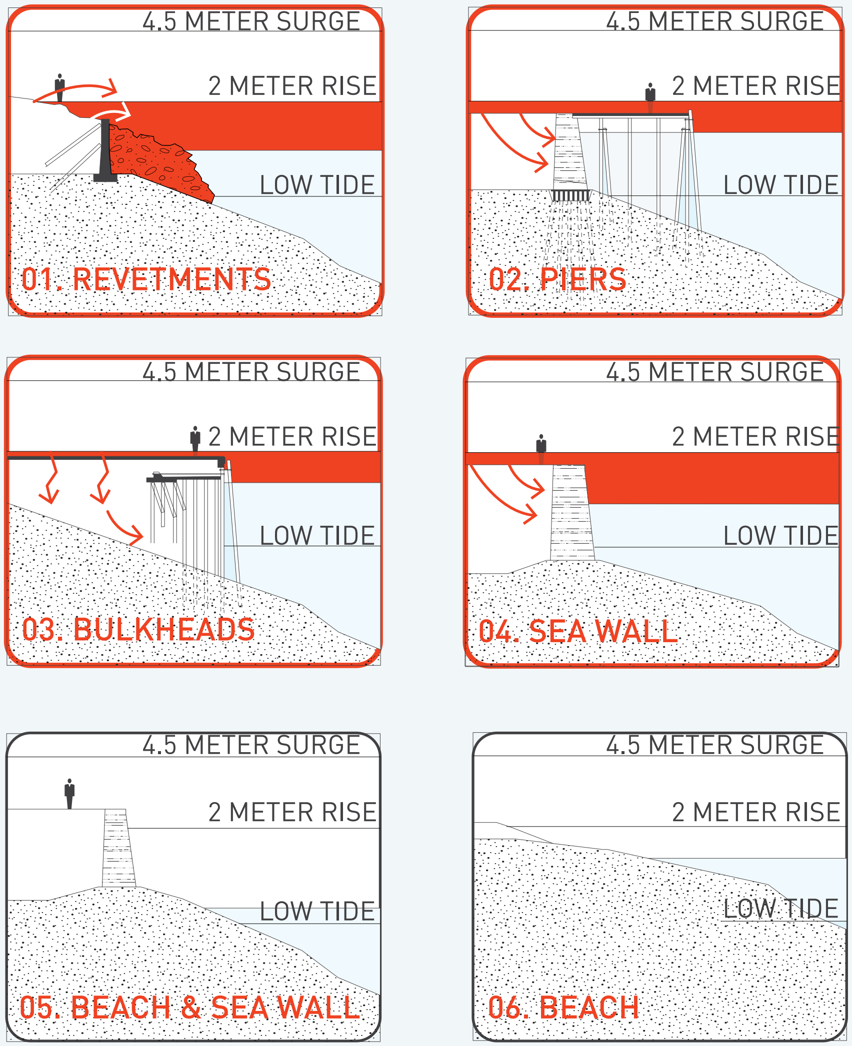
- U.S. Federal Emergency Management Agency

> SOIL STABILITY STRATEGIES

01. Improve soil quality through the use of soft landscape layers.

02. Use subsoil conditions to guide construction techniques used.


HARD EDGED
PIERS
Δ=4.4 M
HARD EDGE MORE
LIKELY TO FAIL IN
FLOODING EVENT
DYNAMIC SOFT EDGE HAS
INHERENT RESILIENCE &
ABSORBS FLOOD WATERS
CONSTITUTION BEACH
Δ=2.74 M
05
06
01
02
03
04



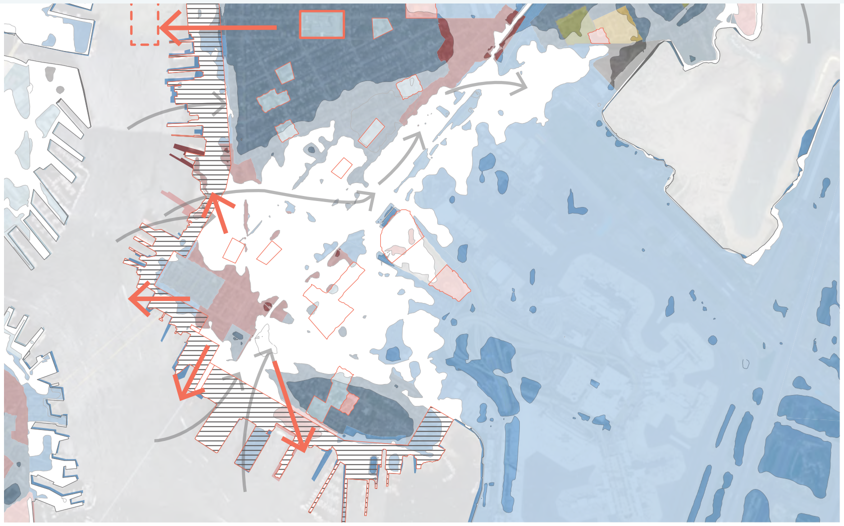
SOFT EDGE HAS INHERENT RESILIENCE !

> ENVIRONMENTAL STRATEGIES

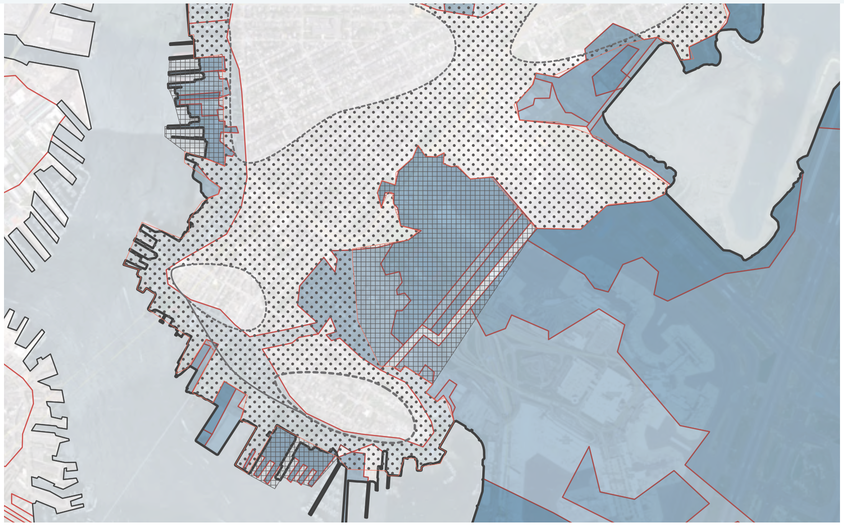
01. Implement soft landscape strategy at currently hard edge locations

02. Focus design on hard edge main ship channel/ inner harbor.

EAST BOSTON SITE MAPPING - SYNTHESIS



LAND TENURE



SUB-STRUCTURE

INFRASTRUCTURES

EDGE CONDITIONS

> NEIGHBORHOOD HAZARDS

Synthesize East Boston Hazards inot zones of vulnerability.

VULNERABILITY <

- LOW VULNERABILITY
- 2100 INUNDATED
- 2050 INUNDATED
- VULNERABLE ELEMENT

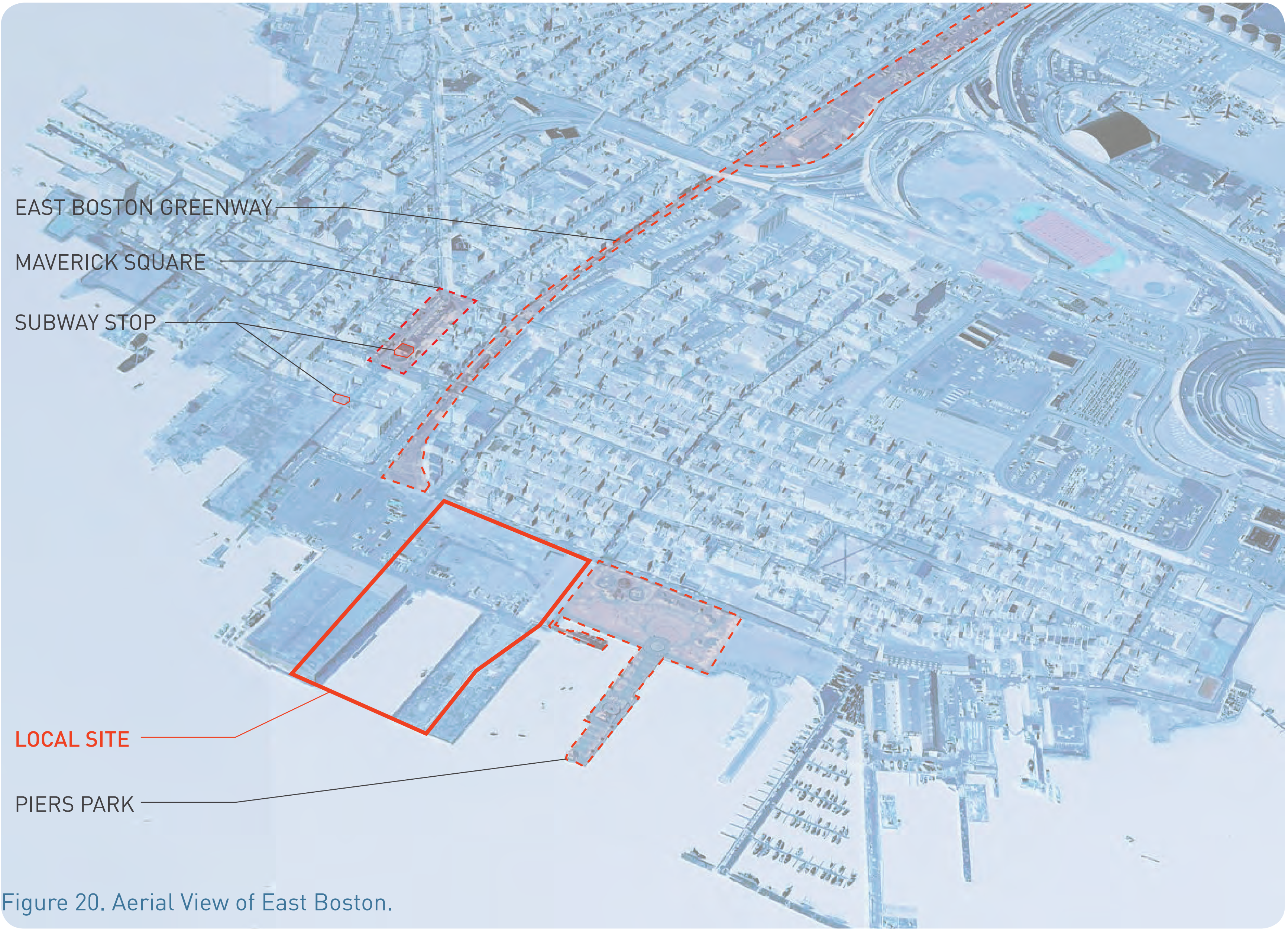


Figure 20. Aerial View of East Boston.

3.3 - SITE

LOCAL WATERFRONT SITE

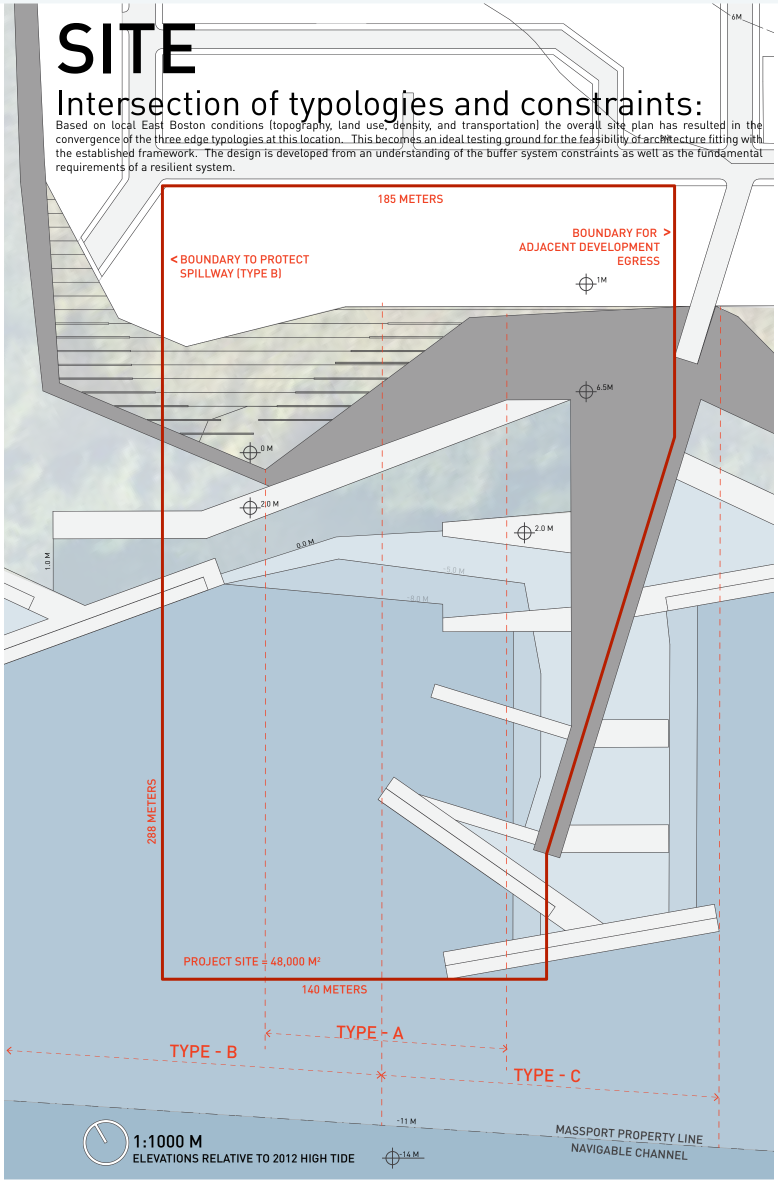
The final step in the process of building urban sea rise resilience is activating this zone through architecture. For this third scale of intervention, the thesis looks at an area of the East Boston waterfront that is roughly the size of two adjacent city blocks. The selected site is adjacent to Maverick Square -East Boston's commercial hub - and is at the terminus of the East Boston Greenway - a new pedestrian and bike path linking the edge in question to Constitution Beach. This low lying ground is a place where sea rise and storm waters could reach deep into the heart of East Boston and becomes one of two spillways that permeate the built fabric in the design project.

As part of the new resilient edge system, this public location demands a building that demonstrates the effects of climate change, sea rise and aspects of the waterfront to a wide audience. The site can become a catalyst for other developments along the new waterfront.

SITE

Intersection of typologies and constraints:

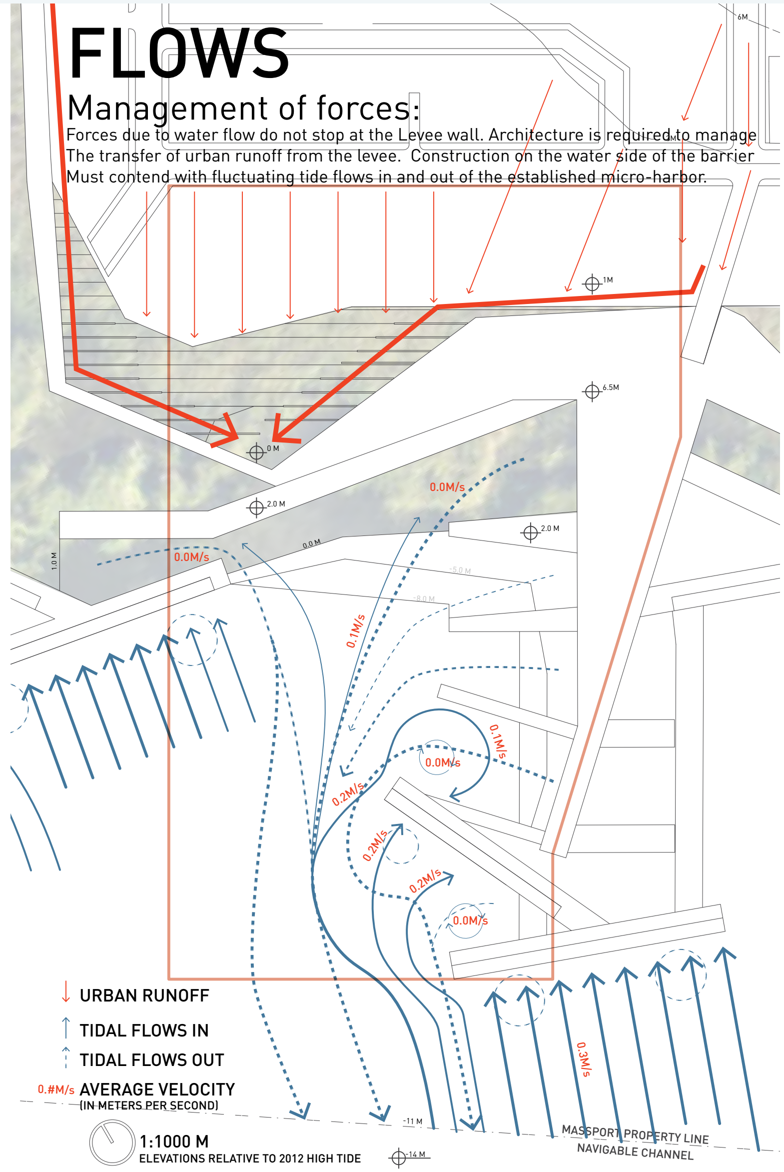
Based on local East Boston conditions (topography, land use, density, and transportation) the overall site plan has resulted in the convergence of the three edge typologies at this location. This becomes an ideal testing ground for the feasibility of architecture fitting with the established framework. The design is developed from an understanding of the buffer system constraints as well as the fundamental requirements of a resilient system.



FLOWS

Management of forces:

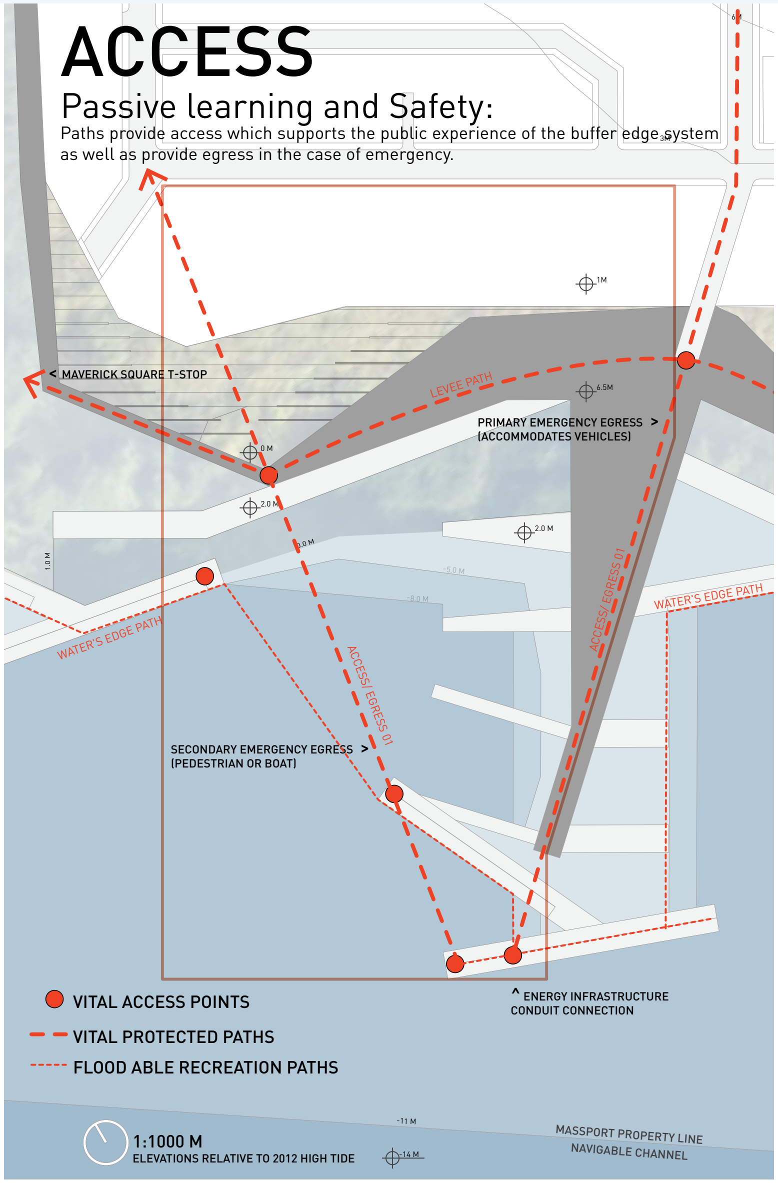
Forces due to water flow do not stop at the Levee wall. Architecture is required to manage The transfer of urban runoff from the levee. Construction on the water side of the barrier Must contend with fluctuating tide flows in and out of the established micro-harbor.



ACCESS

Passive learning and Safety:

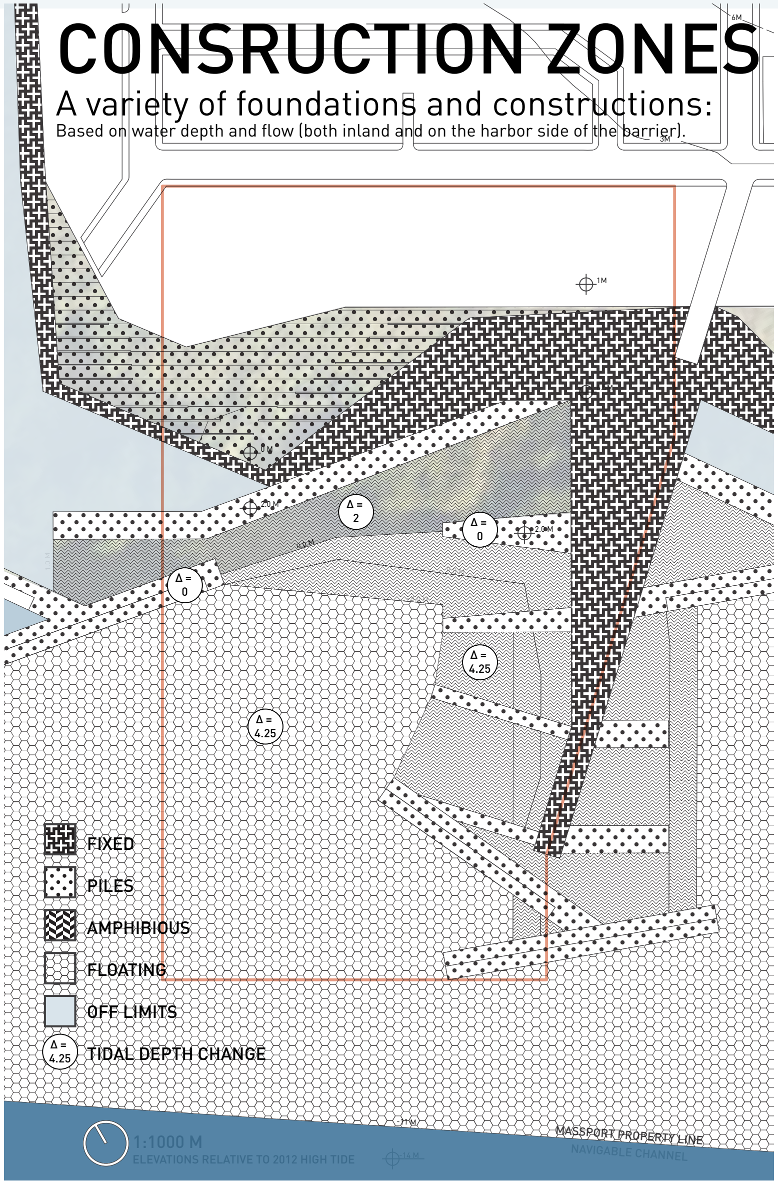
Paths provide access which supports the public experience of the buffer edge system as well as provide egress in the case of emergency.



CONSRUCTION ZONES

A variety of foundations and constructions:

Based on water depth and flow (both inland and on the harbor side of the barrier).



MASSPORT

Owns or operates the majority East Boston waterfront. They have a political interest in appeasing and supporting the East Boston Community which has been impacted by the airport development.

DEVELOPERS

Roseland Property is one actively petitioning owners such as Massport and the Mayor for waterfront properties.
http://www.roselandproperty.com/CORP_SITE/coming_rentals.html

THE CITY

Wants to see the city of Boston continue to grow and attact new residents and businesses.

Figure 21. East Boston Pier 01 Panorama

3.3 - SITE

DOCUMENTATION

The East Boston site sits in the midst of a long redevelopment process as well as political tension. This often overlooked neighborhood has the most risk prone waterfront and yet the least developed relationship to the water of any coastal Boston neighborhood.

Now that South Boston's redevelopment project is winding down, East Boston is again a strong candidate for city investment. Section 3.2 contains a map illustrating the development projects that are just starting up. It is important to understand the local political climate in addition to the physical site characteristics for a full understanding of project context. The photo collage below maps the authorities and actors at play relative to their relationship to the local waterfront focus site.

BRA

Kairos Shen is the man at the Boston Redevelopment Authority who has final say over what gets built along Boston waterfronts.
http://www.boston.com/bostonglobe/magazine/articles/2008/06/29/the_shaper_of_things_to_come

RESIDENTS

Due to a lack of political power, the largely immigrant population of East Boston is particularly vulnerable to sea rise - most of whom live in low-lying areas.

Figure 22. East Boston, Maverick St., Panorama from Metro to Waterfront

Figure 23. East Boston, North West Site Elevation

Figure 24. East Boston, Pier 01 Site facing Maverick Street, Immigrants House

Figure 25. East Boston, North East Site Elevation

Figure 26. East Boston, Pier 01 Site Approaching Waterfront, 1

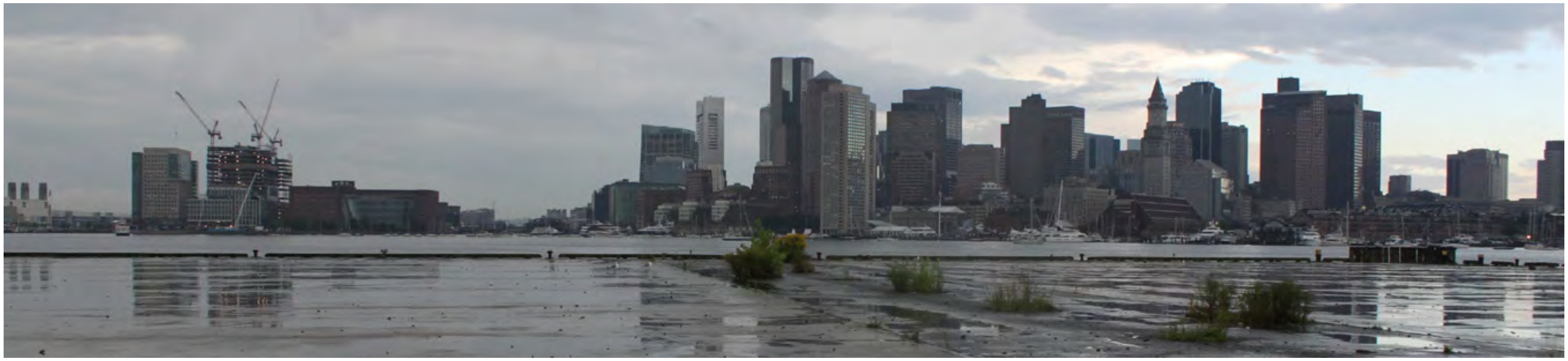


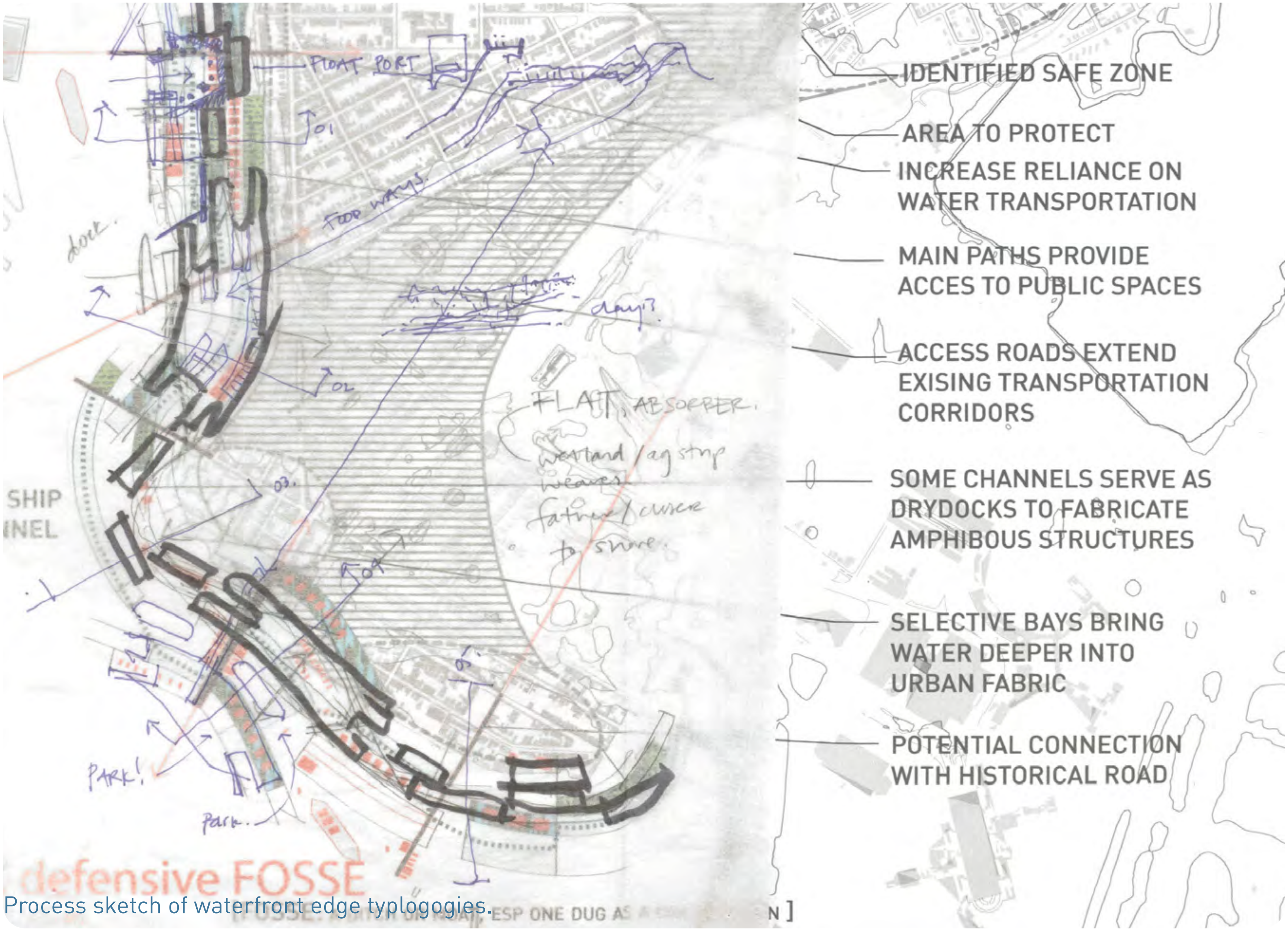
Figure 27. East Boston, Pier 01 Site Approaching Waterfront, 2

Figure 28. East Boston, Greenway facing Pier 01 Site

Figure 29. East Boston, Site Occupants, Fortune Hunting

Figure 30. East Boston, Pier 01 Site, Hard Water's Edge

Figure 31. East Boston, Pier 01 Site, Steel Plating



Process sketch of waterfront edge typlogogies.

4.0 - DESIGN

EAST BOSTON BUFFER

Working at multiple scales has created a natural feedback loop through which I have developed quantitative and qualitative resilience metrics for edge mitigation typologies. From those studies, I have learned how an edge system can; respond to a range of sea rise scenarios, take advantage of existing site conditions, be systematic to be reconfigured to function on different sites and improve experiential and environmental aspects of life in the city.

WATERFRONT IDENTITY

The project redefines East Boston's waterfront edge to give a new (much needed!) identity to the currently faceless side of East Boston. To create a continuity of waterfront experience, the introduction of productive and defensive programs needs to be part of a holistic and organized public park system.

INFRASTRUCTURE

In addition to the supplying the needed defensive infrastructure, this project establishes program drivers that serve the city at large in long term ways, as well as locally at the building level. The new buffer zone builds sea rise resilience across multiple dimensions (physical, social, economic) and scales. This infrastructure - in the form of energy collection, park spaces, etc. tap into the resource potentials of the waterfront.

STEWARDSHIP + EDUCATION

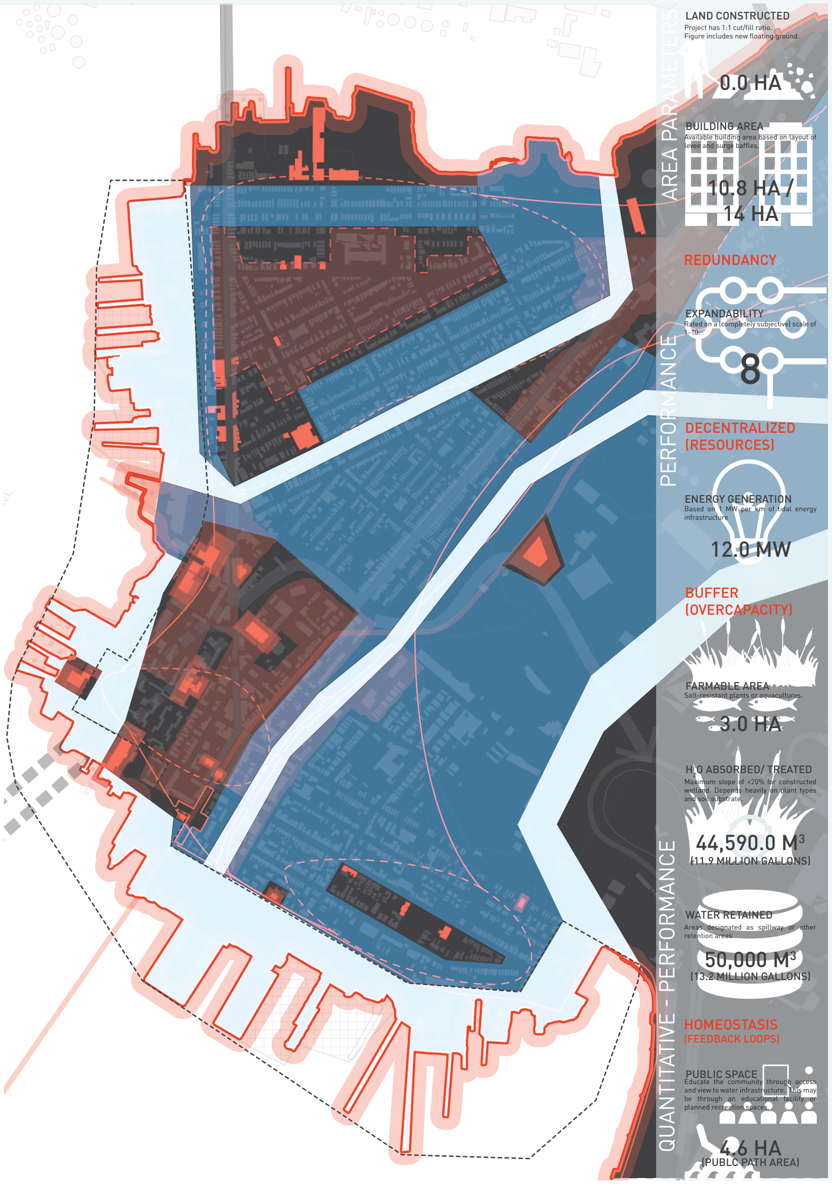
The project increases it's and the city's physical resilience by encouraging activity and within the buffer zone. The waterfront has been used for industry throughout the history of Eastie, and that tradition should continue with new industries that take advantage of relationship with water. How can production fit within a defensive strategy thereby giving everyday purpose and added value to defense infrastructure?

> INFRASTRUCTURE IS NOT A PASSIVE CONDUIT,

but an active producer - of energy, social exchange, natural resource, and economic growth. Consistently conceived as a vegetated space of recreation and bioremediation, infrastructure would be a defining presence in the city, not just a park.

- Praxis 13, WPA 2.0: Working Public Architecture

PROJECT PARAMETERS



The goal is to minimize disturbance of existing soil while integrating soft landscape edges for long term soil retention.

Building to accommodate future growth.

An 'expandable' scheme is adaptable/ transformable to future adaptation to new programmatic or defensive needs.

Energy generation is achieved through types of tidal energy infrastructure. Not calculated, though considered, is the energy consumption reduction by heat coupling.

One of the primary symbiotic programs considered - aquaculture may contribute to local economy as well as provide some storm surge resistance.

As land is inundated by floodwaters, water quality becomes an issue. The strategic location of wetlands in water runoff areas filters and purifies water (as well as capture suspended solids).

Water retention is more dependant on the use of hard infrastructures, but can have dual function such as energy generation.

Public space serves a dual purpose of serving general health needs as well as creating a space for community education about flooding and sea rise.

PREVIOUS EDGE TYPOLOGY STUDIES

PARAMETERS

AREA PARAMETERS

LAND CONSTRUCTED
All schemes assume a 1:1 cut/fill ratio. Figure includes new floating ground.

14.7 HA

BUILDING AREA
Inferred breakdown of 35% housing, 20% office, 25% services, 10% public facilities, and 5% infrastructure, and residential density of 20 M^2 per person from existing.

6.1 HA
= 1,675

ENERGY GENERATION

0.0 MW
heat coupling savings not included...

FARMABLE AREA
Salt-resistant plants or aquacultures

4.8 HA

PERFORMANCE

H_2O ABSORBED/ TREATED
Either requires that depth accommodation made for aquacultures or maximum slope of <20% for constructed wetland. Depends heavily on plant types and soil substrate. Assumes constant 0.3M substrate depth.
http://www.extension.purdue.edu/extmedia/WQ/WQ-10.html

44,950 M^3
11.9 MILLION GALLONS

H_2O OTHERWISE RETAINED
Areas designated as spillway or tidal basins, excludes wetlands.

0.0 M^3

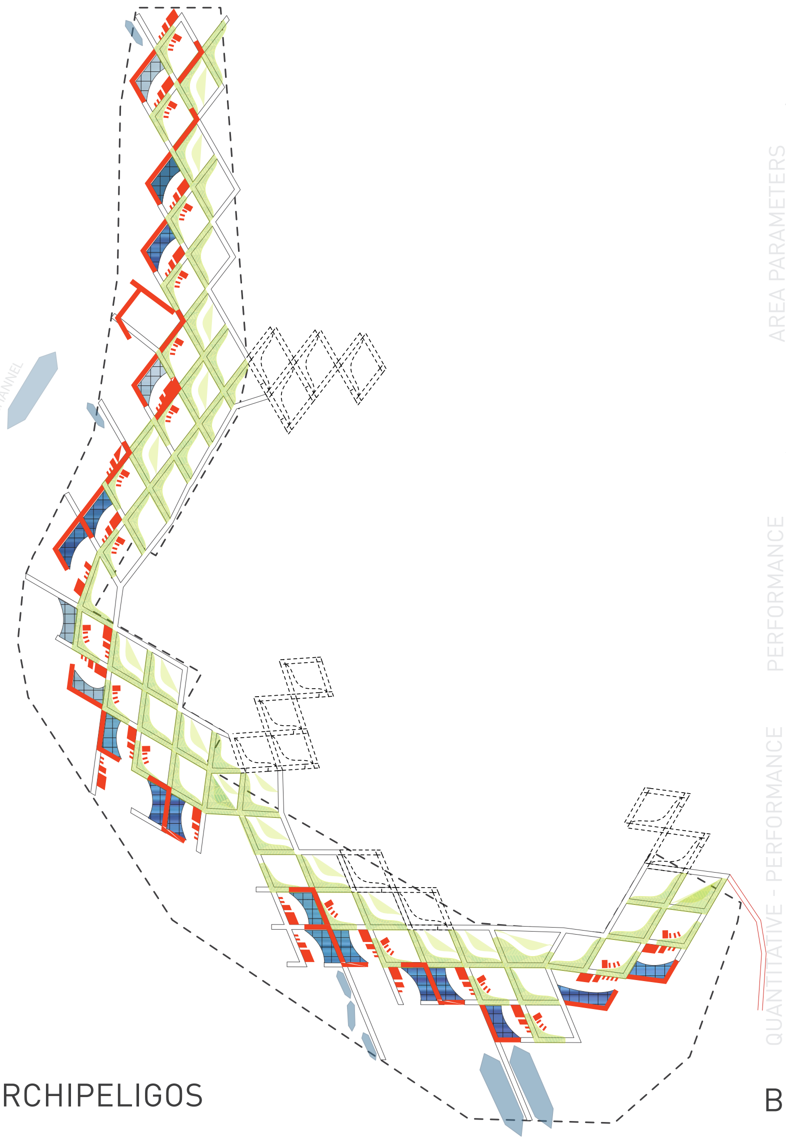
QUANTITATIVE - PERFORMANCE

PUBLIC SPACE
Educate the community through access and view to water infrastructure. This may be through an educational facility or planned recreation spaces.

16 HA
includes access

EXPAND (& ADAPT)ABILITY
Rated on a completely subjective scale of 1-10. When working at such a long timesacale, it is valuable for the scheme to anticipate change in use and extents.

10!



A. WOVEN ARCHIPELIGOS

PARAMETERS

AREA PARAMETERS

LAND CONSTRUCTED
All schemes assume a 1:1 cut/fill ratio. Figure includes new floating ground.

20 HA
(existing site area = 43.65 HA)

BUILDING AREA
Inferred breakdown of 35% housing, 20% office, 25% services, 10% public facilities, and 5% infrastructure, and residential density of 20 M^2 per person from existing.

11.4 HA
= 2,000

ENERGY GENERATION
Based on Islay (2000) precedent of 3.5 kW per meter of tidal energy infrastructure

12 MW
That's enough to power >2,000 homes!

Norway is planning the world's largest (floating) wind turbine to produce 10MW.

FARMABLE AREA
Salt-resistant plants or aquacultures

0 HA

PERFORMANCE

H_2O ABSORBED/ TREATED
Either requires that depth accommodation made for aquacultures or maximum slope of <20% for constructed wetland. Depends heavily on plant types and soil substrate. Assumes constant 0.3M substrate depth.
http://www.extension.purdue.edu/extmedia/WQ/WQ-10.html

44,950 M^3
11.9 MILLION GALLONS

H_2O OTHERWISE RETAINED
Areas designated as spillway or tidal basins, excludes wetlands.

100,000 M^3
public retention pools

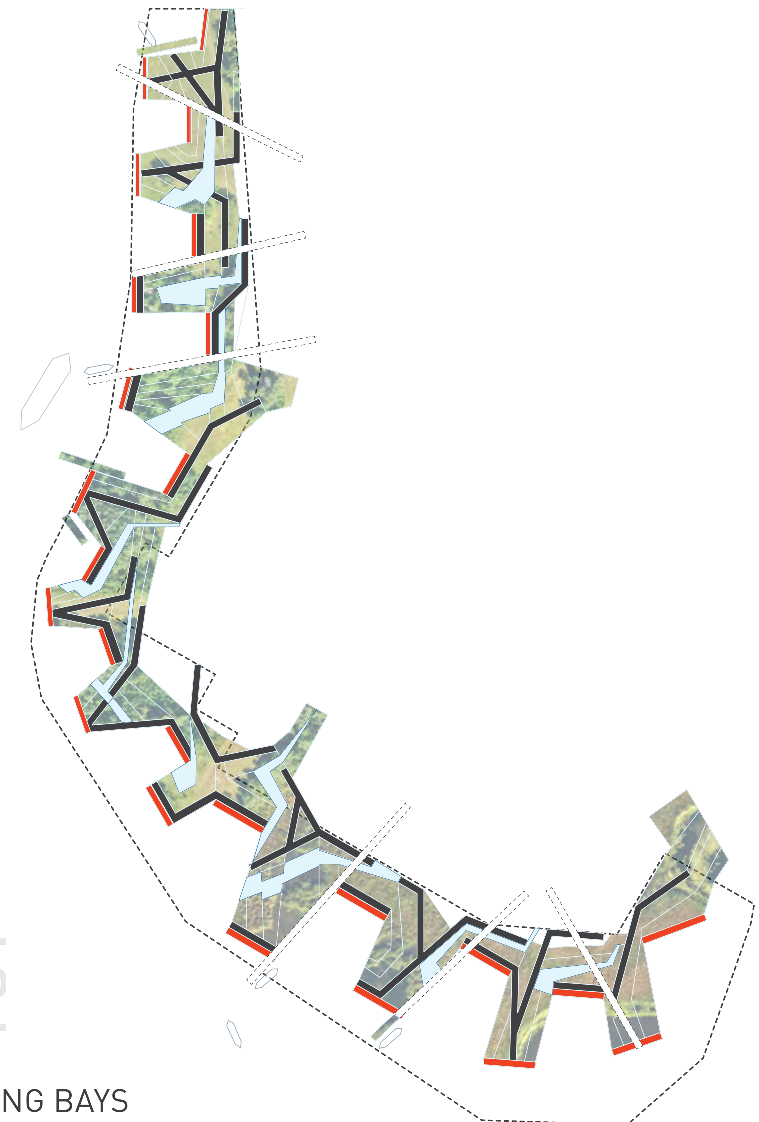
QUANTITATIVE - PERFORMANCE

PUBLIC SPACE
Educate the community through access and view to water infrastructure. This may be through an educational facility or planned recreation spaces.

20 HA
all constructed ground is accessable

EXPAND (& ADAPT)ABILITY
Rated on a completely subjective scale of 1-10. When working at such a long timesacale, it is valuable for the scheme to anticipate change in use and extents.

2



B. BUFFERING BAYS

PARAMETERS

AREA PARAMETERS

NEW LAND CONSTRUCTED
All schemes assume a 1:1 cut/fill ratio. Figure includes new floating ground.

0 HA
(existing site area = 43.65 HA)

BUILDING AREA
Inferred breakdown of 35% housing, 20% office, 25% services, 10% public facilities, and 5% infrastructure, and residential density of 20 M^2 per person from existing.

16 HA
= 2,500

ENERGY GENERATION
Based on Islay (2000) precedent of 3.5 kW per meter of tidal energy infrastructure

8.4 MW
(2,395 linear meters)

PERFORMANCE

FARMABLE AREA
Salt-resistant plants or aquacultures

0(?) HA

H_2O ABSORBED/ TREATED
Either requires that depth accommodation made for aquacultures or maximum slope of <20% for constructed wetland. Depends heavily on plant types and soil substrate. Assumes constant 0.3M substrate depth.
http://www.extension.purdue.edu/extmedia/WQ/WQ-10.html

27,000 M^3
7.13 MILLION GALLONS
in spillway

H_2O OTHERWISE RETAINED
Areas designated as spillway or tidal basins, excludes wetlands.

970,000 M^3
each basin ~ 40,685 m^2 x 12 basins x 2M

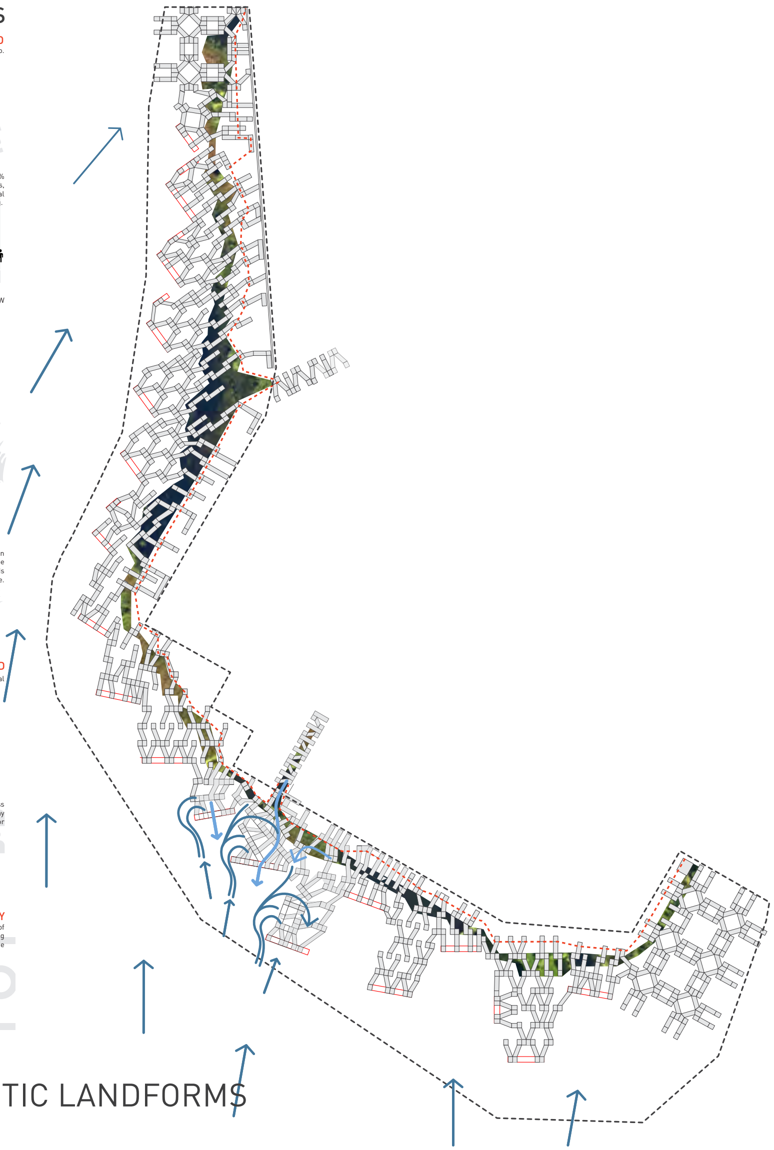
QUANTITATIVE - PERFORMANCE

PUBLIC SPACE
Educate the community through access and view to water infrastructure. This may be through an educational facility or planned recreation spaces.

7.5 HA
includes access

EXPAND (& ADAPT)ABILITY
Rated on a completely subjective scale of 1-10. When working at such a long timesacale, it is valuable for the scheme to anticipate change in use and extents.

6



C. ENERGETIC LANDFORMS

PARAMETERS

AREA PARAMETERS

LAND CONSTRUCTED
All schemes assume a 1:1 cut/fill ratio. Figure includes new floating ground.

20 HA
(existing site area = 43.65 HA)

BUILDING AREA
Inferred breakdown of 35% housing, 20% office, 25% services, 10% public facilities, and 5% infrastructure, and residential density of 20 M^2 per person from existing.

11.4 HA
= 2,000

ENERGY GENERATION
Based on Islay (2000) precedent of 3.5 kW per meter of tidal energy infrastructure

12 MW
That's enough to power >2,000 homes!

Norway is planning the world's largest (floating) wind turbine to produce 10MW.

PERFORMANCE

FARMABLE AREA
Salt-resistant plants or aquacultures

1.8 HA

H_2O ABSORBED/ TREATED
Either requires that depth accommodation made for aquacultures or maximum slope of <20% for constructed wetland. Depends heavily on plant types and soil substrate. Assumes constant 0.3M substrate depth.
http://www.extension.purdue.edu/extmedia/WQ/WQ-10.html

44,950 M^3
11.9 MILLION GALLONS

H_2O OTHERWISE RETAINED
Areas designated as spillway or tidal basins, excludes wetlands.

100,000 M^3
public retention pools

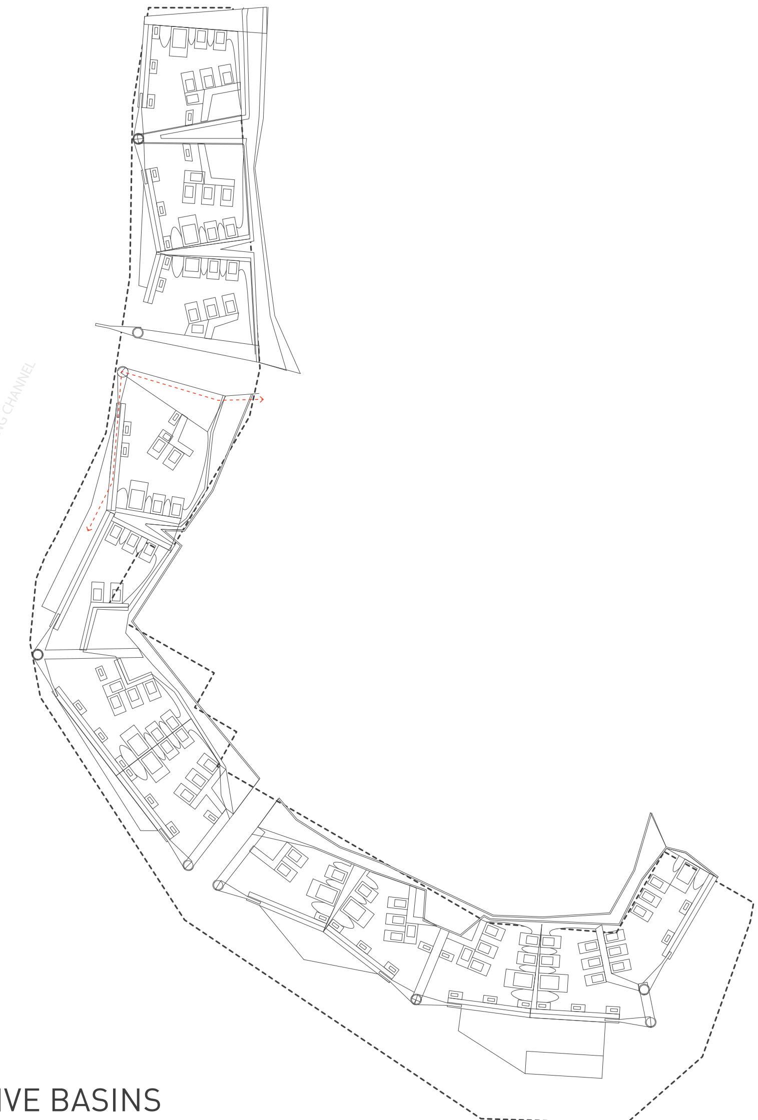
QUANTITATIVE - PERFORMANCE

PUBLIC SPACE
Educate the community through access and view to water infrastructure. This may be through an educational facility or planned recreation spaces.

20 HA
sloping + bridging makes all constructed ground is accessable

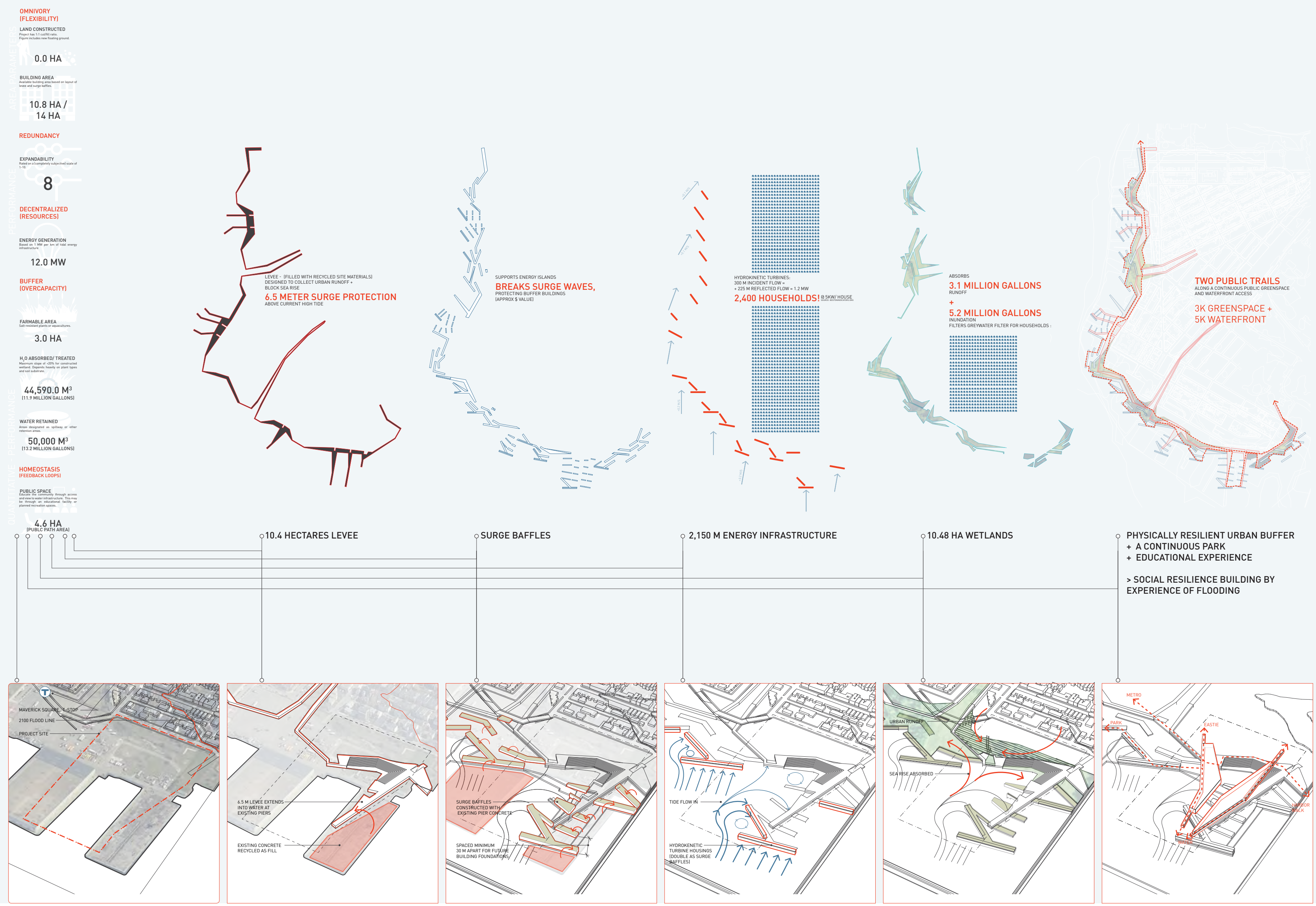
EXPAND (& ADAPT)ABILITY
Rated on a completely subjective scale of 1-10. When working at such a long timesacale, it is valuable for the scheme to anticipate change in use and extents.

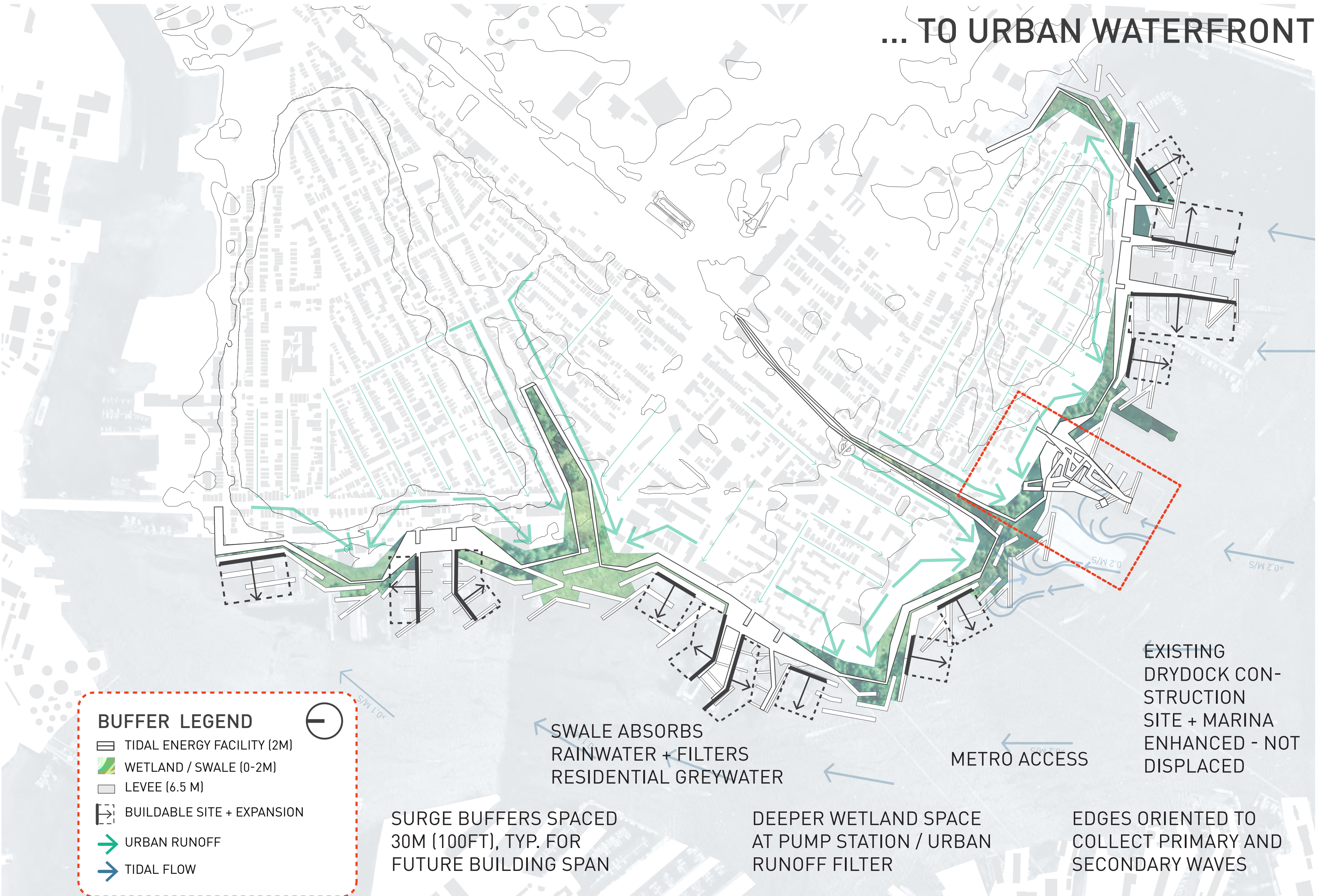
8
system allows for infill and further branching out with floating structures



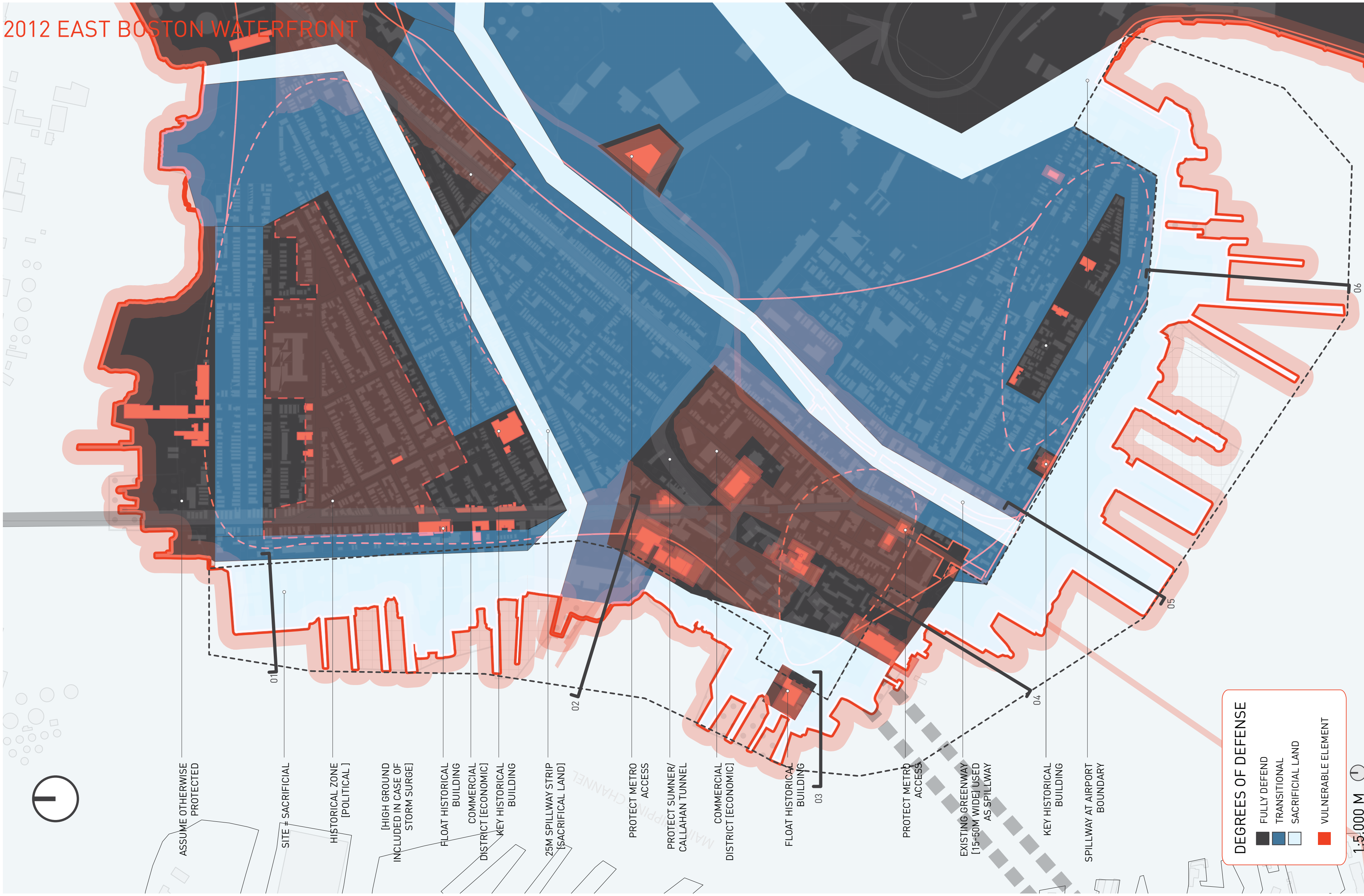
D. PROTECTIVE BASINS

FROM PARAMETERS...





... TO URBAN WATERFRONT
EXISTING DRYDOCK CON-STRUCTION SITE + MARINA ENHANCED - NOT DISPLACED
SWALE ABSORBS RAINWATER + FILTERS RESIDENTIAL GREYWATER
METRO ACCESS
BUFFER LEGEND
TIDAL ENERGY FACILITY (2M)
WETLAND / SWALE (0-2M)
LEVEE (6.5 M)
BUILDABLE SITE + EXPANSION
URBAN RUNOFF
TIDAL FLOW
SURGE BUFFERS SPACED 30M (100FT), TYP. FOR FUTURE BUILDING SPAN
DEEPER WETLAND SPACE AT PUMP STATION / URBAN RUNOFF FILTER
EDGES ORIENTED TO COLLECT PRIMARY AND SECONDARY WAVES

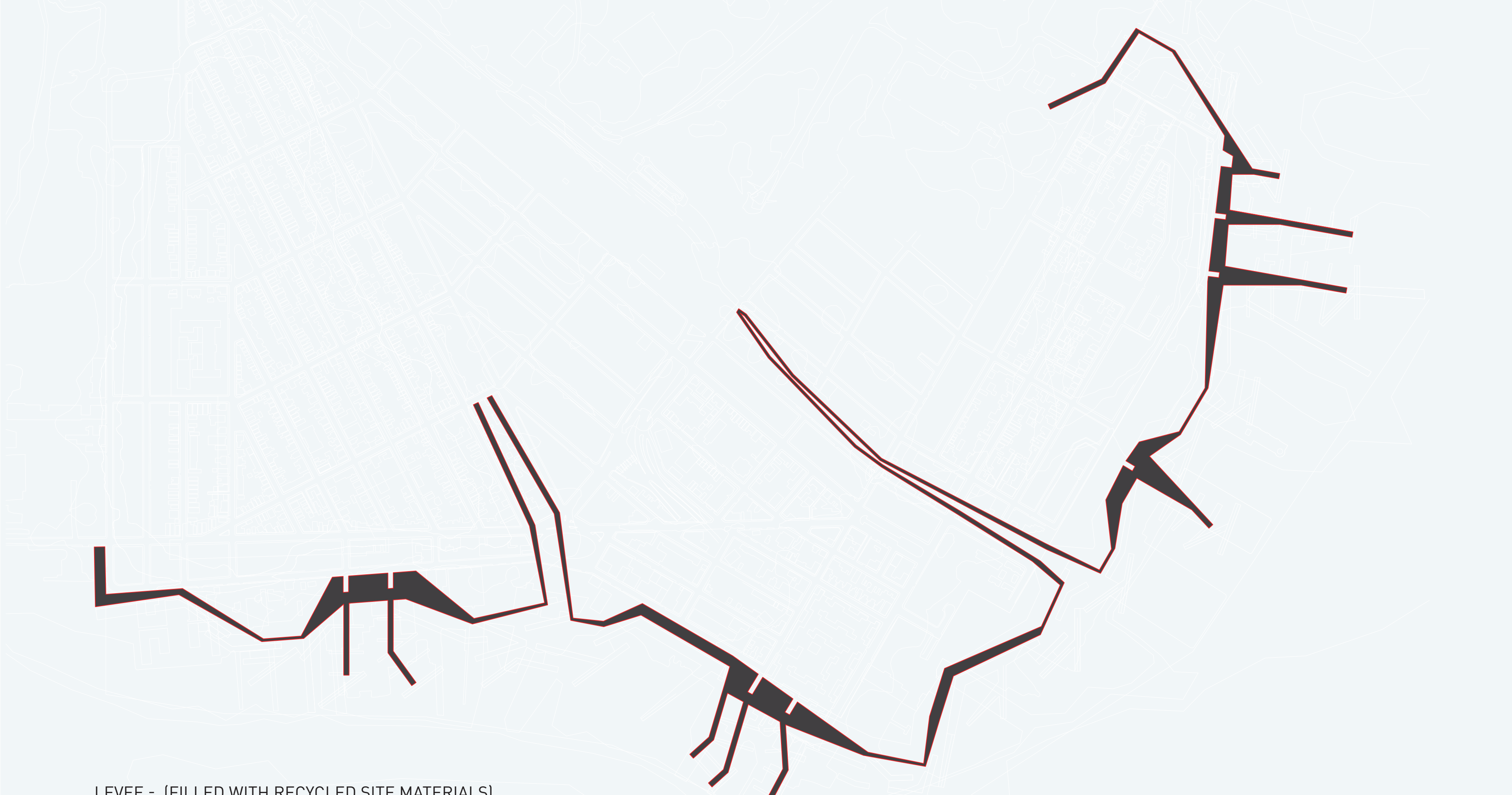

2012 EAST BOSTON WATERFRONT
ASSUME OTHERWISE PROTECTED
SITE + SACRIFICIAL
HISTORICAL ZONE [POLITICAL]
[HIGH GROUND INCLUDED IN CASE OF STORM SURGE]
FLOAT HISTORICAL BUILDING
COMMERCIAL DISTRICT [ECONOMIC]
KEY HISTORICAL BUILDING
25M SPILLWAY STRIP [SACRIFICAL LAND]
PROTECT METRO ACCESS
PROTECT SUMNER/ CALLAHAN TUNNEL
COMMERCIAL DISTRICT [ECONOMIC]
FLOAT HISTORICAL BUILDING
PROTECT METRO ACCESS
EXISTING GREENWAY [15-50M WIDE] USED AS SPILLWAY
KEY HISTORICAL BUILDING
SPILLWAY AT AIRPORT BOUNDARY
01
02
03
04
05
06
MAIN SHIPPING CHANNEL
DEGREES OF DEFENSE
FULLY DEFEND
TRANSITIONAL
SACRIFICIAL LAND
VULNERABLE ELEMENT
1:5,000 M

HARD - EDGE WATERFRONT

00_EXISTING SITE

Project is sited at the intersection of two framework typologies. It is also an exciting site because it is adjacent to Maverick Square and is the terminus of the East Boston Greenway (low lying ground).

2018 EAST BOSTON WATERFRONT - STRENGTHENED



LEVEE - (FILLED WITH RECYCLED SITE MATERIALS)
DESIGNED TO COLLECT URBAN RUNOFF +
BLOCK SEA RISE

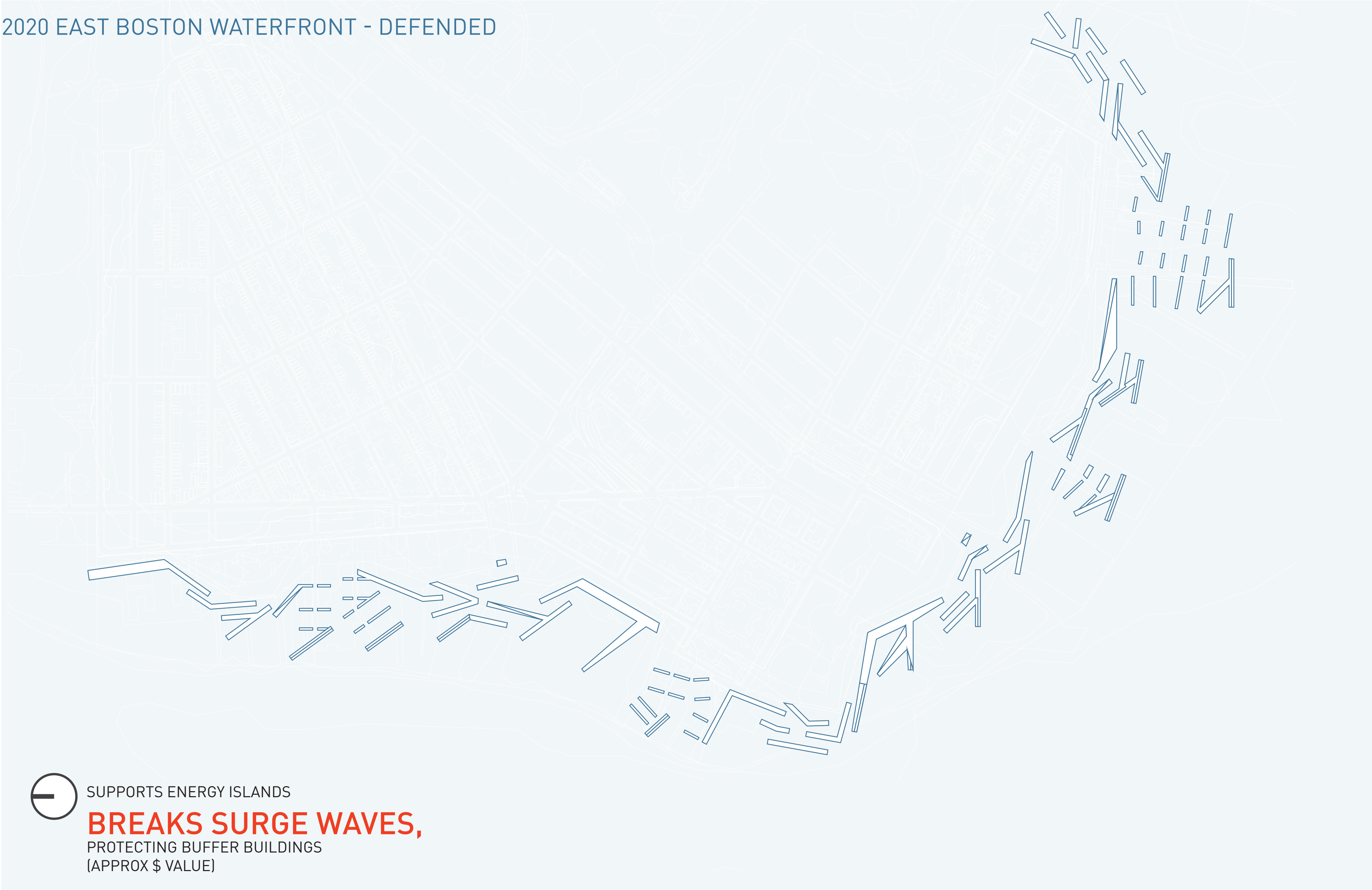
6.5 METER SURGE PROTECTION
ABOVE CURRENT HIGH TIDE

10.4 HECTARES LEVEE

01_LEVEE

is the backbone of the system. It is not only a 6.5 meter high barrier, but a conduit and pathway. The mass of this structure is partially constructed of existing site material to build up a stable base.

2020 EAST BOSTON WATERFRONT - DEFENDED

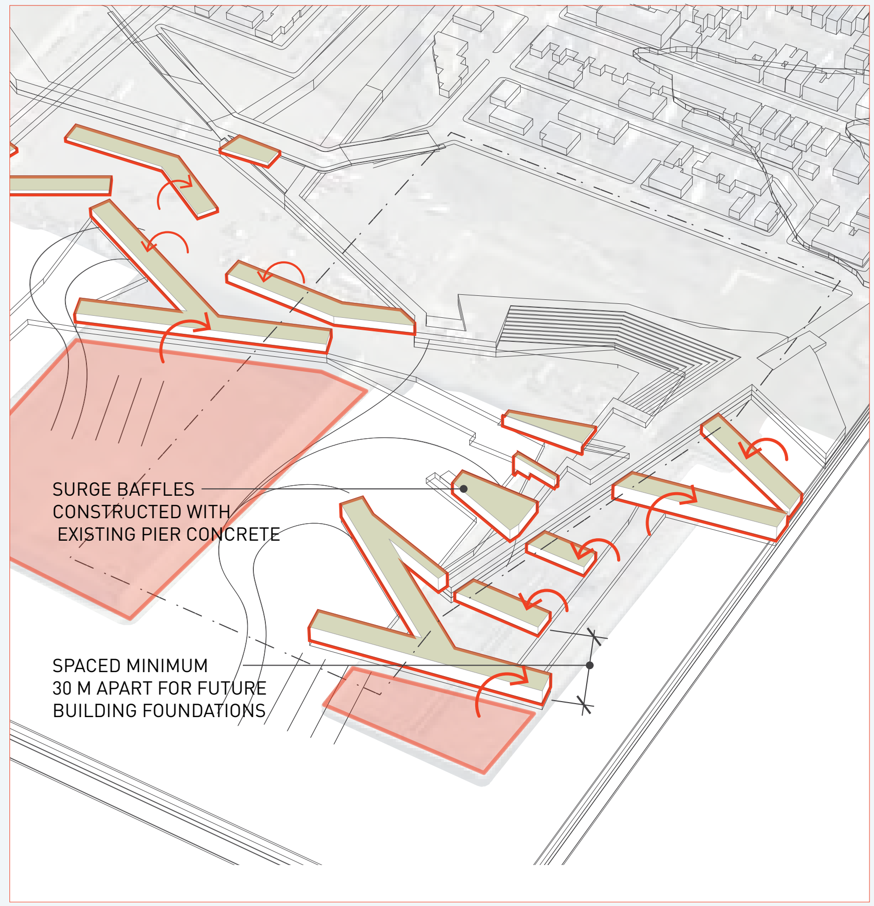


SUPPORTS ENERGY ISLANDS

BREAKS SURGE WAVES,

PROTECTING BUFFER BUILDINGS
(APPROX $ VALUE)

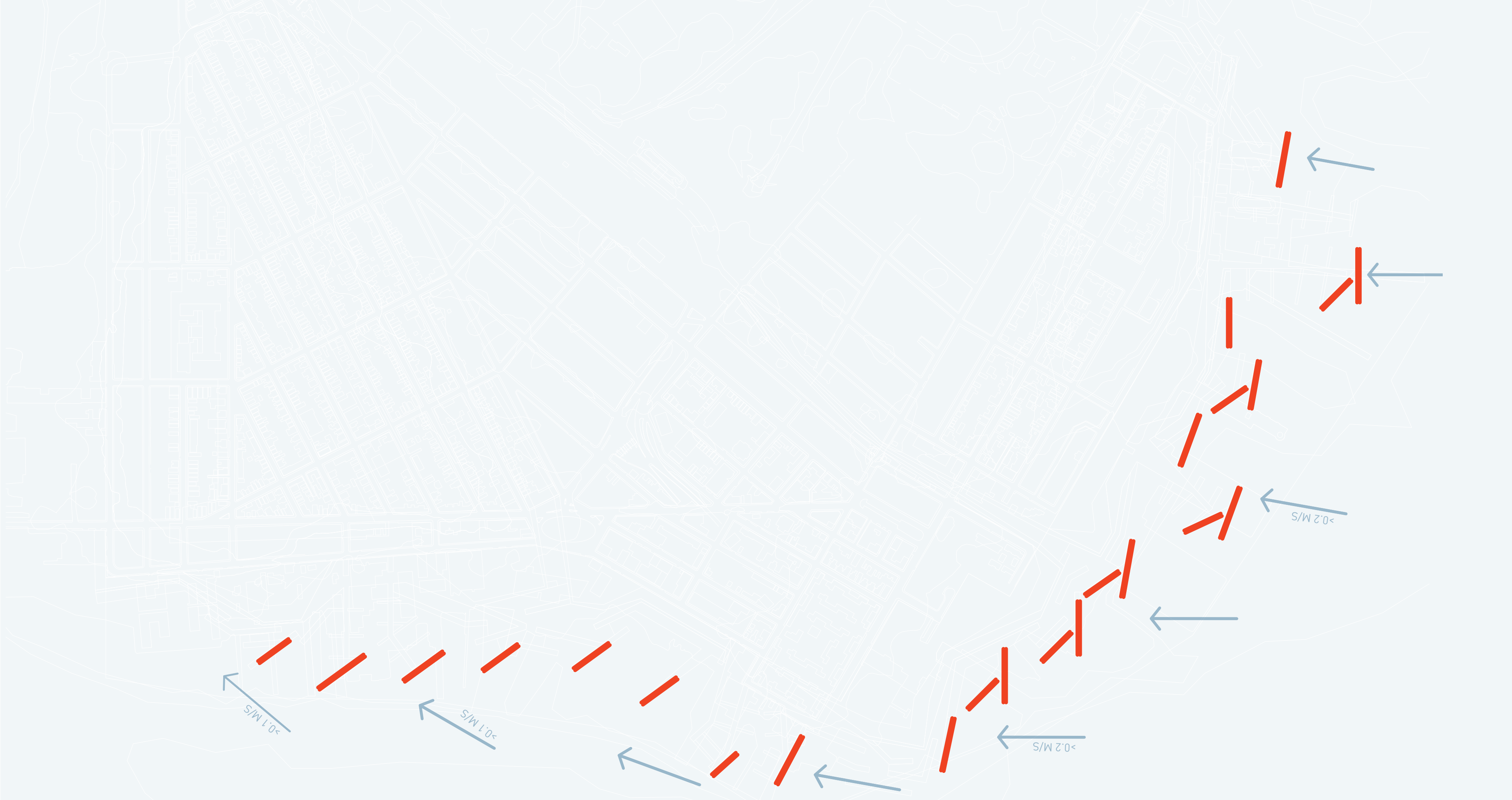
SURGE BAFFLES



02_SURGE BAFFLES

are gabion construction out of the remaining site material to break up surge waves as well as create stable foundations at regular intervals for future construction.

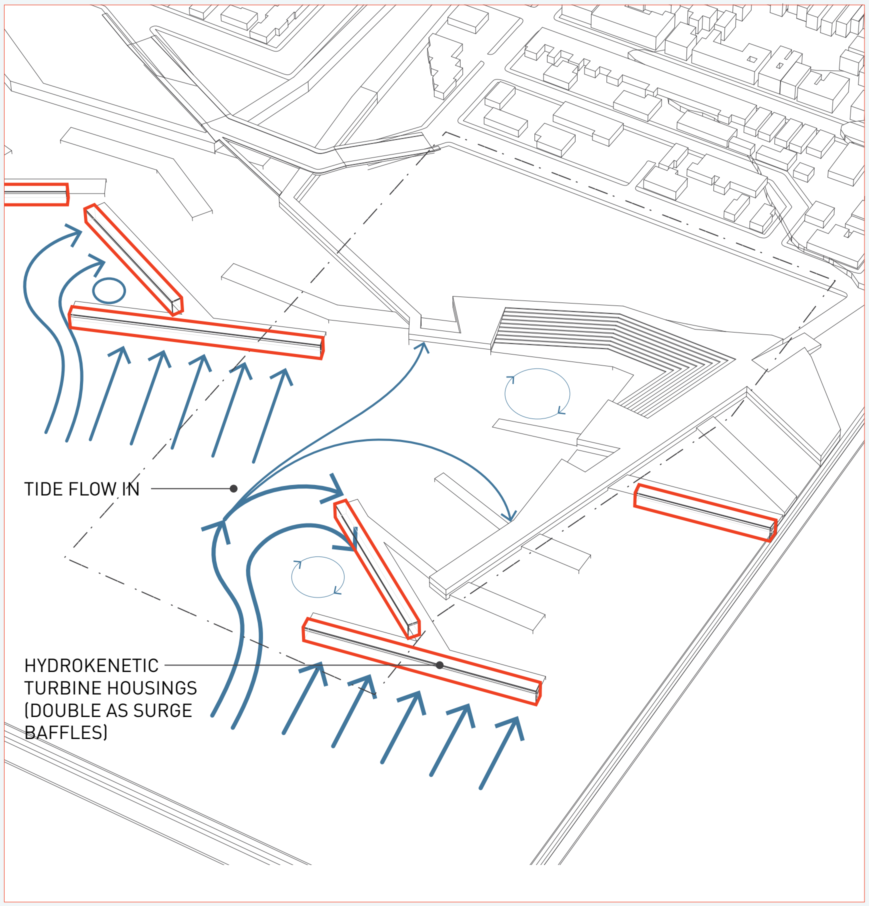
2022 EAST BOSTON WATERFRONT - PRODUCTIVE



HYDROKINETIC TURBINES:
300 M INCIDENT FLOW =
+ 225 M REFLECTED FLOW = 1.2 MW

2,400 HOUSEHOLDS! @ 5KW/ HOUSE
SOURCE: BOSTONINDICATORS.ORG

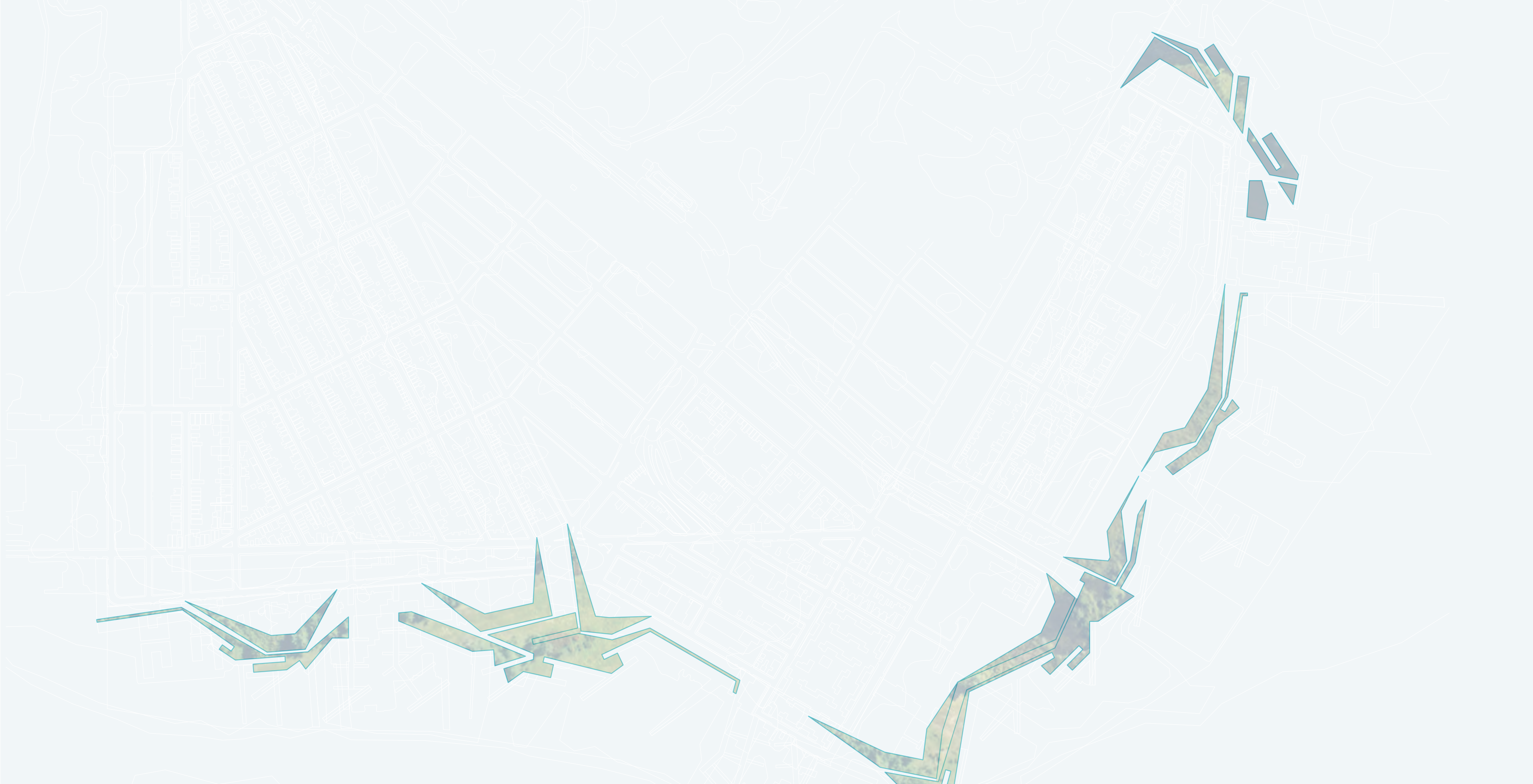
2,150 M ENERGY INFRASTRUCTURE



03_TIDAL ENERGY COLLECTORS

are concrete oscillating water columns (see Appendix 6.4 for more information on hydrokinetic technologies) oriented based on studies of harbor flow (Figure 4).

2025 EAST BOSTON WATERFRONT - SOFTENED



ABSORBS

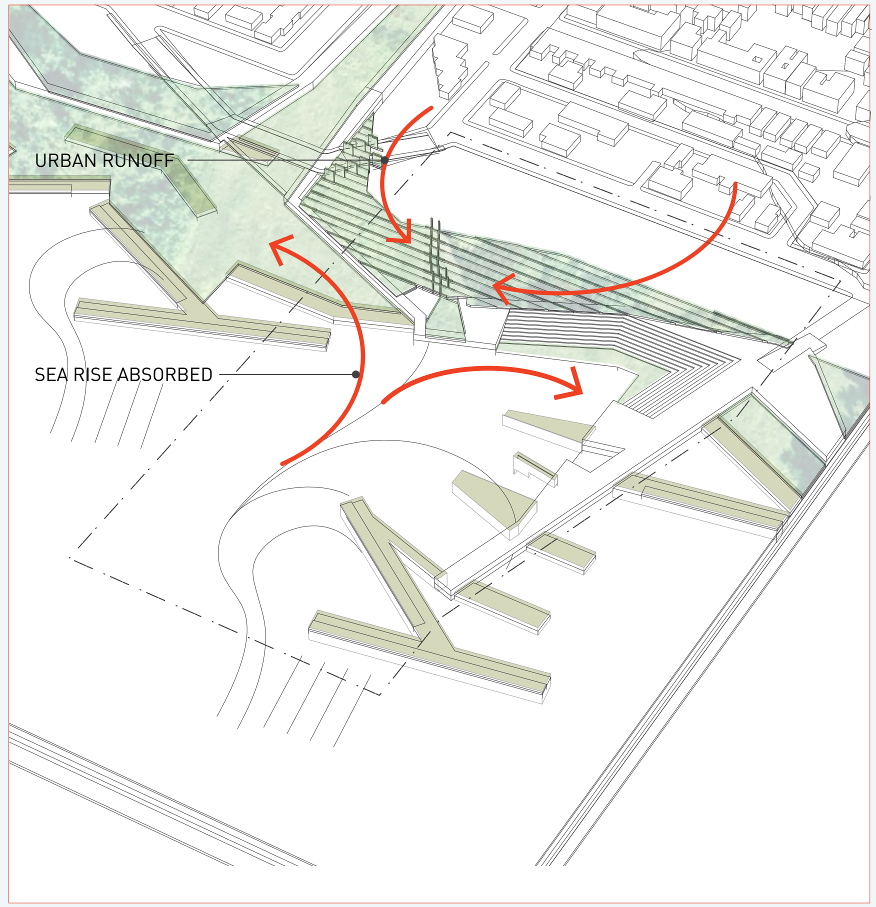
3.1 MILLION GALLONS RUNOFF

+

5.2 MILLION GALLONS INUNDATION

FILTERS GREYWATER FILTER FOR HOUSEHOLDS -

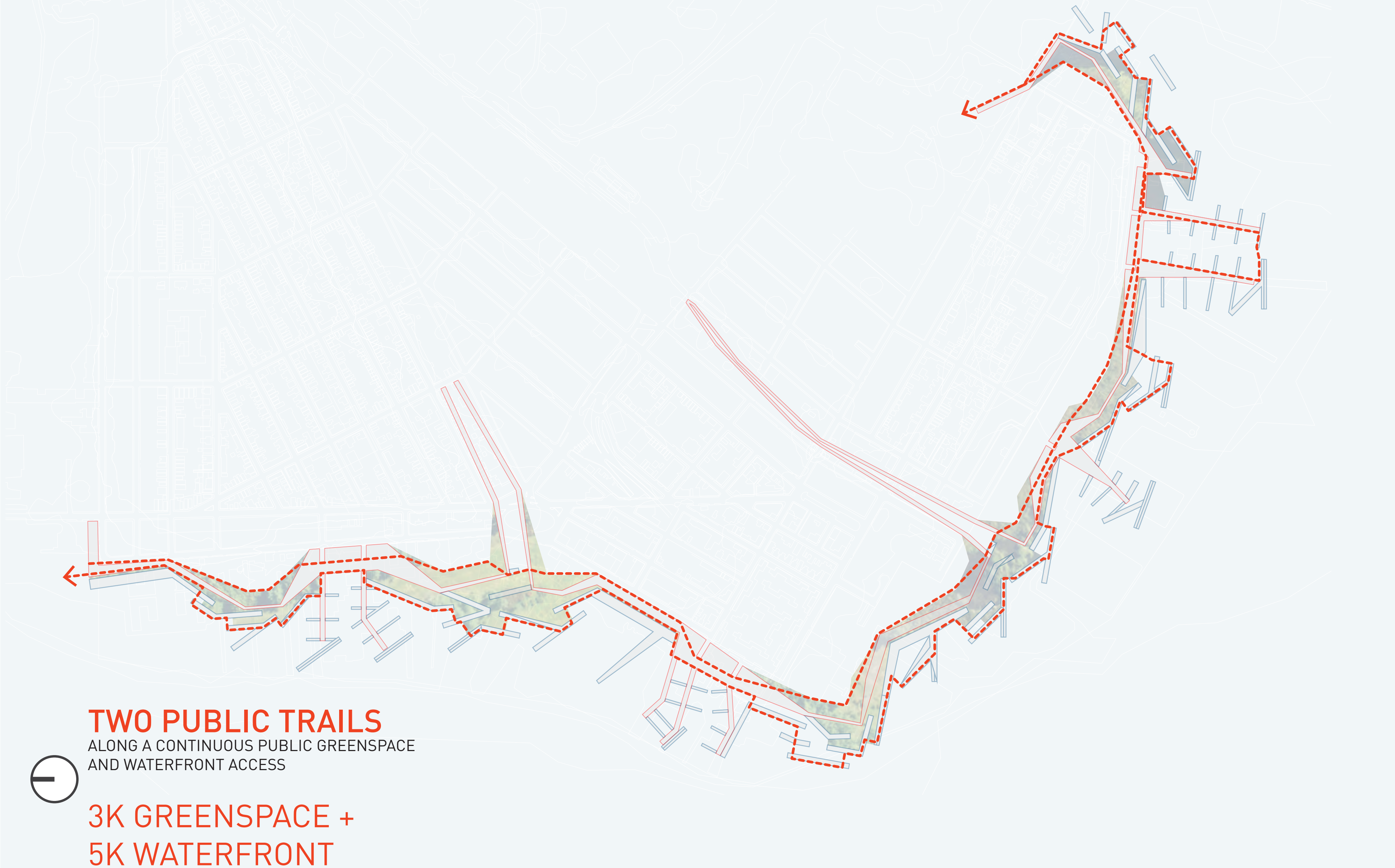
10.48 HA WETLANDS



04_WETLANDS

absorb flood water and are designed with ample space and slope to track with sea rise. The planametric depth is based on tributary area of urban runoff.

2030 EAST BOSTON WATERFRONT - SEA RISE READY!



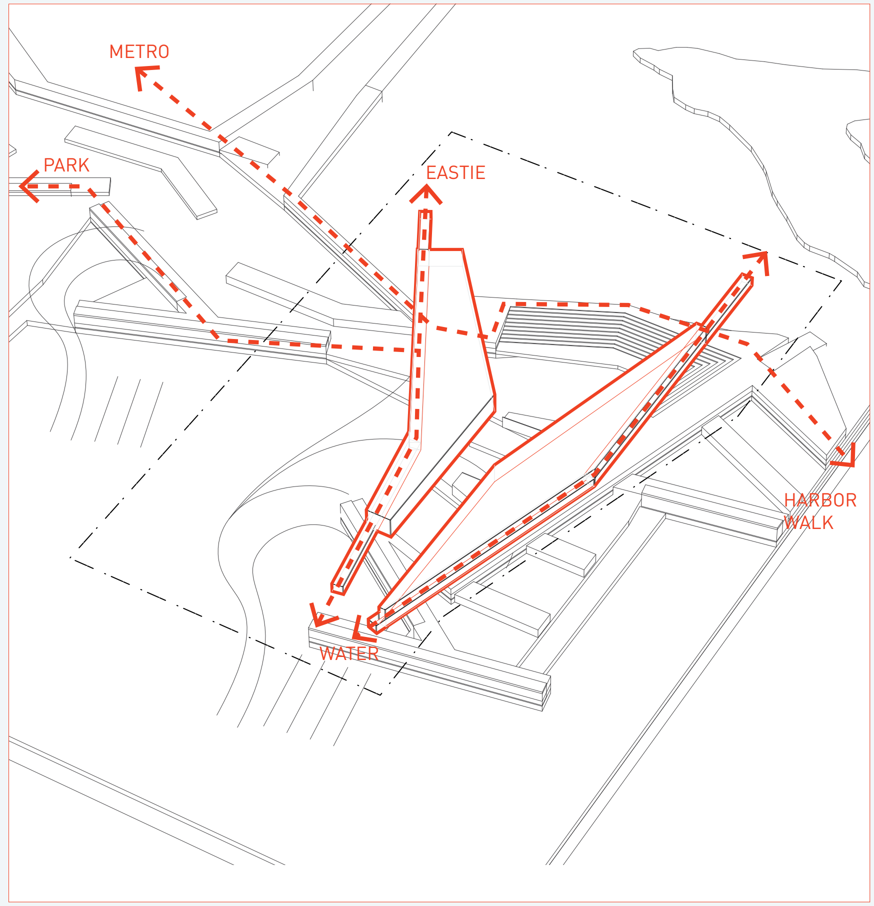
TWO PUBLIC TRAILS

ALONG A CONTINUOUS PUBLIC GREENSPACE
AND WATERFRONT ACCESS

3K GREENSPACE +
5K WATERFRONT

PHYSICALLY RESILIENT
URBAN BUFFER
+ A CONTINUOUS PARK
+ EDUCATIONAL EXPERIENCE

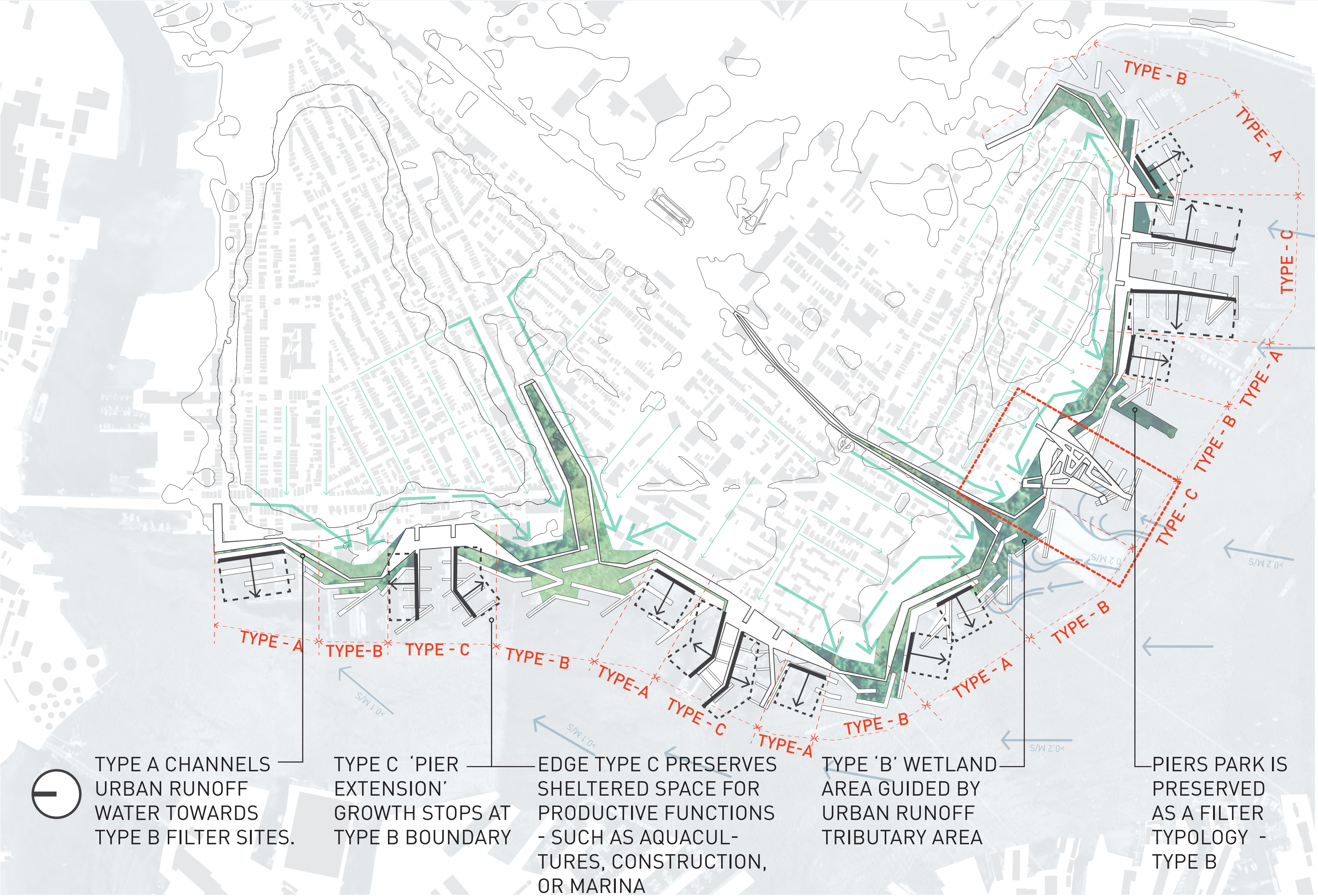
> SOCIAL RESILIENCE BUILDING BY EXPERIENCE OF FLOODING



05_ACCESS PATHWAYS

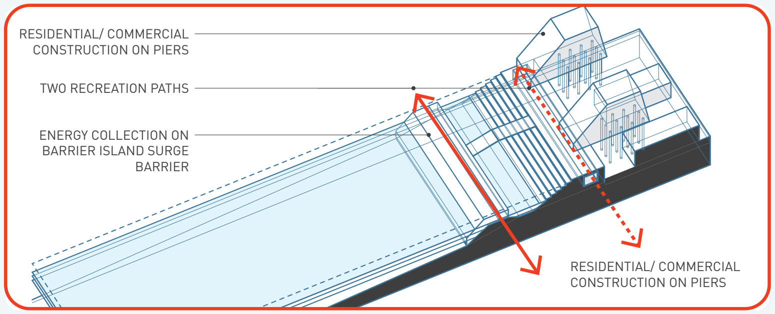
Finally and most importantly is the participation and stewardship of the public via public access paths along and through the buffer zone - allowing dynamic homeostasis to occur.

EMERGENT SYMBIOTIC EDGE TYPOLOGIES



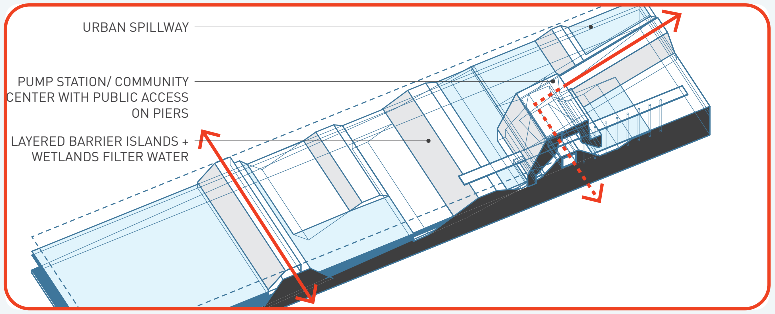
LAYERED EDGE TYPOLOGIES

TYPE A. BUILT EDGE



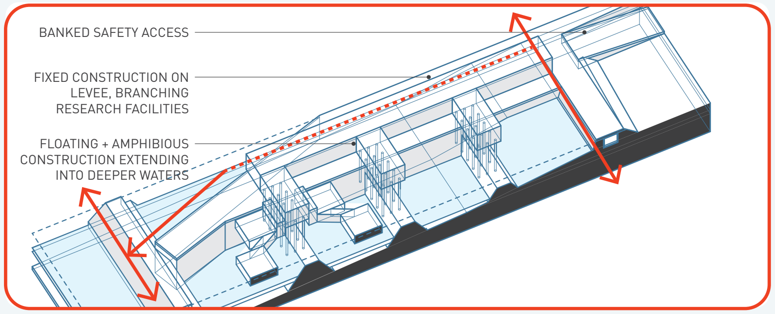
Continues the urban fabric over the levee for a continuity of the city to the waterfront. Public access is prioritized and development takes on a new form of 'urban block'.

TYPE B. ECO FILTER



Serves as a place fo exchange between urban runoff and sea water. Characterized by a gradual and 'soft' section - with no buildings.

TYPE C. PIER ENHANCEMENTS

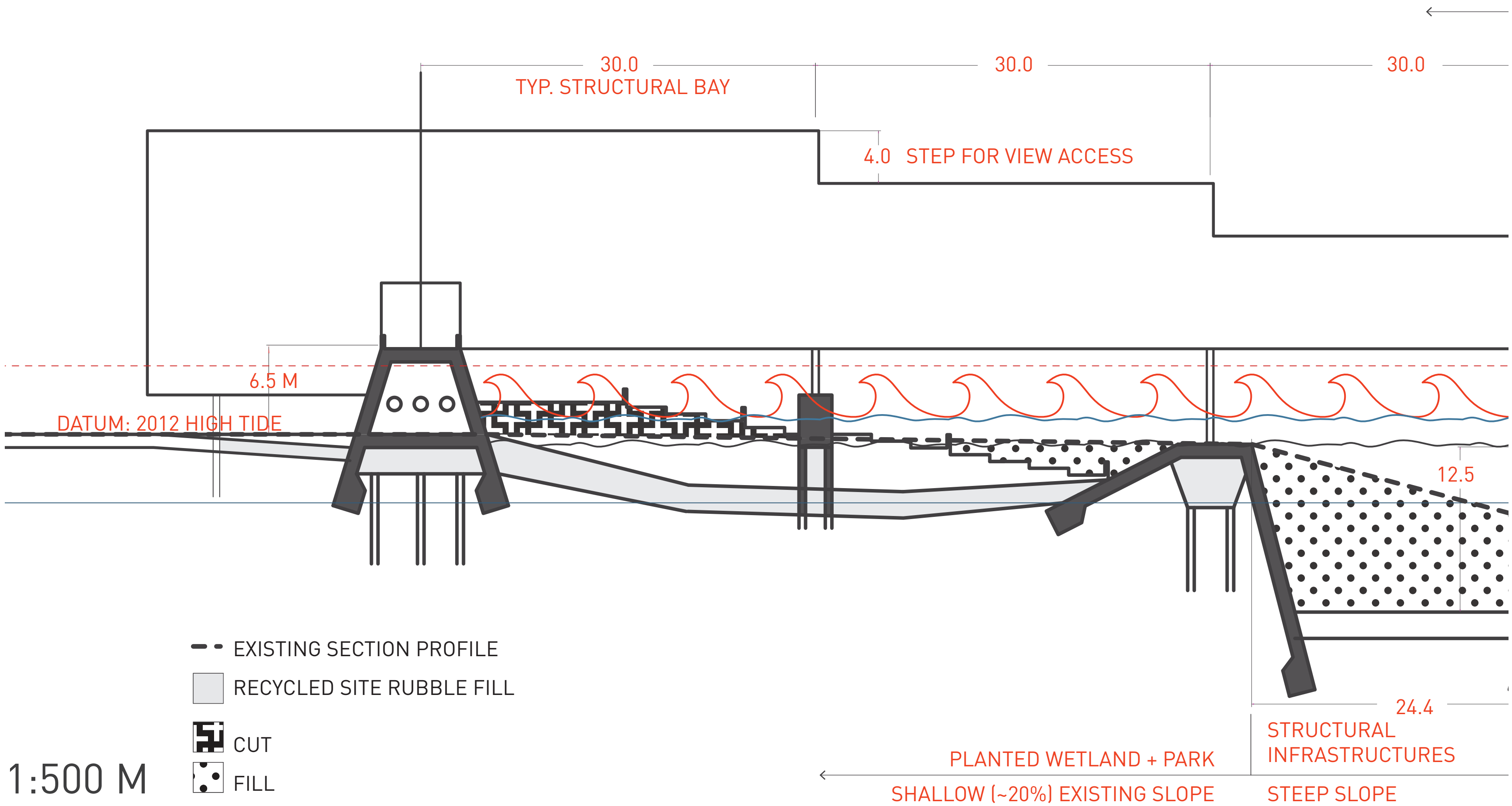


Establishes designated zones for production and echoes existing shoreline forms.

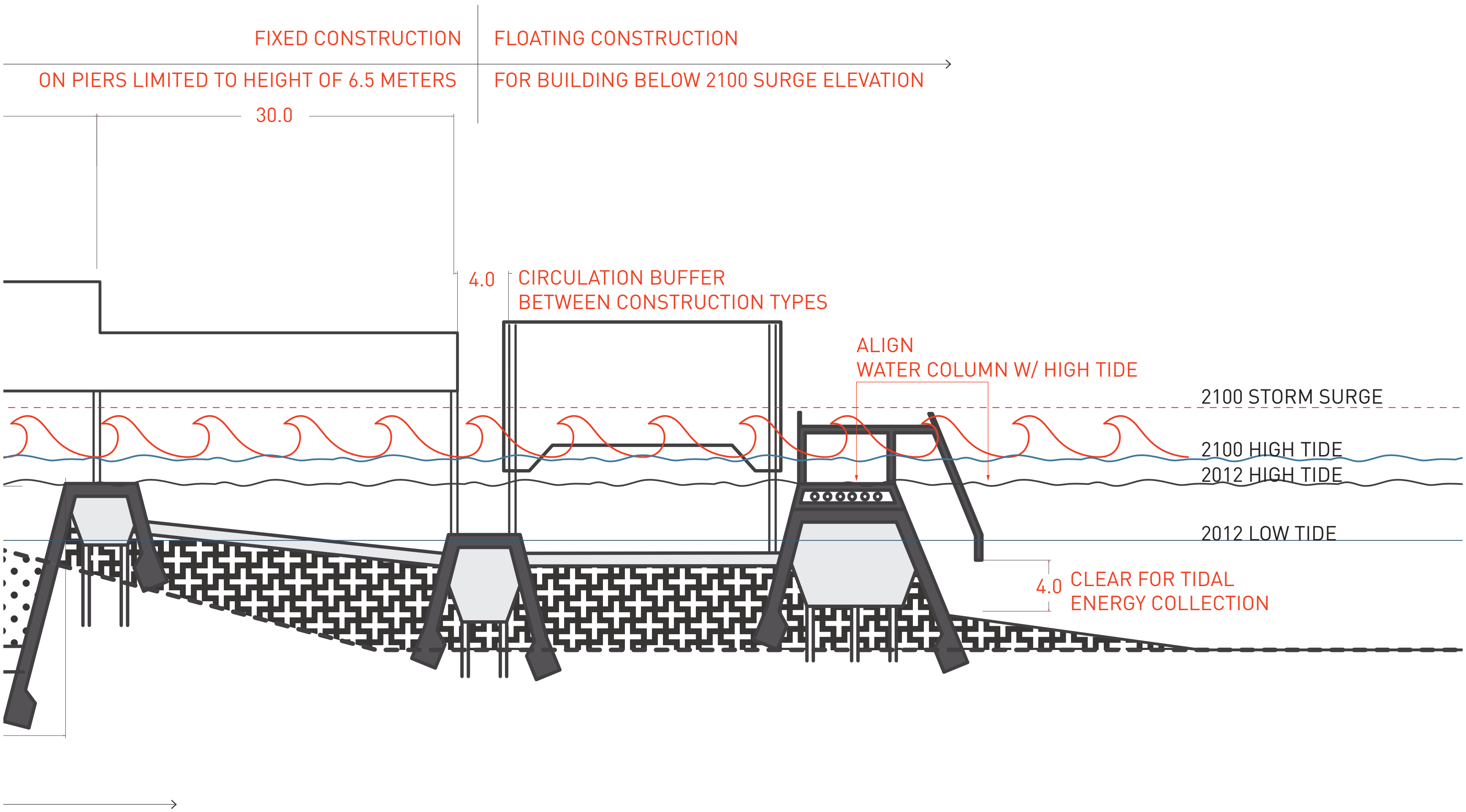
> LAYOUT STRATEGY

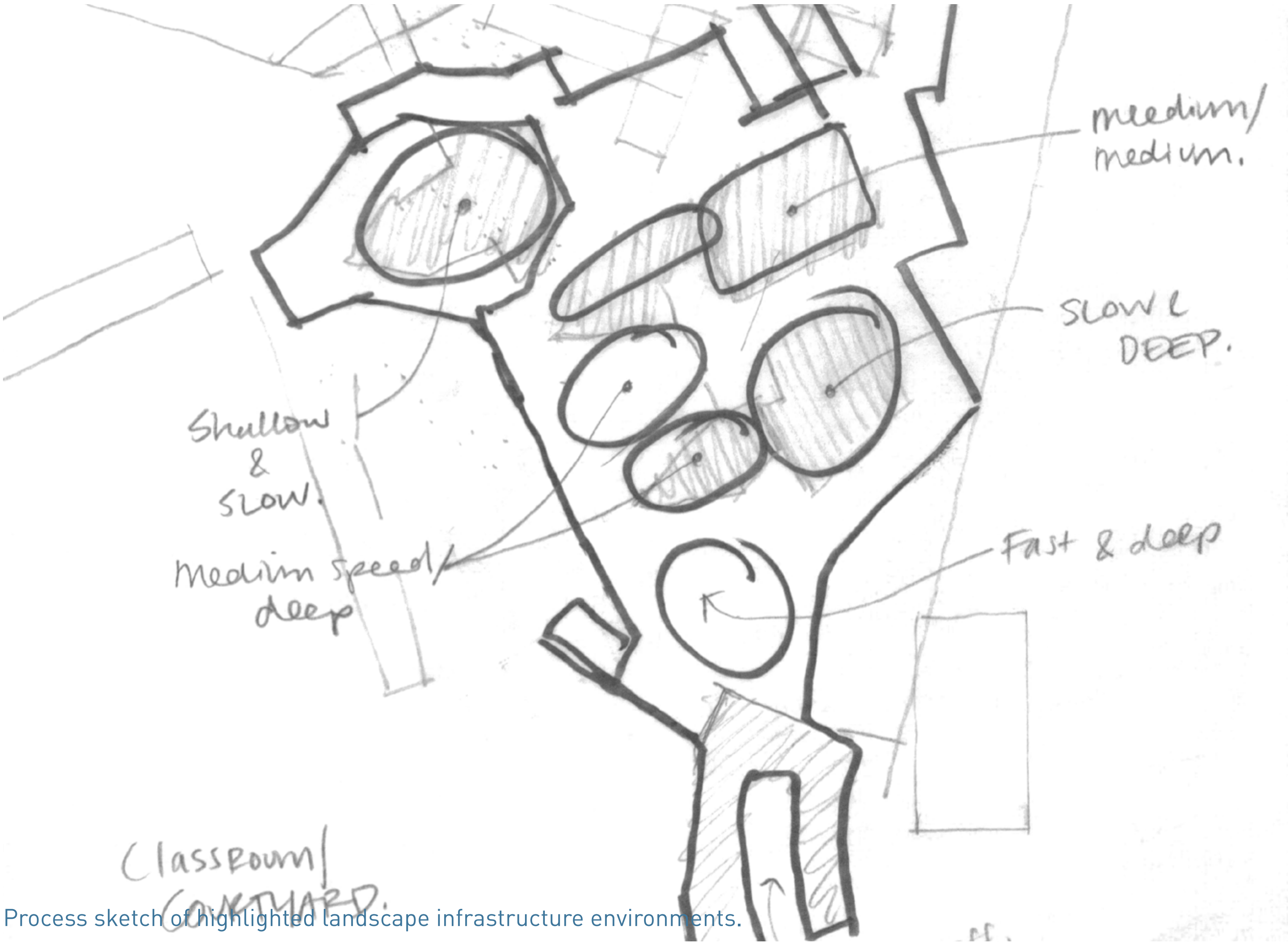
These layers of landscape defense are configured in such a way that THREE EDGE TYPLOGIES emerge on a neighborhood scale.

< LANDWARD SIDE



SEAWARD SIDE >





Process sketch of highlighted landscape infrastructure environments.

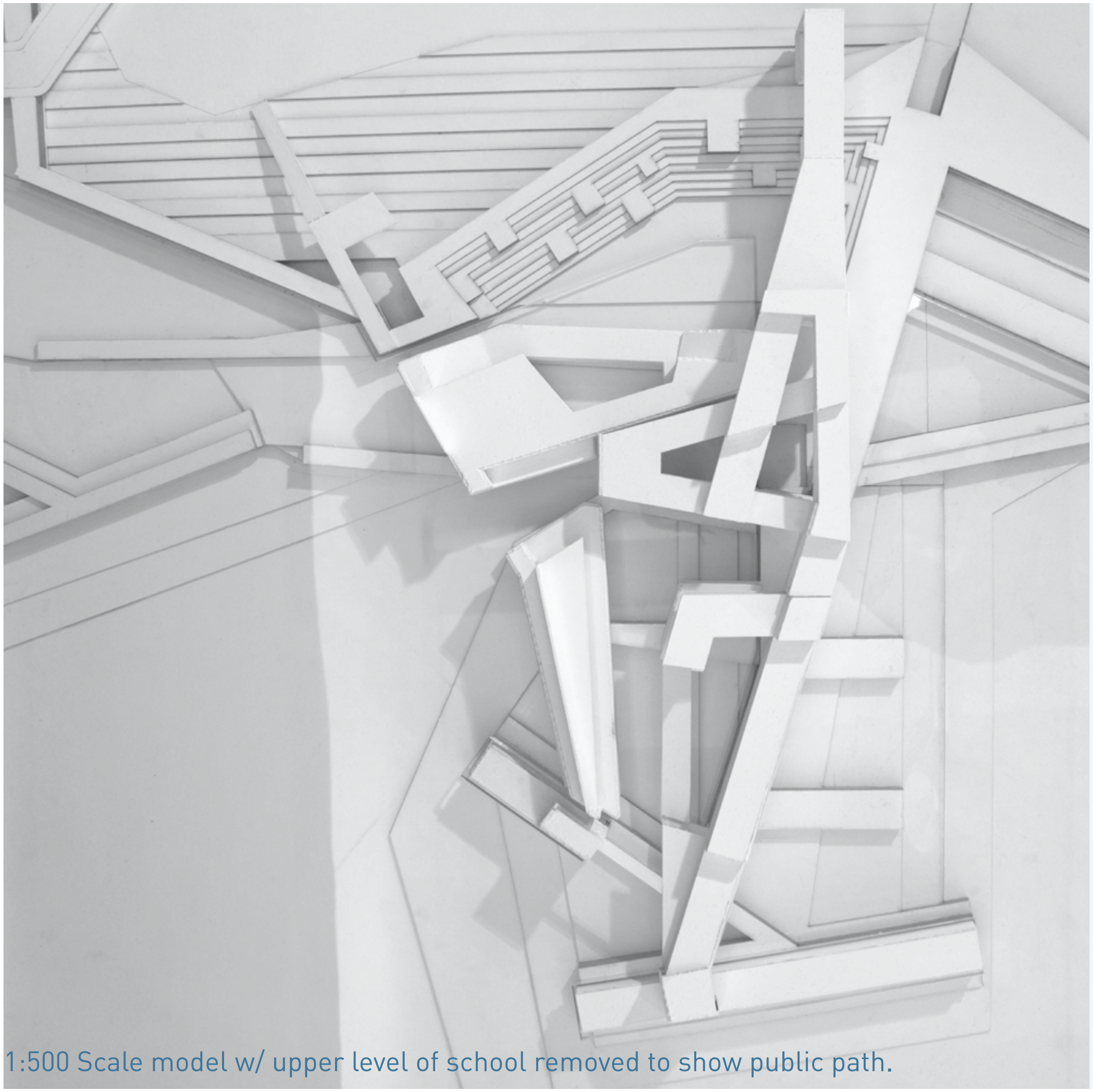
4.3 - DESIGN

RESILIENT WATERFRONT COMPLEX

The final step in the process of building urban resilience is activating the waterfront zone through architecture. The public location of the waterfront focus site demands a building that demonstrates the effects of climate change, sea rise and aspects of the waterfront to a wide audience. Thus, the main formal driver for the project is a public path that weaves pedestrians or bikers through the unique environments created by the infrastructure (refer to plan on page 97). The building serves as a lens for experiencing these environments.

The purpose of this chapter is to convey the new types of urban experiences that can be cultivated through the proposed approach to waterfront infrastructure.

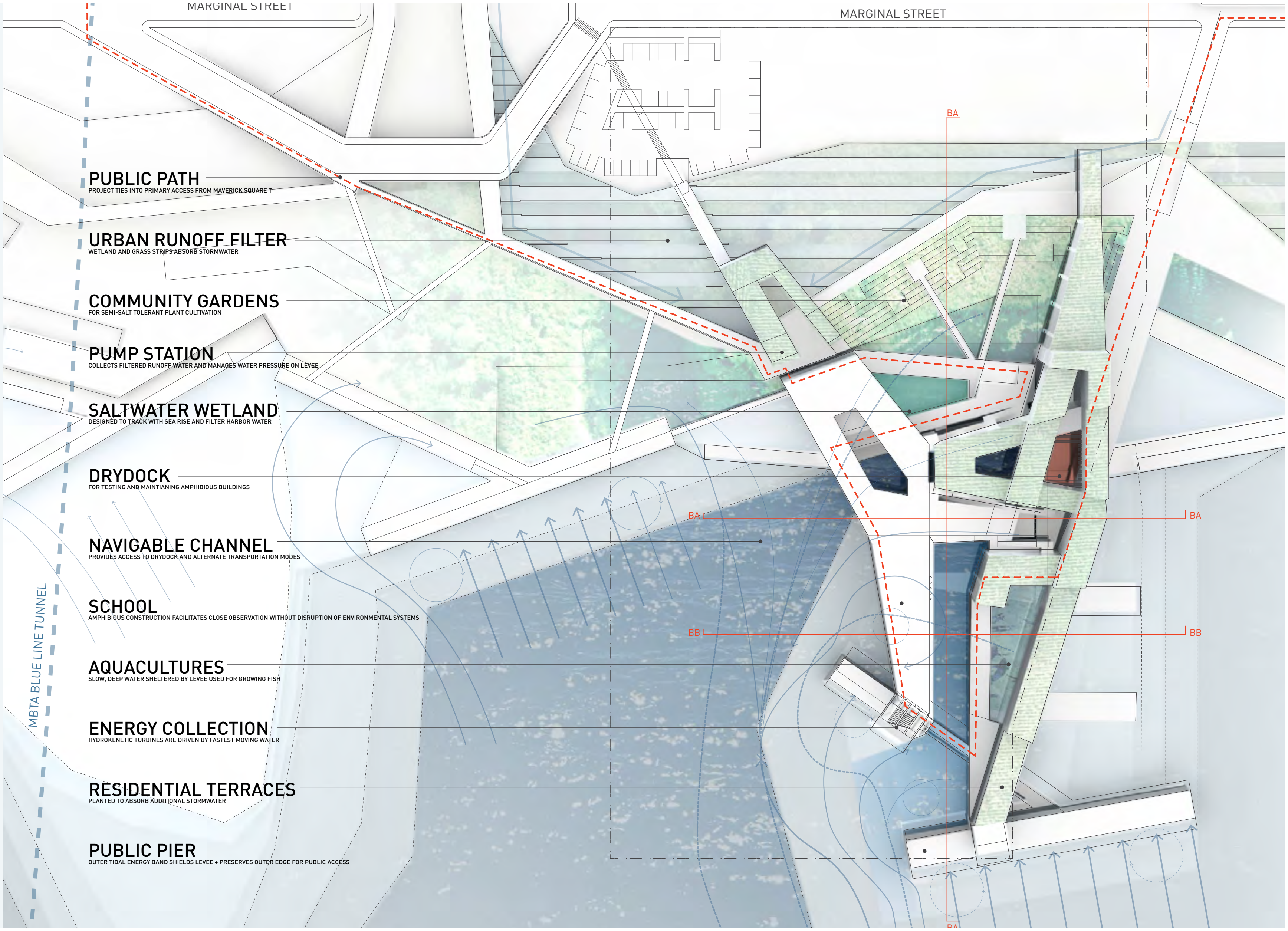
The buffer system's three edge typologies can be combined at different sites depending on existing conditions and varying development demands. This design is a prototype of a catalyst building that might occur along such a buffer system. It is not being proposed as the only building solution for this environment. Just as there have been many edge typology studies, there are been multiple versions of the waterfront complex in this project. See Appendix 6.4 for previous waterfront complex designs.

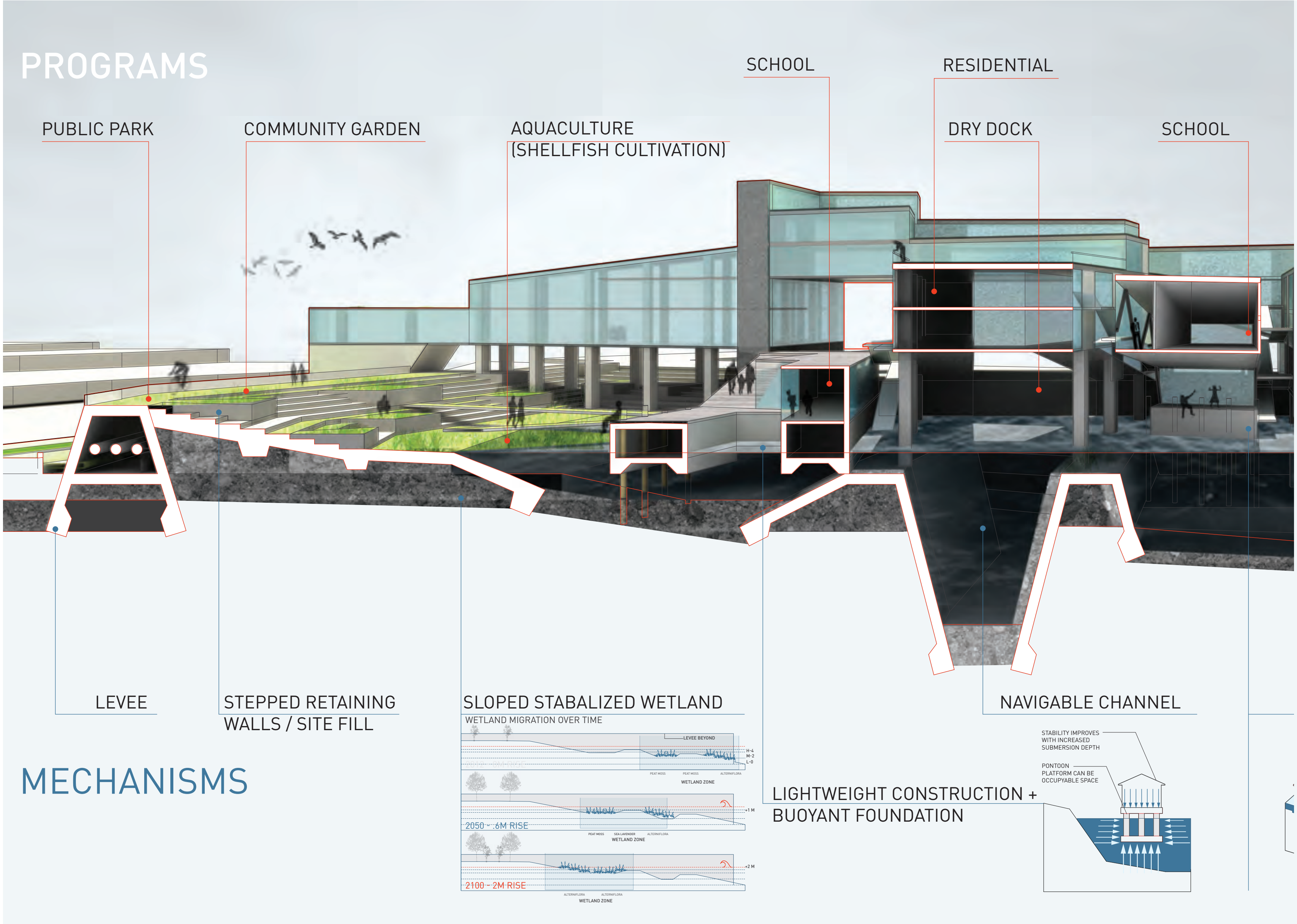


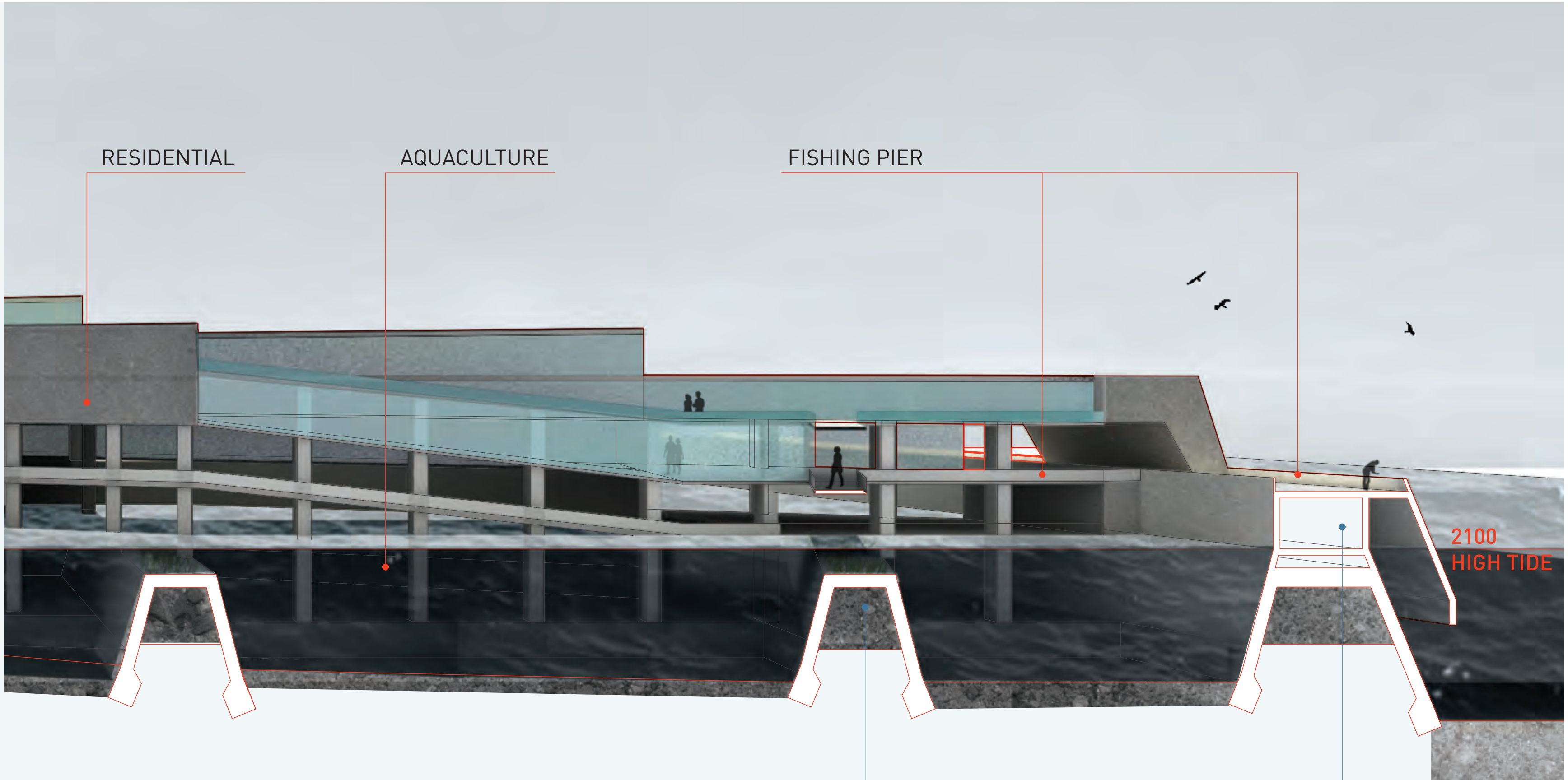
1:500 Scale model w/ upper level of school removed to show public path.

PLAN KEY <

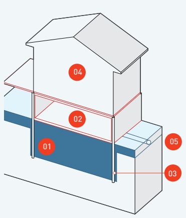
1. School
2. Pump Station
3. Dry Dock
4. Aquaculture
5. Community Garden
6. Energy collection
7. Commercial
8. Residential


MARGINAL STREET
MARGINAL STREET
PUBLIC PATH
PROJECT TIES INTO PRIMARY ACCESS FROM MAVERICK SQUARE T
URBAN RUNOFF FILTER
WETLAND AND GRASS STRIPS ABSORB STORMWATER
COMMUNITY GARDENS
FOR SEMI-SALT TOLERANT PLANT CULTIVATION
PUMP STATION
COLLECTS FILTERED RUNOFF WATER AND MANAGES WATER PRESSURE ON LEVEE
SALTWATER WETLAND
DESIGNED TO TRACK WITH SEA RISE AND FILTER HARBOR WATER
DRYDOCK
FOR TESTING AND MAINTIANING AMPHIBIOUS BUILDINGS
NAVIGABLE CHANNEL
PROVIDES ACCESS TO DRYDOCK AND ALTERNATE TRANSPORTATION MODES
SCHOOL
AMPHIBIOUS CONSTRUCTION FACILITATES CLOSE OBSERVATION WITHOUT DISRUPTION OF ENVIRONMENTAL SYSTEMS
AQUACULTURES
SLOW, DEEP WATER SHELTERED BY LEVEE USED FOR GROWING FISH
ENERGY COLLECTION
HYDROKENETIC TURBINES ARE DRIVEN BY FASTEST MOVING WATER
RESIDENTIAL TERRACES
PLANTED TO ABSORB ADDITIONAL STORMWATER
PUBLIC PIER
OUTER TIDAL ENERGY BAND SHIELDS LEVEE + PRESERVES OUTER EDGE FOR PUBLIC ACCESS
MBTA BLUE LINE TUNNEL
BA
BA
BA
BB
BB
BA


PROGRAMS
PUBLIC PARK
COMMUNITY GARDEN
AQUACULTURE
(SHELLFISH CULTIVATION)
SCHOOL
RESIDENTIAL
DRY DOCK
SCHOOL
LEVEE
STEPPED RETAINING
WALLS / SITE FILL
SLOPED STABALIZED WETLAND
WETLAND MIGRATION OVER TIME
2050 - .6M RISE
2100 - 2M RISE
NAVIGABLE CHANNEL
LIGHTWEIGHT CONSTRUCTION +
BUOYANT FOUNDATION
STABILITY IMPROVES
WITH INCREASED
SUBMERSION DEPTH
PONTOON
PLATFORM CAN BE
OCCUPYABLE SPACE
MECHANISMS



AMPHIBIOUS CONSTRUCTION



01 under non-flood conditions the building sits on a hollow concrete foundation or pontoons which rests on posts set into the ground

02 In the event of water rise the hollow foundation, which can be inhabited, makes the building buoyant

03 At least two morring posts are needed to prevent drift.

04 Light construction keeps the building stable and buoyant

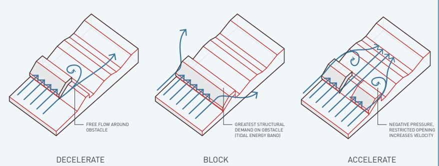
05 Utilities are supplied by flexible pipes, unaffected by flooding

06 As the water subsides, the building may drift back into position.

Source:
http://sealevelrise.blogspot.com/2011_03_13_archive.html

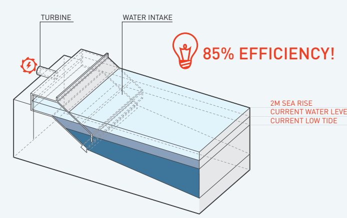
SURGE BAFFLE

WATERFLOW PRINCIPLES

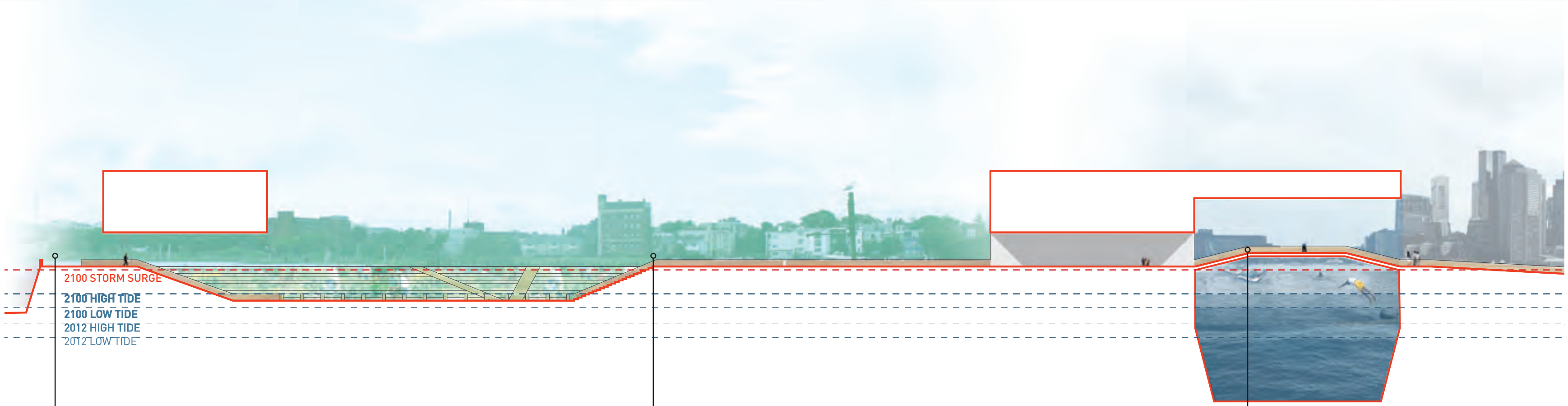


HYDROKINETIC TURBINE

OSCILLATING WATER COLUMN

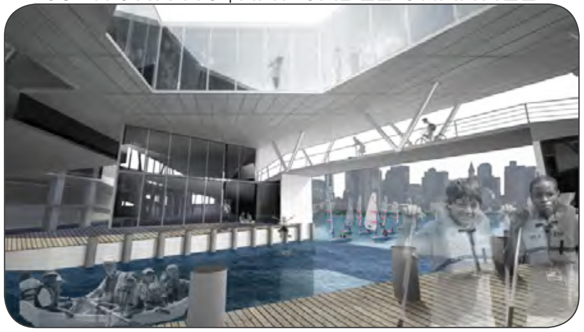


UNROLLED PUBLIC PATHWAY ELEVATION



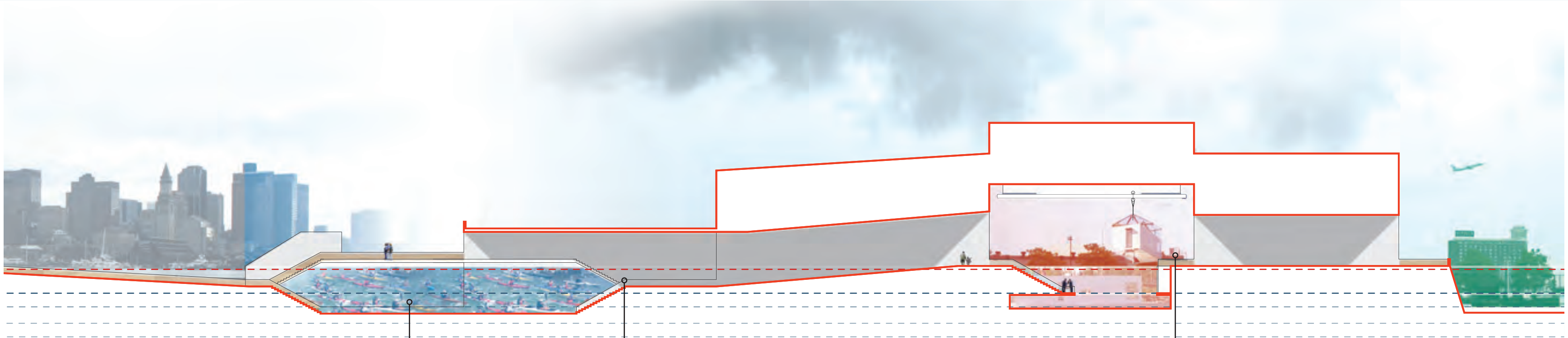
01. APPROACHES & FILTRATION

02. WETLAND & COMMUNITY GARDEN



03. WORKING NAVIGABLE CHANNEL

CURATED EDUCATIONAL EXPEREINCE



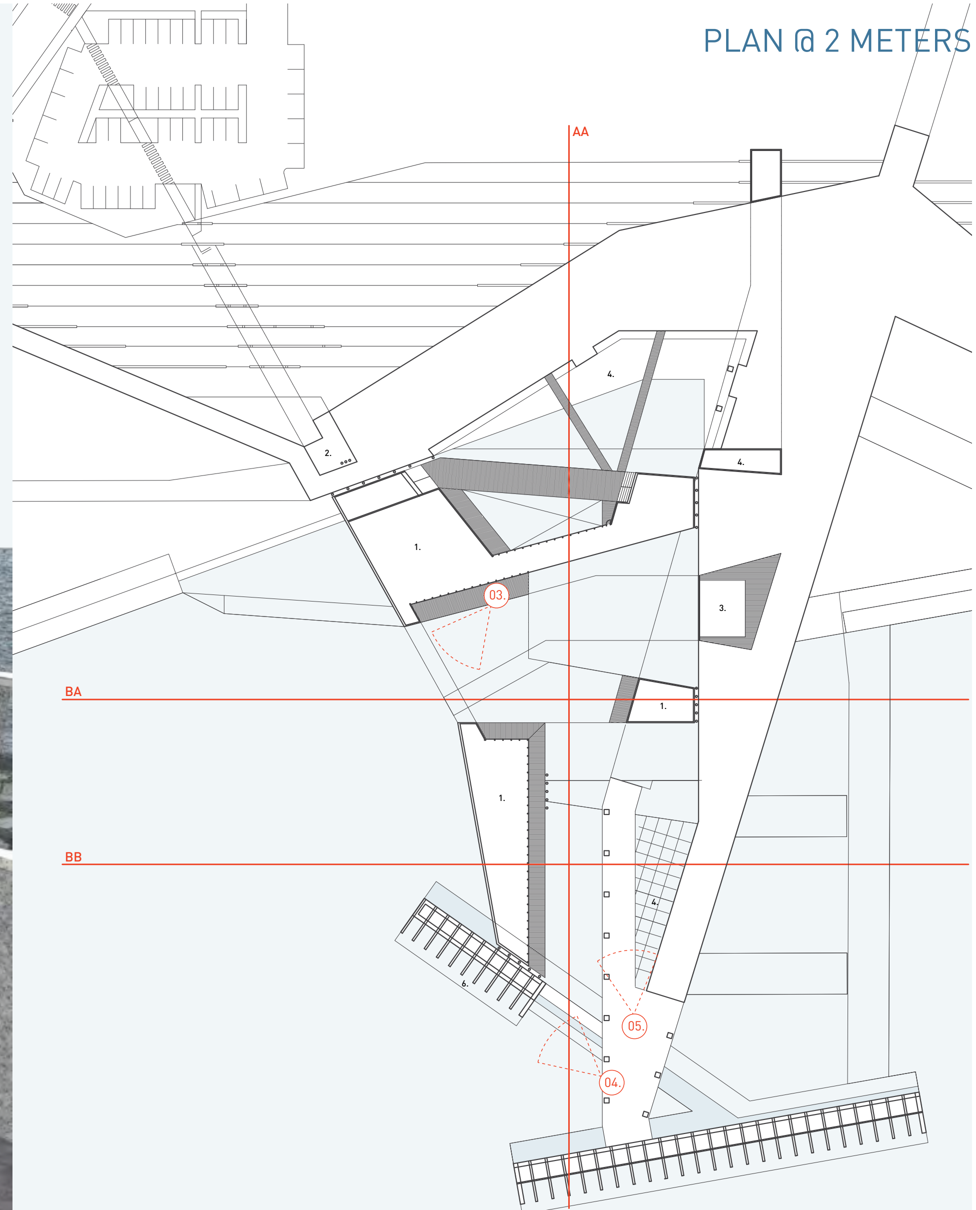
04. ENERGY COLLECTION & RECREATION

05. AQUACULTURES

06. CONSTRUCTION DRY-DOCK

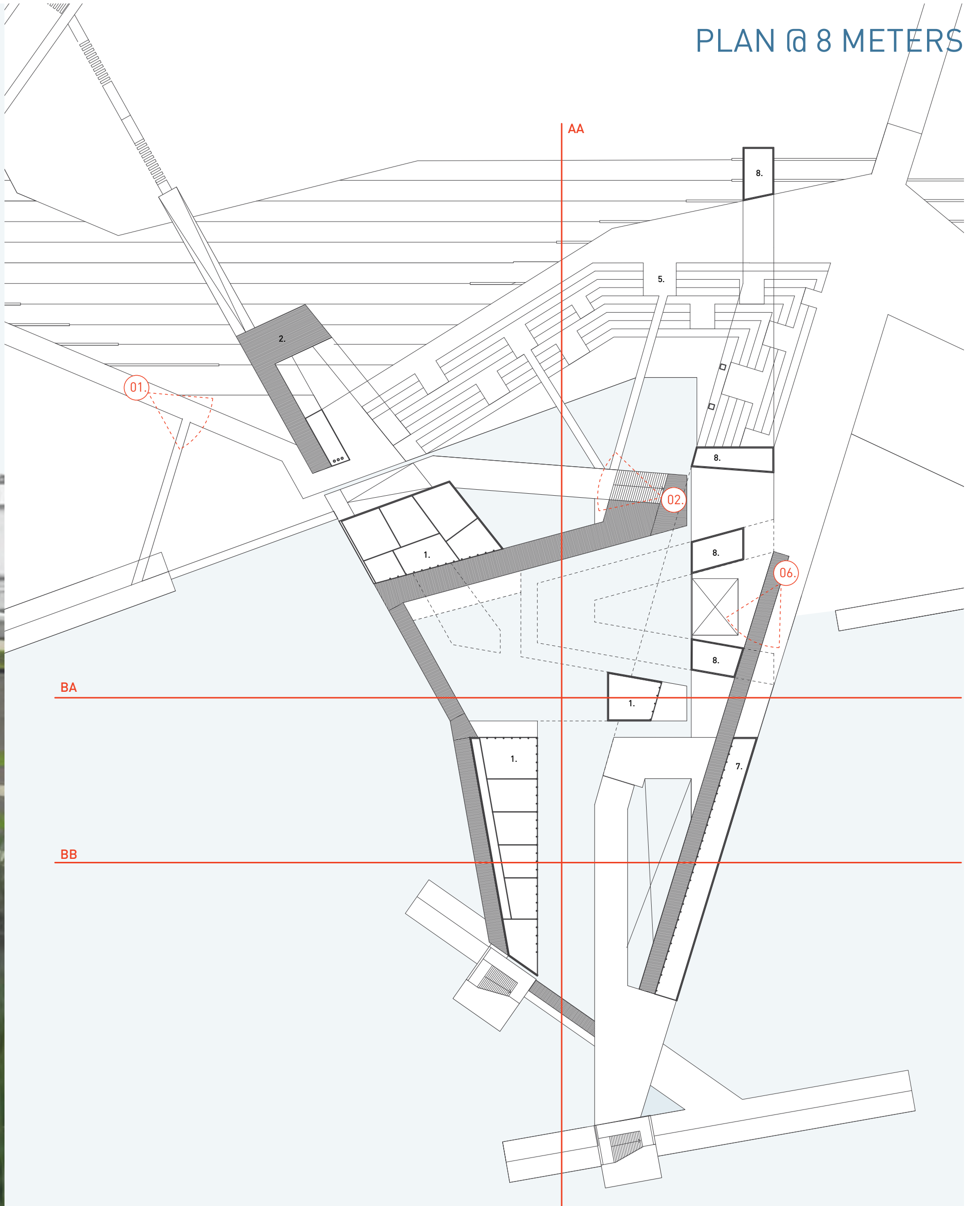
MULTIPLE APPROACHES & FILTRATION

PLAN @ 2 METERS

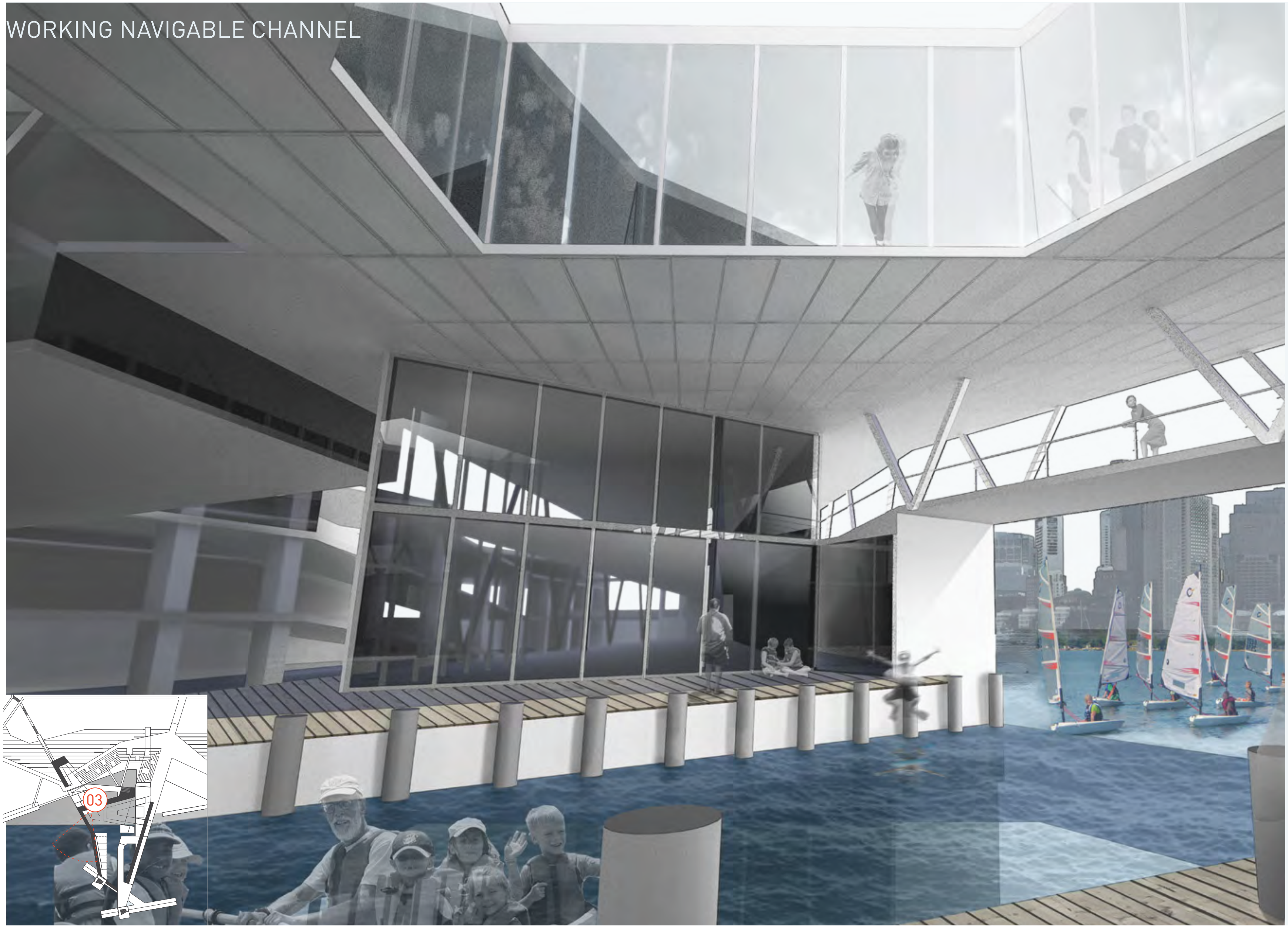


Refer to Plan Key on Page 96

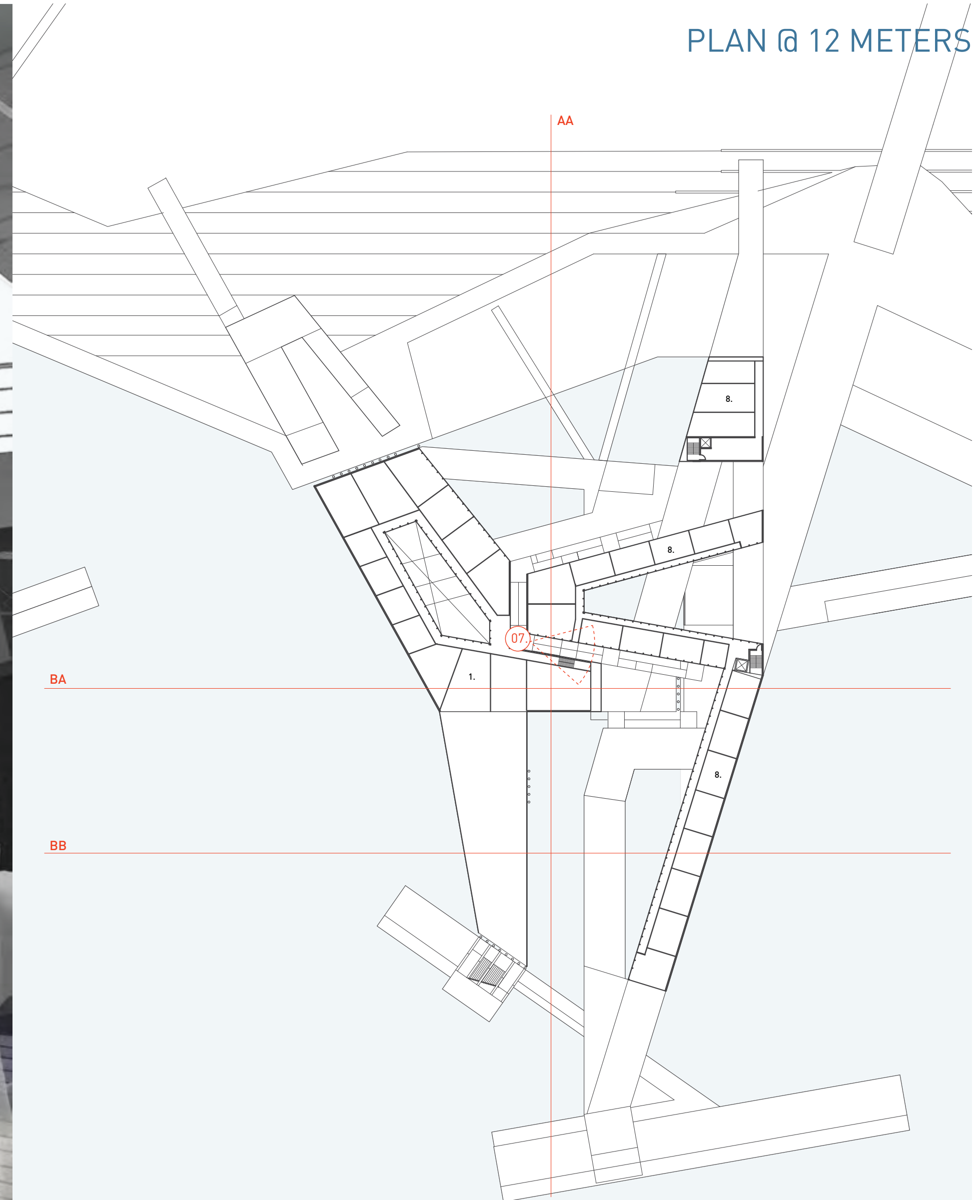
DYNAMIC WETLANDS & COMMUNITY GARDEN FACING EAST BOSTON



Refer to Plan Key on Page 96

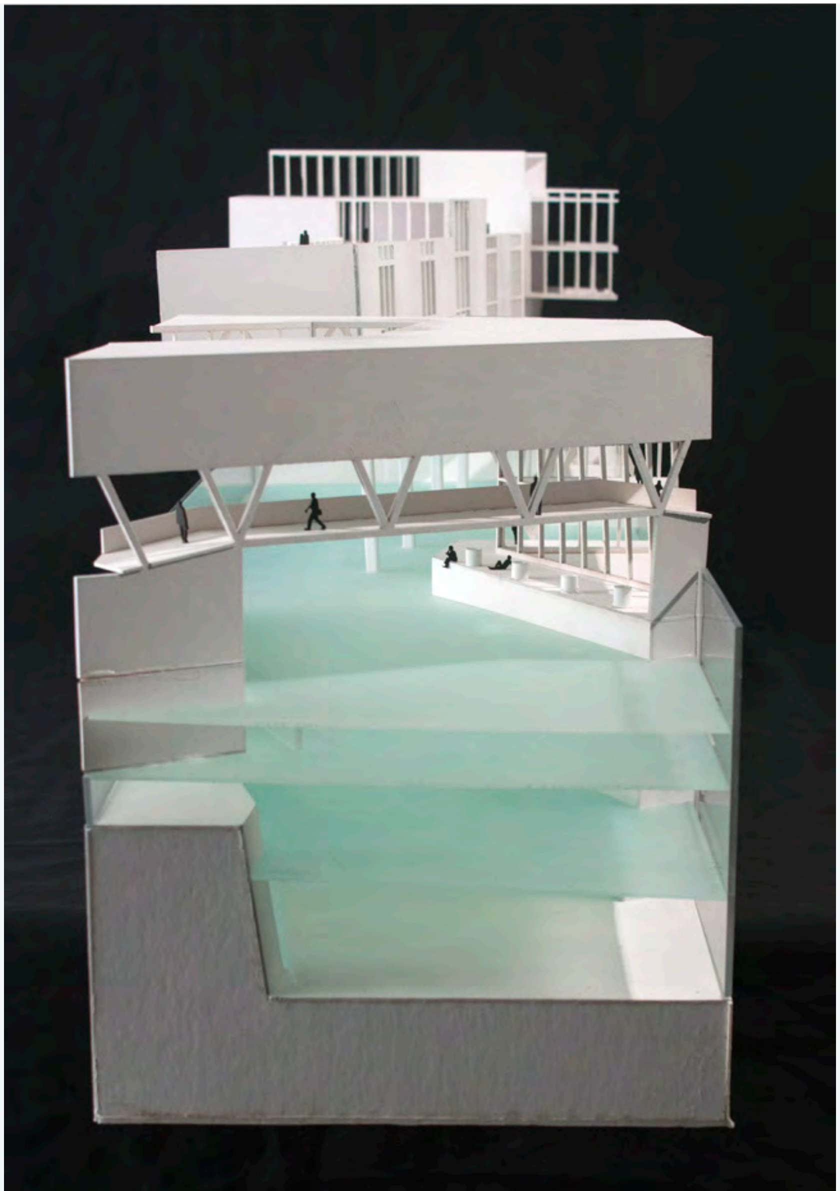

WORKING NAVIGABLE CHANNEL
03

PLAN @ 12 METERS

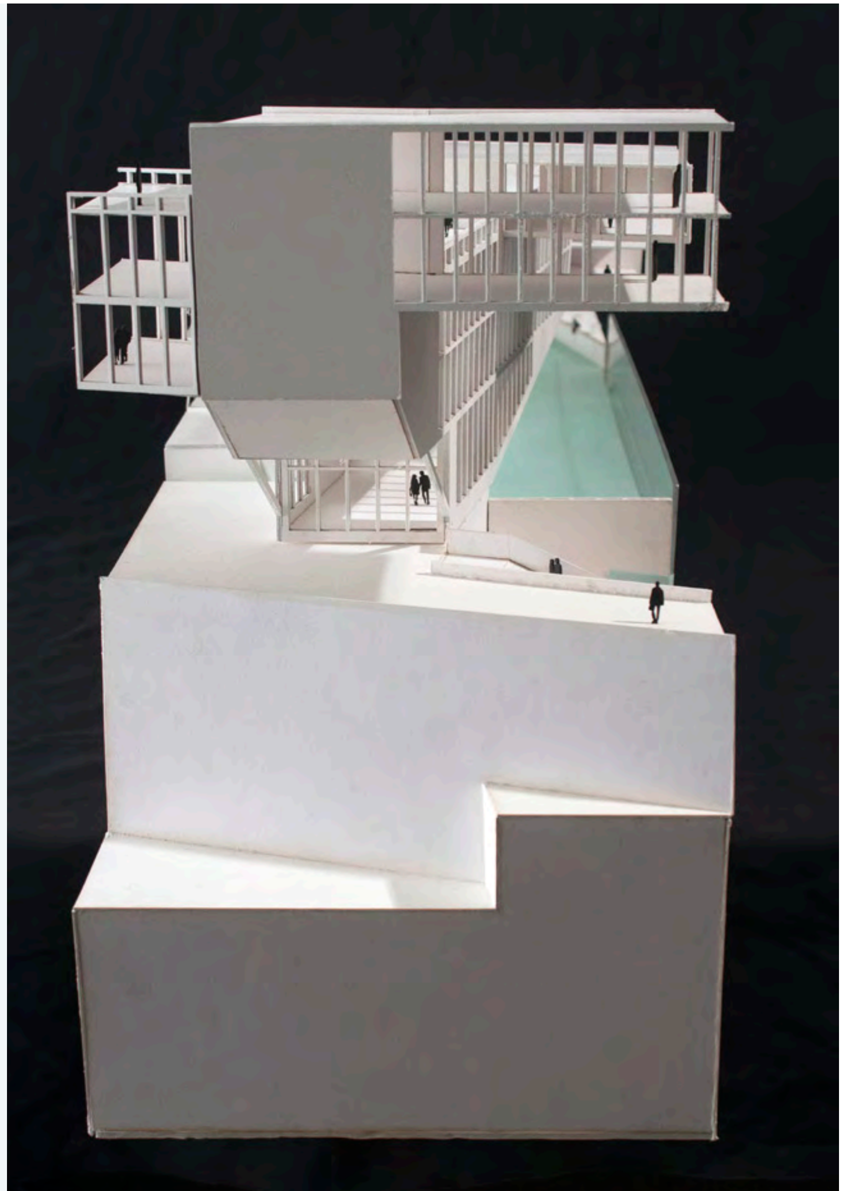


Refer to Plan Key on Page 96

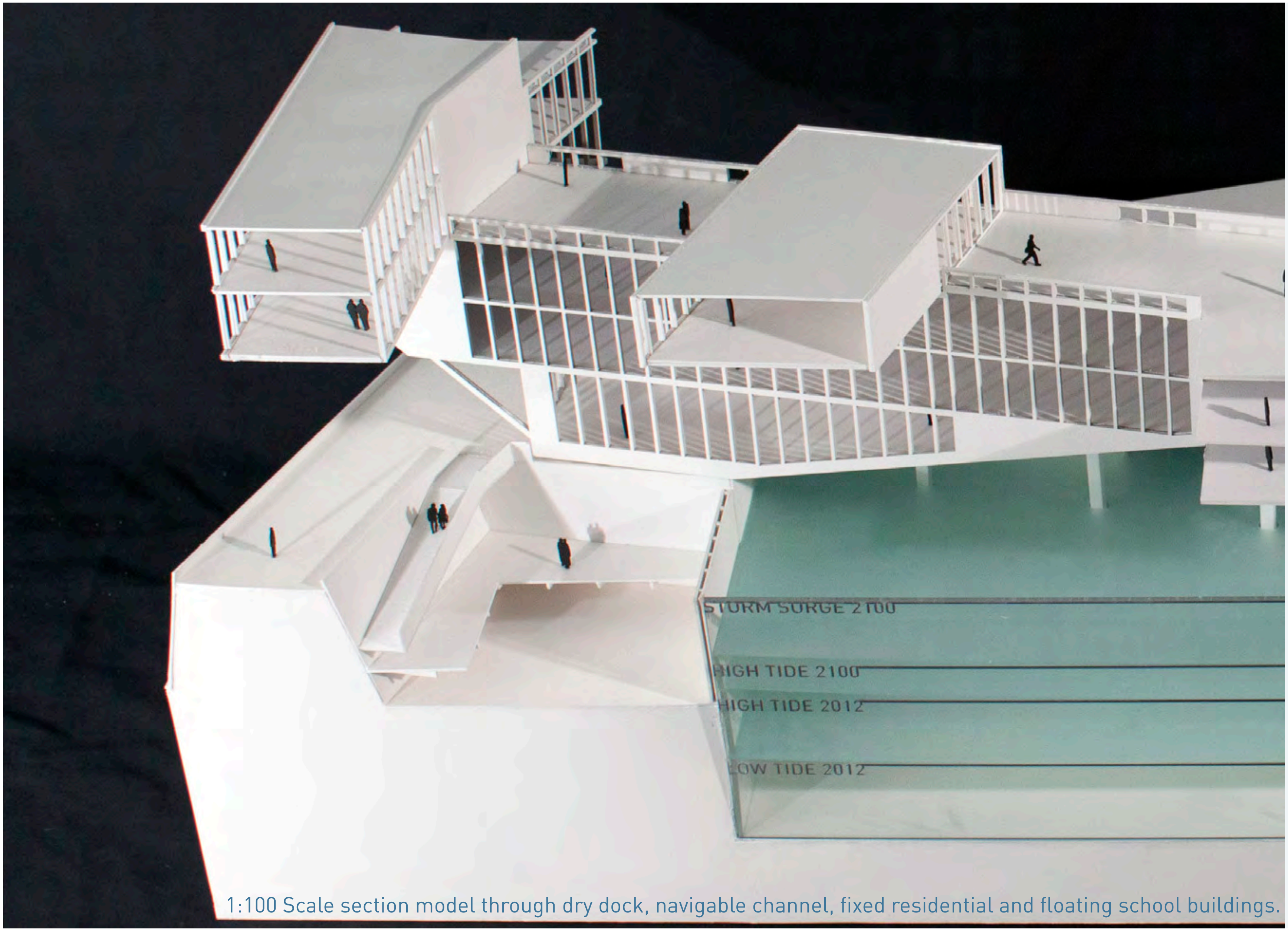
1:100 Scale sectional model traversing working navigable channel.



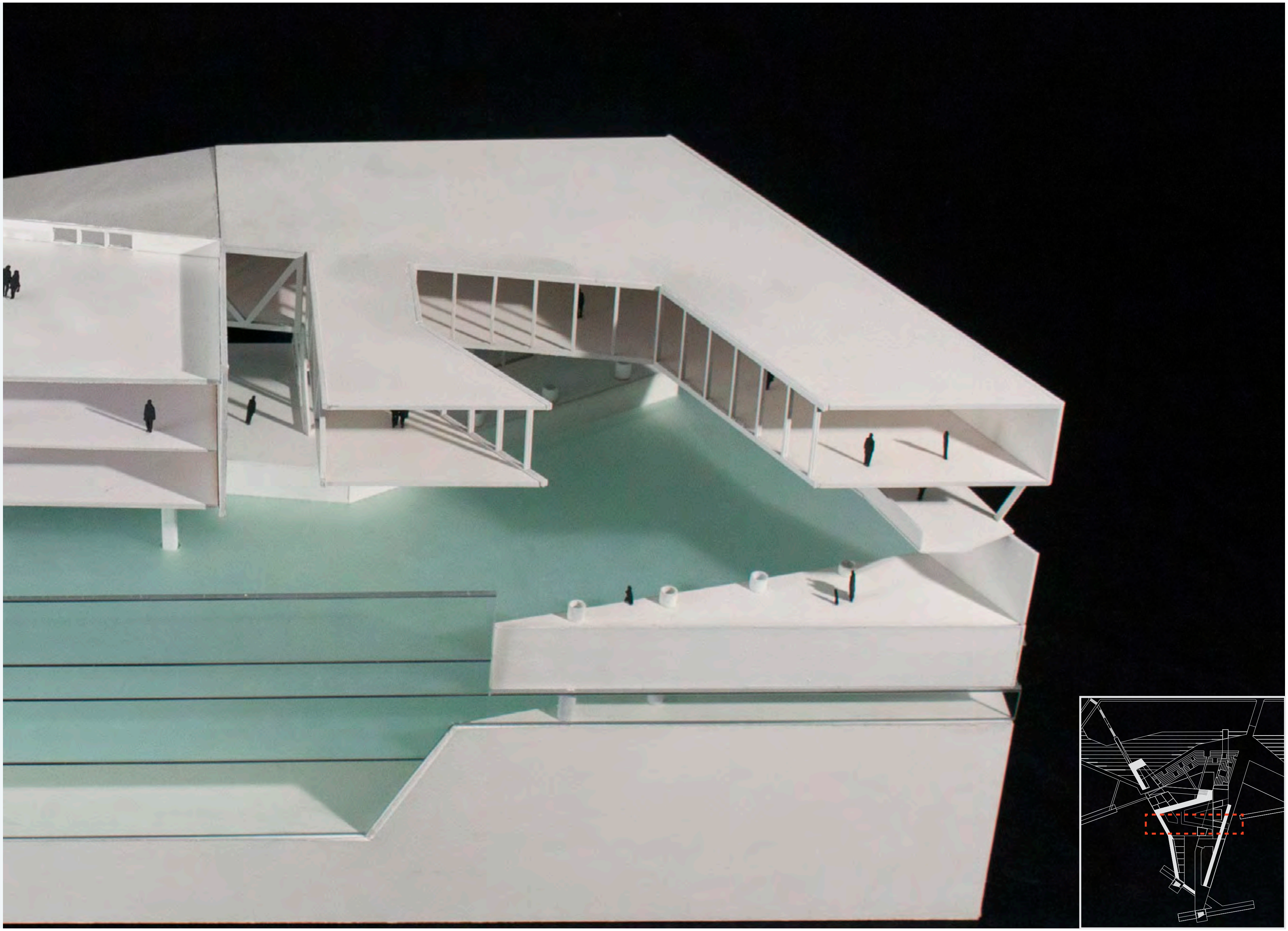
1:100 Scale sectional model channel side elevation.



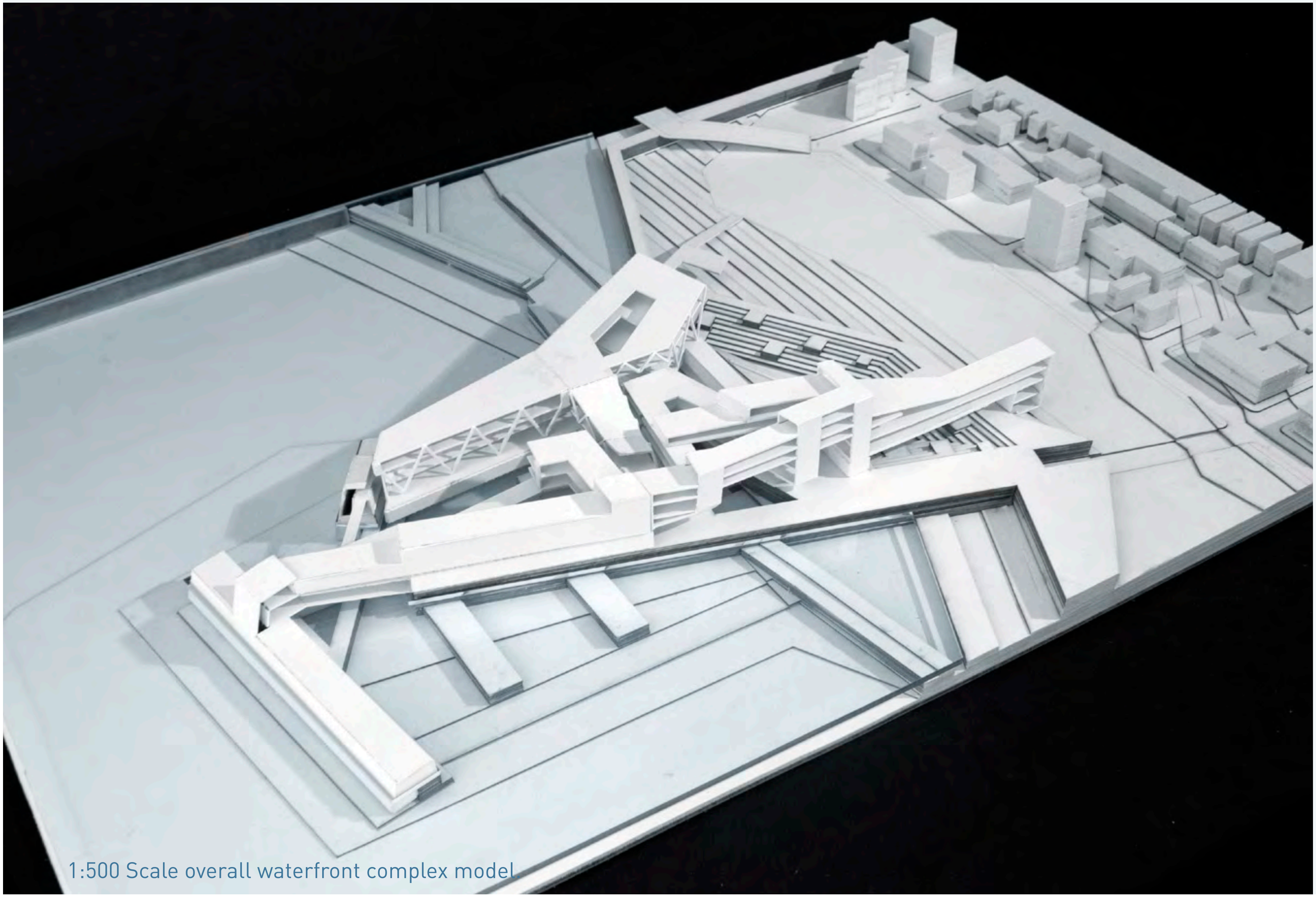
1:100 Scale sectional model levee side elevation.



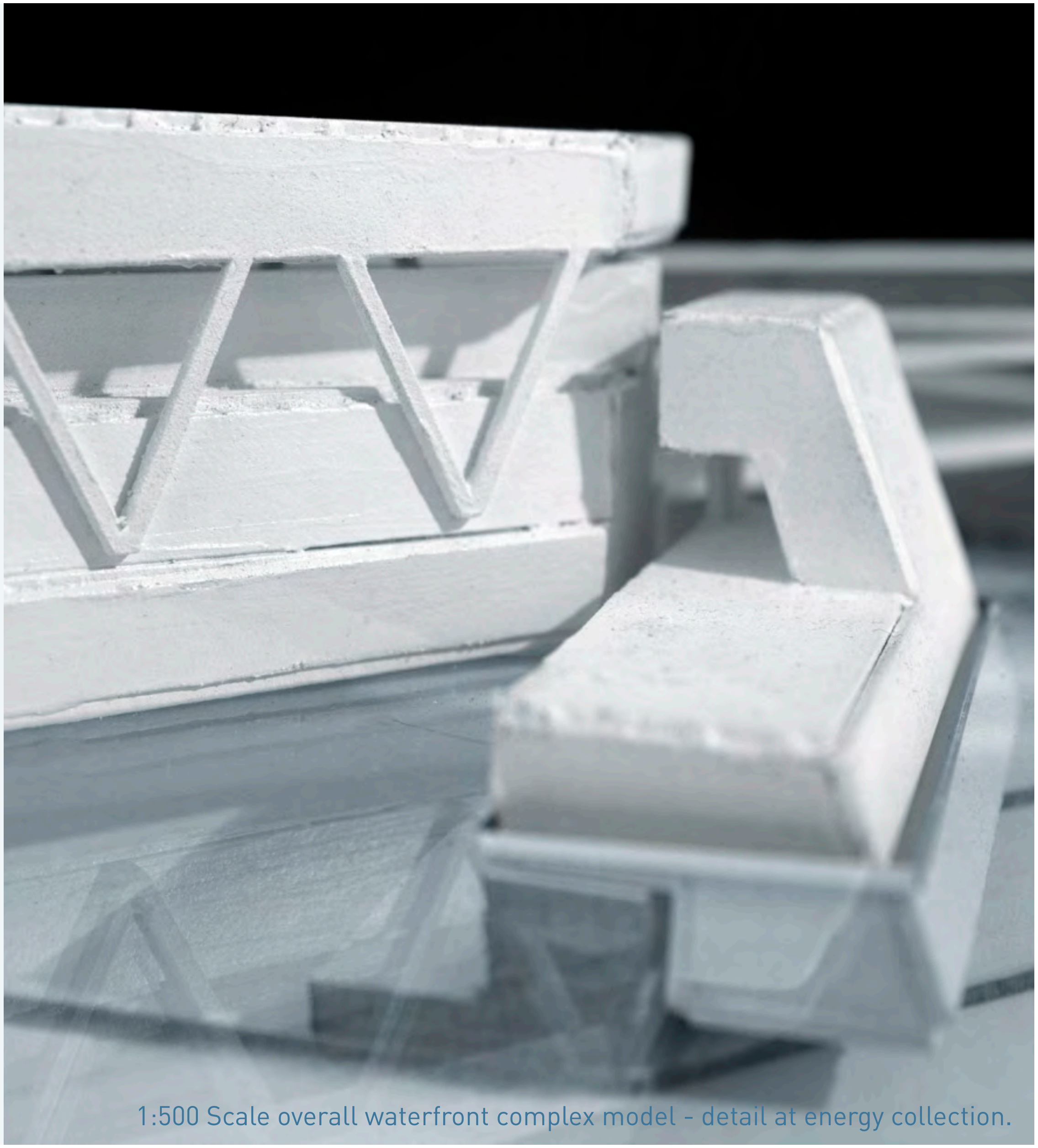
1:100 Scale section model through dry dock, navigable channel, fixed residential and floating school buildings.



1:500 SCALE MODEL



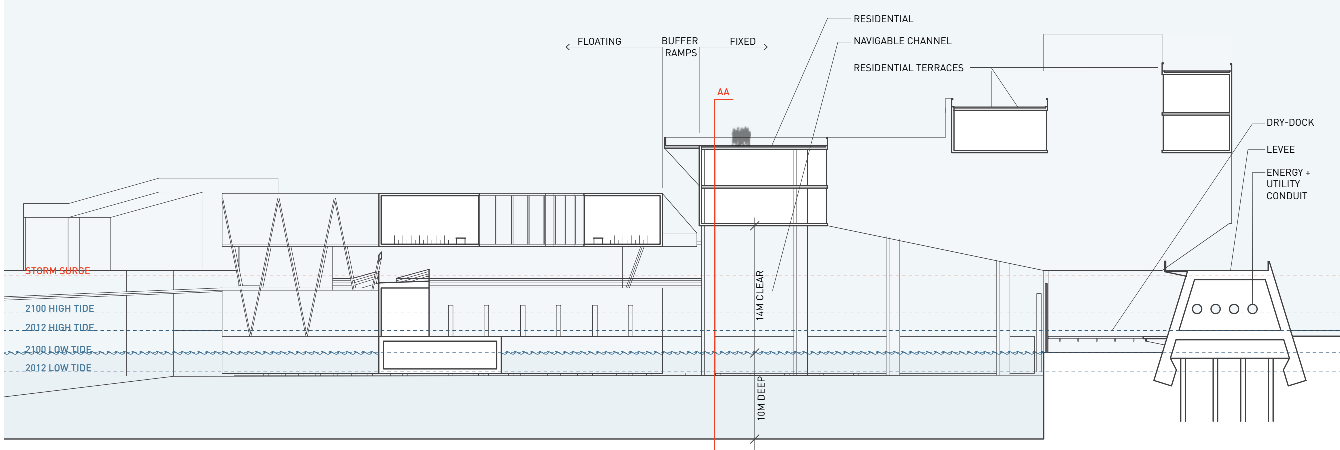
1:500 Scale overall waterfront complex model



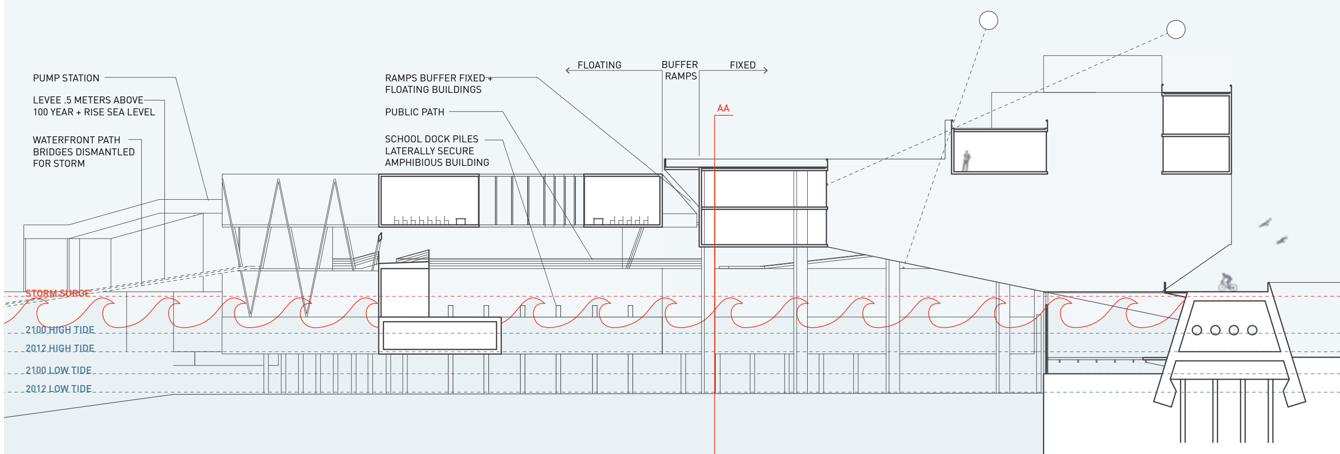
1:500 Scale overall waterfront complex model - detail at energy collection.

MODELS <

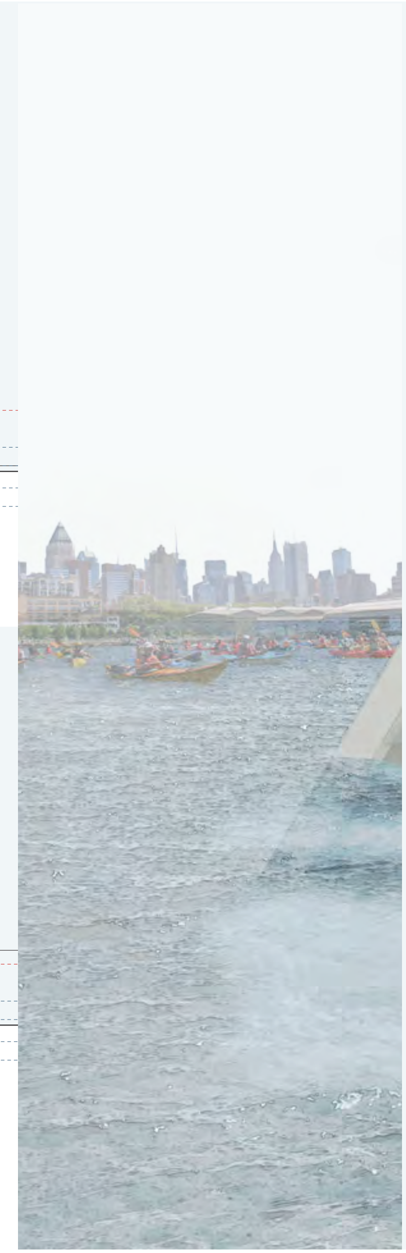
See Appendix 6.3 for detailed model descriptions.



SECTION BA 2100 LOW TIDE

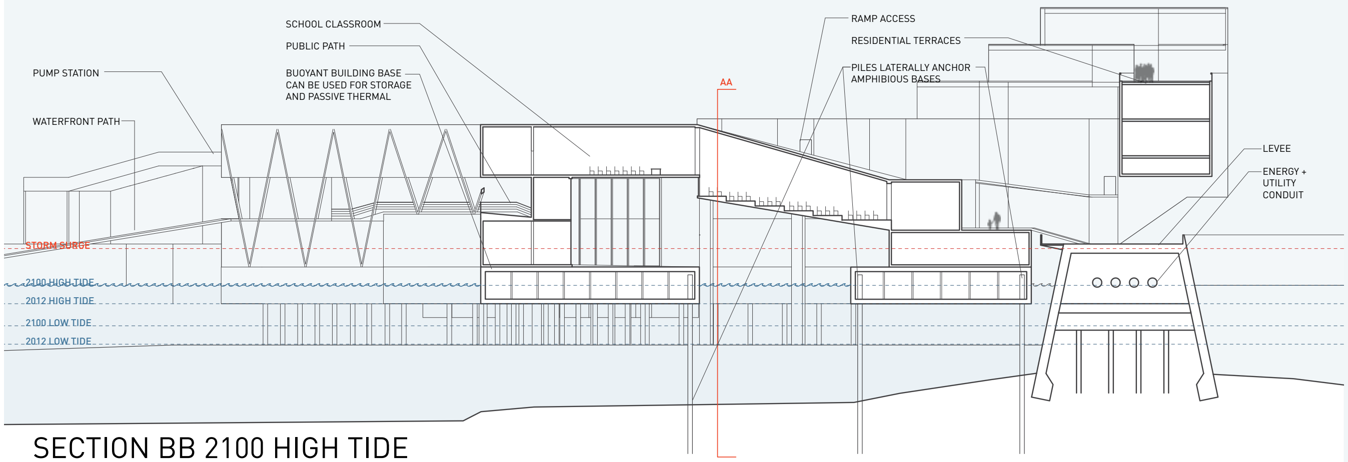


SECTION BA 2100 STORM SURGE

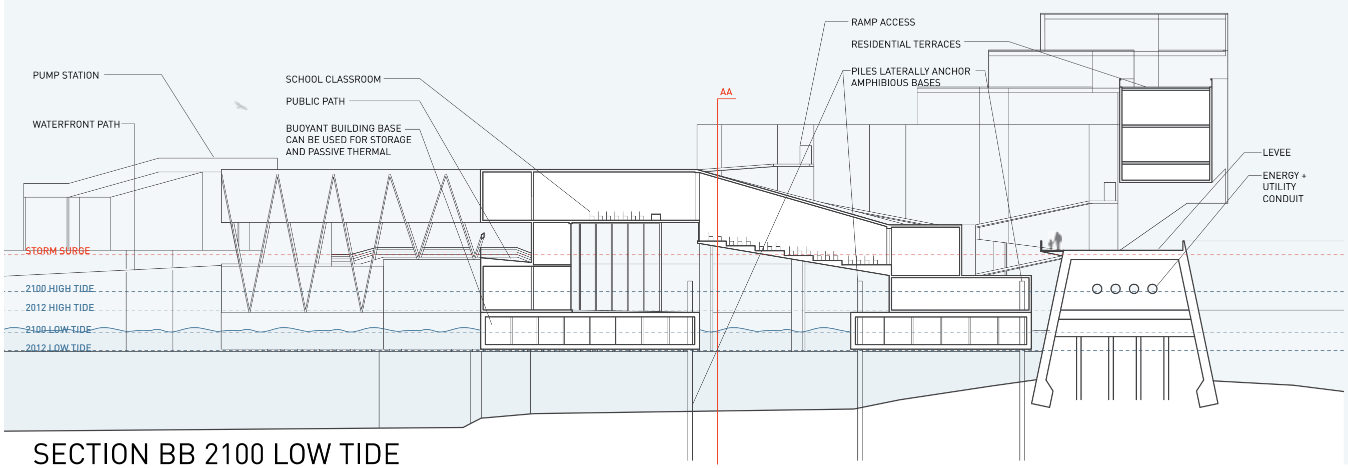


Sections show same cut at two different water levels to illustrate relationship between buildings.

RECREATIONAL CIRCUIT AT ENERGY COLLECTION

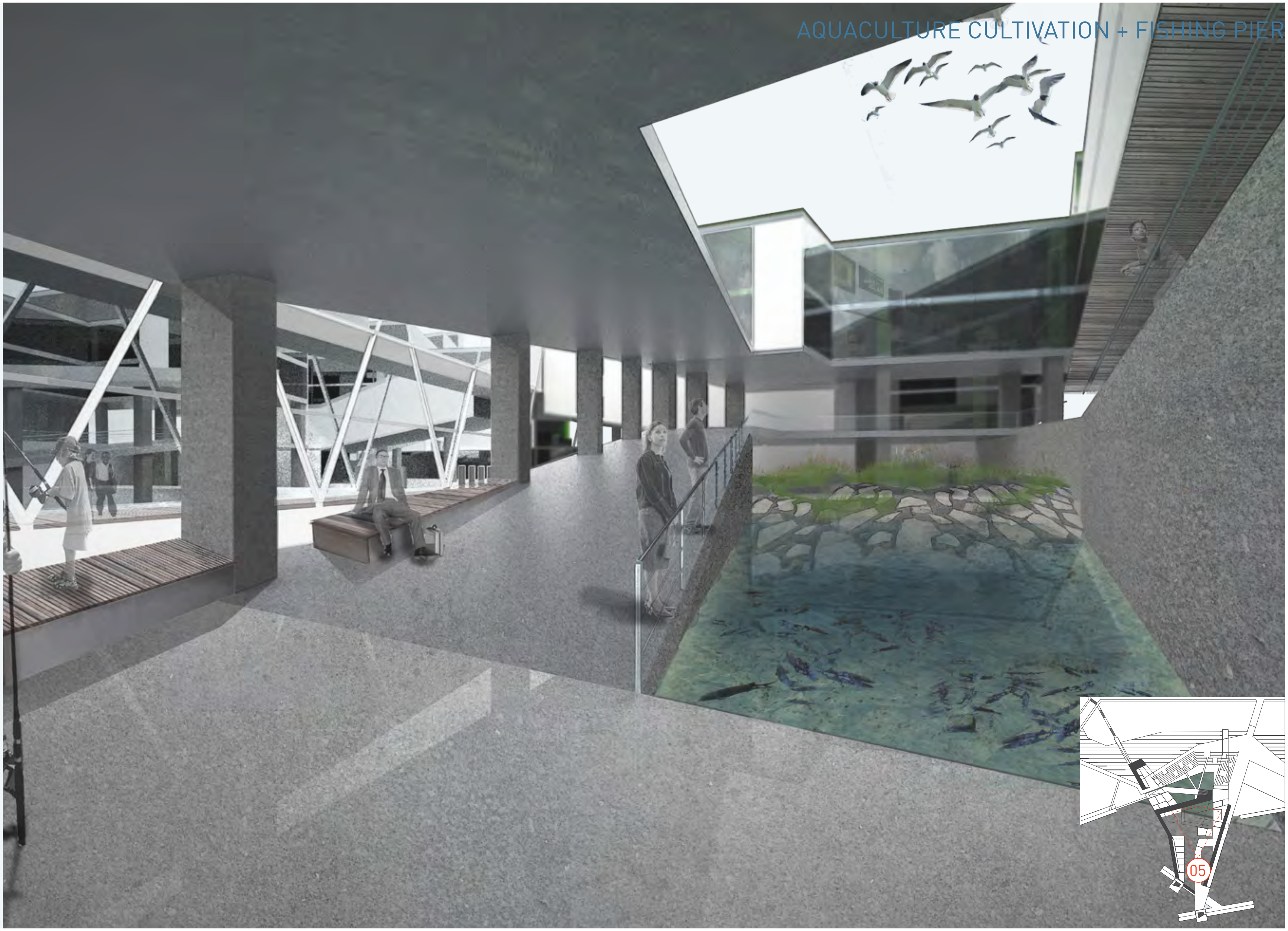


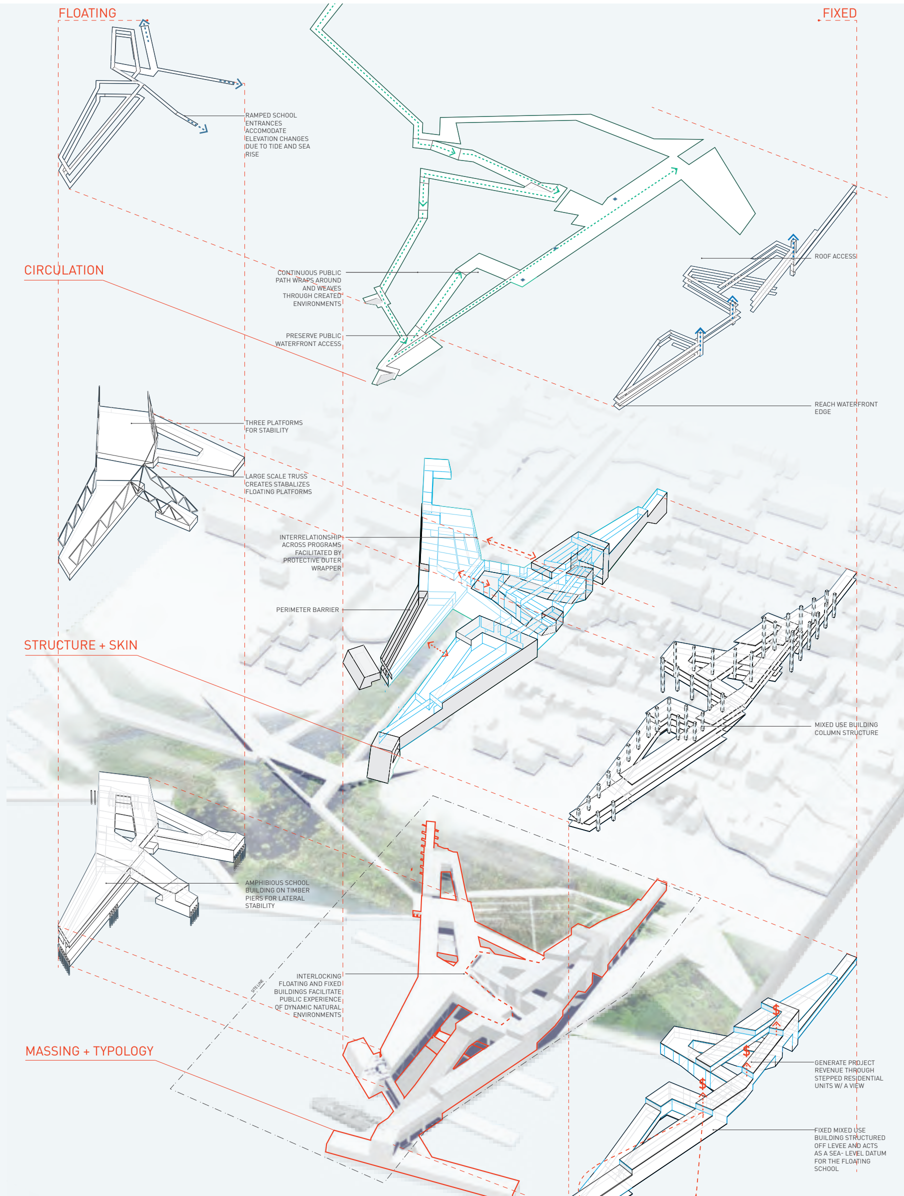
SECTION BB 2100 HIGH TIDE



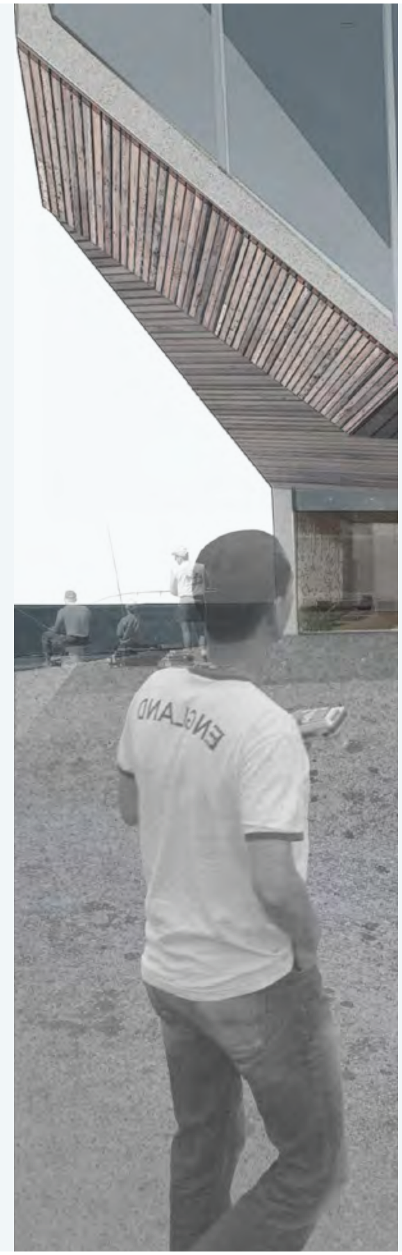
SECTION BB 2100 LOW TIDE

Sections show same cut at two different water levels to illustrate relationship between buildings.


AQUACULTURE CULTIVATION + FISHING PIER
05

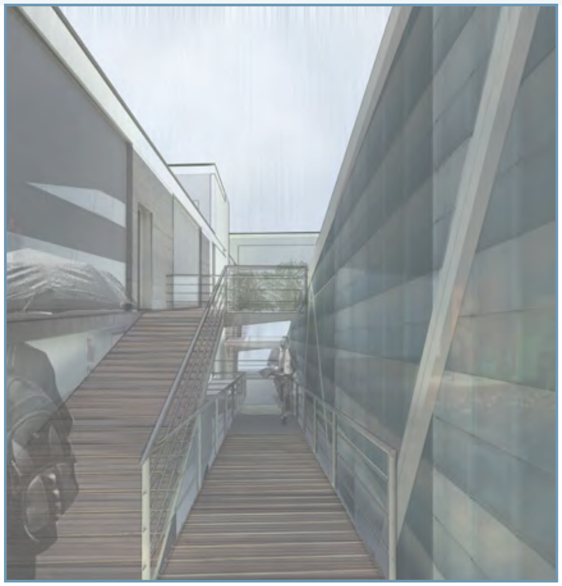


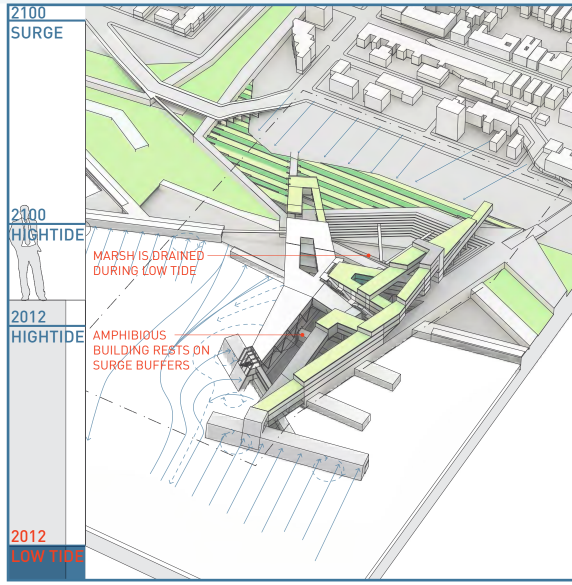
Exploded axon of waterfront complex components.

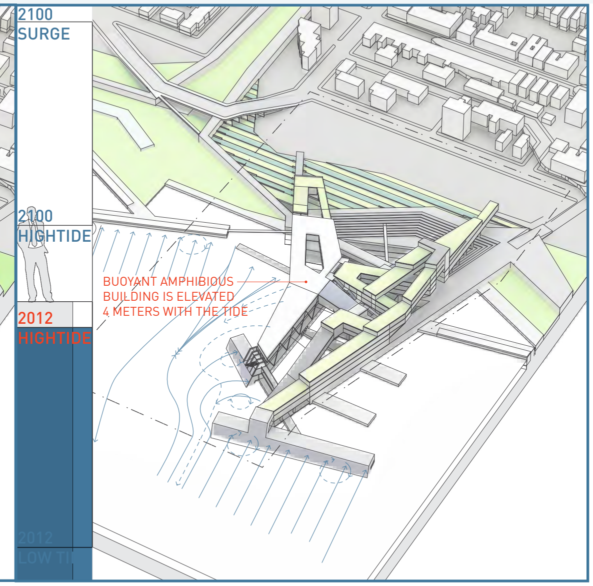


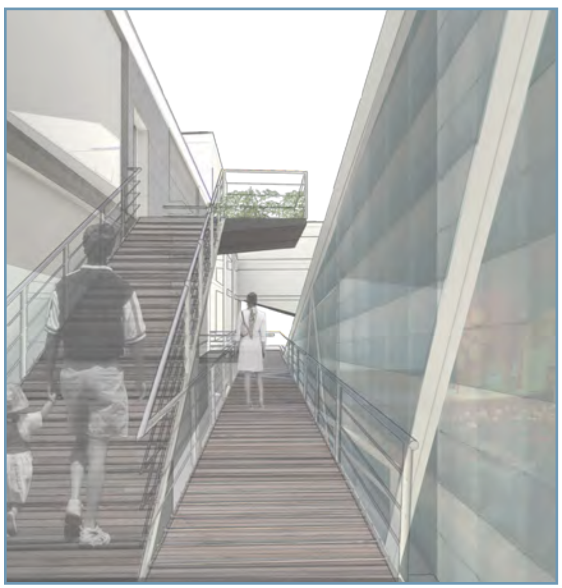

RESIDENTIAL OVERLOOKING CONSTRUCTION DRYDOCK
06

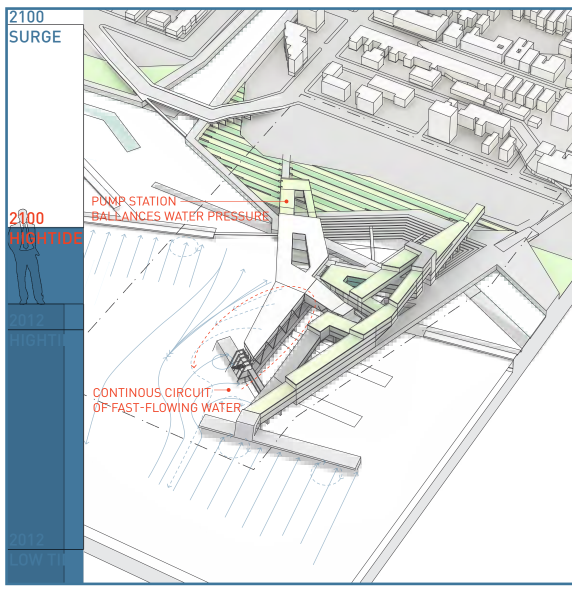
SEA RISE ON SITE

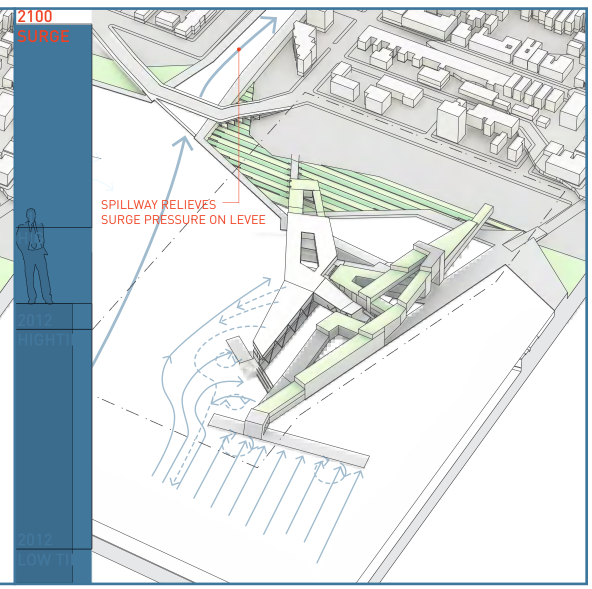












> SEA RISE RESPONSE

Axon diagrams show the impact of tides, floods and surge on site and how the buffer framework locally responds.

On a daily tidal basis, actuated ramps located between the fixed and floating buildings facilitate circulation. These also serve as a material buffer in the event of a surge.

Vignette rendering (far left) show buffer ramp zone during two tidal conditions.

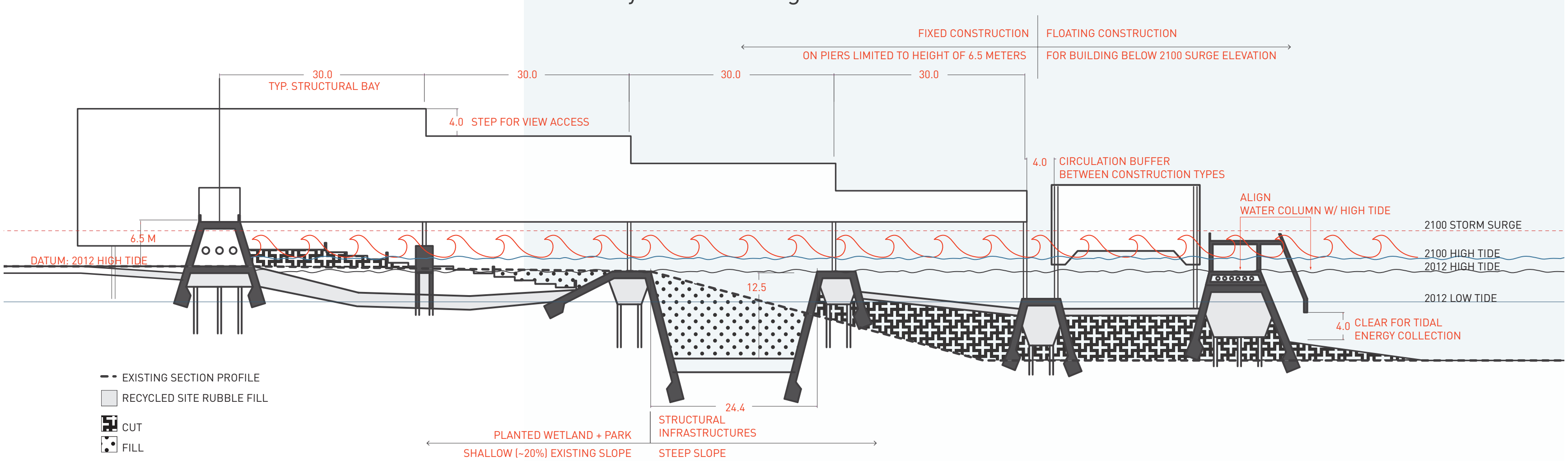
5.0 - CONCLUSIONS

TRANSFERABILITY OF APPROACH

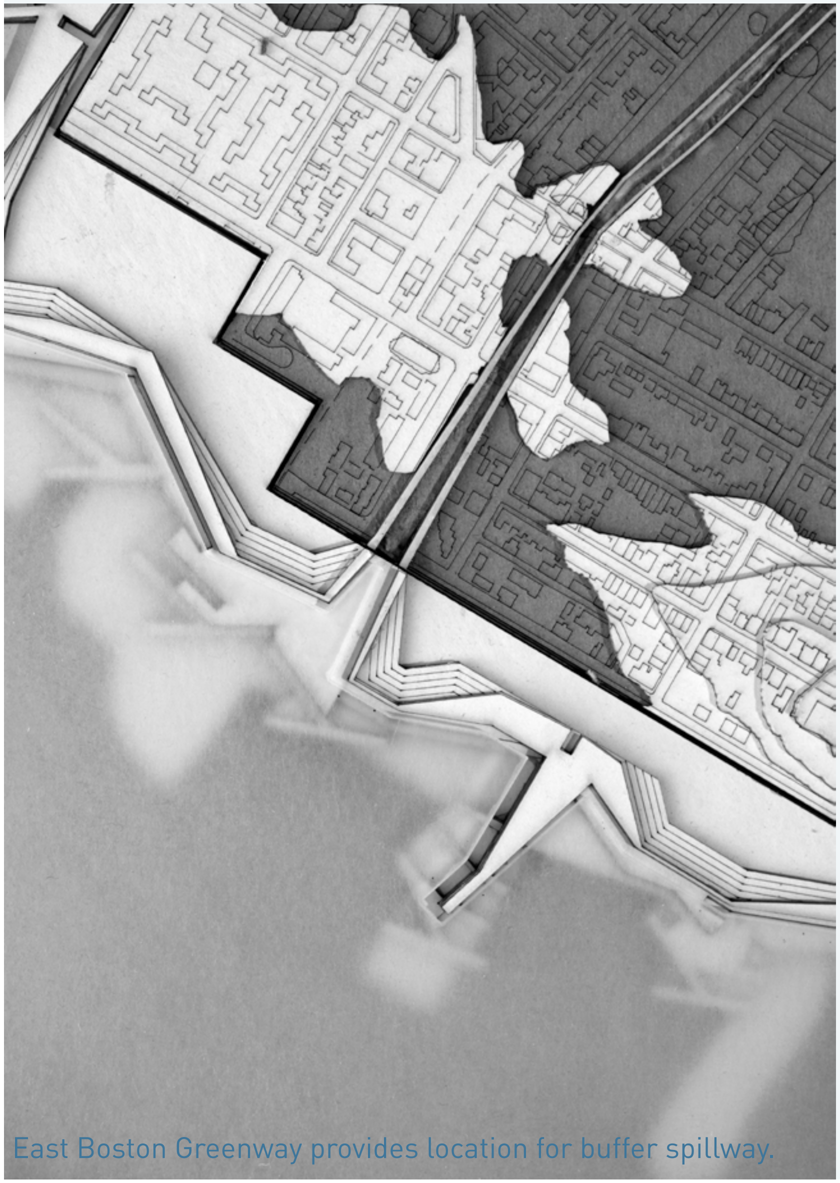
The following pages show how the section and layering parameters that this prototype is based on might be adapted to other sites around Boston Harbor. The main context variables that impact the morphology are; density of context, water flow speed and water depth. This exercise raises the question of how to strategically apply these governing principles of this project at a larger scale.

Though there are a multitude of tangential issues surrounding this topic, this project succeeds in turning the current orientation of Boston's coastal edge inside out to create new experiences and relationships to the waterfront. No longer viewed as a problem, flooding is understood and even welcomed as another of the many dynamic processes at play in the city. This project imagines a future where not only is sea rise a fun experience, but in the process of protecting the built environment, the quality of urban ecosystems are improved to such an extent that they in turn improve the quality of life in the city.

If this project were continued, critical areas to explore further would be; integration of the buffer project with the existing inland context, the interface between elements of architecture and infrastructure at a detail level and the optimization and development of the system at a larger scale.



HARBOR HEALTH



East Boston Greenway provides location for buffer spillway.

ACIDIC

pH = 0	battery acid
pH = 1	sulfuric acid
pH = 2	lemon juice, vinegar
pH = 3	orange juice, soda
pH = 4	acid rain (4.2-4.4)
pH = 5	clean rain (5.5)
pH = 6	healthy lake (6.5)
pH = 7	pure water
pH = 8	**sea water**
pH = 9	baking soda
pH = 10	milk of magnesia
pH = 11	ammonia
pH = 12	soapy water
pH = 13	bleach
pH = 14	liquid drain cleaner

ALKALINE

BOSTON HARBOR NOW >

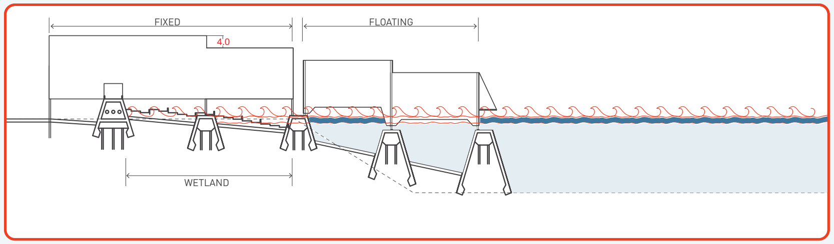
7.25, 2011
7.40, 2010
6.74, 2009
7.79, 2008
7.73, 2007
7.58, 2006
7.83, 2005

Stratifying water on site in plan and section creates varying conditions which add to ecological diversity and enable the growth of valuable wetland and swale ares over time. These play a major role in benefiting the city as a whole as the filter and purify all the urban runoff for east Boston into the upper and inner harbor. Over time, this balances the pH level of the harbor as a whole, encouraging aquaculture growth.

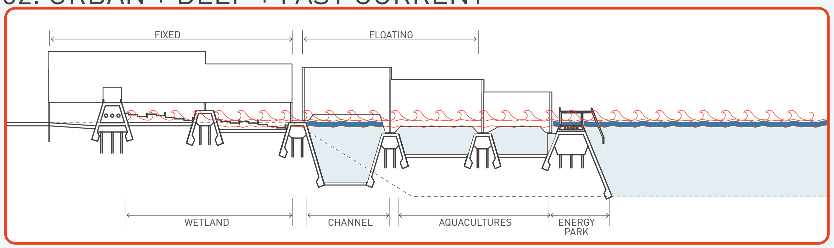
Source: http://www.mwra.state.ma.us/harbor/html/wq_data.htm

Rendering diagram with complex centrally located. Diagram to show general density of waterfront construction and building locations.

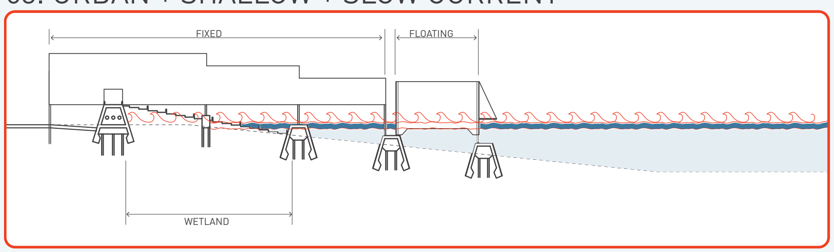
01. URBAN + DEEP + SLOW CURRENT



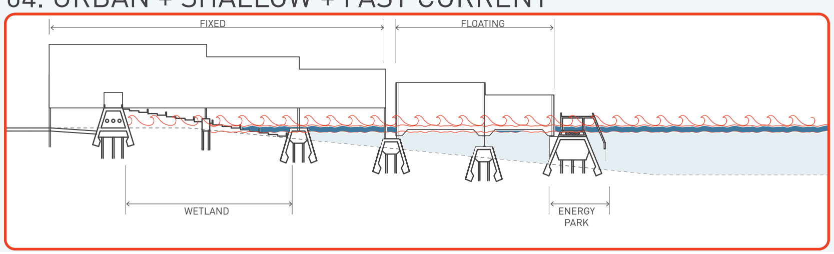
02. URBAN + DEEP + FAST CURRENT



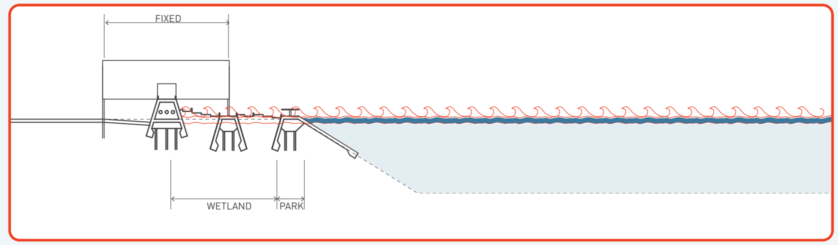
03. URBAN + SHALLOW + SLOW CURRENT



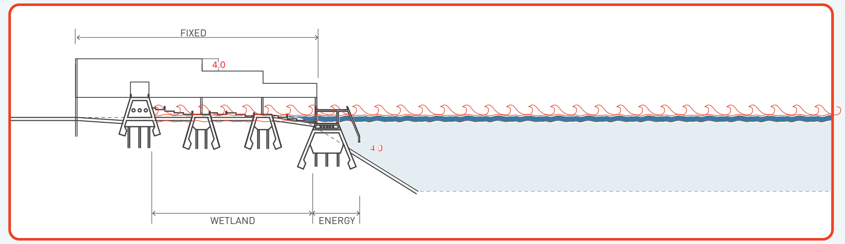
04. URBAN + SHALLOW + FAST CURRENT



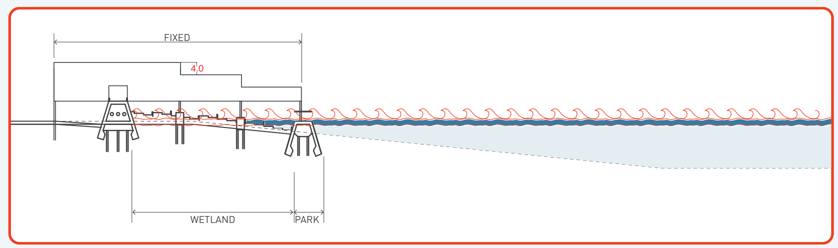
05. SUB URBAN + DEEP + SLOW CURRENT



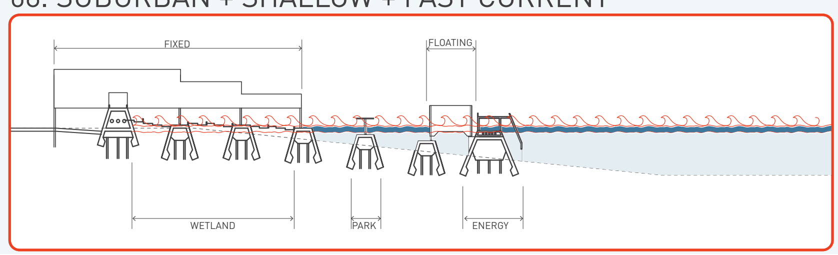
06. SUB URBAN + DEEP + FAST CURRENT

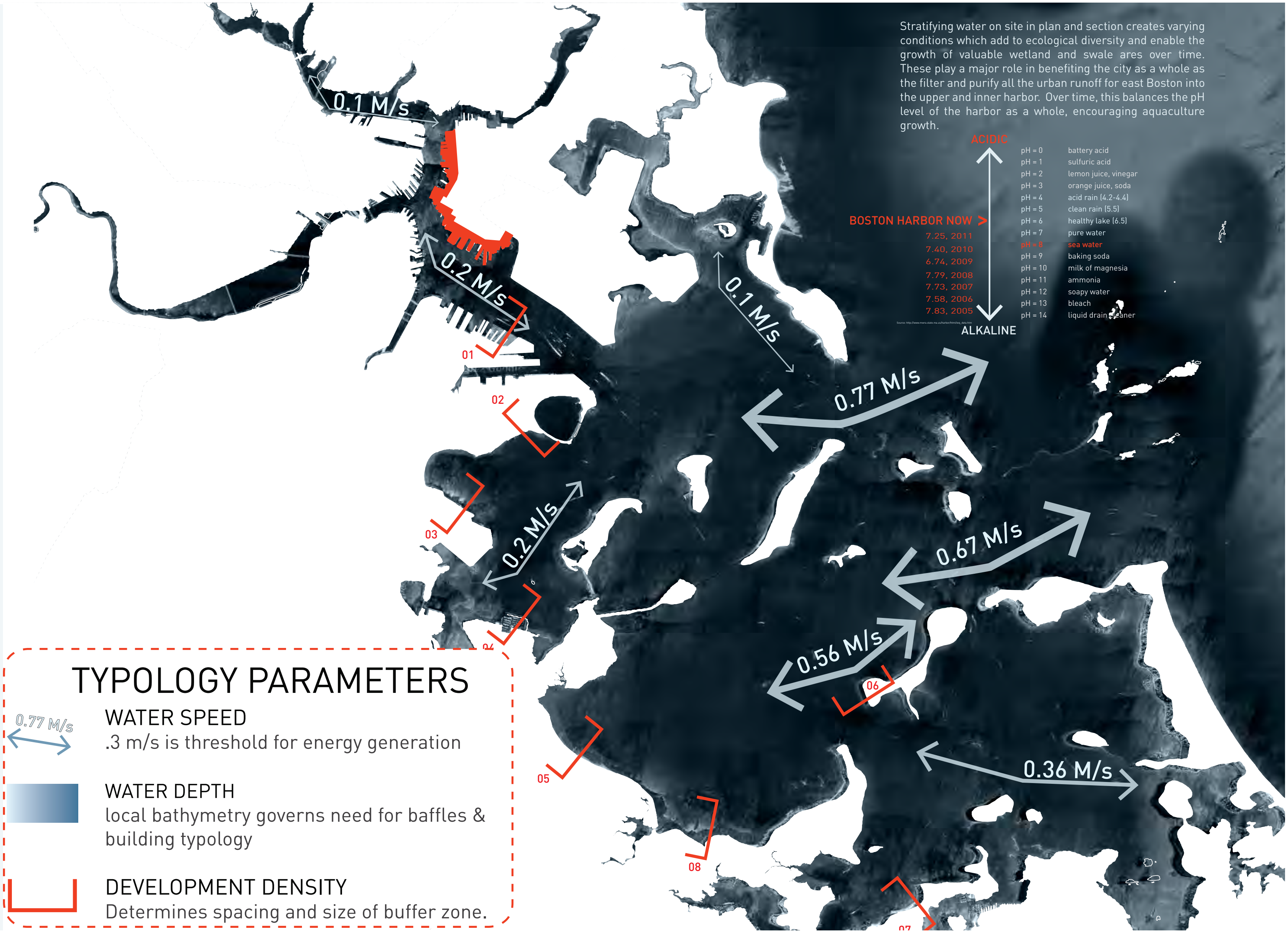


07. SUBURBAN + SHALLOW + SLOW CURRENT



08. SUBURBAN + SHALLOW + FAST CURRENT




Stratifying water on site in plan and section creates varying conditions which add to ecological diversity and enable the growth of valuable wetland and swale ares over time. These play a major role in benefiting the city as a whole as the filter and purify all the urban runoff for east Boston into the upper and inner harbor. Over time, this balances the pH level of the harbor as a whole, encouraging aquaculture growth.
ACIDIC
pH = 0 battery acid
pH = 1 sulfuric acid
pH = 2 lemon juice, vinegar
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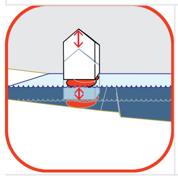
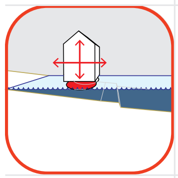
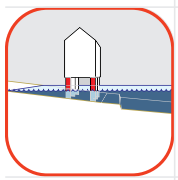
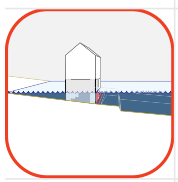
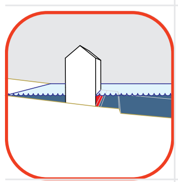
pH = 4 acid rain (4.2-4.4)
pH = 5 clean rain (5.5)
pH = 6 healthy lake (6.5)
pH = 7 pure water
pH = 8 sea water
pH = 9 baking soda
pH = 10 milk of magnesia
pH = 11 ammonia
pH = 12 soapy water
pH = 13 bleach
pH = 14 liquid drain cleaner
BOSTON HARBOR NOW >
7.25, 2011
7.40, 2010
6.74, 2009
7.79, 2008
7.73, 2007
7.58, 2006
7.83, 2005
Source: http://www.mwra.state.ma.us/harbor/html/wq_data.htm
ALKALINE
0.1 M/s
0.2 M/s
0.1 M/s
0.77 M/s
0.2 M/s
0.67 M/s
0.56 M/s
0.36 M/s
01
02
03
05
06
08
TYPOLOGY PARAMETERS
0.77 M/s
WATER SPEED
.3 m/s is threshold for energy generation
WATER DEPTH
local bathymetry governs need for baffles & building typology
DEVELOPMENT DENSITY
Determines spacing and size of buffer zone.

MITIGATION TOOL	DESCRIPTION +SOURCE	RESILIENCE RATING (L, M, H)	ADAPTABILITY RATING (L, M, H)
1.0 - ARCHITECTURE			
 1.1 Amphibious	Source: *Waterwonen in Nederland: Architectuur En Stedenbouw*	H (1,2,3,4,6)	H
 1.2 Floating	Source: *Float!*	M (1,3,4)	H
 1.3 Piles	Source: *Design for Flood-ing*, FEMA	M (3,4)	M
 1.4 Wet Flood proofing	Source: *Design for Flood-ing* ,FEMA	M (1,3)	L
 1.5 Waterproofing	Source: *Design for Flood-ing*, FEMA	L (1)	L

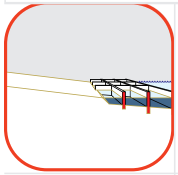
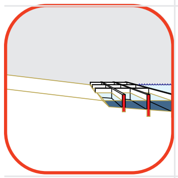
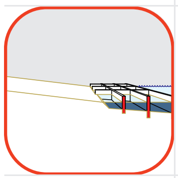
APPENDIX A - SINGLE MEANS, 1

6.1 - APPENDICES

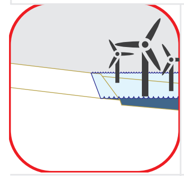
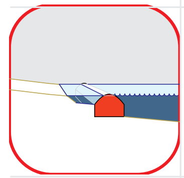
TABLE OF SEA RISE MITIGATION TOOLS BY DISCIPLINE

Refer to Chapter 2.1 for explanation of rating system reasoning and application to the design project. This section contains qualitative evaluation of the range of sea rise mitigation tools used by the following disciplines:

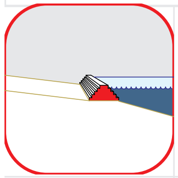
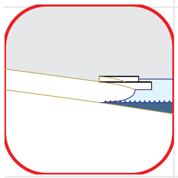
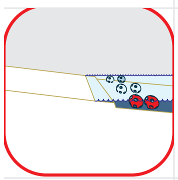
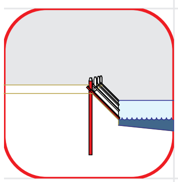
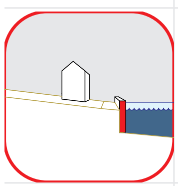
1. Architecture
2. Agriculture
3. Civil Engineering
4. Coastal Management (Civil Sub-Category)
5. Geotechnical Engineering (Civil Sub-Category)
6. Landscape Architecture
7. Naval Architecture
8. Water Resource Engineering (Civil Sub-Category)

MITIGATION TOOL	DESCRIPTION +SOURCE	RESILIENCE RATING (L, M, H)	ADAPTABILITY RATING (L, M, H)
2.0 - AQUACULTURE / AGRICULTURE			
 2.1 Fish Farm	Source: *Float!*	H (1,2, 4, 6)	L - M (delicate nutrient balance depending on type of fish)
 2.2 Muscle Cultivation	Source: *Float!*	L (1)	M (somewhat delicate nutrient balance depending on type of fish)
 2.3 Salt Tolerant Plants	Source: *Design for Flooding: Architecture, Landscape and Urban Design for Resilience to Climate Change*	M (1,4,6)	H

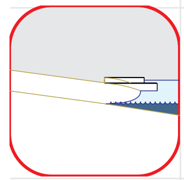
APPENDIX A - SINGLE MEANS, 2

MITIGATION TOOL	DESCRIPTION +SOURCE	RESILIENCE RATING (L, M, H)	ADAPTABILITY RATING (L, M, H)
3.0 - CIVIL ENGINEERING			
 3.1 Energy	Source: *Float!*	H (1, 2, 3, 6)	M
 3.2 Transportation	Semi-Submersible bridges can be configured with a variety of pontoon structures, providing vehicular or pedestrian transportation access in flood situations. Source: *Float!*	M (1, 2, 6)	H

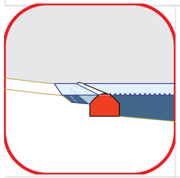
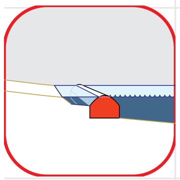
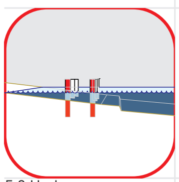
APPENDIX A - SINGLE MEANS, 3

MITIGATION TOOL	DESCRIPTION +SOURCE	RESILIENCE RATING (L, M, H)	ADAPTABILITY RATING (L, M, H)
4.0 - COASTAL MANAGEMENT (CIVIL ENGINEERING SUB-CATEGORY)			
 4.1 Breakwater	Tetrapod or gabion type breakwaters are engineered (unitized) structures that mimic the performance of barrier islands for breaking storm waves. Source: *Flood Control and Drainage Engineering*	L (4)	M
 4.2 Groynes	Source: *Flood Control and Drainage Engineering*	M (1, 4)	L
 4.3 Reef Cultivation	Source: *Float!*	M (2,4)	H
 4.4 Revetments	Source: *Flood Control and Drainage Engineering*	L (5)	L
 4.5 Sea Wall	Source: *Design for Flooding: Architecture, Landscape and Urban Design for Resilience to Climate Change*	L (5)	L

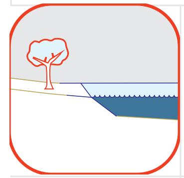
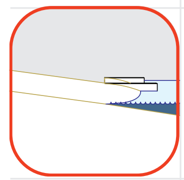
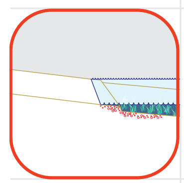
APPENDIX A - SINGLE MEANS, 4

MITIGATION TOOL	DESCRIPTION +SOURCE	RESILIENCE RATING (L, M, H)	ADAPTABILITY RATING (L, M, H)
4.0 - COASTAL MANAGEMENT (CONTINUED)			
 4.6 Beach Nourishment	Source: *Design for Flooding: Architecture, Landscape and Urban Design for Resilience to Climate Change*	M (1, 5)	H
 4.7 Tidal Basin	Source: *Float!*	H (1, 3, 5, 6)	M

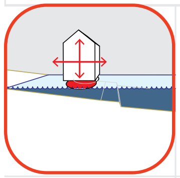
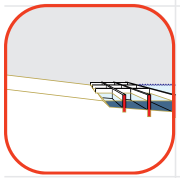
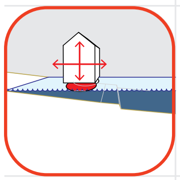
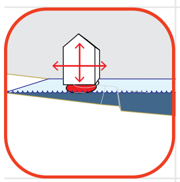
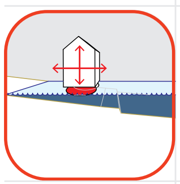
APPENDIX A - SINGLE MEANS, 5

MITIGATION TOOL	DESCRIPTION +SOURCE	RESILIENCE RATING (L, M, H)	ADAPTABILITY RATING (L, M, H)
5.0 -GEOTECHNICAL ENGINEERING (CIVIL ENG. SUB-CATEGORY)			
 5.1 Cssions	Source: *Flood Control and Drainage Engineering*	L (5)	L
 5.2 Geotextiles	Source: *Float!*	M (1, 2, 6)	H
 5.3 Undersea Foundations	Source: *Flood Control and Drainage Engineering*	M (4,6)	M

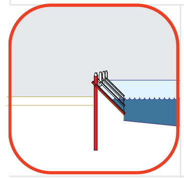
APPENDIX A - SINGLE MEANS, 6

MITIGATION TOOL	DESCRIPTION +SOURCE	RESILIENCE RATING (L, M, H)	ADAPTABILITY RATING (L, M, H)
6.0 - LANDSCAPE			
 6.1 Afforestation	Source:*Landscape Archi-tecture Construction*	M (4,6)	M
 6.2 Swale/ Bioswale	Source: *Landscape Archi-tecture Construction*	H (1, 2, 3, 5, 6)	H
 6.3 Wetland	Source: *Landscape Archi-tecture Construction*	H (1, 2, 3, 5, 6)	M

APPENDIX A - SINGLE MEANS, 7

MITIGATION TOOL	DESCRIPTION +SOURCE	RESILIENCE RATING (L, M, H)	ADAPTABILITY RATING (L, M, H)
7.0 - NAVAL ARCHITECTURE			
 7.1 Artificial Islands	Source: *Float!*	H (1, 2, 4, 6)	H
 7.2 Dry docks	Source: *Float!*	M (1, 5, 6)	M
 7.3 Floating Runways	Source: *Flood Control and Drainage Engineering*	H (1, 2, 4, 6)	M
 7.4 Oil Platforms	Source: *Float!*	H (1, 2, 4, 6)	L
 7.5 Ships	Source: *Float!*	H (1, 2, 4, 6)	L

APPENDIX A - SINGLE MEANS, 8

MITIGATION TOOL	DESCRIPTION +SOURCE	RESILIENCE RATING (L, M, H)	ADAPTABILITY RATING (L, M, H)
8.0 - WATER RESOURCE ENGINEERING			
 8.1 Levee	Sourcce: *Delta Urban-ism: The Netherlands*	L (5)	L
			H

APPENDIX A - SINGLE MEANS, 9

6.2 - APPENDICES

THESIS DEFENSE BOARDS

FINAL REVIEW COMMITTEE:

Felecia Davis
Ph.D. Candidate, Design and Computation, MIT

Antonio DiMambro
Principle, Antonio DiMambro Associates

Eric Höweler
Assistant Professor of Architecture, Harvard University, GSD
Principal, Howeler + Yoon Architects

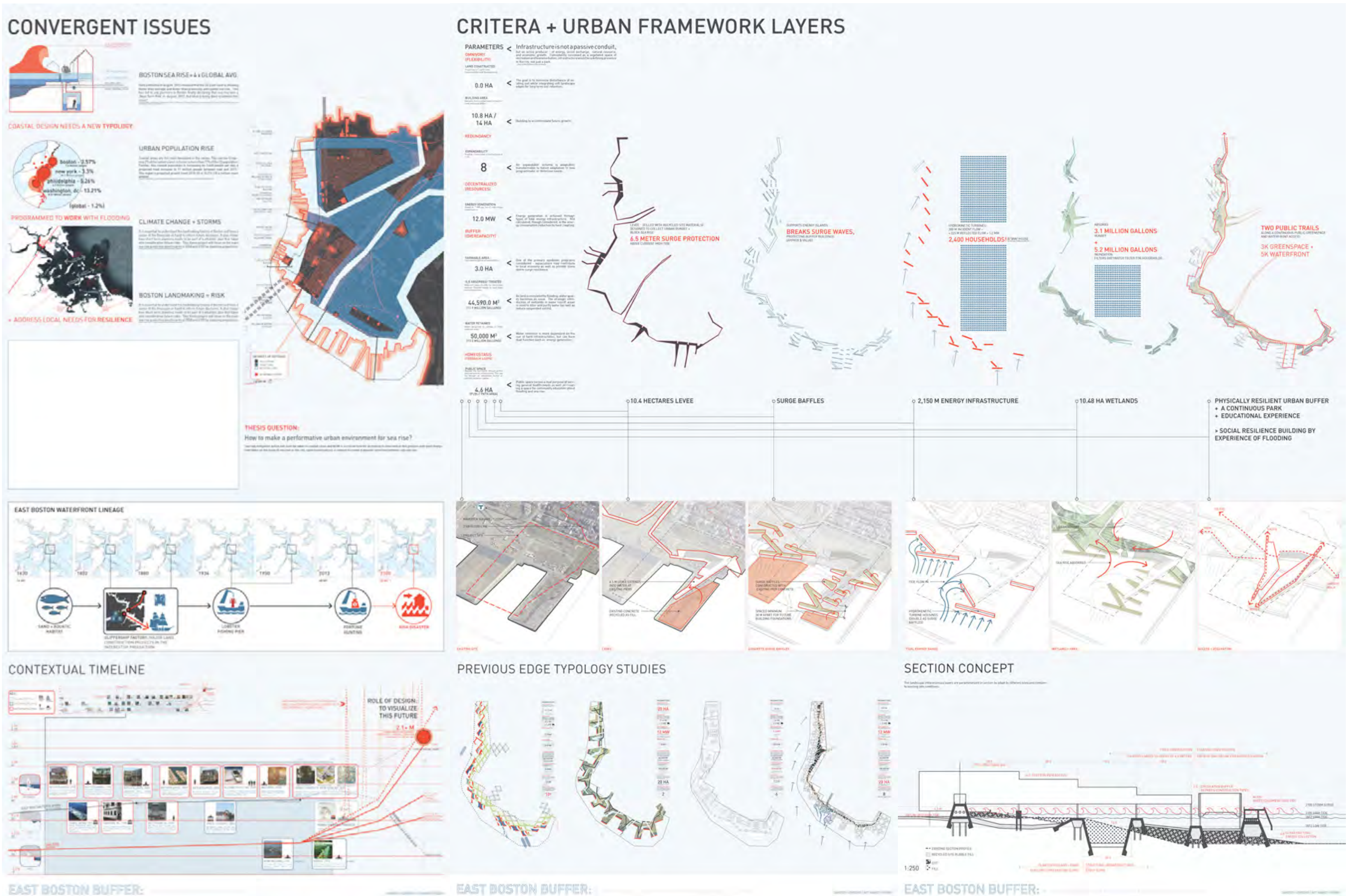
Mark Jarzombek, PhD
Professor, History Theory, and Criticism, MIT

Christoph Reinhart
AssociateProfessor, BT

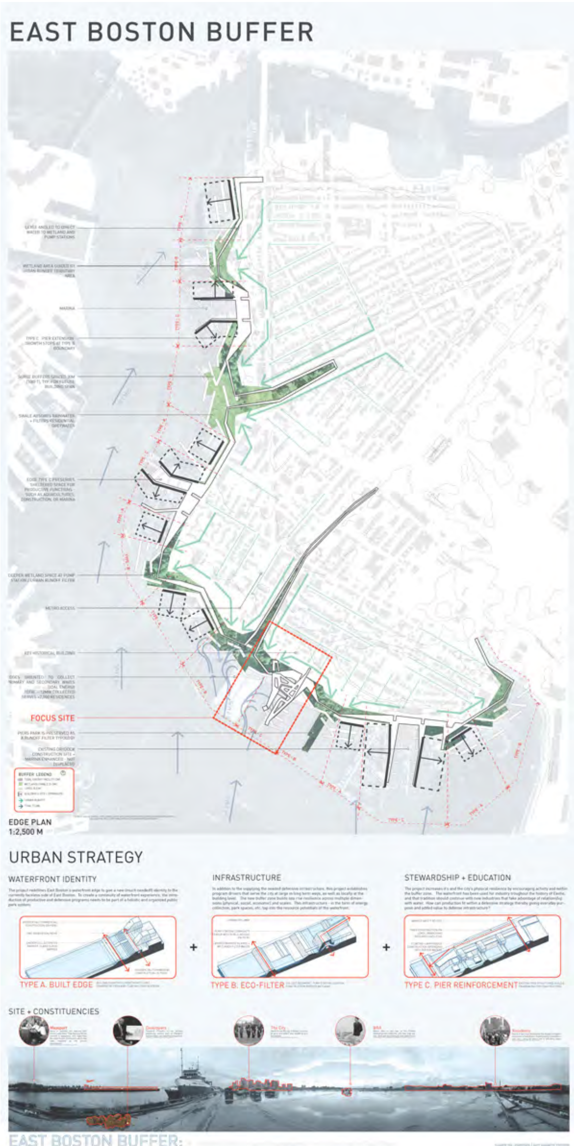
Andrew Scott, BArch
Associate Professor of Architecture
Thesis Supervisor

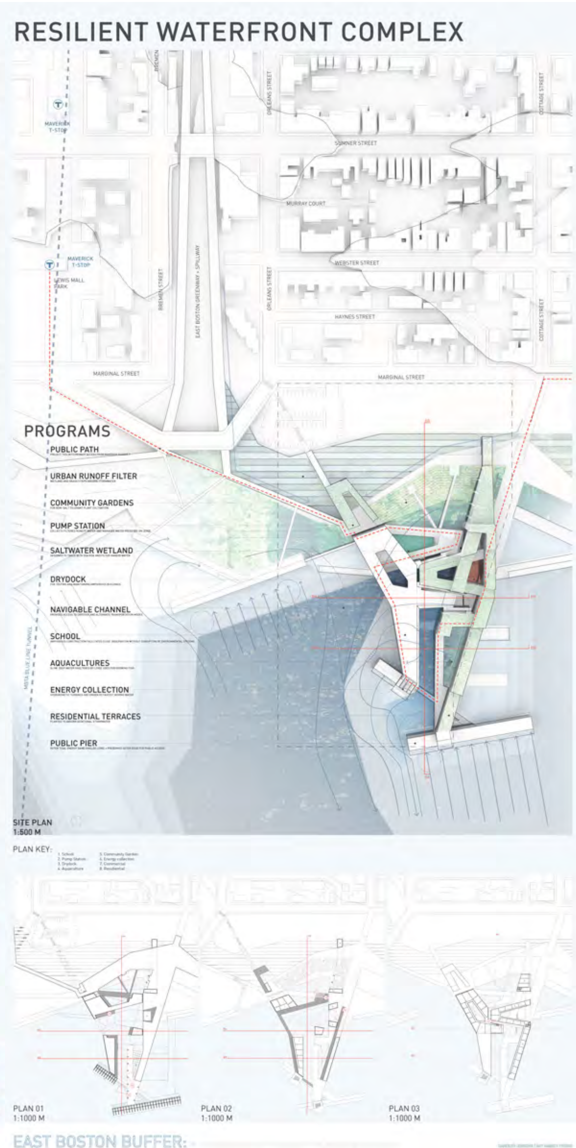
Marc Tsuramaki
Adjunct Assistant Professor, Columbia University, GSAPP
Principal, LTL Architects

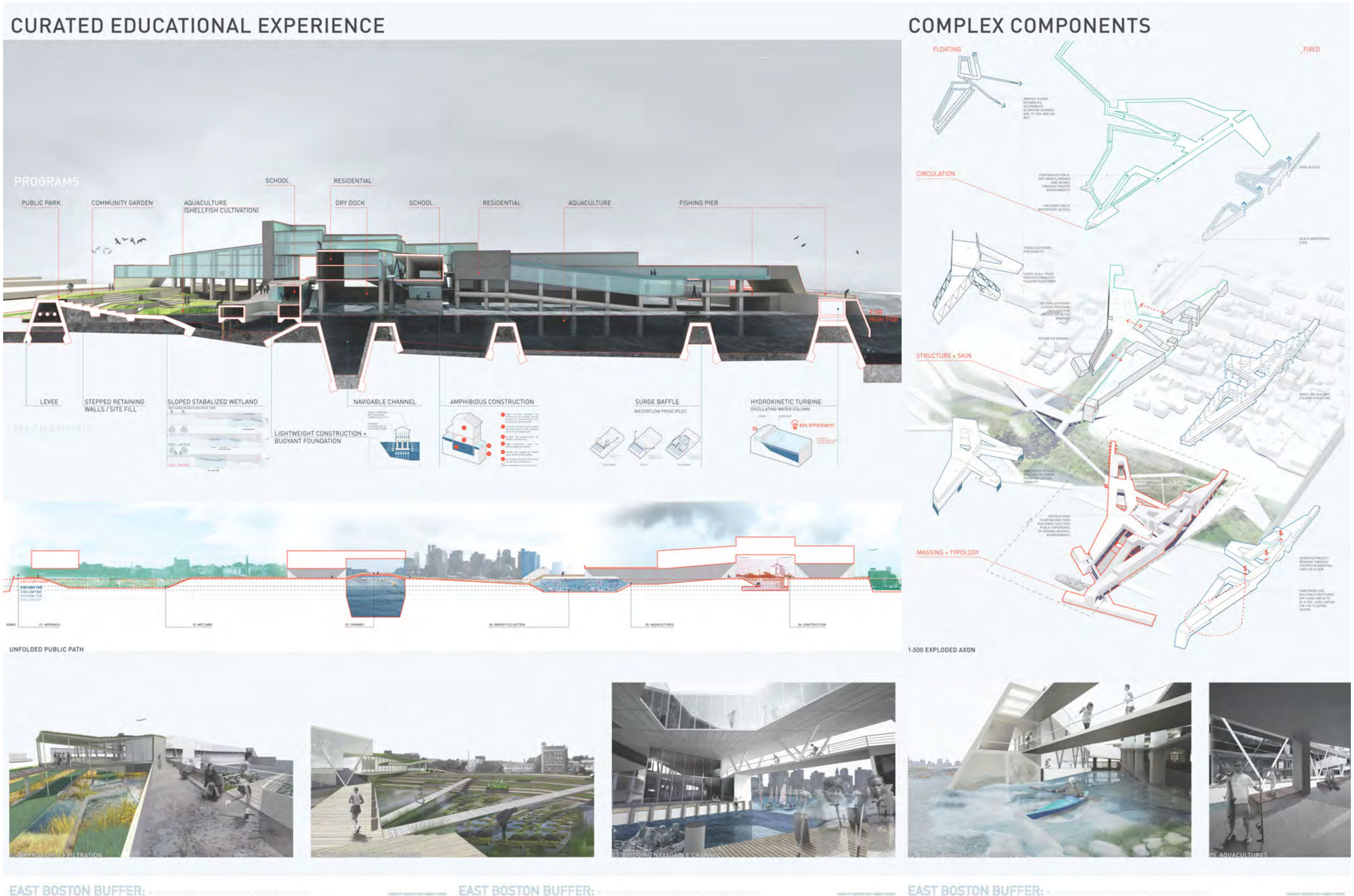
James Wescoat, PhD
Aga Khan Professor

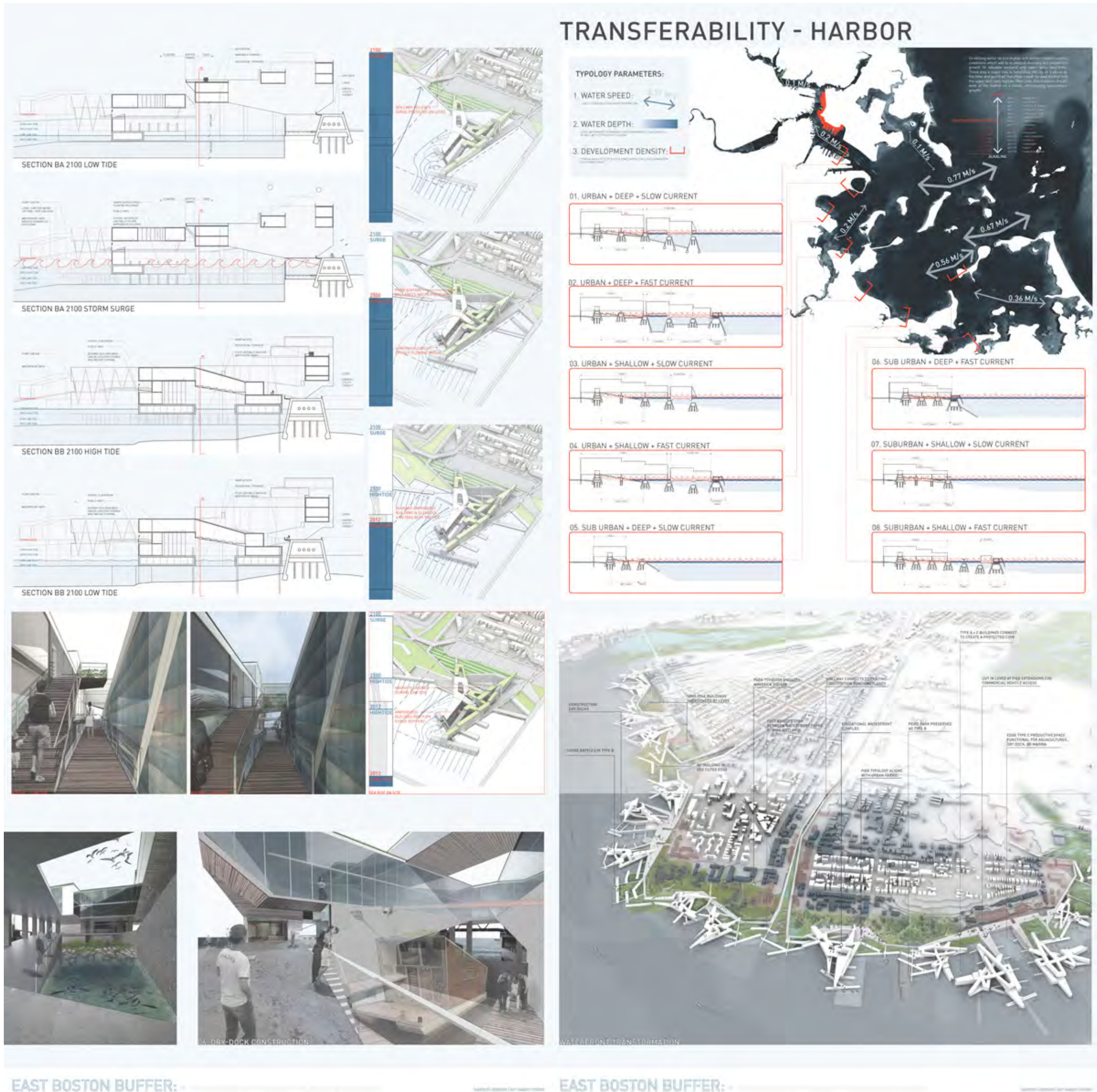


CONVERGENT ISSUES
BOSTON SEA RISE + 4 x GLOBAL AVG
COASTAL DESIGN NEEDS A NEW TYPOLOGY
URBAN POPULATION RISE
boston - 2.57%
new york - 3.3%
philadelphia - 6.26%
washington, dc - 13.21%
(global - 1.2%)
PROGRAMMED TO WORK WITH FLOODING
CLIMATE CHANGE + STORMS
BOSTON LANDMAKING + RISK
+ ADDRESS LOCAL NEEDS FOR RESILIENCE
THESIS QUESTION:
How to make a performative urban environment for sea rise?
CRITERA + URBAN FRAMEWORK LAYERS
PARAMETERS
Infrastructure is not a passive conduit,
0.0 HA
10.8 HA / 14 HA
8
12.0 MW
3.0 HA
44,590.0 M²
50,000 M³
4.6 HA
6.5 METER SURGE PROTECTION
BREAKS SURGE WAVES,
2,400 HOUSEHOLDS
3.1 MILLION GALLONS
5.2 MILLION GALLONS
TWO PUBLIC TRAILS
3K GREENSPACE +
5K WATERFRONT
10.4 HECTARES LEVEE
SURGE BAFFLES
2,150 M ENERGY INFRASTRUCTURE
10.48 HA WETLANDS
PHYSICALLY RESILIENT URBAN BUFFER
+ A CONTINUOUS PARK
+ EDUCATIONAL EXPERIENCE
> SOCIAL RESILIENCE BUILDING BY EXPERIENCE OF FLOODING
EAST BOSTON WATERFRONT LINEAGE
CONTEXTUAL TIMELINE
ROLE OF DESIGN: TO VISUALIZE THIS FUTURE
PREVIOUS EDGE TYPOLOGY STUDIES
SECTION CONCEPT
1:250
EAST BOSTON BUFFER:
EAST BOSTON BUFFER:
EAST BOSTON BUFFER:


EAST BOSTON BUFFER
FOCUS SITE
EDGE PLAN
1:2,500 M
URBAN STRATEGY
WATERFRONT IDENTITY
INFRASTRUCTURE
STEWARDSHIP + EDUCATION
TYPE A. BUILT EDGE
TYPE B. ECO-FILTER
TYPE C. PIER REINFORCEMENT
SITE + CONSTITUENCIES
EAST BOSTON BUFFER:


RESILIENT WATERFRONT COMPLEX
SUMNER STREET
MURRAY COURT
WEBSTER STREET
HAYNES STREET
MARGINAL STREET
PROGRAMS
PUBLIC PATH
URBAN RUNOFF FILTER
COMMUNITY GARDENS
PUMP STATION
SALTWATER WETLAND
DRYDOCK
NAVIGABLE CHANNEL
SCHOOL
AQUACULTURES
ENERGY COLLECTION
RESIDENTIAL TERRACES
PUBLIC PIER
SITE PLAN
1:500 M
PLAN KEY:
PLAN 01
1:1000 M
PLAN 02
1:1000 M
PLAN 03
1:1000 M
EAST BOSTON BUFFER:


CURATED EDUCATIONAL EXPERIENCE
COMPLEX COMPONENTS
PROGRAMS
PUBLIC PARK
COMMUNITY GARDEN
AQUACULTURE (SHELLFISH CULTIVATION)
SCHOOL
RESIDENTIAL
DRY DOCK
SCHOOL
RESIDENTIAL
AQUACULTURE
FISHING PIER
LEVEE
STEPPED RETAINING WALLS / SITE FILL
SLOPED STABALIZED WETLAND
LIGHTWEIGHT CONSTRUCTION + BUOYANT FOUNDATION
NAVIGABLE CHANNEL
AMPHIBIOUS CONSTRUCTION
SURGE BAFFLE
WATERFLOW PRINCIPLES
HYDROKINETIC TURBINE
OSCILLATING WATER COLUMN
UNFOLDED PUBLIC PATH
FLOATING
FIXED
CIRCULATION
STRUCTURE + SKIN
MASSING + TYPOLOGY
1:500 EXPLODED AXON
03. BRIDGING NAVAGABLE CHANNEL
05. AQUACULTURES
EAST BOSTON BUFFER:
EAST BOSTON BUFFER:
EAST BOSTON BUFFER:


TRANSFERABILITY - HARBOR
TYPOLOGY PARAMETERS:
1. WATER SPEED:
2. WATER DEPTH:
3. DEVELOPMENT DENSITY:
01. URBAN + DEEP + SLOW CURRENT
02. URBAN + DEEP + FAST CURRENT
03. URBAN + SHALLOW + SLOW CURRENT
04. URBAN + SHALLOW + FAST CURRENT
05. SUB URBAN + DEEP + SLOW CURRENT
06. SUB URBAN + DEEP + FAST CURRENT
07. SUBURBAN + SHALLOW + SLOW CURRENT
08. SUBURBAN + SHALLOW + FAST CURRENT
0.77 M/s
0.47 M/s
0.56 M/s
0.26 M/s
0.1 M/s
SECTION BA 2100 LOW TIDE
SECTION BA 2100 STORM SURGE
SECTION BB 2100 HIGH TIDE
SECTION BB 2100 LOW TIDE
EAST BOSTON BUFFER:
EAST BOSTON BUFFER:

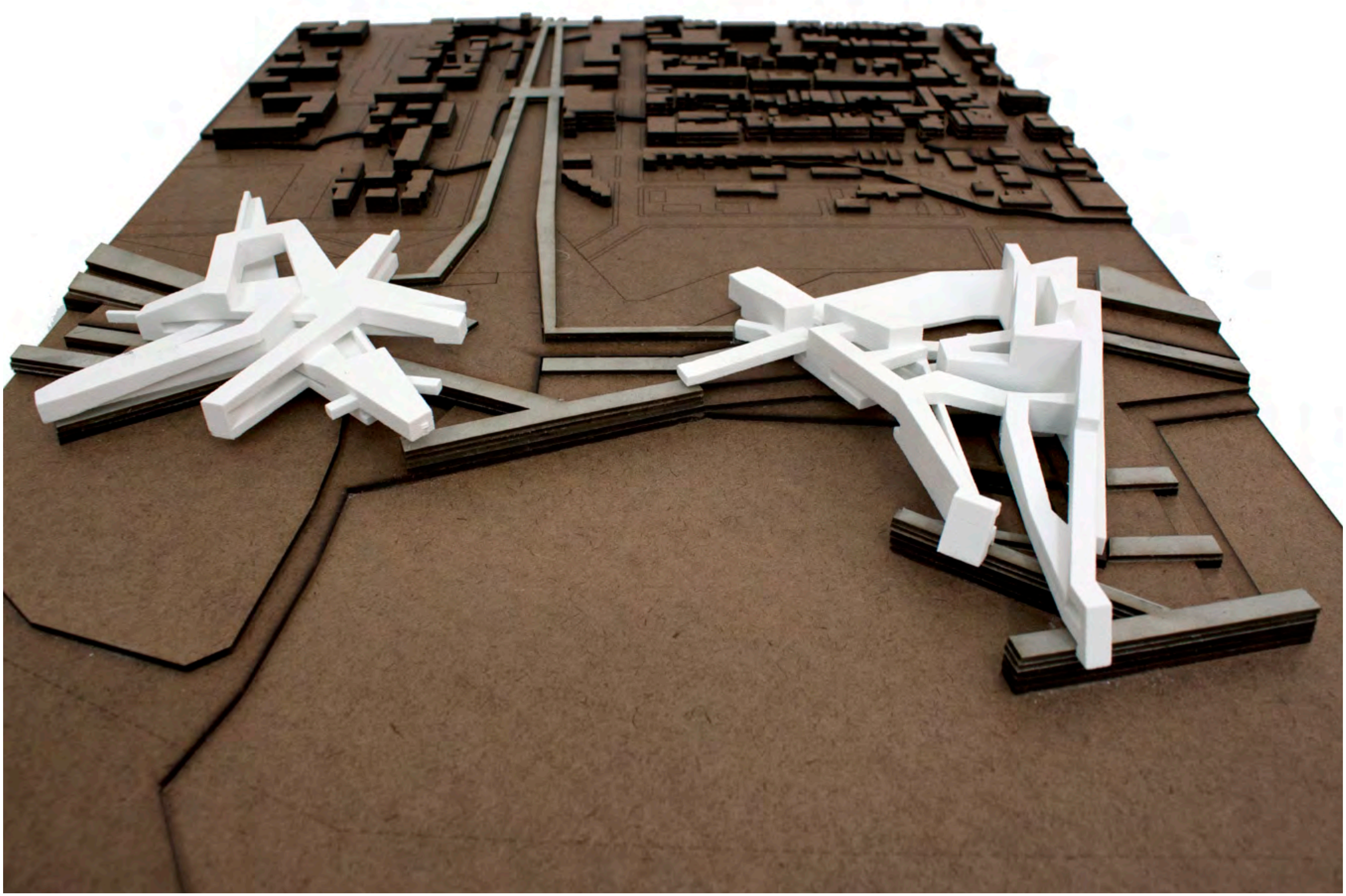
6.3 - APPENDICES FINAL MODELS

1:5,000 M SCALE FINAL CONTEXT MODEL

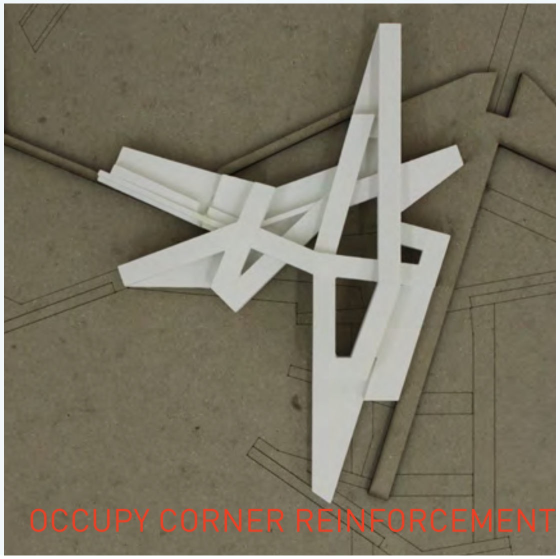
> MODEL SPECS:

1:5,000 meter
laser cut chipboard
acrylic lasercut water

Shows land to be innundated by 2 meter flood in brown chip, with 'dry land' and proposed infrastructure layers in white.



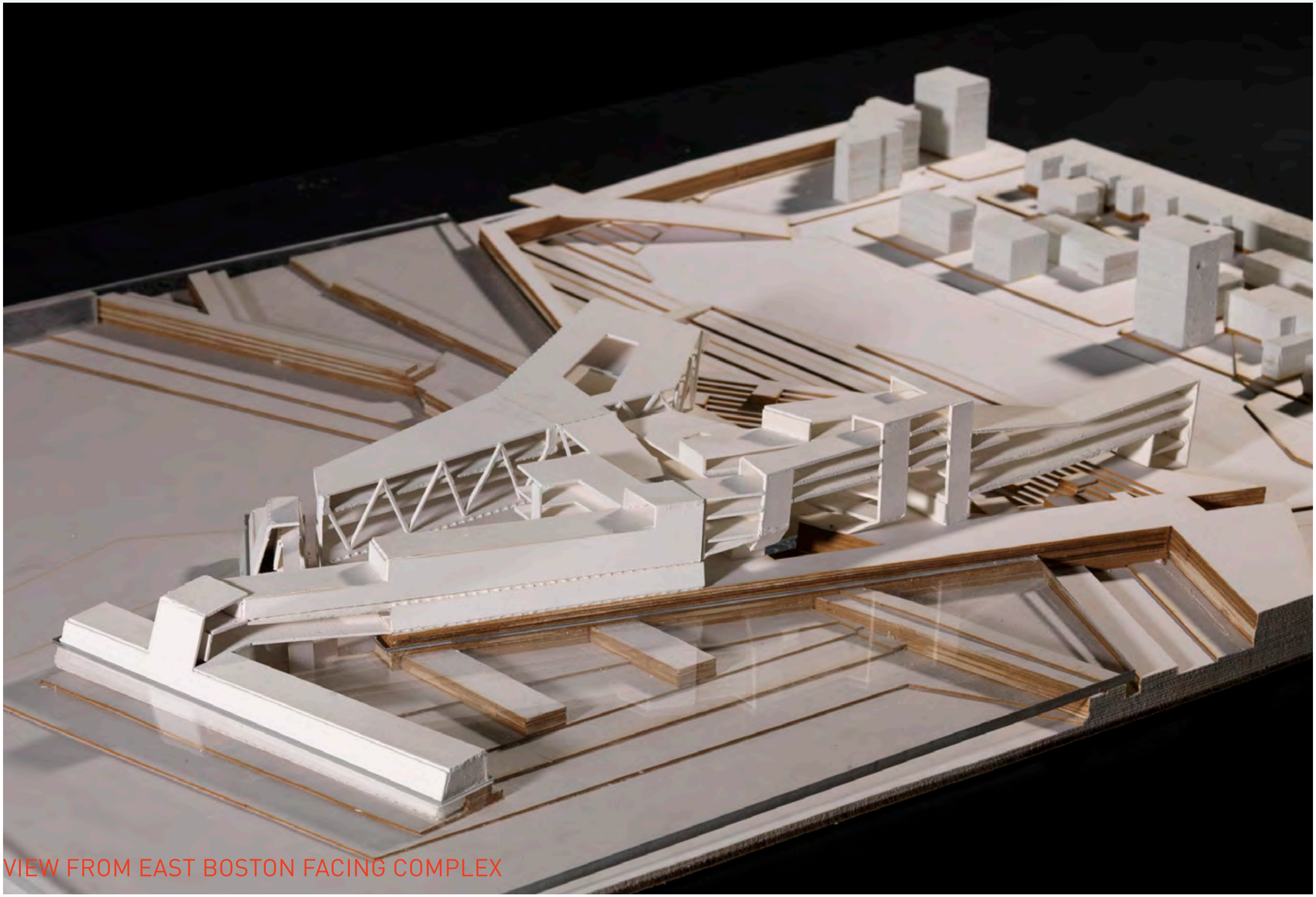
WATERFRONT COMPLEX TYPOLOGIES



> MODEL SPECS:

1:1,000 meter
Laser cut chipboard
laser cut masonite
3D Print models

Shows varying relationships between infrastructure & building, for water-front complex design.



VIEW FROM EAST BOSTON FACING COMPLEX

> MODEL SPECS:

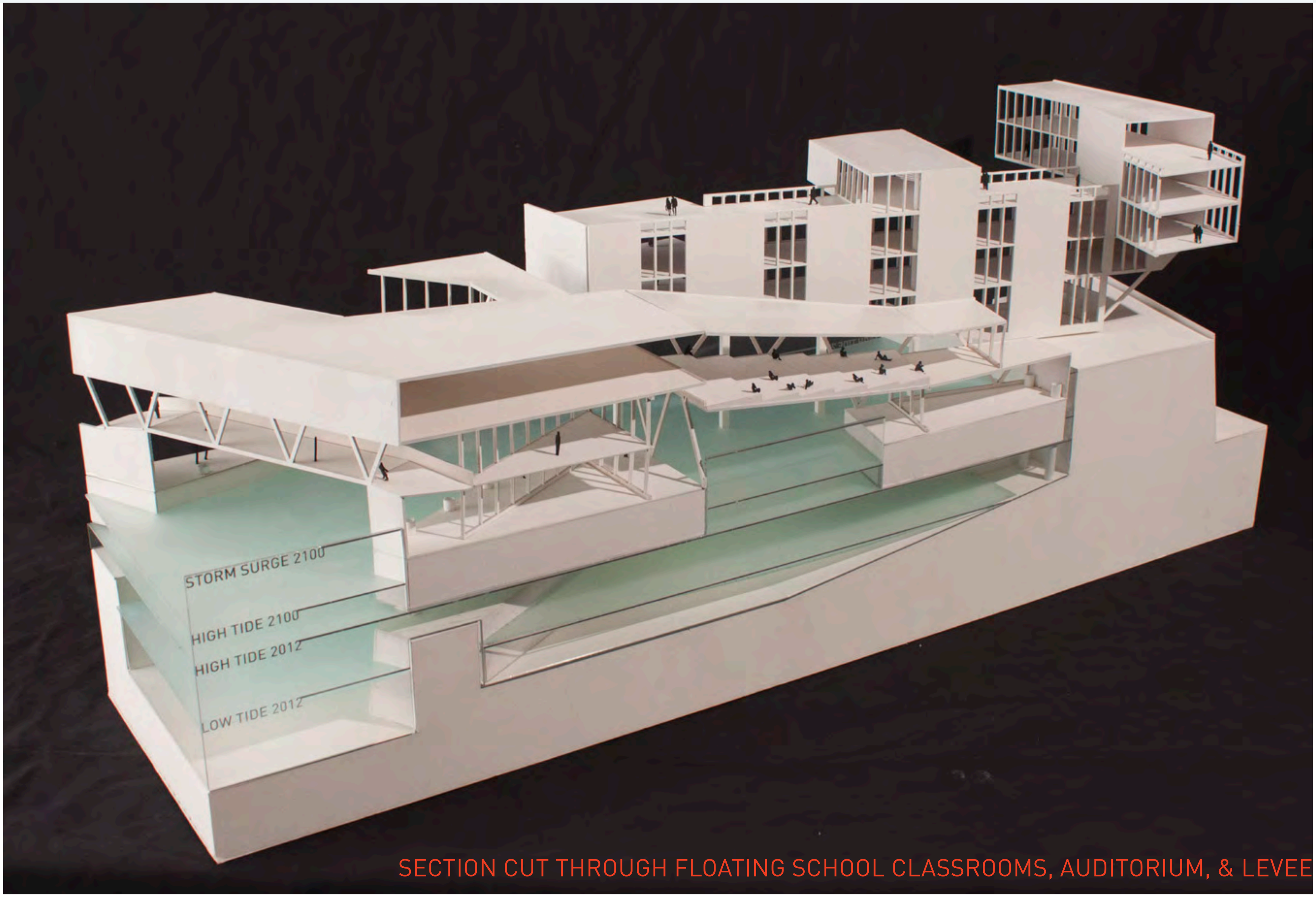
1:500 meter
laser cut museum board
acrylic lasercut water
CNC context buildings

Shows two complex buildings - floating school and fixed residential branching off of levee structure.

VIEW FROM EAST BOSTON FACING COMPLEX

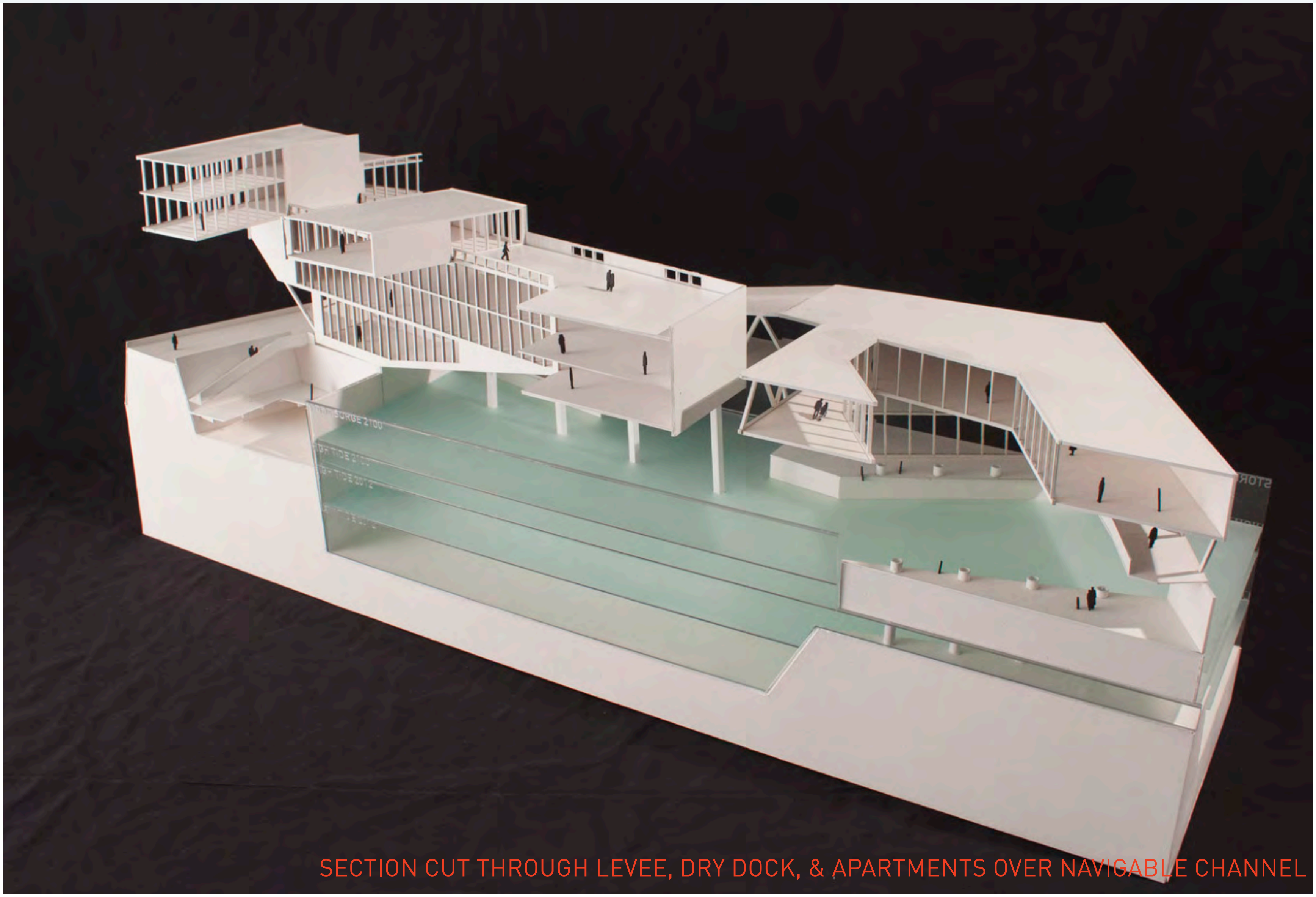
1:100 M SCALE FINAL SECTION MODEL

SECTION CUT THROUGH FLOATING SCHOOL CLASSROOMS, AUDITORIUM, & LEVEE



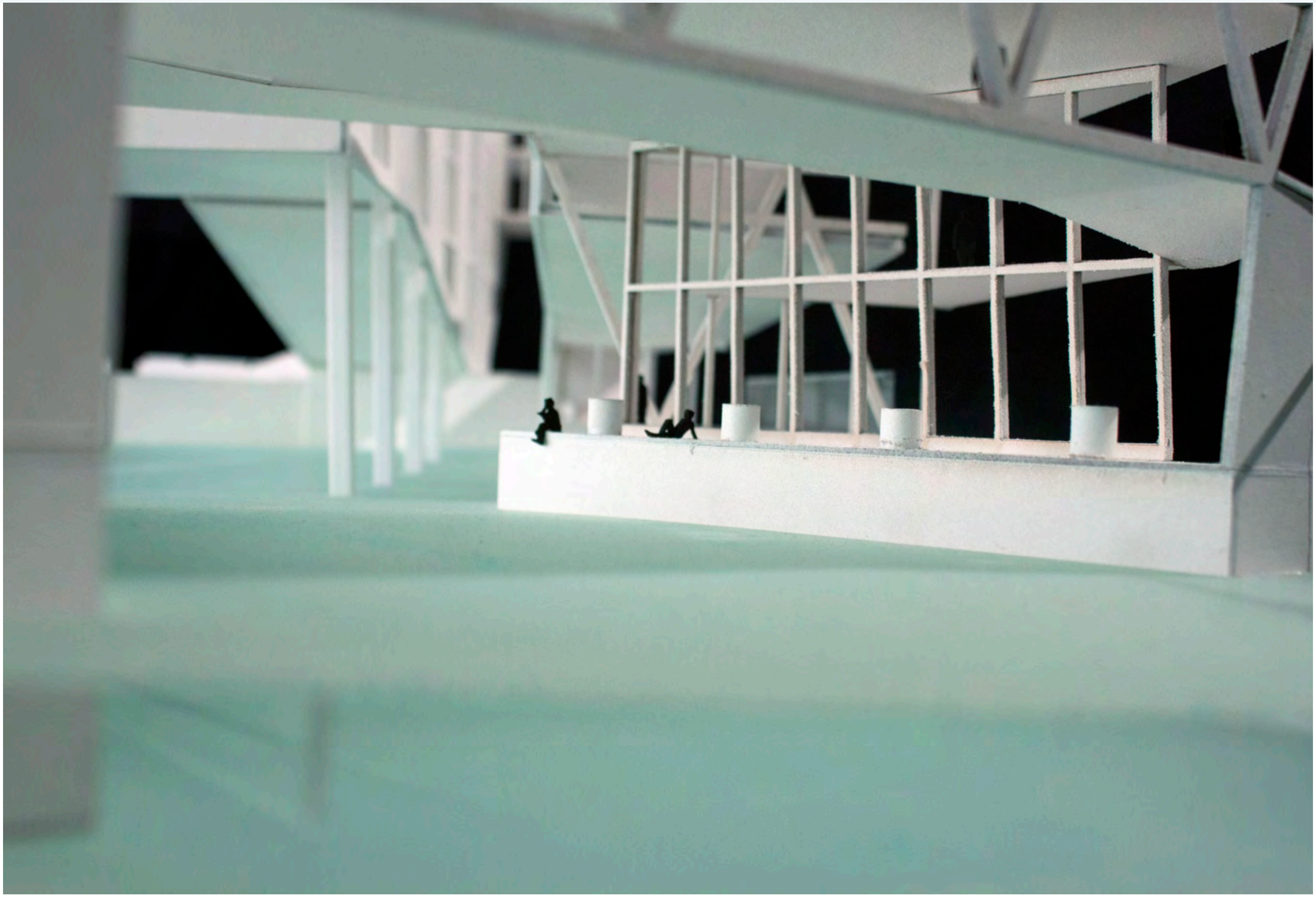
SECTION CUT THROUGH FLOATING SCHOOL CLASSROOMS, AUDITORIUM, & LEVEE

SECTION CUT THROUGH LEVEE, DRYDOCK, & APARTMENTS OVER NAVIGABLE CHANNEL



SECTION CUT THROUGH LEVEE, DRY DOCK, & APARTMENTS OVER NAVIGABLE CHANNEL

1:100 M SCALE FINAL SECTION MODEL



> MODEL SPECS:

1:100 meter
Laser cut museum board
Acrylic laser cut water, stained with fabric dye

Section model shows intersection of two building typologies - fixed and floating.

DETAIL OF SEA RISE DATUMS

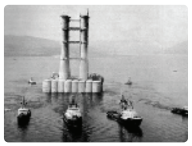
FLOATING

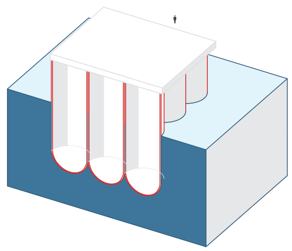
COMPONENTS | PRINCIPLES | AGGREGATION | STABILITY


floating cities (cruise ships)


ALLURE OF THE SEAS: 6,400 PASSENGER CRUISE SHIP, WORLD'S LARGEST


floating platforms

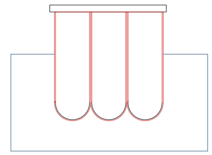

CONDEEP PLATFORM TEMPORARILY FLOATS BEFORE OIL RIG CONSTRUCTION



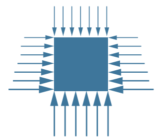
geometry

cruise ships must displace up to 65,000 tonnes in order to float (same as their weight)

geometry of ship and distribution of load determines displacement



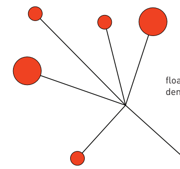
FORCES ON SUBMERGED OBJECT:



ARCHIMEDES' PRINCIPLE:

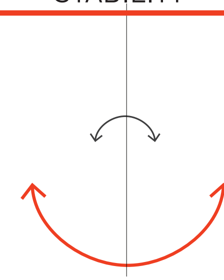
$$\frac{\text{DENSITY OF OBJECT (\_ KG/ M}^3\text{)}}{\text{DENSITY OF WATER (1,000 KG/ M}^3\text{)}} = \frac{\text{WEIGHT}}{\text{WEIGHT OF WATER}}$$

nodes



floating structures lend to high density construction

implications - can use cruise ship principles to create high density developement



geometric studies are necessary to increase stability.

SUBMERSIBLES (SEMI)

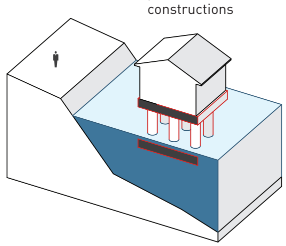

floating bridge


WEST INDIA QUAY FLOATING BRIDGE


floating wetlands


ECOSYSTEM DESIGN - FLOATING FARM

pontoon-based floating constructions



buoyancy: water displacment

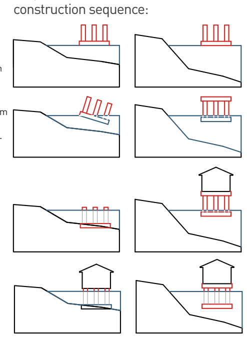
2 types of submersables are based on construction sequence:

buoyant base of foam or air filled pontoons

A. gemetry of platform allows it to sink.
B. Added weight submerses platform

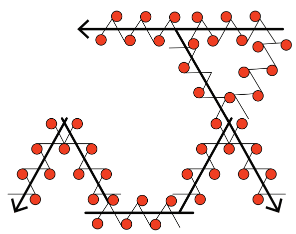
A. Platform rests on sea floor
B. More weight submerses platform

A. Construction
B. Settles into place

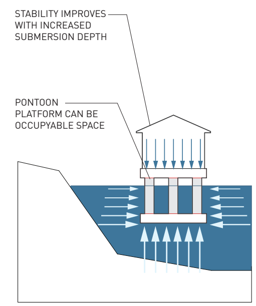


network

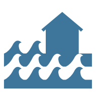
semi-submersibles have breakwater potential - can be used defensively to absorb the potential energy/ dampen storm surges

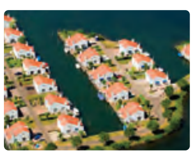


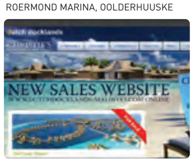
BUOYANCY: WATER DISPLACMENT



AMPHIBIOUS

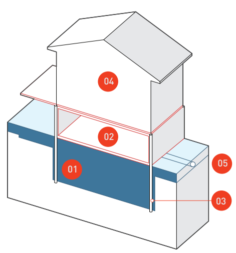

houses (dutch)


ROERMOND MARINA, OOLDERHUUSKE



DUTCH DOCKLANDS MALDIVES

AMPHIBIOUS CONSTRUCTION



01 under non-flood conditions the building sits on a hollow concrete foundation or pontoons which rests on posts set into the ground

02 In the event of water rise the hollow foundation, which can be inhabited, makes the building buoyant

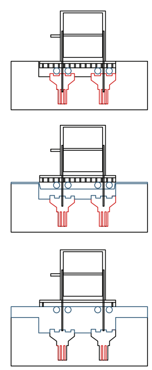
03 At least two morring posts are needed to prevent drift.

04 Light construction keeps the building stable and buoyant

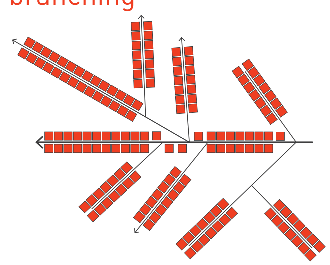
05 Utilities are supplied by flexible pipes, unaffected by flooding

06 As the water subsides, the building may drift back into position.

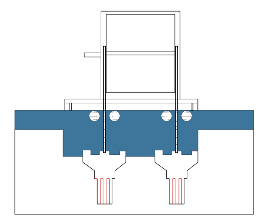
Source:
http://sealevelrise.blogspot.com/2011_03_13_archive.html



branching



amphibious structures are limited by stationary position and utility hookups.



piles keep the structure vertical. the only risk of instability is in the soil.

6.4 - APPENDICES

LIMITATIONS

scale: the semi-submersible approach is limited in FAR or density for human occupation.

ballance: it requires the finest ballance of displaced water.

site: the foundation geometry works best in open water

components: for a large scale infrastructure, the sequence of construction and assembly is more cumbersome

ballance: requires calculated water displacement.

however, pontoon system is stable (if structurally sturdy enough) on dry land or water

also can occupy the submerged part

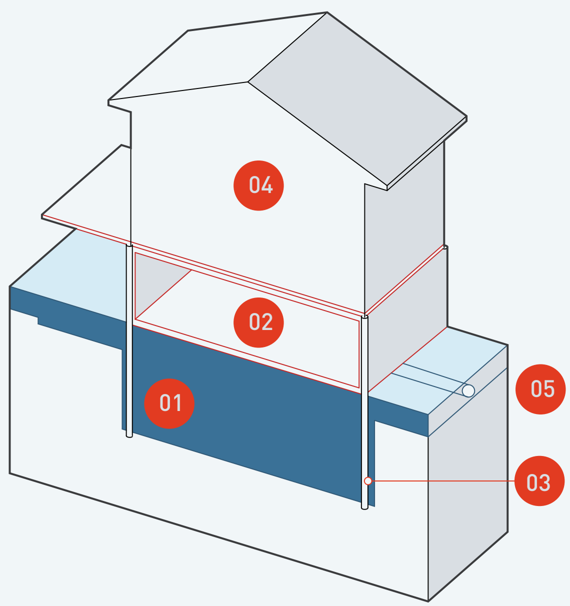
scale and mechanics: the foundation infrastructure required to keep the building in place is limited by economies of scale

requires some water displacement.

system is stable (if structurally sturdy enough) on dry land or water

PREVIOUS RESEARCH & DESIGN STUDIES

This project began with an intnsive research period. As an architecture student, I do not endeavor to become expert at the myriad specialties that would be required to weigh in on such a project in the 'real world'. To keep the project in the realm of architecture, the approach of this thesis was to begin with a research phase (refer to sections 2, 6.1 for additional work from this process) for developing a sufficient understanding these disciplinary tools to incorporate them in a strategic urban plan.



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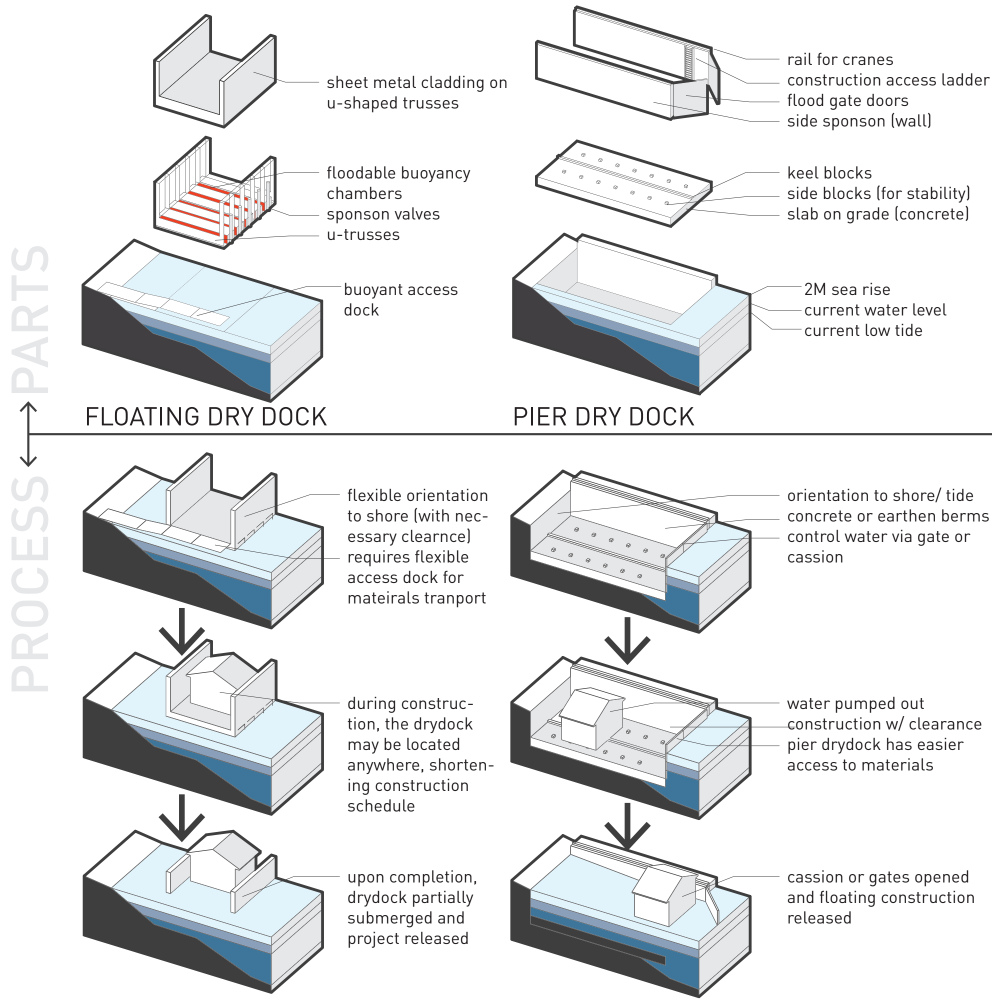
Source:
http://sealevelrise.blogspot.com/2011_03_13_archive.html

CONSTRUCTION DRYDOCK



dry docks have a potentially critical role to play in the transition to an architecturally resilient waterfront.

The two main types of drydock construction are fxed and floating. One the drydock is istalled, both types have potential added benefits in the context of sea rise.

system resilience:

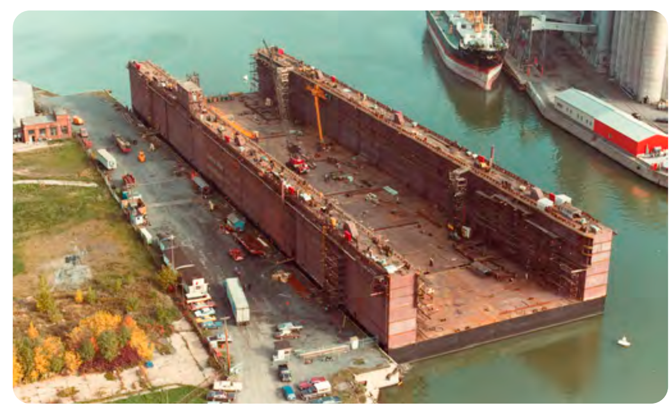
- floating drydock operation is undisturbed by sea rise
- pier drydock doubles as tidal basin during storms

Sources: http://www.brighthubengineering.com/naval-architecture/32659-drydocking-explained-types-of-dry-dock-methods/#, http://www.crandalldrydock.com/Floating_docks_new.html, http://en.wikipedia.org/wiki/Drydock

PRECEDENT:

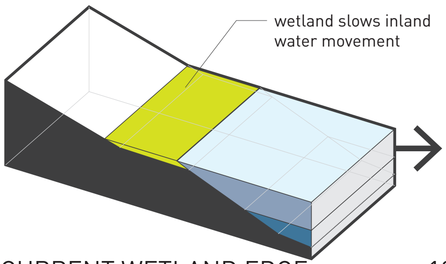
Floating Drydock, Halifax, Nova Scotia

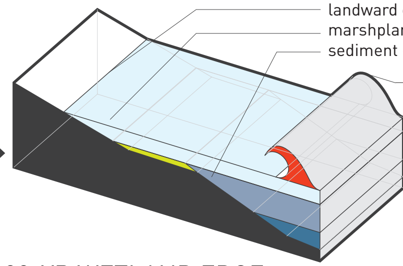
36,000-metric tonne floating dry dock under construction



http://www.crandalldrydock.com/Halifax_floating.html

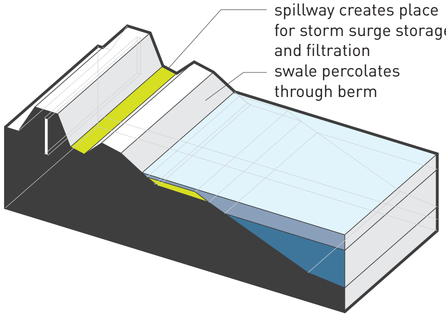
CONSTRUCTED WETLAND

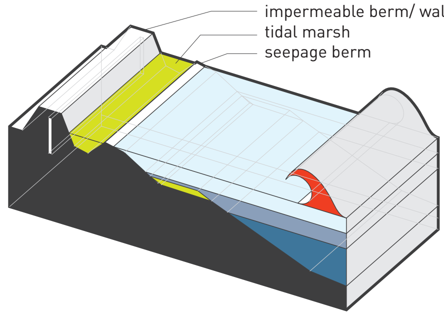




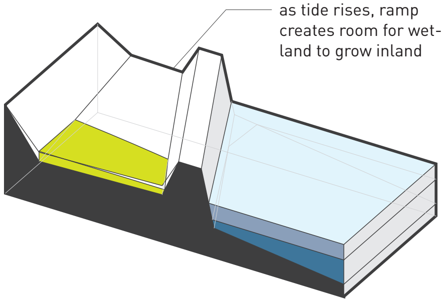
CURRENT WETLAND EDGE

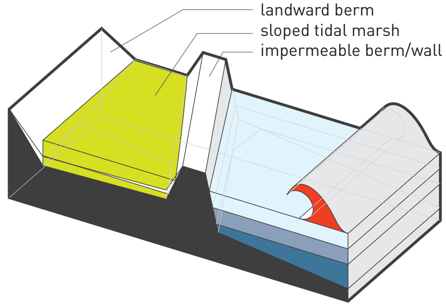
100-YR WETLAND EDGE





STRATEGY 01: BERMED





STRATEGY 02: TAPERED SLOPE

1 ACRE ABSORBS 330,000 GALLONS!

advantages:

- carbon trap (photosynthesis)
- habitat
- hay, peat, phosphate, timber, cranberry, or pelt harvest
- commercial fisheries (fish and shellfish) - Novitzki, Smith, and Fretwell, 1995
- flood storage and desynchronization, shoreline anchoring, surge protection
- wetlands can store and gradually release floodwater

system resilience:

the performance of wetlands is defined by how the wider coastal system, as a whole, responds to inundation. Some marshes will continue to respond resiliently to sea level rise if they have sufficient sediment in circulation and have space for wetlands to migrate. They may erode due to reduced sediment supply caused by engineering activities that have created sinks and draw sediment from circulation that would otherwise feed the marshes and mudflats.

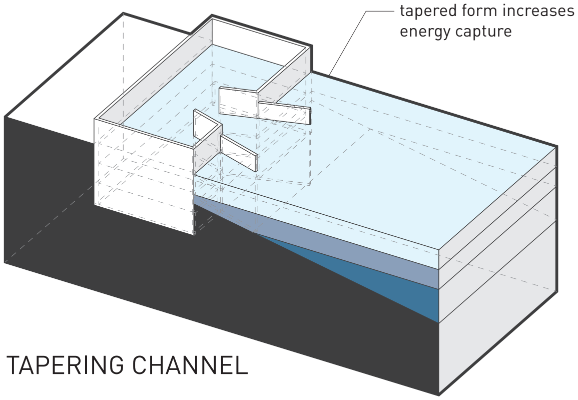
Key is to work with the gradual sea rise increase and allow space for wetlands to grow inwards with the tide change.

precedent:

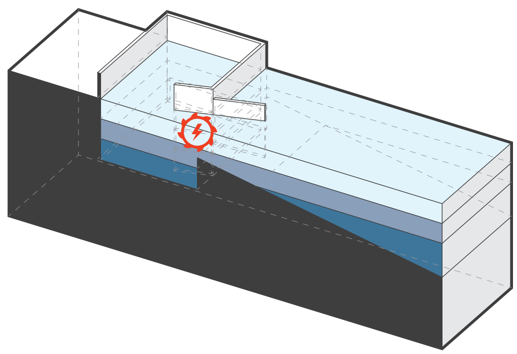
Floating Wetlands, Baltimore, MD

Constructed in August, 2010

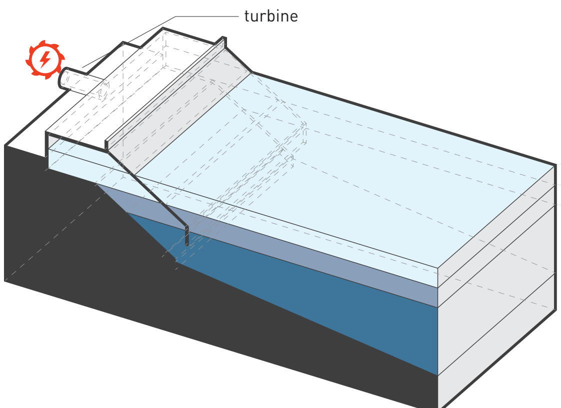
TIDAL ENERGY



TAPERING CHANNEL



TAPERING CHANNEL SECTION



OSCILLATING WATER COLUMN

energy generating wall can be designed to anticipate sea rise.

2M SEA RISE
CURRENT WATER LEVEL
CURRENT LOW TIDE

85% EFFICIENCY!

A source of energy at sea is wave power. The potential energy generator can be generated using fixed and floating installations. with a buoyant installation, use can be made of floats secured to a spindle with a neutral mechanism: when the float rises, it takes the spindle with it; when the float goes down again, it falls to neutral.

One example of fixed installation is a series of tapering channels (tapchans). When a wave flows in the channel ,the temporarily raised water pressure propels part of the water into a reservoir situated at a higher level. From there, the water flows back to sea level through a turbine.

Another method works with an oscillating water column. it makes use of a hanging airtight chamber with a valve half submerged in water. as a wave enters the chamber, the air pressure increases so that air leaves the column via a valve, driving a turbine.

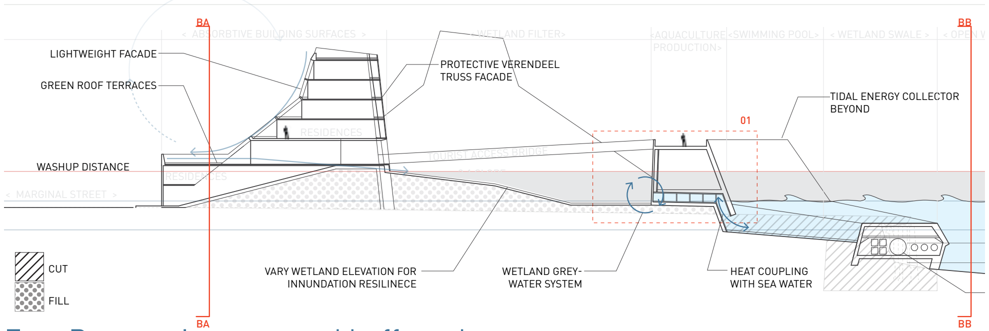
PRECEDENT:

Islay Tidal Power Station, Scotland: construct completed September, 2000.

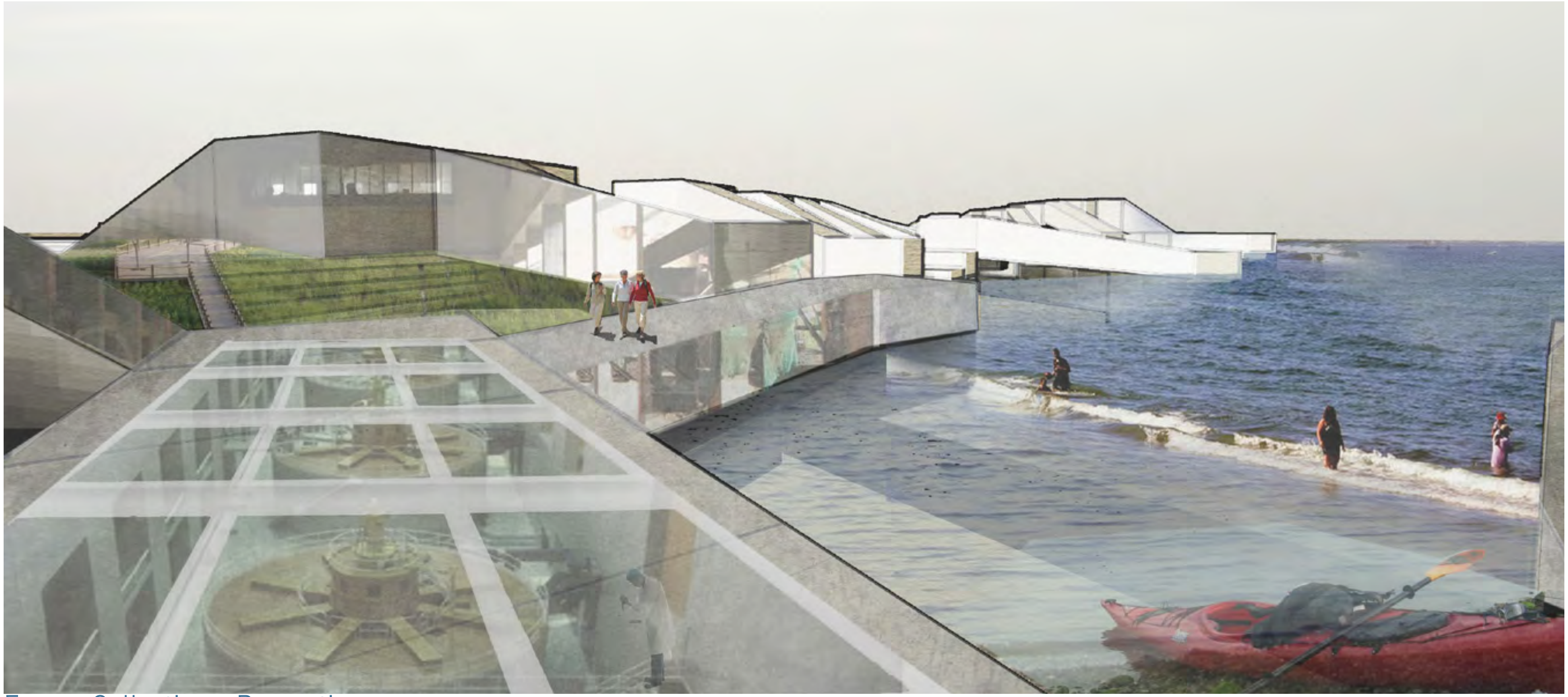
21M wide prototype, total generation: 75kW **(4kW / meter).**

http://www.guardian.co.uk/environment/2008/apr/06/windpower.scotland

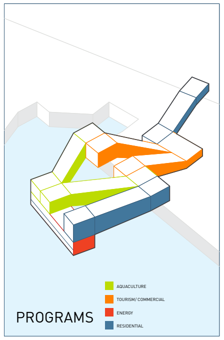
Process sketch of mid-term plan design for the East Boston Buffer.

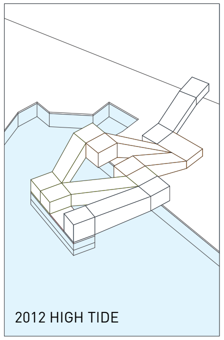


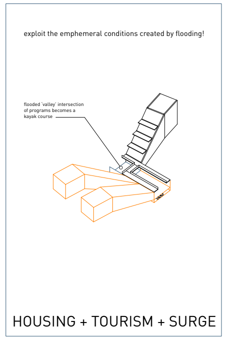
East Boston site proposed buffer edge.

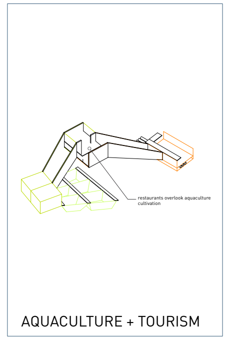


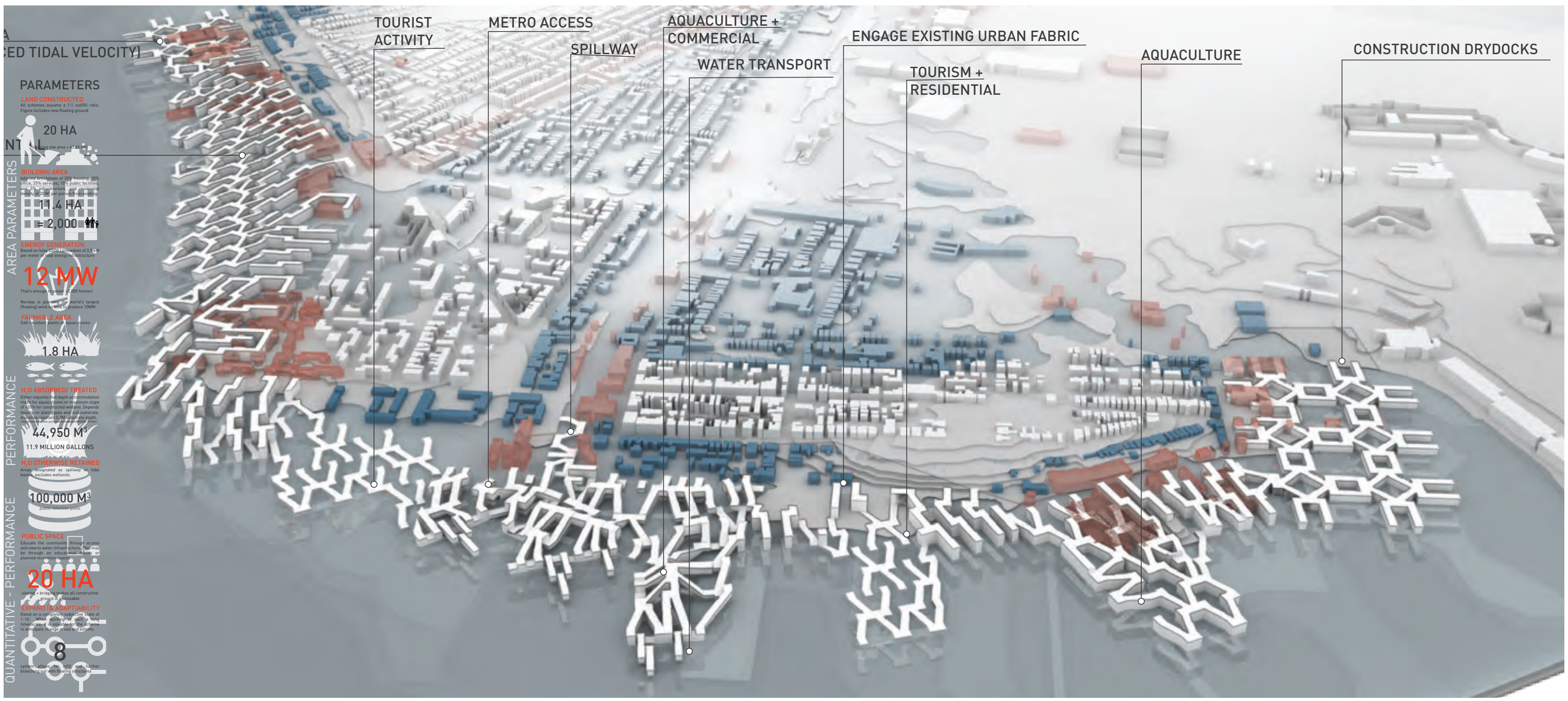
Energy Collection + Recreation











Mid-term design proposal for city-sea buffer.

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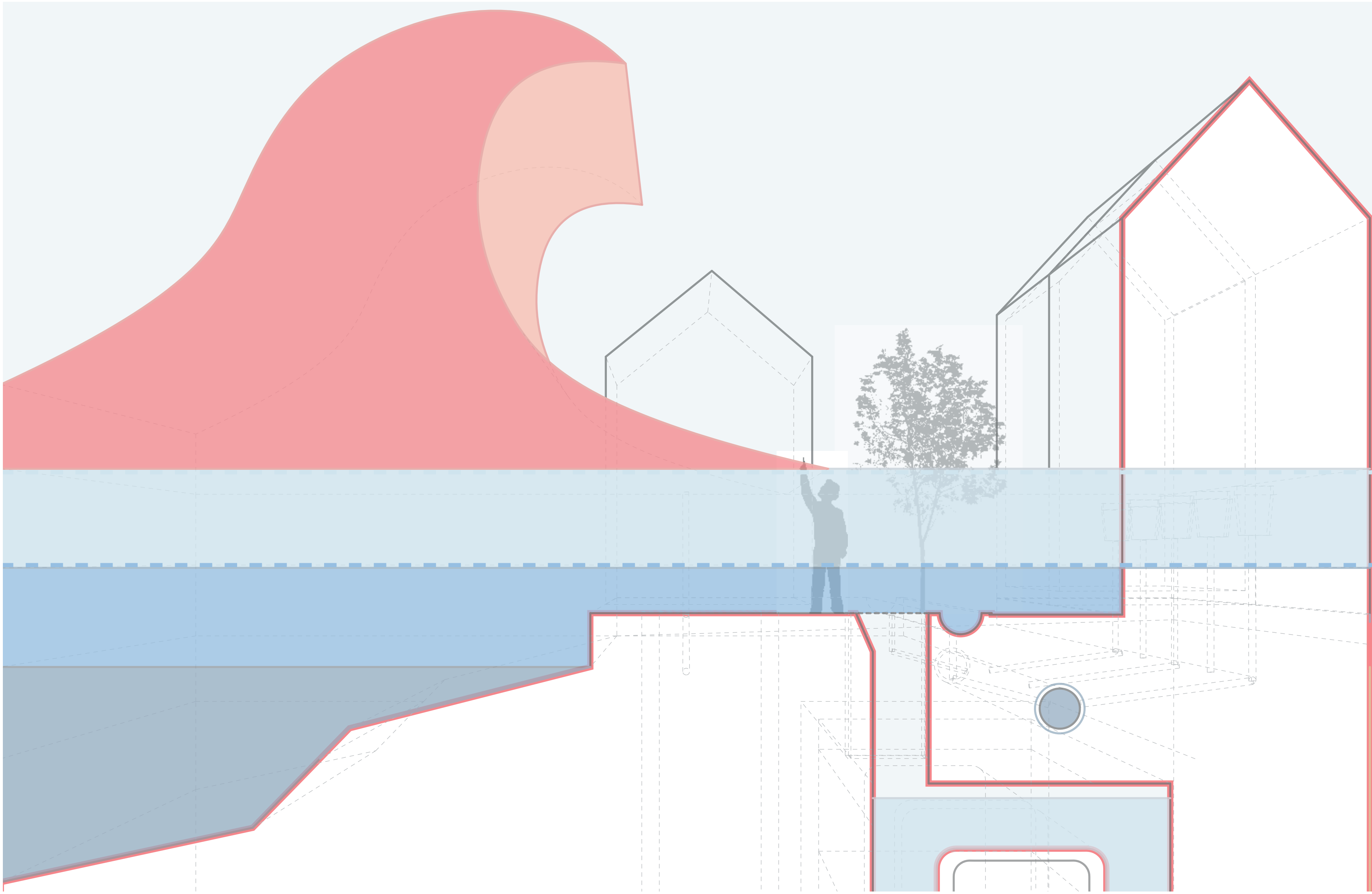
7.2 - WORKS CITED

LIST OF FIGURES

Figures 21 - 31 are Photographed by the Author.



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