Integrating a Resilience Scorecard and Landscape Performance into a Geodesign Process

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Superfund Research Program

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Overview

Uncertainty about the impacts of sea level rise make the ability to forecast future spatial conditions a necessary design tool. Geodesign integrates multiple fields of science with design strategies. We use the resilience scorecard to assess flood vulnerability using projections for the 100 year floodplain with sea level rise by 2100 as a guide to develop a resilient master plan for League City, TX. Future impacts are projected using landscape performance.

Narrative

Geodesign has become more integrated in a number of applications (Wilson, 2014). For example, Geodesign can be applied as a mechanism to inventory, analyze and project a future state of affairs for geographic space (Goodchild, 2012). The framework for a Geodesign process (Stenitz, 2012) specifies six key models to be produced, including representation, process, evaluation, change, impact and decision. Simultaneously, as part of an initiative proposed by the Landscape Architecture Foundation, academic institutions have been collaborating to quantitatively assess the environmental, economic and social benefits of urban design projects (Yang and Binger, 2016). This effort, known as landscape performance, encourages evidence-based designs that are grounded in quantitative performance measures. Unfortunately, many of these performance measures have not yet been fully incorporated into the Geodesign process. There are other analytical-planning methods, such as the resilience scorecard (Berke et al., 2015), which use quantitative performance measures to reduce losses from hazard events through conditional analyses and policy review, rather than projections or post-implementation evaluation metrics. However, while these types of analyses can provide a sound foundation for evaluation models, they are still quite separate from Geodesign approaches.

In this research, the approach allows the integration of the concepts of flood resilience and community design with the fields of landscape architecture, regional planning, land use management, and hydrology in a community of approximately 100,000 residents located on the Texas Gulf Coast. The effects of climate change, such as sea level rise, have had observable ecological, social, and economic impacts on the built environment in this region. Sea level rise has already had a significant impact on Gulf Coast communities, resulting in wetland loss, increased coastal erosion/inundation, and increases in the duration and frequency of flooding from storm surge (Horton et al., 2014). The National Oceanic and Atmospheric Administration (NOAA, 2015) predicts that (in a med-high scenario) the mean sea level will rise at least 0.82 inches per year in the U.S. Gulf Coast, reaching 6.29 feet by 2100. In 2008, Hurricane Ike caused extensive damage to the Texas Gulf Coast, causing 113 deaths and $29.5 billion in damage; approximately 200 of the damaged homes were located in League City, TX (Rego & Li, 2010). League City, due to its location on the Texas Gulf Coast, is highly vulnerable to flood events and other issues related to sea level rise.

Working in partnership with city officials, the authors developed and executed a Geodesign process which integrated the resilience scorecard (Berke et al., 2015) as the evaluation model, a vertical buffer tool (as a process model) to project sea level rise, and landscape performance (as an impact model). The project included an assessment of flood vulnerability and projection of the 100 year floodplain in the year 2100, accounting for increases due to sea level rise. This information is used as a guide for the location of future development, as well as to inform the development of a master plan for a resilient community within a 97-acre site surrounded by urban development in League City. In light of the community's vulnerabilities and the sea level rise projections revealed through the Geodesign process, a series of adaptive flood attenuation mechanisms for protecting the newly designed community from flood events and the eventual impacts of sea level rise are suggested. Finally, landscape performance projections are conducted to measure potential impacts of the proposed master plan.

Non-monetary investments

Special thanks should be given to the funders from the National Institute of Environmental Health Sciences Superfund Program (P42ES027704-01) and the National Science Foundation Partnerships for International Research and Education (PIRE) Program **(**#1545837)**,** both funders for the work. Also, the Senior Planners of League City and staff from the Houston-Galveston Area Council who assisted in both locating and analyzing the site as well as worked with us w\during the engagement process.

Research question

This project integrates policy analysis methods used in developing the resilience scorecard (Berke et al., 2015) with landscape performance tools in a unified Geodesign process. Then, Geodesign change models are used to develop design/planning strategies that promote better responsiveness between local plans and losses from hazard events, including sea level rise. This research seeks to answer the question, how can plan evaluation and landscape performance assist in Geodesign processes to improve resilience in neighborhoods experiencing high hazard exposure? The process of effective design/planning for local climate change depends on a combination of variables that pertain to the planning, design, policy and health impacts of sea level rise. As part of this process, we 1) identify high socially and physically vulnerable neighborhoods through a series of GIS-based spatial operations, 2) identify future flood prone areas in accordance with sea level rise projections on municipal and local scales, 3) design a master plan based on these findings and 4) project future impacts of this master plan using landscape performance measures.

Literature application

The impacts from the combined effects of rapid environmental change and the increasing severity of natural hazards have necessitated new approaches intended to address concerns related to climate change (Walker & Salt, 2006; Folke et al., 2010). Adopting integrated approaches into the design process to develop land use-based solutions to mitigate hazards requires long-term strategies and forward thinking to reduce hazard vulnerability (NRC, 2012). Several studies conclude that it can be challenging to choose an appropriate spatial scale to advance master plans to manage hazards, and that greater emphasis should be placed on the local level to reduce the frequency of hazards (May & Deyle, 1998; Olshansky et al., 2012). An often overlooked element of mitigation is the capability to forecast future circumstances. Communities that have suffered from high hazard exposure often increase pressure on local governments to include resiliency and sustainability in decision-making. From a design/planning perspective, master plans are the most effective tool for long-term action (Schwab, 2010). Vulnerability and hazard exposure are the two major factors influencing community resilience (Walker & Salt, 2006). Resilience is an approach that assumes that people interact with and shape their environment on multiple-scales and that the environment can provide services to sustain the well-being of human societies (Berkes & Folke, 1998; Berkes et al., 2003). Several key factors can lead to unsustainable coastal development and reduced resilience, such as coastal population growth, demographic trends, desires to enjoy coastal living, and policies or financial systems that encourage coastal land development (Beatley, 2009). A lack of awareness of long-term risks and threats associated with living in high-hazard areas can contribute to imprudent development patterns. sprawl, loss of farmland, replacement of natural areas and open spaces with impervious surfaces, and substantial losses of wetlands and other habitats that provide natural buffers from flooding can further exacerbate vulnerability (Newman et al., 2014; Sohn et al., 2014; Newman et al., 2016a). Thus, negligent undervaluing of natural ecosystems and their services can effectively compromise the safety of coastal communities.

Participants

Although enhancing resilience in areas vulnerable to flooding is most effective with participation from the local community, local stakeholders are often left out of the design/planning process. (Steven et al., 2010). The engagement process used to develop this master plan relied on feedback loops that support resilient design and planning. Research and design on these issues in this neighborhood were undertaken using a participatory approach in cooperation with local community members and the senior planners for League City. Green infrastructure, open space planning and community design scenarios were developed through several engagement sessions assisted by community input.

For this project, participatory involvement was initiated four times over an eight-month period. The design was able to incorporate information provided by the senior planners that was used to 1) conduct a site inventory, 2) determine and locate flood-prone areas, 3) develop desired functions for new land uses and, 4) suggest potential infrastructure based on climate change projections. First, an introductory meeting allowed the design team to discuss site-specific problems with League City senior planners, initiating a general discussion to help identify high risk areas within the floodplain, as well as pinpoint current and future flood vulnerable areas. A second meeting presented the city with findings from an initial site analyses. Feedback from the community provided further insight in identifying unseen conditions as well as generated ideas for future land use functions to be incorporated in a conceptual master plan. A third and fourth meeting involved a feedback loop between community members and the design team in which a series of design scenarios were presented and critiqued by neighborhood members. Responses from the community to the design team were then utilized to condense the scenarios into one unified revised master plan.

Methodology

The project took place from Aug. of 2017 until May of 2019. Application of the Plan Integration for Residence Scorecard (Berke et al., 2015) took place from Aug. 2017-Dec. 2017. We assessed League City's network of plans – including its comprehensive plan, hazard mitigation plan, and parks and open space plan – to better understand the policy climate in the community. Sea-level rise was forecast from Dec 2017-Feb. 2018 to surfaces using the FEMA 100-year flood elevations. Data derived from the U.S. Army Corps of Engineer's sea-level rise calculator provided alternative scenarios of sea level increases by 10-year increments up to 2100. By adding sea-level rise to the base elevation of the 100-year floodplains, we determine the projected expansion of current flood zones. To assess the potential impacts of current hazard conditions on the human environment, a series of raster maps were overlaid using Cutter's (2014) 16 factors contributing to vulnerability using weighted overlay procedures, a form of suitability mapping in GIS from Feb 2018-May 2018. Participatory involvement was initiated four times over an eight-month period from May 2018-Jan. 2019. The design incorporated information provided by the senior planners that was used to 1) conduct a site inventory, 2) determine and locate flood-prone areas, 3) develop desired functions for new land uses and, 4) suggest potential infrastructure based on climate change projections. Then the Master Plan was generated from June 2018-May 2019. Borrowing from a national and international series of resilient community design cases, the design develops and incorporates a series of flood attenuation mechanisms (both structural and non-structural. Many measures have recently been developed through landscape performance related research to more scientifically evaluate impacts and more accurately measure the effectiveness with which landscape solutions fulfil their intended purpose and contribute to sustainability. One such tool for measuring landscape performance is the National Green Values™ Calculator (Jayasooriya & Ng, 2014), a tool used in this research from Apr. 2019-May 2019 to project the performance, costs, and benefits of the green infrastructure utilized within the design.

Analytical approach

Using the scorecard method described above, we assessed League City's network of plans. From the scorecard evaluation, it appears that League City is generally supportive of environmentally-sensitive design and prioritizes increasing resilience in the study site and surrounding areas. Policies in three of the city's plans support vulnerability reduction in the site. The local hazard mitigation plan, for instance, restricts new home construction in the most flood-prone areas and supports the elevation or acquisition of properties that are repeatedly flooded. The hazard mitigation plan also has a stated goal to 'preserve, rehabilitate, and enhance natural systems to serve natural hazard mitigation functions.' This goal is echoed in the city's parks and open space plan, which includes several provisions to preserve or acquire open space, and to use that space as a (mostly passive) community amenity. However, while the preservation of current open space is a priority, additional open space provisions are not necessarily mandated. According to League City's Future Land Use Plan (2010), the city is projected to grow by more than 50% in residential development, but only by 1% in green space.

Results of the sea level rise projection show that by 2100, nearly 50% of the League City case site will be covered by the FEMA 100-year floodplain. Should a 6 feet sea level rise occur; 76% of the land on the design site will be affected, with the entire site being covered by the 500-year floodplain. Relatedly, after overlaying social and economic raster data sets in GIS to map factors contributing to flood vulnerability, the GIS output shows that more than 41% of League City has high flood vulnerability, including the entire 97-acre study site, which has the highest flood vulnerable area in the city. In regards to the catastrophic damage these conditions have had on ecosystems, nearly 96 acres of freshwater wetlands and 154 acres of wetlands in the region have been lost since 2008; the site itself has lost 43% of its wetland area in the past 20 years.

Audience targeted

There are four key benefits for flood prone communities and practitioners when integrating the aforementioned tools into a Geodesign process. First, the process allows city officials to develop new knowledge about flood related spatial conditions. Local knowledge related to current issues and desired land uses can be incorporated, while local planners simultaneously gain the ability to spatially distinguish where effective policy to reduce flood risk is already in place and which areas could be in the 100-year flood plain in the future. Second, current and new knowledge can be used as a basis for design- and planning-based decision making. Typically, economic and aesthetic concerns are the primary drivers of design-based decision making. However, the Geodesign process presented here allows for better placement of new development as well as the strategic allocation of necessary infrastructure to help protect it, all based on knowledge generated from representation, process, evaluation, and change models. Third, according to the impact models, the master plan creates a more resilient community compared to conventional development practices. The 60% reduction of the area of the 100-year flood plain due to structural and non-structural placement of flood attenuation mechanisms and the 30% runoff reduction due to green infrastructure show that resiliency is increased. Finally, the process not only allows for increases in current resiliency, but can also better prepare neighborhoods for the future impacts of sea level rise. Most modeling and projections for climate change occur ant the regional scale or larger. As demonstrated in this project, community scaled conditions can be used to proactively inform community layout, resulting in longer-term stability, reductions to future flood risks, and an increased sense of place.

Impact

As noted, borrowing from a national and international series of resilient community design cases, the design develops and incorporates a series of flood attenuation mechanisms (both structural and non-structural). Structural mechanisms include 1) an elevated highway which doubles as an integrated flood wall 2) an engineered levee which acts as a gradual and vegetated slope mimicking a natural levee, 3) a sector style gate which can close when upstream floods occur and, 4) elevated buildings which are built on stilts. Non-structural mechanisms included in the design include 1) a collection of preserved and restored wetland areas and vegetated waterfront edges acting as a riparian zone, 2) dredging locations and excavated sediment in strategic locations to store flood water which is then reused to increase the elevation of developed areas and, 3) bioswales acting as streetscape and urban plaza amenities which convey floodwaters to storage areas and allow for infiltration and filtration of stormwater. The structural and non-structural typologies are strategically applied throughout the site into the green and grey network/fabric, to protect residents and deliver valuable ecological and economic benefits.

Compared with conventional approaches, the Green Stormwater Best Management Practices of the study site design decrease the site impermeable area by 26% and capture 30.3% of the runoff volume required. Simultaneously, the study site design can capture 221,921 ft^3 of runoff, creating $419,901 in annual green benefits by reducing air pollutants and energy use, providing pollution treatment, increasing carbon dioxide sequestration, escalating the compensatory value of trees, and improving groundwater replenishment (these economic benefits reach $13,305,657 by 2100). Facilities proposed for the study site not only create economic and ecological benefits, but also create enormous cultural and social benefits. The study site design decreases the 100-year flood plain with sea level rise from 74 acres to 15 acres by the year 2100 (from 76% coverage to only 16%) and 221,921 ft^3 of runoff can be captured. Also, nearly 2,400 new residents are protected, over 3,000 jobs are created, around $23 million in physical damage is avoided, and nearly $1.3 billion are generated by life cycle benefits by 2100.

Implication of findings

The process presented here is a primarily digital (workflow-based) method of designing multi-scalar space that streamlines the analysis process directly into the design output through design concepts based on logic models developed by the designer/planner and their corresponding collaborative team. As such, there are also several limitations to this approach. First, determinants of geographic arrangement are dependent upon the identified goals of the project, the needs of the region/community, the rationale used by the design/planning team, data availability, the development of innovative technological tools/programs that address contemporary issues and the capability to operate these tools. To be relevant to the current needs of both hazards researchers and practitioners, these logic models must be based on a key issue(s) and use technology as a means for beginning the process of solving this issue. Second, success is limited by data availability, the collaborative team's knowledge of multiple topic areas and the ability to successfully operate a multitude of (sometimes difficult or time consuming) technologies. The ability to build a Geodesign team that can keep up with the rapidly changing technologies and other new and relevant tools for design and analysis is a key component to successful collaborations. Finally, the process we conducted would need to be streamlined to make it more widely available for municipal or other planning actors who do not have access to the same technical equipment and human capital. This requires a network of engaged scholars and planners who are utilizing the process and are willing to share data and provide technical assistance to cities. While cities would run their own impact models - based on their specific master plans - all other models could be provided by outside parties. However, this is most successful when there are dedicated teams that work directly with cities utilizing the process to help develop a master plan that includes meaningful engagement of community stakeholders.

Innovations

This study integrated the resilience planning scorecard, Geodesign tools, and landscape performance calculators to project current flood vulnerability, future flood plain alteration, and potential design impacts for a site in League City, TX. As part of the case study, we sought to determine how plan evaluation and landscape performance can assist Geodesign processes in improving resilience in neighborhoods experiencing high hazard exposure. The emergence of new approaches to the technoscientific blending of integrated research, geography and design (Wilson, 2014; Steinitz, 2008), makes the process presented in this paper a potentially useful method to improve decision making in support of a more resilient future. As indicated by this research, Geodesign, as a movement, is much more than a platform for utilizing GIS for spatial analysis. It can become a data- driven means of analyzing, measuring, predicting, and strategically determining the layout or layout options for geographic space, which can be supported through landscape performance metrics and resilience planning analytics. In traditional planning/design, there are an infinite number of possibilities for the future development of a space. It is the planner/designer's responsibility to determine, based on these possibilities, what the best use of the space is. Perhaps the greatest strength of the framework presented here is that it provides a quantifiable, evidence-based rationale upon which to justify design choices. The framework's ability to predict the impact of future scenarios makes it more powerful that traditional planning/design, combining GIS with other technologies while maintaining the creative aspects of the undertaking so that the role of data in decision making can be somewhat tempered. While theory and analyses can be used to reinforce design-based decision making, the creative intent of the planner/designer can counterbalance some analytical conclusions, making science the primary medium to improve and validate design decisions while still allowing for the creative process to occur.

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STORM SURGE INUNDATION & HISTORICAL HURRICANES
(SLOSH MAXIMUM OF MAXIMUMS)

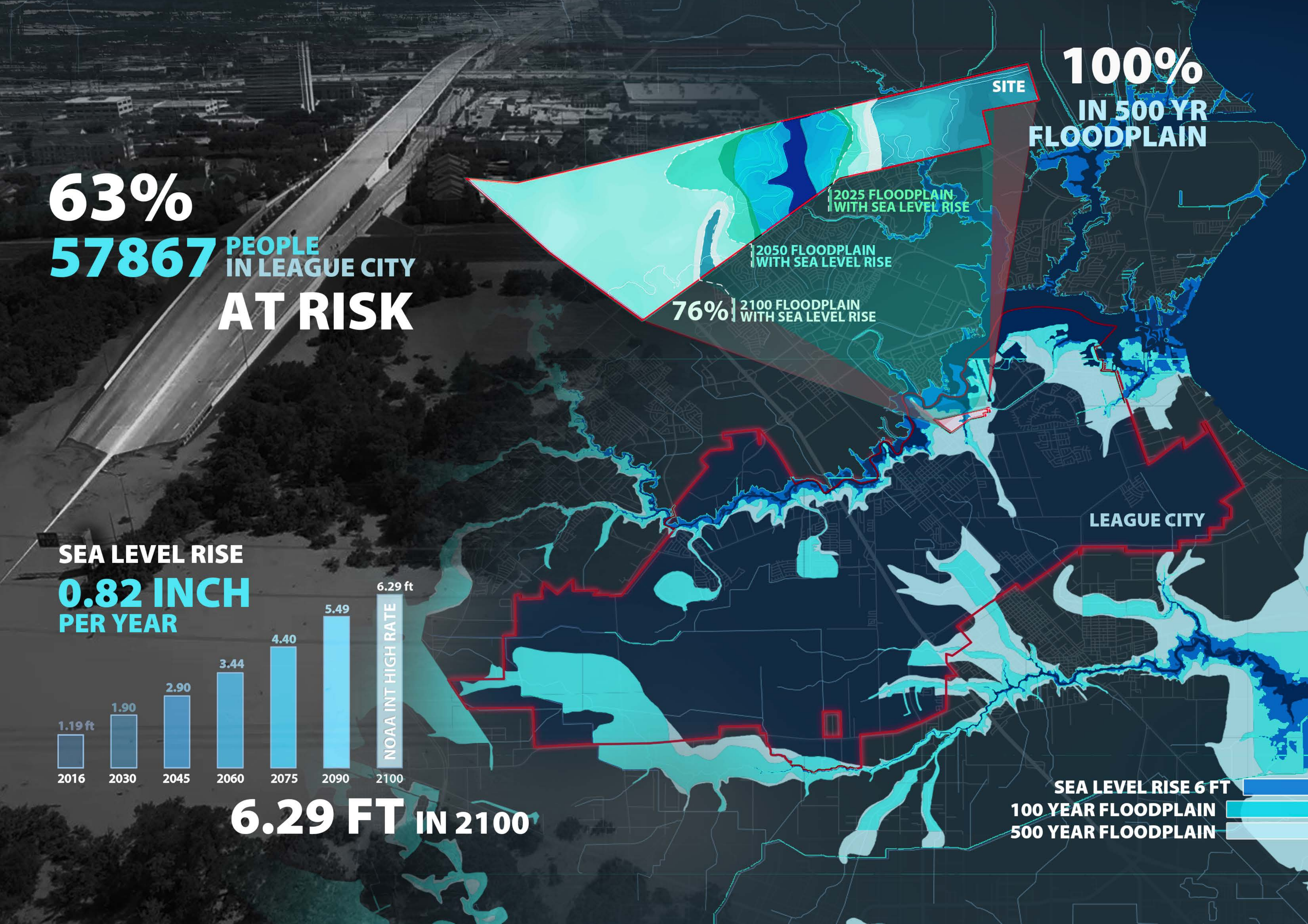
TEXAS HISTORICAL HURRICANES 1851-2014

ALONG ANY 15 MILE SEGMENT OF THE TEXAS COAST
THE FREQUENCY OF A NORMAL HURRICANE IS EVERY 5 YEARS
MAJOR HURRICANE IS EVERY 15 YEARS

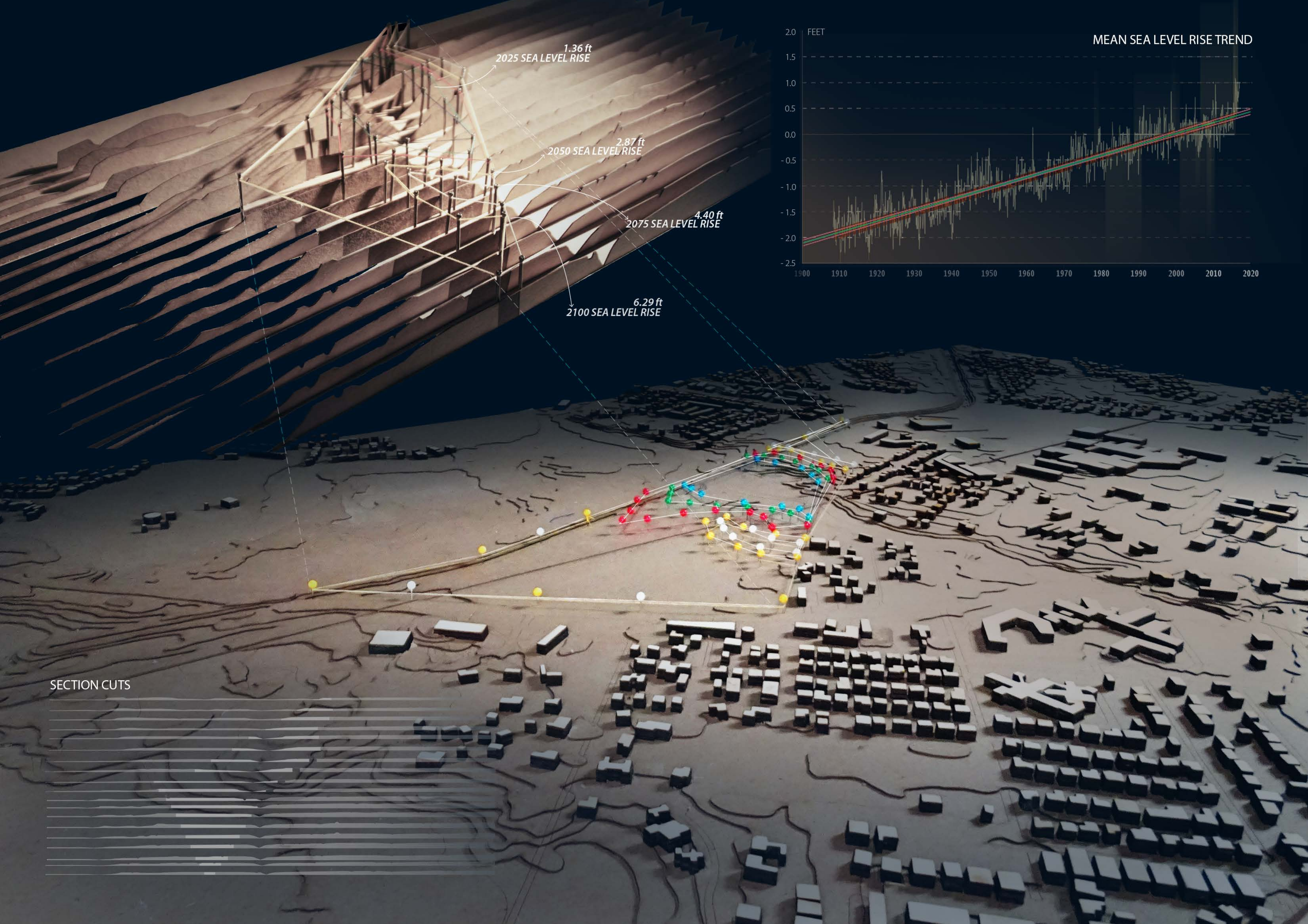
INUNDATION DEPTH

- UP TO 3' ABOVE GROUND
- GREATER THAN 3' ABOVE GROUND
- GREATER THAN 6' ABOVE GROUND
- GREATER THAN 9' ABOVE GROUND

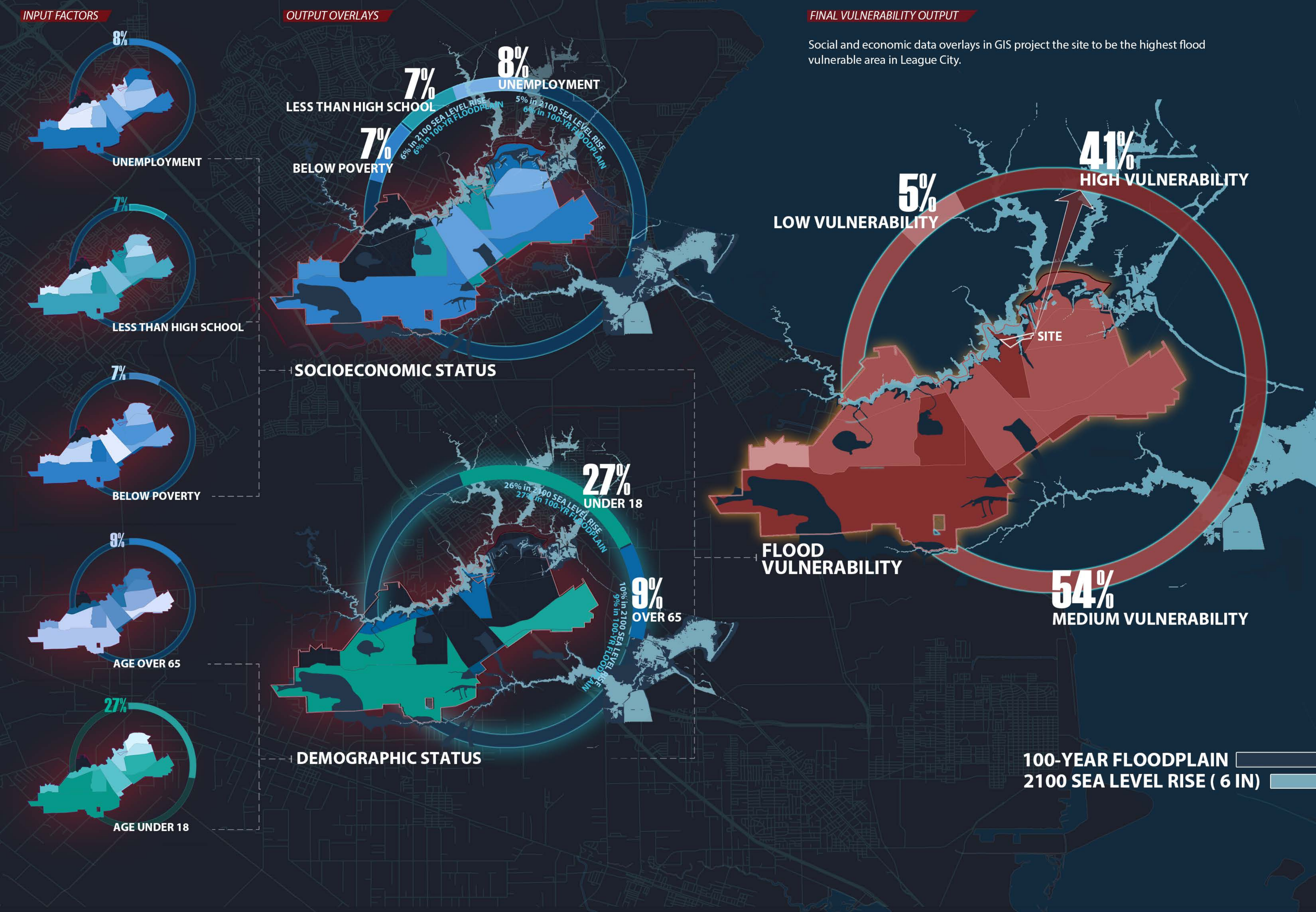
FLOOD PLAIN CHANGE (CURRENT AND WITH SEA LEVEL RISE)



SEA LEVEL RISE MODELING



FLOOD VULNERABILITY

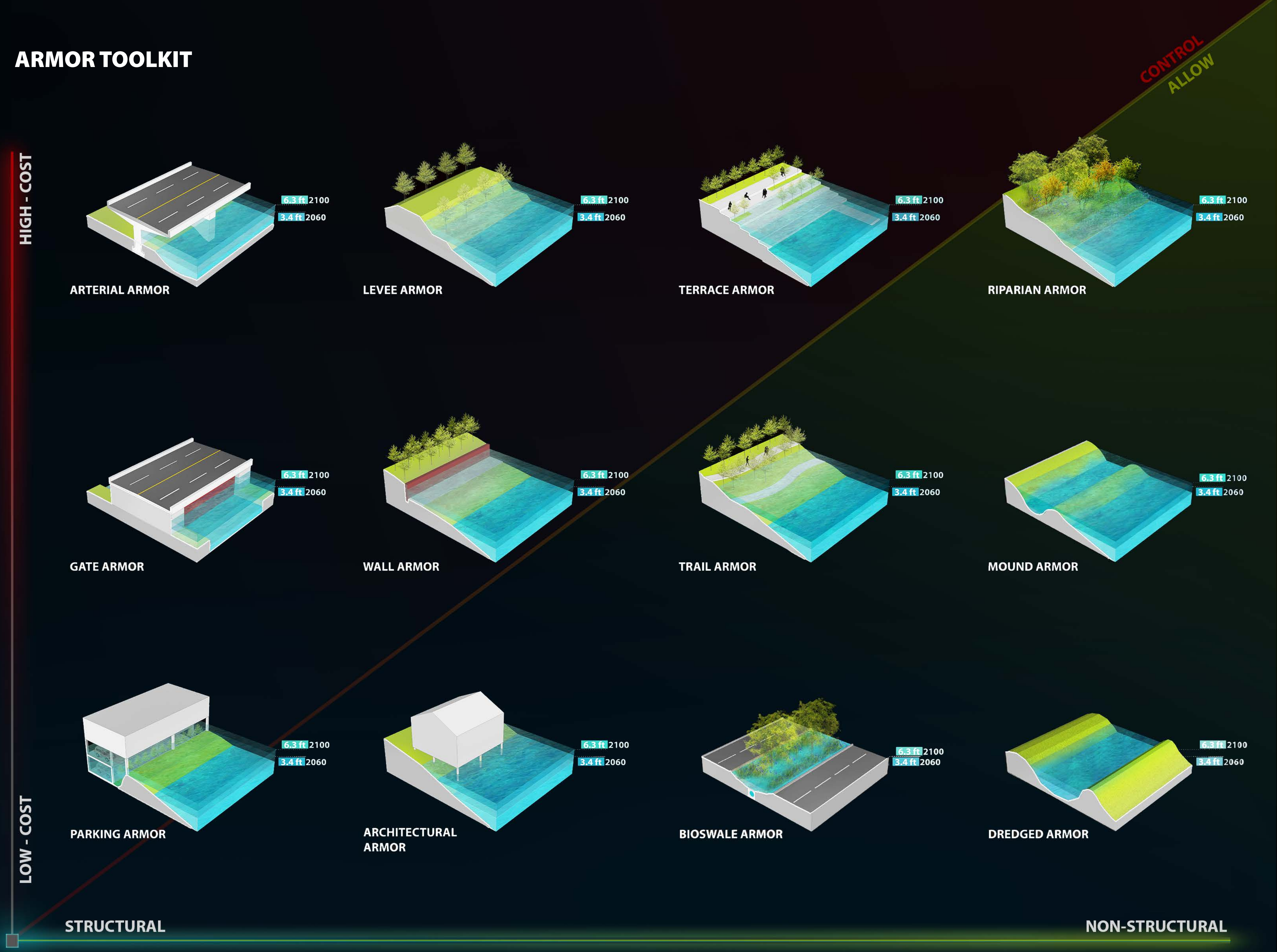


Social and economic data overlays in GIS project the site to be the highest flood vulnerable area in League City.

WETLAND CHANGE IN SITE BOUNDARY

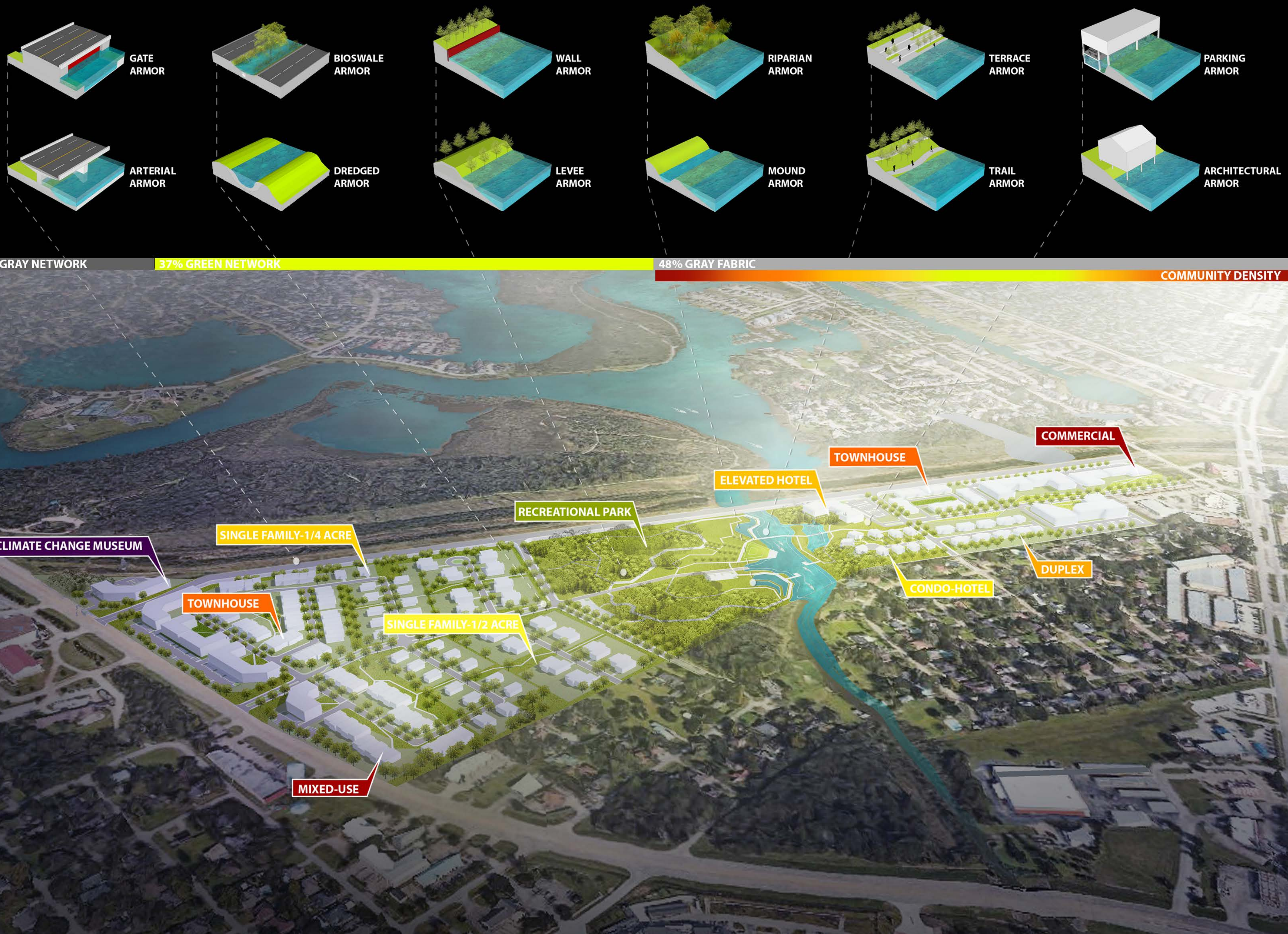
The site lost **43%** of wetland over the past 20 years.

ARMOR TOOLKIT



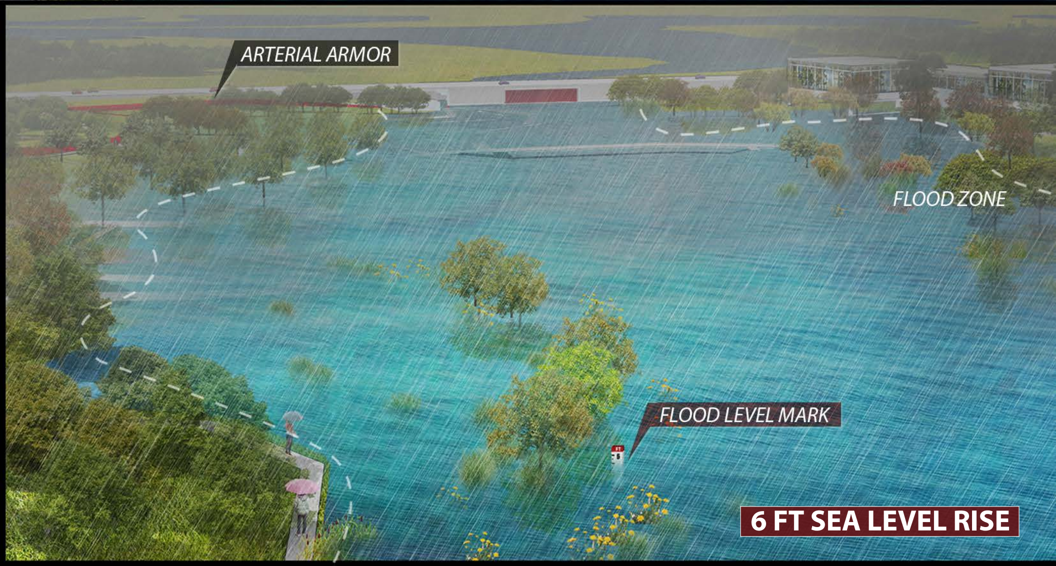
MASTER PLAN
LAND USE PERCENTAGE

ARMOR PLACEMENT



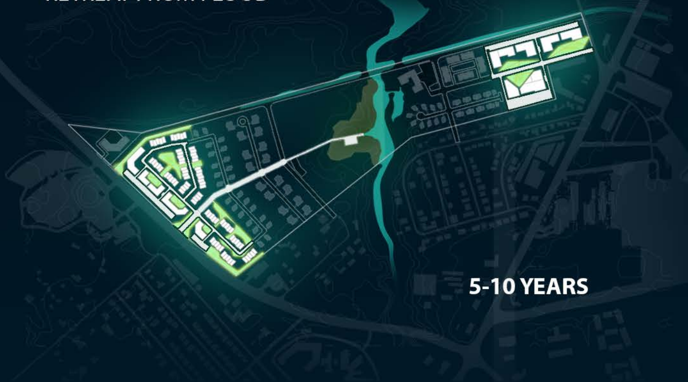

FLOOD FUNCTIONALITY
WALL ARMOR
MOUND ARMOR
ARCHITECTURE ARMOR
TERRACE ARMOR
EXPANDED CREEK EDGE
RIPARIAN ARMOR
FT
6
5
4
3
2
1
The central green space both protects the community and serves as a park with an amphitheater, recreational pier, riparian edge, hotel and other cultural amenities. A green infrastructure system is generated through strategically placed bio-swales, elevated trails and eco-levees; engineered based residential areas, commercial space, and transportation lines also act as multi-functional flood protective structures.
DRY SEASON


GATE ARMOR
BOAT LAUNCH
FLOOD ZONE
DREDGED ARMOR
100 YEAR FLOOD

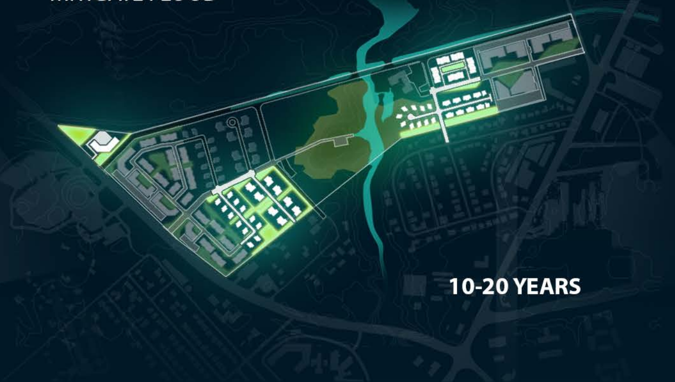

ARTERIAL ARMOR
FLOOD ZONE
FLOOD LEVEL MARK
6 FT SEA LEVEL RISE

DESIGN PHASING

PHASE 1
RETREAT FROM FLOOD

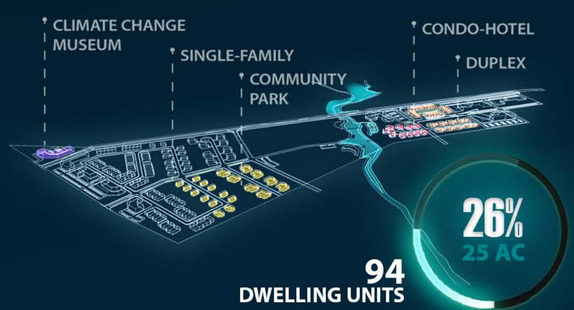


PHASE 2
MITIGATE FLOOD



PHASE 3
CONTROL FLOOD

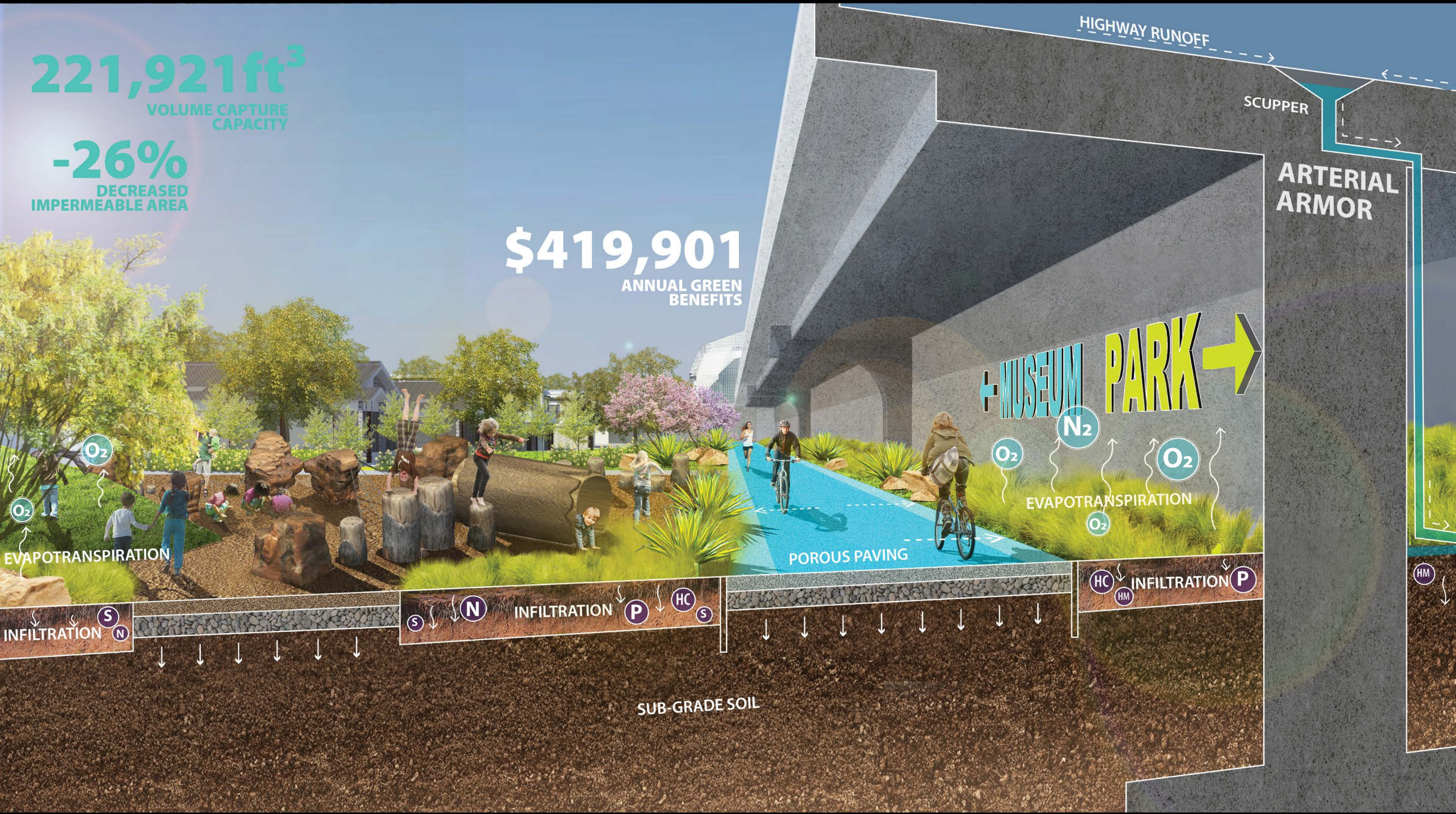
	Phase 1		Phase 2		Phase 3	
GREEN SPACE	10 ACRES	10%	9 ACRES	9%	22 ACRES	23%
GRAY FABRIC	15 ACRES	16%	13 ACRES	14%	9 ACRES	9%
GRAY NETWORK	6 ACRES	6%	3 ACRES	3%	8 ACRES	8%



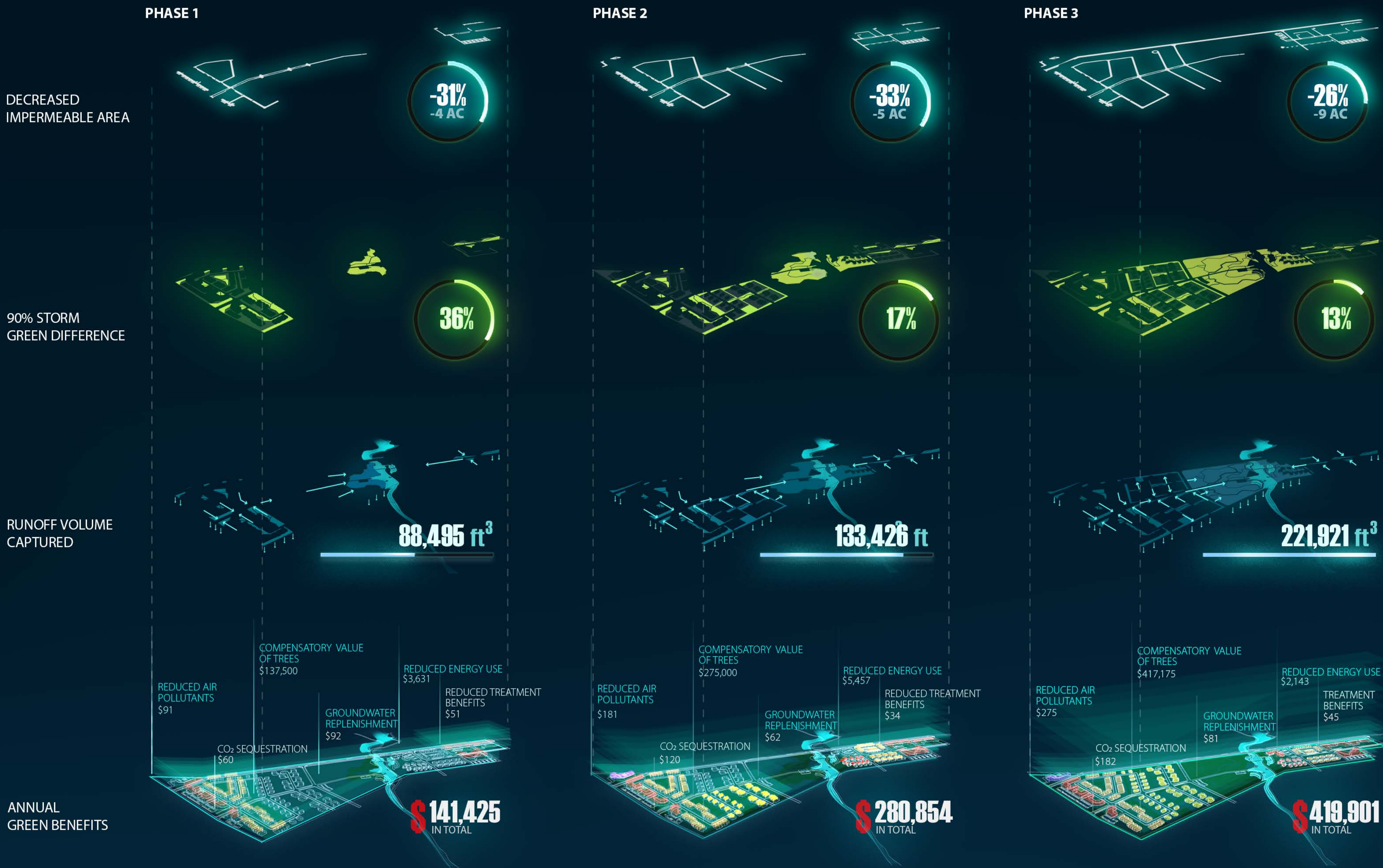
PHASE 1 - RETREAT FROM FLOOD

PHASE 2 - MITIGATE FLOOD

PHASE 3 - CONTROL FLOOD



DESIGN IMPACT CONVENTIONAL TO GREEN



The Green Stormwater BMP(s) applied in this scenario decrease the site impermeable area by **31.1%** and capture **50.8%** of the runoff volume required.

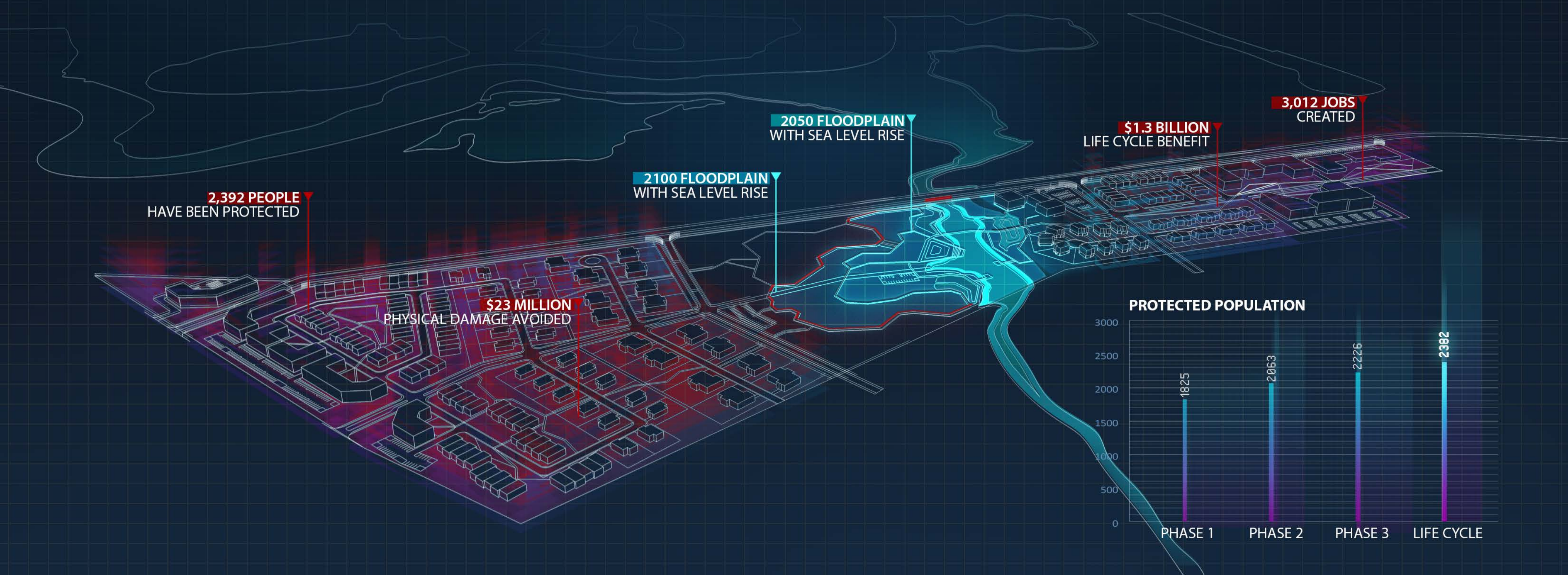
The Green Stormwater BMP(s) applied in this scenario decrease the site impermeable area by **33%** and capture **43.8%** of the runoff volume required.

The Green Stormwater BMP(s) applied in this scenario decrease the site impermeable area by **26%** and capture **30.3%** of the runoff volume required.

DESIGN IMPACT

COST ANALYSIS

BENEFIT ANALYSIS



The design decreases the flood plain with sea level rise by 2100 coverage on site from 74 acres to 15 acres, to only 16%. The National Green Values™ Calculator was used to compare the performance, costs, and benefits of Green Infrastructure (compared to conventional stormwater practices). Project cost includes building construction, gray infrastructure (streets, gates, etc.) and green infrastructure (bio-swale, parkland, etc.) costs. Total Project Benefit = Total Land Value – (Construction Cost + Maintenance Cost).