Projecting Retreat and Rebuilding: Sea Level Rise and Climate Smart Design for Southern Florida's Future Built Environments

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PREMISE

The visioning of future built environments in design driven research is a way of hypothesizing alternative goals that are sometimes difficult to grasp in the present. While the criteria influencing a 'futuring' project's goals and objectives[1] can be reactive to existing phenomena, the design process and project outcomes can generate new understanding of existing phenomena and forge new criteria for dealing with issues common to current regional and local plan scopes as well as the longer term. Projects become critical apparatuses and assessment tools for architects, planners, engineers, scientists and policy makers. Through critique and reformation of multiple factors, such projects are ongoing, and perpetuate further dialogue and understanding so that the legal policies shaping the human environment remain a dynamic process, and hence responsible to changing natural, social, economic and built conditions.

The territory that this study addresses has been reshaped by human habitation. As a result, the eco-systems that were once in place have been radically altered. In particular, flora and fauna species have migrated and changed, and the eastern watershed of the Everglades that was a vital part of the region's eco-system was engineered to meet human needs. Since this study focuses on human habitat, it departs from a precept of selected concepts deriving from the natural domain that be applied towards an artificial restoration of the territory. However, it also recognizes that a restoration of flora and fauna in relation to long-term climatic changes will design much of its own course over the next millennium. Nature, and humans have an ingenious ability to adapt.

The economic motors that will drive the future, long-term development of the region can only be hypothesized. In this study, a number of factors have been considered. These factors include human migration, light industry, the service sector, shipping, and tourism. While it is not possible to precisely foresee how

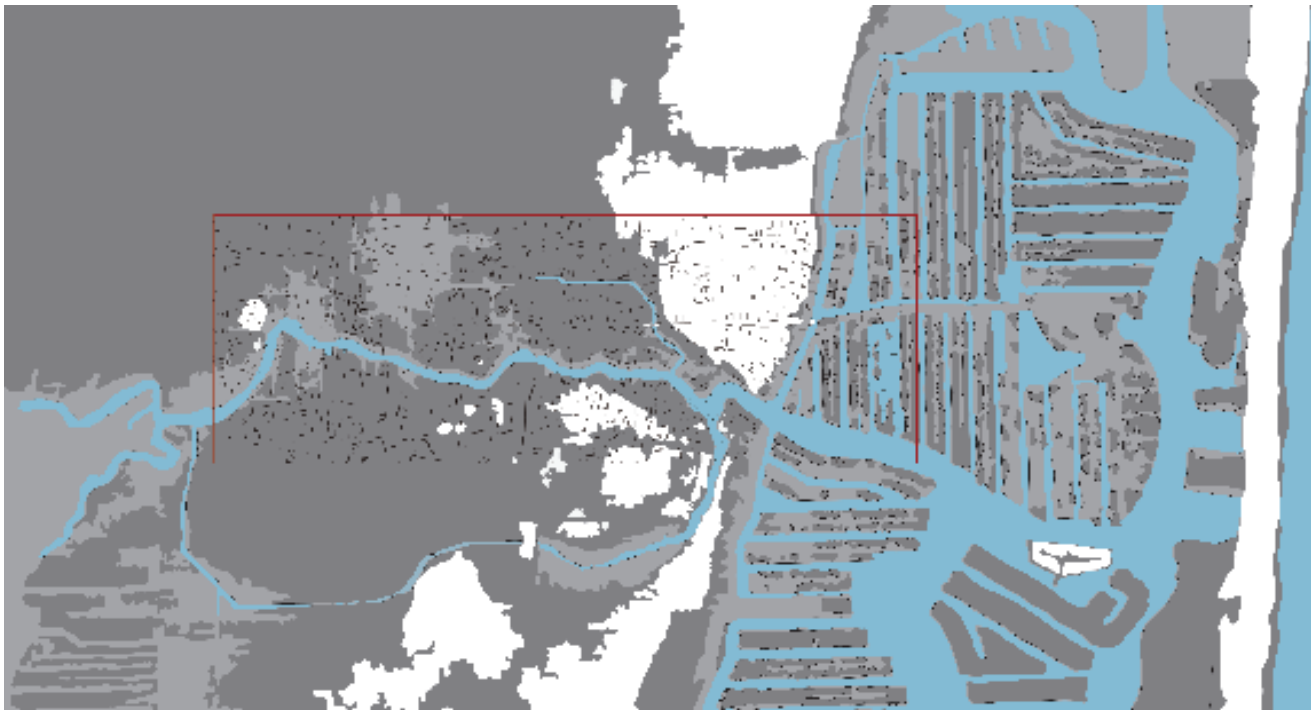
future economies will alter the course of abandonment, retreat, and growth in southern Florida, it is possible to establish a trajectory from which public policies can be put in place in order to thwart disastrous conditions that lead only to the abandonment of place. Simultaneously, this study recognizes as a given condition the ecological system of Southern Florida, grossly exploited due to poor growth policies. While the study deals only with one small geographic area, and does not consider the social impacts of abandonment and retreat, it aims towards establishing equilibrium between the natural environment and the design of built communities. It hypothesizes that the design of better communities can spur enterprise, and in particular, trade and industry, as well as research in the sciences and arts.

The Southeast Florida Regional Climate Action Plan and the City of Fort Lauderdale each specify recommendations for the development of more sustainable communities. In relation to the Regional Climate Action Plan, this design based research undertakes many topic categories including "Growth Areas," (SP-14), "Transportation," (SP-19, SP-23), and "Water Management," (WS-1), among others, and addresses the underlying goal to "Reduce financial and physical losses in our building stock by reshaping where and how we build."[2] In the City of Fort Lauderdale's "Vision 2035" the research project initiatives address the "Overarching Categories" of "Sustainable Development, Quality of Life, and Prosperity" and specifically contribute to the "Working Categories" under "Connected Development" and "Sustainability."[3] Some of the working categories identified by the City that this design project addresses include "Climate Resiliency, Sea Level Rise and Natural Resource Protection", and "Transportation, Pedestrian Friendliness, Smart Land-Use, and Connective Development Patterns." The intersections between the above projects' recommendations and design based research intents, aims towards contributing to the reassessment of vulnerability, selecting courses of action and implementing those actions.

A TRANSFORMING SITE

Permanent inundation of low-lying coastal communities due to climate related changes cause, among other factors, the abandonment of territory, the decay, removal or adaption of existing structures, and the eventual redesign and building of future communities. As nature transforms low-lying regions, existing urban and suburban patterns, and building models used in the developing of Southern Florida communities will become obsolete. This will be due to a lack of buildable area, and the exorbitant cost of raising land elevations and infrastructure across a vast geographical area. As low-lying territories transform, (Figure 1), there will be a need to implement new, more efficient patterns of growth, and urban morphologies tailored to site-specific situations and responsive to the complexity of natural, human, (social, political, economic, etc.), and technological factors.

This research proposes a methodological framework and initial design hypothesis that speculates on how the physical nature of low-lying, subtropical coastal communities can adapt to climate related changes, and in particular, sea-level rise and storm-surge. The site for the investigation is the center of Fort Lauderdale, Florida along a east-west axis, Las Olas Boulevard, and extending from the Atlantic Ocean to the "The Avenue of the Arts." The site was chosen due to its centrality to Broward County; it boasts formidable economic health and



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Study area
Existing waterways
3 Foot sea level rise inundation
6 Foot sea level rise inundation
Remaining land above 6 foot inundation level

Figure 1: Area inundation map of East-Central Broward County. Inundation information interpreted from NOAA maps.*

investment in real estate development, intersects a tract of the navigable New River, and remains a center for leisure and commerce. Broward County is also the stage for a history of sprawling building development, a pattern of development that consequently substituted the natural easterly flow of fresh water from the Everglades through central Broward County for a complex hydraulic system engineering drainage, water supply, and water treatment. Among other uses, pump stations alleviate periodic flooding due to catastrophic events such as heavy precipitation and storm surge, and replenish fresh water back into the aquifer that consequently increases pressure against salt water intrusion.[4] However, as sea levels increase, these techniques become less effective and cannot resolve the potential long-term devastation of the built environment due to sea-level rise and storm surge. In addition, the availability of potable water to Southern Florida communities will become one of the most critical factors affecting human population and density.

The future effects of flooding dictate a partial retreat from existing human habitat due to permanent inundation of land[5] and a rebuilding of territories into "climate smart" urban morphologies that aim to integrate human and natural systems into a socially and culturally responsive design. Although beyond the scope of this paper, the study recognizes in the methodological framework the crucial importance of environmental analysis and its impact, and the social ramifications of human migration over time, which includes a transforming and dynamic local economy where resources and the production and consumption of goods present growth opportunity.

METHODOLOGICAL FRAMEWORK

Drawing from an extensive list of natural, human, and technological factors, (Figure 2), the design research framework appraises hierarchical relationships among diverse inputs and their feedbacks. Specific inputs are identified based on a relative value that the research team identifies as critical to the initial research initiative, and aim to highlight those issues most responsive to the environmental needs and conditions of the regional area and specific site. Intersections between issues are examined in order to better recognize specific characteristics, situations, and potential ramifications of each issue. Following the above initial interdisciplinary analysis, an amalgamation of dominant factors form the set of initial aims and motivations for the design activity, (the making of diagrams, drawings, models, notes, etc.). The design activity can address a collective dialogue among scientific protocols, and the experiential, place-making goals of built form, (Figure 3). The making of artifacts, or "design artifact driven research," highlight specific aims generating iterative variations, and design evolution at multiple scales.[6]

By shifting emphasis among diverse characteristics, a range of project models can be studied, the project models' responsive qualities compared, and new projects can be proposed as contributing to the formation of multiple hypotheses to be further critiqued and tested by environmental scientists, social scientists, economists, transportation engineers, urban planners and policy makers. From the analysis of artifacts, the design team can also attain comparative based results, and bracket key qualities at the intersection of the natural, human, and technological domains. Subsequent alternative design iterations can be modeled and new outcomes attained, while monitoring the evolution of initial research intentions. The sum of the work, activity and artifacts, and its critical analysis is a vorticular process involving interpretation and understanding, and generates multiple measures for identifying social, environmental, and built goals and objectives for policy makers. The challenge for the designer is to be able to understand and assess the relative importance of all possible inputs generating the specificity of context and the dynamics of time in relation to the project's intents and to draw from one's individual interpretative means to project new paradigms.

RE-STITCHING THE TERRITORY

Historic documentation of natural water flow, surrounding hummocks, and islets inspired the conceptual development of an archipelago. A 'bathtub approach' to determine the effects of sea-level rise on existing land areas of the study site was used to define remaining ridges and islands, and existing built areas with high real estate value that could be salvaged by raising street levels and terrain.[7] The project foresees a system of major waterways being maintained, and the addition of minor, shallow waterways that may naturally develop a system of estuaries feeding the lagoon. At a conceptual level, the reintegration of waterways and islets mimic the natural surface hydro-patterns that once flowed through central Broward County. The reestablishment of an archipelago intends to help proliferate indigenous plant species, plant species that have the ability to adapt or migrate to the changing conditions of water salinity over the next century and play a crucial role in the stabilization of waterfront areas. In this respect, a balance is sought between human habitat and the ecosystem as a whole.

NATURE	HUMAN/SOCIO-ECONOMIC	TECHNOLOGY/BUILT
Geological Systems	Migration	Regional Hydro-System
Water and Fresh Water Aquifers	Patterns/Displacement	Water and Spatial Planning
Salt Water Intrusion	Public Engagement	Water Management Systems
Freshwater-Saltwater Interface	Cultural Geography	Aquifer Recharge
]TemperatureandEvapotranspiration	Cultural Patterns	On-SiteWaterCollection/Retention//
Precipitation	Livelihoods	Treatment
Flooding / Erosion	SubtropicalLiving/LifestylePatterns	Erosion Control
Drought	Economic Patterns	LifeCycling:Buildings/Infrastructure
Tropical Storms / Hurricanes	Existing Land Use Patterns	Transportation / Vehicular Modes
Coastal Watersheds	Existing Real Estate Values	Infrastructure Systems
Natural hydro-patterns	Density Patterns	Structural Shoreline Stabilization
Artificial hydro-patterns	Growth Patterns	Protection and Accommodation
Sea Level Rise	Health and Safety	Managed Retreat from Territory
Storm Surge	Site Assessment	Abandoned Territories
Coastal Barrier Islands	Land Ownership	Reclaimed Territories
Barrier Island Migration	G.I.S.ExtendedShorelineAssessment	Amenities: Urban/Town/Rural
Coastal Restoration	G.I.S.ExtendedInlandAssessment	TraditionalStructures/UrbanPatterns
Shoreline Natural Defenses	Strategic Land-Use Planning	Urban Morphology
Plant Species	Policy History	Urban Infill
Plant Migration, Patterns and Displacement	Policy Changes	Urban Density
Shoreline Retreat	Building Code	Urban Models and Typologies
Living Shorelines / Vegetated Shorelines	Zoning Code	Artificial Topographies
Habitat Preservation	Purchase & Development Rights	Emissions Reduction
Food Security	Setback & Deed Restrictions	Passive Energy Systems
Fisheries	Development Incentives	Active Energy Systems
Nutrients and Sediments	Development Disincentives	Energy Conservation
Filtering of Pollutants	Easements and Buffers	Eco-efficiency
Animal Species	Rolling Easements	Enhanced Building Standards
Endangered Species	Budget Constraints	Structural Shoreline Stabilization
Animal Migration	Adaption Measures and Policy-making	Pedestrian Walkability
Habitat Loss	Economic Development and Diversification	Green Islands
NatureDesignandImplementation of Ecological Networks	Climate Change & Real Estate Insurance	Passive Comfort
Agriculture and Land-use	Real Estate and Financing Mechanisms	Scalar Relationships
Microorganisms		Recreation
Disease		Public Space
Marine Coastal Environments / MarineCoastalSystemsBeaches& Dunes		Urban Agriculture
Barrier Islands		Urban Heat Islands
Reefs,Estuaries,Lagoons,Wetlands, Marshes, Slews		
Navigable Waterways		
Afforestation		
Land Management and Conservation		
Forestry		

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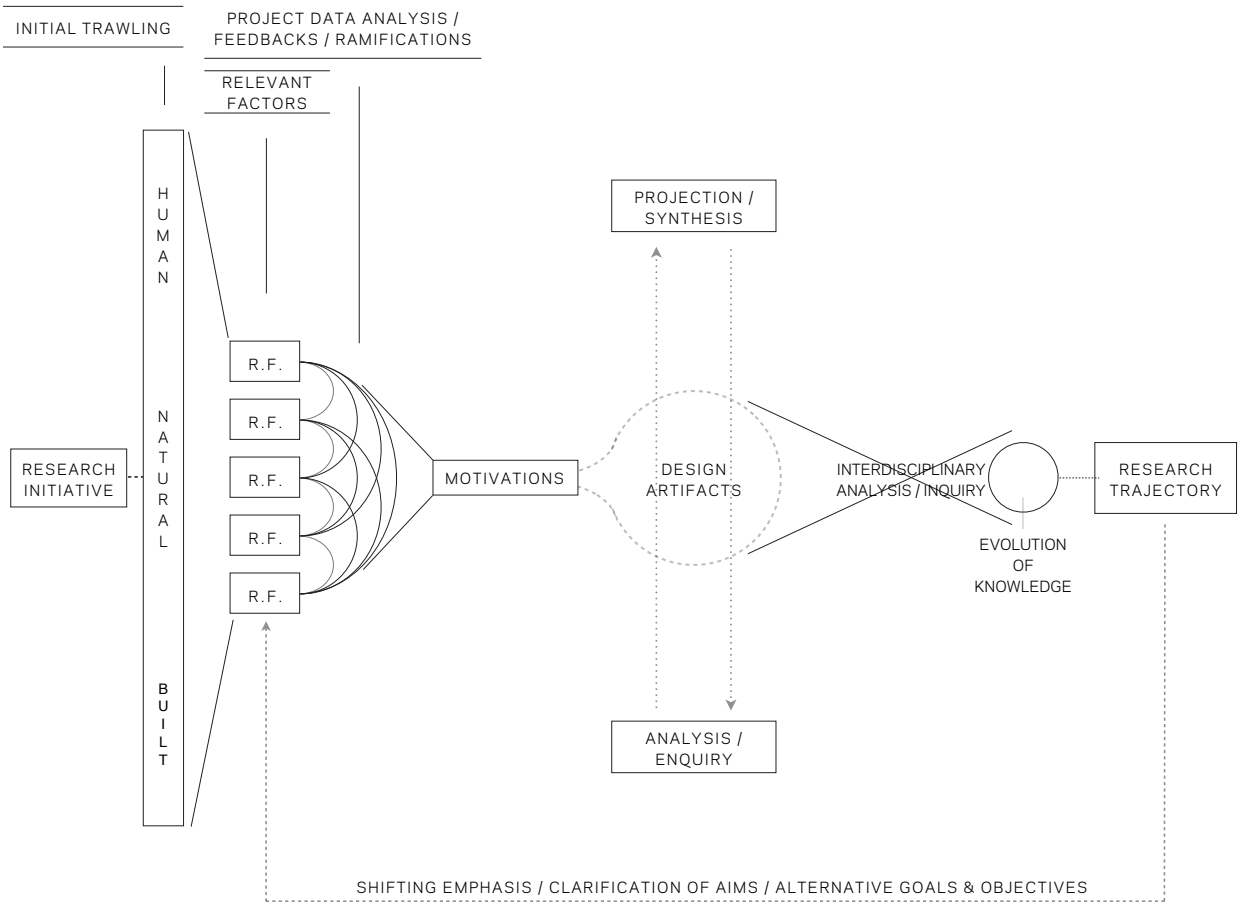
Figure 2: A Partial 'Trawling' of Primary Topics



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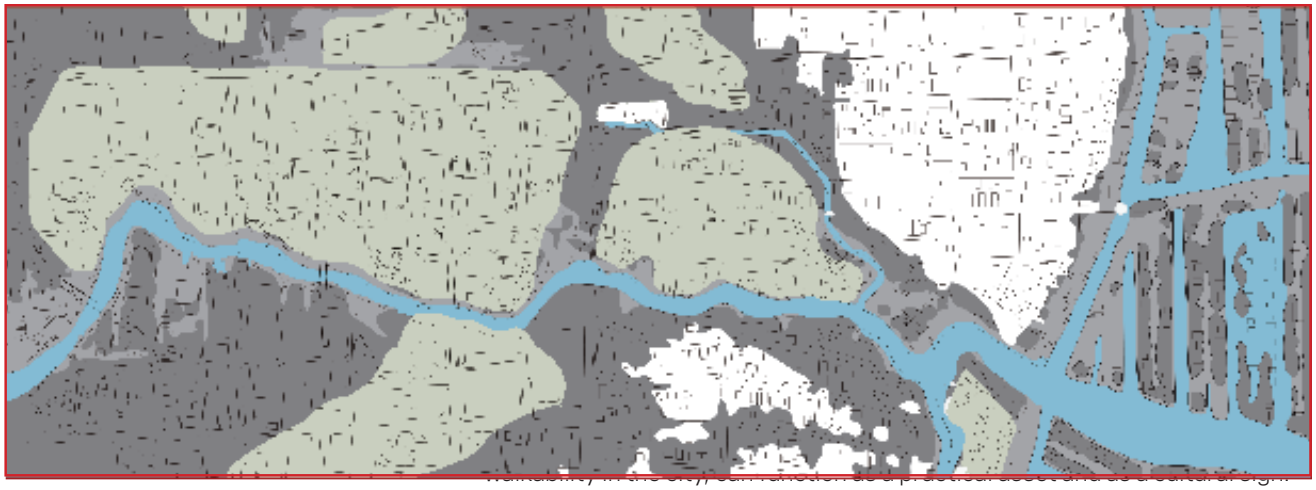
The urban design explores the viability of a self-sufficient, mixed-use schema in relation to an appropriate human population density. The appropriate density model for the study site hinges upon the relationship between the proposed natural system, (archipelago), building volume, and the urban construct's potential for water-harvesting.[8] The availability of potable water will be a major determinant of urban density in the region. In the project response, local, on-site harvesting, filtering, and storage of rainwater seek to reduce the usage of off-site water resources, and thus increase the efficiency of an infrastructure that can be monitored and maintained autonomously within each island community. Average rainfall, human consumption rates, and collection area are three of the many factors governing a density model. Excluding street and building collection of grey water and its reuse, the project goal aims at a 100% reduction in outside potable water resources. The study of appropriate density to water consumption ratios is determined by the roof area to underlying building volume and its projected occupation load. Each building's roof area and the underlying habitable floor area therefore, determine the degree of hydro-autonomy.[9]

The issue of an appropriate urban density, however, goes beyond a technical calculation of resource use. An archipelago of self-contained communities implies local economic autonomy as well as connectivity with external commerce and industry. In response, population levels targeted at maximum density to resource availability can be set and tested against existing urban environments, their geography, density and economic make-up.

Figure 3: Design Research Diagram



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All of the community models adopt basic principals of ventilation and orientation in order to improve passive human comfort and adaptability to climate. The prevailing east by southeasterly winds along the coastal area play a major role in the massing and orientation of building volumes. The raising of the habitable areas above the ground plain increases air-flow through a community. The model formations attempt to increase the cross-ventilation through building volumes by augmenting the pattern of high pressure and low-pressure airflow from windward to leeward facades. The orientation of building mass also intends to funnel air-flow from open area 'high pressure collectors' into more narrow streets and paths. Although empirical testing of comfort levels due to natural ventilation models goes beyond the scope of this research, the common south orientation of long facades responds to the prevailing breezes during the warm season by increasing the potential efficiency of cross-ventilation through buildings.

The growth pattern of an island community, provides for fluctuations, including the migration and proliferation of the natural environment in relation to long-term climate related changes. Rather than distinct boundaries between urban space and building, the project proposes a strategy of interconnectivity of sites, urban patterns, streets and buildings sharing formal qualities such as clustering, gradient massing, and fluidity at multiple scales. Buildings are conceived with space for water storage and treatment, cargo delivery, and waste disposal at the ground level with the pedestrian street level above. Buildings can be designed for flexibility and transforming uses and easy management

Figure 4: Study Site with rebuilt islands

Figure 5: Study Site with urban morphological hypothesis.

of changing technology. The flow of street patterns, and the use of rectilinear and curvilinear surfaces along the perimeters of building volumes suggest an urban space that can morph from more active, paved pedestrian walkways to quite park-like places in natural habitats. Streets oriented on the east-west axis fluctuate between more open spaces and narrow passages. Breezeways and tunnels through building volumes link streets and plazas, providing distinct thresholds connecting the major pedestrian arteries. As they thread through buildings, these passageways also weaken any notion of 'building as barrier' by blending the private space of the building with the public space of the street. The integration of public gardens and fields, and paved places of these pedestrian arteries are proposed with ambiguous transitions between more activated and less activated public and private areas.

The rehabilitation of existing urban areas can be implemented in time-managed sequences. Similar to current economic drivers, the city's adaptive and transformative nature is designed to work more in synthesis with fluctuations in economy, land ownership, and projected growth rates. Urban growth remains transitory, allowing for 'street level' changes in building density to evolve while the dedicated level for infrastructure accommodates expansion of reservoirs, water treatment, waste, cargo and transit.[10] Whether walking through a pedestrian artery or park, or passing through cross-axial thresholds, the multiple transitions foreseen from the growth of an urban pattern responsive to nature and changing technologies will highlight the unfolding of the temporal dimension embodied in an urban place. The 'multiplicity of resonances' that is sought out in the project will give configuration to vast landscapes of human time and its sense of history as experienced and valued culturally.

CONCLUSIONS

Although the methodological framework presented above has only proceeded through the initial stages, the design project advances an interdisciplinary approach towards the notion of a 'managed retreat' and the rebuilding of human habitat: a coordinated adaption strategy through planning, engineering, and the social and environmental sciences, where the built environment becomes more practically oriented to the regeneration of coastal eco-systems while including the needs of humans.

With a focus on building and climate, the project constructs potential strategies for the future transformation of urban models and the eventual legislative responses necessary to achieve city and regional goals. Outcomes from site-specific proposals contribute to the understanding of viable urban alternatives among similar geographic conditions. Topographical and bathymetric maps interactive with morphological models begin to identify transformative situations brought by natural forces and become some of the key apparatuses for building strategic design hierarchies and innovative trajectories for the future development of sub-tropical communities with present technological know-how.

The crafting of long-term comprehensive design projects can lead to the intersection of many of the concrete goals and objectives set forth above. However, without a holistic approach and the resulting illustrative models, the crafting of appropriate legislation and movement to action-oriented implementation of plans can become partitioned, segregated, and therefore short-sited. As illustrated by the numerous State and regional studies, the city's visioning plan, and the Climate Compact's action plans mentioned above, the impact of

ENDNOTES

1. Researchers working in academia and the professions explore a broad range of practices focusing on future impacts and innovative approaches to technology, climate, and society for cities. Among others, the Future Cities Laboratory in Singapore, a research project of ETH Zurich with the National Research Foundation Singapore; The MIT SENSEable City Laboratory, Cambridge, Mass.; Tony Fry and Team D/E/S, Brisbane.

2. Among the numerous regional publications, see: Southeast Florida Regional Climate Change Compact. A Region Responds to a Changing Climate, Southeast Florida Regional Climate Change Compact Counties Regional Climate Action Plan. N.p.: *Southeast Florida Regional Climate Change Compact*, 2012. P.14.

3. City of Fort Lauderdale. *Fast Forward Fort Lauderdale, Our City, Our Vision 2035. Fort Lauderdale: City of Fort Lauderdale*, 2013.

4. Salinity intrusion into fresh-water aquifers due to sea level rise is a major factor affecting the availability of potable water. Guha, H. and Panday, S. "Impact of Sea Level Rise on Groundwater Salinity in a Coastal Community of South Florida." JAWRA *Journal of the American Water Resources Association,* 48 (2012): 510–529.

5. The geological make-up in southern Florida and in particular, the porosity of the limestone substrate makes high-energy intervention strategies such as dikes and dams futile towards preventing sea-level rise. Englander, John. *High Tide on Main Street. Boca Raton: Science Shelf*, 2012, pp. 150-151.

6. The methodological framework is a hybrid model developed from a "design-driven approach" based on the research of Jack

'place-making', (the conservation and stewardship of the natural environment and the embedment of cultural signs into the built environment), will rely on a collective effort of many disciplines. Given the potentially disparate situation in which South Florida areas find themselves today, what lies ahead is an incredible opportunity to create human settlements that are inextricably linked to and bounded by nature. Just as the future rate of sea-level rise is an unknown, the actions taken by research, planning, and policy-making must anticipate future long-term changes that make for better communities today in order to avoid economic and environmental disaster for the region.

Breen and the Delft University of Technology. Breen, Jack. "Design Driven Research." Ways to Study and Research Urban, Architectural and Technical Design, Ed. T.M. de Jong and D.J.M. van der Voordt. *Delft: DUP Science*, 2002. Print. See also: Breen, Jack. "Designerly Approaches to Architectural Research." The Proceedings of the Research by Design Conference 2000. Delft University of Technology: 2001.

7. A hypothetical six feet of sea-level rise established the baseline priorities for defining buildable areas. This figure is based on current high scientific model sea level rise projections for the year 2100. The six foot accumulative level could also be interpreted as the sum of 3 foot SLR and three foot storm surge situations. The Southeast Florida Regional Climate Change Compact currently uses a model that projects sea level rise for the year 2060 at a minimum of 4.5 inches and a maximum of 24 inches. A three-foot rise in sea level on current extreme models is projected for 2100 on the Compact's trajectory model. The United Nations Climate Change Science Compendium 2009 high projection model forecasts a rise ranging from a low of 2.62 feet to a high of 6.56 feet by 2100. See: Southeast Florida Regional Climate Change Compact. A Region Responds to a Changing Climate, Southeast Florida Regional Climate Change Compact Counties Regional Climate Action Plan. N.p.: Southeast Florida Regional Climate Change Compact, 2012, p.7. Print. See also: Landers, Glenn B., P.E. *South Florida Sea Level Rise Projections and Flood Risk Concerns. Rep. Jacksonville: United States Army Corps of Engineers*, 2011. Pp. 8, 9, 23.

8. By the 14th century, the Venetian isles had developed a sophisticated sand filtering system that drew water up into wells from water harvested from roofs, in courtyards and areas which were originally fields, 'campos', and that later were paved.

9. Based on Fort Lauderdale's average annual precipitation of 66.5 inches per year, 1000 sq. ft. of roof area could collect 41,442 gallons per year. Using an average monthly potable water consumption per capita of 360 gallons, the urban density could arrive at an occupancy load of 10 occupants per 1000 sq. ft. of roof. Using the above occupancy load as a base-line, the calculation could supply 100% of potable water needs. The above figure excludes commercial use of water, but also grey water collection, recycling strategies, and water reduction measures that can greatly increase hydro-autonomy. For precipitation data see: Florida Climate Center, Florida State University Center for Ocean-Atmospheric Prediction Studies. http://climatecenter.fsu.edu/products-services/data/1981-2010-normals/ft-lauderdale

10. Rather than calculating a floor space index in relation to 'desired density', the density calculation first considers the number of habitable floor plates per 1000 sq. ft. of roof, and total roof area. The average density based on the urban massing model studies varies from island to island. These densities range from 18,000 to 32,000 per sq. kilometer. However, within the study site, community populations range from 550 to 4,200 inhabitants. The smaller isles are connected with pedestrian and bicycle bridges. For comparison, Fort Lauderdale's current average density equals 4,803/sq. mi., (1,864 inhabitants per sq. kilometer.) The current Broward County density equals 1,205/sq. mile, (468 per sq. kilometer.) See: United States. Federal Government. Statistical Programs of the United States Government. Mapstats. U.S. Government, n.d. Web. <http://www.fedstats.gov/qf/states/12/1224000.html>. For similar data see: <http://www.city-data.com/county/Broward_County-FL

*National Oceanic and Atmospheric Administration