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Science-based Decision Support for Restoration and Conservation Planning in the Northern Gulf of Mexico

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INTEGRATING APPLIED RESEARCH | LINKING KNOWLEDGE TO ACTION | BUILDING PARTNERSHIPS

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List of Acronyms

Acronym	Term
ACS	American Community Survey
BAS	Best Available Science
CAMDBS	Clean Air Markets Division Business System
CCAP	Coastal Change Analysis Program
CPRA	Coastal Protection and Restoration Authority
CRDST	Coastal Resilience Decision Support Tool
CWPPRA	Coastal Wetland Planning, Protection, and Restoration Act
DEM	Digital Elevation Model
DO	Dissolved Oxygen
DOI	U.S. Department of Interior
DRR	Disaster Risk Reduction
DWH	Deepwater Horizon
EBA	Ecosystem Based Adaptation
EBM	Ecosystem-Based Management
EDDMaps	Early Detection and Distribution Mapping System
EPA	Environmental Protection Agency
ESA	Endangered Species Act
FC	Fecal coliform
FEMA	Federal Emergency Management Agency
FRS	Facility Registration Service
GAP	Gap Analysis Project
GEBF	Gulf Environment Benefit Fund
GIS	Geographic Information Systems
GOM	Gulf of Mexico
HASBOS	Harmful Algal Blooms Observing System
HUC	Hydrologic Unit Code
IBTrACS	International Best Track Archive for Climate Stewardship
ICZM	Integrated Coastal Zone Management
IIM	Integrated Island Management
IUCN	International Union for Conservation of Nature
IWRM	Integrated Water Resource Management
LULC	Land Use Land Cover
N	Nitrogen
NAS	Nonindigenous Aquatic Species
NBCD	National Biomass and Carbon Dataset
NCDC	National Climatic Data Center

Acronym	Term
NDMC	National Drought Mitigation Center
NEF	National Ecological Framework
NFHL	National Flood Hazard Layer
NFWF	National Fish and Wildlife Foundation
NHD	National Hydrography Dataset
NDMC	National Drought Mitigation Center
NIDRM	National Insect and Disease Risk Map
NLCD	National Land Cover Database
NMFS	National Marine Fisheries Services
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
NRCS	Natural Resources Conservation Service
NRDA	Natural Resource Damage Assessment
OPA	Oil Pollution Act
OSM	Oyster, Seagrass, and Mangrove
P	Phosphorus
PAD	Protected Area Domain
PDARP	Programmatic Damage Assessment and Restoration Plan
PEIS	Programmatic Environmental Impact Statement
PRISM	Parameter-elevation Regressions on Independent Slopes Model
RESTORE	Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast States
SCA	Strategic Conservation Assessment
SFHA	Special Flood Hazard Area
SPC	Storm Prediction Center
STORET	STORage and RETrieval
TF	Task Force
TIG	Trustee Implementation Group
the Institute	The Water Institute of the Gulf
TMDL	Total Maximum Daily Loads
TRI	Toxic Release Inventory
TPOC	Technical Point of Contact
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USDOC	U.S. Department of Commerce
USFS	US Forest Service
USFWS	United States Fish and Wildlife Service
USLE	Universal Soil Loss Equation

Acronym	Term
WHP	Wildfire Hazard Potential
WSIO	Watershed Index Online

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1.0 Introduction

There are currently multiple large mechanisms to support restoration and land conservation in the northern Gulf of Mexico. To ensure that environmental, societal, and financial benefits of this investment are maximized, it is essential to ensure best use of available science to inform prioritization and planning processes. While extensive research and monitoring have occurred across the northern Gulf of Mexico, they have largely addressed individual questions, been separated by governance boundaries (e.g., between states) or across agencies (federal and state), and been collected at a wide variety of spatial and temporal scales. Synthesizing data that is available across the northern Gulf of Mexico can provide context and best use of this science by informing potential threats to, and benefits from, restoration and conservation projects. This Gulfwide Initiative effort developed a decision support tool, using best available science, to provide context at a local watershed scale for potential restoration or conservation projects.

1.1. RESTORATION AND GOVERNANCE FRAMEWORK IN THE GULF

Implementation of coastal restoration in the northern Gulf of Mexico involves a large number of individuals and organizations in a complex governance framework. Decision-making power over some aspects of a restoration project resides across the entire governance spectrum from individual landowners up to U.S. federal agencies, and every level of local and state government in between. Non-government organizations, private consultants, research institutions and universities, as well as local or regional management mechanisms, also provide important input to project design, engineering and construction, project and ecosystem monitoring, and applied synthesis and research. These individuals and organizations provide support to many aspects of a project and may have decision-making power in terms of operations. Governance structures are well defined under the various protection and restoration mechanisms in Louisiana, the largest four current restoration support mechanisms being the Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast States (RESTORE) Council to restore ecosystem and economy, the Natural Resource Damage Assessment legal process (NRDA), the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) for coastal restoration, and the Gulf Environment Benefit Fund (GEBF). The Restore Council, NRDA, and GEBF are all a result of the settlement process for Deepwater Horizon Oil Spill.

1.1.1. RESTORE Council

The RESTORE Act established a new trust fund in the Treasury of the United States, known as the Gulf Coast Restoration Trust Fund (from https://www.treasury.gov) as well as the Gulf Coast Ecosystem Restoration Council (Council). The Council includes the Governors of the States of Alabama, Florida, Louisiana, Mississippi, and Texas, the Secretaries of the U.S. departments of Agriculture, the Army, Commerce, Homeland Security, and the Interior, and the Administrator of the U.S. Environmental Protection Agency (EPA). One of the primary responsibilities of the Council is to develop and implement a comprehensive plan to restore the ecosystem and economy of the Gulf Coast region (from https://restorethegulf.gov/).

1.1.2. NRDA

To fulfill the legal process related to the *Deepwater Horizon* (DWH) oil spill, the Deepwater Horizon Trustee Council was formed as a collaborative body comprised of a designated Natural Resource Trustee Official from each Deepwater Horizon Trustee (specific state agencies from all five Gulf States, Department of Commerce, Department of the Interior, Department of Agriculture, Environmental Protection Agency). The DWH Trustees are the government entities authorized under the Oil Pollution Act (OPA) to act on behalf of the public to 1) assess the natural resource injuries resulting from the 2010 DWH oil spill, and then 2) plan and implement restoration to compensate the public for those injuries. Each Gulf state has a Trustee Implementation Group (TIG), each one serving as the governing body for a Restoration Area defined in the Consent Decree (one for each Gulf State and one each for the Regionwide, the Open Ocean, and the Adaptive Management and Unknown Conditions restoration areas). TIGs are composed of individual DWH Trustee agency representatives; TIG members work together to accomplish TIG activities, including interacting with the public and stakeholders and planning for, selecting, and implementing specific restoration actions under the Programmatic Damage Assessment and Restoration Plan (PDARP) and the Programmatic Environmental Impact Statement (PEIS).

1.1.3. CWPPRA

Within Louisiana, the CWPPRA Task Force was created in 1990 as the first interagency, state/federal partnership to create, restore, enhance, and protect coastal vegetated wetlands. The Task Force (TF) is comprised of one member each, respectively, from five federal agencies and the State of Louisiana. The federal agencies of CWPPRA include the U.S. Fish & Wildlife Service (USFWS) of the Department of the Interior, the Natural Resources Conservation Service (NRCS) of the U.S. Department of Agriculture (USDA), the National Marine Fisheries Services (NMFS) of the U.S. Department of Commerce (USDOC), the EPA, and the U.S. Army Corps of Engineers (USACE) (CWPPRA, 2014).

1.1.4. GEBF

The National Fish and Wildlife Foundation (NFWF) GEBF arose from the settlement of criminal charges related to the DWH oil spill, to fund projects benefiting the natural resources of the Gulf Coast that were impacted by the spill. In Louisiana, projects focus on actions to restore barrier islands and implement river diversions. The NFWF Board of Directors has the responsibility to administer the funds and works with each of the states to identify projects to remedy harm and reduce the risk of future harm to natural resources affected by the oil spill. NFWF, on an annual basis, consults with the Louisiana Coastal and Protection Restoration Authority (CPRA), USFWS, and the National Oceanic and Atmospheric Administration (NOAA) to identify priority projects for future consideration under the GEBF (from https://www.nfwf.org/gulf/Pages/home.aspx).

1.2. SCIENCE-BASED DECISION-MAKING

Decisions are made based upon both beliefs and values, and scientific knowledge can influence beliefs through facts, expert opinion, or clarification of uncertainties. Informing or changing values is more challenging and requires specific understanding of the decision makers' values that need to be quantified appropriately, such as through monetized benefit-cost analyses (von Winterfeldt, 2013). However, it is often challenging for policymakers and resource managers to assess the validity and significance of results as well as distinguish between unbiased information, conjecture, or advocacy, in the presentation of data (Council of State Governments, 2014). The scientific process works through the development of contrasting hypotheses to explain observed events based on the available data, with a recognized (and ideally quantified) amount of uncertainty for the interpretation. In particular, uncertainty needs to be acknowledged in using this science to support policy setting and decision-making (Council of State Governments, 2014). Application of scientific knowledge into a decision process to meet multiple stakeholder objectives can be effective. One approach is the use of formal processes, including Structured Decision-Making, to develop decision frameworks and formalize a process of internal and external influences on outcomes and decision points (Dalyander et al., 2016). Structured Decision-Making is a facilitation process designed to take the best aspects of science-based, consensus-based, and economics-based management decision-making into an organized, inclusive, transparent, collaborative approach to decision-making support (Gregory, 2012). When a Structured Decision-Making process is iterative or linked over time by decision makers in a policy setting, this becomes a process of adaptive management. Adaptive management is a systematic process to incorporate new and existing knowledge into management decisions and is generally employed when management decisions are hindered by uncertainties in the system dynamics or by uncertainties in how a system might respond to management actions (Williams et al., 2009). It is a learning-based, iterative process to improve management decisions and actions, based on increasing understanding and active feedback between this learning and subsequent decision-making (Williams, 2011). Learning from past decisions and understanding the range of possible future scenarios needs to use science-based “adaptation pathways” to make decisions that allow for maximum future flexibility (Delta Alliance, 2014; Haasnoot, 2013). When fully documented, so that lessons learned from previous decisions are formally incorporated into improving future decisions, decision makers are able to assess the validity and significance of scientific data being provided and identify when targeted knowledge gaps exist, or where data synthesis to develop science-based decision support tools would be beneficial.

1.3. SELECTING AND PRIORITIZING RESTORATION PROJECTS BASED ON BEST AVAILABLE SCIENCE

Monitoring restoration effectiveness continues to be challenging, particularly assessing the off-site benefits of ecosystem-based restoration (e.g., flood risk reductions and support of commercial fisheries) (Niedowski, 2000; Ruiz-Jean and Aide, 2005). A further challenge is to develop effective approaches that link spatial scales – from assessment of individual marsh creation restoration projects to assessment of basin or landscape scale outcomes – and across locations (Neckles et al., 2013). If not addressed, these two challenges greatly limit restoration planning and decision-making. A common gap is for the ecosystem benefits and functions, as well as the potential these have for supporting ecosystem services benefiting humans, to be incompletely integrated into the planning and decision-making process of ecosystem conservation or restoration.

Historically, restoration to a historic or stable ecosystem condition was seen as achievable, however in recognition that ecosystems are highly dynamic and do not tend towards stable states, returning a restored area to the condition of an undisturbed site is widely recognized as unrealistic (Wyant et al., 1995). Desirable restoration outcomes should be defined through identification of desirable ecological and social functions and services that work towards a self-sustaining (if dynamic) ecosystem. These benefits will necessarily require tradeoffs and therefore require management goals and/or community engagement to prioritize relative benefits (Wyant et al., 1995). Motivations for restoration are highly variable, including biodiversity enhancement and ecosystem service provision, such as improved water quality for consumption or recreation. Alignment of the motivation for restoration with planning and monitoring improves prioritization of projects and establishment of realistic expectations amongst stakeholders and implementing mechanisms (Hagger et al., 2017). Trade-offs to prioritize projects based upon the most important ecosystem attribute (for example, wetland vegetation biomass, biodiversity, water quality, nutrient runoff) and the length of time required for potential outcomes to be achieved, will maximize likelihood of meeting programmatic goals (Shoo et al., 2017).

1.4. INTEGRATED ASSESSMENTS

For multiple coastal ecosystems there have been many related efforts to implement integrated management to maximize both ecosystem and community benefits. From both a policy and restoration management implementation perspective however, the important similarities are not always recognized by policy makers (Aswani et al., 2012). These efforts include Ecosystem-Based Management (EBM), Integrated Coastal Zone Management (ICZM), Integrated Water Resource Management (IWRM), and, specifically in response to climate change, Ecosystem-Based Adaptation (EBA) and Disaster Risk Reduction (DRR) (Hills et al., 2013; Mercer, 2010). Principles for a more holistic approach of Integrated Island Management (IIM) has additionally been proposed to ensure co-benefits through increased resilience of socio-ecological systems (Jupiter et al., 2014), as well as how to include aspects of the physical, ecological, economic, social, and governance context into a decision-making framework (Glaser et al., 2018). One decision support tool that was developed to inform an assessment of relative benefits of 65 restoration projects in southern New England, USA, was based around ecosystem services categorized as flood risk, scenic views, education, recreation, bird watching, social equity, and reliability (Martin et al., 2018). That study solely focused on possible ecosystem services that could potentially be realized by surrounding communities and did not include potential ecosystem threats to the sites nor potentially supported ecosystem functions within a watershed context. A successful framework to provide science support to ecosystem management decision-making should be 1) simple and readily understood, 2) use an experimental approach, 3) be strategic and able to evolve, 4) be appropriate for the local context, and 5) be multi-disciplinary (Aswani et al., 2012). The aim of the current effort was to develop a decision support tool for conservation and restoration projects across the northern Gulf of Mexico that would support a decision-making process and meet these five goals.

1.5. PREVIOUS DATA SYNTHESIS FOR DECISION SUPPORT IN THE GULF OF MEXICO

Synthesis of available data is essential to guide restoration efforts in the Gulf of Mexico, including to inform program management on best deployment of resources and to move beyond numerous uncoordinated small scale restoration efforts that do not regain or retain large scale ecosystem functions (Committee on Effective Approaches for Monitoring and Assessing Gulf of Mexico Restoration Activities et al., 2017; Manning et al., 2006; NASM, 2017). With the goal of improving management, restoration planning and evaluation, damage assessment and recovery, and ecosystem health assessment, ecosystem integrity and ecosystem service metrics have been identified for five key ecosystems in the northern Gulf of Mexico. These are salt marsh, mangrove, seagrass, oyster reef, and coral (Goodin et al., 2018). One project on the development of metrics and the Coastal Resilience Decision Support Tool (CRDST) aimed to provide an approach for coordinating future monitoring. That effort specifically recognized that a major impediment to attaining maximum return on investment from restoration efforts in the Northern Gulf of Mexico has been the challenge of collecting, aggregating, and sharing data on ecologically appropriate metrics (Goodin et al., 2018). Other efforts have specifically looked at threats to the 196 U.S. estuaries with respect to fish habitat, categorizing data by land cover, river flow, pollution, and eutrophication (Greene et al., 2015).

1.6. SYNERGISTIC OPPORTUNITY

This Gulfwide Initiative was initiated by leveraging three individual projects and different funding mechanisms to support the best available science for ecosystem conservation, restoration planning, and decision-making. This report summarizes a Gulfwide Initiative approach, methods and example results, and therefore combines all three of the individual projects throughout. Individual outputs specific to the separate projects were delivered as required within the scope of work for those efforts.

1.6.1. RESTORE Council

The first project was funded by the RESTORE Council to identify and collate data sets from across the northern Gulf of Mexico related to potential ecosystem threats (ecosystem stressors), potential ecosystem benefits (ecosystem services), and potential community benefits (human wellbeing metrics) that are relevant to potential conservation or restoration projects. The project identified and developed uniform Geographic Information System (GIS) data layers for 26 primary ecosystem threats layers (summarized into eight categories), a habitat description combined 19 individual ecosystem benefits data layers, and 11 primary community wellbeing metrics (summarized into two categories). These data were summarized into broad categories of threat, two community benefits layers, and then into three overall summary layers of 1) ecosystem threats, 2) ecosystem benefits, and 3) community wellbeing.

1.6.2. Texas Parks and Wildlife Foundation

The second project was funded by Texas Parks and Wildlife Foundation and focused on scientific data available to inform selection of projects for funding through a proposed Gulfwide Conservation and Restoration Fund. That fund is proposed as a bridging fund to provide an alternative to multiple, short-term, and small-scale restoration projects by promoting large and long-term restoration projects and maximize benefits from available restoration investments. The decision support tool will be adapted for informing project selection.

1.6.3. US Endowment for Forestry and Communities

The third project was funded by U.S. Endowment for Forestry and Communities to develop a decision support tool to inform decision-making around the prioritization of forestry conservation and restoration project investments. For a specific project, or suite of projects, the output was a description of each project and a summary for the local watershed (hydrologic unit code [HUC] 12) surrounding the project of the ecosystem threats, ecosystem benefits, and community wellbeing relevant to project implementation.

2.0 Methods and Approach

2.1. APPROACH

To develop the restoration and conservation decision support tool, the initial step was to identify available spatial data layers that were consistent across the Gulf of Mexico by compiling data between years and data sets. To goal of the application of this tool was to provide information about 1) potential ecosystem threats at a potential project site, 2) potential ecosystem functions supported by the project, and 3) potential community wellbeing benefits of a project. Over 60 primary data layers were developed, categorized into eight threat categories, five ecosystem benefits categories, and two community wellbeing categories. Data were converted to a uniform 1 km^2 hexagon grid surface and were primarily summarized at the local watershed (HUC 12) scale immediately surrounding the project. The HUC 12 containing the project was scored relative to varying spatial scales, 1) all the other small watersheds (HUC 12s) in the regional watershed (HUC 6), 2) in the ecoregion containing the project, and 3) across the defined boundary region across the northern Gulf of Mexico coast (Gulfwide).

A project may have high relative benefit within the regional watershed and ecoregion, but be of low overall relative benefit when compared at a Gulfwide scale. This allows the tool to be applied across a variety of implementing mechanisms, with different geographic scope and goals. If possible alternate futures for the site with and without project (such as retention of wetland versus urban development) are known, then the local watershed (HUC 12) can be scored with and without project implementation. The tool does not calculate direct comparisons between projects. However the compiled and separate data for each site can be provided to the end user both fully synthesized or broken into the 11 groupings of variables, as needed. The output from this effort was a data synthesis tool to inform project selection and planning by providing relative measures for the small watershed containing a potential project with the goal of defining the potential 1) ecosystem threats to the site, 2) ecosystem benefits, and 3) community benefits.

The following sections introduce the data collection and classification of each of the three measures – potential ecosystem threats (2.2.2), potential ecosystem benefits (2.2.3), and potential community wellbeing (2.2.4) – before providing more detail about each measure's specific metrics (sections 2.3, 2.4, and 2.5). The development of an application form for the decision support tool is described in 2.7 , and this is followed by a description of how the decision support tool processes selected metrics for proposed projects (2.8).

2.2. DATA COLLECTION AND CLASSIFICATION

Subject matter experts from Alabama, Florida, Louisiana, Mississippi, and Texas, identified through recommendations from each of the RESTORE Act Centers of Excellence, were engaged using best available science (BAS) to highlight the location and severity of known or emerging threats. They then discussed how these were related to essential ecological services in addition to community benefits. The Water Institute of The Gulf (the Institute) coordinated with identified Technical Points of Contact (TPOCs) and other partners around the Gulf to carry out a collaborative literature survey identifying previous work assessing ecosystem threats, ecosystem services, and community benefits at large spatial scales, or integrated efforts at smaller spatial scales within the Gulf of Mexico. All information was sourced from peer reviewed published literature, publicly available government reports or data summaries. These were used to identify key threats, services, or community wellbeing benefits to the Gulf ecosystems.

In the process of developing the map extent (domain), each state partner provided input on the overall extent, as well as appropriate ways to subdivide the geographic extent, for example watersheds or ecoregions. For the overall extent, the two primary boundaries discussed were the Coastal Zone Management area with a buffer of 25 miles for the five Gulf states. The other boundary was the NOAA Gulf states' coastal counties in order to best accommodate the social and census data. Within the overall boundary some potential ways discussed with state partners to divide the data were: ecoregions, various HUC levels (most commonly HUC 6, HUC 8 and HUC 12), and even smaller areas to accommodate a smaller project scale size.

2.2.1. Habitat Layers

An extensive list of habitat layers (19; Table 1) was compiled to help illustrate areas where there is high potential for ecosystem service provision (i.e., ecosystem benefits), as well as to provide ecosystem context for proposed projects (Landers and Nahlik, 2013). At a local scale, a detailed understanding of the habitat can be used to determine localized ecosystem benefits (Landers and Nahlik, 2013). However, at the broader Gulfwide scale, linkages *directly* to ecosystem services were not possible with available data, therefore the habitat types were used as indicative of *potential* services from a project area. Not all of these data layers were used to inform potential benefits of any particular project, rather the most relevant data to the specific project type was incorporated into the decision support tool. The example used within this report is for a forestry project at McNeil, Texas, so layers able to inform potential ecosystem benefits from forest conservation and management are highlighted. The habitat layers include LULC, forestry, wetlands, lithology (geology), aquatic environments, such as oyster/seagrass/mangrove, rivers/streams, lakes/ponds, protected areas, parks, historical objects/structures/buildings/districts, beaches, and critical habitat for endangered species.

The process for creating each detailed habitat layer in a simplified manner was based upon determining the largest area or length of each attribute within a hexagon grid and ascribing it to that hexagon grid. For example, there can be multiple LULC layers within a hexagon, but if cropland was the dominant layer as determined by shape area, then the grid was coded as cropland. This process was replicated for all described attributes at the 1 km^2 hexagon grid scale with the exception of historical objects/districts/structures/buildings. Those attributes were only described by an absence or presence value. For example, if any of the historical attributes were found to be within a hexagon grid, the grid was coded as "present" or "1" regardless of the number of historic sites. At the 100 km^2 level, the NOAA Gulf coast features (mangroves, oysters, and seagrass) were determined by absence or presence in addition to the historical attribute fields.

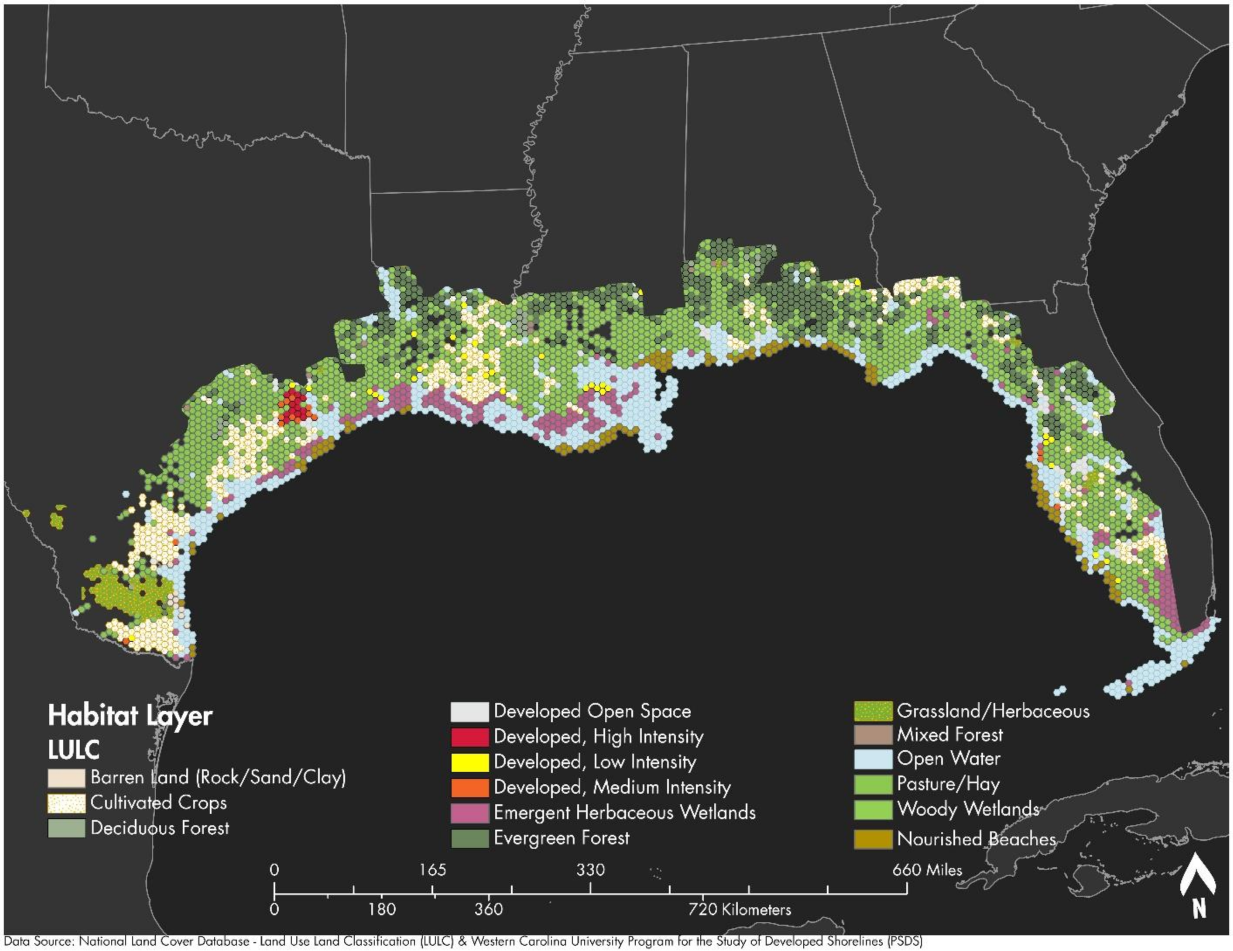
The habitat layer provides context for a potential project', including ecosystem threats, ecosystem benefits, and community benefits. This layer was developed as 19 categories of habitat, each of which comprised multiple data sets and data types (Table 1). The habitat categories either had a specific habitat type listed for a hexagon, or "NA" where no specific habitat was available or relevant. In general, for the 1 km^2 and 100 km^2 habitat maps, presence of each of the 19 categories of habitat was calculated based on the most abundant subset of data within each of the broad 19 categories. This resulted in 19 total maps for the northern Gulf Coast at each of the two hexagon grid scales (example of LULC layer in Figure 1). One exception was determination of the dominant Oyster, Seagrass, or Mangrove (OSM) habitat type. In the 1 km^2 layer, OSM was identified and the relative area of each was compared to determine the dominant habitat type. For the 100 km^2, only absence or presence of OSM was determined.

The water habitat layer was sourced from the National Hydrography Dataset (NHD), and the state geodatabases were a mixture of polygons and polylines. This meant the query per hexagon was the largest area for the polygon or the longest length for the polyline. Both the polygon or polyline name and feature type were also included if they were initially recorded in the NHD dataset. Where possible the name of the river or stream was associated to the data feature. The same process was used on the Endangered Species Act (ESA) Critical Habitat data. Due to critical habitat also being both polyline and polygon, dominant line length or dominant shape area were used to classify a hexagon grid.

Table 1. A list of sub-layers which make up the habitat layer

Data type	Map	Entity	Website	Date Range
Beach Nourishment	1	Western Carolina University	http://http://beachnourishment.wcu.edu/	1991 - 2016
Land Use Land Classification (NLCD)	1	USGS	https://viewer.nationalmap.gov/advanced-viewer/ Presented in Figure xx	2011
Seagrass	2	NOAA	https://www.ncddc.noaa.gov/approved_recs/goma/texas_am/hri/gomaeia/GOMA_	2004
Oyster	2	NOAA	https://www.ncddc.noaa.gov/approved_recs/goma/texas_am/hri/gomaeia/GOMA_ EIA_PIT/Texas/Habitat/habitat/HB_00_habitat_sediments_gis_soultions_2004.xml	2004
Mangrove	2	NOAA	https://www.ncddc.noaa.gov/approved_recs/goma/texas_am/hri/gomaeia/GOMA_EIA_PIT/Texas /Habitat/habitat/HB_00_habitat_sediments_gis_soultions_2004.xml	2004
Historical Objects	3	NPS	https://www.nps.gov/maps/full.html?mapId=7ad17cc9-b808-4ff8-a2f9-a99909164466	2017
Historical Districts	3	NPS	https://www.nps.gov/maps/full.html?mapId=7ad17cc9-b808-4ff8-a2f9-a99909164466	2017
Historical Structures	3	NPS	https://www.nps.gov/maps/full.html?mapId=7ad17cc9-b808-4ff8-a2f9-a99909164466	2017
Historical Buildings	3	NPS	https://www.nps.gov/maps/full.html?mapId=7ad17cc9-b808-4ff8-a2f9-a99909164466	2017
Parks	3	NPS, ESRI USA Parks dataset	https://public-nps.opendata.arcgis.com/, ArcPRO Living Atlas	2017
Endangered Species Critical Habitat - Polyline	4	ESA - USFS	https://ecos.fws.gov/ecp/report/table/critical-habitat.html	1977-2019

Data type	Map	Entity	Website	Date Range
Endangered Species Critical Habitat - Polygon	4	ESA - USFS	https://ecos.fws.gov/ecp/report/table/critical-habitat.html	1977-2019
IUCN	5	USGS	https://www.usgs.gov/core-science-systems/science-analytics-and-synthesis/gap/science/pad-us-data-download?qt-science_center_objects=0#qt-science_center_objects	2015-2016
National Hydrography Dataset – Polygon	6	USGS	https://www.usgs.gov/core-science-systems/ngp/national-hydrography/national-hydrography-dataset?qt-science_support_page_related_con=0#qt-science_support_page_related_con	2002-2018
National Hydrography Dataset – Polyline	6	USGS	https://www.usgs.gov/core-science-systems/ngp/national-hydrography/national-hydrography-dataset?qt-science_support_page_related_con=0#qt-science_support_page_related_con	2002-2018
Parent Geology	7	USGS	https://mrdata.usgs.gov/geology/state/state.php?state=	2005
Forestry Class	8	USFS	ArcPro Living Atlas – USA Forestry	2008
National Wetlands Inventory	9	USFS	https://www.fws.gov/wetlands/	1979-2017
Offshore Bottom Type	10	NOAA	https://www.ncddc.noaa.gov/approved_recs/goma/texas_am/hri/gomaeia/GOMA_EIA_PIT/Texas/Habitat/habitat/HB_00_habitat_sediments_gis_soultions_2004.xml	2004



Data Source: National Land Cover Database - Land Use Land Classification (LULC) & Western Carolina University Program for the Study of Developed Shorelines (PSDS)

Figure 1. The 100 km^2 habitat layer Land Use Land Cover (LULC) habitat category (Map # 1)

2.2.2. Potential Ecosystem Threats Layers

A detailed series of potential ecosystem threat layers were developed to illustrate the wide spatial range of threats and the variation between types of stress.

The overall threat categories identified were:

1) Human population (three metrics)
2) Infrastructure (seven metrics)
3) Land change (five metrics)
4) Pollution (four metrics)
5) Gulf of Mexico (GOM) water quality (one metric)
6) River/estuary water quality (eight metrics)
7) Environmental hazards (eight metrics)
8) Invasive species (six metrics)

Geospatial Data Variables in Vector Format

The *vector*-based data sources were classified based on a threat's presence or absence within the 1 km^2 and 100 km^2 hexagon tessellation grids covering the northern Gulf of Mexico counties in the states of Alabama, Florida, Georgia, Louisiana, Mississippi, and Texas. Boolean values (0 or 1) indicate the presence (1) or absence (0) of an identified threat. Boolean values were used to simplify the data set by providing formatting uniformity among the threats.

Geospatial data variables obtained in a *vector* format by threat category included the following:

- **Human Population**: power plants;
- **Infrastructure**: pipelines, shipping lanes, offshore platforms, ports, hazardous facilities, dams;
- **Land Change**: sea level rise (3 ft), fault zones, land type change (natural to urban and natural to agricultural);
- **Pollution**: historic oil spills, point source pollution, landfill locations, brownfield and superfund sites;
- **GOM Water Quality**: hypoxia;
- **Riverine/Estuarine Water Quality**: dissolved oxygen, nitrogen, phosphorous, pH, fecal coliform, non-point source pollution, impaired streams, impaired water bodies
- **Environmental Hazard**: hurricane landfall intensity, tornado, drought, flood hazard, wildfire hazard potential, harmful algal blooms
- **Invasive Species**: Aquatic fauna, insects, submerged aquatic vegetation, terrestrial flora, terrestrial fauna, forestry risk (all species were isolated from vector format source data)

Geospatial Data Variables in Raster Format

The *raster*-based data sources were classified as present or absent based on zonal statistics operations comparing a unique cell's average threat value with the average of that value across all coastal county cells. This assignment was done for the 1 and 100 km^2 square kilometer hexagon tessellation grids. Cells with higher than average values (compared to the NOAA coastal counties average) for development risk, light pollution, impervious surface, soil erodibility, rainfall, and maximum air temperature were assigned a value of 1, while any below these average values were assigned a value of 0. Correspondingly, cells with lower than average values for minimum temperature were assigned a value of 1 (indicating stress due to lower than average temperature), while any above these average values would be assigned a value of 0.

Geospatial data variables obtained in a *raster* format by threat category included:

- **Human Population**: development risk, light pollution;
- **Infrastructure**: impervious surface;
- **Land Change**: soil erodibility;
- **Pollution**: none;
- **GOM Water Quality**: none;
- **Riverine/Estuarine Water Quality**: none;
- **Environmental Hazard**: rainfall, maximum and minimum air temperature;
- **Invasive Species**: none

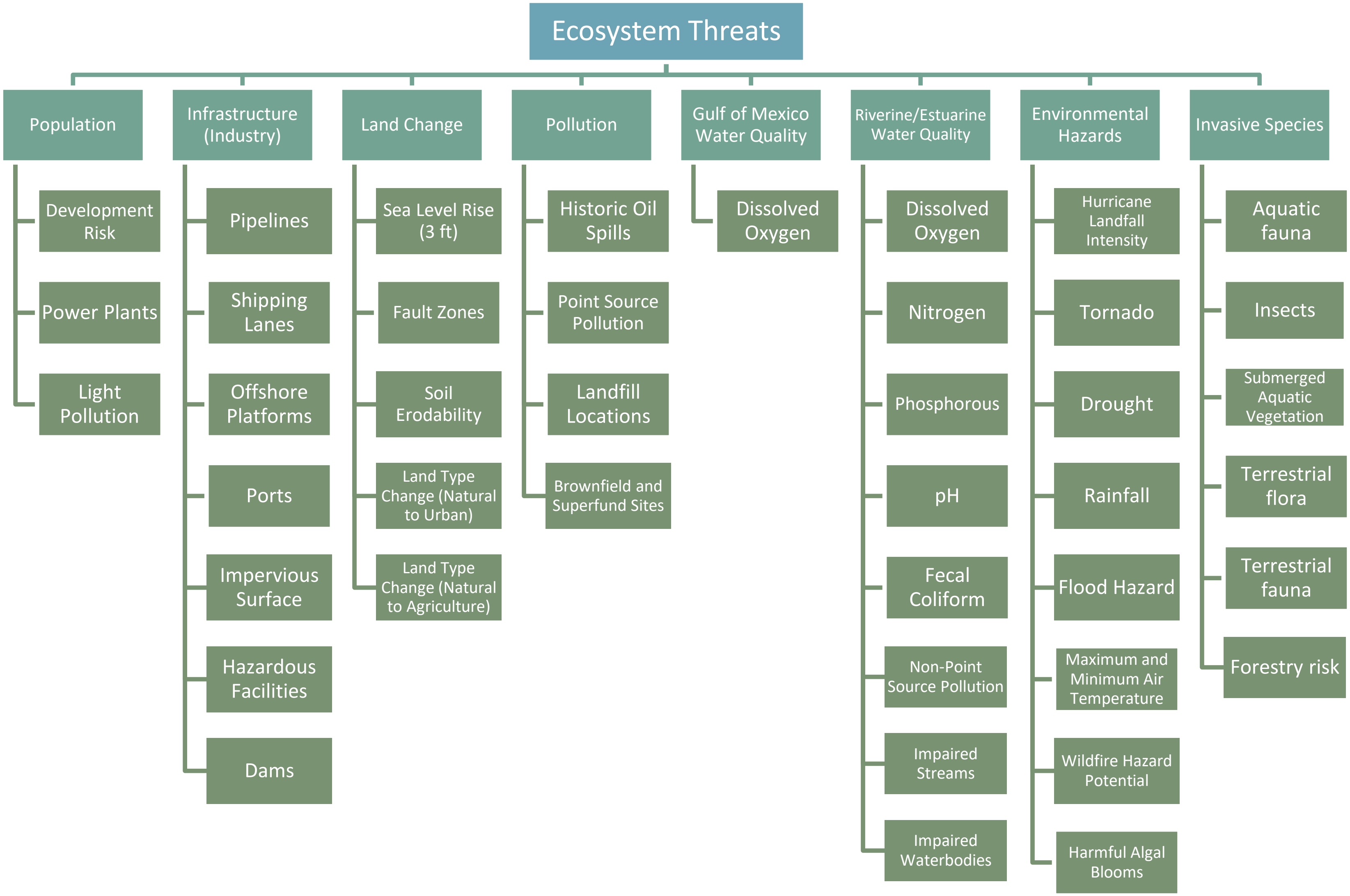


Figure 2. Diagram of the drivers for the ecosystem threats GIS layer showing the group category on the top row with the individual data sets utilized beneath

2.2.3. Potential Ecosystem Benefits Layers

Directly quantifying potential ecosystem benefits at a project scale is indicative only with low resolution data from Gulf wide data layers, the developed approach made best use of available data while recognizing the confidence level was based upon the reliability and resolution of the source data. One benefit of using the decision support tool is that it can provide a basis and framework for setting up project monitoring plans to assess realized project outcomes. The habitat layer (described in 2.2.1) can be used to help identify potential ecosystem benefits. The 19 layers within the habitat layer can be used in the future to help quantity ecosystem benefits by assessing/evaluating presence/absence of beneficial habitat type for a given ecosystem service/function.

Ecosystem Benefits Metrics

In addition to the data summarized into the overall habitat layer, five metrics of highest relevance to a forestry project were chosen for more detailed analysis of potential ecosystem benefits.

These were:

- Total carbon storage
- Habitat connectivity
- Priority habitats index
- Groundwater recharge potential
- Canopy cover

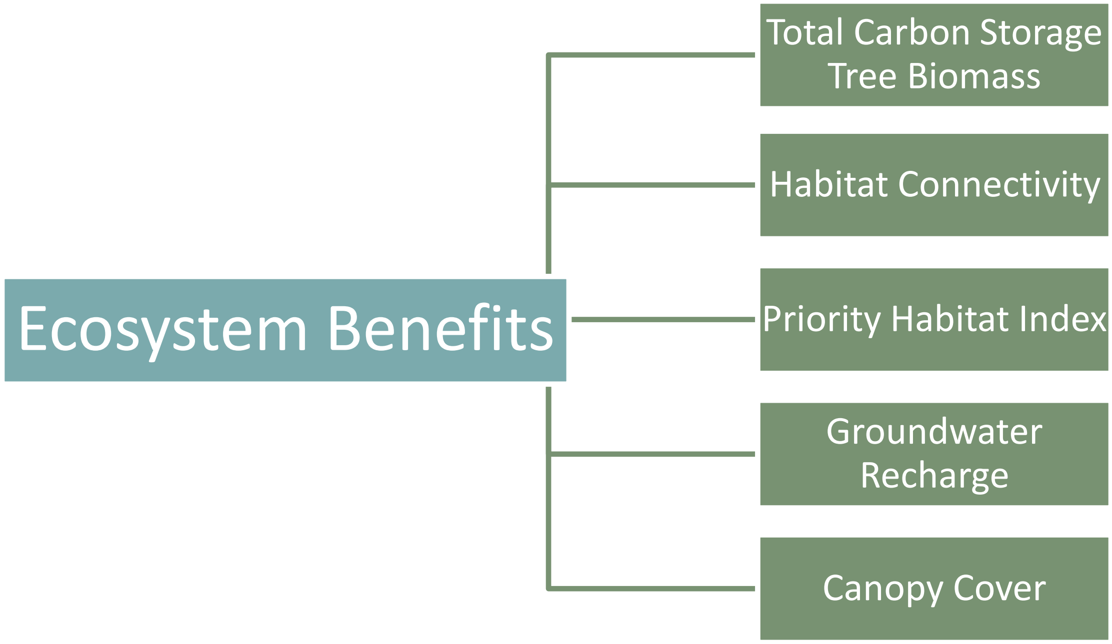


Figure 3. Diagram of the five additional potential ecosystem benefits metrics

2.2.4. Potential Community Benefits Layers

Community benefits data included metrics related to general community wellbeing and ecological functions. Figure 4 shows the structure of how this community benefits layer was created.

Related to General Wellbeing

The metrics related to general wellbeing were:

- Population density
- Income Inequality
- Home ownership
- Per Capita income
- Educational attainment
- Chronic disease prevalence (obesity, diabetes, and cancer incidence)
- Healthy behaviors (the propensity of individuals to engage in physical leisure activities)
- Poverty

Related to Ecological Functions

The metrics related to ecological functions were:

- Employment in renewable natural resource industries (agriculture, forestry, and fishing)
- Population proximity to recreational greenspaces, wetlands, parks, and beaches

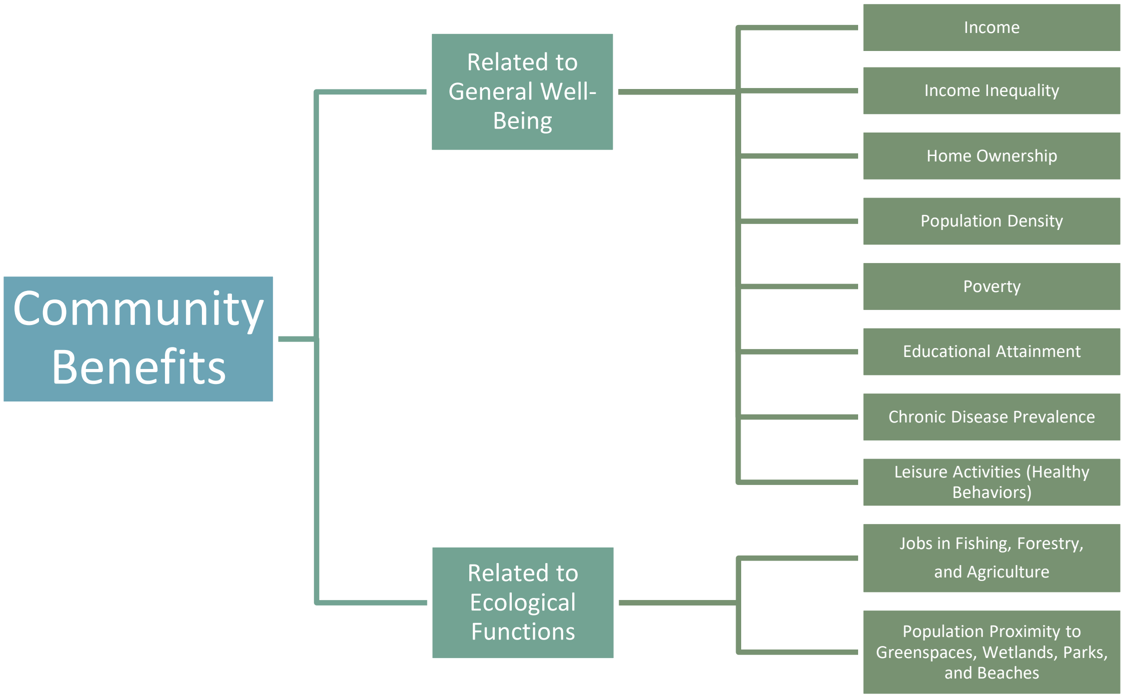


Figure 4. Community benefits data layer components and broader categories

The community benefits data were derived from the U.S. Census Bureau's American Community Survey (ACS) 5-year reports, the Centers for Disease Control and Prevention, and the National Park Service. Data were used for the most recently available time period, between the years of 2013 and 2017. These data were summarized at the U.S. Census-designated block group level. Due to concerns over disclosure of personal data, some of the data were only available at county or census tract levels. In these cases, the data were spatially joined to the block group level in order to calculate overall community benefits scores.

2.3. DEFINING METRICS: POTENTIAL ECOSYSTEM THREATS

2.3.1. Population

The population layers (Table 2) are the human components that have potential direct or indirect links to environmental threats. The location and prevalence of development risk, power plants, and light pollution are directly tied to potential impacts of human population development and increasing human population density.

Development Risk

Population development relates to landscape changes by alteration of hydrology, fragmentation of natural wildlife habitat, and direct removal of habitat. Population development risk also includes infrastructure improvement operations such as road building, and development of power generation, sewage, and water supply infrastructure. The USA Development Risk variable, used in this analysis (Table 2), is a projective outlook detailing the likelihood of the land surface to be impacted by human development activities through the year 2030 created at Colorado State University's Natural Resources Ecology Lab in 2007.

Power Plants

The location and prevalence of power plants is driven by human population development and increasing human population density. Water used to help in cooling, gaseous emissions, and potential for chemical or fuel leaks all have potential for local ecological threat (Madden et al., 2013).

Light Pollution

Light pollution is an increasingly pervasive form of anthropogenic environmental alteration and more than 99% of U.S. residents (80% globally) experience some form of light pollution (Falchi et al., 2016). The prevalence and density of artificial lights result in raised sky luminance during nighttime, astronomical light pollution (reduced ability to view stars), and ecological light pollution (affecting wildlife and wildlife behavior) (Longcore and Rich, 2004). Sixty percent of the population in the lower 48 states have insufficient nighttime darkness to fully transition to nighttime vision, a physiological change where the human eye changes from cone to rod vision (Longcore and Rich, 2004). Nocturnal and crepuscular species, roughly half of all organisms, are directly impacted by artificial light capable of exposing them to predator species. Additionally, the disruption of circadian rhythms caused by exposure to light at night is associated with an increased risk of cancer in shift workers (Stevens et al., 2007).

Table 2. A list of sub-layers that make up the population threat layer

Population			
Layer	**Entity**	**Website**	**Date Range**
Development Risk	Colorado State University	https://landscape.blm.gov/COP_2010_metadata/COP_Urban_Growth_2030.xml	2008-2030
Power Plants	US Energy Information Administration	https://www.eia.gov/maps/	2017
Light Pollution	Cooperative Institute for Research in Environmental Sciences (CIRES), NOAA	https://cires.colorado.edu/Artificial-light	2016

2.3.2. Infrastructure

The infrastructure layers (Table 3) were based upon oil and gas industrial infrastructure and compiled to show both onshore and offshore areas of high density infrastructure.

Pipelines, Offshore Platforms, Ports, and Hazardous Facilities

While the majority of production (extraction) of oil and gas occurs offshore in the Gulf of Mexico, processing requires an extensive network of land-based infrastructure. These can be potentially hazardous facilities, such as gas processing plants, refineries, and petrochemical plants, ports, and a large network of pipelines for transporting products between facilities. Anthropogenic activities in the vicinity of oil and gas production areas increase the potential for communities and biota to be exposed to hazardous chemicals and pollutants associated with these activities (Lee et al., 2015).

Furthermore, there is extensive infrastructure associated with oil and gas development that is not normally included within the oil and gas production hierarchy. These industries include offshore platform fabrication and ship building to facilitate oil and gas exploration and downstream production operations. The construction and maintenance of oil and gas pipelines require direct modification to the environment and are a potential hazard to both communities and biota in close proximity. Releases of chemicals including hydrogen sulfide during oil and gas processing pose a potential threat to terrestrial and aquatic health (United States Environmental Protection Agency, 2003).

Shipping Lanes

Shipping lanes can pose a hazard to marine wildlife and, on a local scale, can increase the potential for wastewater, chemical or oil releases, and pollutants including nitrogen oxides and sulfur compounds.

Impervious Surface

Impervious surface density, in conjunction with agricultural land types, poses a high potential threat to aquatic water quality due to fertilizer and urban pollutant runoff into waterways during high intensity rainfall events. The spatial density of impervious surfaces within a watershed, developed and constructed to support commerce, can lead to increased runoff capable of compounding flooding problems and impacting non flood-tolerant plant and animal species. Impervious surfaces correlate to land development and can influence stream pH levels when a surface is greater than 2% impervious surface (Conway, 2007). It can also have measurable impacts on floral and faunal communities when a surface is greater than 10% impervious (Arnold and Gibbons, 1996; Lussier et al., 2008). When a surface becomes increasingly impervious, the ability for water to infiltrate this surface decreases, leading to increased surface runoff. This can lead to reduced water quality. For example, the introduction of fertilizer nutrients in agricultural and residential runoff can lead to algal blooms in receiving water bodies, potentially resulting in hypoxia (Mitsch et al., 2001).

Dams

The locations of dams, built either for water impoundment or power generation, are another non-oil industry related infrastructure threat. Dams alter the hydrology within a watershed and can impede annual migratory species from reaching spawning locations. Hydroelectric dams can alter both the dissolved oxygen characteristics and the temperature of the waterbody receiving thermal wastewater.

Table 3. A list of sub-layers which make up the infrastructure threat layer

Infrastructure			
Layer	**Entity**	**Website**	**Date Range**
Pipelines	BOEM, EIA	https://www.data.boem.gov/Main/Mapping.aspx; https://www.eia.gov/maps/layer_info-m.php	2018
Shipping Lanes	BOEM	https://www.data.boem.gov/Main/Mapping.aspx	2018
Offshore Platforms	BOEM	https://www.data.boem.gov/Main/Mapping.aspx	2018
Ports	USGS	https://water.usgs.gov/lookup/getgislist	
Impervious Surfaces	USGS	https://nationalmap.gov/small_scale/mld/impe100.html	2014
Hazardous Facilities	EIA	https://www.eia.gov/maps/layer_info-m.php	2018
Dams	USGS	https://www.usgs.gov/products/data-and-tools/gis-data	2018

2.3.3. Land Change

Land change layers (Table 4) include changes that have already occurred (i.e., land type change) as well as factors that could impact future changes (e.g., sea level rise, fault zones, and soil erodibility).

Sea Level Rise

The sea level rise metric is not linked to any type (i.e., eustatic or relative) or time frame (e.g., over 10 or 50 years), rather it represents the spatial extent of water if sea level were to rise three feet above current level. Different projections show variations in the specific time it would take to reach three feet of sea level rise.

Soil Erodibility

Soil erodibility can lead to both gradual and rapid land changes. Impact will be dependent in part on the alterations to the natural ecosystems. The standard measure of soil erodibility is the Universal Soil Loss Equation (USLE), measured as ‘K’, determines the potential for soil loss causing reduced elevation and increased sediment discharge into surrounding water bodies (Gadiga and Martins, 2015).

A = average annual soil loss;
R = rainfall and runoff factor;
K = soil erodibility factor;
L = slope length;
S = slope steepness;
C = crop and cover management factor
P = conservation/support practice

$$A = R\,K\,L\,S\,C\,P$$

Fault Zones

Fault zones can result in rapid land change and have direct impacts upon habitats. Fault zone data were gathered from the Department of Interior (DOI) and plotted as vectors to determine if faults intersect with a given hexagon cell. The absence or presence of a fault zone determines if a cell was classified as stressed or not. Though some faults may not be active, over decades and centuries, land movement can cause damage to structures.

Land Type Change from Natural to Agriculture

Land conversion from Natural to Agriculture can impact the connectivity of forest ecosystems and increase nonpoint source nutrient runoff. For this metric, Natural was determined to be the following classes from the Coastal Change Analysis Program (CCAP): Grassland, Deciduous Forest, Evergreen Forest, Mixed forest, Scrub/Shrub, Palustrine forest Wetland, Palustrine Scrub/Shrub, Palustrine Emergent Wetland, Estuarine Forested Wetland, Estuarine Scrub/Shrub Wetland, and Estuarine Emergent Wetland. Agriculture was determined to be Cultivated Crops or Pasture/Hay from the CCAP program. Any areas that were classified as Natural in 1996 and shifted to one of the Agriculture categories in 2010 were included in this threat layer.

Land Type Change from Natural to Urban

Land conversion from Natural to Urban not only impacts the area converted but can also have impacts on the surrounding lands. Development can impact the connectivity of ecosystems and increase the likelihood in those areas for further development. The same inputs used for land type change from “Natural to Agriculture” were used to identify the ‘Natural areas’, however ‘Urban’ areas were classified by CCAP’s classifications for “High Urban Intensity and Medium Urban Intensity.” Any areas classified as natural vegetation in 1996 and shifted to one of the Urban categories in 2010 were included in this threat layer. This base layer, land use land cover (LULC), was also a product by the USGS through their National Mapping Program.

Table 4. A list of sub-layers which make up the land change threat layer

Land change			
Layer	**Entity**	**Website**	**Date Range**
Sea Level Rise (3 ft)	NOAA	https://coast.noaa.gov/slrdata/	2018
Fault Zones	DOI	https://catalog.data.gov/dataset/fault-zones-in-the-gulf-coast-gcfltzoneg	2004
Soil Erodibility	USDA NRCS, Esri	https://www.arcgis.com/home/item.html?id=ac1bc7c30bd4455e85f01fc51055e586	2018
Land Type Change (natural to agriculture)	NOAA	http://www.csc.noaa.gov/landcover	1996-2010
Land Type Change (natural to urban)	NOAA	http://www.csc.noaa.gov/landcover	1996-2010

2.3.4. Pollution

The pollution layers (Table 5) provide information about potential impacts to quality of air, surface water, and ground water. Each pollution source indicated potential input rather than the location of downstream impacts. Pollution sources in Table 5 are not exhaustive or prioritized but represent the major sources where spatial data were available Gulfwide.

Oil Spills

Oil spills are especially harmful to aquatic and terrestrial animals. The chemical makeup of oil when exposed to living organisms can affect organisms through direct contact, ingestion, and or inhalation ("How Oil Harms Animals and Plants in Marine Environments | response.restoration.noaa.gov," n.d.). Historic oil spills link to the industrial infrastructure layer and inform the potential threat from future spills. The spatial extent of the "oil spill zone" is the extent of historical oil spills and are represented as points. A five-mile buffer of influence was added around each of the points. The individual oil spill shapefiles were circular but were combined into a single shapefile to represent overlapping oil spill areas.

Point Source Pollution

The Facility Registration Service (FRS) database includes the Toxic Release Inventory (TRI), the Clean Air Markets Division Business System (CAMDBS), and the National Pollution Discharge Elimination System (NPDES) and other facilities registered by the U.S. EPA. TRI tracks locations where chemicals are used and where releases have occurred, including over 650 chemicals that have human or environmental health impacts. CAMDBS are emissions monitoring sites of sulfur dioxide, nitrogen oxides, and carbon dioxide. NPDES are locations where point source pollution discharge into U.S. waters via an EPA permit, this includes a broad range of pollutants from dredged soil to sewage to municipal waste. These facilities are known point sources of pollution and are important to consider in determining present and future environmental quality.

Landfills

Landfill locations potentially pollute both the air and surrounding waterbodies, which can negatively impact the environment and human health (Danthurebandara et al., 2012). The landfill layer was sourced from the Homeland Infrastructure Foundation-Level data as point source data. The absence or presence of a landfill site determined whether a hex cell was classified stressed or not.

Brownfield and Superfund Sites

Brownfield sites are properties that have a hazardous substance, contaminant, or pollutant present. They are intended for improvement with assistance from the EPA recognizing that they currently pose potential health risks to surrounding people or ecosystems (Kliucininkas and Velykiene, 2009). Superfund sites are usually more polluted than Brownfield sites and the cleanup is led by the EPA. Superfund sites are likely to have negative impacts on the immediate surroundings as well as connected waterways. Other environmental threats such as flooding or urban development can increase the environmental stress caused by these sites.

Table 5. A list of sub-layers which make up the pollution threat layer

Pollution			
Layer	**Entity**	**Website**	**Date Range**
Historic Oil Spills	Google Earth	https://www.gearthblog.com/blog/archives/2010/05/comparing_the_gulf_oil_spill_to_oth.html	2010
Point Source Pollution	FRS	https://www.epa.gov/frs/geospatial-data-download-service	2000-2019
Landfill Locations	HIFLD	https://hifld-geoplatform.opendata.arcgis.com/datasets/solid-waste-landfill-facilities	2017-2018
Brownfield and Superfund Sites	FRS	https://www.epa.gov/frs/geospatial-data-download-service	2002-2019

2.3.5. Gulf of Mexico Water Quality

The GOM water quality layer (Table 6) identifies areas suffering from hypoxia, which is classified as bottom dissolved oxygen less than 5 mg L^{-1}. Some restoration or conservation action have potential to directly or indirectly impact GOM water quality. This layer therefore serves to indicate the large spatial range of impacts from terrestrial activities (Bricker et al., 2008) and would benefit from expansion in the future for assessment of implementation of restoration at a programmatic scale.

Dissolved Oxygen

The dissolved oxygen layer was created by reviewing the "hypoxia zone" across the years 2015-2018 provided by NOAA’s hypoxia shapefiles. If, in any given year, the average bottom dissolved oxygen was below 5 mg L^{-1}, then the hexagon grid was identified as impaired (Bricker et al., 2008). Data classification was carried out for 2015 and repeated through 2018 to provide a broad zone where hypoxia has occurred.

Table 6. A list of all sub-layers which make up the GOM water quality

Gulf of Mexico water quality			
Layer	**Entity**	**Website**	**Date Range**
Dissolved Oxygen	NOAA	https://www.ncddc.noaa.gov/hypoxia/products/	2015-2018

2.3.6. River/Estuarine Water Quality

The river/estuarine water quality layers (Table 7) are based on EPA's listed 303(d) waters and the additional identification of five major water quality impairments. These additional metrics were used to develop a combined layer of 'Nonpoint Source Pollution' derived from the impaired streams layer and refined using the following point data: *Dissolved Oxygen (DO), Nitrogen (N), Phosphorus (P), pH,* and *Fecal Coliform (FC)*. These five variables were chosen because their environmental effects are well studied, the availability of data is consistent, and they share common application as ecosystem metrics.

In order to classify waters as impaired, two primary datasets were used, 1) the National Geospatial Dataset from the ATTAINS Program 303(d) Listed Impaired Waters (NHD Plus Indexed Dataset with Program Attributes), and 2) data submitted to STORage and RETrieval (STORET) between 2002 and 2019 (NB: database will be renamed as EPA's Water Quality Data Portal in the near future). Between states, the same parameters have multiple names which was managed in the compilation of data. For example, Florida has three different fecal coliform categories, Texas simplifies their fecal coliform to "bacteria", and the rest of the states call it fecal coliform. Appendix 3 shows the naming for the five water quality parameters in each state. After converting all retrieved data to uniform measurements, averages for all data based on the sampling location were calculated. These were classified using the framework within 303d listings, supplemented with literature research (Appendices). Locations identified as stressed were then spatially joined to the NHD polygon and polyline layer within 100 meters to represent a more realistic impaired area.

Nonpoint Source Pollution

Nonpoint source pollution is another data layer associated with impaired streams to identify contributions to nonpoint source pollution, not just the waterbodies potentially impaired. Using the 303(d) impaired streams feature class 'identified as impaired by non-point sources' (Nitrogen, Phosphorus, Fecal Coliform, Dissolved Oxygen, and pH) and data derived from the previously mentioned methodology, vector points were created at every vertex in all polylines identified to be impaired. From these vertices, watersheds were derived from the hydrography toolbox, watershed tool, using a 100 m x 100 m digital elevation model (DEM) for the conterminous United States and D8 flow algorithm. After these watersheds were created, all 1 km^2 hexagon grid cells that intersected the watersheds were classified as potentially contributing to nonpoint source pollution.

Impaired Streams

EPA's 303(d) listed waterbodies feature classes - polyline was used to identify areas where polluted waters have been identified. Section 303(d) of the Clean Water Act authorizes EPA to assist states, territories and authorized tribes in listing impaired waters and developing Total Maximum Daily Loads (TMDLs) for these waterbodies. Hexagon grid cells were classified as impaired if they intersected an impaired polyline. After selecting impaired hexagon grid cells, the number of impaired cells was calculated as a percentage of all hexagon grid cells in that HUC 12 local watershed.

Impaired Waterbodies

EPA's 303(d) listed waterbodies feature class - polygons was used to identify areas where polluted waters have been identified. Section 303(d) of the Clean Water Act authorizes EPA to assist states, territories and authorized tribes in listing impaired waters and developing TMDLs for these waterbodies. Hexagon cells were classified as impaired if they intersected an impaired polyline.

Table 7. A list of sub-layers which make up the river/estuary water quality

River / estuarine water quality			
Layer	**Entity**	**Website**	**Date Range**
Impaired Streams	EPA 303(d) Impaired Waters	https://www.epa.gov/ceam/303d-listed-impaired-waters	2002-2019
Impaired Waterbodies	EPA 303(d) Impaired Waters	https://www.epa.gov/ceam/303d-listed-impaired-waters	2002-2019
Nonpoint Pollution & (Dissolved Oxygen, Nitrogen, Phosphorus, pH, and Fecal Coliform)	USGS/EPA (Water Quality Portal) & EPA 303(d) Impaired Waters & USGS National Landcover Dataset	https://www.epa.gov/ceam/303d-listed-impaired-waters https://www.waterqualitydata.us/ https://viewer.nationalmap.gov/advanced-viewer/	2002-2019

2.3.7. Environmental Hazards

The environmental hazard layers (Table 8) includes a list of threats with wide ranging spatial scales and high variability over time. Extreme climatic and weather events frequently occur along the Gulf coast.

Hurricane

Hurricanes are a frequent natural hazard of the northern Gulf of Mexico that can completely change an ecosystem's functions and makeup due to high winds, storm surge, and large amounts of precipitation. Hurricane tracklines were isolated from NOAA's National Climatic Data Center (NCDC) International Best Track Archive for Climate Stewardship (IBTrACS) dataset. Encompassing the period from 1850 to 2017, this dataset includes linear geodata of hurricane and tropical storm paths. These tracklines were used as the basis for cell selection to determine the historical accumulated occurrence of hurricane and tropical storms along the U.S. Gulf coast. Grid cells containing a track line were classified as "hazard present".

Tornadoes

Tornadoes can present a locally devastating threat to terrestrial organisms and are capable of altering habitat connectivity. Tornado data used in this index were isolated from the NOAA/National Weather Service Storm Prediction Center (SPC) dataset covering the years from 1950 to 2017. Resultant tornado tracklines were used as the basis for cell selection to determine the historical accumulated occurrence of tornado strikes throughout the northern Gulf of Mexico coast. Any grid cell containing a tornado track line was classified as 'threat present'.

Drought

Drought was another environmental threat included in the index. The U.S. Drought Monitor program is produced jointly by the National Drought Mitigation Center (NDMC) in partnership with the University of Nebraska-Lincoln, NOAA, and the USDA. The drought variable is a measure of weeks of extreme (D3) and exceptional (D4) drought by county (parish) in the period spanning 2000 to 2017. An extreme or exceptional drought is likely to result in major crop losses and widespread shortages of water in reservoirs, streams, and groundwater wells. The weeks of D3/D4 drought statistic was joined to county geodata across the entire northern Gulf of Mexico domain. County values above the average county value of the whole northern Gulf of Mexico coast were categorized as positive for all cells within the county.

Rainfall

Extreme rainfall events can result in widespread flooding, habitat alteration, and damage to food supply. Oregon State University's PRISM Climate Group's ongoing '30-year normal' project catalogues the average values for precipitation across the continental United States for the period ranging from 1981 to 2010. The group's output, an 800-meter resolution raster surface, was used as the basis of zonal statistics operations intended to capture above average precipitation across the Gulf of Mexico analysis domain.

Flood hazard

Flooding has the potential to inundate areas that are not normally inundated, damage structure, and drown out ecosystems. Some reasons for floods include heavy precipitation, structure failure, and storm swells. Flood probability data was extracted from the National Flood Hazard Layer (NFHL) dataset published by the Federal Emergency Management Agency (FEMA), available through the federal Open Data program. This data included a spatial boundary file containing the geographic extent of flooding based on annual flood return probability. The significant return period considered by this analysis is known as a 100-year event and has a 1-percent chance of occurring in any given year. The spatial extent of flooded areas during this return period is termed Special Flood Hazard Areas (SFHA) by FEMA. It is important to note that the NFHL is not a comprehensive dataset and is often missing counties whose flooding hazard is still being determined or only has a preliminary determination. Those counties that had available NFHL geodata were joined to create a Gulfwide dataset. The joined dataset was used for cell selection and threat assignment within each hexagon tessellation grid.

Temperature

Extremes of temperature (high and low) can result in ecological stress or changes in species distribution, if the changes persist. Oregon State University's Parameter-elevation Regressions on Independent Slopes Model (PRISM) Climate Group's ongoing '30-year normal' project catalogues the average values for temperature and precipitation across the continental United States for the period ranging from 1981 through 2010. The resultant 800-meter resolution raster surface was used as the basis of zonal statistics to identify above average maximum temperature and below average minimum temperature across the northern Gulf of Mexico domain.

Wildfire Hazard Potential

Wildfires can have a largely damaging effect on an ecosystem similar to flooding. Both events can be rapid events that completely damage an environment. Wildfire hazard potential is not exclusive of human induced fires. Based on the potential for fire, areas are identified through the USFS Wildfire Hazard Potential dataset. Wildfires in some instances are regular occurring events (once every couple years or once a year) that can either help ecosystems or damage them. Not to be considered forest fire likelihood, wildfire hazard potential (WHP) differs in the variables used to calculate the indexed value. The USFS describes this variable as such, “to depict the relative potential for wildfire that would be difficult for suppression resources to contain.” Higher WHP values represent fuels with a higher probability of being severely damaged.

Harmful Algal Bloom

Algal blooms are the result of excess nutrients combined with other environmental variables. These blooms lower dissolved oxygen content and essentially choke out aquatic ecosystems. In addition, these blooms can also harbor toxic pollutants to living organisms which can damage terrestrial species such as alligators and birds. This layer was downloaded from NOAA and the Harmful Algal Blooms Observing system (HASBOS). Point data has been collected since 1953 up to February of 2019 and plotted for the Gulf of Mexico to help understand where algal blooms mostly occur.

Table 8. A list of sub-layers in the environmental hazards sub layer

Environmental hazards			
Layer	**Entity**	**Website**	**Date Range**
Hurricane Landfall Intensity	NOAA (NCDC)	ftp://eclipse.ncdc.noaa.gov/pub/ibtracs/v03r10/all/shp/	1858 - 2016
Tornado	NOAA SPC	https://www.spc.noaa.gov/gis/svrgis/	1950 - 2016
Drought	U.S Drought Monitor, NDMC, USDA, NOAA	https://droughtmonitor.unl.edu	2000 - 2018
Extreme Rainfall	PRISM Climate Group	http://www.prism.oregonstate.edu/	1981 - 2010
Flood Hazard	FEMA	https://msc.fema.gov/portal/home	2019
Max and Min Temperature	PRISM	http://www.prism.oregonstate.edu/	1981 - 2010
Wildfire Hazard Potential	USDA - USFS	https://www.firelab.org/project/wildfire-hazard-potential	2015
Harmful Algal Blooms	NOAA (HASBOS)	https://catalog.data.gov/dataset/physical-and-biological-data-collected-along-the-texas-mississippi-and-florida-gulf-coasts-in-t	1953-2019

2.3.8. Invasive Species

Aquatic fauna, insects, submerged aquatic vegetation, terrestrial flora, terrestrial fauna

Invasive species layers (Table 9) were compiled based on literature and web research utilizing special invasive-focused groups, municipalities, regional entities, state, and other government agencies (Appendix 3). The list of invasive species was not exhaustive, it was selected to best represent each state’s interest based on literature research and data availability. Since there is no ranking for invasive species associated with the Gulf, species were determined on a state by state basis and then aggregated into a common list throughout all the gulf states. Five priority species for each state were identified and represented based on research (Appendix 3). For example, Florida identifies the Brazilian pepper tree, punk tree, and cane toad as priorities to their own state with the addition of the other common invasive species hydrilla and hyacinth. Each state has priority invasive species along with other common invasive species found throughout the Gulf. For example, cogon grass is a prioritized invasive species in Alabama, but it is not limited to Alabama, so cogon grass data was included for all Gulf states where it was available. Other species widely spread include kudzu, zebra mussel, and southern pine beetle.

The spatial data for all species was derived from point data except for Southern pine beetle, which was represented on a county basis. The spatial data were downloaded from the Early Detection and Distribution Mapping System (EDDMaps) and the USGS Nonindigenous Aquatic Species (NAS). Bighead, black, silver, grass, and common carp were downloaded from NAS while the rest: Zebra mussel, Chinese tallow tree, wild boar, nutria, punk tree, kudzu, Japanese honeysuckle, Japanese climbing fern, hydrilla, hyacinth, giant and common salvinia, cogon grass, Chinese privet, cane toad, Brazilian pepper tree, and Asian clam were downloaded from EDDMaps.

The top five species from each state were then grouped into aquatic fauna, insects, submerged aquatic vegetation, terrestrial flora, and terrestrial fauna, with one additional data set included as forestry risk species.

Forestry Risk

Forestry risk is determined from a variety of factors such as insects, fungus, bacteria, and other harmful species. For example, Gypsy moth is known to cause major deforestation which can act as a gateway for other harmful risks to susceptible trees. Therefore, this species was used as an overall risk layer for Forestry Risk. Forestry risk was a composite categorical raster layer which was utilized like vector data, either area at risk or not. The composite risk dataset is the central product of the 2012 National Insect and Disease Risk Map (NIDRM) project. Areas labeled at risk are areas that would be impaired by 25% or more over a 15-year period (2012-2027). The list of factors used in the Forestry Risk layer can be found on USFS’s website for National Insect Disease & Risk Maps. The raster was converted into a polygon classified as absent or present within each hexagon grid cell and a zonal mean was calculated per HUC 12 per the count of stressed cells.

Table 9. A list of invasive species identified and prioritized within each of the five Gulf states. Species in bold represent the identified major invasive species as per their respective state.

Invasive species			
State	**Invasive species included**	**Entity**	**Website**
Texas	**Asian Clam, Carp (Black, Grass, Bighead, Silver, Common**), Giant & Common Salvinia, Hydrilla, Hyacinth, Tallow Tree, Japanese Honeysuckle, Southern Pine Beetle, wild boar, **Zebra Mussel**	EDDMaps, USGS NAS	https://www.eddmaps.org/distribution/; https://nas.er.usgs.gov/
Louisiana	Asian Clam, Carp, Nutria, **Giant & Common Salvinia**, Hydrilla, Hyacinth, **Tallow Tree, Japanese Honeysuckle**, Southern Pine Beetle, **wild boar**, Zebra Mussel	EDDMaps, USGS NAS	https://www.eddmaps.org/distribution/; https://nas.er.usgs.gov/
Mississippi	Carp, nutria**, Giant & Common Salvinia**, Hydrilla, Hyacinth, **Tallow Tree, Japanese Honeysuckle, Southern Pine Beetle**, wild boar, Zebra Mussel	EDDMaps, USGS NAS	https://www.eddmaps.org/distribution/; https://nas.er.usgs.gov/
Alabama	**Kudzu, Japanese Climbing Fern, Cogon Grass, Chinese Privet,** Giant & Common Salvinia, Hydrilla, Hyacinth, Tallow Tree, Japanese Honeysuckle, **Southern Pine Beetle**, Melaleuca, wild boar	EDDMaps, USGS NAS	https://www.eddmaps.org/distribution/; https://nas.er.usgs.gov/
Florida	**Brazilian Pepper Tree, Cane Toad, Giant & Common Salvinia**, Hydrilla, Hyacinth, Tallow Tree, Japanese Honeysuckle, Southern Pine Beetle, **Melaleuca**, wild boar	EDDMaps, USGS NAS	https://www.eddmaps.org/distribution/; https://nas.er.usgs.gov/

Table 10. Invasive species categorized by group and then included within the decision support tool analysis. Forestry Risk is a high-level dataset that reflects forests subject to risk (includes insects, fungus, and root diseases). * indicates that multiple factors including bacteria, insects, root disease, and fungus were prevalent in the forestry risk layer.

Invasive Group	Invasive Species
Aquatic Fauna	Carp (Black, Grass, Bighead, Silver, Common), Asian Clam, Zebra Mussel
Insects	Southern Pine Beetle
Submerged Aquatic Vegetation	Giant & Common Salvinia, Hydrilla, Hyacinth
Terrestrial Flora	Tallow Tree, Japanese Honeysuckle, Kudzu, Japanese Climbing Fern, Cogon Grass, Chinese Privet, Melaleuca, Brazilian Pepper Tree
Terrestrial Fauna	Nutria, wild boar, Cane Toad
Forestry Risk	USDA USFS Risk Species*

2.4. DEFINING METRICS: POTENTIAL ECOSYSTEM BENEFITS

2.4.1. Total Carbon Storage

Carbon storage is a reflection on the amount of organic material within a given area. The amount of organic material can reflect the history of an area and help identify areas associated with ecosystem benefits. Total carbon storage was calculated as the sum of above and below ground biomass. The amount of carbon stored in above ground live forest biomass was calculated by HUC 12 in kilograms carbon per meter (kg/m). Source data was the National Biomass and Carbon Dataset (NBCD) for the year 2000 developed by the Woods Hole Research Center. The NBCD is a 30 m resolution gridded data is dry weight above ground live biomass. Based on the above ground tree biomass, below ground biomass was estimated (USDA Forest Service General Technical Report NRS-18). Both above and below ground biomass can be found in EPA's Enviro Atlas. Mean total carbon storage was calculated directly for all HUC 12s across the northern Gulf of Mexico, it was additionally developed into a 1 km^2 layer.

2.4.2. Habitat Connectivity

Habitat connectivity was determined from the percent of the HUC 12 that is part of the 2001 National Ecological Framework (NEF). Habitat connectivity is important for species to be able to forage, reproduce, hunt, and expand populations ("An Introduction to Habitat Connectivity," n.d.). The NEF is a GIS based model of the connectivity of natural landscapes in the contiguous 48 United States. Mean percent habitat connectivity was calculated directly for all HUC 12s across the northern Gulf of Mexico, it was additionally developed into a 1 km^2 layer.

2.4.3. Priority Habitat Index

The biodiversity priority index layer maps areas of high priority for expansion of conservation in the USA to protect the nation's unique species. Priority habitat helps decision makers understand where species can live and where land is available for them to do so within their given range. The data layer was created using the ranges of multiple endemic species and the amount of land dedicated to protecting those species. The objective of this data layer was to identify areas where conservation would be a priority.

Mean priority habitat index was calculated directly for all HUC 12s across the northern Gulf of Mexico, it was additionally developed into a 1 km^2 layer.

2.4.4. Groundwater Recharge Potential

Groundwater is utilized in various ways including human consumption, agricultural and industrial use, and even commercial use, i.e. car washes. In some unique instances, groundwater is essential in holding the foundation of cities and to prevent subsidence. Groundwater recharge potential was calculated as the product of base flow index and mean annual runoff. This data layer is a product of the USGS and serves as a proxy to help identify areas where groundwater recharge has greater likelihood. Mean groundwater recharge potential was calculated directly for all HUC 12s across the northern Gulf of Mexico, it was additionally developed into a 1 km^2 layer.

2.4.5. Percent Canopy

Percent canopy indicates ecosystem health and habitat connectivity by providing information about intactness and connectivity. Canopy cover was calculated from the National Land Cover Database (NLCD) 2011 USFS Tree Canopy cartographic dataset. Mean percent canopy cover was calculated directly for all HUC 12s across the northern Gulf of Mexico, it was additionally developed into a 1 km^2 layer.

2.5. DEFINING METRICS: POTENTIAL COMMUNITY BENEFITS

2.5.1. Related to General Wellbeing

Population Density (Inverse in overall calculation)

This feature class represents the population density in each block group in the NOAA Gulf of Mexico region. Within this feature class are raw population density and standard scores to show the relative level of population density from one place to the next. High population density was considered a stress. It was a *stressor* within the Community Benefits Metrics. For normalization, the inverse was taken to represent the nature of the data (ie a low population density was potential high community benefit).

Income Inequality (Inverse in overall calculation)

Within this feature class are raw income inequality scores to show the relative level of income inequality between locations. Each block group within a given census tract was assigned the income inequality score of the encompassing census tract. High income inequality was considered a stress. It was a *stressor* within the Community Benefits Metrics. For normalization, the inverse was taken to represent the nature of the data.

Homeownership

Within this feature class are raw home ownership percentages to show the relative level of home ownership between locations. The percentage of home ownership in each block group was measured to determine where development and homesteads are located. It was considered a *benefit* within the Community Benefits Metrics.

Per Capita Income

Within this feature class are raw per-capita income to show the relative per-capita income level between locations. This feature class represents the per-capita income in each block group across the northern Gulf of Mexico. It was a *benefit* within the Community Benefits Metrics.

Education Attainment

Within this feature class are raw educational attainment scores to show the relative educational attainment level between locations. This feature class represents the educational attainment in each block group across the northern Gulf of Mexico. It was a *benefit* within the Community Benefits Metrics.

Chronic Disease (Inverse in overall calculation)

This feature class represents the prevalence of chronic disease in each county across the northern Gulf of Mexico. Chronic disease includes obesity, diabetes, and cancer. These types of diseases were studied because of their link to environmental and lifestyle factors. Chronic disease prevalence was considered a *stressor* within the Community Benefits Metrics. For normalization, the inverse was taken to represent the nature of the data.

Healthy Behaviors

Healthy behaviors data represents the behavior of individuals in each county across the northern Gulf of Mexico. Healthy behaviors are defined as individual's propensity to engage in physical leisure activities on a monthly basis. This measure is a strong metric of health status of residents, whereas inactivity is a metric of chronic disease. Because of this, healthy behaviors were defined as a *benefit* within the Community Benefits Metrics.

Poverty (Inverse in overall calculation)

The poverty scores indicate the relative level of poverty (status and intensity) between locations. The level of poverty in each block group across the northern Gulf of Mexico was determined to identify areas of relative poverty. It was considered a *stressor* within the Community Benefits Metrics. For normalization, the inverse was taken to represent the nature of the data.

2.5.2. Related to Ecological Functions

Natural Resource Employment

This feature class represents the number of people within the total population employed in renewable natural resource industries, such as fishing, forestry, and agriculture. It was considered a *benefit* within the Community Benefits Metrics.

Potential for Recreation

Population proximity to greenspaces, wetlands, parks, and beaches, known as (Potential for Recreation) represents the potential for recreation present in each block group across the northern Gulf of Mexico. It was considered a *benefit* within the Community Benefits Metrics.

Table 11. A list of all sub-layers which make up the community benefits metric layer. The organization that created the spatial files and the data's date range are also indicated.

Community benefits				
Data type	**Entity**	**Website**	**Category**	**Date Range**
Population Density (PD)	ACS	https://data2.nhgis.org/main	Threat (inverse in combined score)	2012-2016
Income Inequality	ACS	https://data2.nhgis.org/main	Threat (inverse in combined score)	2013-2017
Home Ownership	ACS	https://data2.nhgis.org/main	Benefit	2012-2016
Per-Capita Income	ACS	https://data2.nhgis.org/main	Benefit	2012-2016
Educational Attainment	ACS	https://data2.nhgis.org/main	Benefit	2012-2016
Chronic Disease Prevalence	CDC	https://wonder.cdc.gov/	Threat (inverse in combined score)	2013-2015
Healthy Behaviors	CDC	https://www.cdc.gov/physicalactivity/data/index.html	Benefit	2014
Poverty	ACS	https://data2.nhgis.org/main	Threat (inverse in combined score)	2013-2017
Natural Resource Employment	ACS	https://www.census.gov/programs-surveys/acs/about.html	Benefit	2012-2016
Potential for Recreation	NPS, ESRI USA Parks dataset	https://public-nps.opendata.arcgis.com/	Benefit	2017

2.6. DATA PROCESSING

2.6.1. Data Normalization

Project site scores were calculated based on range normalized values (0-1) of the HUC 12 watersheds contained within the scale of reporting. Threat metrics were normalized from the classification of all 1 km^2 hexagon grid cells as 'threat present' or 'threat absent' and the percentage of the watershed with the threat present was the final threat metric. Ecosystem benefits metrics and community wellbeing metrics were normalized from raw data for the listed metric. Scores were then classified as very low (0.00-0.20), low (0.20-0.40), moderate (0.40-0.60), good (0.60-0.80), very good (0.80-1.00). For all stressors and benefits, lower scores represent lower numbers, i.e., 0.00-0.20, and higher scores represent higher numbers, i.e., 0.80-1.00. Some general wellbeing metrics (under community benefits) indicate low quality wellbeing for a high numeric metric value (Chronic Disease, Poverty, Population Density, and Income Inequality) so the inverse normalized scores were calculated to develop a combined score for community wellbeing, where “adjusted inverse score” = 1 **-** [metric]. For example, if the chronic disease metric score equals 0.8 (a high numeric metric value), the adjusted inverse score would be 1 – [0.8] = **0.2**, which is indicative of “poor wellbeing”.

2.6.2.Data Visualization and Mapping

For all threat and ecosystem benefit data sets, a tessellated grid was created to allow for uniform coverage of the northern Gulf of Mexico. It was developed to provide a finer resolution than HUC 12. Initially, a 100 km^2 hexagon was used, but the resolution was not sufficient to inform local or project scale variation so a 1 km^2 hexagon grid was additionally developed.

Tessellated hexagons were used for two main reasons. First, the Strategic Conservation Assessment (SCA) team is working on a Gulfwide landscape conservation prioritization tool, and given collaboration between these projects, it allowed the data transfer. Second, a hexagon is preferred over a square grid as it has a lower perimeter-to-area ratio, which decreases sampling bias from edge effects.

2.6.3. Development a Decision-Support Tool

The Gulfwide Conservation and Restoration Decision Support Tool is based on a spatial data approach that utilizes a variety of ecological and social data layers, including, but not limited to, forest and vegetation type, water quality, wildlife habitats, communities, socio-economic data, infrastructure, and flood related metrics. Applicable metrics can potentially be selected from the compiled data to inform forest, wetland, or other conservation or other restoration types and were cross-walked with the habitats that they can inform (Table 11).

The decision support tool uses three criteria in assessing success potential for conservation and restoration projects.

These criteria are:

1) *Potential ecosystem threats* to the project area (natural or anthropogenic – e.g., flooding or hurricane frequency and watershed impervious surface) (Table 12)
2) *Potential ecosystem benefits* from the project (improving or protecting forestry and wildlife habitats, nutrient reduction and water quality improvement, potential for carbon storage, etc.) (Table 13)
3) *Potential community benefits* from the project (forestry harvest income, public health and safety, access to recreational activities, etc.) (Table 14)

To describe the methods of applying the decision support tool in detail, an application to an example forest conservation project, the McNeil forest conservation project, is presented and discussed below.

Table 12. Habitat types and associated ecosystem threat metrics used in the evaluation of a potential project. Metrics used for the example project in McNeil, Texas are highlighted in blue.

Potential Ecosystem Threat Metrics	Habitat Type					
	Forest	Wetland	Marsh	Beach	Oyster Reef	Barrier Island
Development Risk						
Power Plants						
Light Pollution						
Pipeline Density	X	X	X			
Offshore Platform				X	X	X
Ports						
Hazardous Facilities						
Shipping Lanes		X	X	X	X	X
Impervious Surfaces	X	X	X	X		X
Dams	X	X				
Sea-level Rise (3 ft)	X	X	X	X	X	X
Soil Erodibility	X	X	X			X
Fault Zones	X	X	X	X		X
‘Natural’ to Agriculture Land	X	X	X			
‘Natural’ to Developed Land	X	X	X	X		X
Historic Oil Spill		X	X	X	X	X
NPDES (Point Pollution)						
CAMDBS (Point Pollution)						
Toxic Release Inventory (Point Source Pollution)	X	X	X			
Landfill Locations						
Brownfield and Superfund Sites	X	X	X			
Gulf of Mexico - Hypoxia						
Impaired Stream Length	X	X	X			
Impaired Waterbodies	X	X	X	X	X	X
Nonpoint Pollution	X	X	X	X	X	X
Hurricane Landfall Intensity	X	X	X	X	X	X
Tornado	X	X	X			X
Drought	X	X	X		X	X
Extreme Rainfall	X	X	X		X	X
Special Flood Hazard Areas	X	X	X	X	X	X
Min & Max Temperature						
Wild Forest Fire Potential	X					
Forest risk	X	X				

Table 13. Habitat types and associated ecosystem benefit metrics used in the evaluation of a potential project. Metrics used for the example project in McNeil, Texas are highlighted in blue.

Potential Ecosystem Benefit Metrics	Habitat Type					
	Forest	Wetland	Marsh	Beach	Oyster Reef	Barrier Island
Total Carbon Storage	X	X	X	X	X	X
Habitat Connectivity	X	X	X	X	X	
Priority Habitat	X	X	X	X	X	X
Percent Canopy Cover	X					X
Groundwater Recharge Potential	X	X	X			X

Table 14. Habitat types and associated community benefit metrics used in the evaluation of a potential project. Metrics used for the example project in McNeil, Texas are highlighted in blue.

Potential Ecosystem Benefits Metrics	Habitat Type					
	Forest	Wetland	Marsh	Beach	Oyster Reef	Barrier Island
Human Population Density	X	X	X	X	X	X
Income Inequality	X	X	X	X	X	X
Owner-Occupied Housing	X	X	X	X	X	X
Per Capita Income	X	X	X	X	X	X
Educational Attainment	X	X	X	X	X	X
Chronic Disease	X	X	X	X	X	X
Healthy Behaviors	X	X	X	X	X	X
Poverty	X	X	X	X	X	X
Resource Dependent Jobs	X	X	X	X	X	X
Potential for Recreation	X	X	X	X	X	X

In addition to the contextual habitat data described above for analysis within the Gulfwide Conservation and Restoration Decision Support Tool, two targeted data layers were obtained from the Watershed Index Online (WSIO) and three developed from other sources. WSIO stems from the Clean Water Act, the US EPA has been compiling information on helping assessing watersheds throughout the United States. All WSIO data is summarized to a HUC 12 level and included within the decision support tool as appropriate.

Table 15. A list of ecosystem benefit data and how the data was calculated at the HUC 12 level

Potential Ecosystem Benefit Metric	Entity	Data Calculation Method	Date range	Description
Habitat Connectivity	NEF	WSIO Watershed Index Online	2001	The NEF is a GIS based model of the connectivity of natural landscapes in the lower 48 United States. The NEF is comprised of Hubs and Corridors, with Hubs defined as Priority Ecological Areas that are greater than 5,000 acres in size.
Total Carbon Storage (Above + Below)	NBCD	WSIO Watershed Index Online	2000	Above Ground Biomass - Source data was the National Biomass and Carbon Dataset (NBCD) for the year 2000 developed by the Woods Hole Research Center. The NBCD is a 30-meter resolution gridded dataset of above ground live dry biomass. Below Ground Biomass - Calculated from above ground live forest biomass estimates and an equation relating above and below ground forest biomass published in USDA Forest Service General Technical Report NRS-18. Source data for above ground biomass was the National Biomass and Carbon Dataset (NBCD) for the year 2000 developed by the Woods Hole Research Center. The NBCD is a 30-meter resolution gridded dataset of above ground live dry biomass.

Potential Ecosystem Benefit Metric	**Entity**	**Data Calculation Method**	**Date range**	**Description**
Priority Habitat Index	Biodiversitymapping.org	HUC 12 Zonal statistics	2015	Species richness and other metrics for the maps on the BiodiversityMapping website were calculated with ArcGIS 10.x using equal area grids (Eckert IV or Albers Equal Area Conic). In all cases, extinct species were removed, as were non-native distributions of extant species. Polygons listed with the attribute Vagrant were also removed. In cases where a species range was split into multiple subspecies, these were merged to create a range map for the full species when possible. Richness was calculated using a 10×10km or 100×100km grid, depending on the study. For each grid cell, any species that overlapped any part of the cell counted as a presence of that species. For some groups or areas, a uniform grid was not appropriate (e.g., watersheds for freshwater fish), and a decision was made on the best spatial unit to use that would maintain the highest data quality.
Percent Canopy Cover	NLCD	HUC 12 Zonal Statistics	2011	The National Land Cover Database 2011 (NLCD2011) USFS percent tree canopy product was produced through a cooperative project conducted by the Multi-Resolution Land Characteristics (MRLC) Consortium (www.mrlc.gov). This product is the cartographic version of the NLCD2011

Potential Ecosystem Benefit Metric	Entity	Data Calculation Method	Date range	Description
				percent tree canopy cover dataset for CONUS at medium spatial resolution (30 m). It was produced by the USDA Forest Service Remote Sensing Applications Center (RSAC). Tree canopy values range from 0 to 100 percent. The analytic tree canopy layer was produced using a Random Forests™ regression algorithm.
Groundwater Recharge	USGS	HUC 12 Zonal statistics	2003	This 1 km resolution raster (grid) dataset is an index of mean annual natural ground-water recharge. The dataset was created by multiplying a grid of base-flow index (BFI) values by a grid of mean annual runoff values derived from a 1951-80 mean annual runoff contour map. Mean annual runoff is long-term average streamflow expressed on a per-unit-area basis. The concept used to construct the dataset is based on two assumptions: (1) long-term average natural ground-water recharge is equal to long-term average natural ground-water discharge to streams, and (2) the base-flow index reasonably represents, over the long term, the percentage of natural groundwater discharge in streamflow.

The above metrics were all included within the comparative data summaries within the decision support tool. The process by which the scores were calculated varied between potential ecosystem threats, potential ecosystem benefits, and potential community wellbeing. Based on a GIS model (Figure 6) which selected HUC 12s within the HUC 6 and ecoregion that the project site resides in, standard deviations and standardized values were determined within the three spatial scale domains (HUC6, Ecoregion, and Gulfwide - the NOAA Gulf Coast Counties).

Total Carbon Storage and Habitat Connectivity were available at a HUC 12 scale within WSIO data. A shapefile was developed that had required data attributes (Figure 5) and compared across the spatial scales of interest (HUC 6, Ecoregion III, and northern Gulf Coast (Figure 6).

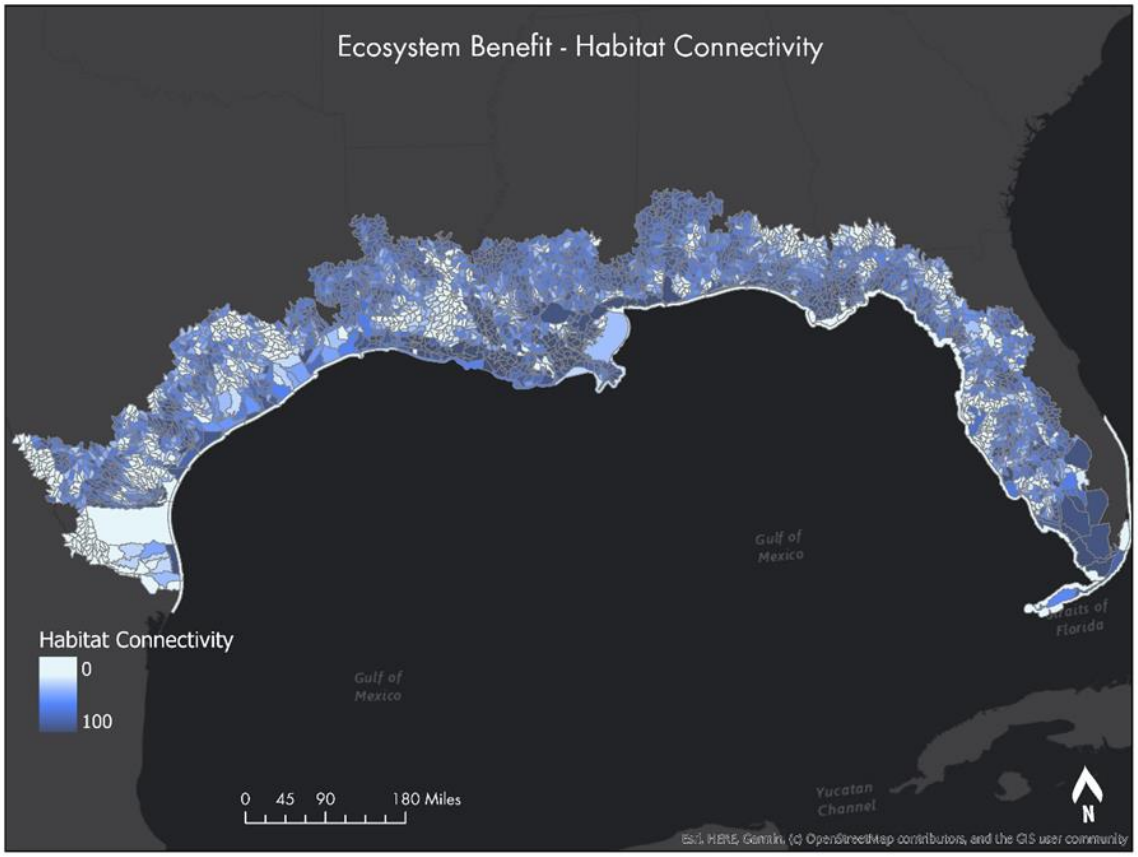


Figure 5. Example WSIO data displayed at the HUC 12 level. This example displays the percent habitat connectivity as calculated in the National Ecological Framework system. Total carbon storage and habitat connectivity were derived from WSIO.

All potential ecosystem threats were calculated using the absence or presence of the threats for each 1 km^2 hexagon cell and calculated at the HUC 12 scale. All 1 km^2 hexagon cells that had greater than 50%

area or their centroid within the HUC 12 were used. All the potential ecosystem benefits metrics were taken from WSIO data since they were already calculated at the HUC 12 level.

The overall community benefit scores were sourced at the census block group scale, the census block that contained the majority of the project site (and project site HUC 12) was used for analysis (Figure 13). For the social-economic data, it was not appropriate to merge data to the hexagon grid, as that data is purposefully compiled for security reasons so that the resolution cannot be meaningfully increased. However, the relative standard deviation was calculated from the block groups, which had a centroid that occurred in the HUC6, ecoregion, or Gulfwide extent relevant to the project site.

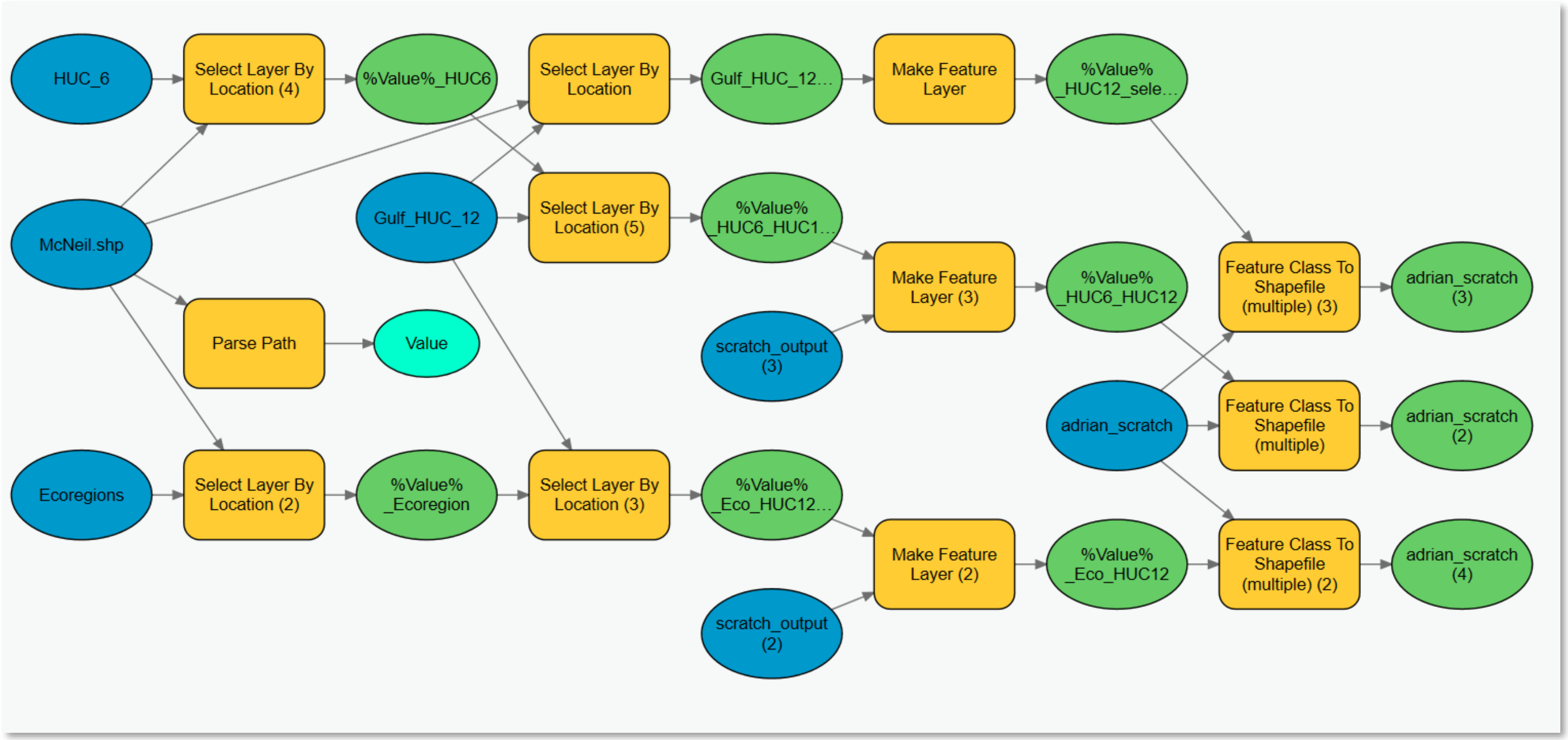


Figure 6. Project domain creation based on project site. This model uses the Gulfwide HUC 12s that contained their centroid in the NOAA Gulf coastal counties, HUC6s, and Ecoregions to take relative domains based on project location.

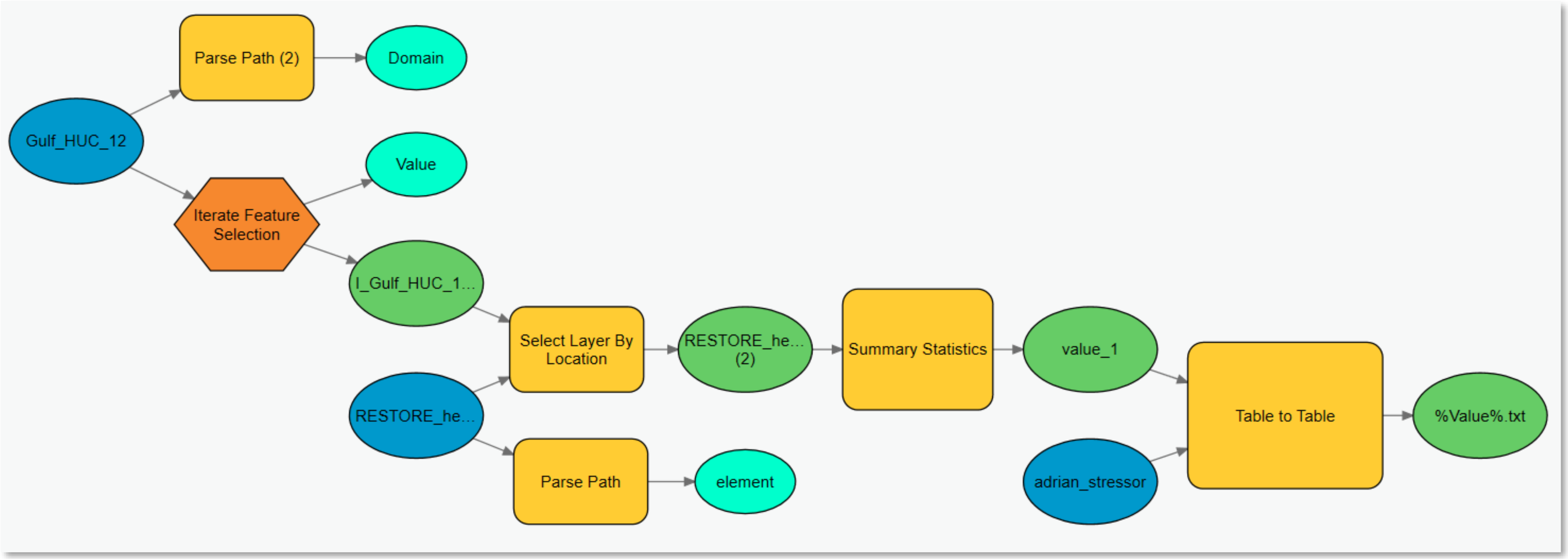


Figure 7. Model that merges the hexagon layers to every HUC 12 and calculates the count percentage for every HUC 12. For example, if five out of 10 hexagon cells within a HUC 12 were deemed stressed, then the metric was 0.5.

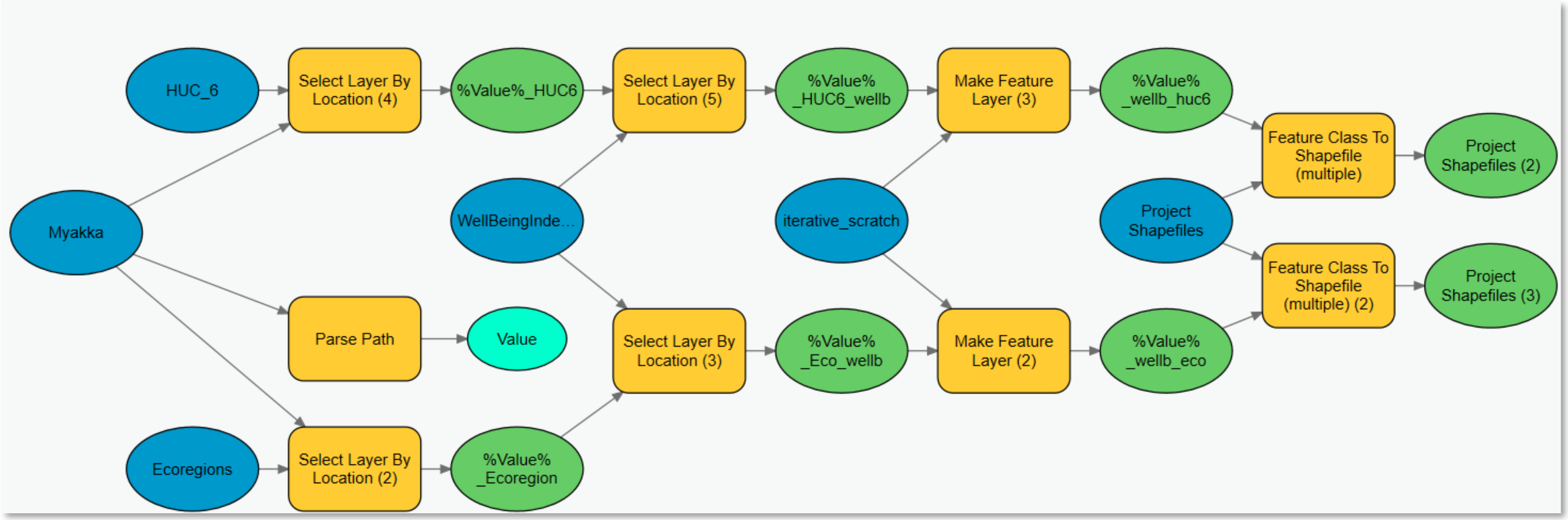


Figure 8. In this model, the input layer is the combined wellbeing index shapefile, and metrics are queried based on the output of Figure 6.

To calculate metrics that did not already have data available at the HUC 12 scale, data were extrapolated to develop a count of cells scored as positive for the stressor within the HUC 12 containing the project (and within the project site when that was appropriate), and for all HUC 12s contained within the HUC 6, within the ecoregion, and ultimately across the entire northern Gulf of Mexico. The first step in summarizing the decision support data was to identify the project site in the context of the 1 km^2 hexagon grid cells (Figure 9). Calculating several metrics at the project scale was not considered informative or reliable since the spatial resolution of the data is greater than the individual project scale. Where possible, a summary of key metrics was calculated for the project site itself, however, most of the data synthesis was based on comparison of the local watershed (HUC 12) containing the project site to surrounding local watersheds within the regional watershed (HUC 6), ecoregion, and across the northern Gulf of Mexico. In instances where the proposed project resided within multiple watersheds, the centroid of the project site was used to determine the primary watershed and the associated data from that watershed. In the event a large project was well represented in more than one local (or regional) watershed, data would be summarized for both local watersheds and/or regional watersheds. For example, the proposed McNeil project resided within two separate local watersheds (Snake Creek – San Bernard River and Peach Creek) (Figure 10). Using the centroid method, the primary local watershed was identified to be Snake Creek – San Bernard River.

To calculate the scores for each metric, hexagon cells that were spatially related to every local watershed were used to calculate a spatial statistic. For example, to calculate the potential stress from pipeline density, 1 km^2 hexagon grids containing pipelines were scored as ‘1’ or ‘present’ and those without were scored as ‘0’ or ‘absent’ (Figure 11). Based on the total number of hexagon grids that spatially relate to the HUC 12 and the total number deemed stressed, a ratio was calculated to represent the “stress factor” of this metric within the local watershed (HUC 12). After the raw value was calculated, standard deviation and the range normalized values were determined based on the local watershed in relation to the regional watershed, ecoregion, and the northern Gulf of Mexico. The process was repeated for all metrics included in the analysis for the McNeil forestry conservation project, listed in Table 12 (potential ecosystem threats), Table 13 (potential ecosystem benefits), and Table 14 (potential community benefits).

$$\text{Metric Score} = \frac{\text{Total number of stressed hexagonin same HUC 12}}{\text{Total Number of Hexagon cells within HUC 12}}$$

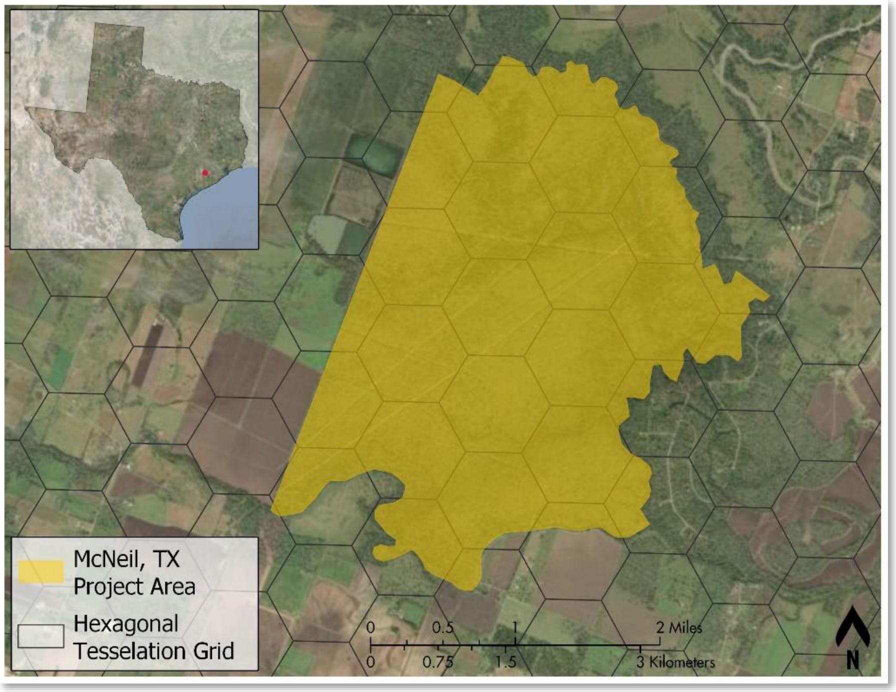


Figure 9. McNeil project site in relation to the 1 km^2 hexagon grid cells

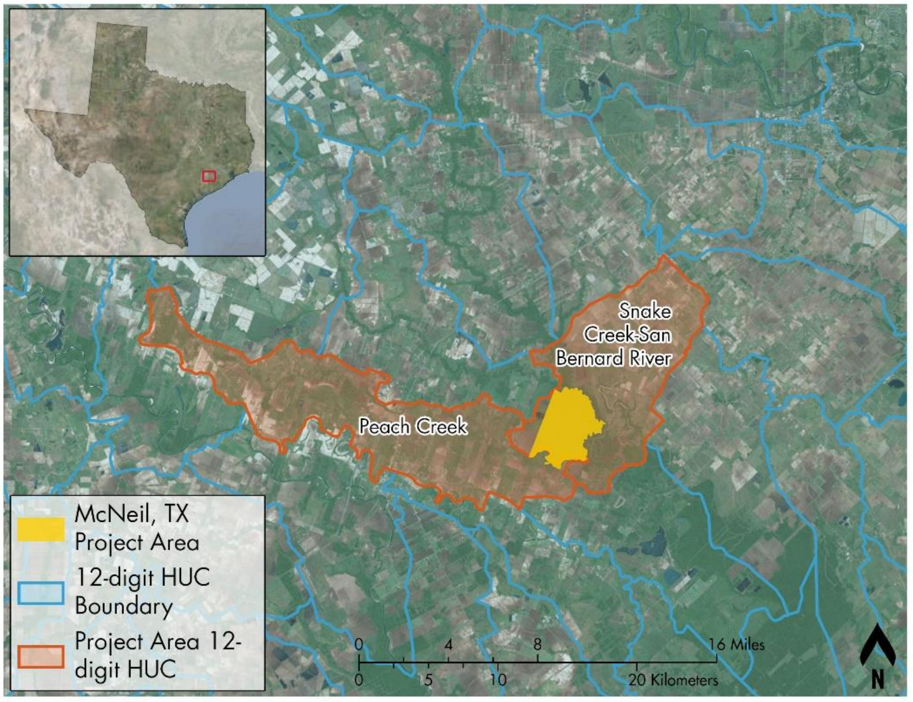


Figure 10. McNeil project site in the HUC 12s that are spatially related

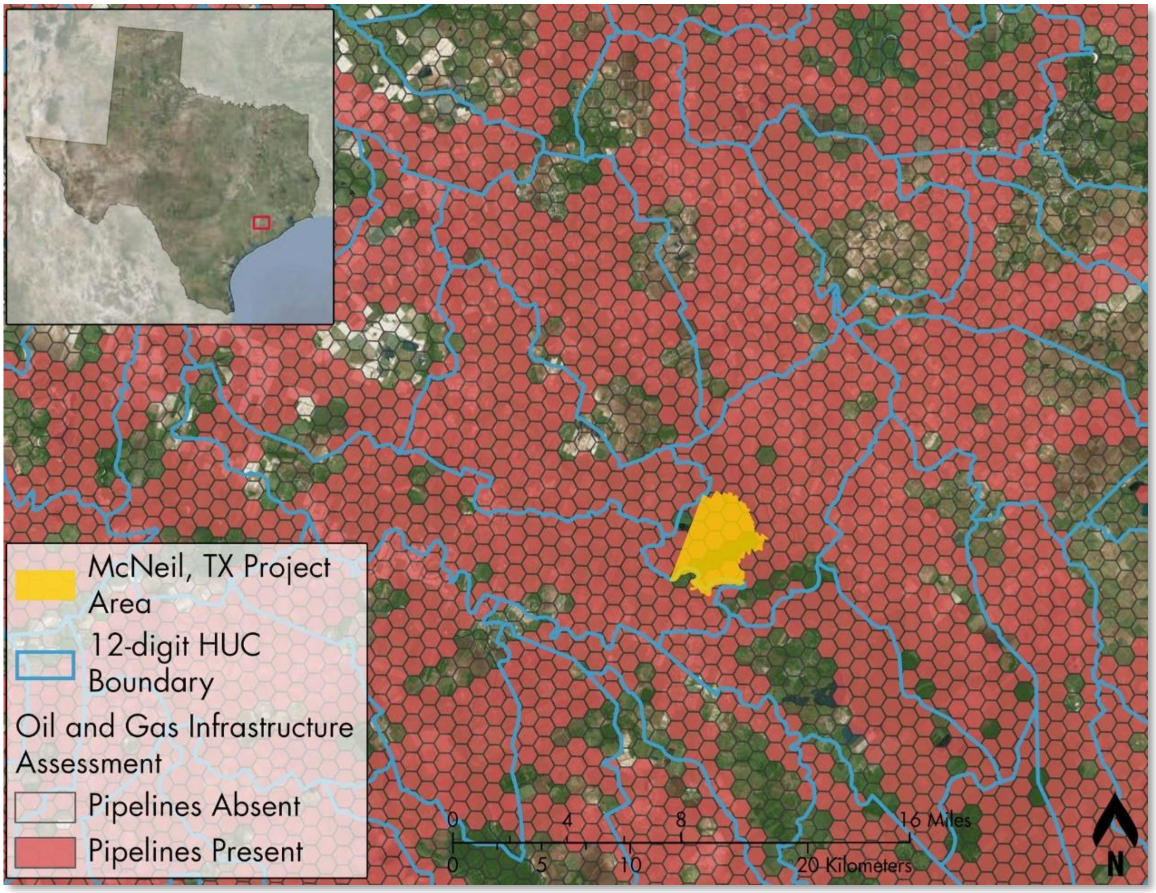


Figure 11. A representation of the pipeline presence data later

2.6.4. Community Benefit Metric Example

To calculate scores for the community benefits metrics (Table 13), census block groups or county level data were used as the primary unit for comparison and synthesis. Census block groups are not based on geographic watersheds, so the spatial areas were not fully congruent between human wellbeing data and ecosystem threats and ecosystem benefits data. The proposed project site was spatially located (Figure 12) and then identified within a block group (Figure 13). Community benefits metrics are challenging to ascribe to a project site due to the scale of data source, spatial patchiness of community data, and project locations (urban predominantly vs land based). Based on the project location, the regional domain (HUC 6) that has its centroid was selected, and the block groups that occur within the HUC 6 were used for spatial comparison; then, all the block groups with centroids within the ecoregion containing the project were located and compared (Figure 14 and Figure 15).

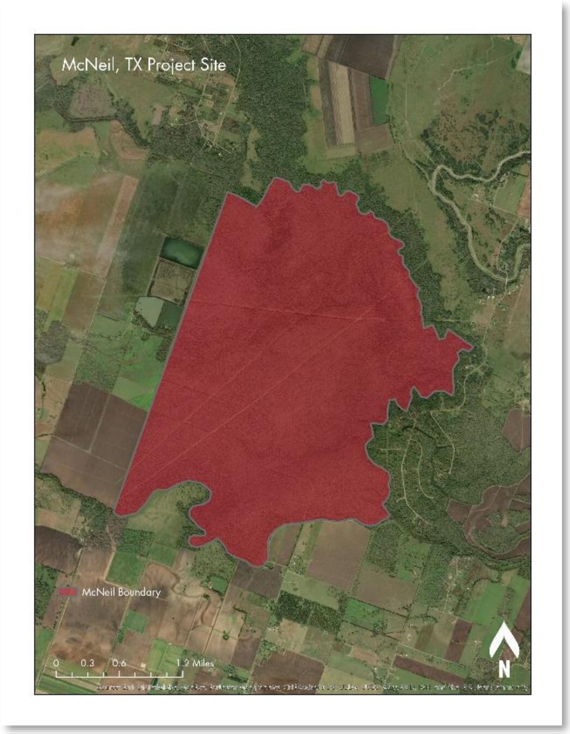
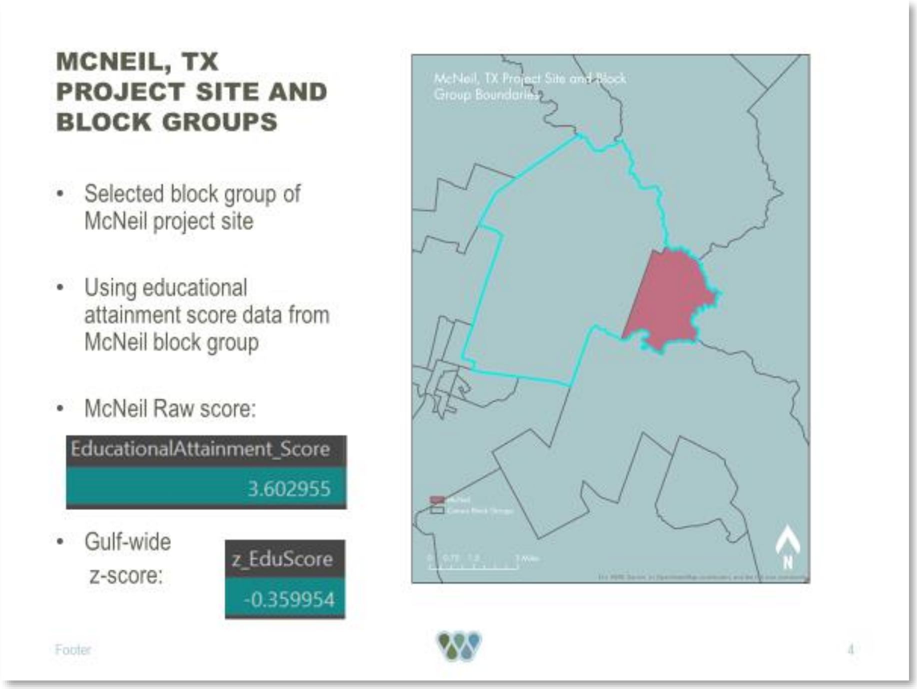


Figure 12. McNeil project site with background imagery



MCNEIL, TX PROJECT SITE AND BLOCK GROUPS

- Selected block group of McNeil project site
- Using educational attainment score data from McNeil block group
- McNeil Raw score:

EducationalAttainment_Score
3.602955

- Gulf-wide z-score:

z_EduScore
-0.359954

Figure 13. McNeil project location within the block group

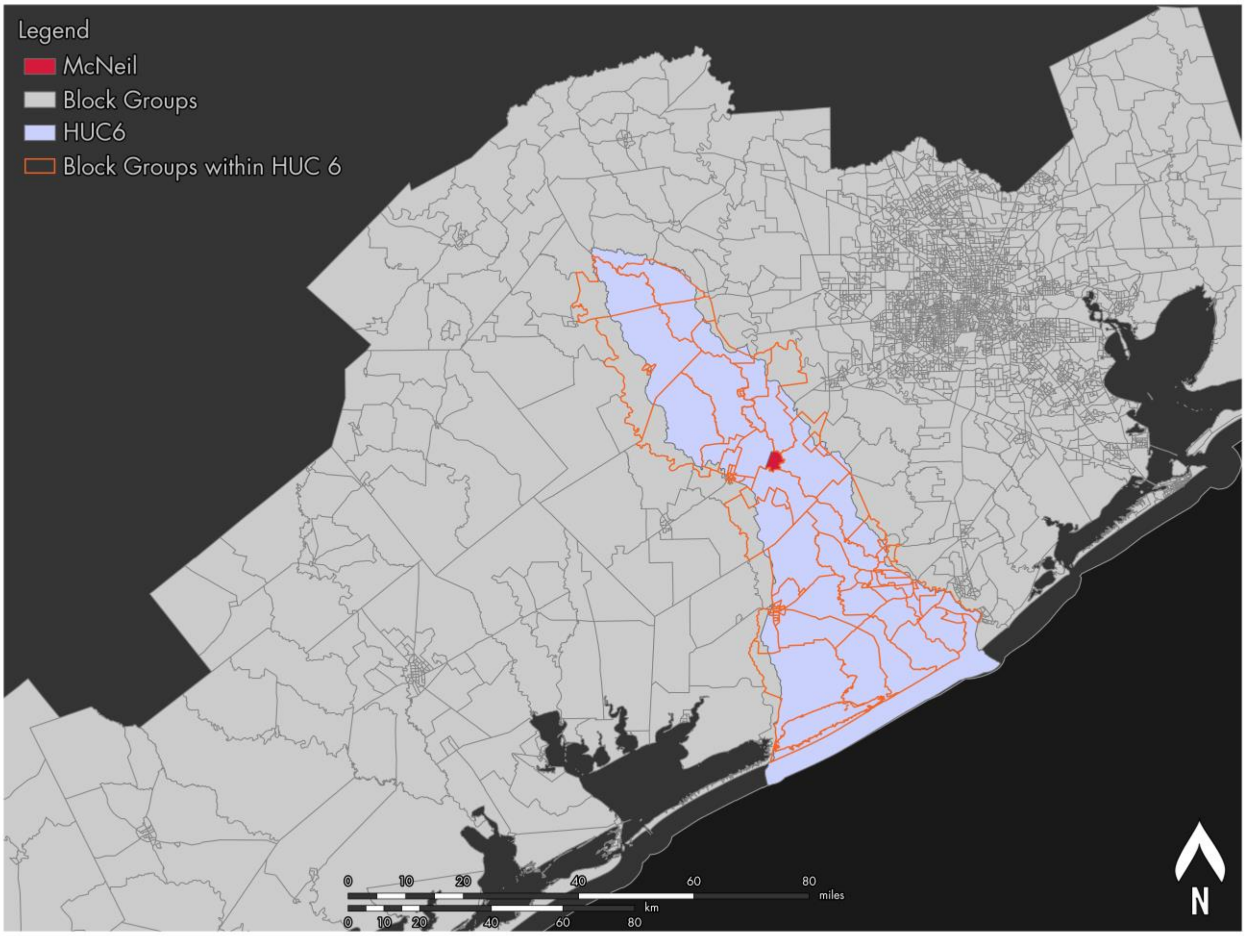


Figure 14. A representation of all the block groups that are within the regional watershed containing the McNeil project site

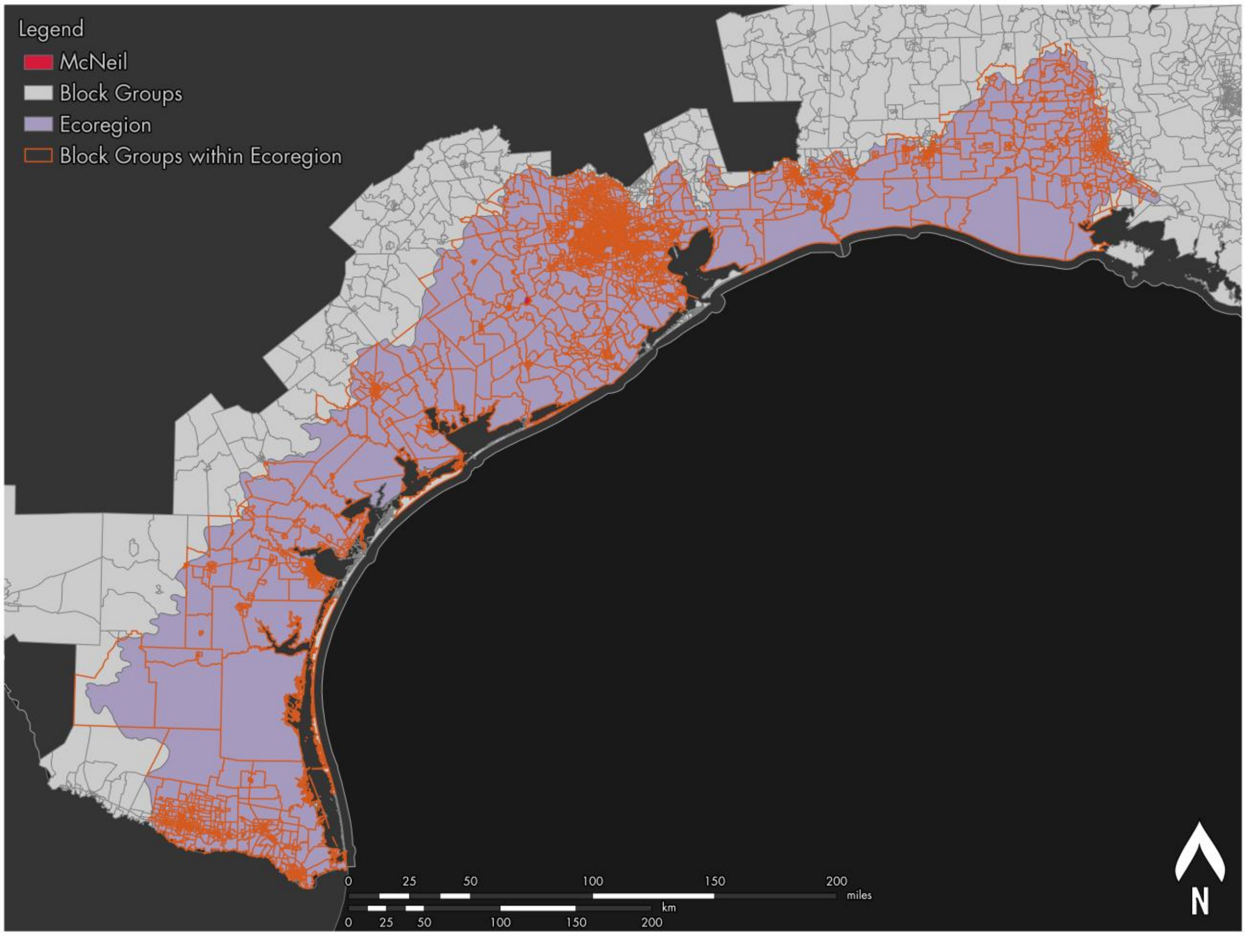


Figure 15. A representation of all the block groups within the ecoregion containing the McNeil project site

2.7. APPLICATION FORM FOR ANALYSIS OF POTENTIAL PROJECTS

In order to analyze potential projects thoroughly and efficiently, an application (or project summary information) form was developed. The Application Form for Proposed Conservation and Restoration Projects (or project summary information form) included project specific information necessary to run the decision support tool (the full form is included as Appendix C). While the decision support tool uses an established suite of metrics based on the habitat type, the application form will also allow end users to specify if particular metrics are important to a specific site or project, for example, connectivity, groundwater retention, or potential for nutrient reduction may be a specific focus for a proposed project. By identifying and providing threats and potential benefits metrics for the project site, it is possible to develop a more targeted and informative data synthesis for project decision support.

For projects to be considered for the Gulfwide Fund, the users will additionally be asked to provide project information on the total project cost (to acquire land, implementation, and monitoring plans) and the duration of the project. The requested project location information (shapefiles or geographical coordinates) will allow for the project to be spatially located so that the project can be analyzed and compared within appropriate watersheds. The application form has a series of questions seeking information on the proposed changes to the project site so that additional scenario assessments “with project" versus "without project" can be made to identify co-benefits that may result from the restoration or conservation project (Appendix C). A short summary report will be created for each project analyzed, which will include details on the overall combined scores for each of the analysis categories (potential ecosystem threats, potential ecosystem benefits, and potential community benefits), as well as observed contextual summaries of data in the context of regional watershed, ecoregion, and across the Gulf.

2.8. DECISION SUPPORT TOOL POST-PROCESSING

The Gulfwide Conservation and Restoration Decision Support Tool can be separated into five steps (Figure 16). The first two are carried out in GIS and the last three are analyzed in 'R', a statistical computing open source software. GIS is used to spatially determine which HUC 12s are within the domains. The first step of the model is to use project locations from shapefiles to identify which HUC 12s are relevant to the project location (Figure 16). The output of the first and second step is two text files that identify HUC 12s within the HUC6 and Ecoregion. Based on the resulting two text files, data is extracted from all the compiled threats, benefits, and wellbeing metrics in R, from which two tables are created (Steps 3 through 5, see output formats in results). These tables help provide a summary score for the project location with comparisons to their domains.

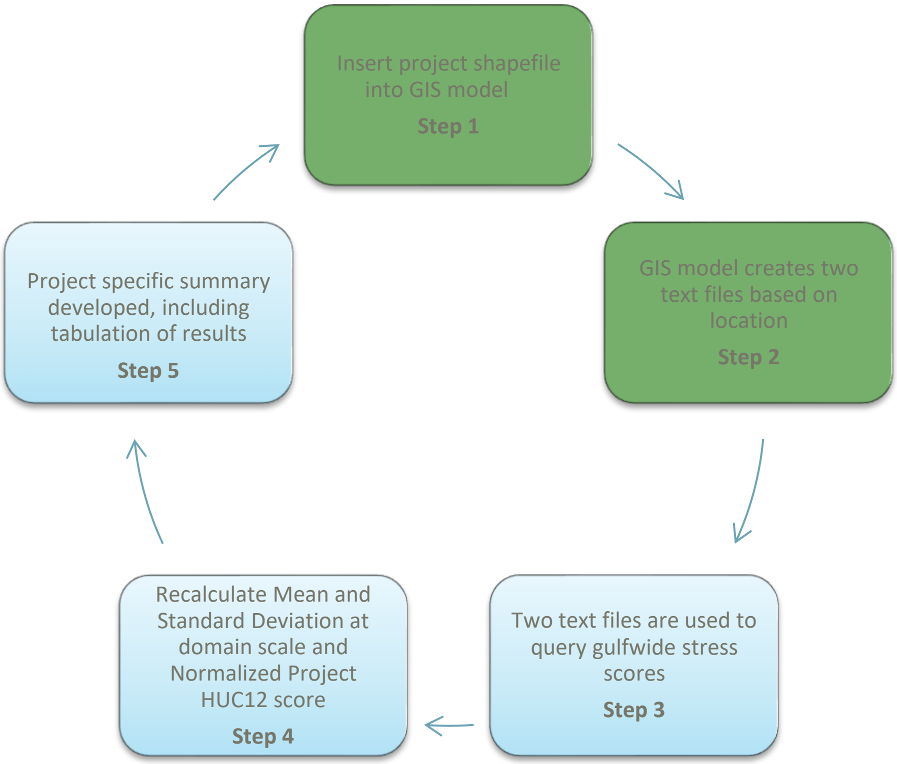


Figure 16. Restoration and Conservation Decision Support Tool flow diagram. Green indicates the step is performed in Arcmap and blue indicates the step is performed in R.

3.0 Results and Discussion

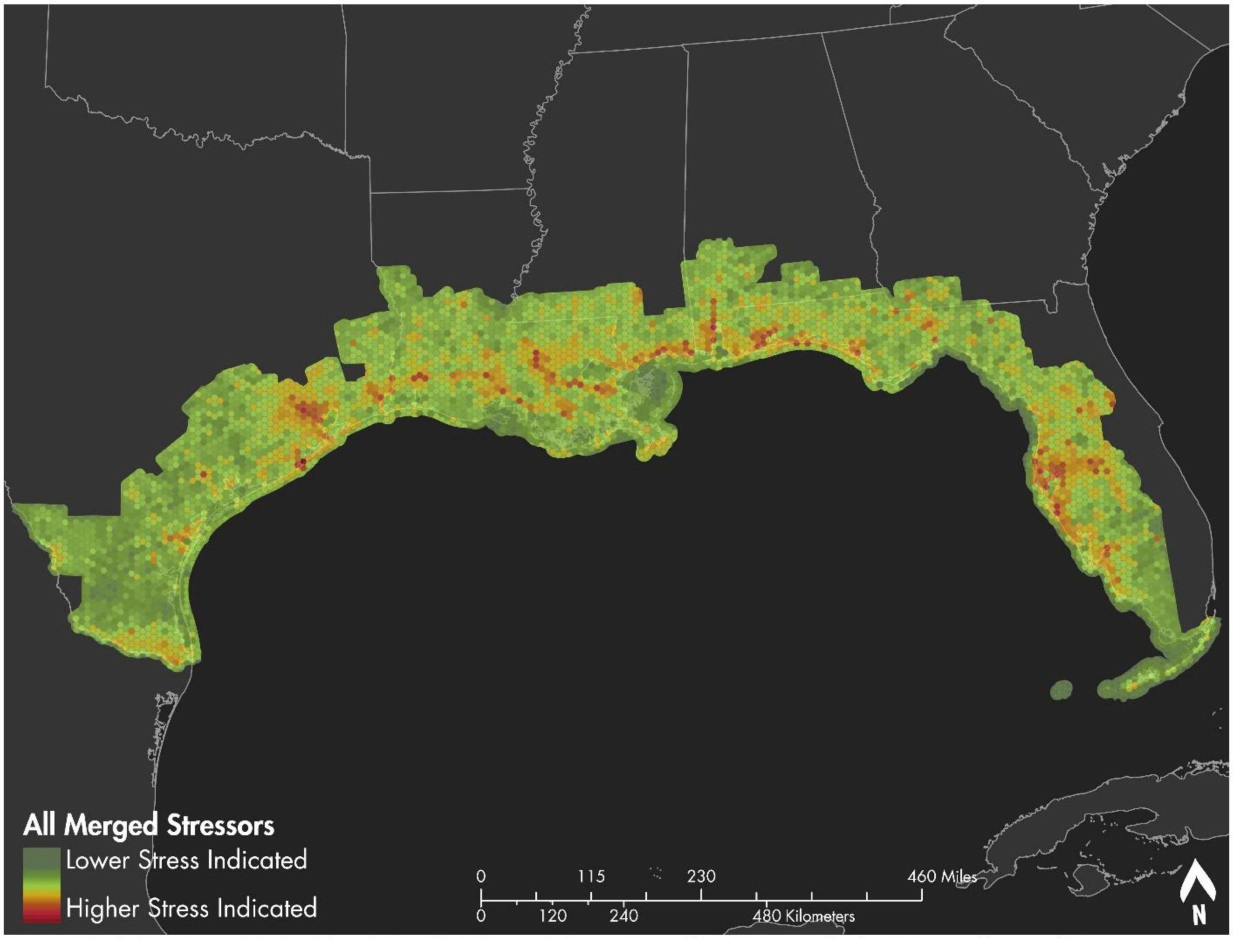
The results and discussion are presented in two sections, firstly summarizing the results for the Gulfwide data synthesis and secondly summarizing the outputs for the Gulfwide conservation and restoration decision support tool.

3.1. GULFWIDE DATA SYNTHESIS

The Gulfwide data synthesis was focused around synthesizing data on Ecosystem Threats, Ecosystem Benefits (as represented via habitat maps), and Community Benefits. These are presented and discussed, with reference to the underlying data sets where appropriate.

3.1.1. Ecosystem Threats

The map below (Figure 17) represents the combined stressor layer at the 100 km^2 hexagon grid scale in order to best depict data Gulfwide. This combined layer includes 40+ primary data layers combined into eight stressor groupings which were human population, industrial infrastructure, land change, pollution, Gulf of Mexico water quality, riverine/estuarine water quality, environmental hazards, and invasive species. A 1 km^2 hexagon grid was also developed and used within the conservation and restoration decision support tool.

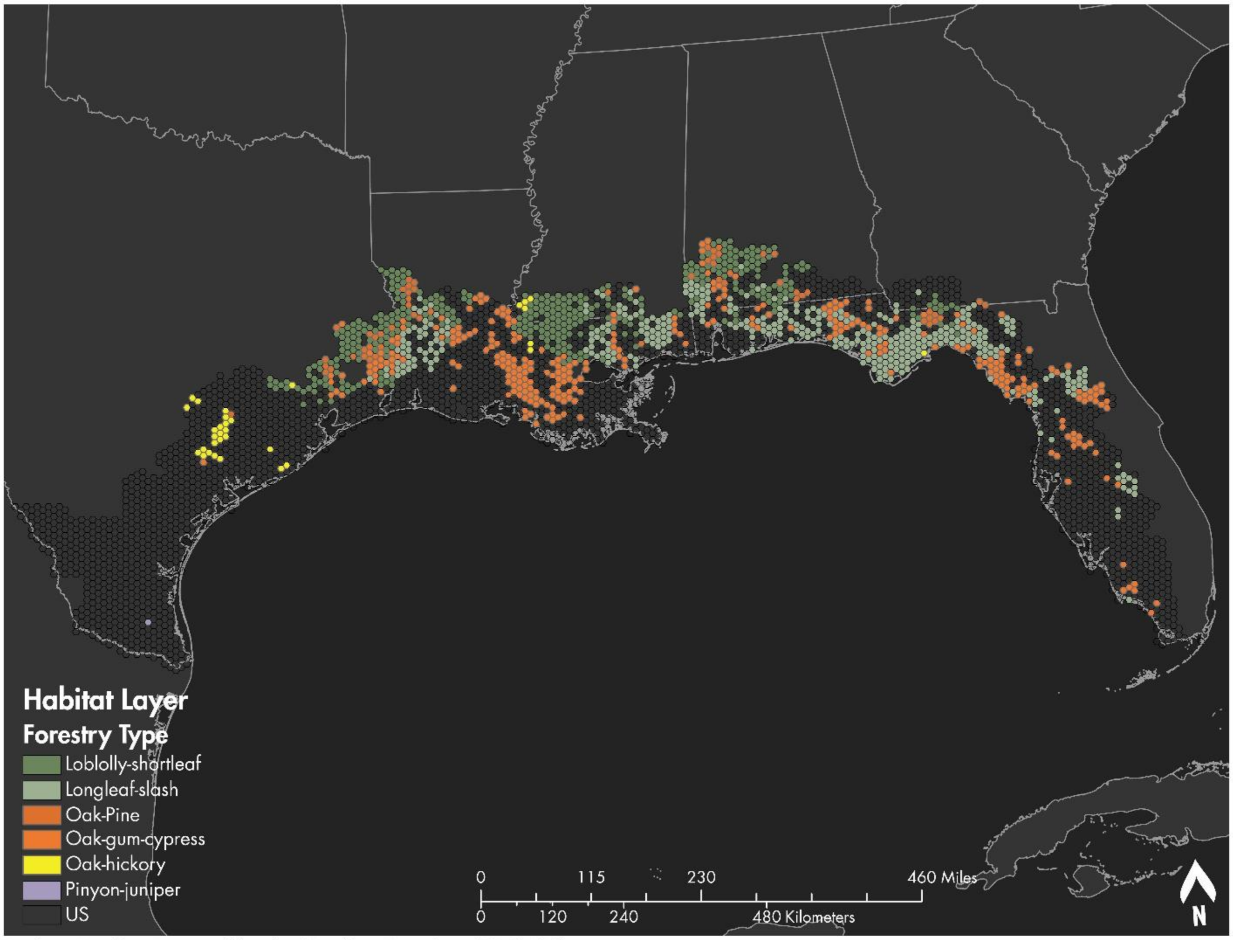


Data Source: BOEM, Colorado State University, EIA, EPA, Esri, FEMA, Google, HIFLD, NDMC, NOAA, Oregon State University, U.S. Bureau of Census, U.S. Department of Agriculture, U.S. Department of the Interior, and USGS

Figure 17. Combined stressor layer which integrates the eight categories shown in the previous figures mapped with 100 km^2 hexagons Gulfwide

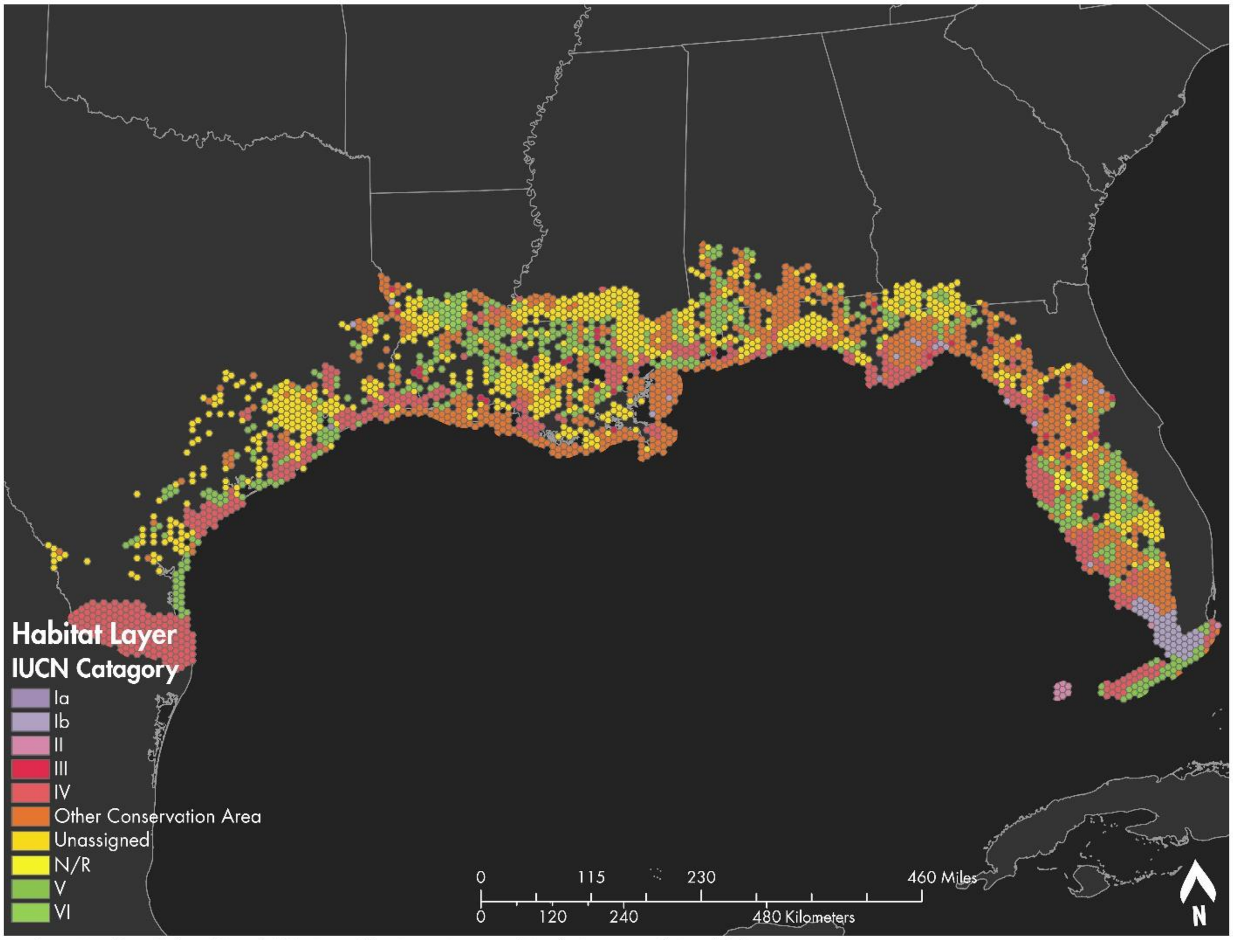
3.1.2. Ecosystem Benefits (Outputs from Habitat Data)

The maps below are shown at the 100 km^2 hexagon grid scale in order to best depict data Gulfwide. A 1 km^2 hexagon grid was also developed and used for calculations in the conservation and restoration decision support tool. A series of data layers relevant to the description of habitats with information on potential ecosystem services provided by a project at a specified location were utilized. Presented here are forest type as an example of one relevant ecological layer (Figure 18), and a summary of Protected Areas Domain (PAD) as an example of a governance layer relevant to conservation and restoration planning decision-making (Figure 19).



Data Source: United States Department of Agriculture & United States Forestry Service (USDA & USFS)

Figure 18. Forestry habitat layer mapped with 100 km^2 hexagons Gulfwide

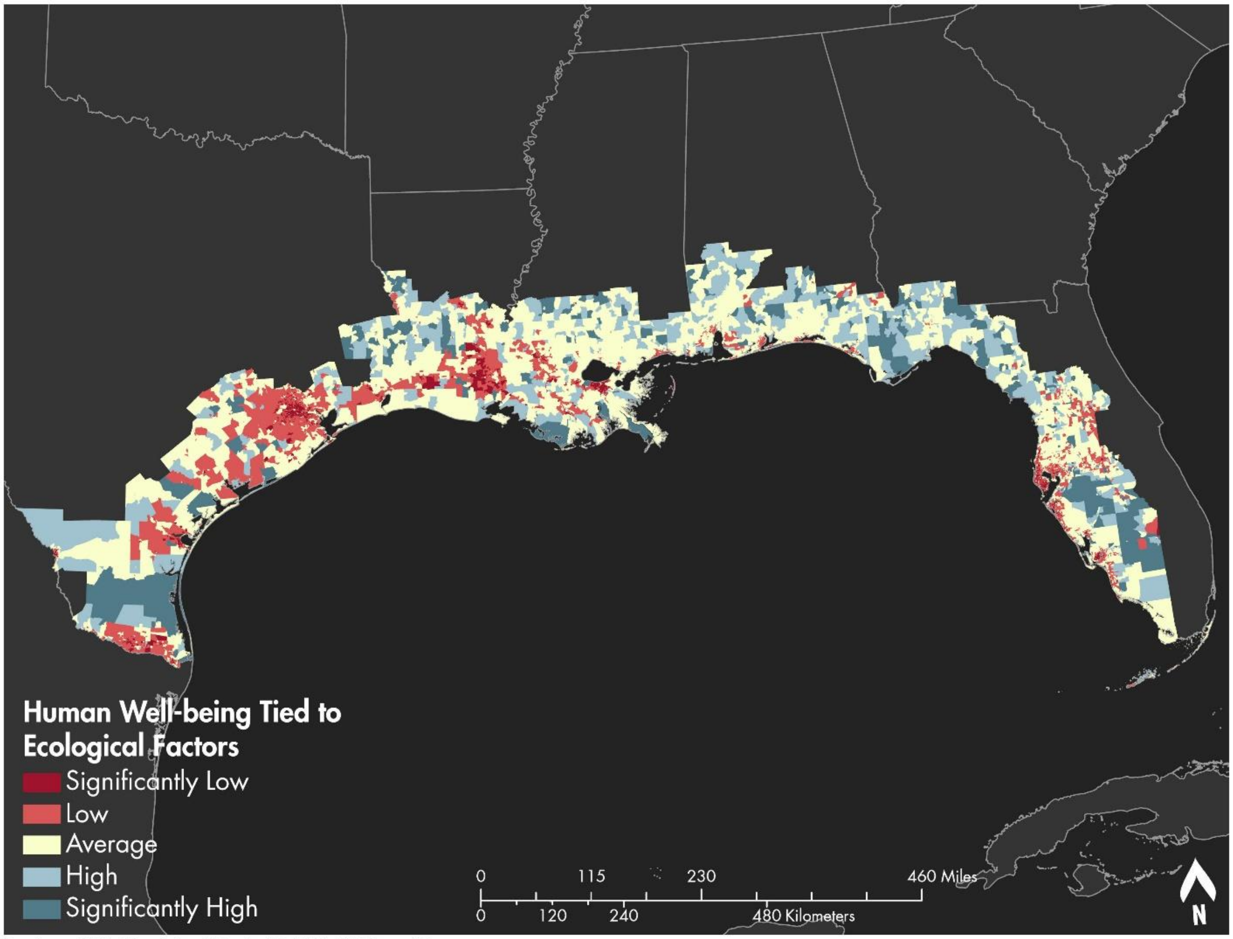


Data Source: United States Geological Survey (USGS) - Protected Area Domain - International Union for Conservation of Nature (IUCN)

Figure 19. Protected Areas Domain (PAD) habitat layer mapped with 100 km^2 hexagons Gulfwide

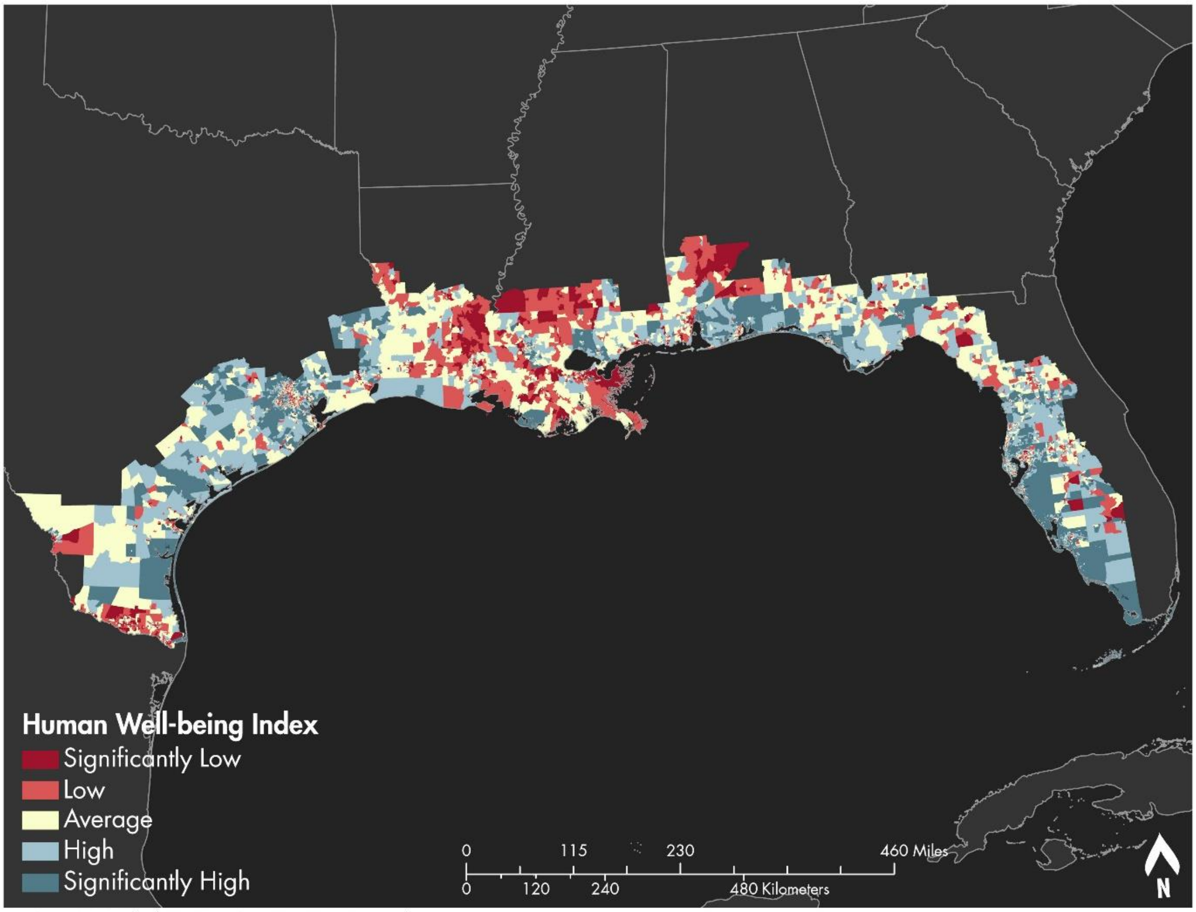
3.1.3. Community Benefits

The maps below (Figure 20 and Figure 21) are represented at the block group scale based on utilized social input data and represent the finest resolution of these data sets. Human wellbeing related to ecological factors is particularly relevant for conservation and restoration projects by summarizing proximity to recreational greenspace and natural resource employment (Figure 20). This highlights some very different areas than the overall combined index of human wellbeing (Figure 21) which also includes a series of metrics related to poverty, health, education, and income.



Data Source: CIRES, Colorado State University, EIA, NOAA, U.S. Bureau of Census

Figure 20. Human wellbeing metrics related to ecological factors mapped Gulfwide at block group level. This includes proximity to recreational greenspace and natural resource employment.



Data Source: CIRES, Colorado State University, EIA, NOAA, U.S. Bureau of Census

Figure 21. Combined human wellbeing metrics mapped by block group Gulfwide. This map combines data from Figure 20 as well as those for general human wellbeing metrics (income, income inequality, home ownership, population density, poverty, educational attainment, chronic disease prevalence, and leisure activities).

3.2. OUTPUT FROM THE GULFWIDE CONSERVATION AND RESTORATION DECISION SUPPORT TOOL: MCNEIL FOREST CONSERVATION PROJECT

The Gulfwide Conservation and Restoration Decision Support Tool uses three broad criteria to inform the potential for success of an identified conservation or restoration project, in this case the McNeil Forest Conservation Project. The criteria include potential threats to the project area (19 metrics) that may reduce the chance of project success or alternately may identify specific challenges within the local watershed that the project could improve. Secondly, the criteria include potential ecosystem benefits from the project (5 metrics), which are largely based on aspects of habitat type and relevant governance considerations, such as proximity to other protected areas. Finally, the potential community benefits (10 metrics) of the project were summarized.

The McNeil Forest Conservation Project is roughly 9.7 mi^2 and within the Western Gulf Coastal Plain Ecoregion characterized by a humid subtropical climate (61-68^{o}F) with an annual rainfall between 40-53 inches. Land use/land cover consists of woody wetlands, cultivated crops, and deciduous forest. Forests are predominately oak and hickory with a 78% canopy cover. Water features on the site consist of stream/river and lake/reservoir. Geological characteristics of the McNeil project site consist of loose and unconsolidated sandy alluvium soil. The project site does not contain any identified critical habitat, historical sites, or parks. (Table 15).

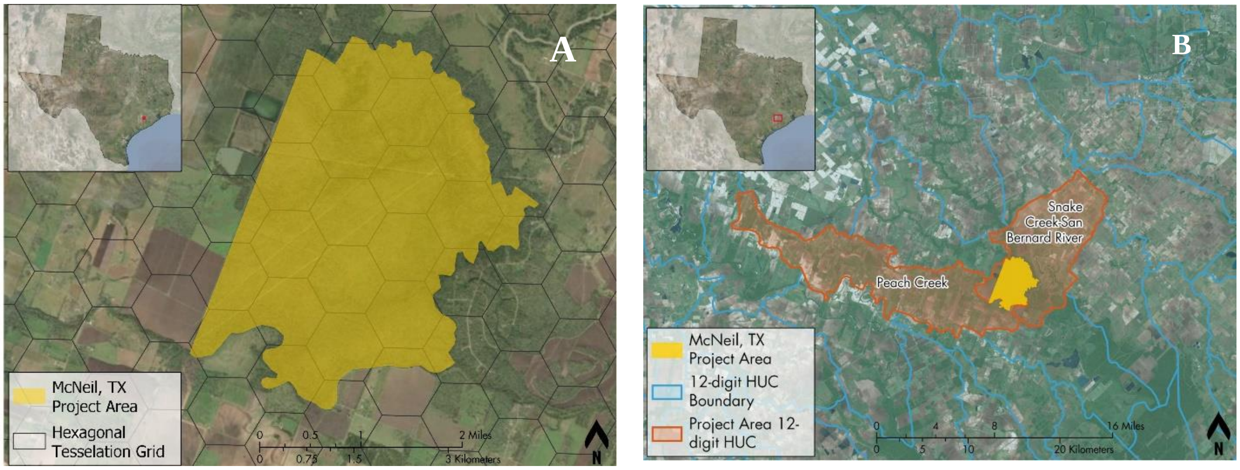


Figure 22. The proposed McNeil Forest Conservation Project site location (A) and the local watershed (HUC12) containing the project site (B)

Table 16. McNeil Forest Conservation Project site features

McNeil Forest Conservation Project Area	
Land use/Land cover	Woody Wetlands, Cultivated Crops, and Deciduous Forest
Water Features	Stream/River & Lake/Reservoir
Forest types	Oak/Hickory, 78% Canopy cover
Wetland types	Freshwater Forested/Shrub Wetland
Nonpoint nitrogen and phosphorus	None
Geology	Alluvium (Sand)
Historical Sites and Parks	None
Critical Habitat	None
Groundwater recharge mm yr^{-1}	51

3.3. POTENTIAL ECOSYSTEM THREATS TO MCNEIL FOREST CONSERVATION PROJECT

The McNeil Forest Conservation Project was evaluated using 19 potential ecosystem threat metrics (Table 17). The score for the local watershed containing the proposed project was compared to regional watershed-HUC6, the surrounding Ecoregion III, and northern Gulf of Mexico coast (Table 18). Oil and gas pipeline density is presented below as examples of how specific metrics can be investigated if they are of particular relevance to a proposed project or funding mechanism.

Table 17. Potential ecosystem threats on the local watershed (HUC12) containing the McNeil forest conservation project site, mean values for all local watersheds within the regional watershed (HUC6), Ecoregion, and Gulfwide, SD – Standard Deviations

McNeil Forest Conservation Project							
Threats (% of area categorized as threat present)	**Project's HUC12**	**Regional Watershed (HUC6)**	**SD in HUC6**	**EPA Ecoregion III**	**SD in Ecoregion**	**Gulfwide**	**SD in Gulfwide**
Pipelines	**87**	**64**	*23*	**61**	*23*	**28**	*28*
Hazardous Facilities	**0**	**1**	*2*	**2**	*6*	**1**	*3*
Impervious Surface	**0**	**0**	*1*	**6**	*17*	**3**	*11*
Dams	**0**	**0**	*0*	**0**	*0*	**0**	*1*
SLR	**0**	**9**	*20*	**22**	*34*	**15**	*30*
Soil Erodibility	**39**	**33**	*18*	**38**	*37*	**25**	*34*
Land Type Change (Natural to Agriculture)	**21**	**28**	*15*	**23**	*16*	**29**	*25*
Land Type Change (Natural to Developed)	**0**	**3**	*3*	**11**	*20*	**10**	*17*
TRI	**0**	**0**	*1*	**2**	*5*	**1**	*3*
Superfund	**0**	**0**	*0*	**0**	*1*	**0**	*1*
Stream Impaired	**13**	**12**	*12*	**5**	*9*	**6**	*10*
Waterbody Impaired	**0**	**0**	*2*	**1**	*5*	**1**	*7*
Nonpoint Pollution	**2**	**4**	*5*	**30**	*42*	**54**	*42*
Hurricane	**0**	**13**	*20*	**19**	*22*	**24**	*25*
Tornado	**1**	**2**	*2*	**6**	*8*	**6**	*8*
Drought	**100**	**100**	*0*	**66**	*47*	**27**	*44*
Rain	**0**	**1**	*2*	**37**	*47*	**68**	*45*
SFHA	**66**	**71**	*15*	**64**	*25*	**70**	*27*
Forest Fire	**3**	**6**	*14*	**15**	*26*	**44**	*44*
Forestry Disease	**0**	**0**	*1*	**1**	*5*	**16**	*25*

3.3.1. Selected Potential Ecosystem Threats Results

Oil and Gas Pipeline Density

Occurrence of oil and gas pipelines was very high (present in 87% of the 1 km^2 hexagonal grid cells) within the local watershed (HUC12) containing the McNeil forestry conservation project site (Figure 23).

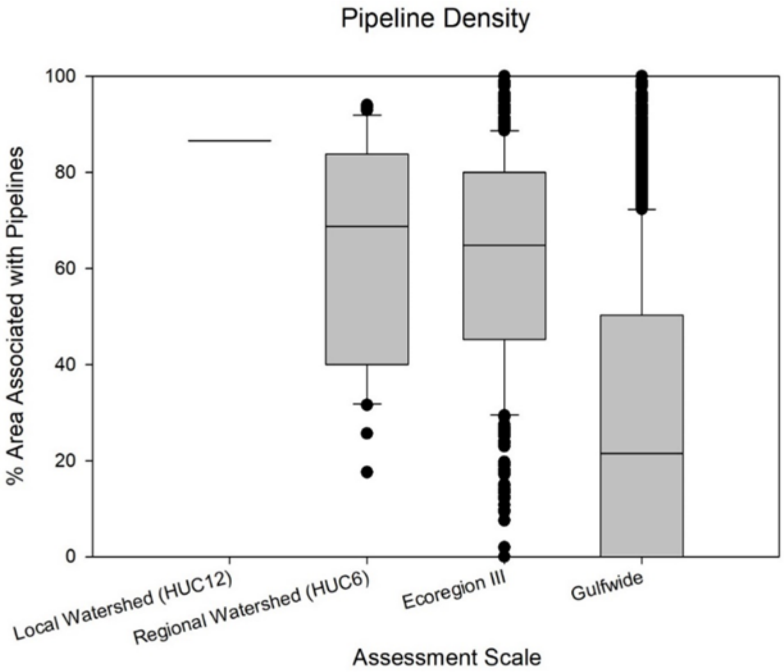


Figure 23. Pipeline densities within the local watershed (HUC12) surrounding the project site and within spatial extents of interest. Graph indicates median, 25th and 75th percentiles, 10th and 90th percentiles, and high and low outlier data points, in comparison to three spatial scales.

3.3.2.Normalized Potential Ecosystem Threats Scores

To compare diverse metrics and calculate an overall relative potential ecosystem threat value for the project site, the results for each metric were normalized linearly on a scale from 0 to 1; with the highest value assigned a 1 and the lowest value assigned a 0 (i.e., normalized over the data range). Therefore, the following results are unitless and bounded between 0 and 1.

The overall potential ecosystem threats to the proposed McNeil Forest Conservation Project were very low (<0.20) when considering the site within the regional watershed, the Western Gulf Coast Plain ecoregion, or across the northern Gulf of Mexico. Eleven of the synthesized metrics were zero, indicating that the local watershed surrounding this project site has the least threat from these factors within the entire Gulf region. Pipeline density, drought, and special flood hazard area were the three largest potential threats to the project site. Some other threats were present but low or very low including, soil erodability, land change from natural to agricultural, length of impaired stream, nonpoint source pollution, tornado occurrence, and forest fires.

Table 18. Potential ecosystem threats to the local watershed containing the McNeil forest conservation project. Values range from the least (0) to most (1) threat (0). (Very low 0.0 – 0.2; low 0.2-0.4; moderate 0.4-0.6; high 0.6-0.8, and very high 0.8-1.0).

McNeil Forest Conservation Project				
	% of area	**Range Normalized Scores**		
Stressors	**Project's Local Watershed (HUC12)**	**Regional Watershed (HUC6)**	**EPA Ecoregion III**	**Gulfwide**
Pipelines	87	0.90	0.87	0.87
Hazardous Facilities	0	0	0	0
Impervious Surface	0	0	0	0
Dams	0	0	0	0
SLR	0	0	0	0
Soil Erodibility	39	0.57	0.39	0.39
Land Type Change (Natural to Agriculture)	21	0.30	0.26	0.21
Land Type Change (Natural to Developed)	0	0	0	0
TRI	0	0	0	0
Superfund	0	0	0	0
Stream Impaired	13	0.28	0.26	0.14
Waterbody Impaired	0	0	0	0
Nonpoint Pollution	2	0.12	0.02	0.02
Hurricane	0	0	0	0
Tornado	1	0.10	0.02	0.01
Drought	100	0	1	1
Rain	0	0	0	0
SFHA	66	0.42	0.66	0.66
Forest Fire	3	0.05	0.03	0.03
Forestry Disease	0	0	0	0
Mean values		**0.14**	**0.18**	**0.17**

3.4. POTENTIAL ECOSYSTEM BENEFITS

The McNeil Forest Conservation Project was evaluated using five metrics of potential ecosystem benefit (Table 19). The score for the local watershed containing the proposed project was compared to the regional watershed-HUC6, Ecoregion III, and norther Gulf of Mexico coast (Table 20). Tree canopy cover is presented below as examples of how specific metrics can be investigated if they are of particular interest to a project or funding mechanism.

Table 19. Potential ecosystem benefits on the local watershed (HUC12) containing the McNeil forest conservation project site, mean values of all local watersheds (HUC12s) within the regional watershed (HUC6), Ecoregion, and Gulfwide. Standard deviation (SD) scores are for the HUC12 containing the project within the three larger geographic domains.

McNeil Forest Conservation Project							
Benefits	**Project's HUC12**	**Regional Watershed (HUC6)**	**SD in HUC6**	**EPA Ecoregion III**	**SD in Ecoregion**	**Gulfwide**	**SD in Gulfwide**
Total Carbon Storage (kg m^{-2})	**0.07**	**0.43**	*0.58*	**0.95**	*1.62*	**5.05**	*4.01*
Habitat Connectivity (%)	**36.88**	**38.33**	*28.19*	**32.68**	*32.03*	**49.98**	*32.42*
Priority Habitat (%)	**1.18**	**1.07**	*0.21*	**0.91**	*0.42*	**4.21**	*4.49*
Percent Canopy (%)	**24.31**	**19.41**	*14.27*	**14.03**	*12.84*	**42.06**	*27.53*
Groundwater Recharge (mm yr^{-1})	**50.8**	**51.4**	*31.53*	**48.82**	*42.52*	**153.8**	*138.09*

3.4.1. Selected Potential Ecosystem Benefits Results

Percent Canopy Cover

Canopy cover within the local watershed (HUC12) containing the McNeil Forest Conservation Project was very low (19%), but within the project site itself was high (78%) (Figure 24).

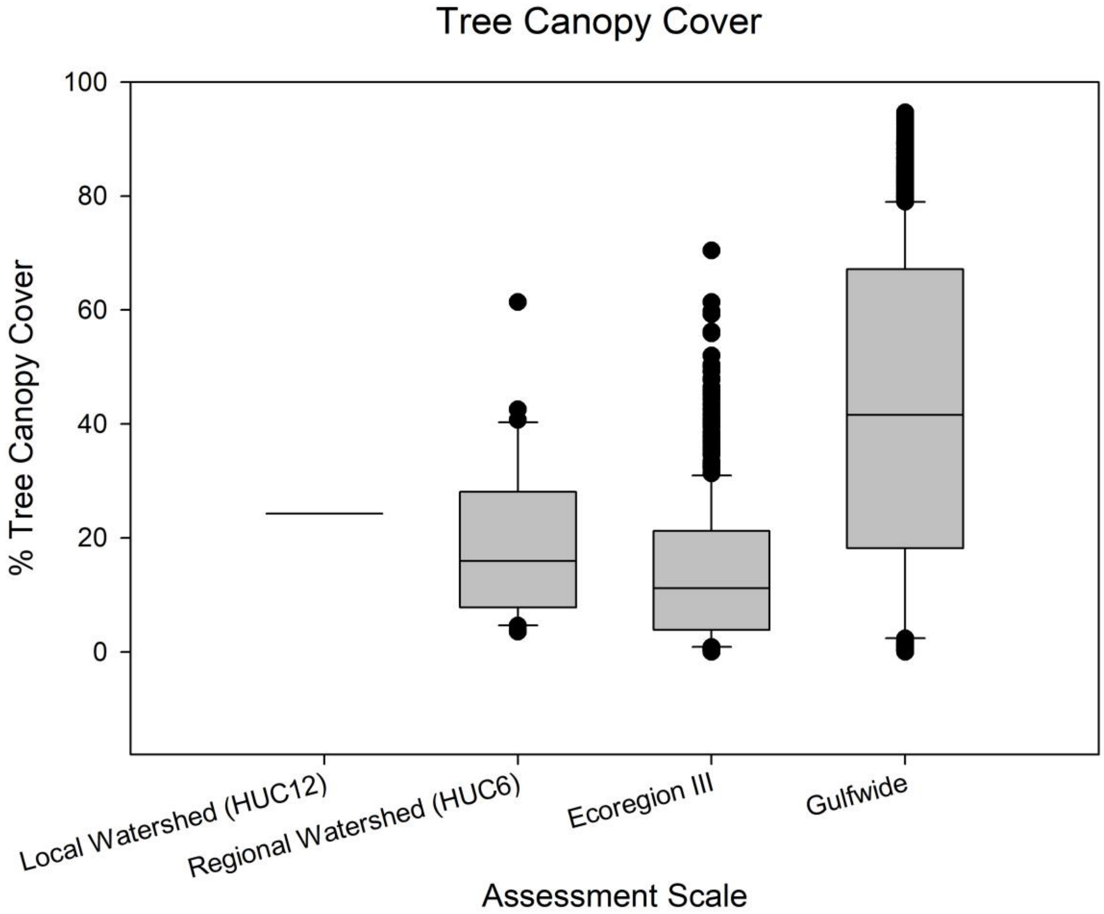


Figure 24. Tree canopy cover within the local watershed (HUC) surrounding the project site and within spatial extents of interest. Graph indicates median, 25th and 75th percentiles, 10th and 90th percentiles, and high and low outlier data points other domains.

3.4.2. Normalized Potential Ecosystem Benefit Scores

To compare diverse metrics and calculate an overall relative potential ecosystem threat value for the project site, the results for each metric were normalized linearly on a scale from 0 to 1; with the highest value assigned a 1 and the lowest value assigned a 0 (i.e., normalized over the data range). Therefore, the following results are unitless and bounded between 0 and 1.

The overall potential ecosystem benefits from the proposed McNeil Forest Conservation Project were low (0.39) for the local watershed containing the project site compared to the regional watershed, low compared to the Western Gulf Coast Plain ecoregion (0.30), and very low when compared across the northern Gulf of Mexico coast (0.14) (Table 20). Potential ecosystem benefits from the project were generally higher when compared within the regional watershed context than within the Ecoregion III or the entire northern Gulf of Mexico coast.

Table 20. Potential ecosystem benefits analysis at different scales for the McNeil forest conservation project. Values range from the least benefit (0) to the most benefits (1). Higher values are more beneficial then lower values. Calculated metrics were linearly transformed so that the largest metric was assigned a value of 1 and the lowest metric was assigned a value of 0. (Very low 0.0 – 0.2; low 0.21-0.4; moderate 0.41-0.6; high 0.61-0.8, and very high 0.81-1.0).

McNeil Forest Conservation Project				
Potential Ecosystem Benefits	**Raw Data**	**Range Normalized Values**		
	Project's Local Watershed (HUC12)	**Regional Watershed (HUC6)**	**EPA Ecoregion III**	**Gulfwide**
Total Carbon Storage (kg/m)	0.07	0.01	0.01	0.00
Habitat Connectivity (%)	36.88	0.40	0.37	0.37
Priority Habitat	1.18	0.80	0.45	0.02
Percent Canopy (%)	24.31	0.36	0.35	0.26
Groundwater Recharge (mm/yr)	80.8	0.39	0.34	0.06
Total Averages		**0.39**	**0.30**	**0.14**

3.5. POTENTIAL COMMUNITY BENEFITS

The McNeil Forest Conservation Project was evaluated using 10 potential community benefit metrics (Table 21). The score for the local watershed containing the proposed project was compared to the regional watershed-HUC6, Ecoregion III, and norther Gulf of Mexico coast (Table 22). Potential for recreation is presented below as an example of how specific metrics can be investigated if they are of particular relevance to the proposed project or funding mechanism.

Table 21. Potential community benefits within the local watershed (HUC12) containing the McNeil forest conservation site and mean values for all local watersheds within the regional watershed (HUC6), the EPA Ecoregion III, and the northern Gulf of Mexico coast (Gulfwide)

McNeil Forest Conservation Project							
Community	**Project's HUC12**	**Regional Watershed (HUC6)**	**SD in HUC6**	**EPA Ecoregion III**	**SD in Ecoregion**	**Gulfwide**	**SD in Gulfwide**
Population Density (mi^{-2})	**0.26**	**51.34**	*85.8*	**523.98**	*1085.2*	**375.8**	*807.63*
Income Inequality	**0.46**	**0.44**	*0.05*	**0.43**	*0.06*	**0.44**	*0.06*
Home Ownership (%)	**58**	**72.49**	*17.56*	**61.08**	*25.93*	**64.58**	*24.18*
Per Capita Income US$	**18,116**	**24,608**	*6,694*	**27,047**	*19,444*	**26,931**	*16,554*
Educational Attainment (unitless score)	**3.6**	**3.58**	*0.4*	**3.75**	*0.96*	**3.9**	*0.82*
Chronic Disease (aggregated %)	**13.6**	**13.26**	*0.89*	**13.06**	*1.36*	**13.42**	*1.95*
Healthy Behaviors (%)	**72.3**	**74.3**	*1.58*	**75.69**	*3.67*	**74.44**	*4.19*
Poverty Score	**28.9**	**26**	*20.4*	**28.27**	*23.31*	**26.71**	*22.65*
Employment in Renewable Natural Resource Industries (%)	**5.0**	**4.0**	*6.3*	**0.9**	*3.01*	**1.36**	*4.34*
Potential for Recreation (aggregated %)	**41.0**	**44.2**	*23.0*	**21.5**	*19.3*	**37.3**	*29.2*

3.5.1. Selected Potential Community Benefit Results

Potential for Recreation

Potential for recreation is an aggregated percentage of greenspace, parks, wetlands, and beach. These were included to represent spaces where individuals can enjoy outdoor leisure activities. The recreational greenspaces are summarized and represented at the U.S. Census-designated block group level. The McNeil forest conservation project site block group had a relatively low aggregated recreational space level when considered at multiple spatial extents.

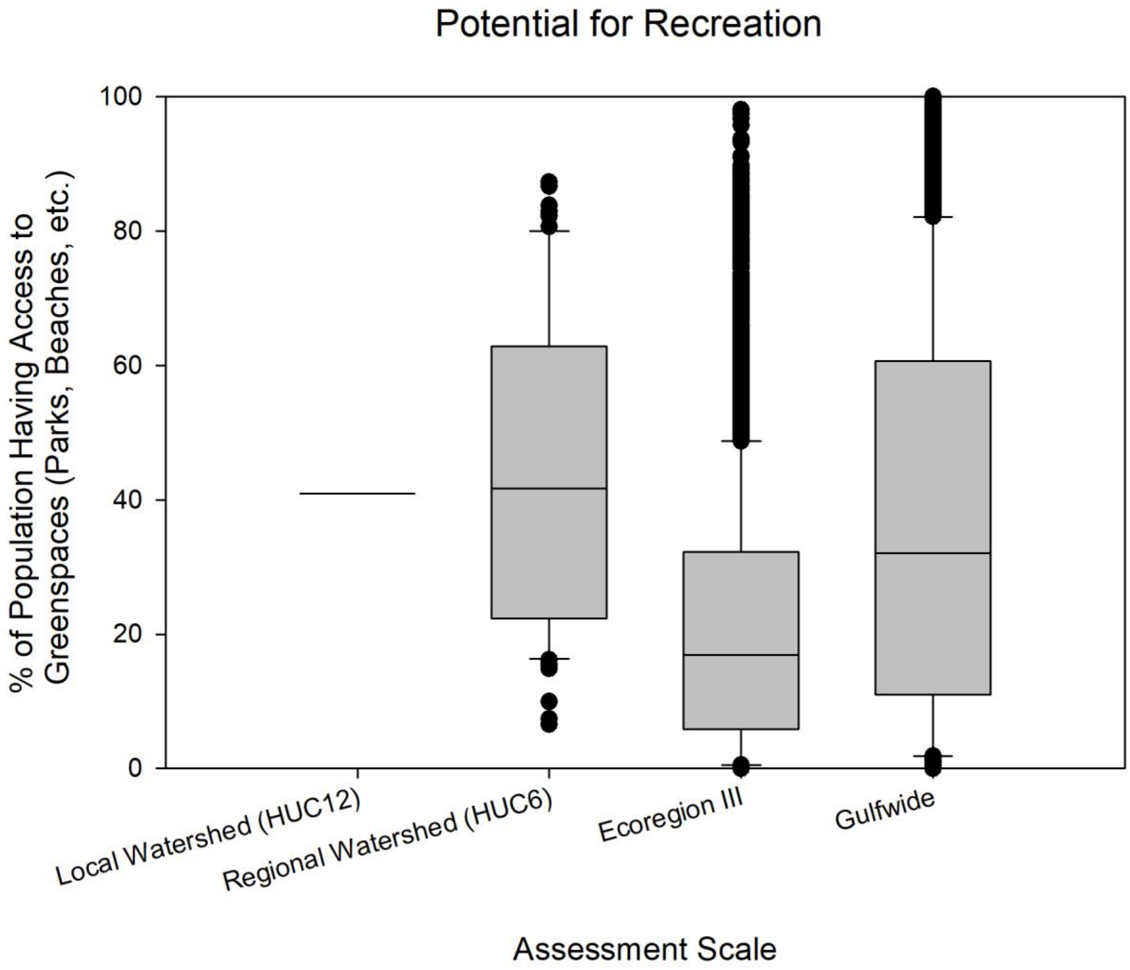


Figure 25. Potential for recreation within the local watershed containing the project site, regional watershed-HUC6, Ecoregion III-EPA, and across the northern Gulf of Mexico. Graphs indicate mean, 25th and 75th percentiles, 10th and 90th percentiles and outliers.

3.5.2. Normalized Potential Community Benefit Scores

To allow for comparison between metrics and to calculate an overall potential ecosystem threat value, the results for each metric were normalized linearly on a scale from 0 to 1; with the highest value assigned a 1 and the lowest value assigned a 0. The overall potential community benefits from the proposed McNeil conservation forestry project are moderate compared to other sites within the regional watershed (0.42), the Western Gulf Coast Plain ecoregion (0.51), or across the northern Gulf of Mexico (0.48) (Table 22).

For all metrics, a score of 1 was the maximum, but for some measures, such as population density, poverty index, income inequality, chronic diseases, a low value for the metric (e.g., low rates of poverty) represented a greater community benefit.

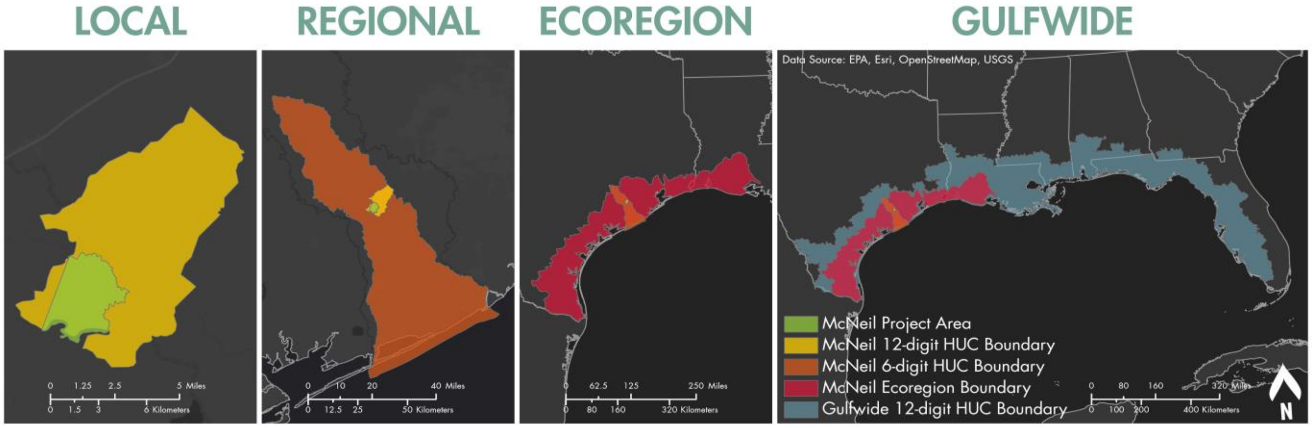
Population density around the project site was low (high community wellbeing) compared to the regional watershed, the ecoregion, and across the northern Gulf of Mexico. Income was moderate compared to the regional watershed, but very low when compared at larger scales. The project site is in an area that has very poor human health metrics when scored regionally, but scored as moderate human health when compared across the Gulf coast. This indicates that the project has potential to provide local health benefits. Per capita income and employment in natural resources sector are very poor on a Gulfwide scale and have potential to be improved by the project. Population density around the project site is low (very good for community wellbeing) and poverty is low (high community wellbeing) compared to all geographic scales. Employment rate in renewable and natural resource industries is currently very poor compared to the local region as well as across the northern Gulf of Mexico.

Table 22. Potential community analysis at different scales for the McNeil forest conservation project. Values range from the least beneficial (0) to the most beneficial (1). '*' indicates metrics where a low value is associated with higher potential for community benefit.
(Very low 0.0 – 0.2; low 0.2-0.4; moderate 0.4-0.6; high 0.6-0.8, and very high 0.8-1.0).

McNeil Forest Conservation Project				
	Raw Data	**Range Normalized Scores**		
Potential Human Wellbeing Benefits	**Project's Local Watershed (HUC12)**	**Regional Watershed (HUC6)**	**EPA Ecoregion III**	**Gulfwide**
Population Density (pop./mi^2)	0.26	1	1.00	1.00
Income Inequality (Gini Index)	0.46	0.46	0.45	0.39
Home Ownership (%)	58	0.48	0.58	0.58
Per Capita Income ($ in 2016)	18,116	0.41	0.08	0.08
Educational Attainment (unitless score)	3.6	0.50	0.39	0.41
Chronic Disease (aggregated %)	13.6	0.07	0.60	0.54
Healthy Behaviors (%)	72.3	0	0.59	0.49
Poverty Index	28.9	0.64	0.86	0.86
Employment in Renewable Natural Resource Industries (%)	5.0	0.19	0.09	0.07
Potential for Recreation (aggregated %)	41.0	0.43	0.42	0.41
Combined Potential Community Benefits Value		**0.42**	**0.51**	**0.48**

4.0 Example Site Output of Decision Support Data

Decision Support Summary: McNeil Forest Conservation Project



Project within local watershed (HUC12)

Project within local watershed (HUC6)

Project within western Gulf Coastal Plain

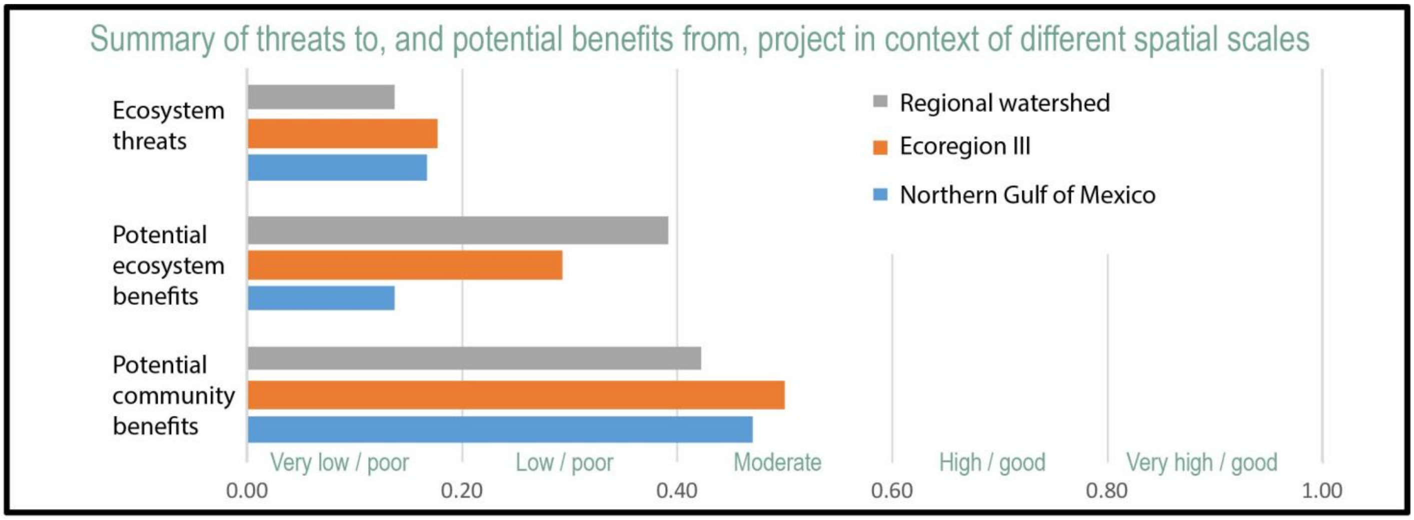
Project within northern Gulf of Mexico Coastal

Project Site Attributes

McNeil Forest Conservation Project Area	
Land use/Land cover	Woody Wetlands, Cultivated Crops, and Deciduous Forest
Water Features	Stream/River & Lake/Reservoir
Forestry	Oak/Hickory, 78% Canopy cover
Wetlands	Freshwater Forested/Shrub Wetland
Non-point Pollution	None
Geology	Alluvium (Sand)
Historical Sites and Parks	None
Critical Habitat	None
Groundwater	51 mm year^{-1}

The local watershed containing the proposed McNeil Forest Conservation Project was found to have very low threats for a forest conservation project, with potential to provide low (to very low) ecosystem benefits and moderate community benefits.

The McNeil Forest Conservation Project is roughly 9.7 mi^2 and is within the Western Gulf Coastal Plain Ecoregion characterized by a humid subtropical climate (61-68ºF) with an annual rainfall between 40-53 inches. Land use/land cover consists of woody wetlands, cultivated crops, and deciduous forest. Forests are predominately oak and hickory with a 78% canopy cover. Water features on the site consist of stream/river and lake/reservoir. Geological characteristics of the McNeil project site consist of loose and unconsolidated sandy alluvium soil. The project site does not contain any identified critical habitat, historical sites, or parks.



RELATIVE POTENTIAL ECOSYSTEM THREATS

Local watershed containing McNeil Forestry Conservation Project **0.0 – 0.2 (very low); 0.2-0.4 (low); 0.4-0.6 (moderate); 0.6-0.8 (high), and 0.8-1.0 (very high)**			
Potential Ecosystem Threats (% of area)	**Regional**	**Ecoregion**	**Gulfwide**
Pipelines	0.90	0.87	0.87
Hazardous Facilities	0.0	0.0	0.0
Impervious Surface	0.0	0.0	0.0
Dams	0.0	0.0	0.0
SLR	0.0	0.0	0.0
Soil Erodibility	0.57	0.39	0.39
Land Type Change (Natural to Agriculture)	0.30	0.26	0.21
Land Type Change (Natural to Developed)	0.0	0.0	0.0
TRI	0.0	0.0	0.0
Superfund	0.0	0.0	0.0
Stream Impaired	0.28	0.26	0.14
Waterbody Impaired	0.0	0.0	0.0
Non-point Pollution	0.12	0.02	0.02
Hurricane	0.0	0.0	0.0
Tornado	0.10	0.02	0.01
Drought	0.0	1.0	1.0
Rain	0.0	0	0
Special Flood Hazard Area	0.42	0.66	0.66
Forest Fire	0.05	0.03	0.03
Forestry Disease	0	0	0
Combined Value **Potential Ecosystem Threats**	**0.14** **Very Low**	**0.18** **Very Low**	**0.17** **Very Low**

The overall potential ecosystem threats to the proposed McNeil Forest Conservation Project are very low (<0.20) when considering the site within the regional watershed, the Western Gulf Coast Plain ecoregion, or across the northern Gulf of Mexico. Eleven of the synthesized metrics were zero, indicating that the local watershed surrounding this project site has the least threat from these factors within the entire Gulf region. Pipeline density, drought, and special flood hazard area are the three largest potential threats to the project site. Some other threats were present but low or very low including, soil erodability, land change from natural to agricultural, length of impaired stream, nonpoint source pollution, tornado occurrence, and forest fires.

RELATIVE POTENTIAL ECOSYSTEM BENEFITS

Local watershed containing McNeil Forestry Conservation Project

0.0 – 0.2 (very low); 0.2-0.4 (low); 0.4-0.6 (moderate); 0.6-0.8 (high), and 0.8-1.0 (very high)

Potential Ecosystem Benefits	**Regional**	**Ecoregion**	**Gulfwide**
Total Carbon Storage (kg m^{-2})	0.01	0.01	0
Habitat Connectivity (%)	0.40	0.37	0.37
Priority Habitat (% of area)	0.80	0.45	0.02
Percent Canopy (%)	0.36	0.35	0.26
Groundwater Recharge (mm yr^{-1})	0.39	0.34	0.06
Combined Potential Ecosystem Benefits	**0.39** **Low**	**0.30** **Low**	**0.14** **Very Low**

The overall potential ecosystem benefits from the proposed McNeil Forest Conservation Project are low (0.39) for the local watershed containing the project site compared to the regional watershed, low compared to the Western Gulf Coast Plain ecoregion (0.30), and very low when compared across the northern Gulf of Mexico coast (0.14). Potential ecosystem benefits from the project were generally higher when compared within the regional watershed context than within the Ecoregion III or the entire northern Gulf of Mexico coast.

RELATIVE POTENTIAL COMMUNITY BENEFITS

Local watershed containing McNeil Forestry Conservation Project

0.0 – 0.2 (very poor); 0.2-0.4 (poor); 0.4-0.6 (moderate); 0.6-0.8 (good), and 0.8-1.0 (very good)

Potential Benefits to Human Wellbeing	**Regional**	**Ecoregion**	**Gulfwide**
(1-) Population Density (pop. mi^{-2})	1.0	1.0	1.0
(1-) Income Inequality (Gini Index)	0.46	0.45	0.39
Home Ownership (%)	0.48	0.58	0.58
Per Capita Income ($ in 2016)	0.41	0.08	0.08
Educational Attainment (unitless score)	0.50	0.39	0.41
(1-) Chronic Disease (aggregated %)	0.07	0.60	0.54
Healthy Behaviors (%)	0	0.59	0.49
(1-) Poverty Index	0.64	0.86	0.86
Employment in Renewable Natural Resource Industries (%)	0.19	0.09	0.07
Potential for Recreation (aggregated %)	0.43	0.42	0.41
Combined Human Wellbeing Benefit Value	**0.42** **Moderate**	**0.51** **Moderate**	**0.48** **Moderate**

The overall potential benefits for wellbeing within communities from the proposed McNeil Forest Conservation Project are moderate compared to other local watersheds within the regional watershed (0.42), the Western Gulf Coast Plain Ecoregion (0.51), and across the northern Gulf of Mexico (0.48). Population density around the project site is low (very good for community wellbeing) and poverty is low (high community wellbeing) compared to all geographic scales. Employment rate in renewable and natural resource industries is currently very poor compared to the local region as well as across the northern Gulf of Mexico.

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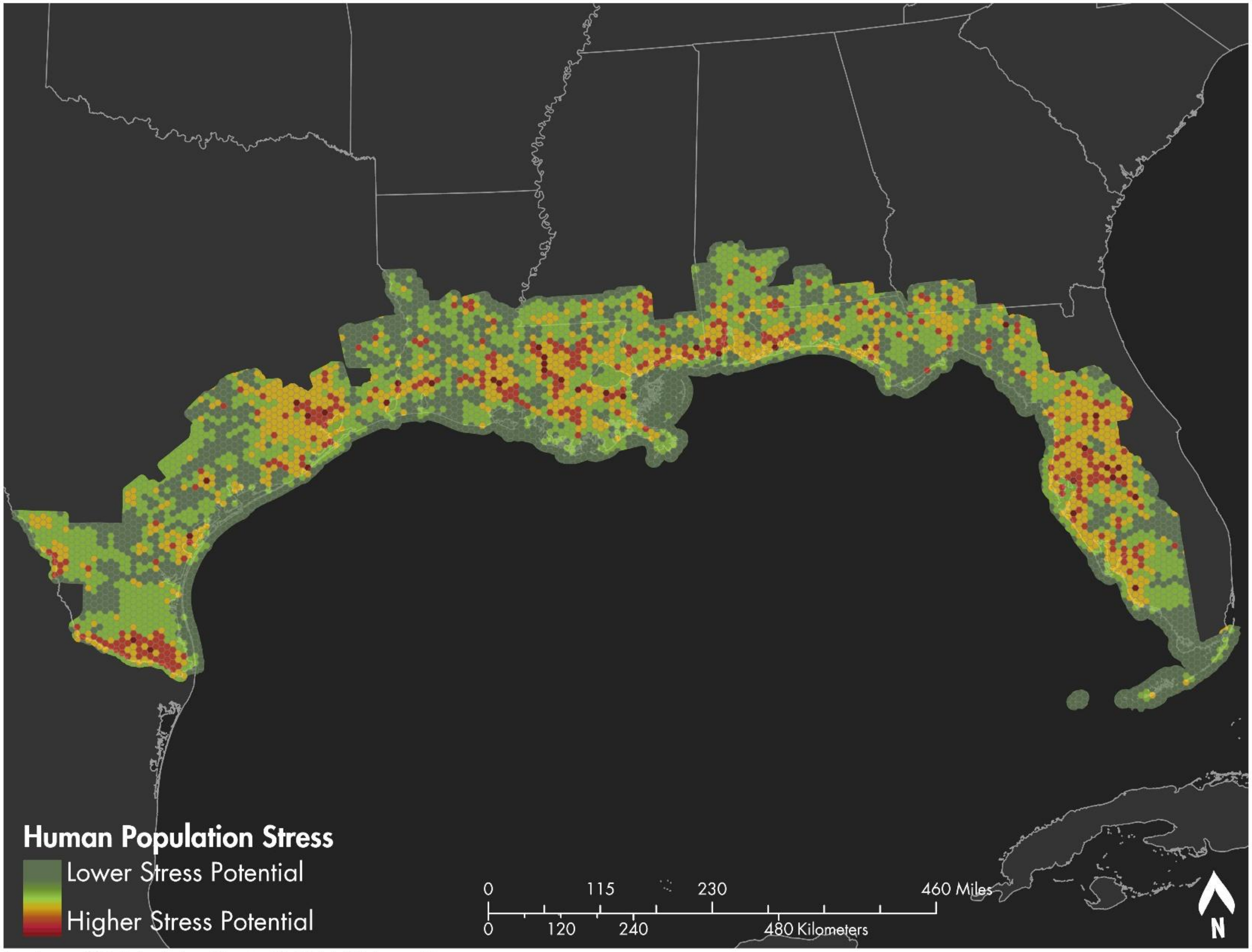
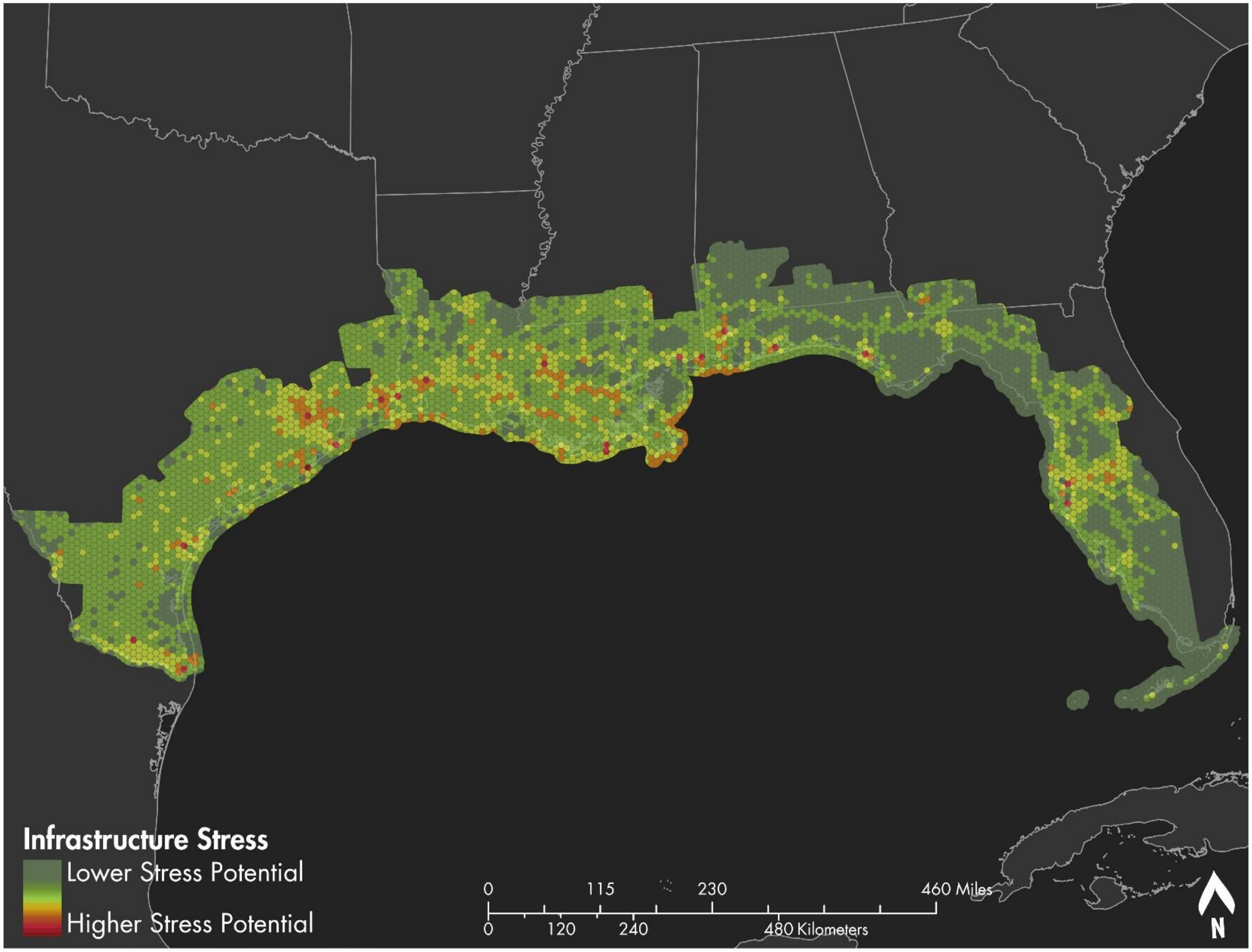
Appendices

APPENDIX A: MAPPING PRODUCT DEVELOPMENT



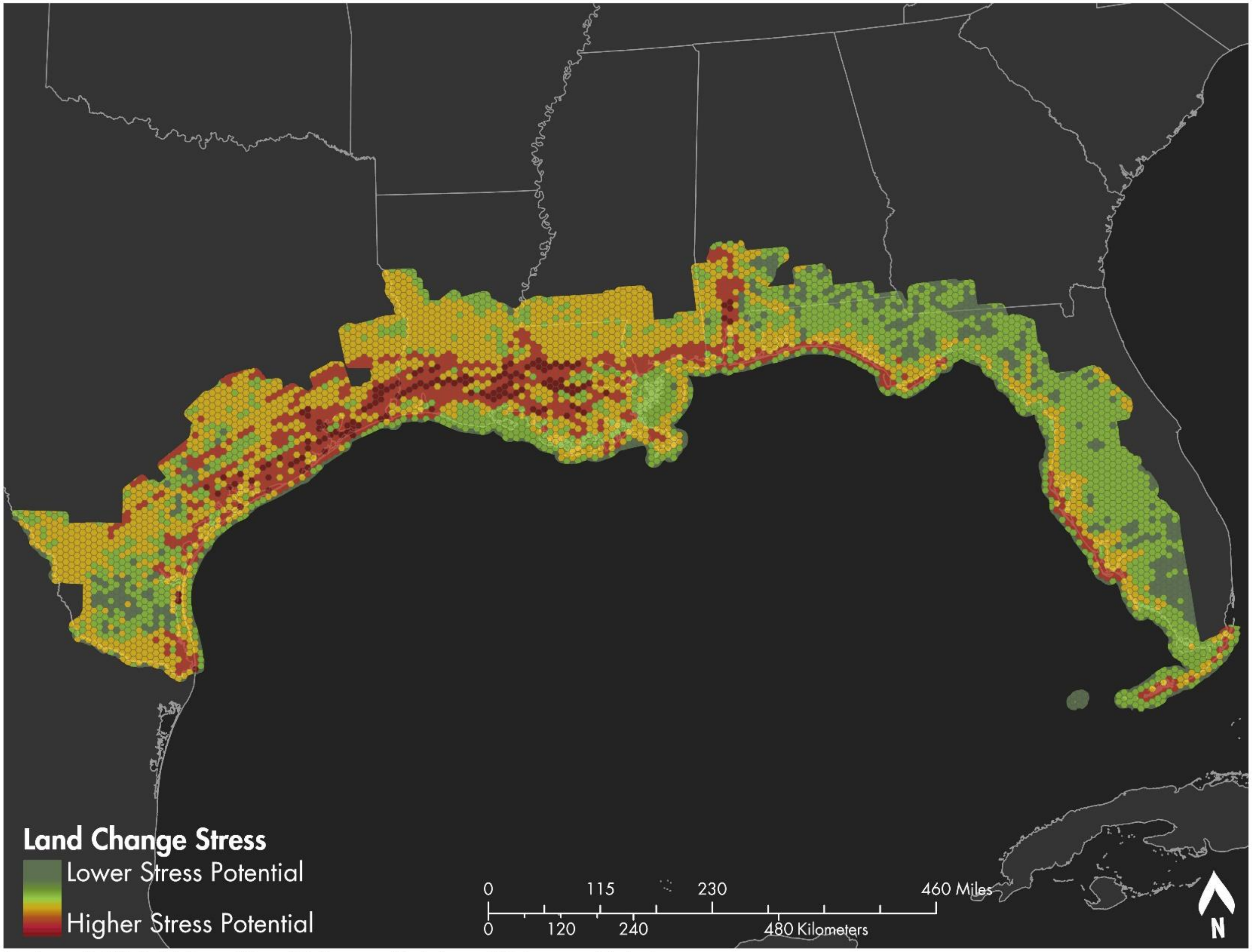
Data Source: CIRES, Colorado State University, EIA, NOAA, U.S. Bureau of Census

Figure 26. Population stressors assigned to the 100 square kilometer hexagon tessellation



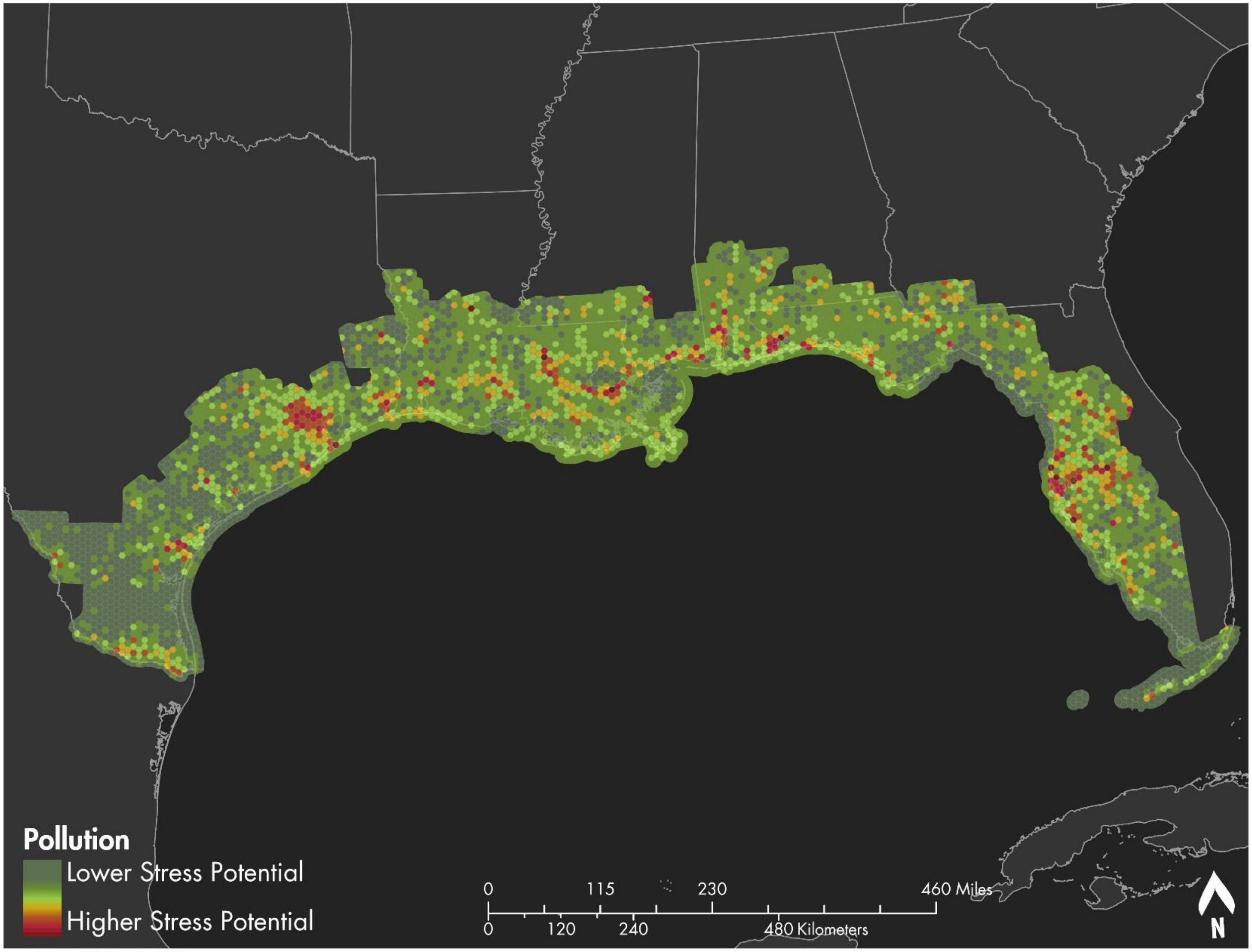
Data Source: BOEM, EIA, Esri, U.S. Bureau of Census, and USGS

Figure 27. Infrastructure stressors assigned to the 100 square kilometer hexagon tessellation



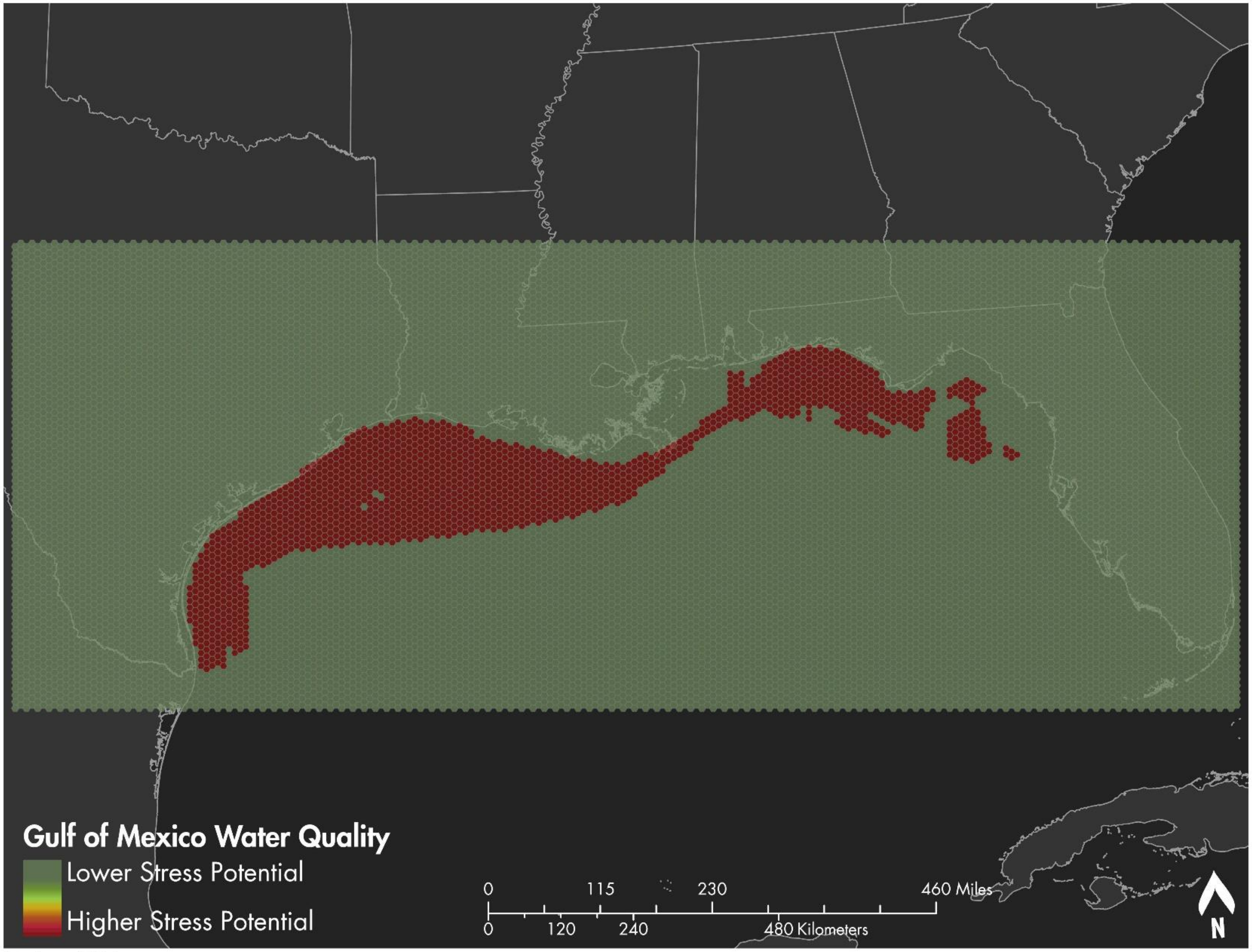
Data Source: Esri, NOAA, U.S. Bureau of Census, U.S. Department of Agriculture, and U.S. Department of the Interior

Figure 28. Land change stressors assigned to the 100 square kilometer hexagon tessellation



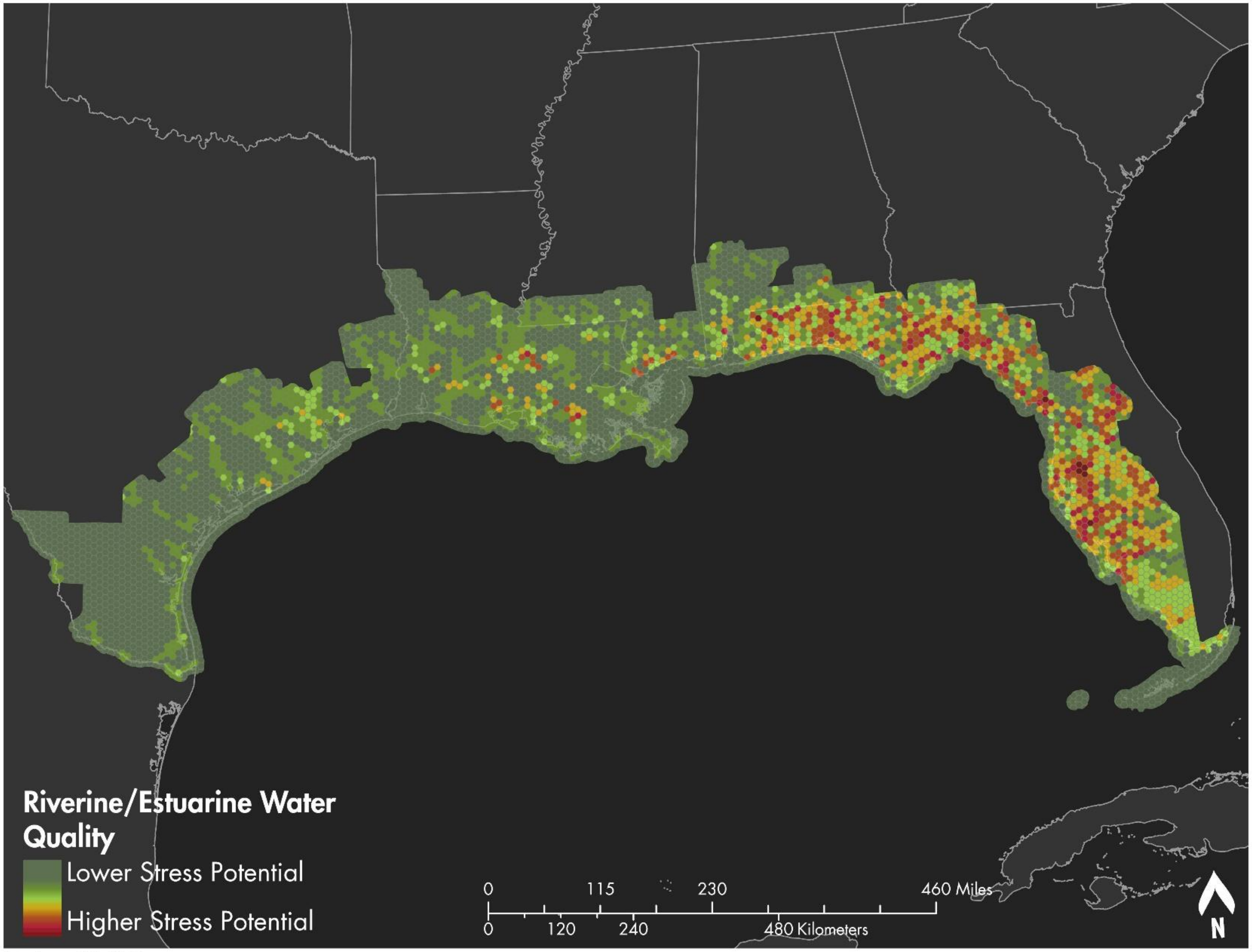
Data Source: EPA, Google, HIFLD

Figure 29. Pollution stressors assigned to the 100 square kilometer hexagon tessellation



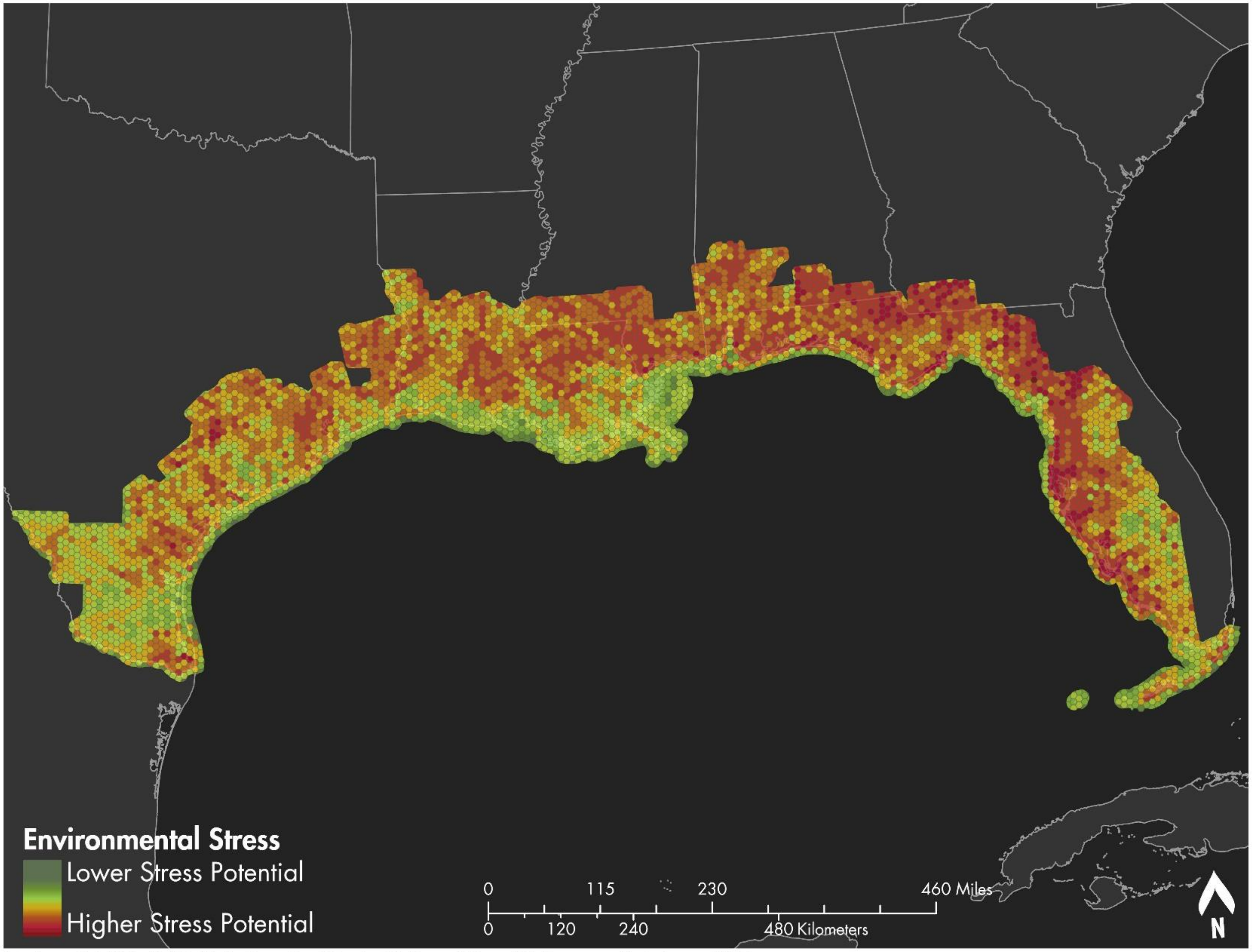
Data Source: NOAA

Figure 30. Gulf of Mexico water quality stressors assigned to the 100 square kilometer hexagon tessellation



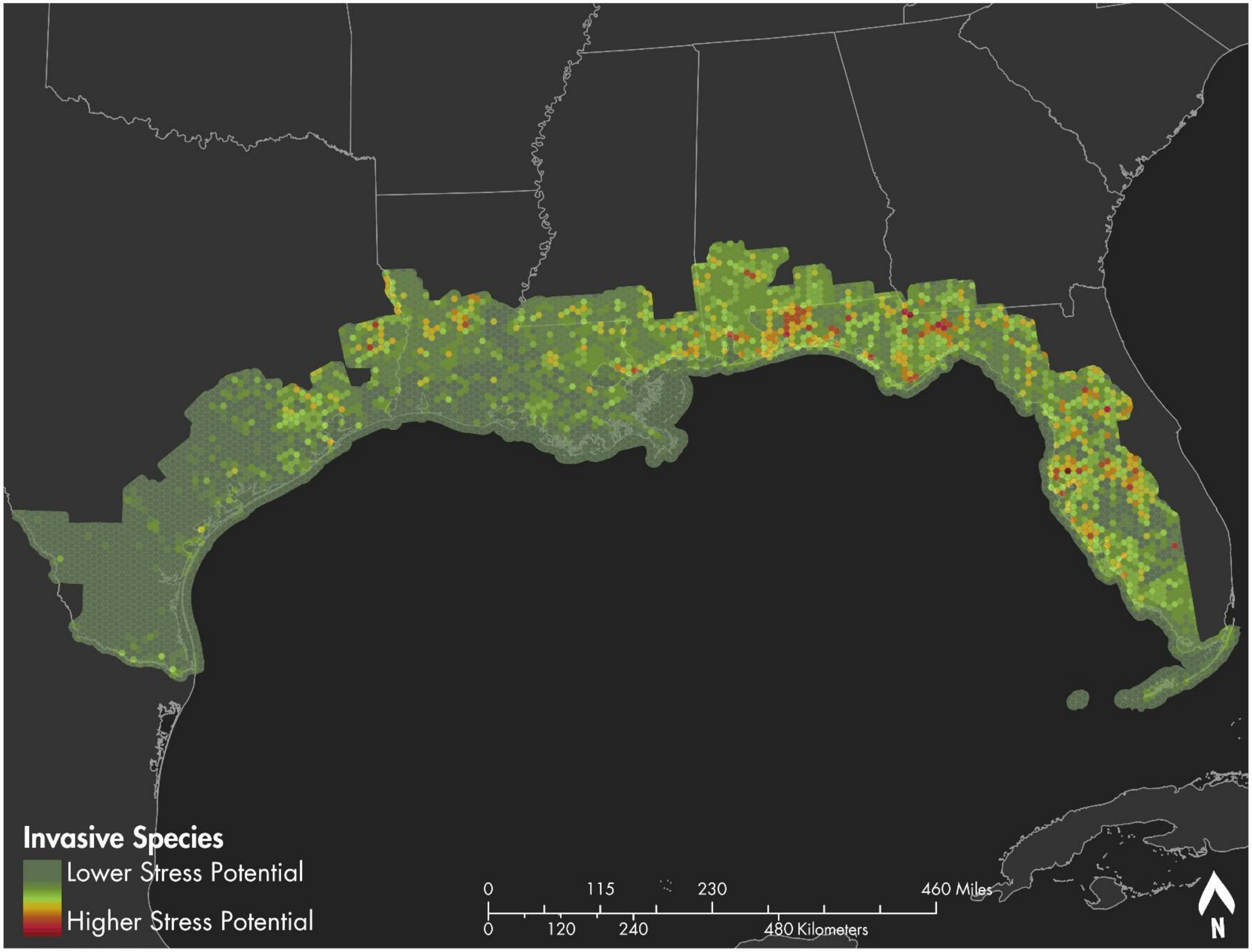
Data Source: EPA, USGS

Figure 31. Riverine/estuarine water quality stressors assigned to the 100 square kilometer hexagon tessellation



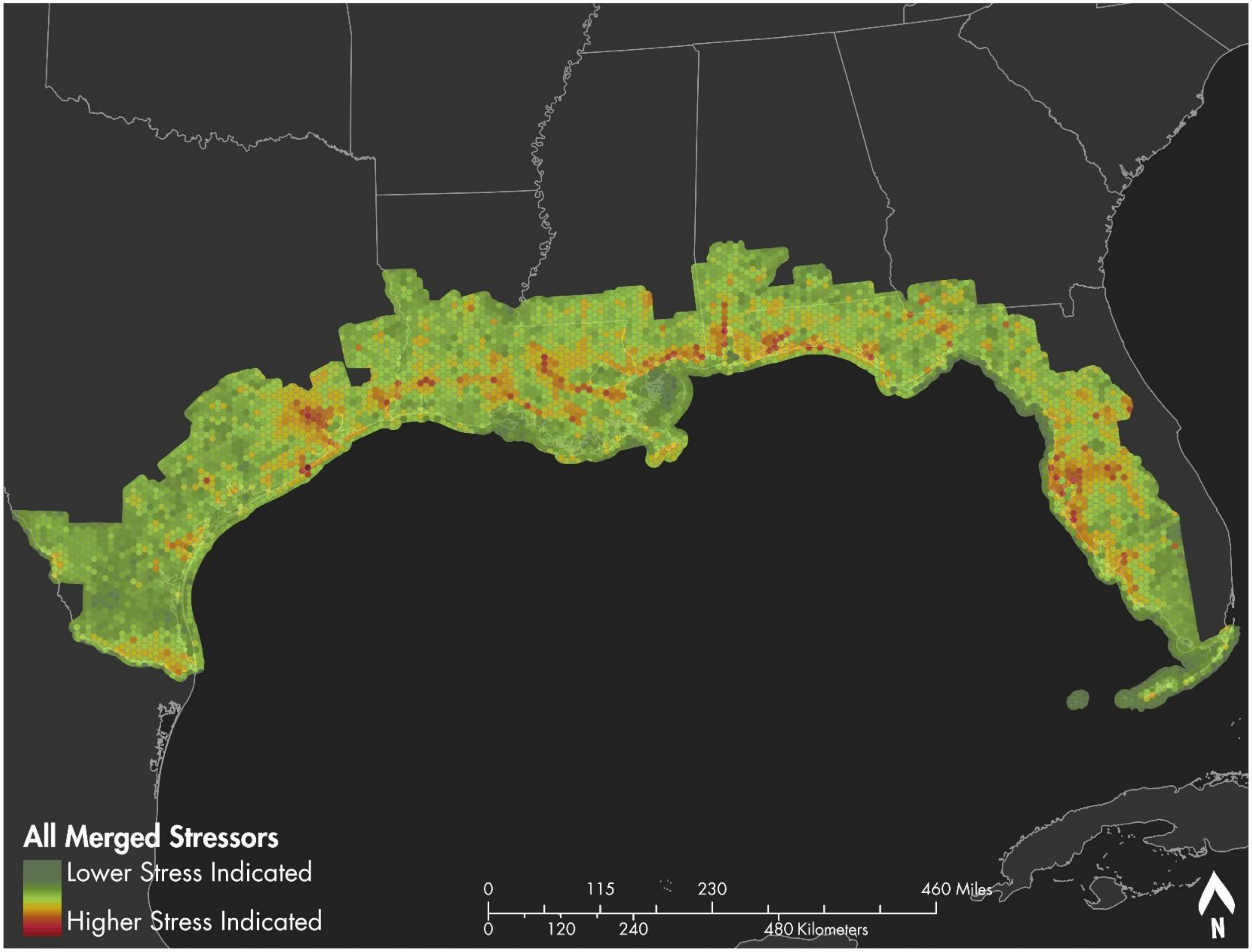
Data Source: Esri, FEMA, NDMC, NOAA, Oregon State University, U.S. Bureau of Census, U.S. Department of Agriculture, and USGS

Figure 32. Environmental stressors assigned to the 100 square kilometer hexagon tessellation



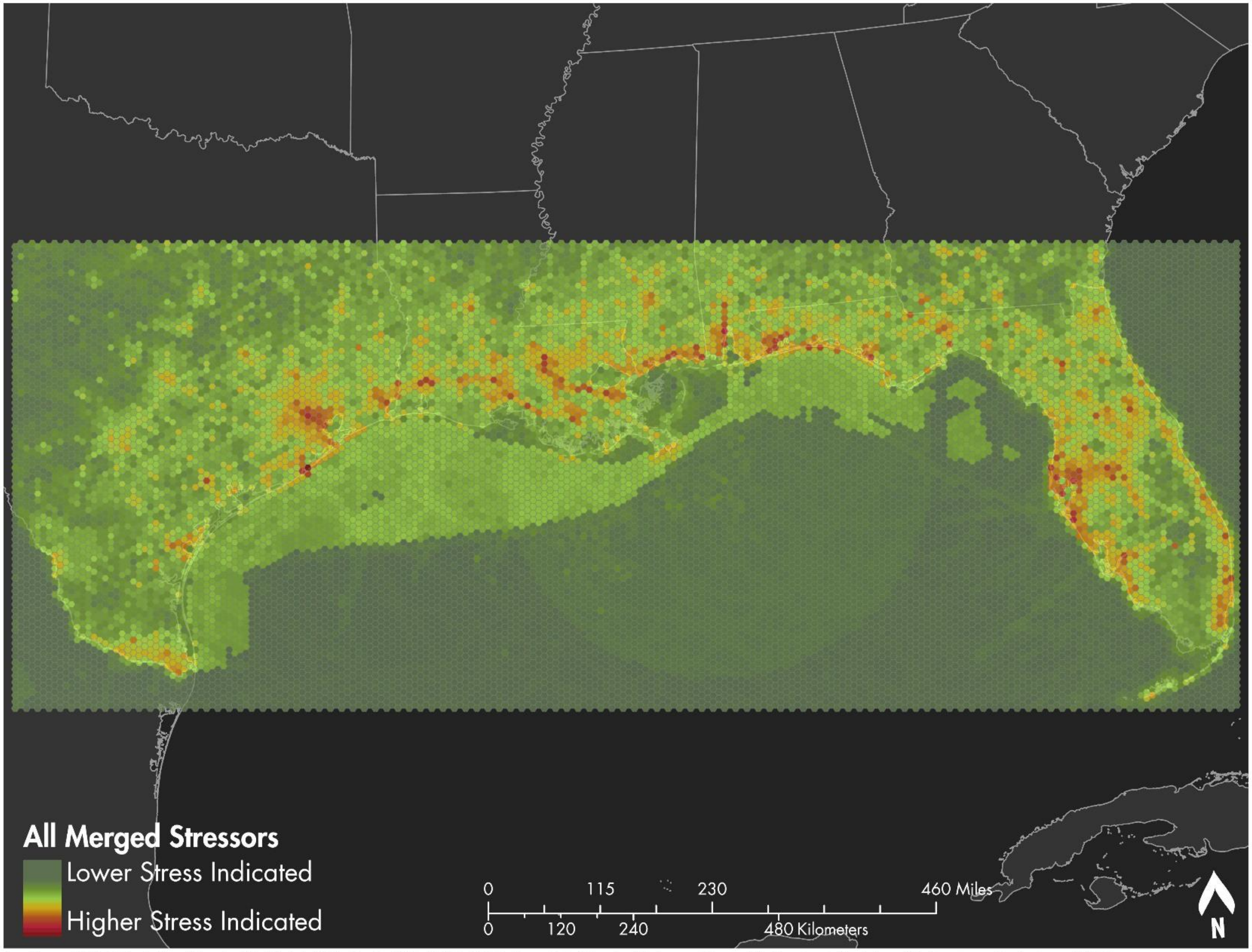
Data Source: EDDMaps, USGS

Figure 33. Invasive species stressors assigned to the 100 square kilometer hexagon tessellation



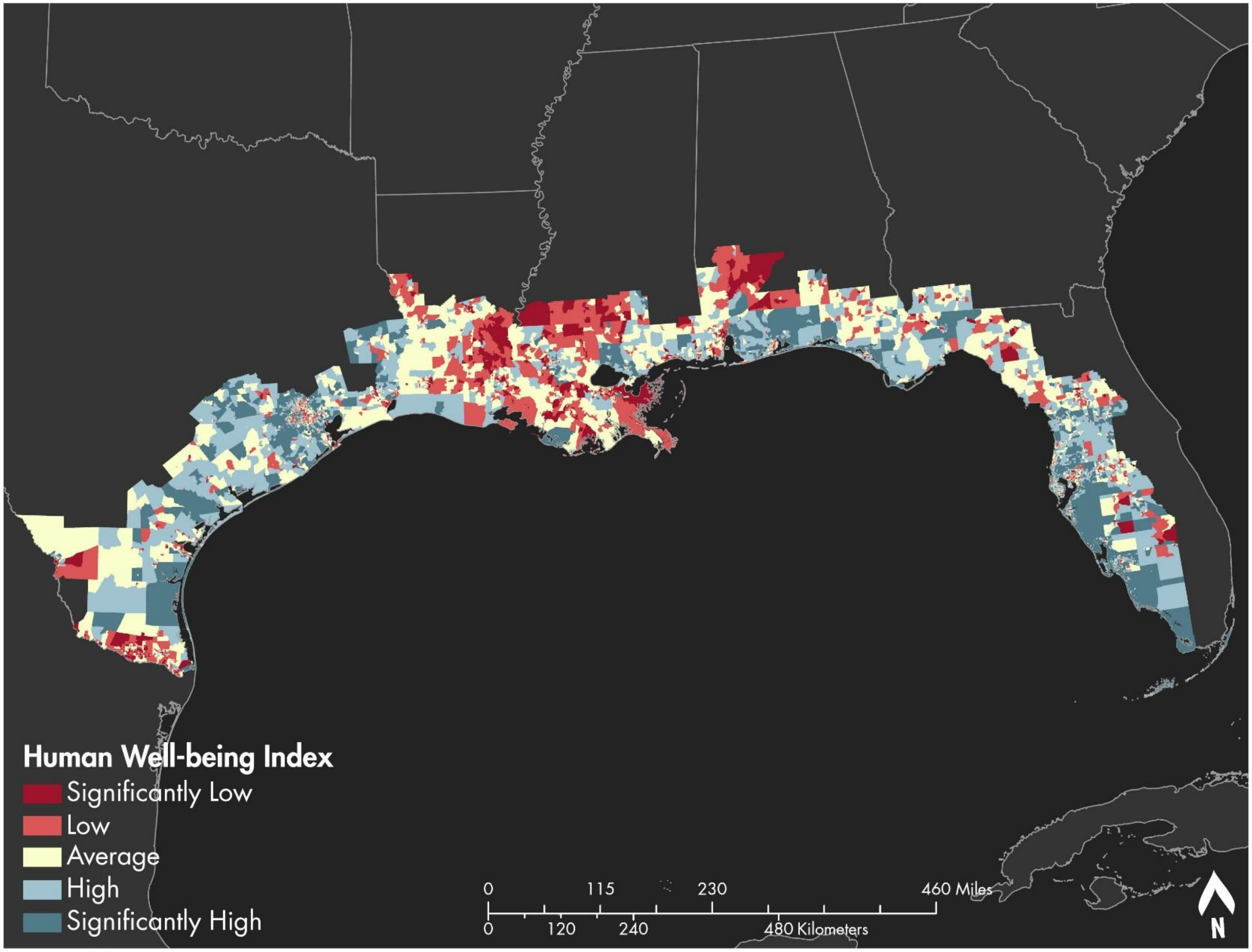
Data Source: BOEM, Colorado State University, EIA, EPA, Esri, FEMA, Google, HIFLD, NDMC, NOAA, Oregon State University, U.S. Bureau of Census, U.S. Department of Agriculture, U.S. Department of the Interior, and USGS

Figure 34. Final merged, summed, and stressor-weighted 100 square kilometer hexagon tessellation



Data Source: BOEM, Colorado State University, EIA, EPA, Esri, FEMA, Google, HIFLD, NDMC, NOAA, Oregon State University, U.S. Bureau of Census, U.S. Department of Agriculture, U.S. Department of the Interior, and USGS

Figure 35. Final merged, summed, and stressor-weighted 100 square kilometer hexagon tessellation without the analysis domain mask



Data Source: CIRES, Colorado State University, EIA, NOAA, U.S. Bureau of Census

Figure 36. Final community index assigned to 2013-2017 American Community Survey census block groups

APPENDIX B: GULF OF MEXICO CONSERVATION AND RESTORATION DECISION SUPPORT TOOL APPLICATION

Gulf of Mexico Conservation and Restoration Fund

Application Form for Proposed Conservation and Restoration Projects

Please fill all fields to the level of specificity known. A range is also acceptable, but please note that evaluation output can only be as accurate as the project input provided.

Organizational information	
Name of Organization:	Name of Primary Contact Person:
Email Address of Primary Contact Person:	Phone Number of Primary Contact Person:

Project information (circle those choices that apply)	
Project type (Conservation or Restoration): Conservation Yes No Restoration Yes No	**Potential natural habitat type:** Forest Wetland Marsh Beach Oyster Reef Barrier Island
Anticipated Cost (Provide range or estimate) Acquisition and/or construction: $000 Monitoring: $ Prior to project: $000 After project: $000	**Anticipated project length** (years/months). Time frame for acquisition/implementation: Start: 00/00/0000 Completion: 00/00/0000 Time frame for monitoring: Start: 00/00/0000 Completion: 00/00/0000
Project area (acres or km^2): **Project location** (latitude, longitude): (Attach shapefile if available)	

SITE HISTORY:

Please provide historical ecological information (i.e. clearcut in 2000, secondary regrowth since then with invasive introduced species; or loblolly pine cleared 1950s, agricultural, pastureland since then) or community (i.e. dominant type of employment) information relevant to the proposed conservation/restoration project site.

PROJECT JUSTIFICATION:

Please provide an explanation of the financial and/or ecological and/or community need for the proposed project (i.e. what is being degraded/lost or what ecosystem services will be lost if the project is not implemented).

Ecosystem Threats (Circle the most appropriate answer)

Potential Ecosystem Threats	Currently present in proposed project site (High or Low)		How will the project change the threats/stressors at the local watershed (Increase, Decrease, or No change)		
Soil erodibility	High	Low	Increase	Decrease	No change
Superfund site density	High	Low	Increase	Decrease	No change
Toxic release inventory density	High	Low	Increase	Decrease	No change
Impaired streams	High	Low	Increase	Decrease	No change
Wildfire hazard potential	High	Low	Increase	Decrease	No change
Hurricane risk	High	Low	Increase	Decrease	No change
Tornadoes risk	High	Low	Increase	Decrease	No change
Extreme rainfall events	High	Low	Increase	Decrease	No change
Droughts	High	Low	Increase	Decrease	No change
Flood hazards	High	Low	Increase	Decrease	No change
Forest diseases	High	Low	Increase	Decrease	No change
Three foot sea-level rise	High	Low	Increase	Decrease	No change
Impervious surface	High	Low	Increase	Decrease	No change
Hazardous facilities	High	Low	Increase	Decrease	No change
Oil and gas pipelines	High	Low	Increase	Decrease	No change
Land use change from “natural” to developed	High	Low	Increase	Decrease	No change
Land use change from “natural” to agriculture	High	Low	Increase	Decrease	No change
Abundance of dams	High	Low	Increase	Decrease	No change
Non-point source pollution	High	Low	Increase	Decrease	No change

Ecosystem Benefits (Circle the most appropriate answer)

Potential ecosystem benefits	Currently present in proposed project site (High or Low)	How will the project change the potential ecosystem benefits of the project site (Increase, Decrease, or No change)
Total carbon storage	High Low	Increase Decrease No change
Soil stability	High Low	Increase Decrease No change
Habitat connectivity	High Low	Increase Decrease No change
Percent forest canopy cover	High Low	Increase Decrease No change
Priority habitat	High Low	Increase Decrease No change
Groundwater recharge potential	High Low	Increase Decrease No change

Community Benefits (Circle the most appropriate answer)

Potential community benefits	Currently present in proposed project site (High or Low)	How will the project change the potential community benefits at the project site (Increase, Decrease, or No change)
Population density	High Low	Increase Decrease No change
Income inequality	High Low	Increase Decrease No change
Owner-occupied housing	High Low	Increase Decrease No change
Per capita income	High Low	Increase Decrease No change
Education attainment	High Low	Increase Decrease No change
Natural resource employment	High Low	Increase Decrease No change
Healthy behaviors	High Low	Increase Decrease No change
Physical health	High Low	Increase Decrease No change
Potential for recreation	High Low	Increase Decrease No change
Poverty	High Low	Increase Decrease No change

Site History and Proposed Changes (Circle the most appropriate answer)

Questions	Answers
Will a percentage of land to be restored to "natural" or historical state	Yes No
If not 100%, how will the non-conserved/restored land be used?	Water (Emergent Herbaceous Wetlands, Woody Wetlands, Open Water) Developed (Low, Medium, High, Open Space) Forest (Deciduous, Evergreen, Mixed) Fields (Shrub/Scrub, Herbaceous, Hay/Pasture, Cultivated Crops) Other (Barren Land, Unclassified)
Will the project site allow for sustainable harvesting of natural resources?	Sustainable Clearcut None
How much sustainable harvesting will be allowed?	0-25% 25-50% 50-100%
Will a sustainable management plan be developed considering maintenance of ecological benefits of the site?	Yes No
Will the project site be accessible to the public for recreational use?	Yes No
Type of recreational use	Public parks Bird watching Hunting Green space Hiking Boat launch/fishing access Beaches Canoeing, kayaking and rafting
Is this a change from private to public access land?	Yes No
Will the proposed project protect existing local jobs, or increase employment opportunity?	Yes No
Will it increase local employment?	Yes No

Questions	Answers
Will there be indirect economic benefits to the community in terms of service industries?	Service industry Construction (direct/indirect) Education Conservation sector Transportation Training

Other Relevant Information

Please provide any references or links to key reports, data, research, websites, or documents about the proposed site.

APPENDIX C: MCNEIL VARIABLES RESULTS

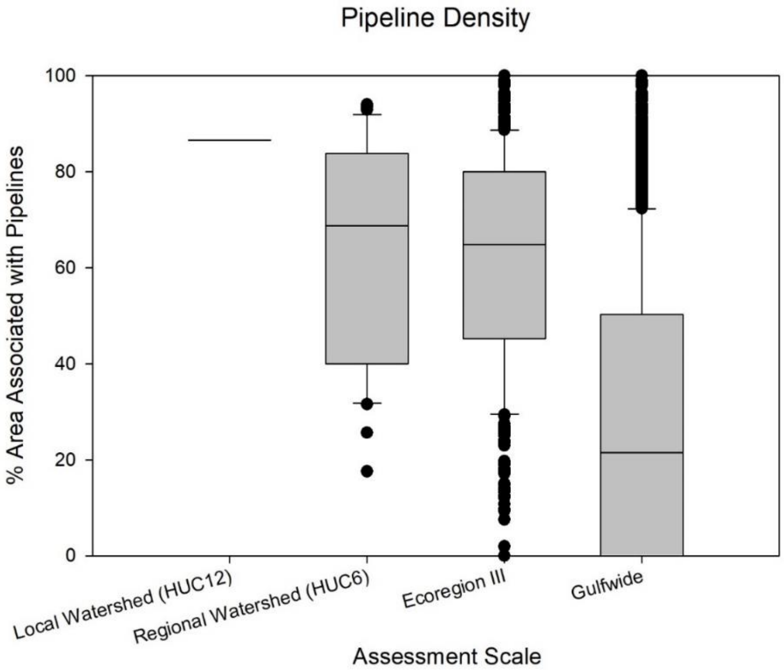


Figure 37. Pipeline densities within the local watershed (HUC 12) surrounding the project site and other domains containing the proposed project site

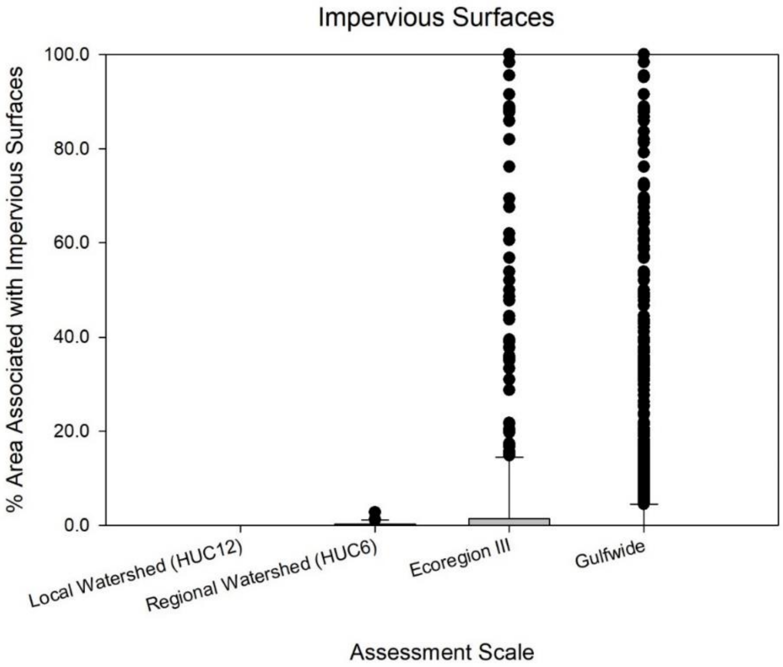


Figure 38. Percent area affected by impervious surface within the local watershed and other domains containing the proposed project site

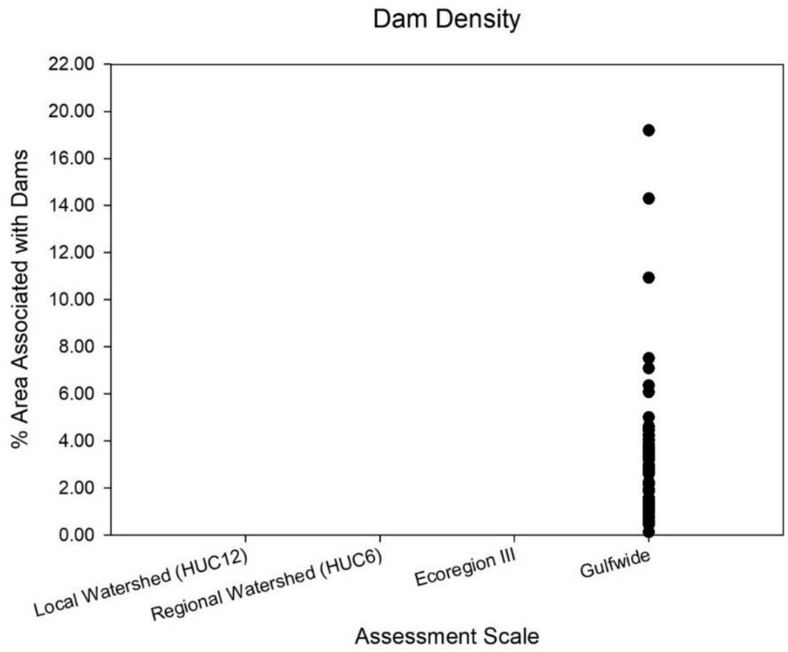


Figure 39. Percent area where dams are present within the local watershed and other domains containing the proposed project site

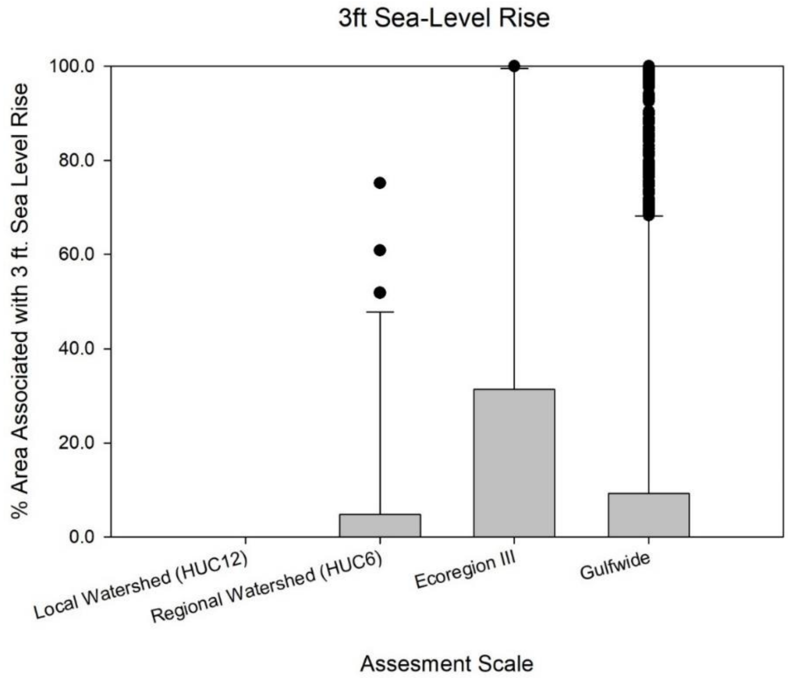


Figure 40. Percent area affected by a 3 ft sea level rise within the local watershed and other domains containing the proposed project site

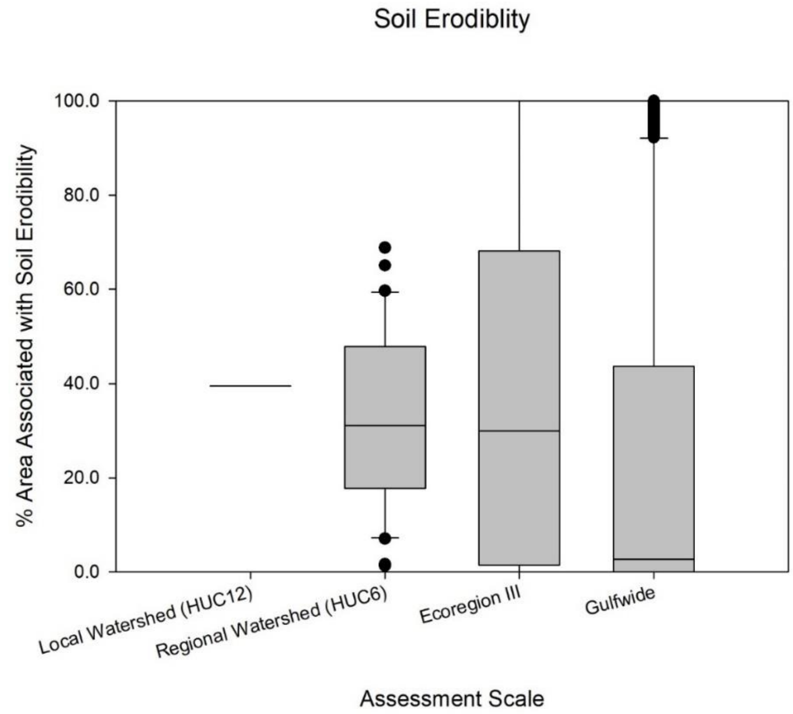


Figure 41. Percent area associated with Soil Erodibility within the local watershed (HUC 12) surrounding the project site and other domains

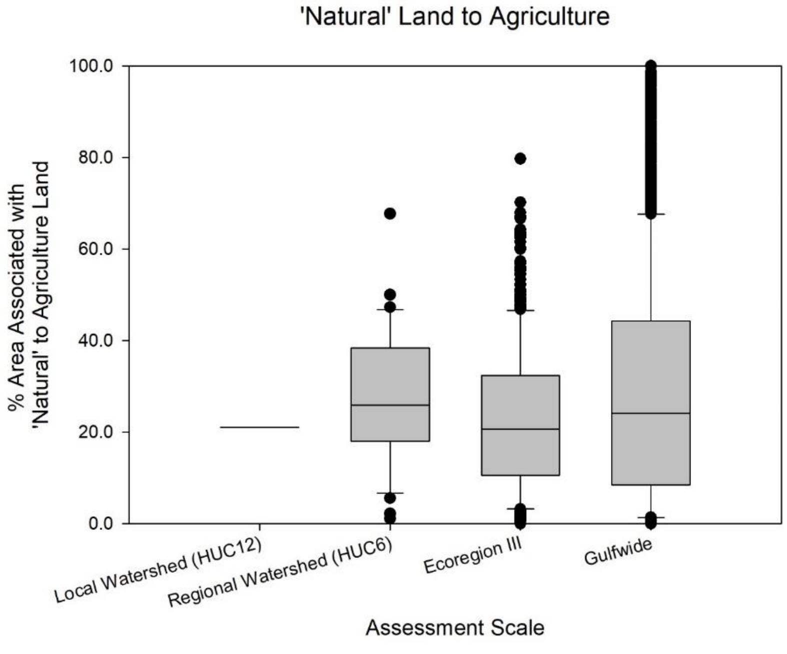


Figure 42. Percent area associated with land change from 'Natural' to Agriculture land within the local watershed (HUC 12) surrounding the project site and other domains

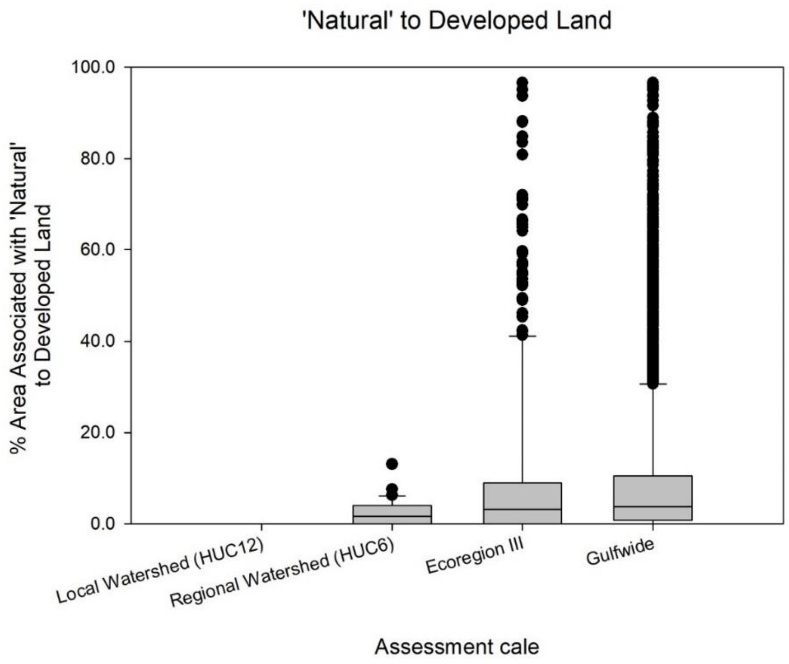


Figure 43. Percent area associated with land change from ‘Natural’ to Developed land within the local watershed (HUC 12) surrounding the project site and other domains

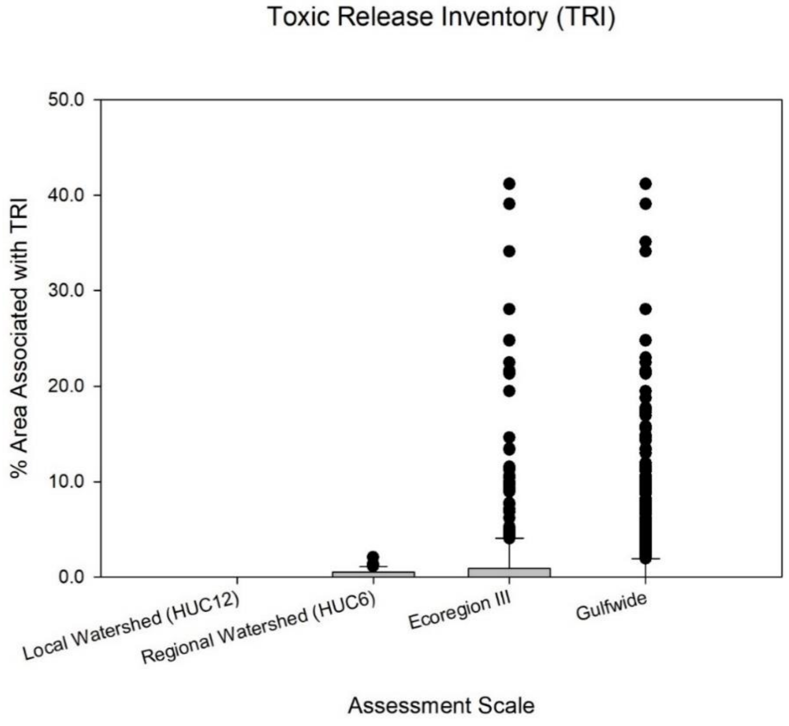


Figure 44. Percent area where Toxic Release Inventory sites are present within the local watershed and other domains containing the proposed project site

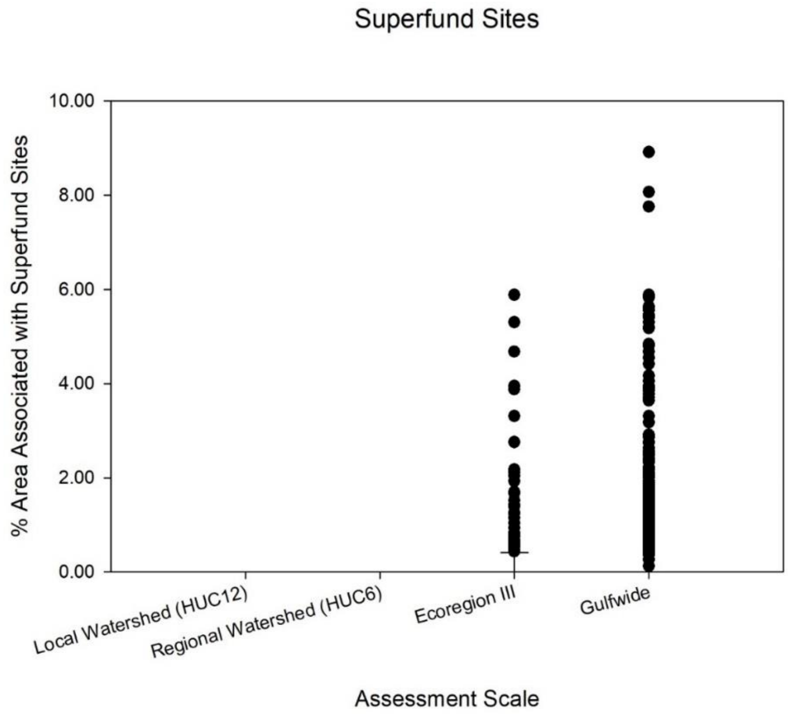


Figure 45. Percent area where superfund sites are present within the local watershed and other domains containing the proposed project site

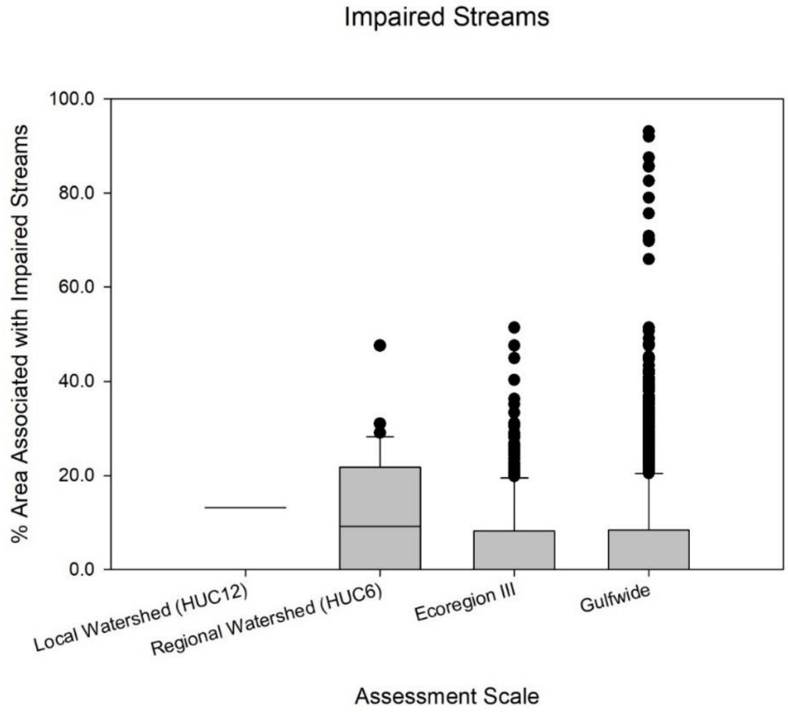


Figure 46. Percent area where impaired streams are present within the local watershed and other domains containing the proposed project site. Data were based on EPA 303D listing

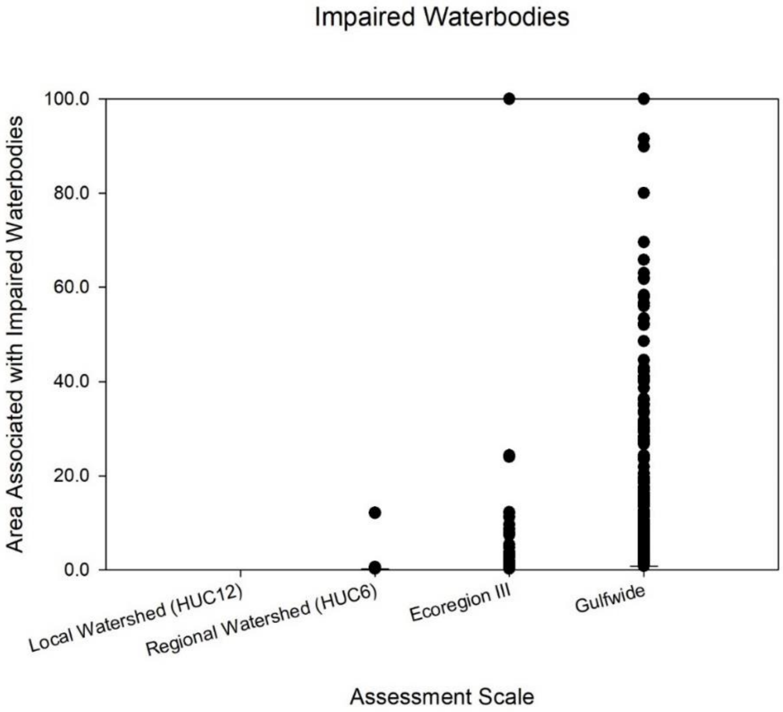


Figure 47. Percent area where impaired waterbodies are present within the local watershed and other domains containing the proposed project site. Data were based on EPA 303D listing.

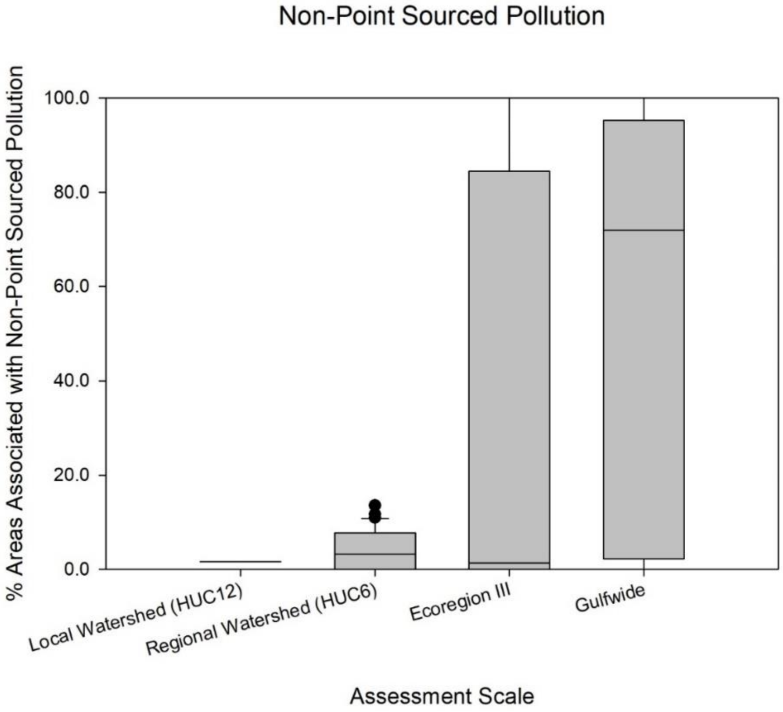


Figure 48. Percent area associated with non-point source pollution within the local watershed and other domains containing the proposed project site

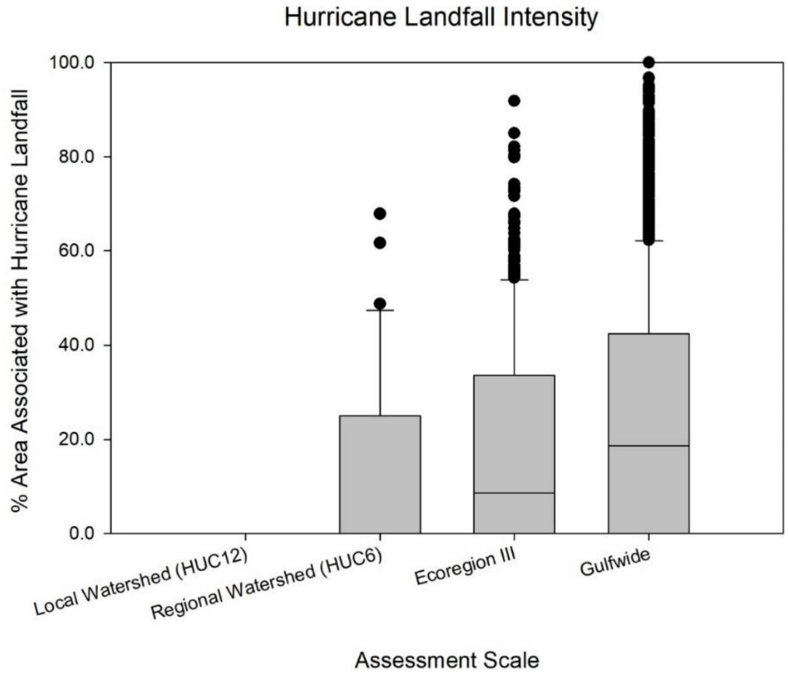


Figure 49. Percent area where hurricane landfalls were present within the local watershed and other domains containing the proposed project site

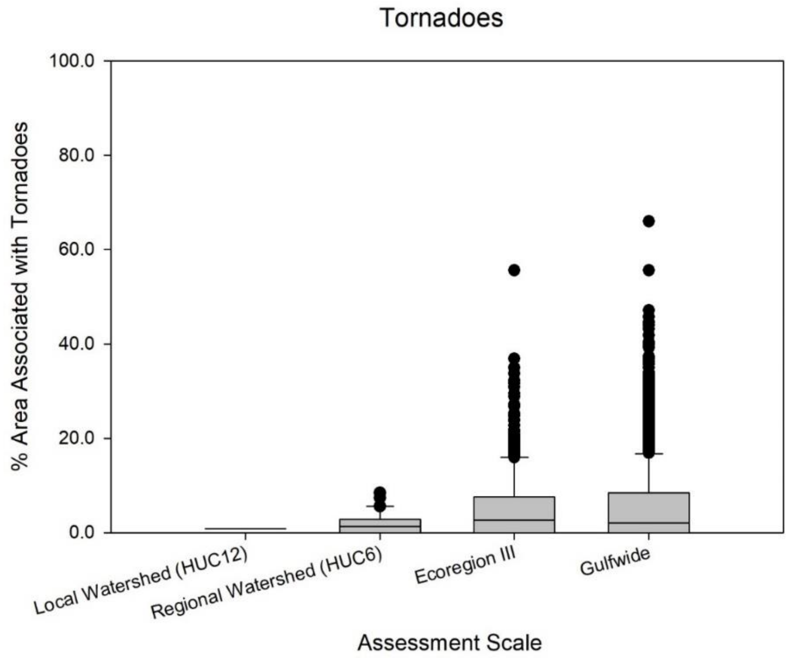


Figure 50. Percent area where tornado touchdowns are present within the local watershed and other domains containing the proposed project site

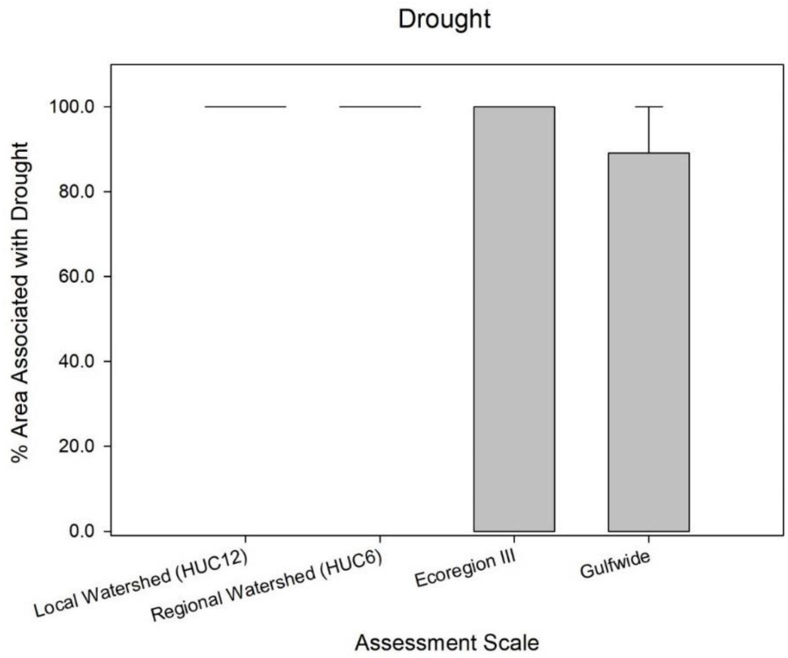


Figure 51. Percent area associated with drought within the local watershed surrounding the project site and other domains.

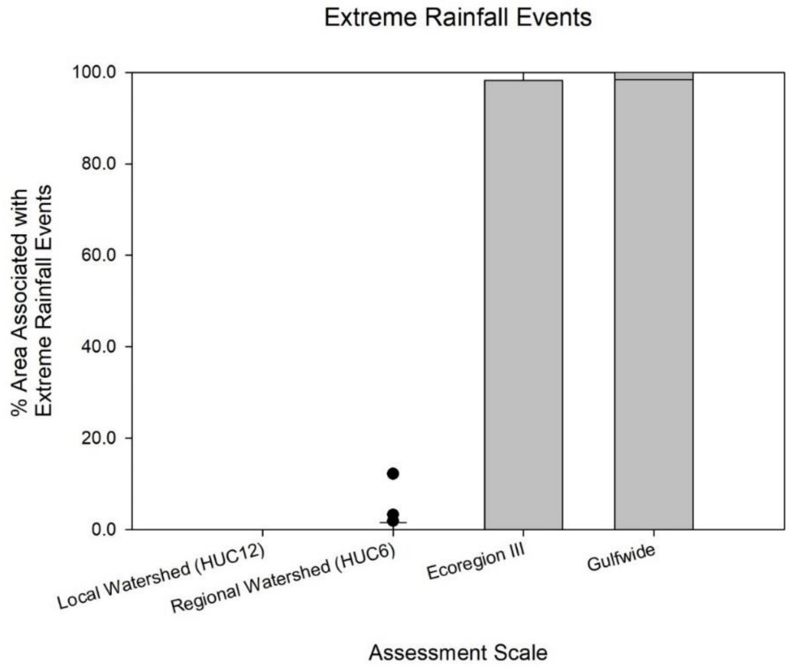


Figure 52. Percent area where extreme rainfall events are present within the local watershed and other domains containing the proposed project site

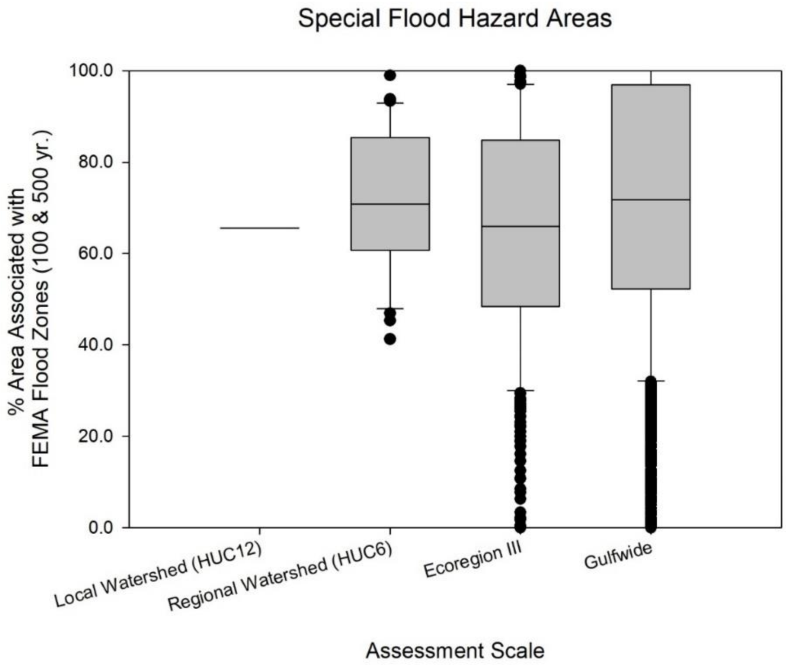


Figure 53. Percent area classified as the FEMA Special Flood Hazard Areas within the local watershed and other domains containing the proposed project site

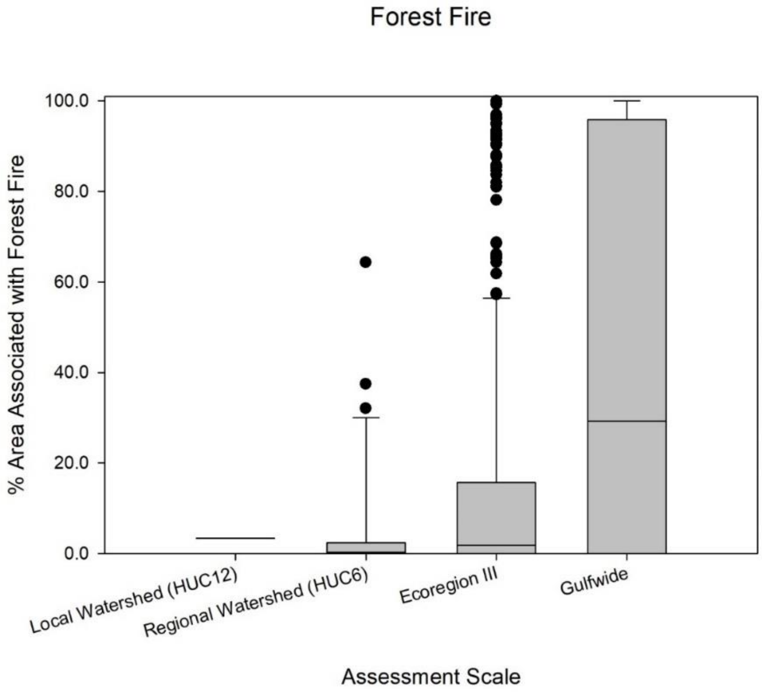


Figure 54. Percent area that are affected by wildfire hazard potential within the local watershed and other domains containing the proposed project site

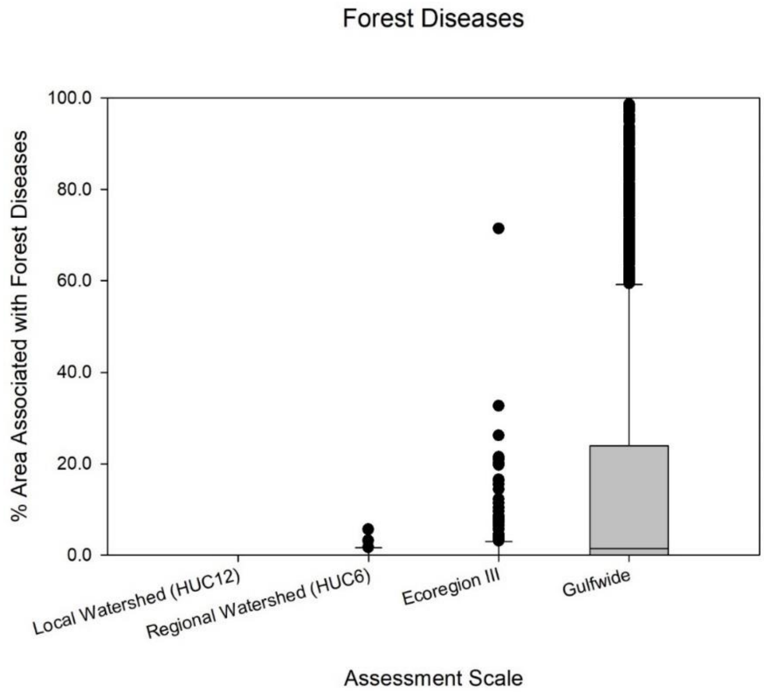


Figure 55. Percent area affected by forest diseases within the local watershed and other domains containing the proposed project site

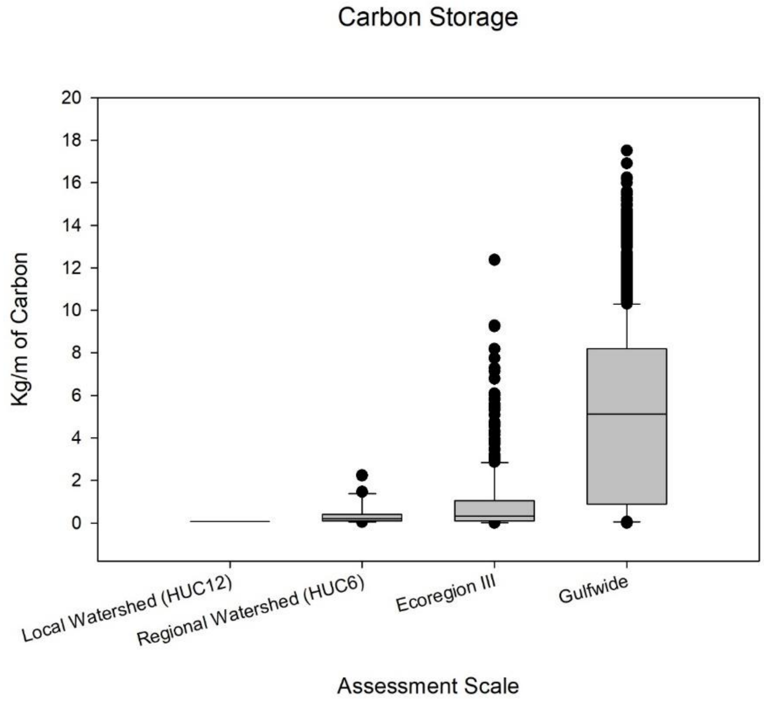


Figure 56. Total carbon storage (kg/m) in above and below ground tree biomass within the local watershed (HUC 12) and other domains containing the proposed project site

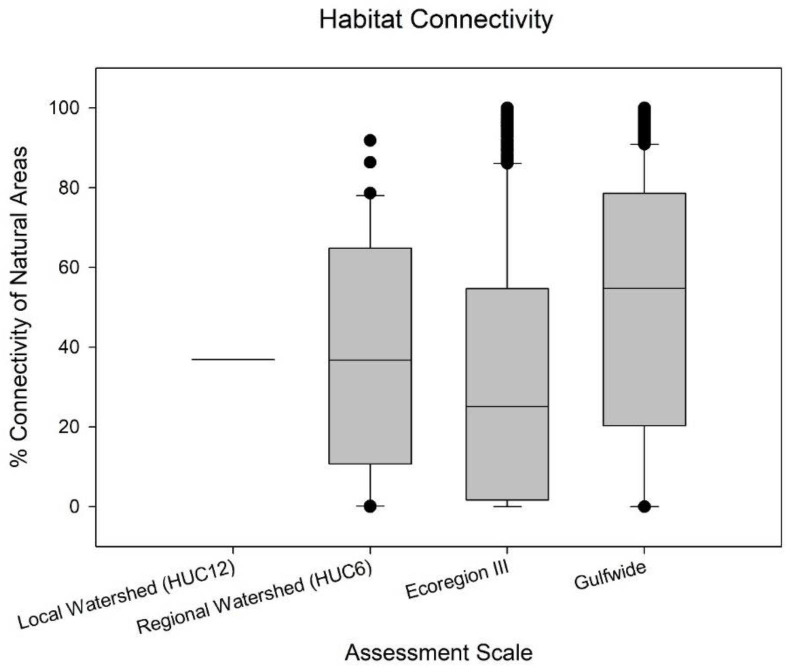


Figure 57. Percent habitat connectivity in the local watershed and other domains containing the proposed project site

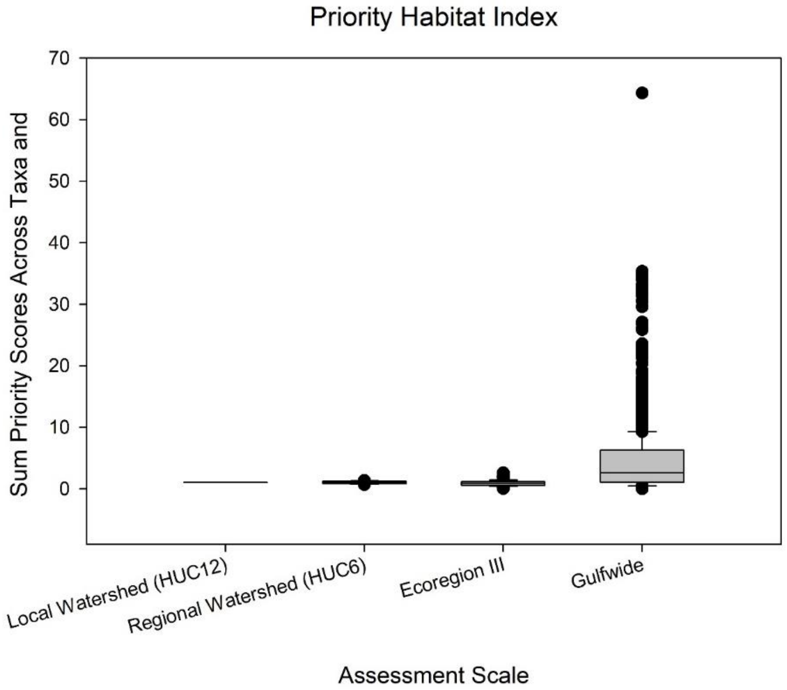


Figure 58. Mean priority habitat index value within the local watershed and other domains containing the proposed project site

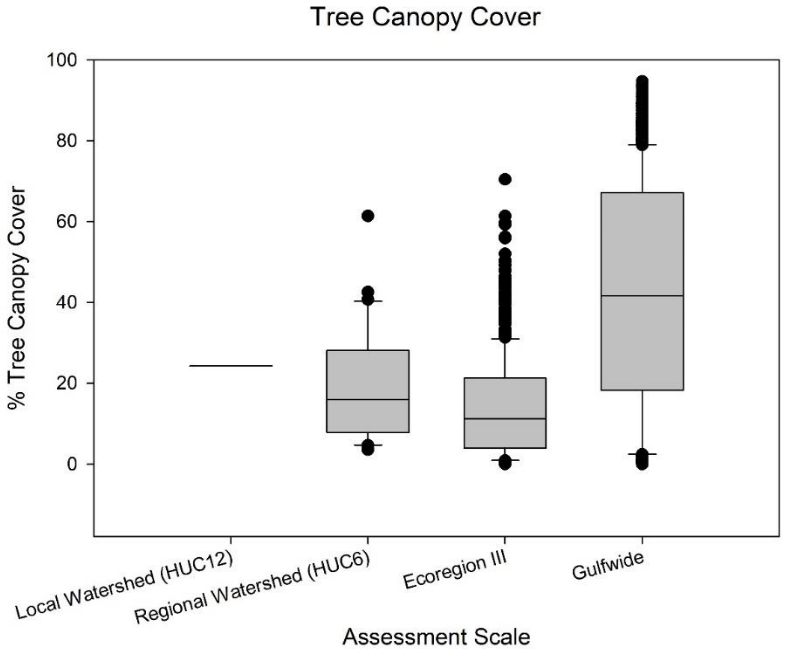


Figure 59. Mean percent tree canopy cover within the local watershed and other domains containing the proposed project site

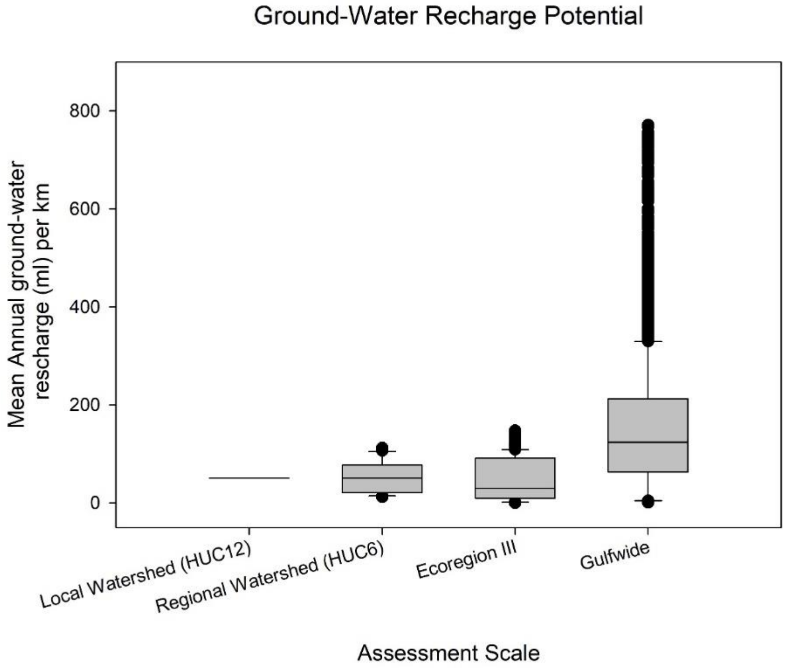


Figure 60. Mean ground-water recharge potential for land areas within the analysis domain

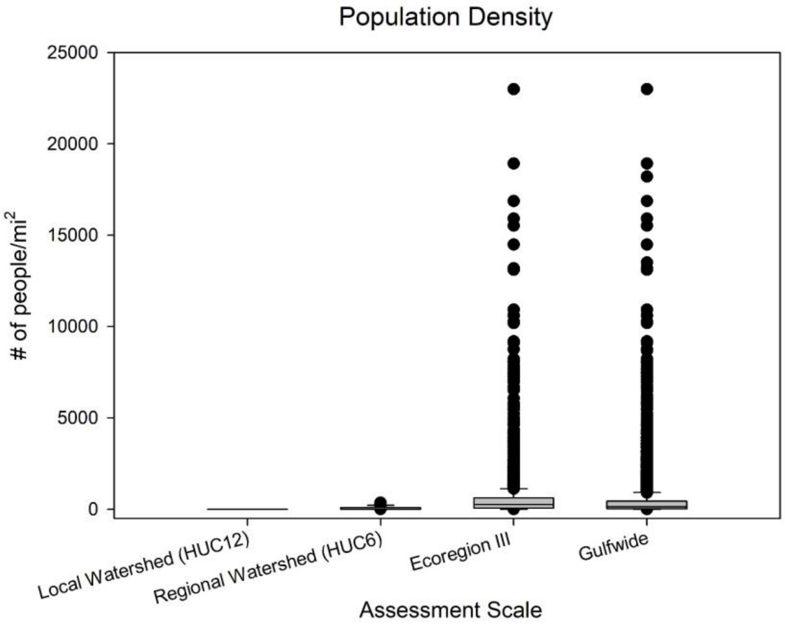


Figure 61. The number of people residing within the local watershed and other domains containing the proposed project site

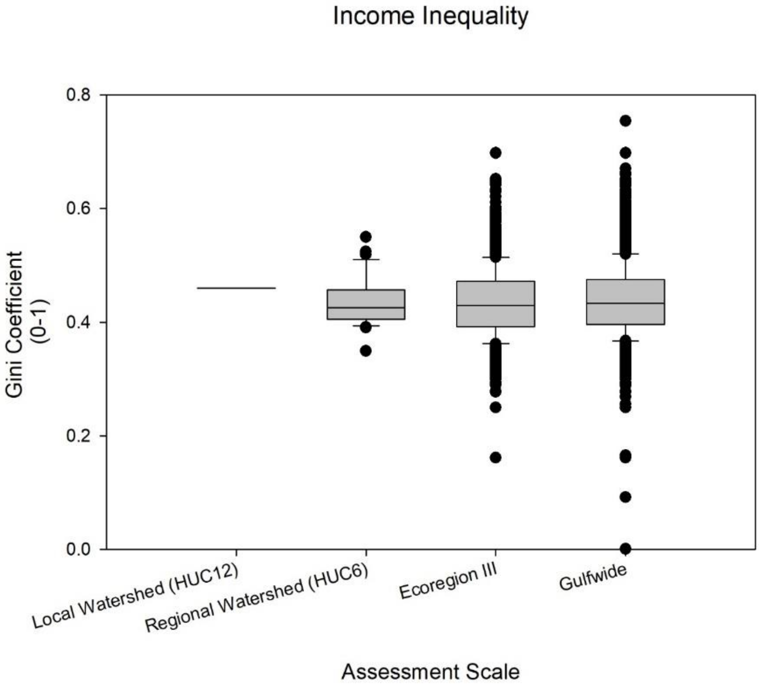


Figure 62. Level of income inequality within the local watershed and other domains containing the proposed project site

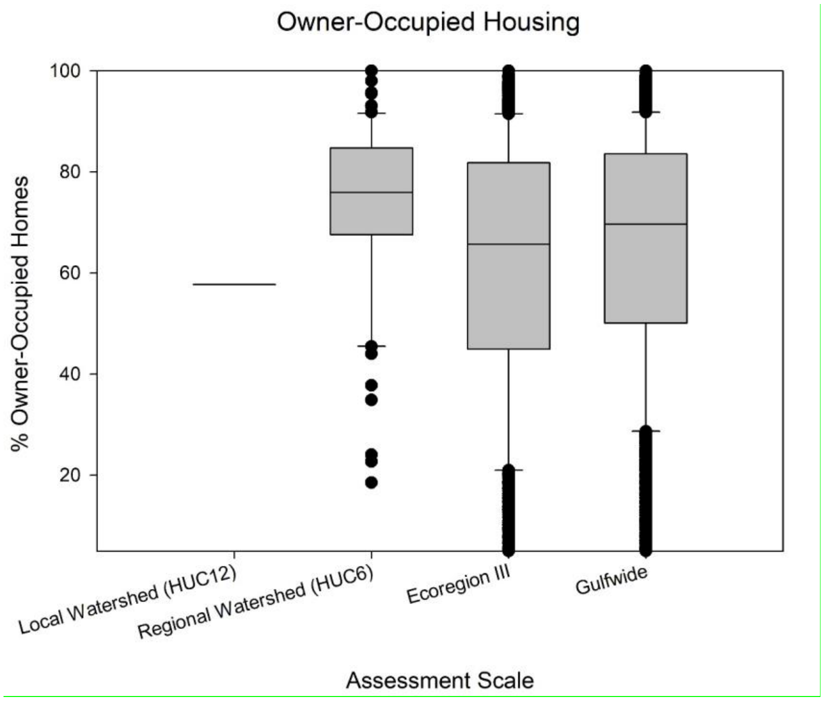


Figure 63. Percent homeownership within the local watershed and other domains containing the proposed project site

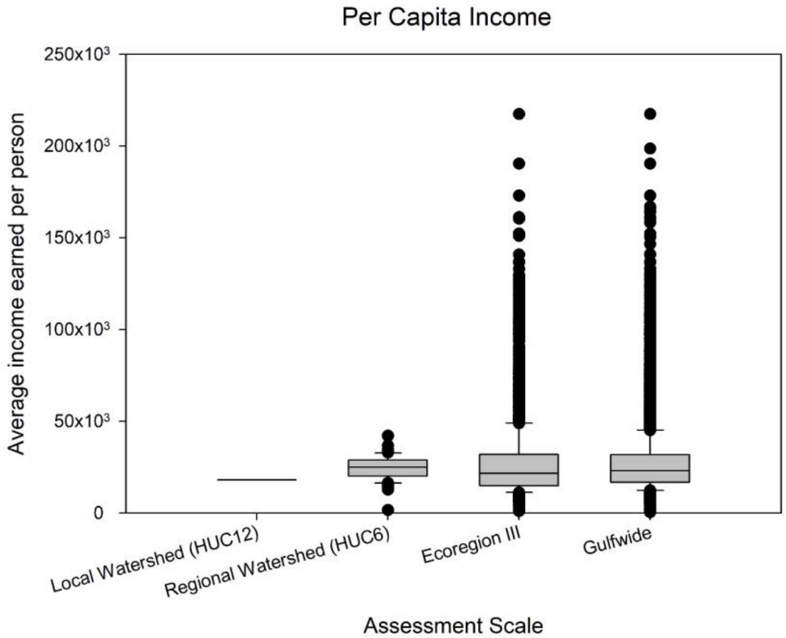


Figure 64. Per capita income within the local watershed and other domains containing the proposed project site

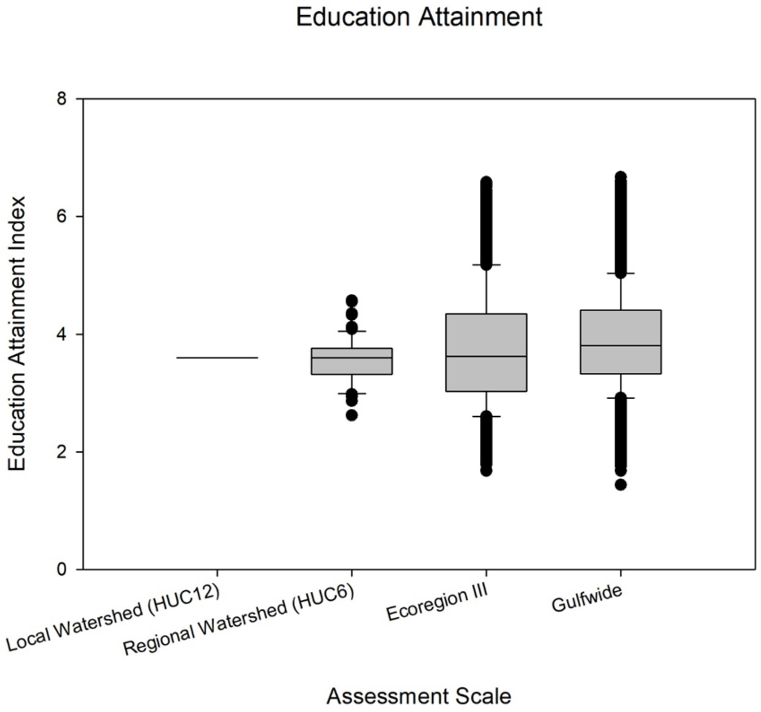


Figure 65. Level of education attainment reached by the adult population (25+ years-old) within the local watershed and other domains containing the proposed project site

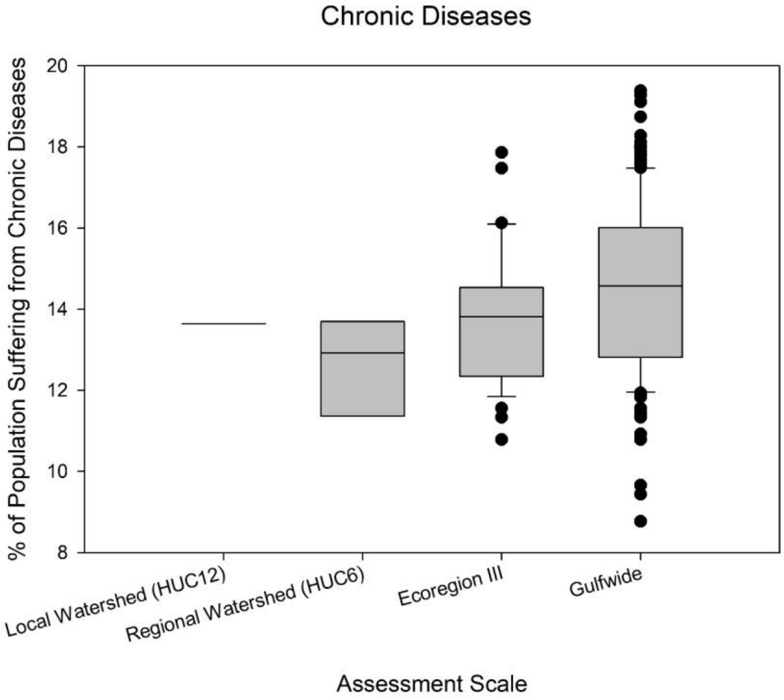


Figure 66. Percent of the population suffering from chronic diseases within the local watershed and other domains containing the proposed project site

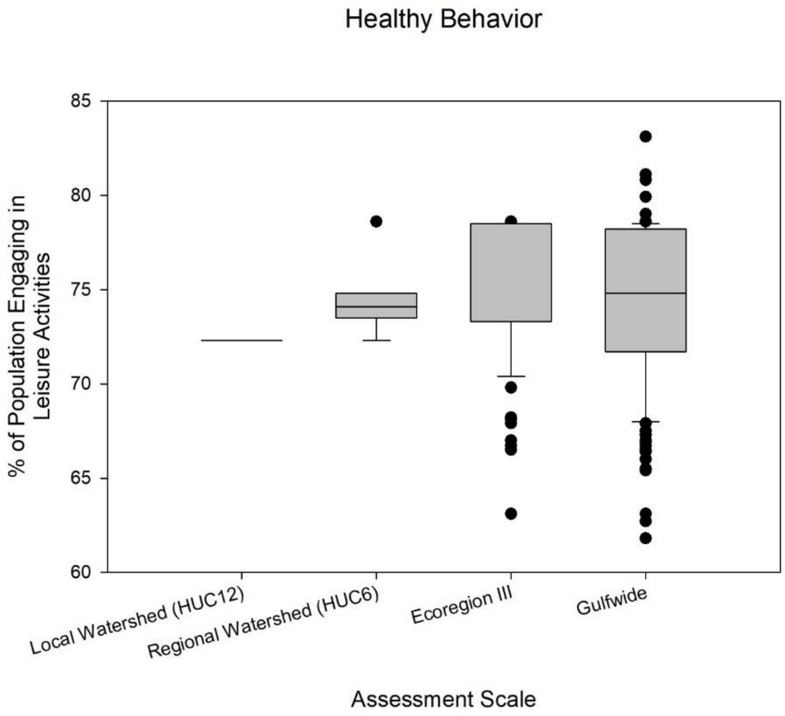


Figure 67. Percent of the population engaging in healthy leisure activities within the local watershed and other domains containing the proposed project site

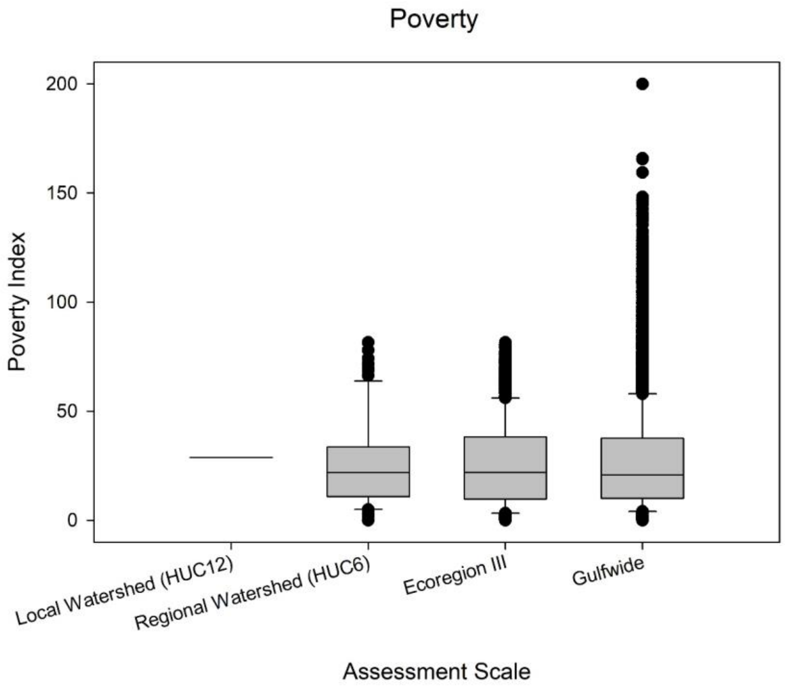


Figure 68. Poverty index (0-200) within the local watershed and other domains containing the proposed project site

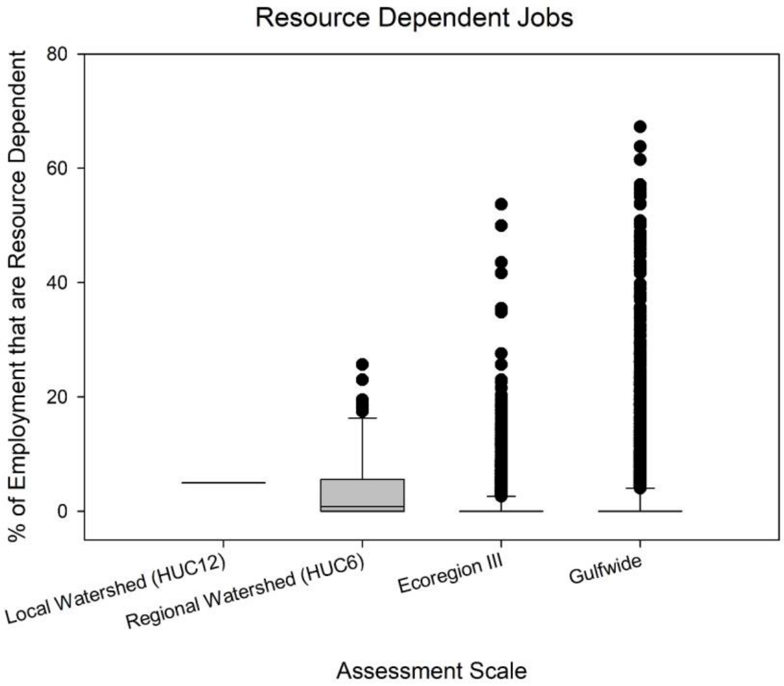


Figure 69. Percent natural resources dependent job rates within the local watershed and other domains containing the proposed project site

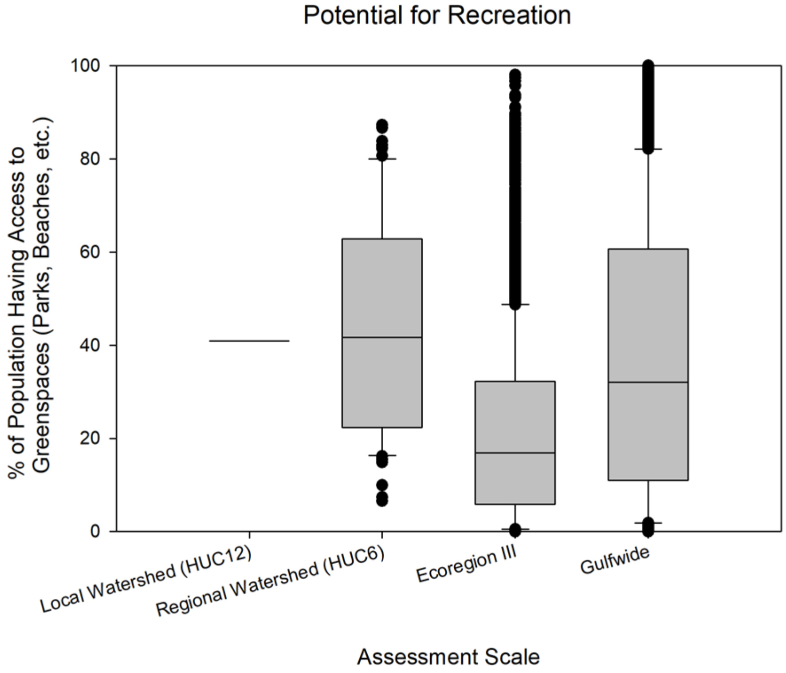


Figure 70. Percent of the population having access to green spaces (parks, beaches, etc.) within the local watershed and other domains containing the proposed project site

APPENDIX D: VARIABLES METADATA

Infrastructure

1. **Impervious Surface**
    - **a.** This field contains the analysis results of zonal statistics operations performed on the impervious surface raster available from the USGS National Map database at https://nationalmap.gov/small_scale/mld/impe100.html. A value of 1 indicates the presence of above average impervious surface as a stressor when compared to the gulf-wide average.
2. **Hazardous Facilities**
    - **a.** This field contains the analysis results from an isolation of hazardous facility sites from the Energy Information Administration (EIA) datasets available at https://www.eia.gov/maps/layer_info-m.php. Hazardous facilities include: Strategic Petroleum Reserves, Petroleum Product Terminals, Petroleum Refineries, Underground Natural Gas Storage, Natural Gas Processing Plants, Natural Gas Market Hubs, LNG Import/Export Terminals, Ethylene Crackers, Ethanol Plants, and Biodiesel Plants. A value of 1 indicates the presence of a hazardous facility point feature within a grid cell.
3. **Pipelines**
    - **a.** This field contains the analysis results from an isolation of pipeline locations from the Energy Information Administration (EIA) and Bureau of Ocean Energy Management datasets available at https://www.data.boem.gov/Main/Mapping.aspx & https://www.eia.gov/maps/layer_info-m.php. Pipelines include: LNG Pipelines, HGL Pipelines, Crude Oil Pipelines. A value of 1 indicates the presence of a pipeline line feature within a grid cell.
4. **Dams**
    - **a.** This field contains the analysis results from an isolation of offshore platform locations from the Bureau of Ocean Energy Management dataset available at https://www.data.boem.gov/Main/Mapping.aspx. A value of 1 indicates the presence of a offshore platform point feature within a grid cell.
5. **Offshore Platforms**
    - **a.** This field contains the analysis results from an isolation of offshore platform locations from the Bureau of Ocean Energy Management dataset available at https://www.data.boem.gov/Main/Mapping.aspx. A value of 1 indicates the presence of a offshore platform point feature within a grid cell.
6. **Ports**
    - **a.** This field contains the analysis results from an isolation of port locations from the USGS dataset available at https://water.usgs.gov/lookup/getgislist. A value of 1 indicates the presence of a port point feature within a grid cell.]
7. **Shipping Lanes**
    - **a.** This field contains the analysis results from an isolation of shipping lane locations from the Bureau of Ocean Energy Management dataset available at https://www.data.boem.gov/Main/Mapping.aspx. A value of 1 indicates the presence of a shipping lane feature within a grid cell.

Environment

1. **Hurricane Landfall**
    a. This field contains the analysis results from an isolation of hurricane tracklines from NOAA's National Climatic Data Center (NCDC) International Best Track Archive for Climate Stewardship (IBTrACS) dataset available at ftp://eclipse.ncdc.noaa.gov/pub/ibtracs/v03r10/all/shp/. A value of 1 indicates the presence of hurricane trackline within a grid cell.
2. **Tornado**
    a. This field contains the analysis results from an isolation of tornado tracklines from the joint NOAA/NWS Storm Prediction Center dataset available at https://www.spc.noaa.gov/gis/svrgis/. A value of 1 indicates the presence of tornado trackline within a grid cell.
3. **Rainfall**
    a. This field contains the analysis results of zonal statistics operations performed on the 30-year normal rainfall raster available from the PRISM Climate Group at http://www.prism.oregonstate.edu/. A value of 1 indicates the presence of above average rainfall as a stressor when compared to the gulf-wide average.
4. **Drought**
    a. This field contains the analysis results from severe and extreme drought tabular data sourced from the U.S. Drought Monitor at https://droughtmonitor.unl.edu/. Tabular data was joined to U.S Bureau of Census TigerLINE geodata at the county level. A value of 1 indicates the presence of above average drought as a stressor when compared to the gulf-wide average.
5. **Special Flood Hazard Area**
    a. This field contains the analysis results from an isolation of the Special Flood Hazard Area feature class available from FEMA as a part of the National Flood Hazard Layer at https://msc.fema.gov/portal/home. A value of 1 indicates the presence of SFHA within a grid cell.
6. **Max Temperature**
    a. This field contains the analysis results of zonal statistics operations performed on the 30-year normal maximum temperature raster available from the PRISM Climate Group at http://www.prism.oregonstate.edu/. A value of 1 indicates the presence of above average maximum temperature as a stressor when compared to the gulf-wide average.
7. **Min Temperature**
    a. This field contains the analysis results of zonal statistics operations performed on the 30-year normal minimum temperature raster available from the PRISM Climate Group at http://www.prism.oregonstate.edu/. A value of 1 indicates the presence of below average minimum temperature as a stressor when compared to the gulf-wide average.
8. **Sea Level Rise**
    a. This field contains the analysis results from an isolation of the spatial extent of 3 ft of sea level rise from the NOAA dataset available at https://coast.noaa.gov/slrdata/. A value of 1 indicates the presence of the spatial extent of 3 ft of sea level rise within a grid cell.
9. **Faults**
    a. This field contains the analysis results from an isolation of the fault zones feature class from the Department of the Interior (DOI) dataset available at

https://catalog.data.gov/dataset/fault-zones-in-the-gulf-coast-gcfltzoneg. A value of 1 indicates the presence of a linear fault zone feature within a grid cell.

10. **Land type change to Urban**
    a. This field contains the analysis results from an isolation of the raster surface detailing land type change between 1996 and 2010 from the Multi-Resolution Land Characteristic Consortium (MRCL) dataset available at https://www.mrlc.gov/datar. Cell centers that transitioned from a natural state to medium or high intensity developed between 1996 and 2010 were isolated and converted to point features. A value of 1 indicates the presence of these transitional point features within a grid cell.
11. **Land type change to Agriculture**
    a. This field contains the analysis results from an isolation of the raster surface detailing land type change between 1996 and 2010 from the Multi-Resolution Land Characteristic Consortium (MRCL) dataset available at https://www.mrlc.gov/datar. Cell centers that transitioned from a natural state to "agriculture" state between 1996 and 2010 were isolated and converted to point features. Agriculture is defined as the CCAP program (Cultivated Crops & Pasture/Hay). A value of 1 indicates the presence of these transitional point
12. **Non-Point Source Pollution**
    a. This metric was calculated by using derived watersheds where non-point source pollution was determined to be. After watersheds were created, the total area of the polluted watershed that overlapped a HUC12 was determined and the percent area that intersects was the metric derived.

Population

1. **Development Risk**
    a. This field contains the analysis results of zonal statistics operations performed on the USA development risk raster available from Colorado State University at https://landscape.blm.gov/COP_2010_metadata/COP_Urban_Growth_2030.xml. A value of 1 indicates the presence of above average development risk as a stressor when compared to the gulf-wide average.
2. **Power Plants**
    a. This field contains the analysis results from an isolation of the power plants feature class from the Energy Information Administration (EIA) dataset available at https://www.eia.gov/maps/. A value of 1 indicates the presence of a power plant point feature within a grid cell.
3. **Light Pollution**
    a. Light pollution is an increasingly pervasive form of anthropogenic environmental alteration and more than 99% of U.S. residents (80% globally) experience some form of light pollution (Falchi et al., 2016). This field contains the analysis results of zonal statistics operations performed on the light pollution raster available from the Cooperative Institute for Research in Environmental Sciences (CIRES) and NOAA at https://cires.colorado.edu/Artificial-light. A value of 1 indicates the presence of above average light pollution as a stressor when compared to the gulf-wide average.

Environmental Benefits

1. **Total Carbon (a + b)**
   - **a.** The amount of carbon stored in above ground live forest biomass in the HUC12 (kilograms carbon per meter). Source data was the National Biomass and Carbon Dataset (NBCD) for the year 2000 developed by the Woods Hole Research Center. The NBCD is a 30-meter resolution gridded dataset of above ground live dry biomass. This indicator was calculated for EPA EnviroAtlas. Detailed information on source data and calculation methods can be found at: https://edg.epa.gov/metadata/rest/document?id=%7B60BE4324-84B3-4C0F-A9A3-22E198F814E6%7D
   - **b.** The amount of carbon stored in below ground live forest biomass in the HUC12 (kilograms carbon per meter). Calculated from above ground live forest biomass estimates and an equation relating above and below ground forest biomass published in USDA Forest Service General Technical Report NRS-18. Source data for above ground biomass was the National Biomass and Carbon Dataset (NBCD) for the year 2000 developed by the Woods Hole Research Center. The NBCD is a 30-meter resolution gridded dataset of above ground live dry biomass. This indicator was calculated for EPA EnviroAtlas. Detailed information on source data and calculation methods can be found at: https://edg.epa.gov/metadata/rest/document?id=%7B0587242D-9CFC-460C-91B1-FC89B65AC66F%7D
2. **Soil Stability**
   - **a.** Mean soil stability in the HUC12. Soil stability is the inverse of soil erodibility. Source data was a 100-meter resolution grid of soil map units and attributes in the Natural Resources Conservation Service (NRCS) Soil Survey Geographic (STATSGO2) database, acquired from the US Geological Survey in July 2013. Mean soil erodibility was calculated as the average of erodibility grid values per HUC12. Mean soil stability was calculated as 1 - Mean soil erodibility.
3. **Habitat Connectivity**
   - **a.** Percent of the HUC12 that is part of the 2001 National Ecological Framework (NEF). The NEF is a GIS based model of the connectivity of natural landscapes in the lower 48 United States. The NEF is comprised of Hubs and Corridors, with Hubs defined as Priority Ecological Areas that are greater than 5,000 acres in size. Source data was the 2001 NEF geospatial dataset produced by EPA Region 4, http://cfpub.epa.gov/roe/documents/NEF_brochure.pdf. Equation used: NEF Area / HUC12 Area * 100.
4. **Priority Habitat Index**
   - **a.** Priority Habitat Index was calculated as a synthesis dataset which analyzed the spatial distribution of specific species native ranges, the amount of dedicated land for conservation and the apparent mismatch between the two. This dataset helps identify areas that should be conserved based on total number of species and overlapping ranges. The dataset can be found here: https://biodiversitymapping.org/wordpress/index.php/download/. For specific methods on how each species range was calculated, follow the below link and https://biodiversitymapping.org/wordpress/wp-content/uploads/2018/12/Methods_and_Permissions_BiodiversityMapping_15December2018.pdf.

5. **Percent Canopy**
    a. Percent canopy is a product of 2011 percent canopy National Land Classification Dataset. The National Land Cover Database products are created through a cooperative project conducted by the Multi-Resolution Land Characteristics (MRLC) Consortium. The MRLC Consortium is a partnership of federal agencies (www.mrlc.gov), consisting of the U.S. Geological Survey (USGS), the National Oceanic and Atmospheric Administration (NOAA), the U.S. Environmental Protection Agency (EPA), the U.S. Department of Agriculture -Forest Service (USDA-FS), the National Park Service (NPS), the U.S. Fish and Wildlife Service (FWS), the Bureau of Land Management (BLM) and the USDA Natural Resources Conservation Service (NRCS). The success of NLCD over nearly two decades is credited to the continuing collaborative spirit of the agencies that make up the MRLC. NLCD 2011 is the definitive Landsat-based, 30-meter resolution land cover database for the Nation.
6. **Groundwater Recharge**
    a. The mean annual natural ground-water recharge dataset was generated by multiplying a grid of base-flow index (BFI) values (Wolock, 2003) by a grid of mean annual runoff values (Gebert and others, 1987). Mean annual runoff is long-term average streamflow expressed on a per-unit-area basis. Natural recharge estimated in this way is very uncertain. The sources of uncertainty in the following list should be carefully considered before the dataset is used. 1. The approach used to create the natural recharge dataset is based on two main assumptions: (1) long-term average natural ground-water recharge is equal to long-term average natural ground-water discharge to streams, and (2) the BFI reasonably represents, over the long term, the percentage of ground-water discharge in streamflow. The extent to which these assumptions are valid determines, in part, the degree to which the mean annual natural recharge estimates can be considered reasonable. Users of the dataset should assess whether these assumptions are valid on the basis of knowledge of the local hydrologic system. Qualifications regarding the first assumption (ground-water recharge and discharge to streams are equal) that should be considered include the following: a. The natural recharge dataset is likely to underestimate "true" natural recharge in areas where ground-water evapotranspiration or near-stream ground-water pumping is significant. Ground-water evapotranspiration and near-stream ground-water pumping reduce ground-water storage and, thereby, also can reduce ground-water discharge to streams. The net result is that recharge to ground water will exceed the discharge of ground water to streams. Ground-water evapotranspiration can be high in arid regions. b. Ground-water discharge to streams does not occur in "losing" streams, which by definition "lose" water to the local ground-water system instead of "gaining" water from the ground-water system. Losing streams are more common in arid regions than in humid regions. c. Ground-water discharge to small streams will be less than total ground-water recharge if some of the recharge flows to deep, regional ground-water systems. Qualifications regarding the second assumption (the BFI reasonably estimates the percentage of ground-water discharge in streamflow) include: a. The BFI may be higher than the true percentage of ground-water discharge in streamflow for snowmelt-dominated streams. Snowmelt generally occurs gradually over time. Whether it enters the stream as ground-water discharge or overland flow cannot be distinguished by the BFI hydrograph separation technique. b. The BFI may be higher than the true percentage of ground-water discharge in streamflow for regulated streams

because regulation dampens rapid temporal changes in the hydrograph (see Supplemental_Information). About one-quarter of the streamgages used to make the BFI grid have been identified as being regulated. The BFI values for these streamgages, however, were not different from the BFI values for streamgages identified as being unregulated. 2. Natural recharge may be only a small component of total recharge. Irrigation can be a significant component of recharge to ground water that greatly exceeds natural recharge. 3. The two grids (the base-flow index and runoff grids) multiplied by each other to make the natural recharge grid are highly generalized in space. The lack of spatial detail in these grids is reflected in the natural recharge grid. Although the natural recharge dataset likely reflects general patterns across broad geographic regions, recharge values at specific sites are unlikely to be accurate. 4. The two grids (the base-flow index and runoff grids) multiplied by each other to make the natural recharge grid are highly generalized over time. The runoff grid represents the 1951-80 mean annual runoff, and the base-flow index grid is interpolated from streamgages with an average record length of 33 years. The mean annual natural ground-water recharge values, therefore, are also long-term average estimates. Additional information about the accuracy of the base-flow index is given in the Supplemental_Information section and in Wolock (2003). Use Constraints References: Gebert, W.A., Graczyk, D.J., and Krug, W.R., 1987, Average annual runoff in the United States, 1951-80: U.S. Geological Survey Hydrologic Investigations Atlas HA-710, 1 sheet, scale 1:7,500,000. Wolock, D.M., 2003, Base-flow index grid for the conterminous United States: U.S. Geological Survey Open-File Report 03-263, digital dataset, available on the World Wide Web, accessed July 8, 2003, at URL https://water.usgs.gov/lookup/getspatial?bfi48grd

Environmental Stressors

1. **Stream Length Impaired**
   a. Length of stream features with a TMDL or listed as impaired and requiring a TMDL under Section 303(d) of the Clean Water Act in the HUC12 (kilometers). Source data for calculating the length of stream features with a TMDL was the EPA Office of Water TMDL Waters geospatial dataset. Source data for calculating the length of 303(d) listed stream features was the EPA Office of Water 303(d) Listed Waters geospatial dataset. Methods were applied to ensure that streams present in both the TMDL Waters and 303(d) Listed Waters datasets were not double counted. (See also TMDL Waters and 303(d) Listed Waters glossary definitions).
2. **Waterbody Area Impaired**
   a. Area of lakes, estuaries, and other areal water features with a TMDL or listed as impaired and requiring a TMDL under Section 303(d) of the Clean Water Act in the HUC12 (square kilometers). Source data used for calculating the area of waterbody features with a TMDL was the EPA Office of Water TMDL Waters geospatial dataset. Source data used for calculating the area of 303(d) listed waterbody features was the EPA Office of Water 303(d) Listed Waters geospatial dataset. Methods were applied to ensure that waterbodies present in both the TMDL Waters and 303(d) Listed Waters datasets were not double-counted. (See also TMDL Waters and 303(d) Listed Waters glossary definitions).

3. **Soil Erodibility**
    a. Average soil erodibility (K) factor in the HUC12. Source data was a 100-meter resolution grid of soil map units and attributes in the Natural Resources Conservation Service (NRCS) Soil Survey Geographic (STATSGO2) database, acquired from the US Geological Survey in July 2013. Calculated as the mean of soil erodibility values in the HUC12.
4. **Density Toxic Release sites**
    a. Density of EPA Toxics Release Inventory (TRI) sites in the HUC12 (sites per square kilometer). The TRI stores information on facilities that handle toxic chemicals; including on-site or off-site land, air, or water disposal, recycling, energy recovery, or treatment. Source data was the EPA StreamCat "Accumulated Attributes for NHDPlusV2 Catchments (Version 2.1) for the Conterminous United States: Facility Registry Services (FRS) : Toxic Release Inventory (TRI) , National Pollutant Discharge Elimination System (NPDES) , and Superfund Sites" dataset (ftp://newftp.epa.gov/EPADataCommons/ORD/NHDPlusLandscapeAttributes/StreamCat/HydroRegions/; downloaded March 2016). The StreamCat dataset reports TRI site density for NHDPlus2 catchments based on TRI site locations stored in the EPA Facility Registration System as of 2014. TRI site densities for NHDPlus2 catchments were aggregated to HUC12 values by calculating the area-weighted mean for catchments that intersect the HUC12. Additional information on the StreamCat TRI density dataset can be found at: ftp://newftp.epa.gov/EPADataCommons/ORD/NHDPlusLandscapeAttributes/StreamCat/Documentation/Metadata/EPA_FRS.html.
5. **Density Superfund Sites**
    a. Density of EPA Superfund program sites in the HUC12 (sites per square kilometer). The Superfund program is responsible for cleaning up the nation’s most contaminated land and responding to environmental emergencies, oil spills and natural disasters. Source data was the EPA StreamCat "Accumulated Attributes for NHDPlusV2 Catchments (Version 2.1) for the Conterminous United States: Facility Registry Services (FRS) : Toxic Release Inventory (TRI) , National Pollutant Discharge Elimination System (NPDES) , and Superfund Sites" dataset (ftp://newftp.epa.gov/EPADataCommons/ORD/NHDPlusLandscapeAttributes/StreamCat/HydroRegions/; downloaded March 2016). The StreamCat dataset reports Superfund site density for NHDPlus2 catchments based on Superfund site locations stored in the EPA Facility Registration System as of 2014. Superfund site densities for NHDPlus2 catchments were aggregated to HUC12 values by calculating the area-weighted mean for catchments that intersect the HUC12. Additional information on the StreamCat Superfund density dataset can be found at: ftp://newftp.epa.gov/EPADataCommons/ORD/NHDPlusLandscapeAttributes/StreamCat/Documentation/Metadata/EPA_FRS.html.
6. **Brownfields**
    a. This field contains the analysis results from an isolation of the air emissions from the EPA Assessment, Cleanup and Redevelopment Exchange System (ACRES) as a part of the Facility Registration Service (FRS) dataset available at https://www.epa.gov/frs/geospatial-data-download-service. A value of 1 indicates the presence of a ACRES catalogued Brownfield site point feature within a grid cell.

7. **Wildfire Hazard Potential**
    - **a.** The mean wildfire hazard potential in the HUC12. Wildfire hazard potential ranges from 1 (very low risk of wildfire) to 5 (very high risk of wildfire) and depict the relative potential for the occurrence of wildfire that would be difficult for suppression resources to contain. Source data was the 2014 USDA Forest Service Wildfire Hazard Potential geospatial grid dataset (http://www.firelab.org/document/classified-2014-whp-gis-data-and-maps; downloaded January 2016). The Wildfire Hazard Potential grid is a 30-meter resolution grid of wildfire potential derived from spatial estimates of wildfire likelihood and intensity generated in 2014 with the Large Fire Simulator (FSim), spatial fuels and vegetation data from LANDFIRE 2010, and point locations of fire occurrence. Calculated as the average of wildfire hazard potential for grid pixels in the HUC12. Areas not assigned a Wildfire Hazard Potential value (non-burnable lands and water) were excluded from the mean calculation.
8. **Forestry Disease**
    - **a.** Binary map of cumulative risk from all forest pests and pathogens.
"Risk" cells show where >= 25% of total BA at hazard. This dataset is a nationwide strategic assessment and database of the potential hazard for tree mortality due to major forest insects and diseases. The goal of NIDRM is to summarize landscape-level patterns of potential insect and disease activity, consistent with the philosophy that science-based, transparent methods should be used to allocate pest-management resources across geographic regions and individual pest distributions. Data can be found here: https://www.fs.fed.us/foresthealth/applied-sciences/mapping-reporting/gis-spatial-analysis/national-risk-maps.shtml.
9. **Historic Oil Spill**
    - **a.** This field contains the analysis results from an isolation of significant aquatic oil spill extents adapted https://www.gearthblog.com/blog/archives/2010/05/comparing_the_gulf_oil_spill_to_oth.html. A value of 1 indicates the presence of a historic oil spill location within a grid cell.
10. **National Pollution Discharge Elimination System (NPDES)**
    - **a.** This field contains the analysis results from an isolation of National Pollutant Discharge Elimination System (NPDES) sites from the EPA Facility Registration Service (FRS) dataset available at https://www.epa.gov/frs/geospatial-data-download-service. A value of 1 indicates the presence of a NPDES point feature within a grid cell.
11. **Clean Air Markets Division Business System (CAMDBS)**
    - **a.** This field contains the analysis results from an isolation of air pollution facilities from the Clean Air Markets Business System (CAMDBS) registry hosted on the EPA Facility Registration Service (FRS) dataset available at https://www.epa.gov/frs/geospatial-data-download-service. A value of 1 indicates the presence of an air pollution point feature within a grid cell.
12. **Landfills**
    - **a.** This field contains the analysis results from an isolation of landfill or solid waste sites from the Homeland Infrastructure Foundation-Level Data (HIFLD) dataset available at https://hifld-geoplatform.opendata.arcgis.com/datasets/solid-waste-landfill-facilities. A value of 1 indicates the presence of a landfill or solid waste point feature within a grid cell.
13. **Toxic Release Inventory**

   a. This field contains the analysis results from an isolation of the toxic release inventory from the EPA Facility Registration Service (FRS) dataset available at https://www.epa.gov/frs/geospatial-data-download-service. A value of 1 indicates the presence of a toxic release inventory point feature within a grid cell.

14. **Gulf of Mexico – Dissolved Oxygen - Hypoxia**
    a. This field contains the analysis results from an isolation of hypoxia occurrence from NOAA NCDDX datasets available at https://www.ncddc.noaa.gov/hypoxia/products/. A value of 1 indicates the presence of a hypoxia point feature within a grid cell.
15. **Invasive Species**
    a. The spatial data for all species was derived from point data except for Southern Pine Beetle which was represented on a county basis. The spatial data was downloaded from EDD Maps and USGS Nonindigenous Aquatic Species (NAS). Bighead, Black, Silver, Grass, and Common Carp were downloaded from NAS while the rest: Zebra mussel, Chinese tallow tree, wild boar, nutria, melaleuca, kudzu, Japanese honeysuckle, Japanese climbing fern, hydrilla, hyacinth, giant and common salvinia, cogon grass, Chinese privet, cane toad, Brazilian pepper tree, and Asian clam were downloaded from Early Detection and Distribution (EDD) Maps. A value of 1 indicates the presence of invasive species in a grid cell.

Well-Being Metrics

1. **Population Density**
   a. Block group level data. Derived from U.S. Census Bureau's American Community Survey (ACS) 5-year report (2012-2016). Population density is calculated by dividing the total population by the area (sqmi) of the block group. The result is a number of persons per sqmi. In addition to the raw population density level, standard z-scores are created, which are calculated as $z= (x-\mu) / \sigma$ where x=the observed value, μ=the mean, and σ is the standard deviation of the dataset. The population density z-scores go into the stressor category of the Human Well-being Index calculation.
2. **Income Inequality**
   a. Census tract data derived from U.S. Census Bureau's American Community Survey (ACS) 5-year report (2013-2017). Limitations in block group demographic data require use of next-smallest spatial unit. Census tract data is spatially joined to block group data in order to calculate final Human Well-being Index exclusively with block groups. Each block group has income inequality data from the census tract it falls within. Income inequality is measured via the Gini coefficient. Each census tract has a score from 0-1 with 0 being the most equal distribution of income and 1 being the most unequal distribution of income. In addition to the raw Gini coefficient inequality scores, standard z-scores are created which are calculated as $z = (x-\mu) / \sigma$ where x = the observed value, μ = the mean, and σ = the standard deviation of the dataset. The income inequality z-scores go into the stressor category of the Human Well-being Index calculation.
3. **Home Ownership**
   a. Block group level data derived from U.S. Census Bureau's American Community Survey (ACS) 5-year report (2012-2016). Home ownership is calculated by dividing the number of homes that are owned by the total number of homes in each block group. In addition to the raw percentage of home ownership, standard z-scores are created, which are

calculated as z= (x-μ) / σ where x = the observed value, μ = the mean, and σ = the standard deviation of the dataset. The home ownership z-scores go into the benefits category of the Human Well-being Index calculation.

4. **Per Capita Income**
    - **a.** Block Group level data derived from U.S. Census Bureau's American Community Survey (ACS) 5-year report (2012-2016). Per-capita income measures the income of a given block group per working-age person (16+ years-old). A single per-capita income number is calculated per block group. In addition to the raw per-capita income numbers, standard z-scores are calculated as z = (x-μ) / σ where x = the observed value, μ = the mean, and σ = the standard deviation of the dataset. The per-capita income z-scores go into the benefits category of the Human Well-being Index calculation.
5. **Educational Attainment**
    - **a.** Block group level data derived from U.S. Census Bureau's American Community Survey (ACS) 5-year report (2012-2016). Educational attainment scores are calculated based on a formula of increasing weight of education level reached (Doak and Kusel). Data for all individuals 25+ years-old within each block group are used. The educational attainment score is calculated by multiplying each successive degree category by a factor that increases by 1 for each higher level of education reached. Educational attainment score = sum [A, (B*2), (C*3), (D*4), (E*5), (F*6), (G*7)] where A = percent of persons with less than 9th grade education, B = percent with 9th to 12th grade education, C = percent with high school diploma, D = percent with some college and no degree, E = percent with associate's degree, F = percent with bachelor's degree, and G = percent with a graduate or professional degree. In addition to the educational attainment score, standard z-scores are calculated as z = (x-μ) / σ where x = the observed value, μ = the mean, and σ = the standard deviation of the dataset. The educational attainment z-scores go into the benefits category of the Human Well-being Index calculation.
6. **Chronic Disease**
    - **a.** County level data derived from Center for Disease Control and Prevention's (CDC) online public health dataset (2013-2015). Limitations in small-scale demographic data require use of county level data. These data are spatially joined to block group data in order to calculate the final Human Well-being Index. Each block group has the healthy behavior value of the county it falls within. The chronic disease feature class is measured by summarizing three categories: 1. obesity 2. diabetes and 3. cancer. CDC county level data are pulled for each of these inputs. Percentages of occurrences are summed for each county. Standard z-scores are derived from these percentages. They are calculated as z = (x-μ) / σ where x = the observed value, μ = the mean, and σ = the standard deviation of the dataset. The chronic disease z-scores go into the stressors category of the Human Well-being Index calculation.
7. **Healthy Behaviors**
    - **a.** County level data derived from Center for Disease Control and Prevention's (CDC) online public health dataset (2013). Limitations in small-scale demographic data require use of county level data. These data are spatially joined to block group data in order to calculate the final Human Well-being Index. Each block group has the healthy behavior value of the county it falls within. The healthy behaviors feature class is measured by using an age-adjusted percentage of individual's propensity to engage in physical leisure activities each month. In addition to these percentages, standard z-scores are calculated as

z = (x-μ) / σ where x = the observed value, μ = the mean, and σ = the standard deviation of the dataset. The healthy behaviors z-scores go into the benefits category of the Human Well-being Index calculation.

8. **Poverty**
   a. Block Group level data derived from U.S. Census Bureau's American Community Survey (ACS) 5-year report (2013-2017). Poverty scores calculated by summing percentage of persons in poverty and poverty intensity (Doak and Kusel). Poverty level includes all persons with incomes below the poverty level. Poverty intensity in this study is defined as the sum of persons with incomes between 50% and 99% of the poverty level and two-times the number of persons with incomes less than 50% below the poverty level. Poverty score = TP + S where TP = total population in poverty and S = poverty intensity which = sum [(1 * X), (2 * Y)] where X = percentage of persons between 50-99% below the poverty level, and Y = percentage of persons below 50% of the poverty level. Poverty scores are created for each block group in the NOAA Gulf of Mexico region as well as standard z-scores, which are calculated as z = (x-μ) / σ where x = the observed value, μ = the mean, and σ = the standard deviation of the dataset. The poverty z-scores go into the stressor category of the Human Well-being Index calculation.
9. **Resource Dependent Employment**
   a. Renewable Natural Resource-Dependent Employment. Block Group level data. Derived from U.S. Census Bureau's American Community Survey (ACS) 5 year report (2012-2016). Percent of residents employed in agriculture, forestry, and fishing industries. Calculated by summing the percentages of each constituent category. In addition to the raw resource-dependent employment percentages, standard z-scores are caluculated as z= (x-μ) / σ where x=the observed value, μ=the mean, and σ is the standard deviation of the dataset. The resource-dependent employment z-scores go into the benefit category of the Human Well-being Index calculation.
10. **Potential for Recreation**
   a. Polygons of parks, wetlands, greenspaces, and beaches are gathered from the National Park Service, ESRI USA Parks dataset, and NLCD (2017 data). These polygons are interpolated to the block group level and spatial statistics of recreational space land coverage is calculated. Recreational space in this study includes parks (including local, state, national parks and wildlife management areas), wetlands, greenspace, and beaches. Percentages of recreational space for each block group are calculated, and z-scores are derived using the formula z = (x-μ) / σ where x = the observed value, μ = the mean, and σ = the standard deviation of the dataset. The potential for recreation z-scores go into the benefits category of the Human Well-being Index calculation.

APPENDIX E: WATER QUALITY AND INVASIVE SPECIES RESOURCES

Table 23. All categories were pulled from the 303(d) TMDL impaired waters geodatabase from the attribute field (1) LWDETAIL1 or (2) Parameter. The attribute field (2) Parameter, indicated by the grey column, is Florida's id field for TMDL categories and they have a different set of TMDLs with different names. Important note is that Florida has no category for pH. This data along with everywhere else was supplemented with raw data download from STORET between the years 2010-2019.

McNeil Forest Conservation Project

Parameter	**Texas**	**Louisiana**	**Mississippi**	**Alabama**	**Florida**	**Georgia**
Dissolved Oxygen	DO	DO	DO	DO	**DO, DO % saturation**	DO
Nitrogen	Nitrogen	Nitrogen	Nitrogen	Nitrogen	**Nitrogen**	Nitrogen
Phosphorus	Phosphorus, Phosphorus total	Phosphorus, Phosphorus total	Phosphorus, Phosphorus total	Phosphorus, Phosphorus total	**Phosphorus, Phosphorus total**	Phosphorus, Phosphorus total
Fecal coliform	Bacteria	FC	FC	FC	**FC, FC(3), FC SEAS**	FC
pH	pH, pH high, pH low	pH, pH high, pH low	pH, pH high, pH low	pH, pH high, pH low		pH, pH high, pH low

Table 24. USEPA Eco Region suggested impaired levels based on ecoregions. These thresholds were used to determine if a point location is likely to be impaired due to Nitrogen or Phosphorus. Ecoregion XIII ambient water quality standards has yet to be published, currently being drafted, and the threshold for the small eco region located in south Florida was given Ecoregion XIV thresholds.

McNeil Forest Conservation Project			
Eco Region	**Nitrogen (mg/l)**	**Phosphorus (ug/l)**	**Reference**
3	0.38	21.88	(United States Environmental Protection Agency, 2000a)
4	0.56	23	(United States Environmental Protection Agency, 2000a)
5	0.67	88	(United States Environmental Protection Agency, 2000b)
6	2.18	76.25	(United States Environmental Protection Agency, 2000c)
7	0.54	33	(United States Environmental Protection Agency, 2000d)
8	0.38	10	(United States Environmental Protection Agency, 2000c)(United States Environmental Protection Agency, 2001c)
9	0.69	36.56	(United States Environmental Protection Agency, 2000b)
10	0.76	128	(United States Environmental Protection Agency, 2000d)(United States Environmental Protection Agency, 2001d)
11	0.31	10	(United States Environmental Protection Agency, 2000e)
12	0.9	40	(United States Environmental Protection Agency, 2000f)
13	0.71	31.25	(United States Environmental Protection Agency, 2000g)
14	0.71	31.25	(United States Environmental Protection Agency, 2000g)

Table 25. US EPA nutrient thresholds utilized for Dissolved Oxygen, Fecal Coliform, and pH

McNeil Forest Conservation Project

Parameter	Threshold	Reference
Dissolved Oxygen	x < 5 mg/l	(Bricker et al., 2008)(Bricker et al., 2008)
Fecal Coliform	x > 100 MPN or CFU	(United States Environmental Protection Agency, 2012)(Environmental Protection Agency, Office of Water, 2012)
pH	6.5 < x < 9	(United States Environmental Protection Agency, 1986)(EPA, 1986)

Table 26. List of organizations from which water quality was retrieved from 2010-2019

McNeil Forest Conservation Project

Alabama	Arkansas	Georgia	Louisiana	Mississippi	Texas
USGS - GA	Arkansas Department of Environmental Quality	Georgia DNR Environmental Protection Division	National Park Service Water Resource Division	Mississippi Band of Choctaw Indians	USGS - OK
Alabama Department of Environmental Quality	Arkansas State University Ecotoxicology Research Facility	EPA Region 4 Athens Lab	Arkansas Department of Environmental Quality	BP Deep Water Horizon	USGS - NM
Georgia DNR Environmental Protection Division	Arkansas Water Resources Center	Suwannee River Water Management Division	LDEQ319	Mississippi Department of Environmental Quality	Environmental Monitoring and Assessment Program

McNeil Forest Conservation Project

Alabama	Arkansas	Georgia	Louisiana	Mississippi	Texas
TDEC Division of Water Resources	Cherokee Nation	TDEC Division of Water Resources	Louisiana Department of Environmental Quality	Alabama Department of Environmental Quality	EPA National Aquatic Resources Survey (NARS)
USGS Mississippi Water Science Center	EPA National Aquatic Resources Survey (NARS)	South Carolina Department of Health and Environmental Control	USGS - LA	USGS - MS	
USGS Tennessee Water Science Center	Equilibrium	USGS - SC			National Park Service Water Resources Division
EPA National Aquatic Resources Survey (NARS)	GBMc & Associates	Tennessee Department of Environment and Conservation			USDA Agricultural Research Service
BP Deep Water Horizon Oil Spill	Mississippi Department of Environmental Quality	Suwannee River Water Management District (Florida)			USGS - TX
Tennessee Department of Environment and Conservation	Missouri Dept. of Natural Resources	Environmental Monitoring and Assessment Program			
USGS - AL	Oklahoma Conservation Commission	USGS Tennessee Water Science Center			

McNeil Forest Conservation Project

Alabama	Arkansas	Georgia	Louisiana	Mississippi	Texas
	TDEC Division of Water Resources	USGS - GA			
	Univ. of Missouri Columbia				
	University of Arkansas				
	USGS - AR				
	USGS Kansas Water Science Center				
	USGS Missouri Water Science Center				
	USGS Oklahoma Water Science Center				

Table 27. List of organizations from which water quality was retrieved from 2010-2019 for Florida

Florida Water Quality Sources	
BP Deep Water Horizon Oil Spill	Dade Environmental Resource Management (Florida)
Alabama Department of Environmental Management	Environmental Monitoring and Assessment Program
City of Tallahassee Stromwater	EPA National Aquatic Resources Survey (NARS)
FL. Department of Environmental Protection South District	FDEP Water Quality Standards and Special Projects (Florida)
Avon Park Air Force Range - 23 WG DET 1 OLA	Fl Dept. of Environmental Protection Central District
Florida Keys NMS - Water Quality Monitoring Program	FL Dept. of Environmental Protection
Georgia DNR Environmental Protection Division	Florida Fl Department Of Environmental Protection Northeast District
HDR Incorporated	Florida Keys NMS - Water Quality Monitoring Program
Lake County Water Resource Management	Guana Tolomato Matanzas (GTM) Esturarine (NERR - Florida)
Lee County	HDR Incorporated
Sarasota County Environmental Services	Lake County Water Resource Management
USGS Georgia Water Science Center	Lee County
Seminole Tribe of Florida	Lee County Hyacinth Control District (Florida)
USGS - FL	Leon County Public Works (Florida)

Florida Water Quality Sources	
South Florida Water Management District	Manatee County Parks and Natural Resources Department (Florida)
Suwannee River Water Management District	McGlynn Laboratories Inc
SMR Communities Inc. (Florida)	McGlynn Laboratories Inc (Florida)
Babcock Ranch (Florida)	National Health and Environmental Effect Research-NHEERL(FL)
Biological Research Associates (Florida)	National Park Service Water Resources Division
Century Reality/Schreuder Inc. (Florida)	Orange County Environmental (Florida)
Charlotte Harbor National Estuaries Program (Florida)	Orange County Environmental Protection (Florida)
City of Cape Coral	Orlando Streets Drainage Stormwater Utility Bureau(Florida)
City of Deltona	Palm Beach County Environmental Resources Management Departm
City of Jacksonville	Palm Beach County Environmental Resources Managemnt(Florida)
City of Naples (Florida)	Peace River Manasota Regional Water Supply Authority (FL)
City of Orlando - Streets and Stormwater Division (Florida)	Polk County Water Resources (Florida)
City of Port St. Lucie (Florida)	Reedy Creek Improvement District - Env Services (Florida)
City of Sanibel Natural Resources Department (Florida)	Sarasota County Environmental Services (Florida)
City of West Palm Beach (Florida)	Seminole County (Florida)

Florida Water Quality Sources	
Collier County Coastal Zone Management Department (FL)	Seminole Tribe of Florida
Collier County Pollution Control (Florida)	SMR Communities Inc. (Florida)
Suwannee River Water Management District (Florida)	South Florida Water Management District
The Conservancy of Southwest Florida	Southwest Florida Water Management District
USGS Alabama Water Science Center	Southwest Florida Water Management District (FLDEP)
USGS Mississippi Water Science Center	Apalachicola National Estuarine Research Reserve (Florida)
Alachua County Environmental Protection Department (Florida)	

Table 28. List of resources from which invasive species were identified per state

McNeil Forest Conservation Project				
Alabama	**Florida**	**Louisiana**	**Mississippi**	**Texas**
invasiveplantatlas.org	myfwc.com/wildlifehabitat/nonnatives	lsuagcenter.com	invasivespeciesinfo.gov/us/mississippi	texasinvasives.org
aces.edu	eddmaps.org	nas.er.usgs.gov	mdwfp.com	stateimpact.npr.org/texas
eddmaps.org	wikipedia.org/list_of_invasive_species_in_the_everglades	wlf.louisiana.gov	eddmaps.org	eddmaps.org
se-eppc.org	bugwoodcloud.org	tulane.edu	extension.msstate.edu	tsuinvasives.org
https://www.invasivespeciesinfo.gov/us/alabama	https://www.invasivespeciesinfo.gov/us/florida	defenders.org	se-eppc.org	tpwd.texas.gov
		plants.usda.gov	extension.msstate.edu/natural-resources/invasive-plants	https://www.invasivespeciesinfo.gov/us/alabama
		https://www.invasivespeciesinfo.gov/us/alabama	https://www.invasivespeciesinfo.gov/us/alabama	

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