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Theorizing the resilience district: Design-based decision making for coastal climate change adaptation

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Abstract

Today, coastal cities face mounting pressures to plan for increased exposure to chronic flooding, and ultimately significant sea level rise. The required investments in urban adaptation are inherently expensive, uncertain and long-term. These factors pose significant challenges for both effective choice and collective action.

This paper argues that metropolitan 'resilience districts' offer the appropriate decision-making unit (DMU) to analyze, plan and implement resilience strategies. The working concept of 'resilience districts' for urban areas vulnerable to coastal flooding was first coined by a design team at the Massachusetts Institute of Technology spurred by a case study on the New Jersey Meadowlands from the 'Rebuild By Design' (RBD) competition. Cities have since begun using this term for their own resilience policies, failing to recognize the original intentions of its meaning.

This analysis details a resilience districting strategy for the Greater Boston Metropolitan Area. The research culminates with a generalizable urban planning and design framework for protecting critical infrastructure, 'thickening' regional soft systems and transferring density to less vulnerable areas. The overall theme emphasizes landscape as a critical public safety service.

Climate change / coastal flooding / risk / resilience districts

Introduction

Human settlement has always been inextricably tied to bodies of water for sustenance, trade and a more accommodating climate. For coastal cities, this relationship is increasingly fraught with risk due to the likely catastrophic effects of climate change. Record-breaking storm surges and increasing precipitation rates (most consequential), pose immense challenges for long-term urban adaptation. Between now and the end of the twenty-first century, the current population along the Atlantic and Gulf coasts of the United States may well double. Much of this expanded regional population will inevitably settle in areas strongly exposed to coastal flooding. A sea level rise of 1.8 m, unfortunately a reasonable expectation, could put as many as 13.1 million people in harm's way by 2100, and recent research suggests even greater increases are possible.[1] The resulting flooding will not merely impact the region's coastlines and floodplains; it will also have a cascade effect throughout adjacent communities where infrastructure failure and service disruptions may also be catastrophic (Fig. 1).

It is too late to make mitigation the primary strategy for defending against climate change. Today, cities, non-profits and non-governmental organizations have turned their attention beyond mitigation and have focused on adaptation strategies as a primary instrument for enhancing urban resilience.[2] This new focus has been strongly reflected in the disciplines of urban planning and landscape architecture, as demonstrated by salient recent initiatives in the United States. These include the 'Rebuild By Design' (RBD) initiative, 'Changing Course: Navigating the Future of the Lower Mississippi River Delta' design competition, the 'National Disaster Resilience Competition' (NDRC) and the 'Resilient By Design: Bay Area Challenge' initiative.

In part through these efforts, 'resilience' as a term has expanded from its original ecological and environmental contexts. It has come to denote broader social and cultural mandates, rendering it more broadly applicable but also increasingly diffuse. For example, in 2007 'resilience' was consid-

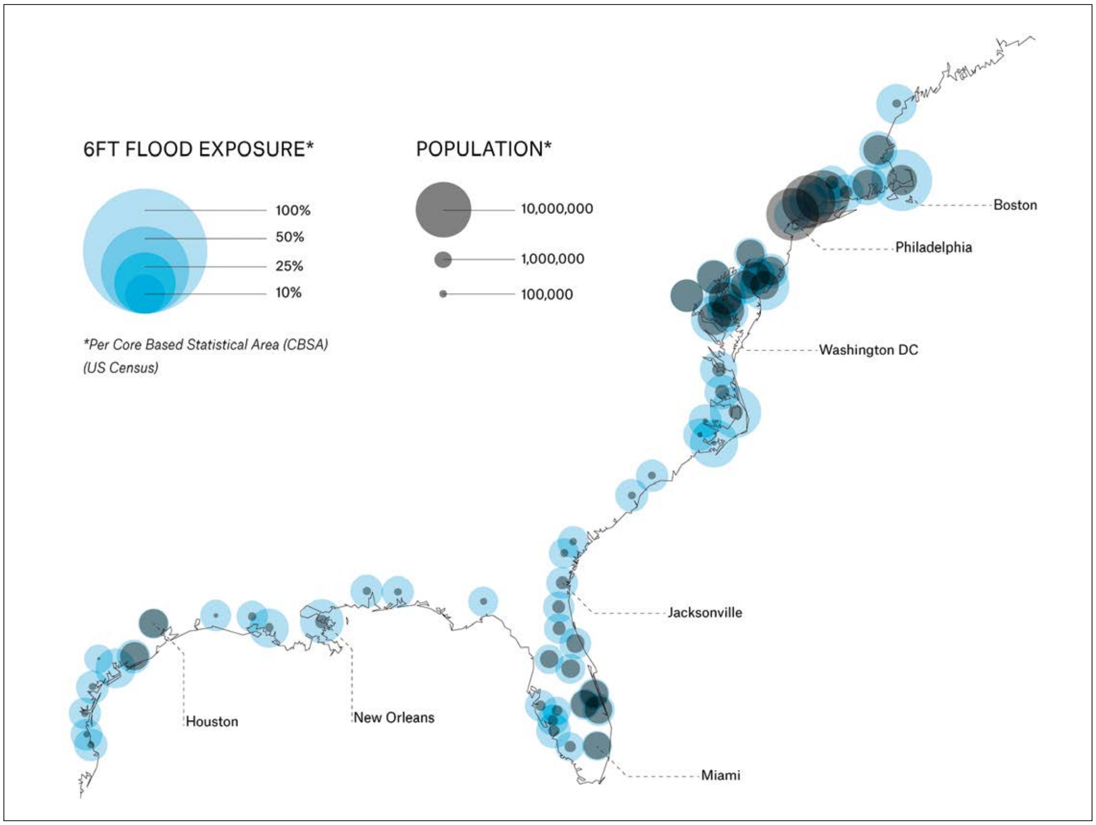

Figure 1 Flooding of Atlantic and Gulf coasts with 6 feet (1.8 m) of sea level rise. Data sources: 2016 US Census, USGS EROS Archive – Digital Elevation – SRTM 1 Arc-Second Global

ered 'the physical ability of a system to absorb a shock while maintaining structure and function', but five years later, its definition had broadened to include the politics of preparation, planning, recovery and adaptation.[3] The evolving vernacular role of this term reflects both an increased sense of urgency around issues related to climate change and the need for more innovative and intense disciplinary engagement from planning and design professionals.

In the United States, landscape architects and allied urban policymakers must find new ways to invest in, design and govern urban areas vulnerable to climate change. The traditional approach of localized, defensive engineering strategies will be woefully insufficient. Rather, long-term resilience projects must extend both further along the coastline and further inland so that whole regions, not merely local areas, are protected. They must incorporate a broader, regional cross section of urbanized communities and connected landscape systems that are at risk together.

In this sense, one of the most compelling trends in the field of resilience planning has been the proliferation of various districting schemes for organizing long-term coastal adaptation. For centuries, districting in the United States has been a pragmatic tool for protecting resources, distributing services and ensuring representation in the face of uncertainty. In this essay, we explore the role of districts within the context of resilience planning and design as the country and the world prepare for significant climate change. We analyze various ways of structuring and scaling urban districts based on regional scenarios. Then, using the Greater Boston Metropolitan Area as a case study, we articulate a theoretical framework for 'resilience districts' designed to mitigate systemic risks for regions. These must also achieve agglomeration benefits and optimize future land use at the regional level.

Districts as decision-making units (DMUs)

Well-designed resilience projects yield significant expected savings relative to their costs, often many times over. Nevertheless, actual expenditures by municipalities on resilience tend to fall well short of the totals needed for high-value regional projects.[4] Traditional public policy suggests that in order to secure adequate funding for large-scale project implementation, the size of the decision-making unit (DMU) should be optimized in order to incorporate significant externalities.[5] Tugging in the opposite direction, decision-making effectiveness should not be compromised by incorporating too variegated a domain.

As the size of the DMU increases, decision-making effectiveness tends to suffer from extended processes of negotiation and compromise. Shrinking the DMU to account for a smaller portfolio of mutual risks and assets might reduce the need for compromise, thereby strengthening the resilience potential. However, two sets of costs would arise. The first set of costs would raise the relative magnitude of externalities that extend beyond the DMU, thus raising the tally of uncounted or underweighted costs and benefits. The second set of costs relates to the fact that small DMUs allow potential funders to move relatively locally. That is, business owners and other capital interests that would be a primary source of funds may simply opt out. Their required contribution to local resilience can be no greater than the benefits and protections they are likely to secure from the district. As departures of prime funding agents take place, the remaining tenants and land owners may no longer have sufficient capacity to finance their own protection.

These features lead to the spatial Goldilocks principle of urban resilience. Individual projects are not only too small to achieve their desired effect, but also fail to incorporate important externalities. The metro region, or even a substantial city, is too large and heterogeneous to provide the necessary policy support over the long term. The Goldilocks midpoint, the urban district, has been a pragmatic and readily understood approach for US urban planning for centuries.

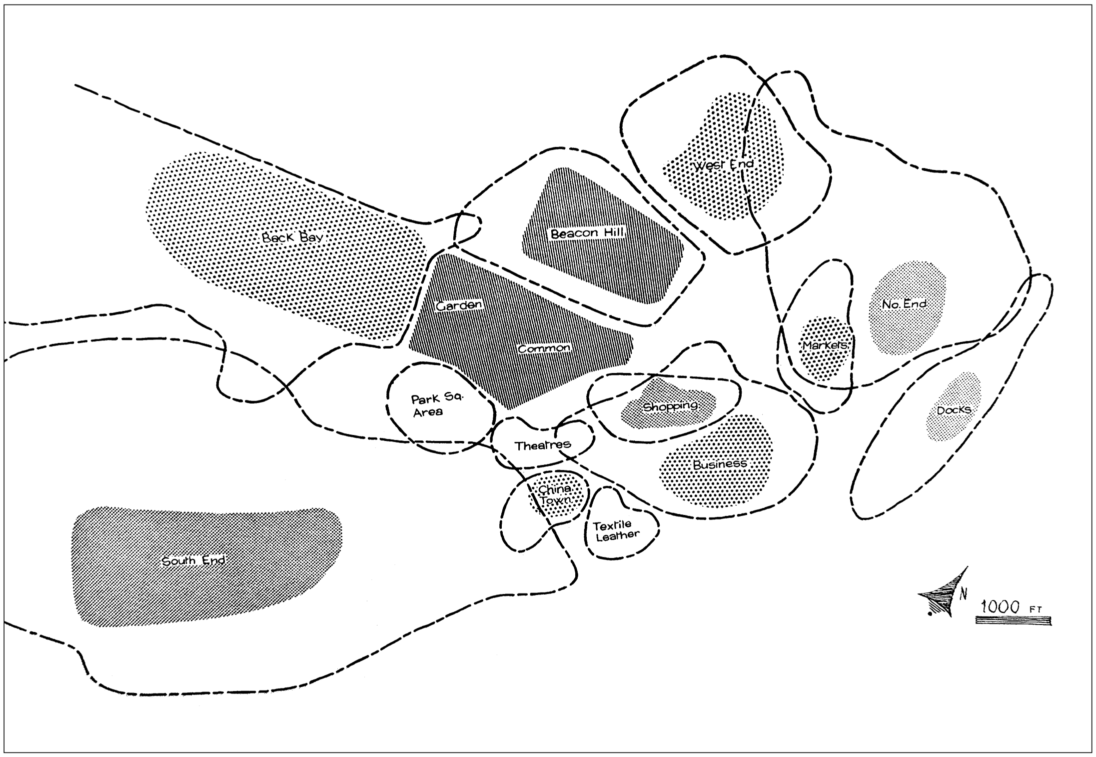

Figure 2 Perceived boundaries of 1960 Boston districts. Image source: Kevin Lynch, *The Image of the City* (Cambridge, MA: MIT Press, 1960), 69.

Districts in contemporary discourse

As cities continue to feel increased pressures to make expenditures to cope with climate change, there has been a growing trend towards safeguarding urban lands through the development of 'ecodistricts'. Increasingly, public-private partnerships have promoted the aesthetic, environmental and economic benefits of these urban ecodistricts, and lauded their ability to be 'small enough to innovate quickly, yet big enough to have a meaningful impact'.[6] On the other hand, some urbanists have expressed concerns that such themed districts often become islands of affluence for the rich and powerful, and as such threaten to undermine broader planning goals of social equity or environmental sustainability.[7] This raises complex questions about how to design resilience districts that do not further exacerbate the social inequities and resource disparities that are already a significant threat to the health and survival of cities.[8] Proactive urban visions must grapple with these competing factors: addressing local nuances of social and environmental conditions while enabling scarce but cost-effective infrastructure funding. To find a healthy compromise will require landscape architects and urban design professionals to take a more active role within regional governance structures.

Nearly all urban districts are formed around the distribution of services, the protection of resources or the control of land use. Landscape is often considered a valuable urban amenity in terms of public health, recreation and aesthetics. As such, many urban districts aim to include contiguous open spaces within their jurisdictions. However, as landscape architects and urban planners look to develop an equitable framework for resilience districts given the threat of sea level rise, landscape must be understood not merely as a recreational or aesthetic element, but as a critical protective service. This acknowledgment allows environmental systems to become the primary organizational structure from which the rest of the districting strategy is most effectively deployed.

Designing districts for extreme uncertainty

Kevin Lynch describes districts as 'the medium-to-large sections of the city, conceived of as having two-dimensional extent, which the observer mentally enters "inside of". [They are] recognizable as having some common, identifying character' from the outside through their edges or landmarks.[9] This description offers a practical but limited criterion for understanding the concept of a district by defining it through a discrete set of static, observable parameters. Today, within the context of urban resilience, these defining parameters must be reconceived using a more fluid, performance-based model. Districts must be understood not simply as spatial units, defined by aesthetic qualities or physical characteristics, but as flexible tools that can guide urban adaptation in response to environmental, social and political uncertainties. The strategies deployed by a district must be able to account for and facilitate the simultaneous management of multiple overlapping urban systems. They must address the dynamic ways in which individual components relate to each other, both before, during and after a threatening event such as a storm or flood (Fig. 2).

Many common districting strategies are defined by parameters that are much more relevant to adaptation planning than Lynch's simple description could possibly encompass. Water and sewerage districts—whose boundaries are naturally determined by service capacity—are drawn in accord with underground infrastructure networks; their edges and landmarks are not always visible. School districts often shift, appropriately, in response to census updates, thus providing a flexible structure to support new settlement patterns. The jurisdictions of yet other districts, such as urban fire districts, often overlap, ensuring redundancy at the district edges, a safety feature given the need for rapid delivery of public fire services.[10]

Each of these districts is operated by deploying a spatial strategy that responds directly to its particular set of challenges. From provision of health and safety services and security of critical infrastructure, to administration of public policy and regulation of economic investments, meeting each of these challenges helps assure urban resilience planning and design (Fig. 3).

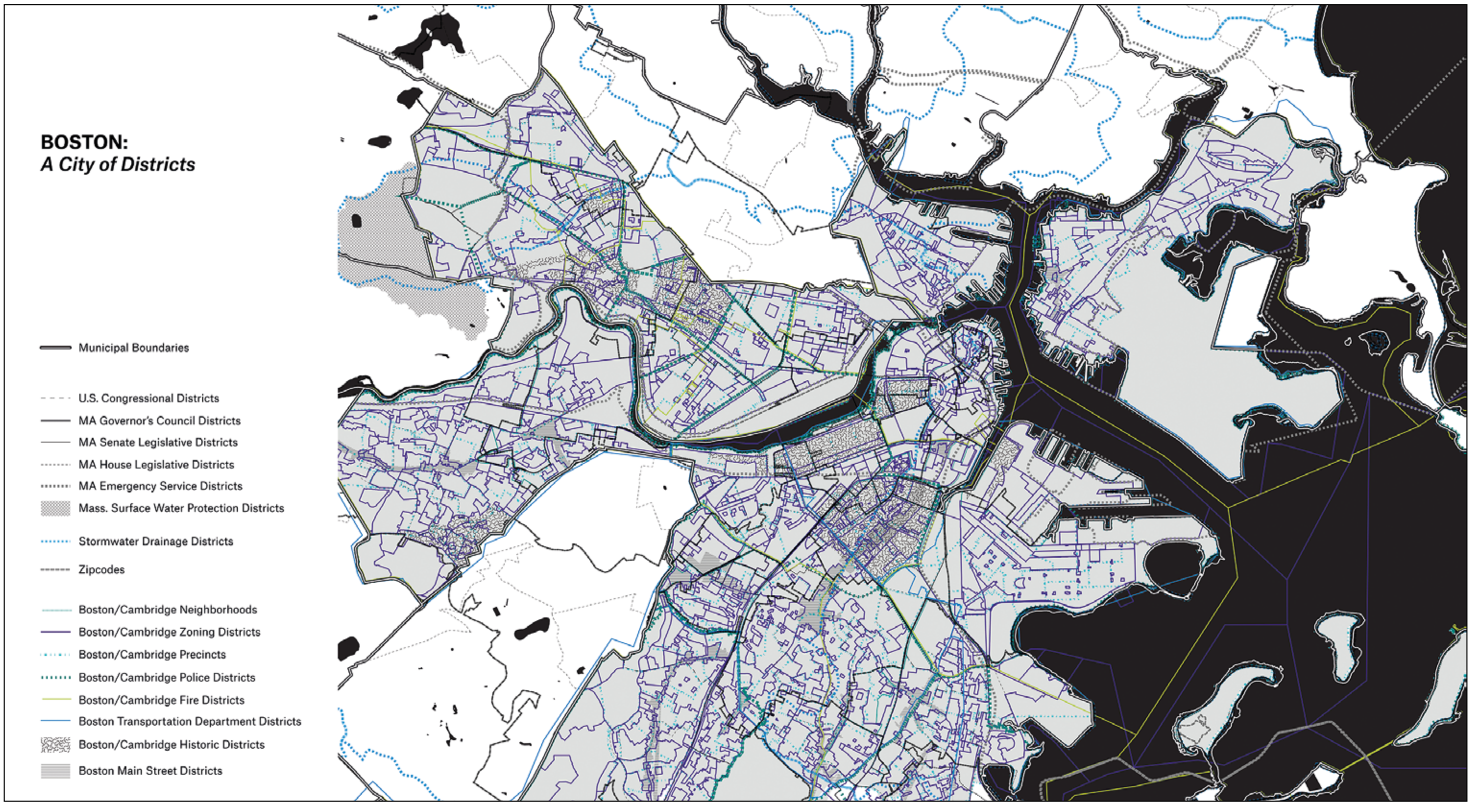

Figure 3 Existing districts of Boston.

Data sources: MassGIS, 2016 US Census, FEMA, NOAA, Verizon, Massachusetts Department of Environmental Protection, Massachusetts Department of Public Health.

BOTH IMAGES MIT LCAU, ZUS AND URBANISTEN, 'NEW MEADOWLANDS' PROJECT TEAM (REBUILD BY DESIGN)

Figure 4 Aerial perspective of the Meadowband resilience district in New Yersey.

Figure 5 Rebuild By Design public meeting.

After the storm: the New Meadowlands project

In the wake of Hurricane Sandy and as a part of the RBD competition, the Norman B. Leventhal Center for Advanced Urbanism at MIT (LCAU) coined and developed the first funded and actionable concept of 'resilience districts' in the context of New Jersey's Meadowlands. The proposal resulted in a $150-million (€137.5-million) pilot project for the Meadowlands' communities.[11] This idea expanded on the tradition of urban districts that have long been built for flood control or economic development. For example, the term 'resilient district' was once used to describe ad-hoc 'multicounty development and planning bodies' in response to the Deepwater Horizon disaster of April 2010.[12] An earlier effort, though narrower in scope, was Jeb Brugmann's 'resilience zones' to promote traditional market-based planning tools to protect economic assets and systems.[13]

The LCAU team inventoried the Meadowlands region and investigated sites where regional ecology, hydrology and infrastructure overlapped. It then developed a set of landscape strategies predicated on ownership, governmental jurisdiction and funding availability. The proposed districts formed a continuous urban armature along the flood zones, dubbed the Meadowband. District-based strategies would help mitigate damage from extreme weather events and would identify additional infrastructure and development opportunities in the region (Fig. 4).

A coalition of area stakeholders including mayors, ecological activists, business owners, local residents, neighbourhood groups and private developers joined together and articulated their desires to transform the Meadowlands into a stronger, more ecologically sound and economically competitive area. Knit into landscape infrastructure, the public-private partnership vision secured community buy-in to meet its long-term costs so as to secure benefits for owners and tenants. The built future of the project, similar to many of the RBD proposals, and indeed the entire process, is only just underway, but elsewhere, along the US Atlantic coastline, cities have already begun to plan their own resilience districts (Fig. 5).[14]

Before the storm: climate-ready Boston

The implications of Hurricane Sandy were well understood far beyond the New York City region. Had the storm made landfall five hours earlier, Boston and much of the New England coast would have experienced unprecedented flooding.[15] This realization, combined with the fact that the Greater Boston Metropolitan Area had only narrowly escaped five similar events in five years, added urgency and focus to the city's adaptation efforts.[16]

Shortly after Sandy, two separate mapping and modelling efforts made the growing risks to Boston from flooding and sea level rise both evident and more precise. First, the FEMA Flood Insurance Rate Map revision increased Boston's land area in a Special Flood Hazard Area by 70 per cent to 2,800 acres (1,133 hectares). This revision more than tripled the number of residences designated within the 100-year floodplain to 13,400 homes and 'at-risk' businesses multiplied 12.5 times to 2,500.[17] That a single storm could lead to such a vast escalation in assessed properties at risk raised alarms. Second, an engineering study suggested that the same 1 per cent annual chance of flood hazard coupled with sea level rise could flank or overtop the New Charles River Dam within forty or fifty years.[18] Reverberations from the dam's inadequacy would be catastrophic; the entire regional economy would be disrupted.

Environmental innovation and leadership are Boston hallmarks. The city's past adaptive approaches have ranged from raising entire city blocks in vulnerable neighbourhoods to landscape-scale soft infrastructure projects in the Charles River Basin.[19] Professional firms and other non-profits have produced significant public data to support municipal decision making in the adaptation process.[20] On other fronts, researchers and advocacy organizations have estimated potential losses and identified community-level hazards from climate change and sea level rise.[21] Most recently, in July 2018, the city began a planning process focused on zoning and design guidelines for a flood resiliency zoning overlay district, signalling an expanded engagement with district-scale resilience planning and urban design.[22] Big thinking and bold planning will be required. Recently, local designers envisioned transformative mega-projects including harbour-wide flood barriers and streets converted to canals.[23]

A proposed 'resilience district' framework for the Greater Boston Metropolitan Area

A long-standing rule of location within metropolitan areas is that activities gravitate to reside in locations ideal for them. Hence, the choices of hundreds of thousands of decision makers have, over the course of centuries, put industries and residences, docks and parks, in logical yet low-lying places. Up until recently, relocation decisions have more or less kept pace with shifts in the economy and the inflows and outflows of residents, but today, climate change is on the verge of upsetting this accommodating pattern of location selection. Even low-lying areas miles from the coast, such as Alewife (a transit hub in Cambridge, Massachusetts), are at risk of serious flooding related to sea level rise. The leisurely pace of relocation decisions, whereby a small fraction of activities moves over the course of a decade, will not be nearly swift enough to prevent severe, perhaps catastrophic damages. A massive exodus from high-risk coastal areas and strong and highly expensive protective emplacements are surely needed. How can decisions and implementation of such major measures take place in mere years, rather than decades or centuries? We have developed our proposed resilience district strategy as a potential answer. Boston represents our case study as a plausible site for application.

Our strategy starts with the recognition that Boston sits at a remarkable intersection of history and geography. Extensive marshes and mud flats, which formerly protected the city's harbours, have been backfilled during the past two centuries. Industrial waterfront development and regional transportation infrastructure benefitted, but the price was a massive loss of resilience protection. Today, nearly half of the present metro area is built at roughly the same low elevation: within 20 feet (6 m) of Mean Higher High Water level (MHHW). Local flood exposure will be significantly influenced by microtopographic features.[24] The National Oceanic and Atmospheric Administration's Sea, Lake and Overland Surges from Hurricanes (SLOSH) model reveals that a Category 4 hurricane could threaten 42 per cent of Boston's population and over 335,230 housing units. The threat is widespread. More than forty-five potential breach points could lead to localized flooding throughout the city and surrounding areas (Figs. 6 & 7).

Comprised of dozens of individual municipalities, the Greater Boston Metropolitan Area is the fourth-most densely populated region in the United States.[25] Though many Boston-area communities are not strictly coastal, even those with less direct flood exposure will likely experience severe losses from sea level rise and higher precipitation-caused flooding when utility service is severely disrupted and transit systems fail. Yet despite this cascade of consequences, until recently coastal resilience decisions have been made autonomously by individual municipalities. Comprehensive

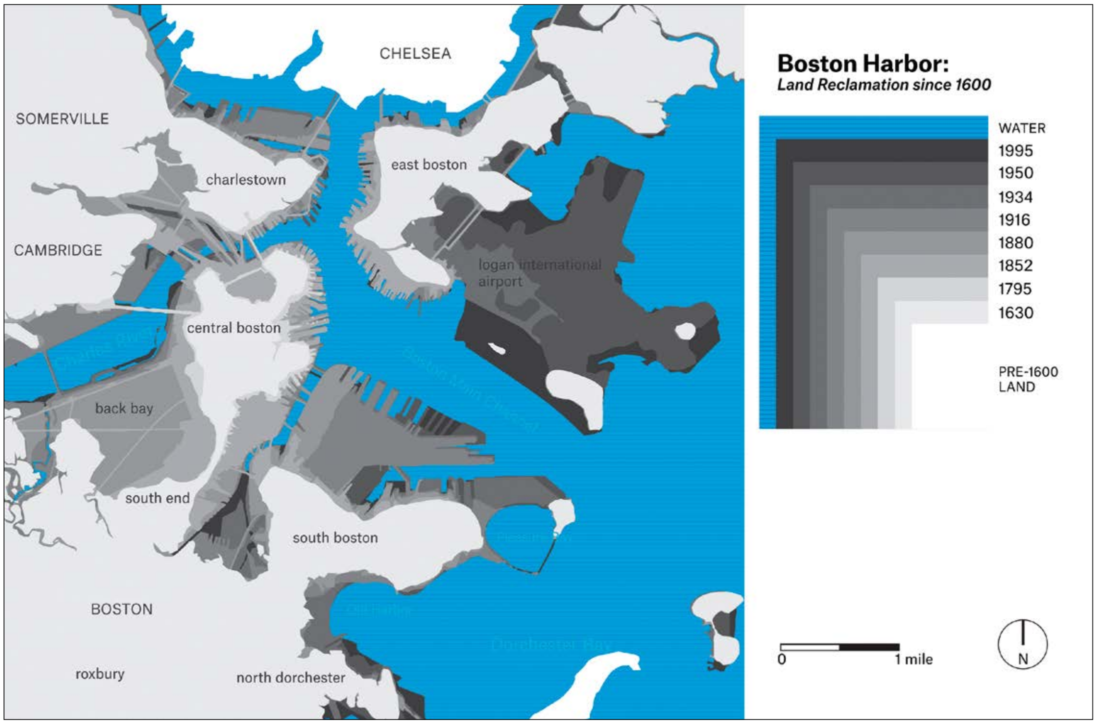

Figure 6 Map of reclamation projects over time along Boston Harbor coastline. Map redrawn by authors, based on original from: Alex Krieger and David Cobb (eds.), *Mapping Boston* (Cambridge, MA: MIT Press, 1999), 118.

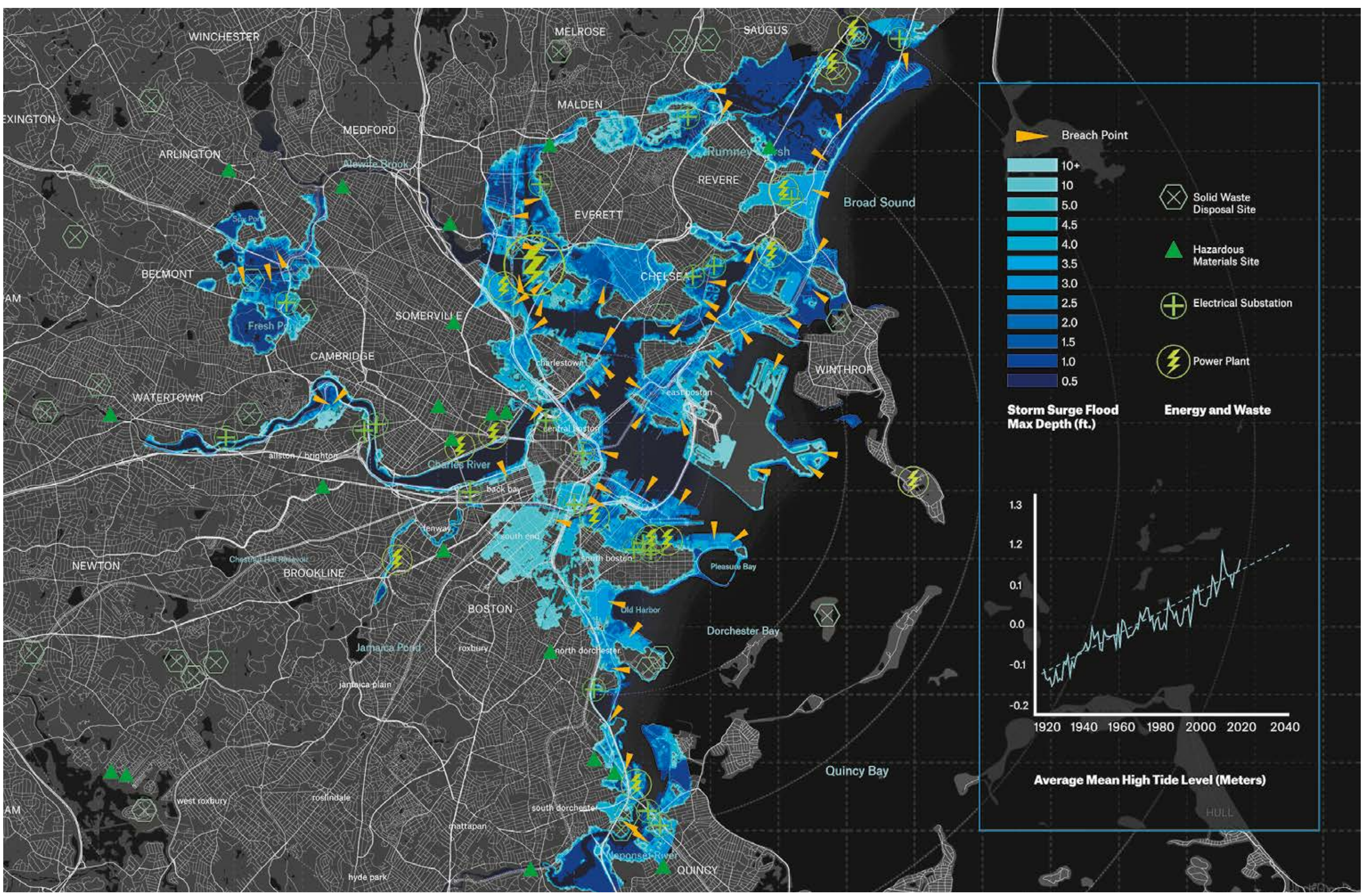

Figure 7 Storm surge model showing critical infrastructure and potential breach points around Boston Harbor.

Data sources: MassGIS, Massachusetts Department of Transportation, Boston Harbor Association.

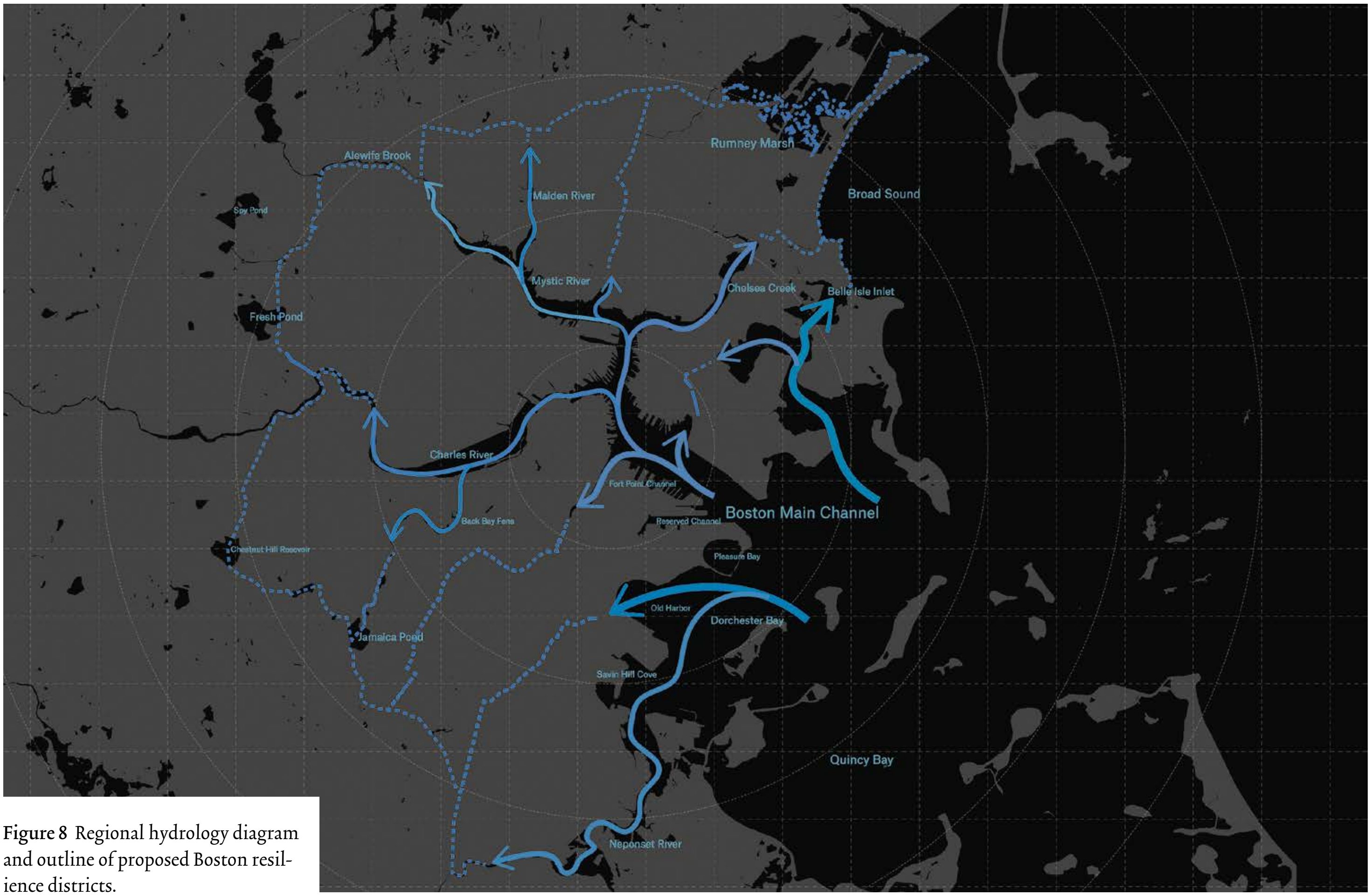

Figure 8 Regional hydrology diagram and outline of proposed Boston resilience districts.

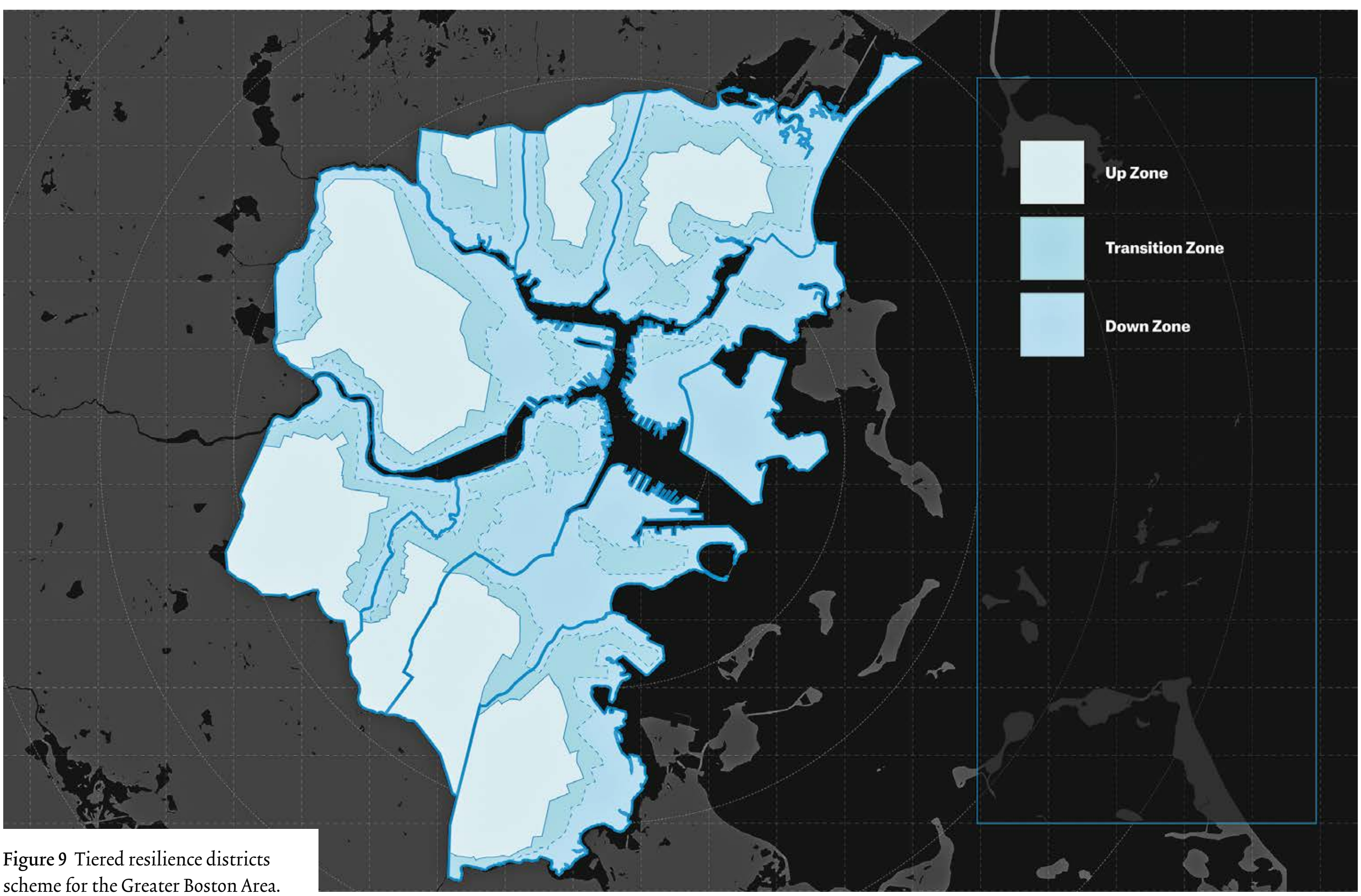

Figure 9 Tiered resilience districts scheme for the Greater Boston Area.

regional coordination simply did not exist. In 2015, fifteen regional mayors convened to form the Metro Mayors Climate Preparedness Taskforce, a hopeful first step towards a more collaborative approach. To date, however, these collaborative efforts have focused solely on mitigation strategies. Single communities within dense metropolitan areas cannot possibly meet the challenges of sea level rise by acting alone. Our proposed resilience district scheme is designed to aggregate neighbourhoods from adjacent cities and towns based on mutual flood exposure and shared benefits of district-wide adaptation strategies. Appropriate districts will be defined by identifying the region's underlying landscape systems, which will serve as a primary organizational framework. Instead of following predefined municipal boundaries, resilience districts are determined by tracing the region's primary hydrology. Coastlines, rivers and wetlands will often serve to define the outer boundaries of a district.

Once the resilience districts have been identified, they will be subdivided into three distinct zones: a 'down zone', where risk is the greatest, an 'up zone', most secure against risk, and a 'transition zone', where activities are expected to shift as risk eventuates. This strategy of subdivision is designed to facilitate the process of putting resilience measures in place. Those measures would protect critical infrastructure, draw thick lines of defence and transfer density from areas at greatest risk, i.e. away from coastlines and other flood-prone bodies of water, to the higher, drier land of up zones. Those up zones are where the most-at-risk communities have the potential to relocate yet remain within the reach of existing community networks (Figs. 8 & 9).

Resilience zones

To elaborate, the down zone is the low-lying area in each resilience district with the greatest exposure to coastal flooding. Resilience projects in this zone should protect critical infrastructure using walls, berms and levees, while expanding the hydrological capacity of the district using engineered wetlands and other forms of soft infrastructure. This zone will probably see the highest level of expenditure. Over time, property owners in the down zone will gradually transfer unused development rights to plots in less vulnerable zones or sell these rights back to the city. The city in turn may transfer or sell these rights to a private or municipal development rights bank.[26] Down-zone areas can then be converted to more flux-receptive land uses such as floodable parks, constructed wetlands and/or adaptive waterfront industries.

Throughout the down zone, a rating system would be deployed to evaluate existing and proposed structures for their ability to withstand storm surge flooding, saline conditions and wave action. This measure of flux-receptiveness or hydro-adaptiveness would be parallel in concept to existing metrics for environmental performance employed by the US Green Building Council. Other flood-exposed communities along the Atlantic and Gulf coasts, such as Broward County, Florida, are already pioneering research into such a building or zoning code.[27] Over time, existing buildings rated 'vulnerable' would be retrofitted or rezoned. For example, down-zone areas in East Boston could encourage water-dependent logistical and production activities such as shipping and aquaculture.

These down zones should be designed comprehensively to produce a new public waterfront, to provide vibrant connections with multimodal transportation networks across the harbour, to anchor public spaces and activate private development. In ecological restoration areas, well-considered earthworks could mould open spaces and restore critical habitats (Fig. 10). The up zone encompasses most of the resilience district's higher elevation. Though the direct effects of flooding are less prevalent here, indirect effects of regional infrastructure failure could still inflict major losses. The transfer of development rights here from the down zone can help support increased density and provide real estate options for down-zone residents who wish to relocate within reach of critical local resources such as schools and hospitals. A special permit process within the up zone could help to ensure equitable access to public benefits like open space, a strategy that complements long-standing environmental planning goals such as 'transit-oriented development'.

In Boston, there is a precedent for using such discretionary powers on reclaimed land. The Massachusetts Public Waterfront Act, commonly referred to as Chapter 91 of the Massachusetts General Laws, is the public trust doctrine that oversees the use of the Commonwealth's tidelands. Applied to harbour-edge development, it is the oldest programme of its kind in the nation. Currently protecting public access, safety, livelihoods and critical ecology, it could help aid the transition of historical boundaries of water and land into a gradient of wet to dry conditions (Fig. 11).

A 'transition zone' lies between the down and up zones. This zone acts as a staging ground for the continual evolution of the resilience district. Over time, the more exposed outer edge of the transition zone will become the new urban waterfront. Building codes here will be updated periodically to reflect this eventual transformation. Meanwhile, new infrastructure can be added along the zone's less risky inner edge in order to support increased density in the up zone. Permits for new development should privilege projects that offer support for residents to remain in place by ensuring that they have both the social and economic resources to maintain their livelihoods and the critical facilities and support services to remain safe during future storm events.

The transition zone will also incorporate a thick line of defence that combines hard and soft infrastructure, leveraging opportunities that capitalize on existing linear features such as highways and rail corridors. Coupled with hard structures (walls, dams, dikes and stairs), protective soft infrastructure such as earthworks (terraces, mounds and berms) would be built parallel to the coastline (Fig. 12).

To select a metaphor from the somewhat remote field of medicine, the resilience district concept can be thought of as an instrument of triage. It identifies the places within an ecologically connected area that almost certainly will ultimately perish, perhaps soon—the down zones—the areas that are likely to have a long and healthy existence—the up zones—and the areas that can survive for now but will likely face significant risks down the road—the transition zones. The difference from the medical triage process is that this triage process will foster the survival of the overall organism, the metropolitan area. That is because the three zones are strongly linked by externalities.

The ultimate aggregation of as many as ten resilience districts in the Boston region might suggest a new coordinating role for public agencies, but such agencies should not be a requirement for action. Decision making in these districts will require multiple layers of community participation and sustained professional involvement as better information about the impacts of climate change continues to emerge. The resilience

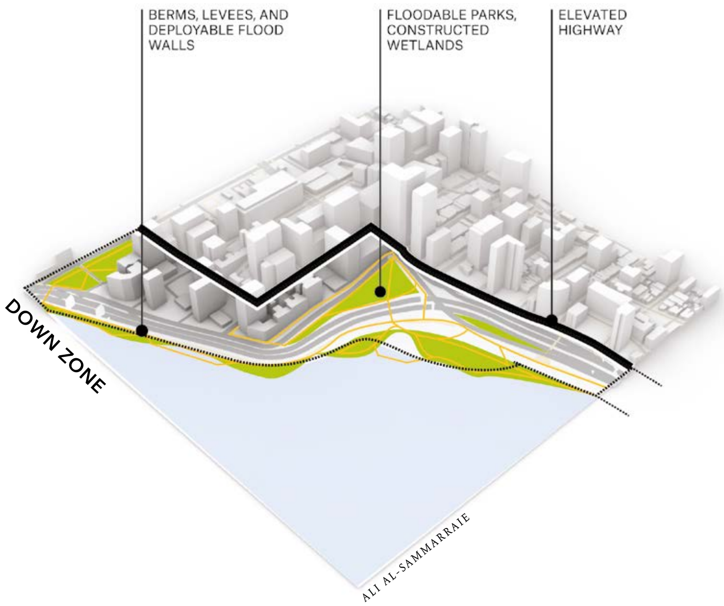

Figure 10 'Down zone' diagram. Source: LCAU.

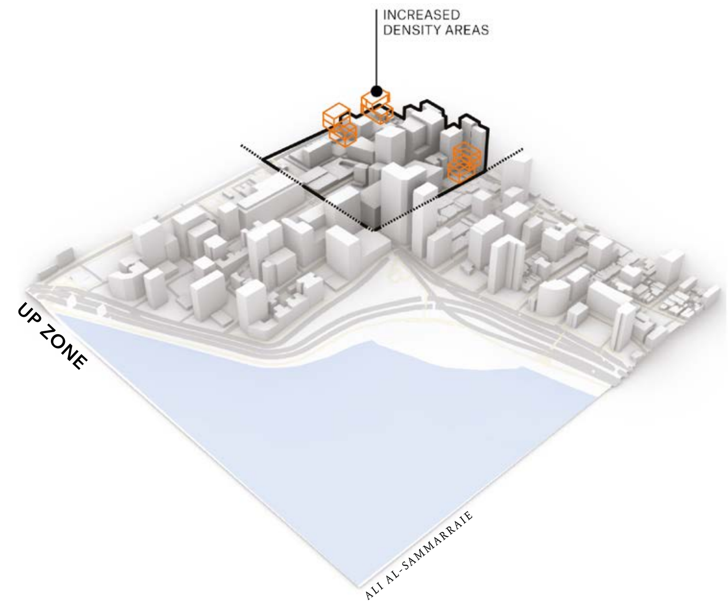

Figure 11 'Up zone' diagram. Source: LCAU.

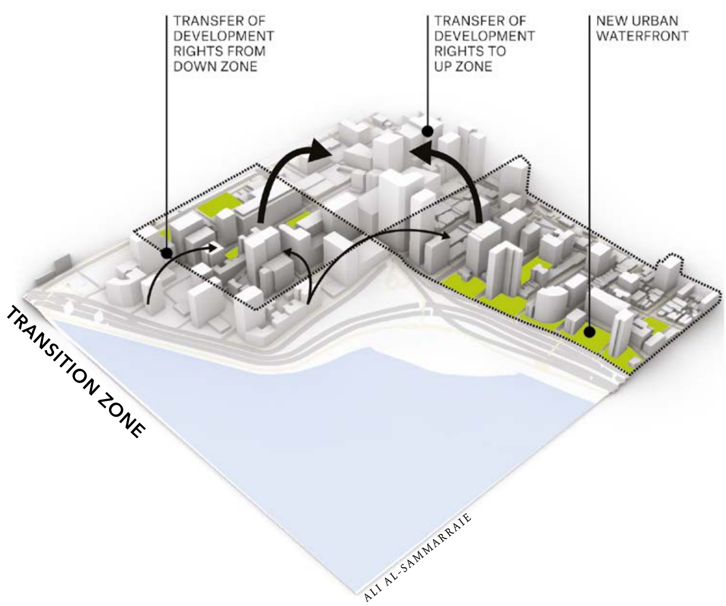

Figure 12 'Transition zone' diagram. Source: LCAU.

district framework, as outlined here, offers a simplified legal framework for calibrating adaptation responses to various degrees of urban climate risk. Such responses will be required if our major metropolitan areas are to effectively take on the unprecedented threats from climate change. Resilience districts have the potential to engage both citizens and experts in the Herculean challenge of implementing the massive realignments of people and resources to confront rising waters and significantly more severe storms. The resilience district concept is general, but each metropolitan area will have to deploy the framework in a distinct fashion, in response to its topography and hydrology as well as local social and political realities.

Conclusions and future directions

Today, in the face of almost inevitable severe climate change, cities must be able to look far beyond their immediate planning horizons and the terms of elected officials currently in office in order to engage with a highly uncertain future that stretches for decades, not merely years. The concept of resilient districts has the potential to enable such flexible long-term planning. Though districting strategies have long been a mainstream part of urban planning and design in the United States, the resilience districts proposed here represent a radical departure from historical approaches. They shift away from the traditional decision-making units that operate through political designations, such as municipalities or states, into aggregations of communities based on shared flood exposure. Thus, regional hydrology, topography and other landscape systems become the primary drivers for—potentially radical—adaptations, in urban form. There are two major challenges to making metropolitan areas resilient: structuring a framework for making effective decisions and securing the finances for paying for those decisions. This analysis, and its delineation of the concept of resilience districts, has focused overwhelmingly on the first of those challenges. We recognize the central importance and immense problem of financing. There are multiple major impediments: first, districts and tax authority are not coextensive; second, the most cost-effective actions are anticipatory and preventive. In virtually any political context, however, substantial pre-disaster expenditures on adaptation will be difficult or even impossible to achieve. Community leaders and politicians rarely look beyond the immediate future. Low-probability events such as severe floods, even when risks are elevated, are unlikely to happen on their watch. These observations imply that however decisions are taken, efforts to boost resilience will be woefully insufficient. The resilience district concept recognizes this reality. It hopes to promote decisions that are effective, even if they are insufficient.

One of the greatest challenges for resilience-focused urban design is that implementation is often only possible after important but lengthy processes of public outreach and environmental impact review. Frequently, these processes will not begin in earnest until after a devastating storm event, which is when the political will and investment capital may ultimately be unlocked to facilitate localized rebuilding efforts. Districts with prepared plans in place would be more likely to obtain immediate federal and state reconstruction funds, funds that are often only available for a limited time following a catastrophic event. The scale of the resilience district, and the relative flexibility of its tiered structure, provides a more agile decision-making unit, one capable of implementing 'shovel-ready' urban design proposals to recover from past flood events and prepare for future ones.

Landscape architects have long advocated urban design processes that can better accommodate environmental flux in the public realm. In the future, if they emerge as decision participants and not merely passive advocates, landscape architects can counter the growing cost of inaction from sea level rise and coastal flooding. Resilience districting offers landscape architects and other design professionals a flexible mechanism for reframing the physical response to the urgency of climate change at the local and regional levels, the levels at which effective action must be taken (Figs. 13, 14 & 15).

Acknowledgments

The MIT Center for Advanced Urbanism (CAU) is now called the MIT Norman B. Leventhal Center for Advanced Urbanism. The name change occurred in June 2016, during the drafting of this essay. All work reference from 2012 to 2016 may be found in the public domain under CAU. The authors would like to acknowledge Fadi Masoud, Assistant Professor of Landscape Architecture and Urbanism, John H. Daniels Faculty of Architecture Landscape and Design, University of Toronto, for his contributions to earlier versions of this work done within the LCAU.

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Figure 13 Rendering showing Boston Harbor (with proposed resilience districts outlined). Source: LCAU.

A Includes parts of **East Boston** and **Revere**
B Includes parts of **Dorchester, Roxbury,** and **Mattapan**
C Includes parts of **South Boston** and **Jamaica Plain**
D Includes **Downtown Boston,** and **Back Bay**
E Includes parts of **Allston** and **Brookline**
F Includes parts of **Cambridge, Somerville,** and **Charlestown**

Figure 14 Rendering showing Boston Harbor (with proposed design scenario). Source: LCAU.

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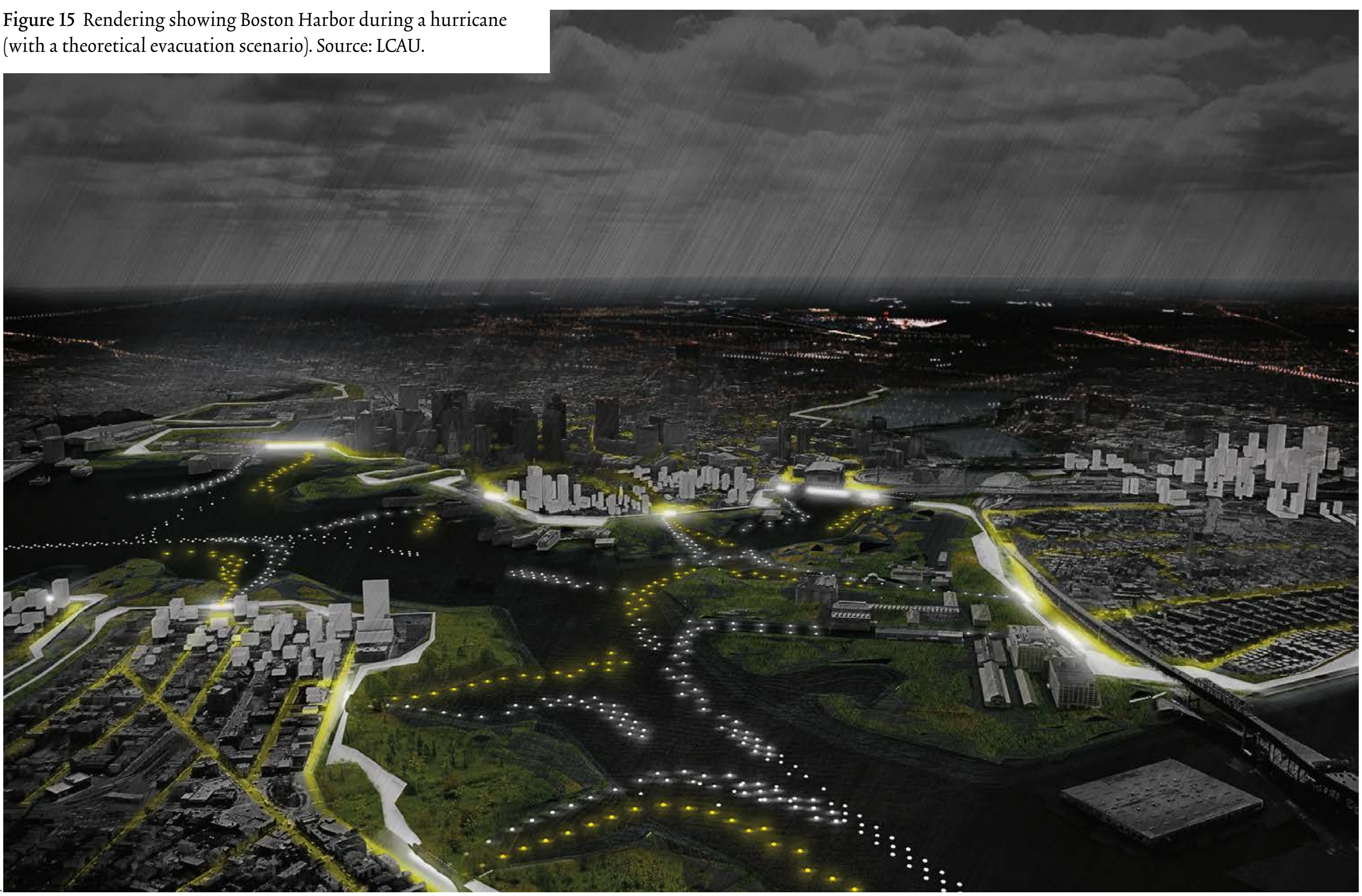

Figure 15 Rendering showing Boston Harbor during a hurricane (with a theoretical evacuation scenario). Source: LCAU.

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NOTES

1 Robert M. DeConto and David Pollard, 'Contribution of Antarctica to Past and Future Sea Level Rise', *Nature* 531/7596 (31 March 2016), 591–597.

2 Arup, 'City Resilience Framework', The Rockefeller Foundation (April 2014), www.rockefellerfoundation.org/report/city-resilience-framework/.

3 Intergovernmental Panel on Climate Change, 'AR4 SYR Synthesis Report Annexes - Glossary R-Z' (2007), www.ipcc.ch/publications_and_data/ar4/syr/en/annexessglossary-r-z.html.

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5 The term 'externalities' here refers to costs imposed on (negative externalities) or benefits provided to (positive externalities) parties other than the decision maker. That is because the decision maker will give insufficient weight to those costs or benefits.

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