(Geo)Design Coastal Cities: Design with Data (and Nature too)

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ABSTRACT - *The geography of a coastal city, such as its native geological, biological, and physical conditions, plays an important role in understanding the impacts of climate change upon the area. To better identify strategies for adaption to global climate change, planners and designers need better tools and techniques to learn and analyze the geographical context of their cities on coastlines worldwide. This article describes an urban design studio conducted in the spring of 2014. Students in this class explored the future of North Carolina coastal cities in light of rising global sea level. Geodesign using GIS and other visualization tools enabled the students to focus on urban morphology, development patterns, and environmental characteristics of the city in order to identify new interventions that can support a new set of relationships between urbanity and nature.*

Keywords: climate change, coastal planning, geodesign, GIS, urban design pedagogy

Cities in any given geographic location are subject to a variety of natural phenomena such as hurricanes, floods, earthquakes, and other hazards. Continuing changes in global climate patterns have altered the natural processes of atmospheric, hydrological, and oceanographic nature around the world. The frequency and severity of floods, storms, droughts, and other weather-related disasters are expected to increase within our lifetimes. While the occurrences of these events cannot be accurately predicted, their impacts can be studied and managed through coordinated efforts on

hazard mitigation. To ease losses of life, property, and function of a city, design professionals and city officials need to plan for and strengthen their infrastructural systems to be disaster-resistant. This will require all design and planning decisions to be made based on an integrated hazard mitigation strategy (FEMA, 2013; WBDG, 2017).

One of the major challenges facing coastal cities is how to prepare and respond to the devastating forces of natural events, such as flooding, storm surge, and sea level rise. Various scientific studies have begun to point out the vulnerability of many coastal cities to the eventual impacts of global climate change. The Intergovernmental Panel on Climate Change (IPCC), for example, has released a series of reports that highlight observed current and future projected climate changes.¹ Starting in 1988, IPCC began assessing scientific, technical and socio-economic data associated with climate change. According to IPCC's most recent study, its Fifth Assessment Report (AR5) released in 2014, global average sea level has risen an average of approximately 0,19 m [7.5 in.] over the period from 1901 to 2010 and the average rate of sea level rise has been larger since the mid-19th century than it has been over the two previous millennia. In addition, extreme sea levels, as experienced in storm surges, have increased since 1970, being mainly a result of rising mean sea level (IPCC, 2014). The IPCC report and other similar studies point to average global sea level rise of one to two meters by the year of 2100.² Even with the most conservative estimates, one meter of sea level rise will still present significant challenges for coastal cities worldwide. Such challenges require careful planning with regard to present and future resources.

It is important to note that sea level rise, however, will not affect coastal cities in equal ways. The impacts that global climate change has upon these coastal areas may vary due to many factors, such as their native geological and biological conditions, uneven levels and varied types of human intervention and development, or proximity to currently existing polar ice caps. Some areas will see potentially higher water levels while others may feel the effects of related issues such as increases in tidal ranges and storm surge reach. It is clear that the geographical context of any coastal city plays a crucial role in not only understanding the impacts of climate change upon specific areas but also potential strategies for adaption to and mitigation of environmental changes associated with global climate change.

Given these circumstances, two critical questions emerge: How can planners and designers better understand the geographical context of their cities? And, what tools and methods can enable them to do so in an efficient way? These questions go beyond conventional planning or urban design methods of analysis and point to the need for both academics and practitioners to reach beyond disciplinary boundaries. In this sense, the field of geography may very well shed some light on the answers to these

questions. Geography, as an academic subject, focuses upon place and its processes of production, human-made or natural, across both space and time. As a science, it seeks to organize and describe the world (McElvaney, 2012). Geography offers humans a set of tools for understanding, from traditional mapping for navigation and location to modern geospatial information systems for data analysis and decision-making (Artz, 2010; 2012). In particular, recent developments in the emerging field of geodesign offer new sets of theories and digital tools that bridge planning, urban design and geography and that hold the promise of a new avenue for addressing the impacts that global climate change has upon coastal cities worldwide.³

In an attempt to test the potential of geodesign as a design method applicable to questions of urban development in relation to climate change, the School of Architecture at the University of North Carolina at Charlotte launched an urban design studio aimed at addressing critical research questions through interdisciplinary design exploration. This semester-long studio course, offered in the spring of 2014, combined two classes together with a total of twenty-six students from a graduate-level program in urban design and an upper-division undergraduate-level class in architecture. Students in this “super-studio” worked in close consultation with the urban design and planning staff of the City of Wilmington’s Planning Department on a real-world project to explore the future of North Carolina coastal cities in light of rising global sea level. Working in teams, students focused upon several critical issues and key sites in an effort to both inform on-going local planning discussions and to highlight future challenges due to sea level rise along the North Carolina coast where Wilmington is located. The story of this collaboration with the City of Wilmington and the work of the super-studio highlight the role that geodesign can play in both the academy and in the profession. This story will be illustrated through this essay beginning firstly with the three underlying pillar principles that serve as the theoretical foundation for geodesign. The essay then discusses how these three principles were put to use in the development of the operational framework of the studio project, including the rationales behind the design of the learning exercises used in the studio. The essay concludes with a discussion of the outcome of the super-studio as well as some final thoughts on potential next steps for further research and design initiatives.

GEODESIGN AND DESIGNING WITH NATURE

GIS (Geographic Information System) has been a driving force for advancing environmental understanding and promoting better planning and decision making since its beginning in the 1960s. It does so by enabling, for example, urban planners to analyze, interpret and visualize geographic and spatial data; this is of particular value when managing and assessing complex data sets that represent interrelated urban systems (Aspinall et al., 1993; Goodchild, 1987; Kliskey, 1995). Having the ability to access large

data systems can help in decision making processes that inform a range of municipal processes. Interestingly, design disciplines have only recently taken advantage of the power of GIS. Many urban designers, for example, view design as a process of arranging physical elements, man-made or natural, in a way to best realize a particular purpose related to place type, land use, human activity, identity, and community character. In many cases, spatial form is guided by morphological patterns often disassociated from the social, economic or political contexts from which the pattern may first have emerged. Place, in this sense, is produced through spatial characteristics that are said to lead to “good city form”⁴ (Lynch, 1981).

Geodesign brings GIS into the process of designing human built environments and—by extension, brings complex data sets into the overall design process. It integrates geographic information with design thinking, which can result in a systematic method for spatial planning and place-making (Albert & Vargas-Moreno, 2012; Ervin, 2011). Design decisions, in such a process, can be viewed within larger contexts. Carl Steinitz, the noted Harvard Professor of Landscape Architecture and Planning, defines geodesign as “changing geography by design”⁵ (Steinitz, 2013; 2016). His emphasis is on the active role of design in shaping our surroundings to our desired uses. He argues that the action to change geography ought to consider broader-scale plans beyond individual projects for a better understanding of the influence of and consequence for the native landscape. Similarly, Dr. Michael Flaxman’s frequently-quoted definition of geodesign states that “geodesign is a design and planning method which tightly couples the creation of design proposals with impact simulations informed by geographical contexts, systems thinking, and digital technology” (Steinitz, 2013, pp 12). Flaxman, the CEO and founder of Geodesign Technologies, views this coupling as the bringing together of creativity and scientific rigor. His definition also stresses the uniqueness of geodesign as the merger of geography and design through computation and, in particular, through geospatial technologies such as GIS (Flaxman, 2009; 2010). In this view, geodesign is a set of methods that enable technologies for planning and designing built and natural environments in an integrated process, including project conceptualization, design specification, stakeholder participation and collaboration, design creation, simulation, and evaluation (Lee et al., 2014). Geodesign (or geodesigning), therefore, builds upon the conventional creative design process of sketching an idea, evaluating it, and redrawing the design (Albert & Vargas-Moreno, 2012). This process requires the creation of a sketch or model (physical or virtual), followed by an iterative process of quick re-design and evaluation of alternatives in order to reach a desired result (Miller, 2008; 2012). Geodesign also has its roots in alternative futures analysis, which is used as an environmental assessment approach for helping communities make decisions about land consumption and environmental protection. It provides a large-scale perspective on the collective effects of multiple development policies affecting the quality of the

environment and natural resources within a geographic region. The Upper San Pedro River Basin Project by Carl Steinitz and his students at Harvard (Steinitz et al., 2003) and the Willamette River Valley Project by David Hulse and his colleagues in Oregon (Hulse et al., 2002) both demonstrate how this approach helps articulate a suite of alternative visions for the future by iterations of concept development, impact assessment, and project refinement.

What makes geodesign unique, however, is the utilization of modern geospatial tools to provide rapid feedback on different design proposals and their potential impacts within specific contexts. One of those contexts - perhaps one of the most important factors in a design process - is that of natural systems. Geospatial design enables a designer to maintain multiple factors in play during a design process and to keep those factors as impactful and active elements. This is one way that geodesign can help designers keep a focus upon natural systems. Design that takes into consideration the native landscape of a place or region is not a new phenomenon. Ancient cultures built settlements in close proximity to natural resources and with good physical barriers for defenses to the wilds (McElvaney, 2012). More recently, Ian McHarg, in his book *Design with Nature*, which was published in 1969, promoted a design framework that encouraged humans to achieve synergy with the nature. In his view, design that considers both human needs as well as environmental facts in the context of both space and time help ensure a balance is struck between the two. McHarg also set forth a geospatial-based technique of overlaying different layers of geographic information to evaluate the impacts of human-made design interventions upon the nature. His pioneering work not only had a fundamental influence on the field of environmental planning but simultaneously solidified the core concepts of the young field of GIS around its inception in the early 1970s.⁶ Following McHarg's footprints, geodesign enables designers to think about geospatial data as part of a creative decision-making process and to translate geographic analysis into built forms. This eventually results in design outcomes that more closely follow natural systems (Zeiger, 2010).

DESIGNING WITH NATURAL SYSTEMS IN WILMINGTON, NC

The ability of geodesign to enable designers to address both current and future conditions was a fundamental reason for integrating this method into our studio, which focused upon the coastal urban context of Wilmington NC, USA. Wilmington, in the spring of 2014, was implementing a revision to local planning documents through a comprehensive planning and community engagement process. Urban flooding following severe weather, recent hurricane experiences along the eastern seaboard and North Carolina, and a growing interest in sustainable urban design strategies all led the City of Wilmington's Department of Planning to invite our School of Architecture and Urban Design Program to provide additional information

for their overall comprehensive planning process. As a result, our studio took the position that the exploration of future conditions brought on by climate change would be important to address. This gave us a planning horizon of the year 2100 and a sea level rise condition of 2 meters over present levels. From an academic standpoint, this planning horizon provided both an opportunity to rethink urban design strategies by enabling students to project far into the future and it enabled us to look at a coastal urban setting as a potential research venue that might yield innovative strategies for urban transformation (in the near and long term).

Three Elements of Geodesign

Again, geodesign provided the tool by which these opportunities could be addressed. This studio's premise and associated assignments each built upon the belief that geodesign, by its very nature, is a way of thinking, framing, and implementing the design of human built environments that gives designers ways of holding themselves accountable to specific design constraints (such as the presence of water - both now and in the future). Any discussion about geodesign's underlying frameworks must also, therefore, address the ways in which design, as a process, is conceptualized (Wilson, 2015). In this regard, geodesign has three fundamental elements that tie closely to three common conceptions of design processes: Evaluation, Visualization, and Collaboration. These three elements further enable the deployment of geodesign as a design framework (Lee, 2015).

Element 1: Evaluation - Design as an iterative feedback loop of concept generation, performance evaluation, and design refinement.

As previously mentioned, geodesign tightly couples the creation of design ideas with performance evaluation and impact assessment informed by geographic analysis (Flaxman, 2009; 2010). Geodesign can produce databased design options and in turn lead to informed decisions (Dangermond & Artz, 2012). Geodesign enables designers to sketch alternative design scenarios and quickly get feedback on performance and suitability by comparing design proposals to geospatial data behind GIS.

Element 2: Visualization - Design as spatial thinking relying on seeing in our mind's eye what the intended outcome could be.

Design at the geographic scale implies an effort to create something that is functionally efficient and environmentally sound. It requires an ability to generate a macro-level, or bird's-eye, view of the designed thing embedded within landscape in the mind's eye of a designer. This type of broad-scale image reveals both the process and the product in a conscious way before it eventually becomes realized. Geodesign, using the cartographic and graphical capabilities built into GIS, allows designers to visualize spatial relationships within and to map potential impacts of their design (Ervin, 2016).

Element 3: Collaboration - Design as a participatory process requiring an inclusive, communicative, and interdisciplinary approach to information sharing and deliberation.

Geodesign emphasizes collaboration and relies on a joined effort that draws upon inputs from different fields, including landscape architecture, environmental science, engineering, urban planning, and community development (Slotterback et al., 2016). In order to increase public engagement and collaborative learning, geodesign offers different tools and channels for individuals to communicate, share data, and design collectively (all of which is crucial to a geodesign-based approach).

A Framework for Geodesign

The three fundamental elements of geodesign served as the underlying principles for the development of the studio's assignments, their sequence and the processes through which the studio was to proceed.

The evaluation element of geodesign, for example, informed the development of initial studio assignments including both analysis procedures and design responses. With GIS as its core technical unit, geodesign enabled a systematic approach to understanding and managing information about the geographical context of the city. It allowed the class to inventory, analyze, and display large complex spatial datasets in an effective way (Ball, 2010). In our case, these datasets included information about the city's current physical conditions, environmental and watershed conditions, demographic growth centers, projected areas for growth (as indicated in local planning documents), and transportation networks. GIS provided direct access to layers of information that the students translated into design influences as they sought to understand Wilmington as an urban ecosystem. While the use of GIS-based information may not be new, within the context of an urban design studio, the use of this tool provided students with a way of managing large amounts of information without being overwhelmed. The ability to balance large amounts of information against spatial conditions gave students a way to enter into a design investigation easily.

Their experience reinforces David Cowens's assessment that GIS serves as a decision-support system enabling the integration of spatially referenced data in a problem solving situation. He argues that a typical GIS project workflow consists of four consecutive stages starting from 1) identifying project objectives; 2) creating a project database; to 3) analyzing the data, then finally 4) presenting the analysis results (Cowens, 1988). This studio expanded on this simple model and adopted Carl Steinitz' six-stage model of landscape change, which is broadly recognized as the theoretical base for the geodesign framework ⁷ (Dangermond, 2009; Steinitz, 2013). These six modeling stages are framed by a set of critical questions that designers ask themselves during the life

cycle of a design project. These six modeling stages are further divided into two phases: assessment and intervention.

The assessment phase involves first three stages of Steinitz' model that describe and assess the geographical context of a place as it is. The intervention phase includes next three of his stages describing the place as it could be and evaluating possible design alternatives and their potential impacts.

In the first phase of geodesign, landscape assessment, designers conduct their initial analytical steps by asking themselves three questions:

- 1) How should the landscape be described? This question asks for actions to conceptualize the landscape - the geography - and inventory the findings into a series of thematic data layers.
- 2) How does the landscape operate? This requires combining data and the use of spatial analysis techniques to understand landscape processes and describe how the geographical context might change over time.
- 3) Is the landscape functioning well? This involves the creation of composite representations of the landscape, usually in the form of maps, that combine a number of dissimilar things in a way that reveals areas that may be more favorable than others for certain activities.

Overall, this assessment phase consists of examining existing conditions and determining whether the current conditions are operating well or not. The second phase of geodesign involving landscape intervention begins once the landscape assessment is completed. Three more questions are presented in this phase:

- 4) How might the landscape be altered? This question triggers the development of alternative design scenarios.
- 5) What differences might the changes cause? This is answered by a quick evaluation of the potential impacts of those possible changes proposed in the previous step.
- 6) Should the landscape be changed? This integrates considerations of policies and values into decision making.

In general, the information produced by this intervention phase is used to help designers and decision makers weigh the pros and cons of each decision factor so they can weigh alternative solutions and make the most informed decision possible.

Studio Processes

Based on this geodesign framework, this studio project was conducted in two major steps following the two phases of geodesign outlined above.

The first set of exercises explored basic tenets and techniques of urban analysis and established the foundations of sustainable urban design theory and practice that would be applied later to develop alternative design proposals. Additionally, students working in teams examined patterns in Wilmington's urban and natural environments in an effort to move beyond simple descriptions of the landscape to more robust interrogations of the data. Geospatial analysis was seen as a means of interrogation that enabled the formulation of basic questions in this first phase of the project. GIS tools enabled the students to create an overall site analysis of the entire Wilmington metropolitan area with an emphasis upon the identification of key case study zones that captured areas challenged by differing impacts from climate change and sea level rise. These key zones represented the various urban and suburban conditions found within greater Wilmington.

The actual technical procedures for this phase of the project were developed closely following the sequence of the first three modeling stages in Steinitz' geodesign workflow as listed below:

- 1) Representation model: How should the landscape be described?
Project activities for this stage were focused on establishing GIS data layers, using attribute-based operations to generate thematic maps (such as identifying vacant parcels), linking external demographic data from census to selected maps, registering imagery onto GIS data layers, and creating 3D representations of the site. Data were gathered through online sources, such as data files downloaded from the City of Wilmington and US Census Bureau, and through site visits to the city. Esri ArcGIS Desktop served as the main software tools suite for the project.⁸
- 2) Process model: How does the landscape operate?
Project activities for this stage were mainly focused on identifying the relationships among various man-made physical features in the landscape (such as buildings and roadways), natural features and landforms (such as elevations and waterways), and human activities and phenomena (such as population distributions and land uses). This was done by using map overlay techniques combining multiple thematic maps together to reveal patterns and relations. ArcMap in the ArcGIS Desktop was the application for these operations.
- 3) Evaluation model: Is the landscape working well?
Project activities for this stage were focused on setting up measures for design performance assessment based on metrics of judgment, community value, design intent, and goals/objectives. This assessment stage involved the participation of a diverse set of subject matter experts from various city departments who

were involved in defining issues, metrics, and the proper methods of analysis. A set of common values/goals was identified, including

- 1) protecting existing communities from rising sea level;
- 2) rebuilding communities in areas susceptible to future rises in sea level;
- 3) addressing valuable public shoreline infrastructure;
- 4) re-imagining new shoreline configurations for the City of Wilmington.

The three remaining modeling stages (change, impact and decision models) in Steinitz' geodesign workflow served loosely as a guide for the second phase of the project focused on the development of design proposals.

- 4) Change model: How might the landscape be altered?
Project activities for this stage were focused on developing design scenarios based on the overall site analysis from the assessment phase.
- 5) Impact model: What differences might the changes cause?
Project activities for this stage included testing scenarios using the indicators, measurements, and community values that were identified from the evaluation stage.
- 6) Decision model: Should the landscape be changed?
Project activities in this stage were focused on finalizing criteria for decision-making, producing outcomes, and presenting outputs.

Building from the overall site analysis in the first assessment phase, which identified four key case study zones, student teams then began focusing upon each of the key zones through the second iteration of mapping exercises and site analysis, which in turn provided the platform for specific design investigations in various key zones. The second iteration of processes began with an examination of the impact of sea level rise, storm surge and current flooding patterns upon to the overall physical fabric of the key zones. Students then used map overlay techniques again to visualize relationships among other variables, such as detailed street network, building fabric, land use, vacant parcels, and topography on this sub-area scale. Based upon the information derived through this step, areas within each of the key zones were identified as "ripe", or ready for intervention. These ripe areas became the specific demonstration sites for final design interventions. Factors such as intensity of climate change related impacts, urban identity, demographic growth, civic initiatives aimed at targeting growth, and proximity to key infrastructural opportunities all contributed to the selection of the final design demonstration sites within the four key zones: Downtown, Midtown/College Street Corridor, Coastal, and Post-industrial zones.

VISUALIZATION AND DESIGN AS SPATIAL THINKING

Focused studies involving these key sites enabled students to move from a macro, or metropolitan, scale to a micro, or more focused neighborhood, scale in which urban character and spatial identity could factor into design decisions alongside climatic conditions. In essence, this smaller scaled set of studies enabled a more detailed visualization of existing, impending and proposed conditions. This came in various forms ranging from diagrams, to maps to 3D perspectives. Mapping and diagramming are effective tools to communicate important project information and design intents. Geodesign relies on traditional cartography as well as modern graphical representations of geographic information to allow designers to visualize data in an effective way and see in their mind's eye their design responses to site conditions. This can be accomplished by utilizing a variety of software applications, including conventional GIS tools such as ArcGIS Desktop, 3D GIS or modeling programs such as 3D Analyst⁹ or SketchUp, and/or cloud-based platforms such as Google Earth and ArcGIS Online.¹⁰ One special emphasis is, therefore, put on the inter-operationality among and integration of these tools to ensure efficiency of graphics production and increase accuracy of representations. This studio project incorporated a series of visualization processes and produced a variety of maps and graphics throughout the project processes.

One important strategy in the assessment process was to use the idea of an urban transect as an initial diagnostic tool by including sea level rise projections as a feature. This illustrated that some parts of the metropolitan area would face greater impacts from sea level rise due to their proximity to the coastline or to lower elevations, therefore, triggering population displacement and infrastructure losses. For inland neighborhoods away from the coastline, the effects of sea level rise might be felt differently both in terms of potential increases in heavy rains and urban flooding, storm surges, and in terms of population displacement. These inland areas will be on the receiving end of forced resettlement due to potential migration away from coastal areas, which indicates that some areas previously not seen as growth targets may, in fact, need to plan for inland migration. Increases in infrastructure capacity, housing and public spaces will then be needed to address the impacts of population growth in these inland areas. A series of maps were created by the class to process this urban transect idea as described below.

The assessment phase began with generating a series of base maps that charted sea level rise at both one and two m [3.3 and 6.6 ft.] based on topographic analysis to visualize the potential impacts of rising sea water upon the Wilmington metropolitan. This initial step identified where a new projected sea level waterline could be located, which became one layer on a new blue print of the city. Additionally, new three m [10 ft.] storm surge was mapped. The combined effects of these were identified by examining existing elevation data and existing parcel maps (Fig. 1).

Figure 1.
Topographic
analysis reveals
the potential
impacts of rising
sea water upon
the Wilmington
metropolitan.

By overlapping elevation data with current ecological network in the metropolitan area, the studio established a green print of existing greenways, parks, wetlands, and preserved habitats. With the existing green network identified, students then located proposed greenways and parks while simultaneously examining current vacant parcels that are threatened by sea level rise, storm surges and projected future flooding. These sites, which were termed sacrificial due to their likelihood and degree of projected water-related impacts, became targets for incorporating Low Impact Development (LID) technologies to act as stormwater buffers to ease the impact of sea level rise and storm surges (NCSU, 2009). This process also helped the studio establish an estimate regarding the number

Figure 2. An estimate of population displacement was made by overlaying Wilmington's green network, existing parcels, and areas at risk of sea level rise and storm surges.

of households and/or individuals that may be displaced due to climate change and sea level rise. It also helped identify the amount of buildings and infrastructural elements (roads, for example) may have to be rebuilt due to the impacts of climate change (Fig. 2).

With the urban transect maps in hand, the studio also identified areas of projected growth that might be re-imagined to capture both people coming to Wilmington from outside the city as well as local residents that may be displaced as sea level rise. These potential receiving areas included areas currently facing declining economic uses (such as post-industrial sites), areas ripe for conventional redevelopment. This search was combined with a social vulnerability index analysis that mapped a variety of population-based information, such as income, number of people age 65 and older, and access to resources, such as schools, parks, and transportation (Fig. 3).

By combining individual maps, concentrations of data began to reveal certain patterns and direct the studio's investigations into key case study zones. By overlaying social vulnerability with major infrastructure, vacant land, sea-level rise plus storm surge, and ecological networks that consist of existing greenways, parks, wetlands, and preserved wildlife habitats, the studio identified ripe areas, which were potential candidates ready for redevelopment due to the impacts of climate change (Fig. 4).

Further combined with areas of projected growth, the resulting map enabled a set of key zones to come into focus, some of which were in threatened (sacrificial) areas and others in established (receiving) areas: 1) a historic zone around downtown Wilmington; 2) a suburban zone along Midtown/College Street Corridor and around University of North Carolina at Wilmington; 3) a marina and coastal zone along the coastline; 4) a suburban/post-industrial zone near Monkey Junction and the industrial areas along Cape Fear River (Fig. 5).

COLLABORATION AND STUDIO RESULTS

Geodesign promotes practices that merge spontaneously participatory design methods with geospatial technologies to respond to the demand to have multiple voices heard and ideas taken from those who involved in the process. While public input was not integrated into the overall experience of the course, the studio built upon an interdisciplinary knowledge base with students coming from different design programs, encouraged collaboration among students themselves and between city staff.¹² In addition to face-to-face communications through site visits or meetings for in-house project reviews, various digital channels were deployed to encourage collaboration and information sharing, including ArcGIS Online, a cloud-based geospatial content management system for storing and managing maps, data, and other geospatial information. A remote file sharing server on campus was set up for all students to share GIS datasets and other files needed for the project, such as scanned map images, photos, satellite imageries, and other

Figure 3. Social vulnerability index analysis considers social/demographic conditions of local neighborhoods to determine their needs for (re)development.

Figure 4. Overlay analysis reveals certain patterns and informs design investigations into key case study zones.

Figure 5. The resulting map enables four key zones to come into focus.

graphics and written materials. The combination of virtual and in-person collaborations with city officials provided students with insights into the participatory access that geodesign can afford designers. In this sense, the studio utilized city officials as surrogate public participants in order to provide both expert opinion as well as overall qualitative feedback. However, this limited form of collaboration could not fully simulate the kind of large scale community involvement that geodesign may afford in practice.

The second iteration of mapping and analysis exercises concluded with the identification of selected demonstration sites within the four key zones, as mentioned before. This was followed by the final iteration of analysis focused on the development of design strategies targeting these selected demonstration sites. These sites were viewed as representative of the various urban landscapes in the city, each paired with specific design recommendations proposed by the student teams. The following section provides brief descriptions of key design strategies for the selected demonstration sites within the four key zones.

Downtown Wilmington Historic Zone: Protect, Defend, and Soften

Topographic data revealed that downtown Wilmington and its historic core were founded upon high ground and, thus, the majority of the downtown area is considered safe from threats associated with sea level rise. However, low lying areas near the Cape Fear River's edge and along inlets and marshes could be significantly affected by rising sea level and the reach of expanded flood plains due to climate change (Fig. 6). These areas provide ripe opportunities to establish a protective ecological edge to downtown. Additionally, according to various census-based projections, the downtown area is expected to grow in population due, in part, to its pedestrian friendly urban fabric, concentration of jobs and amenities, and its proximity to coastal attractions. In order to accommodate this population growth in downtown,

Figure 6. The second iteration of mapping analysis for Downtown Wilmington Historic Zone.

AN URBAN DESIGN PROPOSAL TO THE SEA LEVEL RISE IN WELLINGTON WATER MANAGEMENT AND TRANSECT

Protection methods

1. Combine landscape facilities with water management system
2. Transferable quality from entertainment to water filter
3. Connected by underground pipe

Figure 7. Proposed transect design and water management strategies for Downtown Wilmington Historic Zone.

phased development should be strategically concentrated around improved infrastructure with a network of green streets connecting public open spaces. LID technologies for storm-water management, such as bio-retention and vegetated swales, should be introduced (NCSU, 2009). The integration of green infrastructure and LID will both enhance the qualitative experience of the city and add to its resilience against increased threats of heavy rains, storm surge and flooding. This new urban ecosystem should be embedded within the existing gridded street pattern to create an integrated urban ecosystem that connects and extends the riverfront to the city core through new greenways, permeable green streets, and public open spaces and parks (Fig. 7).

Midtown Wilmington Suburban Zone: Repair, Intertwine, and Attack

The College Street Corridor in Wilmington's Midtown has recently been impacted by regular urban flooding events tied to seasonal rainfall, which have been constantly degrading this area's urban infrastructure, environmental conditions, and water quality. Midtown is an important cultural node within Wilmington's larger metropolitan landscape: College Street is a major commercial arterial and the gateway to the University of North Carolina at Wilmington (Fig. 8). As an auto-oriented landscape, this area presents an opportunity to repair and strengthen its suburban fabric while attack its existing and future climate-related challenges. An existing patchwork of open spaces and greenways, revealed by

Figure 8. Site mapping analysis for Midtown Wilmington Suburban Zone.

Figure 9. Proposed design strategies for green permeable streets in Midtown Wilmington Suburban Zone.

Marina and Coastal Zone: Retrofit, Repair, and Attack

Figure 1 consists of three maps of the oceanfront zone in Wilkes-Barre, PA, illustrating different planning scenarios. Each map includes a north arrow and a scale bar from 0 to 2 miles.

- Left Map: Resilient Infrastructure**
 - Resilient Infrastructure:**
 - Storage Area
 - Continuous North Bridge
 - Green Streets / Storage Street
 - Existing City Parks
 - Proposed Wetland Parks
 - New Barrier Beaches
 - Sea-Level Rise:**
 - Sea Level Rise in 2100
 - Proposed Floodway (2100)
 - State District
- Middle Map: Land-Use / Transect Planning**
 - Land-Use / Transect Planning:**
 - T-1: Mixed-Use System
 - T-2: Low-density Residential
 - T-3: Suburban Residential
 - T-4: Urban Residential
 - T-5: High-density Urban
 - T-6: High-density Urban (with)
 - Industrial / Commercial & Marginal
 - End of Area
 - Sea-Level Rise:**
 - Sea Level Rise in 2100
 - Proposed Floodway (2100)
 - State District
- Right Map: Projected Population Displacement**
 - Projected Population Displacement:**
 - Populations Displaced by Sea-Level Rise
 - Sea-Level Rise:**
 - Sea Level Rise in 2100
 - Proposed Floodway (2100)
 - State District

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Among all the properties in this coastal zone, 4,170 parcels were identified by the GIS analysis to be the properties that would suffer the most severe damage from rising sea water. These properties should be retrofitted with LID storm-water treatment techniques (such as water catchment and bio-retention) and transformed into sponge slips that can attack rising tides and allow storm surge water to be absorbed and slowly discharged. Established neighborhoods within the predicted storm surge impact areas but not immediately adjacent to the coastline should be redeveloped, retrofitted and repaired in order to establish a network of open green public spaces to function as bio-retention basins during storm events. Architectural forms should be transformed to include raised lower levels intended to absorb the impacts of storm related flooding. The existing commercial corridors further away and parallel to the coastline should be intersected with smaller permeable urban grids to serve as an urban-scaled filter to absorb and dissipate heavy rains, flash floods, or severe storm surges (Fig. 11).

Post Industrial Zone: Retreat and Reconnect

The southern half of Wilmington metropolitan includes a range of spatial typologies from industrial riverfronts to low lying inland watersheds to suburban coastal areas already prone to seasonal flooding. Existing workforces and residential communities in this zone are vulnerable to the increased threat of flooding, in part, due to area's lack of connectivity, which weakens the ability to evacuate these areas in the event of a natural disaster (Fig. 12). A new connected urban fabric should be introduced to reclaim and repair the aging industrial areas. The proposed new ecological network will link the two coastal edges of Wilmington - the riverfront to the west and the ocean coastline on the east - by stitching together wetlands, proposed greenways, existing civic recourses, and new green infrastructures that support the circulation of both people and water. Strategic connectivity through multi-programmed infrastructure (recreation as well as water management) provides new urban thread with which to reconnect the disparate industrial and suburban typologies (Fig. 13).

A PRELIMINARY CONCLUSION AND A DISCUSSION OF COURSE OUTCOMES

This studio resulted in eight sub-area master plans and twenty individual site design projects, including selected sites in urban areas such as downtown Wilmington and those in more rural or suburban settings near city's coastline. Project reports and other materials produced by the class, including maps, drawings, and analysis results were shared with the City of Wilmington Planning Department after the conclusion of the project. Although an in-depth evaluation on the effectiveness of the geodesign framework is out of the scope of this paper, which is certainly an important next step, feedback from the students provide a glimpse into the potential

pros and cons of applying geospatial tools and analysis methods in the processes of planning and designing human built environments.

Informal exit interviews with the students revealed in general a positive view towards geodesign as a valuable tool for designers. One student argued that the use of GIS and its associated tools coupled with other software such as SketchUp and Google Earth allowed better analysis and visualization of the site, which in turn led to a more well-versed design response. Some pointed out the advantage of using maps as a communication tool to interact with stakeholders involved in the project.

Understanding the city's position and community needs through mapping exercises enabled the class to become more knowledgeable of those

Figure 11. A demonstration master plan for integrated design strategies incorporating resilient green infrastructure for Marina and Coastal Zone.

pressing issues tied to the different attributes of the sites as well as the program requirements of the clients. However, students were concerned with some fundamental limitations embedded in the geodesign concept due to its analytical and technical nature. One student pointed out that GIS tools and plug-ins were able to answer most of the design questions posed in order to analyze the site as well as to evaluate the design proposal using the available metrics from the plug-ins results. However, the result of the analysis was not fully conclusive because there are other factors that were not considered in the GIS analysis.

Geodesign may be an alternative way of planning and designing resulting in a more informed design decision. However, as demonstrated in this class project, this process fell short in terms of the ability to create actual planar and sectional representation drawings that are typically required in the

Figure 12. Site mapping analysis for Post Industrial Zone.

final deliverable of a design project. There was still a need to work on other rendering software such as CAD and Adobe programs to further visualize the design. In addition, the vision to have a feedback-loop formed between formulation of design ideas and performance assessment/measurement was not quite realized in the project due to lack of familiarity to the subject matters that were supposed to support the class with engineering metrics and/or scientific measures to enable the process. A better coordination between design deliberation and technical procedures is certainly anticipated in order for any hope to advance this particular type of design approach.

Geodesign offers alternative approaches to planning and design leading to more informed decision-making. However, any design or planning practice requires broad knowledge including theory, methods, and tools.

Figure 13. Proposed strategies for new green infrastructures supporting the circulation of both people and water in Post Industrial Zone.

It also requires attention to be paid to intention, purposes, and contexts. In this regard, the geodesign method employed by any individual must vary depending on his/her initial intent, and so do the tools he/she decides to use. To be successful with geodesign, a designer must be capable of deploying a variety of tools (evaluation, visualization, collaboration) in order to analyze design problems, formulate solutions, and understand trade-offs from different perspectives.

Essentially, geodesign relies on a scenario-based approach to solving problems. Because design scenarios are all unique, it may be ideal to use different tools for different types of analysis for each scenario. An ideal setting for teaching/learning/testing this particular geodesign method, therefore, should be established with the following two important actions:

1) employing a variety of software packages that can be integrated in various ways in response to different design proposals and scenarios at various geographic scales; 2) exploring theories and processes that can better involve stakeholders in the selection of appropriate metrics/measures for performance evaluation and efficient channels for communication and collaboration.

GIS, geodesign and other graphic tools provided the means through which specific design interventions were visualized for this studio project. GIS-based analytical tools enabled design students to map and evaluate the potential impacts of rising sea level, changing coastal patterns, and the projected reach of future storm surges. This geodesign framework and its associated tools and techniques, such as map overlay, imagery processing, and 3D visualizations, enabled analysis of geographical contexts and comparison between design and development scenarios. The combined research and design efforts of this course identified various ways by which not only the City of Wilmington may begin to address the impacts of climate change but also other cities throughout the region may address to strengthen their urban infrastructures. As sea level rises, cities like Wilmington face significant challenges, which will continue to change their relationships with their coastal edges. This represents an opportunity to develop greener and more resilient infrastructure and urban forms that can withstand future climate change. The information gathered here provides the foundation upon which to build additional research into analytics and visualization tools and their applications for climate-related design challenges.

Notes

1. The Intergovernmental Panel on Climate Change (IPCC), sponsored by the United Nations, has published five comprehensive assessment reports reviewing the latest climate science and data. IPCC is currently in its Sixth Assessment cycle. The AR6 Synthesis Report is expected to be finalized by 2022.
2. Other studies include: 1) The Synthesis Report of the Arctic Climate Impact Assessment released in 2004; 2) a report on global warming by the U.S. Global Change Research Program released in 2009; 3) the State of New York Sea Level Rise Task Force 2010 Report; and 4) the ClimAID 2011 Responding to Climate Change Report.
3. Geodesign is an invented word, according to Carl Steinitz. Its origin is unclear. However, Bill Miller, Director of Geodesign Services at Esri, mentioned in a personal communication that Jack Dangermond may have invented the term in 2006, the year Esri introduced its experimental product, ArcSketch. Many point to the Specialist Meeting on Spatial Concepts in GIS and Design, which took place at the University of California at Santa Barbara in 2008, as the inception of geodesign. That conference was intended to more squarely understand the potential of integrating design more fully into GIS. Held annually since 2010, Esri's Geodesign Summit has then become a major gathering of professionals interested in, or working at the intersection of, geography and design.
4. With the publication of *The Image of the City* in 1959, Kevin Lynch intended to understand the process of exploring city form. Lynch looked at connections between human values and the physical forms of cities. To Lynch, the key to developing a good understanding of city form is identifying a set of performance dimensions, with the recognition that each locale will prioritize these criteria differently.

5. Matt Artz, GIS and Science Manager at Esri, in an article published on Directions Magazine, March 11, 2010, first mentioned this definition of geodesign by Carl Steinitz. In Steinitz' words, "geodesign is an ongoing process of changing geography by design." For him, geodesign is based on the interaction between design professions, the people of the place, information technologists, and geographic sciences.
6. Ian McHarg's "overlay method" describes how different information can be layered and combined geographically to identify suitability for different types of development and use. This particular technique eventually forms the basis of many complex analyses and reports performed with GIS. Roger Tomlinson's work with the Canadian government in the 1960s on the development of the Canadian Geographic System (CGIS) is widely recognized as the beginning of the modern computational geography. Similar efforts took place at Harvard's Laboratory of Computer Graphics and Spatial Analysis between the 1960s and 1970s. These efforts were unique because they adopted a layer approach system to map handling, closely related to McHarg's "map overlay method."
7. Carl Steinitz' six-stage model of landscape change was first published in his paper "A Framework for Theory Applicable to the Education of Landscape Architects (and Other Environmental Design Professionals)" by *Landscape Journal* in 1990. Based on this model, Carl Steinitz has conducted alternative futures analysis for several projects, including the Upper San Pedro River Basin Project in the early 2000s. He further elaborated his ideas in his 2012 book *A Framework for Geodesign* and proposed a comprehensive framework for those interested in learning and applying geodesign approaches in design projects.
8. Environmental Systems Research Institute, Esri, is a major international supplier of GIS. Its flagship product, ArcGIS Desktop, includes a suite of integrated applications, including ArcMap, ArcCatalog, and ArcToolbox.
9. An extension to ArcGIS Desktop, 3D Analyst provides tools for 3D visualization, analysis, and surface generation. The class used 3D Analyst to add shading to the elevation model to increase the perception of depth in the 3D view and enhance details of the topography.
10. ArcGIS Online, Esri's cloud-based geospatial content management system, served the class as a search engine for GIS data and allowed the students to store and share their data and maps.
11. GIS has been used as a tool for public engagement and has its roots in the field of Public Participatory GIS (PPGIS), which intends to bring mapping practices to grassroots communities in order to promote public discourse and problem solving for shared challenges.
12. This class project did not involve actual interaction with community members outside of a selection of city officials; participation was limited and public opinions gathered were subject to biases. This presents an opportunity of improvement for future study.

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