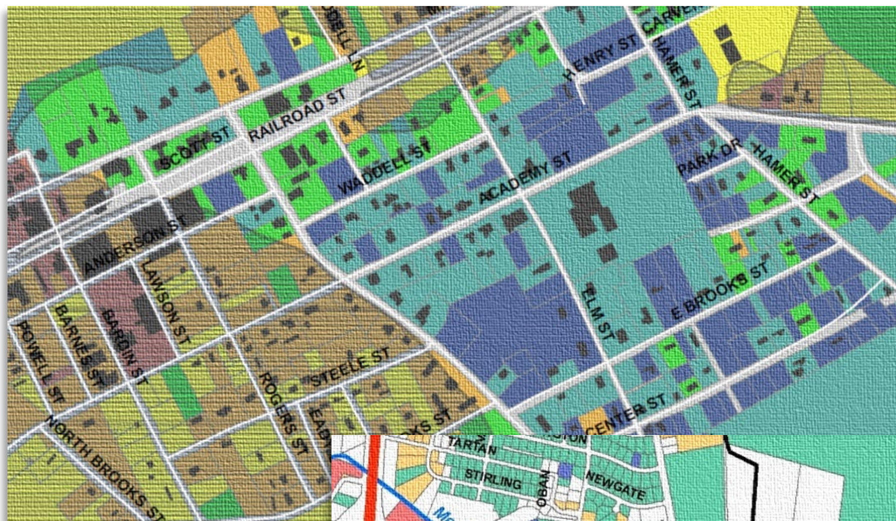
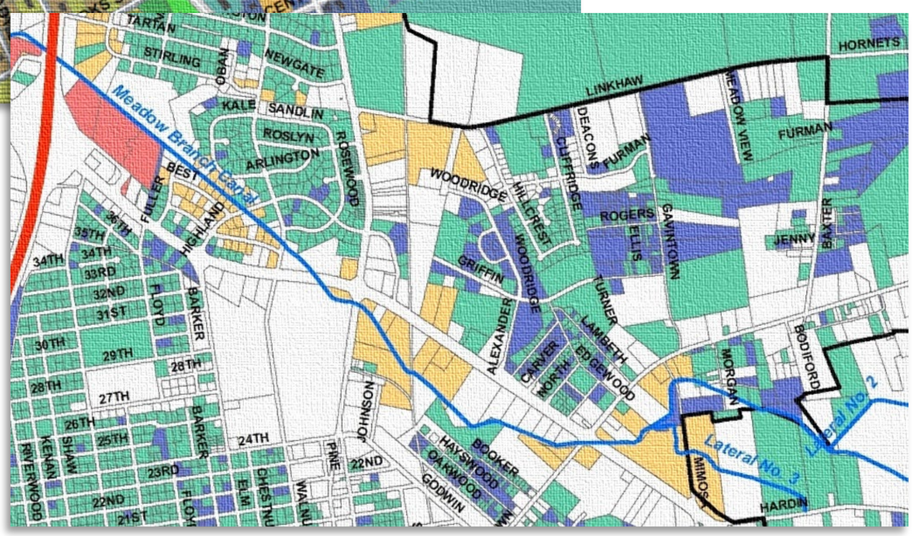
Technical Memo:

Land Suitability Analysis for Post-Disaster Housing Relocation





HMDRRI
Hurricane Matthew Disaster Recovery and Resilience Initiative

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This memo draws significantly from the UNCCH master's project paper by HMDRRI team member Christian Kamrath, cited in the references and with a hyperlink shown in the Appendix.

PART ONE
Overview and Purpose of a Relocation Strategy

After Hurricane Matthew, almost 35,000 homes were left damaged in North Carolina with about 5,000 families finding their homes in a condition that was unlivable (NC Dept. of Commerce, 2017). Further, the state's action plan for the Community Development Block Grant – Disaster Recovery (CDBG-DR) states that the number one priority "is to allow families to return to their homes…" and ensure that "…resulting recovery programs also account for long-term sustainability…" helping "…homeowner[s] and renter[s] finding safe and suitable housing rather than simply rebuilding a damaged unit" (NC Dept. of Commerce, 2017). The importance of safe, affordable housing after a disaster was reiterated time and time again during initial meetings with community officials and public visioning sessions that HMDRRI facilitated and has been noted as the corner stone of successful long-term recovery because it "can be a platform for families' education, health, and economic wellbeing" (Brennan, 2011; Brennan and Lubell, 2012; Cohen, 2011).

An assessment of affordable housing in the Eastern North Carolina Region conducted by HMDRRI concluded that even prior to the storm "One in two renters is cost-burdened; one in three homeowners with a mortgage is cost-burdened, and one in six homeowners without a mortgage is cost-burdened by housing costs, indicating very low incomes and high utility costs or property taxes." (Nguyen et al., 2017). While the region is struggling to find affordable housing, they also have found many homes at considerable risk to flooding. As a result of the flooding from Hurricane Matthew, the State of North Carolina received over 3,000 FEMA Hazard Mitigation Grant Program applications, with communities and individuals within them eligible to choose between: a) demolition and reconstruction, b) elevation or c) acquisition or "buyout."

For the residents who are eligible and choose to participate in the buyout program, several important questions and concerns arise for both the participants and community leaders:

- Where can participants move, based on their financial situation, the amount of aid received, and their desired location, housing type, neighborhood type, etc.?
- Are there enough affordable options outside of the floodplain given the pre-existing lack of affordable housing and number of buyout program participants?
- What might new and more resilient affordable housing look like?
- To what extent is the municipality and county at risk of losing tax revenue if participants relocate outside of the community?
- What will happen to the buyout land afterward and who will be responsible for its maintenance? Will it become a vacant lot of grass, return back to nature, or transformed into an amenity such as a park or garden?

A major goal of HMDRRI's work and the primary purpose of the Relocation Strategy is to help communities assist residents who participate in the buyout program relocate to areas within their community that are at a reduced risk for future flooding.

The three components of the Relocation Strategy described below work to complement each other in answering these questions while striving to meet other general recovery goals.

This Technical Memo focuses on describing the background, methods and results of the third component, the Land Suitability Analysis.

Using results from the intake survey and recommendations from HomePlace, combined with the land suitability analysis (LSA), communities will be able to make decisions that can limit the loss of their property tax base and reduce future flood risk by limiting future development in the floodplain. Table 1 shows how each of the components is designed to meet various goals of the relocation strategy (RS) outlined by HMDRRI and influenced by input from each community.

A comprehensive post-disaster survivor intake survey about how and where flooded buyout participants prefer to relocate has not been done before as a way to inform redevelopment housing. This unique pairing of the survivor's needs and preferences with best design practices for sustainable and healthy housing development will make successful relocation more viable. Finally, integration with the multi-variate LSA provides the spatial perspective required to ensure the RS complements existing plans that have goals to reduce flood risk or revitalize an area of the community.

The **Relocation Strategy (RS)** can stand alone as a useful tool or be integrated into a larger disaster recovery plan for communities. The RS consists of three main components:

a) **Disaster Survivor Intake Survey**[1]: information gathering technique designed to better understand survivors' current financial situation, preferred housing and neighborhood characteristics (size, cost, location, etc.)

b) **HomePlace – A Conversation Guide for Communities**[1] **, Rebuilding After Hurricane Matthew**: menu that provides high-quality, community-specific designs and strategies at household, community, and regional scales and addresses home rebuilding factors of accessibility, curb appeal, affordability, comfort, efficiency, and flexibility. It also includes a Greenspace Concept plan which illustrates how existing and expected future open space (i.e., parks, trails, "buyout properties", etc.) can be integrated with public health and economic development goals. (HomePlace reports are separately written for each of the six HMDRRI communities.)

c) **Land Suitability Analysis (LSA)**: land use-planning tool that uses geographic information systems (GIS) to identify potential areas for redevelopment, using set of variables with specified criteria and weights, which identify parcels with a reduced risk to flooding, are within the municipal limits, and help meet other community development goals.

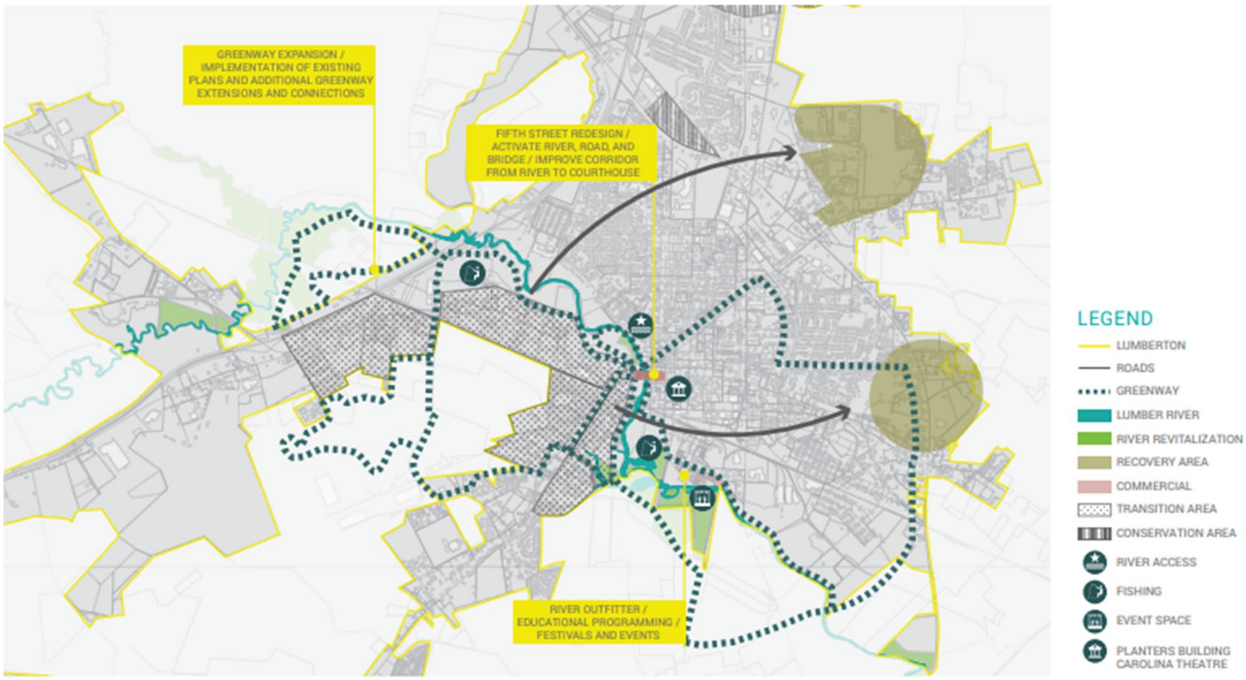
Table 1. Goals of the HMDRRI Relocation Strategy (RS).

Goal	Disaster Survivor Intake Survey	HomePlace Conversation Guide	Land Suitability Analysis (LSA)
Discover desired characteristics (household type, income, location, etc.) of potential buyout participants	X		
Understand local needs and preferences for post-disaster housing	X	X	
Incorporate best design principles for resilience and local vernacular to guide housing redevelopment		X	X
Tie together potential greenspace/greenways and recreation needs with future economic and housing development strategies	X	X	X
Identify areas within community that have reduced flood risk suitable for infill development or multi-family development			X

The HomePlace Guide is "a means of communicating the potentially significant roles that buildings, landscapes, and communities could play in disaster recovery, to include addressing the challenges and opportunities associated with the relocation of flood-prone housing" (HMDRRI HomePlace, 2017a). While each community is unique in its physical layout and various housing, greenspace, and economic development needs, a number of similar actions have emerged including:

- Increasing accessibility and recreational opportunities to and along the local waterway through greenway trails, boardwalks, environmental education, and beautification of nearby streets (e.g., public art, tree planting etc.)
- Reuse of past or expected flood buyout properties as parks or greenspace, community gardens or event space as well as enhanced wetland restoration and management that could serve to alleviate future flooding.
- Relocation of flood buyout participants found in 'transition areas' to regions within municipal boundaries, but outside the most hazardous flood zones deemed 'recovery areas'. In some cases, concepts include development of new village cores in less vulnerable areas.
- Floodproofing of historic buildings or downtown corridors to preserve community character while increasing resilience to future flooding.

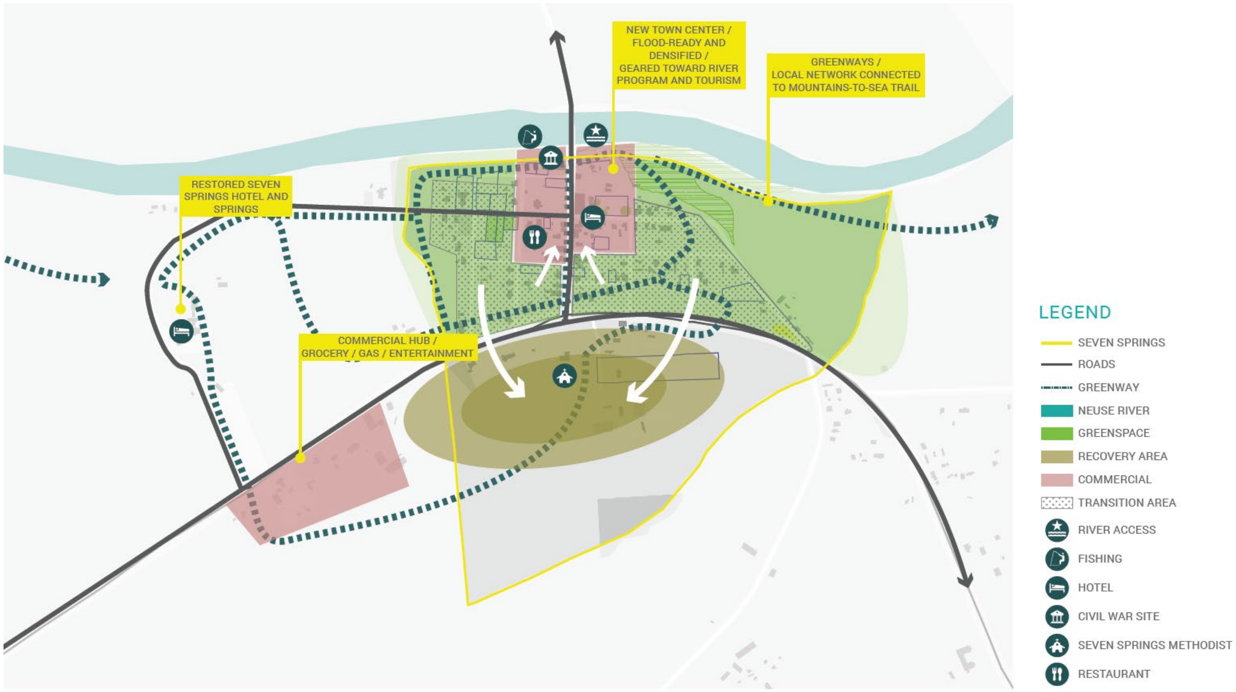
Figure 1. City of Lumberton Green Space Concept.



Community Example: Lumberton Combined Buyout-Greenspace Strategy

Along with addressing housing needs, Lumberton is looking to reduce risk for a number of public facilities (i.e., public works, electric utility, county school administration, etc.) by either relocating them outside the 100-year floodplain or by elevating them in place, meeting the base flood elevation along with 2 foot freeboard requirement. The Green Space Concept (Figure 1) involves a combination of strategies including: increasing access and visibility of the Lumber River along the Fifth Street Corridor; transforming former buyout properties into a programmed park and event space that could host a river outfitter that connects to future greenways and trails, and the relocation of homes outside of the 100-year floodplain (HMDRRI, 2017b). These components of the Relocation Strategy aim to help address not only some of Lumberton's long-term recovery needs but also supports the city's long-term goal to enhance their level of resilience.

Figure 2. Town of Seven Springs Green Space Concept.



Additional ideas are presented in the Town of Seven Springs Green Space Concept (Figure 2) where almost the entire town's footprint lies in a flood zone. The potential recovery area is on a bluff, which is situated at much higher elevation (HMDRRI, 2017c). The LSA works to provide greater detail about the suitability of the parcels in the recovery area knowing there are other forces at work in each community that influence the viability of future affordable housing development in new locations.

Additional planning activities have been informed by the LSA for Seven Springs, and documented in the Seven Springs Recovery Plan. The plan builds upon HomePlace and the Greenspace concept referenced above and includes a summary of a flood retrofit study that was conducted by HMDRRI for their historic downtown. Individual buildings were surveyed by a team of flood experts to see which ones would be candidates for employing either dry or wet floodproofing measures. Regarding open space, especially parcels acquired through a buyout program, the plan considers a range of options, including recreation uses and cultural events such as re-enactments of battles during the Civil War, recognizing the "Battle of Whitehall" in 1862 and the presence of The Neuse ironclad war vessel on the north side of the river. The plan reflects larger areas of potential residential use on higher ground south of Highway NC-55, plus a few small parcels on the north side of the highway, as determined by the LSA.

Communities have been awarded a number of grants (via CDBG-DR[1], Golden LEAF Foundation, etc.) for projects related to storm drainage and flood gates, reconstruction, repair and relocation of

[1] CDBG-DR funds may supplement, but cannot duplicate, funding available from FEMA or other federal agencies. CDBG funds are approved by Congress. These flexible grants, administered by the U.S. Department of Housing and Urban Development (HUD), can be used to assist disaster recovery and resilience efforts by local governments, states, or tribes. CDBG may be used to fund a broad range of activities so long as they meet at least one of three national objectives: 1) benefit low- and moderate- income persons, 2) help prevent or eliminate slums or blight, or 3) address urgent risks that pose a serious and immediate threat to the health and wealth of the community where other financial resources are unavailable. (U.S. HUD, 2016).

facilities, and revitalizing communities while addressing the immediate needs of the residents most heavily impacted by the storm.

Applying the LSA will take a significant amount of time, energy, investment, planning and determination on the part of municipal officials and their staff, their recovery partners, and of course, the survivors themselves. The challenges and opportunities seen in HMDRRI communities are numerous and varied, but each community is taking steps to reinvent itself in a way that makes it more resilient to future flooding. HMDRRI has facilitated taking many of the first steps in a long recovery process, including the development of the LSA which can inform future resilient housing development strategies.

PART TWO
Land Suitability Analysis Process and Methods

I. Approaches to Conducting a Land Suitability Analysis

Conducting an LSA involves selecting and assigning weights to a combination of variables that can be represented on a map to develop an index that shows where certain areas may be more or less suitable for a predefined purpose. Variables can be environmental (e.g., the boundaries of a flood zone), political (e.g., the boundaries of a municipality), physical (e.g., the proximity to existing drinking water infrastructure), or related to other plans (e.g., zoning or future land use designation). Most LSAs aim to identify best and worst areas for a specific use of land such as commercial development, agriculture production, or habitat restoration and are designed to inform a community's decisions about "where it should do what." Dr. Jacek Malczewski's[2] reviewed GIS-based LSAs and identified three general approaches: 1) computer-assisted overlay mapping, 2) multi-criteria decision-making methods (MCDM), and 3) artificial intelligence (AI) methods (2004). The simpler, more accessible computer-assisted overlay and MCDM approaches are often combined to form a hybrid solution, which was used in this project, and can still be powerful without having to use more complex AI methods.

Technical Note: Choices of Computer Method

Site evaluation studies have been part of urban development for millennia, influencing the layout of human settlements of all kinds. An overlay method was first pioneered with transparent sketch paper to depict streams, hills, and other landforms to be used or avoided. Professor Ian McHarg at the University of Pennsylvania formalized this method in his 1969 book, Design with Nature. Computer-assisted overlay mapping is the most basic advancement beyond McHarg's original manual method and where GIS's capabilities are introduced. McHarg's work can be described as the first discretized raster suitability analysis, a method also used by Burrough et al., who used simple overlays of data layers to eliminate undesirable areas, step by step (1993).

MCDM, which can be separated into two approaches of multiobjective methods (i.e., mathematical programming models) and multiattribute methods (i.e., weighted linear combination [WLC], analytical hierarchy process [AHP], etc.) involves "the utilization of geographical data, the decision-maker's preferences and the manipulation of the data and preference according to specified decision rules" (Malczewski, 2004). Multiattribute methods such as the WLC or linear combination model developed by Hopkins are the simplest and most common within LSAs (Hopkins, 1977). AI methods such as 'neural networks' are more complex, less transparent, and less easily integrated into the GIS environment making the approaches "inaccessible to most planners, mangers and decision-makers" and it is "unlikely that that [their] solutions or set of solutions…will be acceptable to those who make decisions regarding land use and the public" (Malczewski, 2004)."

[2] Dr. Jacek Malczewski is a Professor in the Department of Geography at Western University in London, Ontario, Canada.

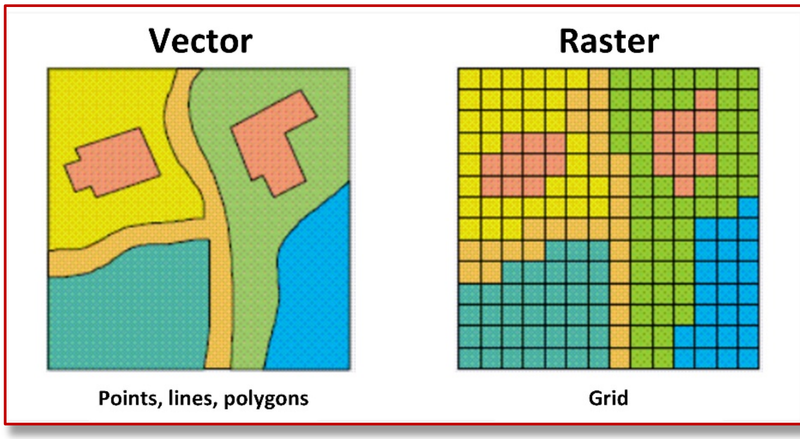


Figure 3: Diagram of vector vs. raster geographic information system (GIS) data.

Suitability analyses can also be separated by the type of underlying GIS data used which include raster-based (a matrix of uniform grid cells or pixels) or vector-based (points, lines and polygons with defined spatial boundaries) (Figure 3). Most LSAs use the raster data model for area-oriented structure which allows for easier operation of proximity, buffer and overlay analysis (Malczewski, 2004).

One example of raster-based LSAs were conducted by Bertie County, North Carolina, (which includes the Town of Windsor[3]) for the county's 2015 land use plan.[4] The plan seeks to "provide information to local decision-makers on land that may have fewer environmental and regulatory restrictions, land where services can be provided at lower cost, or land that is most attractive given its proximity to existing development or to the waterfront areas" (Bertie County, 2015). The county's approach was simple and not geared toward disaster recovery, but is still useful knowing the spatial relationships between various sets of landscape features.

Other land suitability analyses that focus on affordable housing such as those used by the Central Florida Regional Planning Council or a group at Portland State University offer other approaches, but do not incorporate natural hazards or flooding risk as a component, severely limiting the tool's ability to guide development patterns that reduce risk and increase a community's resilience to flooding (CFRPC, 2014; Mallon et al., 2017).

Because the goal of HMDRRI RS and LSA is to identify specific parcels of land within a community that would be most appropriate for resilient housing infill development or for redevelopment, a vector-based hybrid computer-assisted overlay and WLC were used to incorporate flood risk and other variables described in Section III of this Technical Memo. For local governments and recovery partners seeking to relocate flood survivors to safe, permanent housing, the vector-based approach to an LSA facilitates the identification of suitable property for development or redevelopment.

[3] The Town of Windsor, NC, which is one of six communities assisted by HMDRRI, was provided an LSA.
[4] Coastal counties like Bertie are required to perform a land suitability analysis as defined in the Coastal Area Management Act. Section .0702 (c)(5).

Lessons Learned Internationally: Using LSA in Nigeria After a Flood

"Suitability Analyses used in a post-disaster context": A literature review found only a few examples describing how an LSA was used in a pre- or post-disaster context. A 2016 report on Reducing Disaster Risk by Managing Urban Land Use from the Asian Development Bank recommends the inclusion of hazard information into existing land suitability analysis used for master planning, but doesn't provide many details about its usefulness in recovery planning or provide examples.

Ibrahim et al., 2015 used a raster-based weighted overlay technique to perform an LSA for the resettlement of flood disaster victims in Lokoja, the administrative capital of the Kogi State in Nigeria which sits near the rivers Niger and Benue. The LSA included variables such as elevation, proximity to the river channel, slope, land cover, and proximity to infrastructure. This resulted in the identification of five potential resettlement sites of at least 100 hectares each, which covered only 4.14% of the total land (Ibrahim et al., 2015). After 272 housing units targeted for flood survivors were built on these sites, Abdulquadri et al., 2016 then conducted an evaluation of the development that was partly guided by Ibrahim et al.'s work to see if redevelopment goals were met. The evaluation's findings conclude that disaster risk reduction, through non-structural measures such as multi-hazard vulnerability analysis, the LSA, and relocation of housing outside high risk zones, was "achieved." However, results for other categories such as structural measures, social recovery and others were "not achieved" due to a lack of community consultation regarding the relocation site, building design types, and construction process.

Each of the factors not achieved during the Lokoja flood-survivor relocation were addressed in the HMDRRI RS approach.

Often referenced and hailed as a success of hazard mitigation, resident relocation, and post-disaster planning, the city of Kinston, NC[1] endured major floods during Hurricane Fran in 1996 and again during Hurricane Floyd in 1999. After hundreds of voluntary buyouts were completed, the City implemented several programs, as described in the box below.

Community Example: Call Kinston Home

"…Call Kinston Home, a redevelopment effort focused on relocating families to existing neighborhoods located outside the floodplain (emphasizing the use of infill lots), thereby avoiding sprawl into the countryside while maintaining the city's tax base and revitalizing established neighborhoods; establishing a community-college led program called Housing and Employment Leading People to Success (HELPS) which sought to assist low income families (primarily renters) involved in the housing relocation program with job training (focused on the reconstructions and repair of flood-damaged housing) and financial counseling in order to assist them become the first-time home buyers; developing a green infrastructure plan that guided the use of large amount of now vacant land adjacent to the Neuse river; and relocating a flood-prone waste water (that released raw sewage into the river following Hurricanes Fran and Floyd) as well as several local junkyards thereby improving local water" (Smith 2011, pp 65).

While Kinston's green infrastructure plan for acquired property has not been fully implemented, the city's efforts to reduce future flood risk while supporting relocation of flood survivors within city are both admirable and cost-effective. For Kinston, its adept use of GIS, strong vertical integration, and experience with past floods like Hurricane Fran in 1996 greatly aided the success of the project post-Floyd.

Community Example: Staten Island, NY

Hurricane Sandy in 2016 caused extensive damage, personal injury and loss of life on Staten Island, one of five boroughs comprising New York City. Researchers studied the storm's effect in relation to previous planning, especially a sustainability analysis of Staten Island performed by Professor Ian McHarg as reported in his famous 1969 book, Design with Nature. McHarg examined the island's land suitability with attention to ecological planning by analyzing physical and cultural characteristics of land features and biophysical vulnerabilities such as tidal inundation and coastal flooding. Results show (1) that a significantly lower percentage of urban damage would have occurred in Hurricane Sandy if land development had followed McHarg's guidelines and (2) how conflicting economic and social ideals of development and zoning issues could explain why McHarg's study would have been difficult to implement. The findings illustrate the tradeoffs between economic development and long-term environmental benefits. (Wagner, 2016)

Other communities have likely used some form of a GIS-based LSA in the post-disaster context, but their reported use and levels of success have either never been documented or are not readily accessible. Further research should be done to assess the use of the tool and its historical application in pre- or post-disaster recovery planning or resilience planning in general.

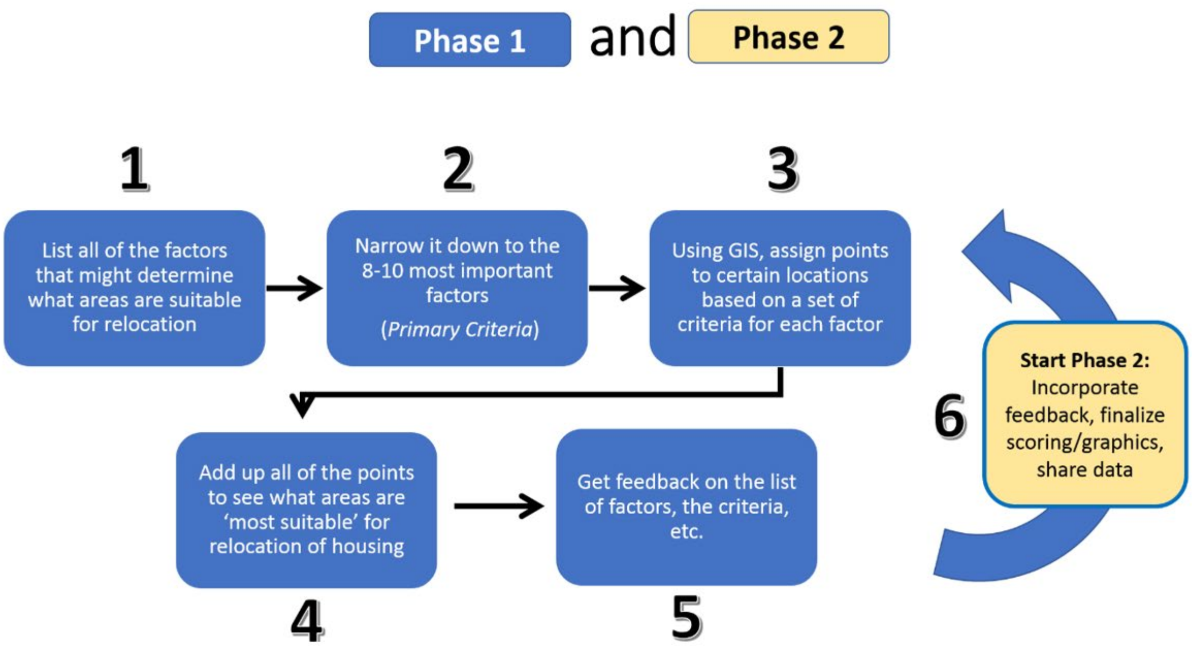
II. LSA Process Overview

A multi-phase approach was conducted to identify variables, the associated criteria, and thresholds for use in the LSA that incorporates stakeholder feedback and achieves HMDRRI's RS goals, while considering the different issues, constraints, and opportunities found within each community. The approach follows best practices for GIS-based LSAs to incorporate both 'hard' and 'soft' information by following the steps illustrated in Figure 4.

Phase one consisted of several steps including: 1) listing all potentially relevant factors for housing development suitability; 2) prioritizing and selecting a subset of variables within the comprehensive list that contributes to the LSA goal; 3) identifying thresholds and relative weights for short list variables; 4) conducting a preliminary LSA using GIS; and 5) obtaining community feedback on factors, criteria, and thresholds. Phase two builds off the phase one preliminary LSA and incorporates feedback from stakeholders who either have interest in the results or expertise in an area that is related to the analysis or to the variables or data being used. Since the LSA is part of a larger Recovery Strategy, community input involved identifying a set of preferences and needs through a comprehensive survey of flood survivors, including those who have applied for the HMGP buyout program. This process can and should be further informed by existing plans, knowledge of existing (or lack of) affordable housing stock, and other factors.

As a vector-based, hybrid computer-assisted overlay and WLC method, the analysis depends on the creation of an overlay rule or threshold that determines how and whether a parcel is attributed points for a given variable (Phase 1 – Step 3). The simplest rule to apply in this situation is the 50/50 rule. For example, if a property has less than 50% of its area covered or overlapping with any given

Figure 4. Multi-phase LSA process used by HMDRRI.



variable such as the 100-year flood zone, it would be considered to have a lower risk of flooding and therefore attributed points toward a higher suitability score (Figure 5).

A Using this 50/50 threshold, each vector-based variable (i.e., jurisdictional boundaries, water infrastructure buffer, etc.) can be overlaid on top of existing parcel boundaries and have their overlapping percentage calculated which then determines the attribution of points toward overall suitability. Though the method's simplicity allows for easy execution, replication, and explanation, it also has its limitations as far as accounting for and displaying the variability in percentage overlap. However, providing alternate perspectives as described below, can help to address this issue. The 50/50 rule does was not necessary for every variable because some are included or associated with the parcel data already (i.e., size, zoning) and can have points directly attributed based on set thresholds.

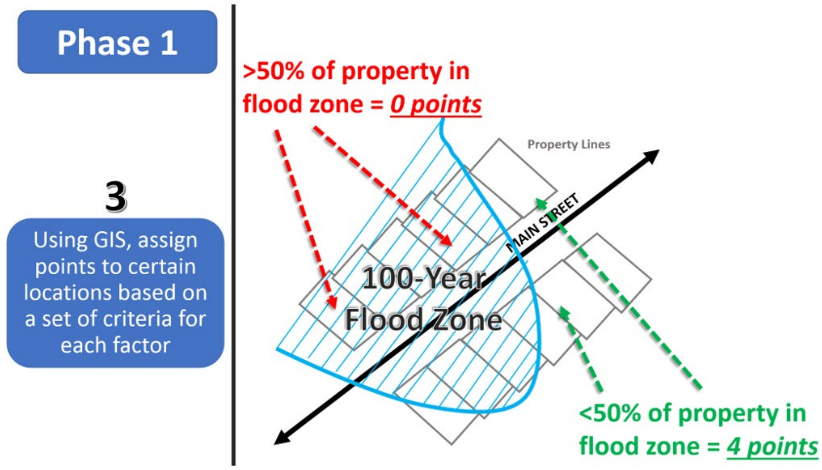


Figure 5. Conceptual example of the 50/50 rule used in Phase 1 - Step 3 for parcel point attribution.

III. LSA Variable Identification, Weighting, and Procedures

A. Identifying Variables and Thresholds for the LSA

The selection of variables to include in the LSA began with a broad review and consideration of 36 variables of various types (i.e., proximity to community services, transportation, environment and topography, planning, and flood risk) (Appendix Table A1). Many variables were not applicable in all communities (i.e., proximity to hazardous waste sites, sea level rise vulnerability) or may not be major determinants of a site's development potential (i.e., bus stop proximity, park proximity, etc.). To accommodate these differences, members of the HMDRRI team prioritized the top 8 to 10 variables based on past LSA experience, available knowledge about flood risk issues, and past relocation efforts. Comparison of each member's interpretation led to strong consensus on the most important factors to focus on to conduct a preliminary LSA. Described in further detail below and in Table 2, some of the key variables included the designated 100- and 500-year flood zones, proximity to existing water and sewer infrastructure, land/building vacancy, parcel size, and zoning.

Many variables such as the municipal boundary or 100- and 500-year flood zones have thresholds of a Boolean nature (binary in/out or yes/no) and therefore, had simple criteria for point attribution. Other factors such as parcel size and zoning contained a range of values, both quantitative and qualitative, and needed criteria and thresholds established. These were determined after further exploration of the variability of each factor and discussion with HMDRRI team members about what planning and development concepts were most applicable. Descriptions and justifications of each variable, its associated thresholds, and data sources are explained below and summarized in Table 2.

Table 2. LSA Variables and Criteria Thresholds.

Category	Variable	Criteria Thresholds	Points	Max
Jurisdictional Boundaries	Municipal Limits	Out	0	1
		In	1	
	Extraterritorial Jurisdiction (ETJ)	Out	0	1
		In	1	
Proximity to Infrastructure	Water Line (0.25 mi. buffer)	Out	0	1
		In	1	
	Sewer Line (0.25 mi. buffer)	Out	0	1
		In	1	
Parcel Size*	Infill Potential	< 3,000 ft^2	0	2
		3,000 ft^2 - 20,000 ft^2	1	
		20,000 ft^2 - 100,000 ft^2	2	
	Multi-Structure Potential	100,000 ft^2 - 500,000 ft^2	1	3
		500,000 ft^2 - 1,000,000 ft^2	2	
		> 1,000,000 ft^2	3	
Building/Land Vacancy	Vacant/Abandoned Building	Occupied - FP	0	3
		Vacant - FP	2	
		Vacant - NO FP	3	
Vulnerability to Flooding	Floodway	In	0	2
		Out	2	
	100-yr Floodplain (Zone AE)	In	0	4
		Out	4	
	500-yr Floodplain	In	0	1
		Out	1	
	Hurricane Matthew Flood Extent	In	0	2
		Out	2	
Areas of Future Development	Zoning	Comm., Manuf., Cond Use Comm/Manuf.	0	2
		Agr. Mixed Use Res, Cond. Use Mixed Use Res.	1	
		Res.	2	
*Each parcel, based on its size will fall into one of two categories: infill potential OR multi-structure potential with possible totals of 23 and 24 respectively. Totals could be less than 23 if not all same variables are included total composite score.			Total:	24

Vulnerability to Flooding/Flood Risk

Data Sources: NCEM, 2017

(Floodway, 100-Year Flood Zone; 500-Year Flood Zone; and Hurricane Matthew Flood Extent)

Perhaps the most crucial set of factors for the Relocation Strategy and LSA are related to flood risk and vulnerability. The 100-year floodplain (Zone AE) or base flood elevation delineates the area that is expected to be inundated by a 0.1% annual chance flood. The 500-year floodplain represents the area of inundation experienced by a flood with 0.2% annual chance of occurring. Hurricane Matthew's flood extent is also relevant as the flood of record for many rivers in the area and generally followed boundaries between the 100- and 500-year floodplains. The event's flood extent represents areas that officials and residents have actually seen flood versus designated floodplains which are calculated using hydrology models and statistics, methods that include a degree of uncertainty or inaccuracy.

Together, these flood risk variables account for both estimated flood risk that is tied to various regulations and programs as well as the community's actual experience. These factors present a range of three possible flood elevations, which, while somewhat duplicative, provides a more comprehensive view of a property's vulnerability to future flooding and meets a main goal of the Relocation Strategy to develop in safer areas.

Jurisdictional Boundaries

Data Sources: Various county GIS programs and NC OneMap, 2017

(Municipal Limits; Extraterritorial Jurisdiction (ETJ)

Municipal governments in North Carolina have control and influence both within their corporate boundaries and in additional adjacent area designated as its Extraterritorial Jurisdiction, or ETJ (see Owens, 2013). For a number of reasons, it is important for the Land Suitability Analysis to extend its view to include the ETJ. To promote orderly development and the efficient investments in infrastructure and the provision of services, the most common practice is to annex land prior to development. Where that does not happen, the ETJ helps avoid problems, by applying municipal development standards, zoning, and proper layout of subdivisions for residential, commercial and industrial development. Following a disaster in which buyouts occur on flood-prone land, for example, there may be insufficient land within the community to find relocation sites not hampered by hazard vulnerability, requiring an assessment of lands outside the community but within the ETJ. The Land Suitability Analysis concept is well suited to this extended purpose. For the reasons cited above, annexation prior to development is the best practice but planning prior to annexation is fully appropriate, and this fits well with the planning support offered by application of LSA methods. For the post-Matthew recovery plans, the emphasis is on residential relocations, however in the future it may be useful for commercial and industrial business developments, too.

Proximity to Existing Infrastructure

Data Sources: NC OneMap, 1997

(Water Distribution System; Sewer System)

New housing development is much more cost-effective when it is located near existing water and sewer infrastructure. These factors are key to identifying suitable areas for infill development. One limitation of these data is that it is outdated (1997), but is the most comprehensive data set applicable to communities across the state. The use of a 0.25-mile buffer helps to address some of this uncertainty. New or revised LSAs could also include additional infrastructure related variables such as distance away from major highways/interstates which may not be suitable from an environmental health standpoint as well as distance to arterial roads as a way to measure access to essential community resources.

Parcel Size

Data Sources: Various county GIS programs and NC OneMap, 2017
(Infill Potential; < 3,000 sq. ft.; between 3,000 and 20,000 sq. ft.; and between 20,000 and 100,000 sq. ft.)

Some lot sizes are suitable only for development of single-family homes or lower densities. The thresholds were selected based on size of existing single-family home building footprints and lots sizes within the community in which the LSA was conducted. For example, in Fair Bluff and Lumberton, the smallest existing lots in the town that have single family homes on them are at least 3,000 sq. ft. and the median parcel size found within either ETJ is about 21,000 sq. ft. Therefore, any parcel less than 3,000 sq. ft. would not be considered suitable while the other two categories already do or could support a small- to medium-size single family home and larger homes for which existing lots did not exceed 100,000 sq. ft. Square feet was used instead of acres because some lot sizes were so small that multiple decimal places would have been required to display variability.

(*Multi-Structure Potential: between 100,000 and 500,000 sq. ft.; between 500,000 and 1,000,000 sq. ft.; and >1,000,000 sq. ft.)*

Larger lots may be suitable for development of multiple structures or moderate density replacement housing, to include apartment buildings. This form of development could be more attractive to developers or investment partners that can house a greater number of relocated families. Thresholds were selected based on the size of larger parcels within the community that had multiple housing structures on them. Further insights on ideal lot sizes for various types of housing development in each community may influence these factors and their thresholds.

Building/Land Vacancy

Data Sources: NC OneMap and NCEM, 2017
(Structure on Parcel: 'Yes' or 'No'; Building Footprint Present: FP or NO FP)

Two sources of data were used to create a proxy to determine which lots were vacant because they would be the easiest ones on which to develop relocation housing, whereas if there is a building footprint (FP), it may or may not have to be demolished. NC OneMap standardized parcel data includes a field describing the parcel either as having a structure 'Y' or not having one 'N'. A proxy was created because it was observed that some properties listed as "N", not having a structure appeared to have building footprints on them when overlaid in GIS. The latest building footprint data was obtained through North Carolina Emergency Management so that three categories could be created with the goal of identifying properties listed as having no structure that also do not have a building footprint on them. The following categories listed from lowest to highest relative suitability include: YesStruct - FP; NoStruc - FP; and NoStruc - NO FP.

Areas of Future Development

Source: Municipal or County Government (Lumberton, Fair Bluff, Windsor, Seven Springs, Kinston, Princeville)
(*Zoning: Commercial, Manufacturing, Residential, CUP Residential, CUP Manufacturing*)

Existing zoning reflects the community's intent for use of that property, usually based on a number of factors. It may be more difficult to develop replacement housing on properties that have been zoned for non-residential uses, such as manufacturing, whereas a property already zoned for residential purposes will not require a rezoning, or other procedural action. Fair Bluff's zoning ordinance is fairly simple and contains just seven categories (Table 3) whereas other communities had dozens of possible zoning categories that were consolidated into like groups for simplicity. Examples of zones that were of greatest interest for the RS and LSA include Neighborhood Residential, Medium Density Residential and Moderate Density Residential, all of which would require little to no extra administrative burden and comply with broader land use goals. Developing housing in zones such as light manufacturing – wholesale (LM-W) or highway service – business (HS-B) would probably constitute a major departure from the community's comprehensive plan and zoning map.

Table 3. Fair Bluff Zoning Codes.

Zoning Code	Description
CB-O:	Central Business - Office
MED:	Medium Density Residential
HS-B:	Highway Service – Business
MOD:	Moderate Density Residential
LM-W:	Light Manufacturing – Wholesale

Altogether, the twelve variables described above represent the factors that determine a parcel's composite suitability for housing development or redevelopment. The factors and thresholds determine the results of the LSA, thereby informing decisions that are intended to meet resilience goals of the HMDRRI RS of reducing flood risk, retaining flood survivors within their communities, and minimizing construction costs.

B. Weighting

Perhaps as important as the selection of variables for the LSA is the determination of the relative weights attributed to different factors and for various thresholds. For almost every variable, there are zero points given for the most undesirable or unsuitable case and more suitable cases incrementally receive one additional point. This falls in line with typical WLC or simple 'additive weighting techniques' used in other LSAs. The exceptions to this incremental case are with two of the variables related to the vulnerability of flooding. One of the primary goals of the RS is to reduce flood risk for the buyout participants as they relocate. For estimating flood risk, the most direct measure is the 100-year flood zone (1.0% annual chance of occurring), hence the highest weight (Outside = 4; Inside = 0). Hurricane Matthew's Flood Extent is also a prominent variable since it ties to the direct experience and lasting memory of the community and is in some cases the flood of record, warranting a higher weight beyond a single point (Outside = 2; Inside = 0). Since the 500-year flood zone in Fair bluff includes and goes beyond both the 100-year flood zone and Hurricane Matthew Flood Extent, it represents the area least likely to flood. For development to occur outside this area would be operating at the highest standard for reducing flood risk and receives just one additional point.

For variables such as municipal limits, extraterritorial jurisdiction, and water/sewer line buffers, large continuous swaths of parcels are affected, meaning changes in weight would not necessarily distinguish parcels within those areas as more or less suitable. These "'base" variables can be thought of as the bottom layer in the WLC or simple additive weighting process so they were assigned 0 or 1 point. Another variable with a higher weight and potential maximum score included building/land vacancy. Vacant land with no structures is much easier to develop new housing than property that meets all the other criteria, but has already been developed and is occupied.

Although the weights associated with each of the criteria are somewhat subjective, the idea is to be consistent across the variables so that no one variable is inappropriately weighted or scored. The relative weights and thresholds are something that should change slightly depending on the community, its values or preferences, as well as any special circumstances.

C. GIS and MS Excel Suitability Scoring Procedures

The LSA was done using ArcGIS 10.5 (ArcMap and ArcCatalog) and Microsoft Excel 2013 and involved a series of steps using several geoprocessing tools. Some of the data used for the LSA required some minor processing (i.e., creation of 0.25-mile buffer around existing water and sewer lines) in GIS, but after all relevant data layers were vectorized, the next step was to apply the 50/50 rule described earlier. This was done primarily using the Tabulate Intersection tool found under the Statistics section of the Analysis Tools in the ArcToolbox. Tabulate Intersection calculates the overlapping area and its percentage of total area between two vector-based data layers (i.e., parcel and 100-year flood zone) (see Appendix Section A). For all variables that were not already part of the parcel data set (i.e., zoning, parcel size, etc.), Tabulate Intersect was used to calculate the overlapping area percentage, which fell either below or above 50%.

With each calculation, there was a new table created containing: 1) a common identifier (i.e., FID); 2) the calculated area in specified units; and 3) the percentage of overlap for the parcel and data layer of interest. The table is in the "comma separated values" form (csv). After conducting each Tabulate Intersection, the results of the output table can be compiled into one Excel spreadsheet which can then be joined with the original parcel data file using the common identifier. After joining, each parcel record contained the necessary data to begin calculating scores using the thresholds and weights. After exporting the joined table from ArcMap back into MS Excel, this is a straightforward procedure that uses a combination of IF and nested IF-AND functions. The result is the joined table with eleven new data fields appended to the end, containing the relative scores for each variable. Creating one final field for summing the scores tabulates the composite suitability score for each parcel record. Rejoining this fully scored spreadsheet to the parcel GIS file using the common identifier, the user can then symbolize the total suitability score into six equal interval classes with a range of colors (e.g., oranges and reds communicating inappropriate or unsuitable areas and greens and blues denoting higher suitability for development).

Map colors or patterns be altered or changed based on preferences of stakeholders involved. Step by step procedures can be found in the Appendix Section A. Communities participating in the HMDRRI recovery planning process are provided with GIS files, data spreadsheets and other materials needed to make their own future adjustments and updates.

Example of Community Feedback: Fair Bluff

The LSA's goals, initial methods, variables and thresholds selected, relative weights, and results were shared and discussed with the Town of Fair Bluff at a Town Council meeting. One Council member proposed incorporating flood depth, however a HMDRRI team member explained this factor is already accounted for by using various flood risk variables since each of their areal extents represents a different magnitude of flooding event. The comment was valuable, though, because it brings up the idea for future LSAs to include another flood risk threshold such as "experienced less than 2 feet of flooding" which could relate to the suitability or feasibility for encouraging elevation of the structure as an alternative to acquisition and demolition.

Example of Community Feedback: Lumberton

The LSA's goals, initial methods, variables and thresholds selected, relative weights, and results were shared and discussed with the Lumberton Technical Advisory Committee (TAC). The TAC was receptive to the LSA concept and acknowledged the value of LSA. The City was generally receptive and acknowledged the value of LSA, eager to know more about its relationship to the rest of the long-term recovery plan that was being developed by HMDRRI.

IV. Limitations of the LSA Method

Any GIS-based LSA will necessarily incorporate a set of assumptions in order to make the analysis manageable. Yet, any addition of assumptions can introduce uncertainty about the validity of the methods being used. These factors can limit the effectiveness of the LSA, whether due to inaccurate data, shortcomings of a chosen method, or lack of stakeholder engagement. For example, the water and sewer line data from the statewide data set (NC OneMap) follows a uniform and convenient format, however, some of the information may not reflect current conditions. Most water and sewer distribution data is privacy protected for security reasons and is more difficult to obtain since the 9/11 terrorist attacks in 2001.

Another limitation is that this LSA could not include more advanced measures of flood risk such as future floodplain conditions, which would consider future development upstream of each participating community as well as the projected increase in frequency and intensity of heavy rainfall events caused by climate change. While this has been completed for cities such as Charlotte, Lumberton and other municipalities do not have the capacity to undertake this level of flood risk planning and, to date, no other organization has conducted such an analysis for the area. This may not be as applicable within many communities that are not expected to grow significantly in population or see an increase in impervious surface area, but since floodplains are a product of what occurs in an entire watershed, this is a potentially powerful variable for investing in and siting long term housing developments. The LSA also did not include a filter for specific land use variables that are not suitable for development such as cemeteries or land in close proximity to airports.

Another consideration is that the higher weight (3 points) assigned to the largest parcels (>1,000,000 ft^2) may be misleading for cities/towns with prime or productive farmland within the ETJ which some would argue is much less likely to be developed. Upon further investigation using aerial imagery, the largest parcels do indeed appear to be working farms. The weight for the largest parcels could be lowered or a simple crosshatched overlay could be used to show alternate perspective by highlighting known working farms on top of total suitability score.

There is also potential value of LSA in assessing development potential ETJ, especially in areas with large vacant land parcels. In such cases, this tool can call attention to opportunities to mitigate flood risk before the municipality receives development proposals. For some locations, there may be an incentive to utilize mitigation techniques to upgrade a site's LSA rating. One consequence of the LSA map may influence, in a positive way, developers' site proposals so consideration can be given to flood hazard areas and remedies before initial plans are drawn.

Finally, the use of the linear combination method does not account for interdependent variables (Hopkins, 1977), but these facts are acknowledged with HMDRRI's LSA and no significant interdependencies were determined to significantly alter results.

PART THREE
LSA Results

I. Interpretation and Findings of the LSA

The result of the LSA comes in two major forms: a table and GIS map. The map shows the spatial pattern of suitability for parcels found within a given community's ETJ and the table provides the detailed characteristics of each parcel analyzed. After the preliminary LSA is complete, both of the outputs can be further refined with additional analysis and data manipulation or filtering.

A. Table Output

Table 3 below represents a sample output from the Fair Bluff LSA that includes characteristics of some of the most suitable properties. The larger parcel shapefile for LSA contains the attributes for each of the variables, the underlying percentages of overlap as well as the individual factor scores and composite suitability score for every parcel analyzed. The most relevant information (parcel owner, address, size, etc.) can be extracted from the larger file and printed in order to compliment the LSA map. In ArcGIS, the same filtering can occur and then be used to select or highlight the specific parcels on the community map for easier interpretation. These selected parcels can then be converted into their own table for consolidation and printing of results. One step beyond this would include consideration of additional factors not included in original LSA such as property ownership, land value/acquisition cost, proximity to airports, schools, grocery stores and other commercial activity centers or employers. Having both the general and more specific LSA maps accompanied by a table with detailed parcel characteristics is crucial to informing a larger discussion about potential buyout participant relocation or housing recovery areas within a community.

Table 4 is one example of this type of output and lists the 16 highest scoring parcels which all lie outside the 100-year flood zone, overlap less than 50% with the 500-year flood zone and Hurricane Matthew Flood Extent, zoned for either moderate or medium density residential, of adequate size for infill development (20,000 -100,000 ft^2), listed as vacant, and do not have a structure located on them.

*Table 4. Top 16 Highest Scoring Properties from LSA in Fair Bluff, NC.**

ID	Property #	Total Score	Total Value	Acres	Sq. Ft.	Zoning	Building/Land Vacancy	Matthew Extent % Overlap	500-Yr % Overlap
1	87753	18	$ 19,100	0.76	33,304.43	MED	VACANT - NO FP	1.91	19.33
2	18139	18	$ 10,300	0.72	31,379.41	MOD	VACANT - NO FP	0	38.93
3	17918	18	$ 6,700	0.55	23,974.00	MED	VACANT - NO FP	0.24	0
4	18138	18	$ 19,900	1.55	67,621.25	MOD	VACANT - NO FP	0	0
5	17357	18	$ 9,200	0.54	23,400.33	MOD	VACANT - NO FP	0	0
6	17886	18	$ 11,400	0.76	32,898.26	MED	VACANT - NO FP	0	0
7	18271	18	$ 8,200	0.50	21,973.06	MED	VACANT - NO FP	0	0
8	63107	18	$ 17,300	0.58	25,261.77	MED	VACANT - NO FP	0	0
9	82556	18	$ 6,400	1.59	69,298.00	MOD	VACANT - NO FP	0	0
10	82895	18	$ 3,900	0.50	21,799.79	MOD	VACANT - NO FP	0	0
11	85628	18	$ 5,400	0.91	39,640.43	MOD	VACANT - NO FP	0	0
12	92300	18	$ 3,000	0.50	21,799.86	MOD	VACANT - NO FP	0	0
13	93877	18	$ 3,000	0.50	21,799.79	MOD	VACANT - NO FP	0	0
14	95258	18	$ 2,500	0.50	21,799.99	MOD	VACANT - NO FP	0	0
15	96017	18	$ 3,000	0.50	21,799.79	MOD	VACANT - NO FP	0	0
16	96072	18	$ 3,000	0.50	21,801.06	MOD	VACANT - NO FP	0	0

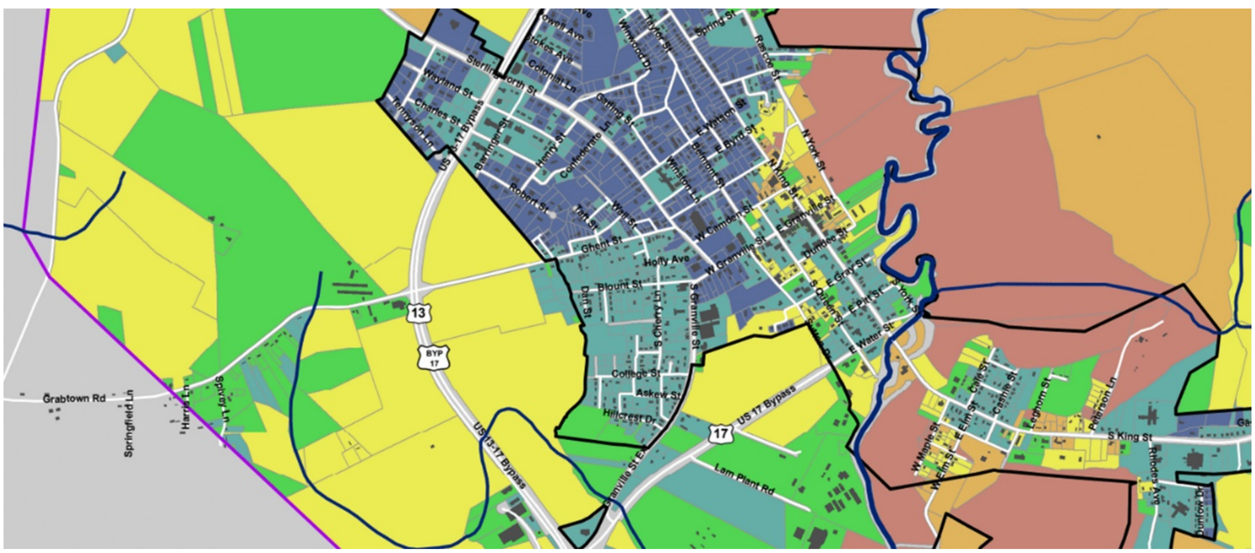
**An additional 86 properties had a total score of 17 (highest suitability) in Fair Bluff.*

B. Map Output

The results of the LSA reveal significant spatial variation in the total suitability score within each Town's ETJ. This variation is easier to see across a municipality when it's of smaller size (i.e., Seven Springs, Fair Bluff, Windsor, and Princeville) made up of only a few thousand parcels whereas larger communities LSA maps (i.e., Lumberton and Kinston) comprised of tens of thousands of parcels require a zoomed in perspective (Figure 8). In some cases, communities such as Fair Bluff and Kinston have areas in close proximity to one another, but with major differences in suitability, most likely a result of the irregular shape of the floodplain boundary and its relative weight within the scoring. Within areas of high or highest suitability, the difference is often whether or not it's vacant and has a favorable zoning designation.

There are often many smaller scattered individual lots on higher ground and if vacant, could serve as opportunities for lot-by-lot infill development. On the other hand, most communities also possess several larger parcels within their ETJ, often located near municipal limits that are not zoned for residential development, but could support denser multi-structure housing or a cluster of single-family homes that are in areas much less vulnerable to flooding. However, further investigation of the larger parcels may reveal that they are working farms which are not likely to be seen as suitable for development. For communities with plans already in motion for new development, using the LSA results can support the desire to develop in a way that is more resilient to future flooding impacts.

Figure 6. Excerpt of LSA map for Windsor, NC.



Windsor is somewhat unique because it is a low-lying historic downtown located adjacent to a river that is subject to tidal influence from Albemarle Sound and the Atlantic Ocean. Other notable features of long-term development in Windsor is that large vacant developable parcels exist in and adjacent to the community that may be suitable (Figure 6). For the historic downtown, a HMDRRI flood retrofit study has identified measures that may be compatible with the buildings' historic integrity. For residences subject to shallow flooding, it may be suitable to raise the structures two feet above the base flood elevation as stipulated in their Local Flood Damage Prevention Ordinance.

In Fair Bluff, additional maps or portrayals of land suitability were created at a smaller scale, focused on specific areas within the Town to illustrate the parcels that may be considered partially developable based on their intersection or overlap with the 100-year floodplain, shown as cross-hatch pattern in Figures 7A and 7B. This is important because there are some larger parcels (i.e., south of Academy Street) that received lower scores because of the amount of overlap with the 100-year floodplain (>50%), but contain areas on the property that are at lower risk of flooding and therefore are potentially developable.

For Lumberton and its larger spatial footprint (20,000+ population), a slightly different approach was used to depict suitability (Figure 8). Without changing underlying data or analysis, it is easier to visualize areas to consider for housing relocation or development and areas to avoid. This example shows how an LSA can be tailored in order to best convey the data outputs to interested stakeholder groups.

Ultimately, this enhanced perspective allows the public and decision-makers to see one of the key underlying factors of the LSA, the 100-year flood zone, superimposed on top of the general LSA. This could be done with other variables as well (i.e., zoning, infrastructure buffer, or parcel vacancy) to show the nuance involved with the LSA that gets lost or smoothed over when integrated into a composite score. If desired, similar exercises could be done for other variables such as zoning, property owner name, property value, etc.

Figure 7A & 7B. Alternate Perspectives of the LSA: Total Suitability and 100-year Flood Zone.

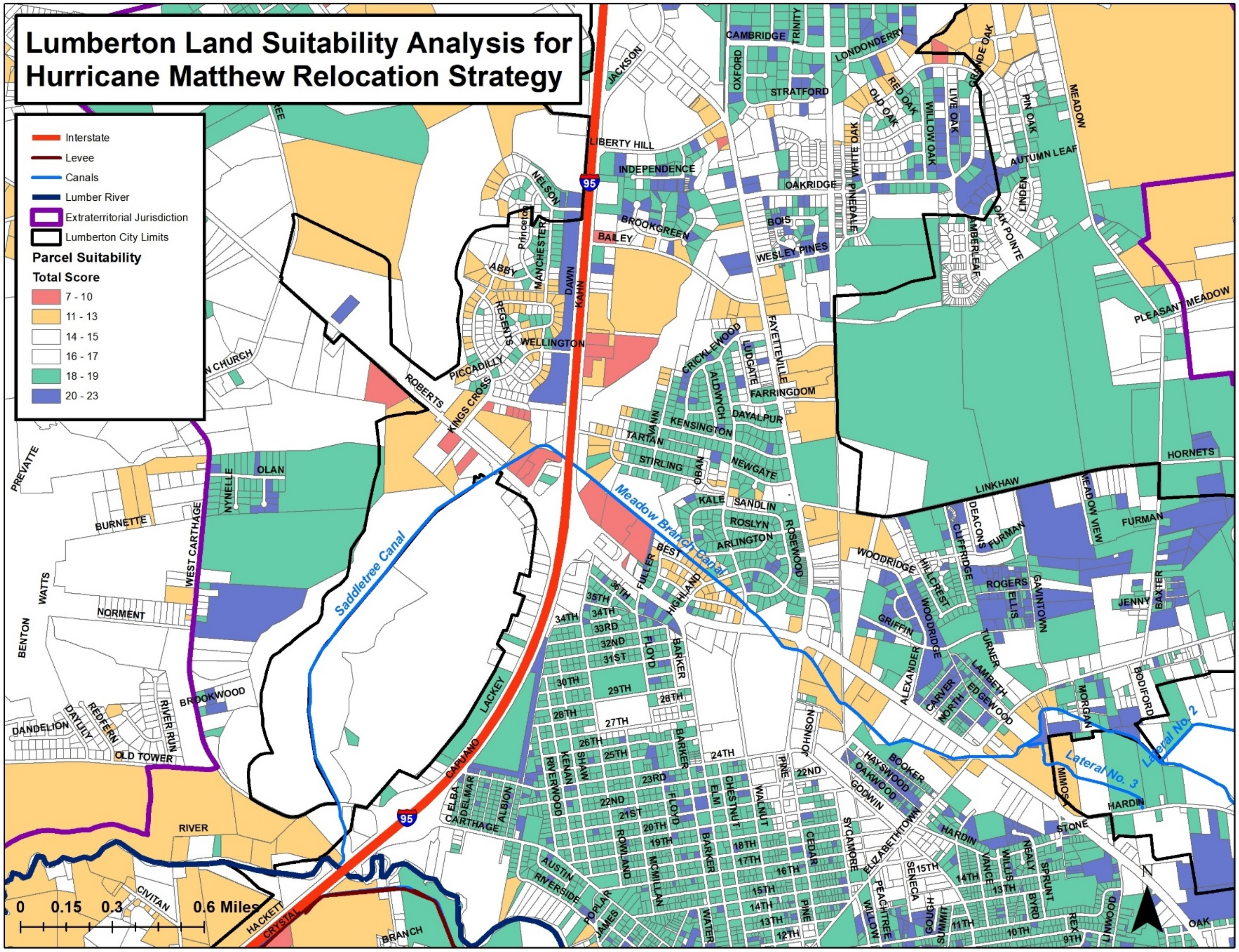


Figure 8. Highest and Lowest Suitability in North Lumberton.

PART FOUR

Conclusions and Next Steps

Investigate further the parcels with high or highest suitability. In each community, there are dozens if not hundreds of individual parcels within city limits that are considered to have the 'highest' composite suitability, may be vacant and/or acquirable and could support multiple types of housing. For some municipalities, dozens of small-medium size vacant lots exist in areas of reduced flood risk that could support infill development of single-family homes. A few larger parcels meet all the same criteria and could support a cluster of single-family homes or denser multi-family structures that could alleviate the lack of affordable housing in the area.

Data limitations can be accommodated. There are limitations found in any GIS-based LSA. For this project, an effort was made to minimize them as much as possible. At the same time, limitations must be acknowledged and accounted for when interpreting the results. The spatial and quantitative analyses attempt to replicate real and pragmatic factors that influence routine development and risk management practices. In other words, the model attempts to mimic reality. For LSAs, statistician George Box's phrase "All models are wrong, but some are useful" applies. This notion is one reason this technical memo is needed for interpretation of LSA results. Data availability and inaccuracy (i.e., water and sewer infrastructure) may influence the overall result, but it should not preclude communities from making informed decisions. Despite some of the limitations, residents and decision-makers in each of the communities can still apply the results and adapt the process as needed when engaging in future planning efforts.

Consider other relevant spatial data and perspectives. Utilizing information and other plans or policies with a spatial component (i.e. economic development, hazard mitigation, comprehensive, etc.) can insure complimentary design solutions that build resilience. Recovery leaders could gain insights from other disaster response and recovery programs such as FEMA Public Assistance projects, Individual Assistance (IA) data, and CDBG-DR, which may be directly or indirectly related to the housing relocation process. Furthermore, depending on the potential demand for and availability of developable land for housing construction, the LSA and larger RS could inform the allocation of federal and state funding to build replacement housing in locations identified in the LSA. These post-disaster data sources include useful information such as the demographics of flood survivors, expected investments in infrastructure repair, and the status of local affordable housing markets. Additionally, portraying single components such as the 100-year flood zone on top of the total suitability score illustrates a certain level of nuance that may reveal previously undiscovered opportunities (i.e., "partial developability'"). Similarly, variables such as property value and current owner can be displayed as labels with accompanying tables for easier interpretation. The top scoring parcels could also be extracted from the larger data set and super-imposed on a variety of other base maps along with other relevant variables (i.e., parks and green space, community assets, zoning overlays, etc.). Top-scoring suitability parcels could also have GIS network analysis performed to determine estimated walk, bike, drive, and bus distances/times from properties to various community assets or landmarks.

Pair the development of an LSA with design-oriented public engagement activities and work through a local recovery committee. In alignment with HMDRRI's Recovery Strategy objectives, the LSA can be informed by community design workshops or charrettes that explore geospatial relationships between various community assets and best practices in greenspace design and reuse of buyout properties. Use of an LSA during the planning process should be iterative including regular community feedback over several meetings or workshops where the focus is on general recovery issues. An open dialogue should be fostered between residents and other stakeholders involved in the buyout program and LSA ideas should be solicited via workshops, telephone hotlines, office hours, website updates, social media engagement, print materials, and other methods as identified.

If an advisory group or recovery committee has been formed, its involvement in LSA matters can help build community awareness. Regular consultation with financial, real estate, design and engineering professionals can help maintain familiarity and lead to a more sustained effort, including an implementation process. If possible, engagement measures should be conducted prior to a disaster when issues of "speed versus deliberation" and "time compression" are not present. This engagement and discussion can also occur during other community planning initiatives whether it's creating or updating comprehensive land use plans, economic development plans or others.

Engage early in the process with local community organizations such as community development corporations (CDCs) and other housing stakeholder groups (local/state housing finance agencies, religious groups, non-profits, and private groups such as Purpose Built Communities or NeighborWorks to explore synergistic programs and funding mechanisms that support holistic housing recovery goals. Neighborhood associations, CDCs and other preexisting or emergent community groups can be the difference-maker in implementation since they are flexible, can identify and secure resources, provide case management as well as "assume debt, provide grants, loans… and develop property" (Smith 2011, pp 119). Groups such as Purpose Built Communities, NeighborWorks and Habitat for Humanity are in the business of financing the construction and repair of affordable housing as well as facilitating inter-generational wealth building through new homeowner assistance programs.

Work with stakeholders who may have an interest in developing or contributing to plans for adaptive reuse of soon-to-be acquired properties because of the buyout. Invite natural resource agencies, community land and conservation trusts, local/state/national park agencies, nearby schools, neighboring residents, watershed groups, community gardening organizations, and others interested in green space or vacant lots, to discuss opportunities for adding natural or recreational value to acquired sites.

I. Implications for Future Planning and Use of LSAs

Along with the devastation seen as a result of Hurricane Matthew, the record-breaking 2017 hurricane season in the U.S. is a stark reminder of the great challenges we as a civilization face in preparing for, responding to, and recovering from major natural hazard events. For many communities, the rain came down harder, the wind blew faster, and the water levels rose higher than had ever been seen before. Along with recovery from these events, current and future generations are simultaneously trying to understand how to plan and invest more effectively knowing that in an era of climate change, these risks are only expected to increase. Major events like hurricanes Matthew, Harvey, Irma, Maria, and now Florence have produced a set of extremely difficult circumstances for the thousands of people affected. They have also brought people together in amazing ways. The human spirit often shines during response and recovery as everyday heroes emerge and local officials call for the need to 'build back better'. However, the physical and emotional trauma that transpires in the aftermath of an event often reveal the disproportionate impact felt by communities of modest wealth and communities of color who were struggling prior to the event. Opportunities to invest in alleviating these disproportionate impacts are limited and at the federal government level, lean towards a reactive instead of proactive approach. Pre-event planning offers another opportunity to create positive change with and for those with the greatest levels of vulnerability.

Every year, more accurate data is collected, analyzed, and visualized through new tools that increase awareness and understanding of our country's natural hazard risks. Some tools are also getting better at linking together community goals and addressing multiple issues at once. HMDRRI's approach to the LSA is an example of how a tool can be flexible, yet powerful in its ability to inform a relocation strategy. Supported by the indigenous knowledge of a community, planning approaches like this can be used to guide a more resilient and equitable recovery following Hurricane Matthew, Florence and in advance of the next storm.

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Appendices

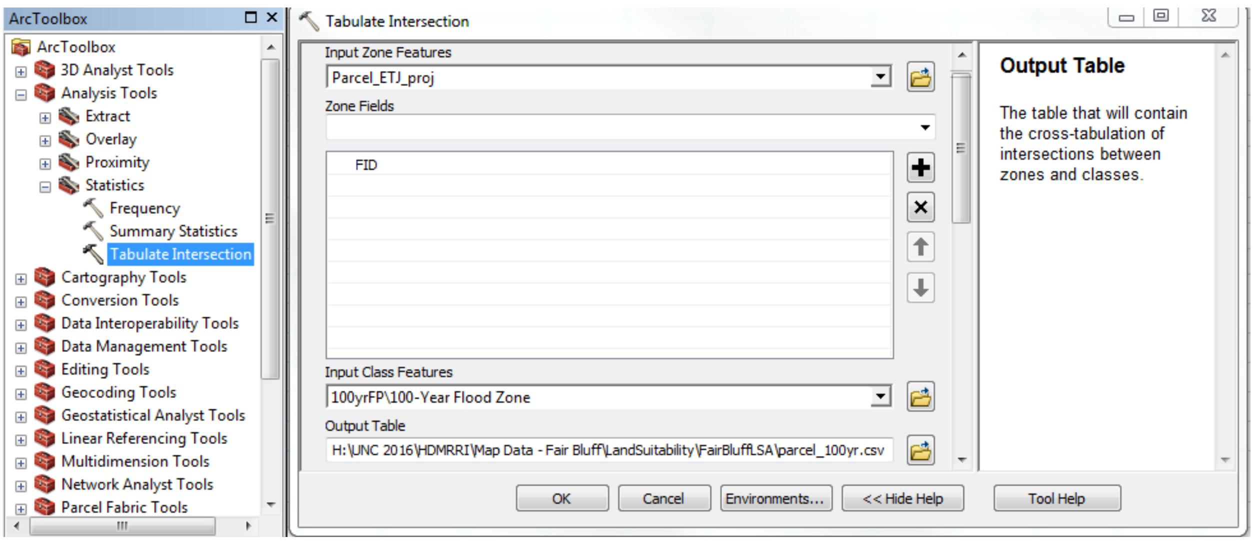
Table A1. Master list of LSA variables considered.

Category	Criteria	Source	Used in LSA
Accessibility of service and facilities	Existing jurisdiction proximity	Census	
	Proximity to commercial area	Local/Plans	
	School proximity (primary, secondary, post-secondary)	Census	
	Hospitals proximity	Census	
	Utility infrastructure connectivity (water, wastewater, electricity, communications)	County/State	
	Park/playground proximity	Local	
Transportation	Bus stop proximity	Local	
	Major highway proximity	Census	
Socioeconomic Factors	Population density	Census	
	Community preference	Survey	
	Renter / owner	Census	
	Neighborhood Type	Local	
	Ratio of less mobile people / disability / aged	Local	
	Land value	Census	
Environment and Safety	Protective infrastructure integrity	Local	
	Drainage	Survey/Local	
	Reliance on protective infrastructure	Local	
	Proximity to water bodies	State	
	Proximity to known / potential environmentally hazardous waste sites	NC DEQ	
Topography	Slope	USGS	
	DEM	USGS	
	Water table depth	USGS	
	Tidal factors	USGS	
	Soil composition	SSURGO	
	Vegetation composition	State	
	Vegetation density	State	
Planning	Areas of future development (zoning or Future Land Use)	Local	
	Parcel Size	Local	
	Land/Building Vacancy	Local/State	
	Large infrastructure project	Plans	
	Economic development areas	Plans	
Flood Risk	Historical value / significance	Survey	
	FEMA Flood Zones (100- and 500-Year)	NCEM	
	Sea level rise (LiDAR)	NOAA	
	Hurricane Floyd flood extent	NCEM	
	Hurricane Matthew flood extent	NCEM	

Appendix Section A. Step by Step GIS and Microsoft Excel Procedures

1. Collect and vectorize all data
    a. Create base parcel data set that contains all parcels for LSA
    b. Ensure base parcel data set includes parcel related variables (i.e., Zoning, Size (acres or ft^2), Parcel Use, Existence of Structure, etc.)

2. Calculating overlapping area using "Tabulate Intersection" tool and include the following as inputs:
    a. Input Zone: Parcels
    b. Zone Fields: common identifier (i.e., FID or PIN)
    c. Input Class: *variable of interest* (i.e., 100-yr flood zone)
    d. Output: *100yr.csv*



3. Conduct Tabulate Intersection for all variables needing it. Then join the csv. back to parcel shapefile attribute table and after each iteration of "Tabulate Intersection" it is necessary to add 2-3 more fields with the appropriate statistics
4. With each calculation, there was a new comma separated values (csv) table created containing 1) a common identifier (i.e., FID), 2) the calculated area in specified units, and 3) the percentage of overlap for the parcel and data layer of interest.
5. After conducting each Tabulate Intersection, compile results of each table into one excel spreadsheet
6. Rejoined table to the original parcel data file using the common identifier.
    a. After joining, each parcel record will contain data the necessary data to begin calculating scores using the thresholds and weights.
7. Export the joined table from ArcMap back into MS Excel,
8. Find and replace "<null>" values with "0" assuming that changing value to 0 won't affect suitability score unintentionally.

9. This is a simple procedure done using a combination of IF and nested IF-AND functions.
   a. Example formula for Proximity to Water Infrastructure: =IF(AND(AH2>0, AH2<50), 0, IF(AND(AH2>50, AH2<101), 1, 0))
   b. Example formula for multiple thresholds variable such as parcel size: =IF(AND(W2>0,W2<3000),0,IF(AND(W2>3000,W2<20000),1,IF(AND(W2>20000,W2<100000),2,0)))
   c. Example formula for text related field such as zoning: IF(AS2="Central Business District",0,IF(AS2="Light Manufacturing - Warehouse",0,IF(AS2="Highway Service-B",1,IF(AS2="Low Density Agriculture",1,IF(AS2="Medium Density Residential",2,IF(AS2="Modular Residential",2,0))))))
10. The result is the joined table with eleven new data fields appended to the end containing the relative scores for each variable.
11. Create one final field for summing the scores creates the total or composite suitability score for each parcel record.
12. Rejoining this now fully scored spreadsheet to the parcel GIS file using the common identifier,
13. Symbolize the total suitability score into six equal interval classes with range of colors (i.e. oranges and reds communicating inappropriate or unsuitable areas and greens and blues denoting higher suitability for development).