

2012

# A discourse on geospatial technology applications in predictive analytics and evidence-based decision support for disaster research and management

Steven Matthew Ward

*Louisiana State University and Agricultural and Mechanical College*, [steven.matthew.ward@gmail.com](mailto:steven.matthew.ward@gmail.com)

Follow this and additional works at: [https://digitalcommons.lsu.edu/gradschool\\_dissertations](https://digitalcommons.lsu.edu/gradschool_dissertations)



Part of the [Social and Behavioral Sciences Commons](#)

---

## Recommended Citation

Ward, Steven Matthew, "A discourse on geospatial technology applications in predictive analytics and evidence-based decision support for disaster research and management" (2012). *LSU Doctoral Dissertations*. 869.

[https://digitalcommons.lsu.edu/gradschool\\_dissertations/869](https://digitalcommons.lsu.edu/gradschool_dissertations/869)

This Dissertation is brought to you for free and open access by the Graduate School at LSU Digital Commons. It has been accepted for inclusion in LSU Doctoral Dissertations by an authorized graduate school editor of LSU Digital Commons. For more information, please contact [gradetd@lsu.edu](mailto:gradetd@lsu.edu).

A DISCOURSE ON GEOSPATIAL TECHNOLOGY APPLICATIONS IN PREDICTIVE  
ANALYTICS AND EVIDENCE-BASED DECISION SUPPORT FOR DISASTER  
RESEARCH AND MANAGEMENT

A Dissertation

Submitted to the Graduate Faculty of the  
Louisiana State University and  
Agricultural and Mechanical College  
in partial fulfillment of the  
requirements for the degree of  
Doctor of Philosophy

in

The Department of Geography and Anthropology

by

Steven Matthew Ward

B.S. Louisiana State University, 1999

M.S. Louisiana State University, 2001

December 2012

## ACKNOWLEDGMENTS

*You can get help from teachers, but you are going to have to learn a lot by yourself, sitting alone in a room.*

-- Dr. Seuss, 1986

To suggest that the pages of this dissertation are merely a documentation and summary of my research would be woefully inadequate. What is not captured within the lines of this document may very likely be the most valuable outcome of this entire process. When I began my academic career I imagined myself in an office on campus immersed in scholarship and deliberation, reaping the intellectual recompenses of being surrounded by brilliant people. In reality, working on my Ph.D. has been equal parts humbling journey and intellectual growth, all fueled by the extraordinary people who have steered me along the way. Without these people guiding and supporting me, this work would have never been realized. It is these personal connections which bind this document together and serve as the greatest gift I have received throughout this process. To each and every person who impacted this work along the way, I owe my deepest and sincerest gratitude. This was a journey which took place in the evenings and on the weekends, stealing precious time from my family, friends, and responsibilities. I will never be able to quantify the sacrifices made on my behalf by those close to me, but I can acknowledge these unselfish acts with a wholehearted thank you.

My most sincere thanks are extended to my wife Winona, whose personal support and seemingly limitless patience has been unequivocal throughout this process. I promise that never again will you have to utter the words: *Are you working on school stuff this weekend?* This accomplishment is as much yours as it is mine, I love you. To my daughters Piper and Corinne, both born during this time, I apologize about the days I have missed being with you and hope in time that you realize your contribution to my efforts. While I can honestly state that I underestimated the difficulty of raising the two of you, I have been forever changed by the reward you bring to me. You are both too young to comprehend now, but in time will realize that you kept me grounded and laughing throughout this entire process.

To my major professor Michael Leitner, I would like to say: *“Ich danke Ihnen sehr”*. You have been a gracious guide and patient advisor who gave me just enough freedom to make mistakes and learn from them, while offering me steadfast support and instruction...truly an embodiment of the word “mentor”. Never once did you discourage me or become intolerant of my work and family schedules, always greeting me with a smile and a laugh. I will forever be grateful to you for this unsurpassed kindness and unbiased support.

I would also like to extend my sincere gratitude to my parents Robert and Linda Ward as well as my in-laws Terry and Lorraine Landry. Your love and encouragement throughout this journey extends far beyond these written words and I am proud that you get to share this accomplishment with me. I wish had a nickel for every time you selflessly dropped everything and watched the children so I could be free to work or Winona could have a break. None of this would have been possible without you.

To Scott Knaus and my colleagues at GEC, Inc., I am grateful for the support and flexibility during this process. It is rare to find a supervisor and workplace who offer so much freedom and encouragement to an employee pursuing an advanced degree. In you I found a place where I could both learn and apply knowledge simultaneously. Special thanks go out to Jacques Bagur, Mark Forsyth, Jonathan Puhls, and George Hudson for expert advice, editing and assistance with interpretation of data.

I am also extremely thankful to the rest of my graduate committee (Melanie Gall, Fahui Wang, & Bob Rohli) for offering appreciated review of my dissertation and insight into my research. Dr. Gall has been one of the most critical pieces to this process; balancing frank criticism with unwavering encouragement in a way which always seemed to reinvigorate me when I was in a slump. You taught me to avoid “hoping” and “believing” in my work, and to trust in my writing and my questions. Additional thanks must be extended to Dr. Gernot Paulus from Carinthia University of Applied Sciences. Without you I would have never extended the boundaries of my research. Your support of my time in Austria was irreplaceable and I truly had the experience of a lifetime.

To Dr. Chris Emrich of the Hazards and Vulnerability Research Institute, I am forever grateful. We first discussed my research in detail over a glass of Woodford Reserve in Emmitsburg, MD nearly four years ago. Since then we have shared a few more glasses of bourbon but more importantly become friends. I cannot thank you enough for being an objective ear, always there to offer opinion and guidance. You have been a valued and respected guide who I can never thank in words alone...I guess I owe you a bottle of bourbon.

To everyone else that I haven't mentioned; each and every one of you has helped my development as a scholar, a father, a husband and a colleague along this sometimes lonely, often frustrating, and infinitely rewarding journey. It is our relationships that truly inspired this document and deserve the most recognition. Thank you all...and to your incessant question the answer is; *Yes, I finally finished this thing.*

## TABLE OF CONTENTS

ACKNOWLEDGMENTS .....	ii
LIST OF TABLES .....	vi
LIST OF FIGURES .....	vii
LIST OF ABBREVIATIONS.....	viii
ABSTRACT.....	ix
CHAPTER 1: INTRODUCTION.....	1
1.0 Introduction .....	1
1.1 Current Knowledge .....	2
1.2 Components of Disaster .....	4
1.3 Recovery Indicators.....	6
1.4 Research Questions .....	7
1.5 Methodological Approach.....	8
1.5.1 Developing the Metric .....	8
1.5.2 Evaluating the Metric .....	10
1.5.3 Alternative Geography .....	11
1.5.4 Research Based Methods.....	11
1.7 Research Significance .....	12
CHAPTER 2: INVESTIGATING RECOVERY PATTERNS IN POST DISASTER URBAN SETTINGS: UTILIZING GEOTECHNOLOGY TO UNDERSTAND POST- HURRICANE KATRINA RECOVERY IN NEW ORLEANS, LOUISIANA .....	13
2.0 Introduction .....	13
2.1 Study Area.....	14
2.2 Defining the Problem .....	15
2.3 Parameters .....	17
2.4 Methodology .....	17
2.5 Results .....	20
2.5.1 Recovery.....	23
2.5.2 Scale .....	24
2.5.3 Sensitivity.....	26
2.6 Conclusion and Recommendations .....	26
CHAPTER 3: VALIDATING A SPATIAL RECOVERY INDEX:QUANTIFYING RECOVERY AT THE NEIGHBORHOOD LEVEL IN NEW ORLEANS, LOUISIANA .....	29
3.0 Introduction .....	29
3.1 Context .....	30
3.2 Spatial Recovery Index: Components .....	32
3.3 Spatial Recovery Index: Results .....	33
3.4 Evaluation.....	37
3.4.1 Evaluation: New Orleans Index.....	38
3.4.2 Evaluation: United States Postal Service Data.....	41

3.4.3 Evaluation: Social Vulnerability Index .....	42
3.5 Results and Discussion.....	45
<b>CHAPTER 4: AUGMENTING AUSTRIAN FLOOD MANAGEMENT PRACTICES THROUGH GEOSPATIAL PREDICTIVE ANALYTICS .....</b>	<b>47</b>
4.0 Introduction .....	47
4.1 Flood History and Study Region .....	48
4.2 Spatial Recovery Index: Methods and Results.....	50
4.3 Carinthia Case Study .....	51
4.3.1 SRI 2009 .....	51
4.3.2 SRI 2010.....	52
4.3.3 SRI 2011 .....	54
4.4 Risk Perception in Austria.....	57
4.4 Discussion .....	59
<b>CHAPTER 5: RESEARCH BASED DECISION SUPPORT IN HAZARD MITIGATION: LOUISIANA NORTHSORE FLOOD AND HURRICANE PROTECTION.....</b>	<b>61</b>
5.0 Introduction .....	61
5.1 Translating Research to Practice .....	63
5.2 Study Area and Geography .....	65
5.2.1 Population.....	66
5.3 Methodology .....	67
5.3.1 Flood Exposure Analysis.....	68
5.3.2 Flood Loss Estimation.....	69
5.3.3 Social Vulnerability Analysis.....	70
5.4 Flood Exposure Analysis Results.....	71
5.4.1 Repetitive Loss Analysis .....	73
5.5 Flood Loss Estimation Results .....	76
5.6 Social Vulnerability Analysis Results.....	79
5.7 Combined Analysis .....	82
5.8 Discussion .....	83
<b>CHAPTER 6: CONCLUSION .....</b>	<b>86</b>
6.0 Summary of Results .....	86
6.1 Significance .....	88
6.2 Path Forward .....	89
<b>REFERENCES .....</b>	<b>91</b>
<b>APPENDIX A: FLOOD VULNERABILITY DECISION SUPPORT MATRIX .....</b>	<b>107</b>
<b>APPENDIX B: PERMISSIONS .....</b>	<b>111</b>
<b>VITA.....</b>	<b>113</b>

## LIST OF TABLES

3.1. Spatial Recovery Index Variables.....	32
3.2a. Lowest Rated Neighborhoods Based on USPS, RI, VI, SoVI, and NOI Data.....	35
3.2b. Highest Rated Neighborhoods Based on USPS, RI, VI, SoVI, and NOI Data.....	35
4.1. Recovery and Vulnerability Elements Included in the 2012 Austrian SRI.....	54
5.1. Summary of Major Flood Events (Data from FEMA and NOAA).....	72
5.2. Total Flood Insurance Claims, January 1, 1978 – June 30, 2008.....	74
5.3. USGS Stream Gages.....	75
5.4. NOAA Precipitation Gages.....	75
5.5. SoVI <sup>NS</sup> 2000 and 2009 Components.....	80

## LIST OF FIGURES

2.1. Orleans Parish Study Area Detail .....	16
2.2. Orleans Parish Schools Open as of February 2008 – Represented as Point Data and Interpolated Raster .....	21
2.3. Results of Recovery Indicator (RI), Vulnerability Indicator (VI), and Spatial Recovery Index (SRI).....	22
2.4. Results of Hot Spot, Geographically Weighted Regression, and Zonal Analyses on SRI Results .....	25
3.1. Spatial Recovery Index .....	33
3.2. Spatial Recovery Index Composite Analysis Output.....	36
3.3. SoVI and SRI Bivariate Mapping Analysis .....	44
4.1. Study Area in Carinthia Austria.....	49
4.2. Three Components of 2009 SRI Analysis .....	51
4.3. 2010 Kosar SRI Compared to 2009 Ward SRI.....	53
4.4. Comparison of 2009, 2010, and 2011 SRI Results .....	55
4.5. Global Spatial Autocorrelation – Moran’s I Results.....	56
4.6. Local Spatial Autocorrelation – Hot Spot Analysis (Getis Ord $G_i^*$ ) .....	56
5.1. Northshore Study Area .....	66
5.2. Flood Vulnerability Analysis Process Path.....	68
5.3. Northshore Repetitive Loss and Severe Repetitive Loss Claims.....	73
5.4. Northshore High Flood Vulnerability Areas.....	77
5.5. HEC-FIA Impact Areas .....	78
5.6. HEC –FIA Derived Economic Loss Estimates .....	79
5.7. SoVI <sup>NS</sup> Change from 2000 to 2009.....	81
5.8. SoVI <sup>NS</sup> Related to SFHAs.....	82
6.1. Disaster Life Cycle .....	88



## LIST OF ABBREVIATIONS

ACS – American Community Survey  
ADCIRC - Advanced Circulation  
AKC - Akaike Information Criterion  
ANOVA - Analysis of Variance  
CMUA - Complex Multiple Utility Assignments  
CPRA – Coastal Protection and restoration Authority  
CUAS - Carinthia University of Applied Sciences  
DEM - Digital Elevation Model  
DFIRM – Digital Flood Insurance Rate Map  
ESDA - Exploratory Spatial Data Analysis  
ESRI - Environmental Systems Research Institute  
ESS - European Social Survey  
FEMA - Federal Emergency Management Agency  
FIRM – Flood Insurance Rate Map  
GBS - General Building Stock  
GIS - Geographic Information System  
GIT - Geographic Information Technology  
GNOCDC - Greater New Orleans Community Data Center  
GWR - Geographically Weighted Regression  
HAZUS - Hazards United States  
HEC-FDA - Hydrologic Engineering Center Flood Damage Assessment  
HEC-FIA - Hydrologic Engineering Center Flood Impact Analysis  
LiDAR - Light Detection and Ranging  
LUCIS - Land Use Conflict Identification Strategy  
MUA - Multiple Utility Assignments  
NFIP - National Flood Insurance Program  
NOAA – National Oceanic and Atmospheric Administration  
NOI – New Orleans Index  
NORPC - New Orleans Regional Planning Commission  
PCA - Principal Components Analysis  
RI - Recovery Indicators  
RL – Repetitive Loss  
SFHA - Special Flood Hazard Area  
SPAC - Spatial Autocorrelation  
SoVI - Social Vulnerability Index  
SoVI<sup>NS</sup> - Social Vulnerability Index Northshore  
SRI - Spatial Recovery Index  
SRL –Severe Repetitive Loss  
SUA - Single Utility Assignments  
UN - United Nations  
UNOP - Unified New Orleans Plan  
USACE - United States Army Corps of Engineers  
USGS - United States Geological Survey  
USPS - United States Postal Service  
VI - Vulnerability Indicators

## ABSTRACT

Continued population growth and development in vulnerable locations across the world are creating a new geography of hazards and disasters. Increasing storm frequencies coupled with unrelenting efforts to control flooding through structural means will undoubtedly intensify the intersection between flood hazards and humans. Accordingly, the baseline capacity of places to prepare for and rebound from disaster events adequately is negatively impacted. Hurricane Katrina brought this reality to the forefront of disaster science and management in 2005. Concurrent with the increased awareness of evolving hazardscapes has been the identification of deficiencies in how components of disasters are studied and managed. The topic of recovery represents one of the least understood elements in hazards geography, owing most of its existing catalogue of knowledge to social sciences and public administration. This dissertation summarizes an effort to develop a spatial metric which quantifies recovery from flood events as well as the evaluation of applying these research based methods in practical environments. The study theorizes that recovery can be measured by assessing the proximity of critical elements within the built environment. These elements (buildings) represent hubs of social activity necessary for social networks to flourish in post disaster settings. It goes on to evaluate and apply this metric in both New Orleans, LA and Carinthia, Austria, in order to identify cultural bias in model design prior to conducting a case study where research based predictive analytics are used in a real world mitigation plan. The outcome of the study suggests that recovery is indeed measurable spatially and is heavily influenced by culture and scale. By integrating this new understanding of recovery into potential mitigation strategies, planning for risk reduction expenditures can more appropriately consider the drivers of place-specific vulnerability.

## CHAPTER 1: INTRODUCTION

*Globalization will make our societies more creative and prosperous, but also more vulnerable.*

-- Lord Robertson, NATO Secretary General, 2001

### 1.0 Introduction

A review of current disaster based literature in geography will illustrate a severe paucity of comprehensive research by geographers in the arena of disaster recovery. It appears as if the majority of established researchers in this field are content to focus their efforts on the issues preceding disasters, as well as the immediate physical results of disaster events. As a result, the responsibility of understanding the topic of recovery has thus far been the primary focus of researchers in the fields of social science and public administration. With the intent of improving the collective knowledge base centered upon recovery, the following essay series offers an overview of the challenges and benefits of incorporating predictive analytics in disaster based research and application. This study suggests that as the lines between hazards research and real world disaster management begin to blur, geospatial technology will be increasingly interwoven throughout the academic and practical sides of the discipline. This project has attempted to reduce the aforementioned void in hazards geography by exploring multiple aspects of recovery through the use of geospatial technology, predictive analytics, and qualitative analysis, to determine if the spatial dimensions of recovery can be measured, what factors drive these spatial dimensions, and how research based tools can be applied in the real world. The scope of the research takes the reader from developing and vetting a metric for recovery in New Orleans, to using the metric in Europe in order to identify socio-cultural influences on recovery, and finally returns to the Gulf Coast to leverage translational research in a real world setting to verify the importance of predictive analytics and exploratory tools.

Similar to the inspiration of Gilbert White brought about by the flooding of the Mississippi River in the early portions of the twentieth century(White, 1945), the twenty-first century has seen extreme weather events and terrorist activities ostensibly launch a renewed interest in the study of disasters and their intersection with man (Flynn, 2007). While mainstays such as Cutter, Tierney, Quarantelli, and Goodchild have kept the research alive and relevant, it is the new generation of academics who bear the responsibility of driving the evolution of this intellectual subject into the latter twenty-first century (Gaile & Willmott, 2003). Despite the fact that events such as the terrorist attacks on September 11, 2001 and the interstate bridge collapse in Minneapolis, MN in the Summer of 2007 have drawn widespread attention and focus due to their sudden and alarming impacts, flooding associated with hurricanes and intense rain events appear to present the most pervasive hazard to society at the moment (Flynn, 2007). Research by Anthes et al. (2006), Landsea et al. (2006), and Webster et al. (2005) suggests that the temporal fluctuations of extreme weather events are on the cusp of a high intensity period. Coincident with these findings is an increase in the quantity of research focused on the variables contributing to these events and how humans can sustainably coexist in hazardous environments. This increase in scholastic attention includes a more robust academic focus in the field of hazards geography (Gaile & Willmott, 2003). Despite these findings, acute disaster events continue to draw more focus than chronic events (Cutter, 1994). This phenomenon is undoubtedly rooted in the fact that American society is more accepting of voluntary risks than involuntary risks (Cutter, 1994). In

other words, Americans are more willing to deal with a hurricane they know is coming than a terrorist attack that is unpredictable. Every portion of the built environment along the American Gulf Coast represents an increase in potential loss and subsequent need for recovery associated with hazard events. Because societies around the world are economically and socially tied to vulnerable geographies, the need to study and understand the spatial components of hazards will never subside (White, 1973). The 2005 Hurricane season exposed the inability of the American public to understand the concept of vulnerability and accept responsibility for living beyond its geographic sustainability more than any single disaster event in history. In order to reinstate accountability for negligent awareness regarding disasters, the United States must use the New Orleans archetype as a catalyst for sustainable development in the future. At risk populations have not responded to disasters as predicted by past studies, thus making it more important than ever to explore all aspects of disaster (Perry, 1979; King, 2007; White, 1973).

### **1.1 Current Knowledge**

Disaster research has always existed as a cooperative multidisciplinary academic subject (Gaile & Willmott, 2003). Research trends have seen the discipline become entrenched in the social sciences, often overlooking spatial aspects at the expense of comprehensive social analysis (Kates, 1971). The first major dichotomous split in hazards geography was seen in the nineteen 1960s when the study of hazards within the context of human and environmental interactions was abandoned just as other fields were adopting this approach (White, 1973; Kates, 1971). At this time hazards geography was predominantly driven by public policy and focused on the perceived practicality of cost benefit analyses (White, 1973). This trend of public policy guided research had strong ties to the agendas set forth by the Disaster Research Center and Office of Civil Defense in light of the Cold War political environment of the 1950s and 1960s (Quarantelli, 1988). Research by Kates (1971) and White (1973) found that the increase in hazards practitioners and observers spearheaded the field's migration to the social sciences during the 1960s. As a result, anthropogenic response and adaptations to disasters over the last 40 years has been very well documented, providing a solid platform for expanding this research into new areas (Kates, 1971).

The most recent shift was seen in the latter parts of the 1970s as disaster research began to move away from extreme events toward more complex concepts of social theory in the nineties (Gaile & Willmott, 2003). The decade of the 1990s saw an abrupt increase in the incorporation of technology to aid in spatial modeling of social issues associated with disasters. While enormous strides were made to advance the field during this time period, its focus was still restrained within a very narrow scope of study (Gaile & Willmott, 2003). Quarantelli (1988) believes that the field was still dominated by sociologists through the end of the century. Even hazards geography itself has seen some of its most highly regarded researchers focus their efforts on social vulnerability and environmental justice in lieu of the more traditional and broader geographic concepts identified in the middle of the twentieth century (Gaile & Willmott, 2003). Even the comprehensive work on risk and hazards by Covello & Mumpower (1985) do not look beyond the social aspects of disaster, much less the ability of a community to recover (Covello & Mumpower, 1985). The faults in recent disaster research are a result of a preoccupation with time and space coupled with a neglect of assessing post disaster recovery (Cutter, 1994). Cutter (1994) points to the fact that disaster studies also experienced a shift in scale during this time period. She cites the general shift toward more regionally based studies as a potential

shortcoming of the field (Cutter, 1994). Are the spatially discrete aspects of disasters so well understood that there is a need to study these events at the regional level? Without a doubt, the answer to this question is no. The evolution of this field to a more specified divergence of study should not be considered a surprise and appears to be a normal part of the maturation process all developing academic fields experience (Johnston, 1979). Current political policy in the United States has also caused the disaster community to overlook the ideas of mitigation and recovery (Flynn, 2007). This shift toward a reactive management approach to disasters is symptomatic of a government hyper-focused on terrorist activities and unable to make difficult decisions regarding recovery and mitigation (Flynn, 2007). This current attitude is one of the major factors contributing to the diluting of recovery efforts in disaster studies and management.

Quarantelli (1988) states that it is imperative for disaster researchers to work within the context of all portions of a disaster. His early work recommends that all stages of disasters, including hazards, risk, vulnerability, and recovery are clearly defined at the onset of a study in order to set the stage for analysis (Quarantelli, 1988). This ideology has strong ties in the idea of systems theory and is repeated often by his peers in subsequent literature. Cutter (1994) maintains this notion by postulating that the ability of a community to recover is a direct measure of its risk perception. In turn, the level of recovery experienced by an area can be seen as a direct function of its damage levels (Kates, 1971). The idea of opportunistic recovery must not cloud the overall assessment of recovery. Those areas with increased damage levels may have more opportunities for recovery, although they may not achieve the same level of recovery after a disaster event. It is important to look at the city as a whole in order to avoid conclusions based on the amount of recovery rather than the level of recovery. If there is too much damage to an area, the population may be too scared to return, while mild damage to a community may instill a false sense of security and dictate recovery efforts that do not realize the reality of the risk posed by the disaster (Mileti, 1980). O'Keefe et al. (1976) makes reference to this phenomenon in his research when indicating that the increase in the frequency of disasters is not changing, but the potential for damages associated with disasters is increasing along with at risk populations (Kates, 1971; O'Keefe et al., 1976). Drawing on the early work of White and his focus on human and environment interactions, a number of researchers have pointed out that there would be no disaster if no population were present (O'Keefe et al., 1976; Mitchell et al., 1989). Anthropogenic influences on natural settings have driven the development and defined the need for the study of hazards and recovery (Slovic, 1987). Additionally, disaster research has often been initiated by human adjustments to disasters and guided by political policy after disasters have initiated the need for this research. Disasters can never be completely mitigated for, thus ensuring the long term need for disaster research to stay relevant and dynamic (Mileti, 1980).

While a wealth of literature focuses on the ideas of response and vulnerability, a large intellectual void exists regarding the study of recovery indicators outside of social sciences. The field of disaster research in the United States has been established since the mid-twentieth century and was solidified with the work of Gilbert White (Cutter, 1994). White took a very broad look at his floodplain management studies, incorporating all aspects of disaster research from physical geography and demographics, to economics and planning. In doing so he was able to not only study vulnerability and disaster management, but also postulate on recovery and best management practices (White, 1988). His notion of developing alternative approaches to flood risk analysis and mitigation were groundbreaking at the time and still represent one of the greatest challenges to practitioners today. How has the field progressed to where it is today?

Why are geographers seemingly unwilling to tackle the issue of recovery despite citing its obvious links with vulnerability in current literature? In short, geographic research in the hazards field is like any research, guided by popular social trends and media. Given time it will exhaust its current research focused on vulnerability and begin approaching the same problems from more diverse angles utilizing different techniques.

## **1.2 Components of Disaster**

It is no surprise that the concept of vulnerability has been one of the most heavily studied aspects of disaster events by researchers in all fields. The idea of vulnerability is an extremely important component of disasters and at times has been used to describe or study all aspects of a disaster. Multiple indices for quantifying social vulnerability and physical/economic vulnerability at variable geographic scales have been developed over the last two decades (Boruff et al., 2005; Cutter, 2007). Although all of these indices seek to describe the same component of disasters, all offer a slightly different approach and include capricious parameters. In accordance with the lack of research on recovery, none of the aforesaid indices includes any reference to recovery or ability of a community to recover (Boruff et al., 2005). Why have geographers dedicated more time and to aspects of disasters other than recovery? It is difficult to comprehend how such a condition can exist in a country whose academic community is as advanced as the United States, yet recent history has shown a blatant disregard for responsible and comprehensive disaster research in developed countries worldwide (Mitchell et al., 1989). As late as the 1980's, England was still wrestling with this same problem after the devastating effects of a wind storm left much of the country without utilities for an extended period of time (Mitchell et al., 1989). The scarcity of literature seeking to analyze recovery from a spatial perspective would suggest that so little is known about the events leading to recovery that it is not prudent to study recovery itself. In reality the science of spatial vulnerabilities is in its infancy, thus making the study of spatial aspects of recovery even further underdeveloped (Cutter, 2001). In order to resolve this problem and create conditions favorable for proper hazards management, it is extremely important to understand all aspects of disasters (Reed et al., 2006a). These components are not limited to preparation and response to disasters, but also the complex intermingling of vulnerability, risk, and recovery. Technical risk analysis is not always the best tool for summarizing a disaster. It is often the intricate dynamics between the qualitative and quantitative components of an event that capture its impact in an inclusive manner (Kasperson et al., 1988). Taking this into consideration, the city of New Orleans cannot approach the idea of recovery as an independent body guided by the frequency and intensity of past events (Slovic, 1987). According to Liverman (1990), recovery and vulnerability are difficult to separate due to the strong links between the biophysical, social, economic, and political aspects of each. The idea of cumulative risk incorporates all of these factors in its assessment of disasters and must be understood in order for a population to begin measuring recovery (Carreno et al., 2007).

Additional research has gone even further by suggesting that recovery is entirely a function of community vigilance (Carreno et al., 2007). This idea is further linked to implications of strong geographic dependencies of recovery. Reed et al. (2006a) believes that policies and plans in place prior to a storm have a large effect on the geography of the disaster itself as well as the spatial distribution of recovery. He goes on to state that disaster events have shown that immediate access to heavily damaged areas has long been the driving force behind the spatial distribution of utilities recuperation. Furthermore, this trend can be extrapolated out to all

services that communities depend upon to conduct normal daily activities regardless of socioeconomic status (Reed et al., 2006b). A recent study which made an early assessment of the repopulation of New Orleans found that the rate and spatial distribution of recovery would be guided by the repopulation of the most heavily damaged areas of the city, despite their economic and social composition prior to the storm (McCarthy et al., 2006). These geographic variations also exist over temporal dimensions from place to place, although studies utilizing multidimensional indicators are extremely difficult to conduct quantitatively (Cutter, 2001).

Depending on the framework or context of the study being employed, vulnerability can be defined in a number of ways. Despite the numerous definitions of vulnerability in current literature, there appears to be a limited intellectual window within which it is defined and studied. That is, the vagaries seen in the concept of vulnerability span a remarkably narrow field of view and offer little consideration to the idea of recovery or ability to recover. When viewed through a systems theory approach, a disaster event is in reality a series of complexly intertwined components whose actions at any level have measurable repercussions system-wide (Cutter, 1994). Therefore, it is not appropriate to measure vulnerability without accounting for a community's ability to recover. Moreover, recent disaster events in the United States have demonstrated an increased need for the study of vulnerability/recovery science due to the insubstantial contributions provided to disaster management by predictive science (Weinberg, 1985; Cutter, 2001). These current inadequacies point to the distinct need for a recovery index within the sphere of hazards research in geography.

In order to conduct a study of this nature it is first necessary to define the concept of recovery. The lack of substantial empirical studies of spatial recovery patterns on record means that no established academic backbone or definition for the context of this study exists (Cutter et al., 1996 & Reed et al., 2006b). Recovery is simply defined as the return of a system to its original state after a period of change (Takeda et al., 2003). Although this definition is easily understood and applicable to many areas of research, it is too static in nature to apply to this study. For the context of this study, the definition of recovery adopted by the National Disaster Management Authority (NDMA) of India provides an adequate fit:

*Recovery - Decisions and actions taken after a disaster with a view to restoring or improving the pre-disaster living conditions of the stricken community, while encouraging and facilitating necessary adjustments to reduce disaster risk.*

*-- NDMA, 2007*

Simply returning to existing conditions is only one stage of recovery. Recovery cannot be seen as complete once original conditions are met, and must be seen as a process of improving upon and adapting existing conditions and management practices in order to become more resilient in preparation for the next event. The recovery process includes many aspects which contain important spatial components. These include: reconstruction, improved community livelihoods, reevaluation of city-planning practices, zoning, and codes, in addition to the adoption of mitigation measures (Swaroop, 2000). The 1995 earthquakes in Kobe, Japan are a startling example of the importance of understanding all components of recovery. While the government was able to rebuild the physical environment relatively quickly, the recovery was conducted as a standardized program. All of the affected areas were reestablished at a uniform level. Rather than

letting natural recovery patterns evolve organically, the recovery efforts failed to recognize the importance of the social class and the necessity of a diverse social environment to ground the recovery process. As a result many areas affected by this earthquake have still not experienced “life recovery” (Takeda et al., 2003). At the same time, it is important that recovery is not confused with mitigation efforts (Bogard, 1988). From a disaster management perspective, mitigation measures are functions of vulnerability while recovery can be viewed as an emergency management function that is intimately correlated with vulnerability (Takeda et al., 2003).

The time period following a disaster is critical to the long term sustainability of a community. It is this recovery period that offers more opportunity to enact remedial measures than any other time (Swaroop, 2000; Natural Hazards Center, 2005). In this sense, recovery can be viewed as a component of vulnerability. Cannon et al. (2003) suggests that vulnerability should be defined with a predictive component with unfixed levels of preparedness, resilience, and ability to recover. In addition, Kasperson et al. (1988) and Cutter et al. (2003) point to the multi-faceted nature of vulnerability and recovery by recommending that exposure to the components of a hazard and societal resilience should be considered when discussing recovery. Wu et al. (2002) and Clark et al. (1998 & 2000) also reinforce the interconnectivity of vulnerability and recovery by advocating the fact that the vulnerability of a particular area is robustly tied to its resilience, or ability to recover from a disaster event.

### **1.3 Recovery Indicators**

When assessing the recovery of a particular region after a disaster event, one must look to various qualitative and quantitative indicators in order to evaluate the level of improvement which has been achieved. Selecting the criteria used in a recovery index is very important as not all parameters are within the proper temporal or cultural context. The issue of context is related to the fact that the importance of specific indicators over time can vary (Cutter, 1996). It is also important to understand the potential for interaction effects between indicators as some will act to amplify or dilute the effects of others (Takeda et al., 2003). One must also take into consideration the distinction between the opportunistic influx of cash and labor in post disaster environments, as these short term signals of recovery offer no long term benefits (Natural Hazards Center, 2005). The indicators in this study are not only being selected in order to assess recovery of different portions of New Orleans, but will also be used to determine whether discrete vagaries in spatial settings of these devastated communities have any influence on their ability to recover. While recovery is most often measured as a function of human condition, it is hypothesized that populations cannot thrive without a viable social network. These social networks are nurtured within portions of the built environment which offer a haven for their growth and development. In turn, understanding the distribution of the elements which support social capital is critical to understanding the capability of a community to recover from disaster. These spatial variants or “spatial indicators” will be helpful in reducing the weight placed on traditional social indicators in future vulnerability and recovery studies, offering a rapid and easily deployable approach to post disaster management. In order to keep this study as geographically focused as possible, indicators associated with race, socioeconomic background, and population demographics will be purposely left out of the index. With this being said, it is important that this tool be developed as a dynamic instrument which can be altered and amended based on the temporal and geographic context of its application. In cases where qualitative data



are collected and quantified in order to include in this study, it is imperative that the methodology behind this process be well established and documented.

There is a cited need to adopt a more holistic approach to evaluating recovery and vulnerability in order to improve upon existing qualitative indices (Barroca et al., 2006). The indicators utilized in this study will be firmly grounded in literature and past studies associated with measuring vulnerability and recovery at the international level. These include land use planning, social support networks, housing, physical & mental health, economic & financial situations, government assistance policy, and social infrastructure/preparedness (Takeda et al., 2003). It is interesting to compare an event in a developed country to similar disasters in underdeveloped nations and see that regardless of how advanced the wounded society is, the same basic signs can be used to guide and assess recovery. Moving away from actual case studies into more theoretical analysis of disaster recovery demonstrates little variation from the actual criteria employed by practitioners world-wide. Participatory process, quality of life, economic vitality, social and intergenerational equity, environmental quality, and disaster resilience are all considerations which have to be made when identifying recovery progress (Natural Hazards Center, 2005). When identifying recovery parameters associated with the man-land tradition of geography, Reed et al. (2006a) point to socioeconomic, biophysical, cultural, historical, and political factors as being the driving forces behind post-disaster revitalization.

#### **1.4 Research Questions**

In consideration of the general lack of current research interest in the field of disaster recovery, I formulated this study based on three primary research questions and hypotheses. Through a series of four essays, these questions were explored in an attempt to improve upon existing knowledge in the field rather than find decisive solutions.

**Question 1:** Can a spatially based index be developed to quantify the ability of a community to recover from disaster?

Current research points to social indicators as the driving force behind recovery. These indicators are currently in use by organizations such as the United Nations to assess recovery of disaster impacted regions. It is believed that if too much weight is placed on these social factors and that there are other significant contributing factors which are being left out of comprehensive recovery assessments. Through the use of geostatistics, geospatial modeling, and traditional recovery indicators, this study will seek to determine if any spatial indicators of recovery exist. I anticipate that the results of this recovery index will identify a number of spatial factors contributing to the recovery process in New Orleans. Some of these factors might include proximity to transportation corridors, elevation, and proximity to undisturbed areas.

**Question 2:** Are there external factors influencing the ability to quantify the spatial distribution of recovery?

Factors such as scale, location, level of measurement, and culture are generally considered a source of limitation to the value of tools intended to measure recovery, vulnerability, and risk. Of particular interest is the issue of scale, as so many current metrics are used at scales which do not support decision making and management needs. This study will determine the most appropriate

level of measurement for this type of research. It is anticipated that positive results will be seen at the neighborhood level, making this an appropriate scale for analyzing recovery patterns. Due to the strong relationship between the two, it is assumed that the trends identified at the neighborhood level will also be seen at the Planning District level. The results based on the zip code boundaries may fluctuate due to the fact that the make-up of these areas is considered to be more heterogeneous than the other levels of measurement used in this study.

**Question 3:** Are tools such as a spatial recovery index capable of being used and acknowledged in an applied environment?

It is presumed that the results of this study will be able to offer guidance to officials who are assessing recovery. If used properly, the tool will help identify those areas of the recovery initiative that are working and those program areas that are not. This study will offer these results through simple correlation of geographic characteristics to recovery rates. They should not be used in an attempt to define causation. The results of this study will act as a reference point when comparing recovery goals determined at the onset of this project to pre-storm conditions across the city.

## **1.5 Methodological Approach**

The original intent of this study was to develop a metric for recovery, validate the metric, gain an understanding of its non-spatial influencers, and test it in a real world setting. While the overall essay series highlighting this study overlaps a variety of scientific disciplines, the intersection of all of the science is grounded in Geographic Information Systems (GIS). GIS has proven itself to be a viable and reliable tool for the study and analysis of disaster related data (Scott & Cutter, 1996). With this being said, it is important to understand that a GIS based index or analysis is limited by the quality of the data and bias of the developer (Scott & Cutter, 1996). With careful consideration of these limitations, it is reasonable to utilize GIS technology and qualitative analysis to determine if the geographic characteristics of the City of New Orleans have led to the development of an incomparable urban hazardscape (Scott & Cutter, 1996; McCarthy et al., 2006). A Comprehensive GIS based Recovery Index will allow hazards researchers to look beyond the literature based on social vulnerability and develop a methodology to study geographic patterns of recovery (Scott & Cutter, 1996). While many researchers will point out that quantitatively based indices suffer from a variety of fallacies and are victims of poor science and subjectivity, most literature suggests that this approach is still a relevant and acceptable spatial analysis technique (Wilson & Crouch, 1987; Freudenburg, 1988; Weinberg, 1985). Recovery datasets generally have important temporal and spatial dimensions. This means that the collection time and scale are very important in assessing data suitability. This limiting factor means that a GIS based approach is limited to the obtainable data rather than the best data (Cutter, 2001).

### **1.5.1 Developing the Metric**

The first essay in this series explores the potential for developing a spatially based measure of recovery. The tool developed in this study is referred to as the Spatial Recovery Index (SRI), and is based on the aforementioned idea that physical structures act as anchors for social networks, driving their development by providing communities with synergy. While identified as a

recovery index, the tool was inspired by Gilbert White's push for alternatives to structural solutions to floods in concert with Susan Cutter's work on social vulnerability. Susan Cutter has taken the assessment of vulnerability to a new level of detail with her Social Vulnerability Index (SoVI) (Cutter, 2007). Cutter (2007) seeks to identify the characteristics of a population which shape its overall vulnerability through a relatively straightforward spatial modeling technique. This index incorporates a large volume of social demographic parameters to assess vulnerability at various administrative levels. While SoVI offers a generalized visualization of community vulnerability it could be improved upon by incorporating a spatial component of vulnerability as well as a factor associated with the ability of an area to recover after a disaster event. In an effort to determine if this recovery indicator is quantifiable, this essay has identified a number of factors which will be used to develop a recovery index for the City of New Orleans.

Guided by empirical analysis and the framework set forth in the literature, the parameters which will be potentially incorporated into this study are churches, childcare, healthcare, education facilities, infrastructure, crime rates, building permits, postal service activity, maintenance of public grounds, neighborhood association activity, economic activity, flood depth, elevation, proximity to transportation/contraflow corridors, and proximity to flood control structures. This list is not conclusive by any means and is subject to change based on the availability, coverage and maintenance of these datasets. In addition, other datasets which arise throughout the course of this study may offer valuable information and will be included on a case by case basis. These indicators may also be collapsed into more generalized components to make the modeling process easier to develop and increase the interpretability of subsequent sensitivity analyses. The data for this study has been gleaned from open source sites including the Louisiana Recovery Authority (LRA), Greater New Orleans Community Data Center (GNOCDC), the New Orleans Regional Planning Commission (NORPC), the Brookings Institute, a number of private corporations, and the Federal Emergency Management Agency (FEMA). The proposed modeling process will use a raster based linear overlay technique. The choice of a raster based analysis as opposed to a vector based investigation allows for greater control over the parameters of the model, and limits the error associated with data resolution and format issues. Converting all of the datasets to a raster based format with the same grid cell distribution will homogenize the datasets and allow the model to produce results which are more representative of real world conditions. It is imperative when conducting this kind of analysis to understand your datasets and the limitations of those datasets.

In order to prepare the datasets for input into the model, they will all have to be converted from vector format to a raster dataset based on 5 meter grid cells. Utilizing smaller grid cells to index recovery rates across the city will significantly improve the results and the efficacy of the algorithm. This conversion process eliminates concerns which result from multiple data formats (points, polylines, & polygons) and normalizes the data into a consistent standard. This generic model will be scrutinized and refined prior to running any analysis or dealing with any data in order to identify any inadequacy or fault in the procedure. The final result of the model will be a grid layer with index scores for each unit in the cell array. This rating can be used to categorize the level of suitability associated with development of a particular area based on predetermined recovery criteria. As each parametric variable is added to the model, a concurrent sensitivity analysis will visualize the effects of the data set on the final output. This process will assist in building the most efficient model possible. Any data which results in negligible or unnecessary effects on the model will be removed or reevaluated for inclusion in a subsequent step. Spatial

modeling techniques often violate the tenets set forth by Occam's Razor (Principle of Parsimony) and should be kept as simple as possible to avoid uncertainty in analysis and practicality (Haining, 2003). The accuracy of a model can be inversely related to the number of variables and complexity of its structure. Too many factors and functions make it difficult to identify between the data interaction effects and independent variable effects (Fotheringham et al., 2000). In the absence of a defensible method for assigning weights to variables, an additive method will be used to quantify recovery (Gillet, 2007; Rygel et al., 2006). Although it is a simplified approach, this will still be effective in identifying superficial levels of geographic dependency.

The final results of this model will then be used to assess the most appropriate scale at which recovery should be studied. By running the aforementioned methodology on study units varying in scale, it will be possible to identify the smallest unit to which this study can be applied. It is important that the results of this study are produced and analyzed at the same scale management decisions are being made (Carreno et al., 2007; Wilbanks & Kates, 1999; Clark et al., 2000; Cash & Moser, 2000). Analyzing these data at different geographic divisions will also help determine if recovery trends appear to project themselves on surrounding areas (Cutter, 2001). The scale of this type of study is extremely important. If your study area is too large, recovery trends may be disguised or diluted, if it is too small, many issues may be overlooked (South Pacific Applied Geoscience Commission - SOPAC, 2005).

The purpose of the SRI model is to provide decision makers and planners with a "one-stop-shop" for assessing the spatial distribution of recovery, and identifying geographic indicators which contribute to improved recovery in post-disaster environments. Utilizing this index will allow public officials to make informed decisions about funding of recovery projects and resource allocation, while also acting as a complimentary tool to the social vulnerability assessments. Results of this model could be utilized as a standalone product or recoded for use in a more detailed social vulnerability index for the city.

### **1.5.2 Evaluating the Metric**

The following paper in the essay series focuses on the evaluation of the SRI as a measure of recovery. Because no other metric of this nature exists, the paper explores the idea of what recovery means and how it can be measured. Through the identification of proxy measures of recovery, the study evaluates the efficacy of the SRI when compared to other assessments of recovery. The data are analyzed using a variety of geospatial statistics as well as exploratory spatial data analysis. These techniques offer a blend of both quantitative and qualitative analyses, and assist in assessing the fidelity of the SRI.

The final portion of this paper will focus on identifying exactly what the SRI is and is not measuring. The paper goes on further to evaluate the separate components of the SRI, leading to a new understanding of its capabilities and limitations. While a number of past studies have focused specifically on the development of vulnerability indices primarily for policy analysis, the evaluation of the SRI determines that it may be considered as a representation of community resilience (Eriksen & Kelly, 2007). Due to the cited links between vulnerability, recovery, and resilience, it is reasonable to believe that this study can be used in the same way to analyze the vulnerability and preparedness programs in the city. Essentially, the tool that is being evaluated

in this study can be used to guide response and recovery decisions by emergency managers and planners. The results of this index will offer these individuals a resource to assess programmatic management of recovery. In essence, it will help determine if the recovery process is functioning effectively. This index will not be a separate program evaluation tool and must be used within existing evaluation protocols. The challenge will be to determine if it is sensitive enough to enhance existing program evaluation studies.

### **1.5.3 Alternative Geography**

Upon establishing a level of confidence in the functionality and results of the SRI, the third essay details an attempt to determine if the model could be applied in a different locale. Because the model had been developed and evaluated in New Orleans with data from a single event, it was necessary to apply it in a new environmental, physical, and cultural setting. This new application of the SRI assisted in the identification of bias associated with its narrow scope of development.

The Province of Carinthia in Austria was selected as a location which varied enough in risk, geography, and demographic character to test the SRI for bias in development. Although the region is not subject to the impacts of hurricanes, it has a long history of flooding associated with winter precipitation and heavy rain events during the spring and summer. Due to variances in data and geography, multiple iterations of the model were run over a two-year period prior to identifying a scenario which began to capture a true representation of recovery potential. What was unexpected was the notion of risk perception associated with culture, and how much this would appear to influence a model based purely on spatial distribution of at-risk elements within the built environment. The identification of this latent socio-cultural variable is considered extremely valuable, as it points to the fact that human and social values are nearly inescapable in the assessment of any phase of disaster, thus further solidifying the necessity to manage disasters with a multi-disciplinary approach.

### **1.5.4 Research Based Methods**

The final portion of this series of essays was an attempt to bring the idea of translational research in disaster science full circle. Many challenges were faced in identifying an opportunity to apply any research based initiative, let alone the SRI which was still in its infancy. In light of the Louisiana Coastal Protection and Restoration Authority's evolving outlook on coastal risk and flood mitigation, an opportunity to utilize research based methodology in a real world study became available in late 2010. While the SRI was not employed in this study due to its limited application and lack of refinement, a number of other research based techniques were approved for application. The goal was to leverage these non-structural alternatives to mitigation planning in an effort to refine understanding of regional vulnerability, just as it is envisioned that the SRI could improve the process used to disseminate mitigation funds after a disaster.

The study was focused on the Northshore region of St. Tammany and Tangipahoa parishes on Lake Pontchartrain. Having received a fraction of mitigation money already put to use in New Orleans following Hurricane Katrina, the Northshore community had a need to maximize their mitigation budgets. Gaining a better understanding of the distribution of vulnerability and what factors contribute to its variance was at the forefront of this reconnaissance study. To accomplish these goals a multi-disciplined approach including flood exposure analysis, flood loss estimation, and social vulnerability analysis was developed and executed over a period of eighteen months.

The process relied on heavy involvement and input from regional stakeholders, government officials, and the impacted public. This participative science approach in combination with the non-traditional assessment of flood risk has presented an alternate view of flood risk for decision makers to consult when prioritizing the mitigation expenditures.

### **1.7 Research Significance**

It is all too easy to marginalize the issue of recovery to a purely social event, as it is often measured at the human level - those who have recovered versus those who have not (Natural Hazards Center, 2005). This study will be one of the first to quantitatively measure recovery in a post-disaster urban setting to identify its non-social characteristics. It is the aim of this study to look beyond the social disaster and conduct research which penetrates the cursory boundaries defined by popular themes of social and racial inequity through applied research. The results of this study will help fill a void in current disaster research conducted by geographers by developing and viewing the assessment of recovery through an applied perspective. It is expected that this study will not only identify the ability to measure recovery, but also help to determine whether or not the recovery process in New Orleans is working effectively. This study will also advance the field of hazards geography by developing a tool which can be proactively utilized in other research and disaster prone regions to quantify recovery capability. This value can then be used to augment preexisting vulnerability studies for the area. The capacity to comprehensively assess the ability of specific areas to recover based on spatial orientation, will offer planners and public officials an invaluable tool for guiding post disaster recovery efforts and mitigation planning.

## CHAPTER 2: INVESTIGATING RECOVERY PATTERNS IN POST DISASTER URBAN SETTINGS: UTILIZING GEOTECHNOLOGY TO UNDERSTAND POST-HURRICANE KATRINA RECOVERY IN NEW ORLEANS, LOUISIANA<sup>1</sup>

*If there was no New Orleans, America would just be a bunch of free people dying of boredom.*  
-- Judy Deck, a New Orleans resident, 2009

### 2.0 Introduction

To improve current disaster research in the discipline of geography, it is necessary to expand upon existing research paradigms in the field. Currently this means extending the geographic study of hazards beyond the event and into the recovery process. The lack of substantial empirical studies of spatial recovery patterns on record means that no established academic backbone or definition for the context of this study exists (Cutter et al., 1996; Reed et al., 2006a). This project has attempted to address the lack of research focused on disaster recovery by utilizing geospatial technologies, qualitative analysis, geoprocessing procedures, spatial modeling, and geospatial statistics to develop a greater understanding of the geographic variables guiding recovery in a post-disaster urban environment. Using the City of New Orleans, Louisiana, as the overall project area, this study attempted to interpolate the recovery fabric of the entire city through the use of traditional and non-traditional indicators of recovery. The purpose of this study was to provide decision makers and planners with a one-stop-shop for assessing the spatial distribution of recovery, and identifying geographic indicators that contribute to improved recovery in post-disaster environments.

In order to keep this study firmly entrenched in geographic concepts and avoid reproducing a social assessment of recovery, social demographics were purposely avoided in the indexing and modeling stages. Rather than utilize social metrics to assess recovery, this research has focused on the relationship between the ability of a community to recover and variations in proximity to social institutions within the built environment. The spatial assessment of recovery in New Orleans has permitted the identification of spatial indicators of recovery, offered insight into the issues associated with scale that are commonly associated with spatially based evaluations, and produced a tool which demonstrates potential for use within a local program evaluation framework. From a broader disaster management perspective, the tools and results of this study have also offered further support to the systems theory approach to disaster research (Cutter, 1994; Mileti, 1980).

---

<sup>1</sup> This chapter previously appeared as:

Ward, S., Leitner, M., & Pine, J. (2009). Investigating recovery patterns in post disaster urban settings: Utilizing geotechnology to understand post-Hurricane Katrina recovery in New Orleans, Louisiana. In P. Showalter & Y. Lu (Eds.), *Geotechnical Contributions to Urban Hazard and Disaster Analysis*, New York, NY: Springer.

Reprinted with kind permission of publisher Springer Science and Business Media.

This chapter highlights the initial segment of a study that is anticipated to extend into the spring of 2009. During this timeframe, the authors hope to utilize emerging datasets, multiple iterations of the model, varying statistical techniques, and groundtruthing in order to develop and calibrate an unbiased and transparent methodology of quantifying spatial patterns in recovery and identifying those geographic variations that guide its progress. Due to the difficulties in conducting multivariate analysis with multiple temporal scales, the initial portion of this study highlighted in this chapter has focused on a static measurement of recovery through February of 2008.

## 2.1 Study Area

The City of New Orleans is an ideal candidate for this type of study. The impacts of Hurricane Katrina coupled with the social dynamics and vulnerable geographic setting offer a living laboratory for empirical study. Being more than two years removed from the disaster of Hurricane Katrina, the city of New Orleans has had sufficient time to progress and recover to a quantifiable degree; thus making it an appropriate candidate for a case study (Wilbanks & Kates, 1999). The transformations occurring on a daily basis in New Orleans are not biased by the observer or researcher and offer a truly organic view of post disaster recovery. Although a ten parish region was heavily impacted by this storm, the City of New Orleans was selected as the focal area. The geographic boundaries of this study area are limited to Orleans Parish. The city is bordered by Lake Pontchartrain to the north, Jefferson Parish to the west and southwest, St. Bernard Parish to the east, and Plaquemines Parish to the south and southeast. Orleans Parish and its surrounding region are depicted in Figure 2.1.

In order to conduct this research using a case study methodology, sub segments of the city were used to define recovery rates spatially. The smallest areas employed in this study are neighborhoods. Due to the scale of available input data, as well as the use of the neighborhood boundaries by the Greater New Orleans Community Data Center (GNOCDC) and New Orleans Regional Planning Commission (NORPC), it was determined that neighborhoods represented the most discrete level of measurement practical for this study. Each neighborhood will be considered a case for the purpose of this study. The value of a case study lies in the fact that it seeks to explain the observable fact in question (recovery), within the context of the real world through the use of empirical investigation and multiple sources of supporting evidence (Swaroop, 2000). Kates has also suggested that the use of neighborhoods in the study of urban areas is the most appropriate level of measurement due to the diverse characteristics of the human use system seen at the parcel, tract, and block level (Kates, 1971). Wu et al. (2002) and Cutter (1996, 2001) also suggest the importance of the neighborhood level of measurement through the application of the idea of Hazards of Place. Focusing the study on areas that are too small will mask overall issues of recovery and emphasize opportunistic recovery patterns that do not sustain themselves for the entire recovery period (Kates, 1971). Careful consideration of this issue will help resolve the modifiable areal unit problems which often plague this type of study (Cutter et al., 1996).

The neighborhood boundaries used for this study were defined by the city in the late 1970s and early 1980s. This original dataset has been further refined by the Brookings Institute for data analysis purposes. There are 73 distinct neighborhood areas in the city based on this current dataset (GNOCDC, 2007). These boundaries are useful because they are coincident with census

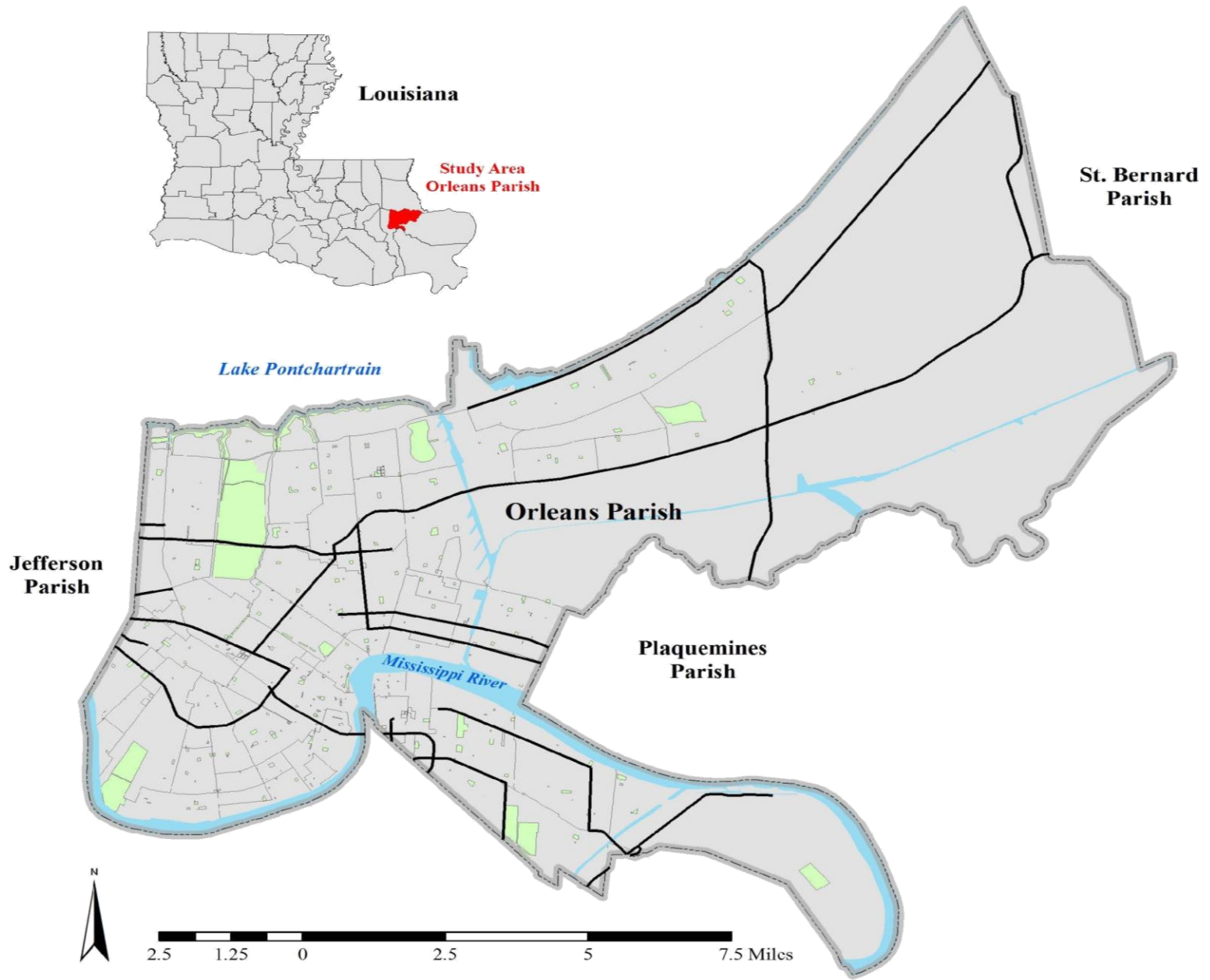


tracts throughout the city, making it easier for future studies to identify demographics associated with each area (GNOCDC, 2007). For the purpose of this study, two neighborhood areas were dropped from consideration. The northeastern portion of Little Woods and entire Lake Catherine neighborhood units are located at the extreme northeastern end of the parish and represent large areas of wetlands that have never been developed. These areas were largely unpopulated prior to the storm and have little use beyond recreation and outdoor sports. It was determined that leaving these large areas within the study boundary could potentially skew the results of any future analysis due to lack of data, population, or social activity in the region. In addition to removing the undeveloped neighborhoods in the extreme northeastern portions of the parish, this study also excluded all areas representing parks, green spaces, ponds, lakes, canals, and wetlands. It was determined that leaving these areas in the study would also bias the results of any interpolation techniques used to standardize datasets prior to analysis. From this point, the study took on a broader focus and analyzed the same results based on the boundaries of the eighteen different zip code areas in the city. While the neighborhoods in this study area were expected to be somewhat homogenous, the boundaries for zip codes in the city appear to be more arbitrary in nature. The final level of measurement used in this study was the Planning Districts boundary file. These boundaries are based on the neighborhood distinctions and represent generalized areas of the city for management purposes. These Planning District boundaries were designated in 1999 and are the same recovery districts being used by the Unified New Orleans Plan (UNOP) group studying and guiding the recovery of the city (UNOP, 2007).

## **2.2 Defining the Problem**

When viewed through a systems approach, a disaster event is in reality a series of complexly intertwined components whose actions at any level have measurable repercussions system-wide (Cutter, 1994). In turn, vulnerability can be seen as a component of recovery while the ability to recover can be seen as a component of vulnerability. Therefore, it is not appropriate to measure vulnerability without accounting for a community's ability to recover. Moreover, recent disaster events in the United States have demonstrated an increased need for the study of vulnerability/recovery science due to the insubstantial contributions provided to disaster management by predictive science (Weinberg, 1985; Cutter, 2001). These current inadequacies point to the distinct need for a recovery index within the sphere of hazards research in geography.

When assessing the recovery of a particular region after a disaster event, one must look to various qualitative and quantitative indicators in order to evaluate the level of improvement which has been achieved. The indicators in this study were selected in order to assess recovery of different portions of New Orleans, as well as determine whether discrete vagaries in spatial settings and vulnerabilities of these devastated communities have any influence on their ability to recover. These spatial variants or spatial indicators will be helpful in reducing the weight placed on traditional social indicators in future recovery studies, offering a more comprehensive and less biased approach to post disaster management. With this being said, it was important that this tool be developed as a dynamic instrument that could be altered and amended based on the temporal and physical context of its application.



**Figure 2.1: Orleans Parish Study Area Detail**

## **2.3 Parameters**

The general indicator groups utilized in this study have been based on those outlined by the United Nations (UN) in the 2005 Tsunami Recovery project. The categories used by the UN to assess recovery in the countries affected by the tsunami were designed to be used from a regional perspective and include; shelter, finance, infrastructure, health, education, and livelihoods (UN 2005). While these basic categories are too general for direct application to this particular study, they were used as a guide for the development of indicator categories more appropriate for a study at a finer resolution. The UN study also offers strong support to the use of spatial datasets and indicates the importance of geography in the recovery process (UN, 2005). A wealth of hazards literature has focused on the recovery after the 1995 earthquake in Kobe, Japan. Recovery studies in this area have utilized a more detailed and dynamic set of indicators in order to assess recovery. These include land use planning, social support networks, housing, physical and mental health, economic and financial situations, government assistance policy, and social infrastructure/preparedness (Takeda et al., 2003).

Importantly, none of the recovery studies referenced in the development of this index have focused on a direct measure of population as an indicator of recovery. To simplify the idea of recovery, one may be inclined to simply rely on the measure of change in population from a pre-disaster environment to the post-disaster environment. Due to concerns expressed by the NORPC and GNOCDC over the soundness of early population estimates, as well as data availability, it was determined that this model would maintain integrity by not using population as a direct measure of recovery. In addition to this, work by Takeda et al. (2003) notes that population alone cannot be relied upon as a sound metric for recovery. Despite the return of a significant population to Kobe, Japan, after the 1995 earthquake, “life recovery” has not been fulfilled (Takeda et al., 2003).

In order to organize the parameters for this study into logical groups, a modified principal components analysis was employed through the framework of the Land Use Conflict Identification Strategy (LUCIS) developed by Carr and Zwick (2007). The LUCIS model offers a proven data organization framework for application within this model. The use of utility assignments and organized grouping of data in the LUCIS model were uncomplicated to apply to the development of the Spatial Recovery Index for this study. Guided by empirical analysis and the framework set forth in literature, the parameters incorporated into this study represent social institutions within the built environment which lend themselves to the recovery of social networks across the city as well as spatial vulnerability metrics which have recovery implications. These parameters include churches, childcare, healthcare, education facilities, infrastructure, economic activity indicators, flood depth, elevation, proximity to transportation/contraflow corridors, municipal services, recreation activity, and proximity to flood control structures.

## **2.4 Methodology**

This study utilized Geographic Information Systems (GIS) technology and qualitative analysis to determine if the geographic characteristics of the City of New Orleans have had an influence on the rate, level, and distribution of recovery (Scott and Cutter, 1996; McCarthy et al., 2006). The GIS based Spatial Recovery Index (SRI) developed by this study looks beyond the literature based on social vulnerability and assists in the development of a methodology to study

geographic patterns of recovery (Scott and Cutter, 1996). Quantitative assessment has long been a preferred choice of disaster geographers attempting to assess risk and vulnerability, thus it makes sense to apply this technique to measuring recovery (Weinberg, 1985; Freudenberg, 1988). It is important that the model developed for this analysis and datasets employed are flexible (Carreno et al., 2007). This type of spatial modeling requires large sums of diverse datasets to be standardized and digested in a relatively short period of time. The multi-layered data management techniques inherent in the typical functions of GIS packages meant that a spatial model was in fact the most appropriate approach to employ when considering the scale and focus of this study (Lloyd, 2007). Utilizing this index will allow public officials to make informed decisions about funding of recovery projects and resource allocation, while also acting as a complimentary tool to other social vulnerability assessments.

The model developed for this study utilized a progressive raster based approach to integrate all of the variables into a single coded index value. Utilizing a simple index to visualize and quantify the final outcome of this model was important for interpretations and analysis by independent parties. The progressive raster based process starts with a few base data elements and incrementally adds data layers to the model. As these data sets were added to the model their categorical values were recoded to represent levels of measurement on a recovery scale. This recoding process is precarious and presents one of the most difficult steps in the entire development process. The challenge is to standardize all of the parametric variables objectively into a single quantitative level of measurement in a transparent and justifiable manner.

The framework of the model was based on the LUCIS model developed by Carr and Zwick (2007) to assist in the identification of land-use conflicts, and was developed within the modeling environment of Environmental Systems Research Institutes (ESRI) ArcGIS 9.2 Platform. The model developing tool within ArcGIS was used to document the generic backbone of the model prior to integrating any data layers. This backbone provided an abridged schematic of the model which visualized the process steps into a logical organizational structure. Based on the LUCIS data management schema, the data used in this study were generalized into Single Utility Assignments (SUAs), Multiple Utility Assignments (MUAs), and Complex Multiple Utility Assignments (CMUAs) (Carr and Zwick, 2007). Each SUA represented a raw dataset such as hospital locations, health clinics, and elder care facilities. These SUAs were then grouped into a general category and combined through a raster calculation process into a MUA such as Health. All of the MUAs can then be combined into a single CMUA to represent Recovery Indicators for the City of New Orleans. The ranking and calculation processes are discussed in detail in subsequent portions of the methodology section. Utilizing this stepwise raster based approach to develop the final spatial index was important in the analysis of the results. By organizing each input variable into separate SUAs, MUAs, and CMUAs, it was easy to measure the level of influence each component had on the final outcome of the index through the comparison and analysis of standardized raster files.

The model was organized into two main CMUA components that fed into the final SRI CMUA. The first component was a measure of Recovery Indicators (RI) that included MUAs for Health (hospitals, health clinics, elder care facilities), Education (schools, after school programs, and libraries), Economy (banks, gas stations, and grocery stores), Municipal Services (fire, police, emergency medical services, and post offices), and Social Activity (churches, child care facilities, and recreation facilities). The second CMUA was a measure of Spatial Vulnerability

Indicators (VI) which contribute to recovery. Spatial Vulnerability can also be considered to be a measure of the ability of an area to recover based on measurements of proximity and level of damage sustained during the storm. This CMUA included MUAs representing Katrina Flood Depth (flood depth grid and flood mask), Geographic/Topographic Variables (LiDAR elevations, and navigable water), Flood Control Variables (levees, pump stations, and canals), and Transportation Variables (highways, interstates, evacuations routes, contra-flow corridors). It is important to include these spatial vulnerability metrics in the assessment of recovery as they are important in dictating the ability of a particular area to recover.

Due to the fact that this is the first segment of a long term study with subsequent data sets and input variables yet to be determined and acquired, each input into this system was assigned an equal weight. The raster grid utilized in this study was based on 5 meter grid cells coincident with those from the Light Detection and Ranging (LiDAR) Digital Elevation Models (DEM) for the city. This grid was selected because it was the same one utilized after the storm in raster data depicting elevation, flood depth, flooded areas, and flood duration. Each of the original vector based SUA datasets was converted to raster format using a Euclidean Distance interpolation technique. Based on the theory of distance decay this study assumed that the contribution of a particular facility or structure to overall recovery declined as the distance from it increased due to the increased likelihood of an individual using a facility in close proximity. Past studies have supported this validation by looking at the relationships between homestead location and visits to hospitals, clinics and other service facilities based on distance (Muller et al., 1998; Lin, 2002). The selection of Euclidean distance over Manhattan (rectilinear) measurements is due to the difficulty in obtaining detailed and accurate network data for the City of New Orleans. Research has indicated that Euclidean measurements commonly offer distances in the order of 20% less than real network distances, making them an adequate indexing tool based on the scale of the input data (Lin, 2002; Francis et al., 1992). The Euclidean distances are classified into five categories using a natural break classification method. This index ranged from 1-5 and represented, low, medium-low, medium, medium-high, and high levels of recovery suitability. Those input variables that were already in raster format (i.e. flood depth and elevation) were reclassified to created recovery suitability index using the same classification method. For example, areas with the highest elevation were assigned a value of five, while those with the lowest elevation were assigned a value of one. The location where a facility or institute is operating at the time of this study is assigned a value of 5 for recovery suitability for the specific category. As distance from the facility increases, a place receives decreasing values for its recovery suitability index for the same category. Figure 2.2 represents the data for schools and the reclassified raster data ready for input into the model.

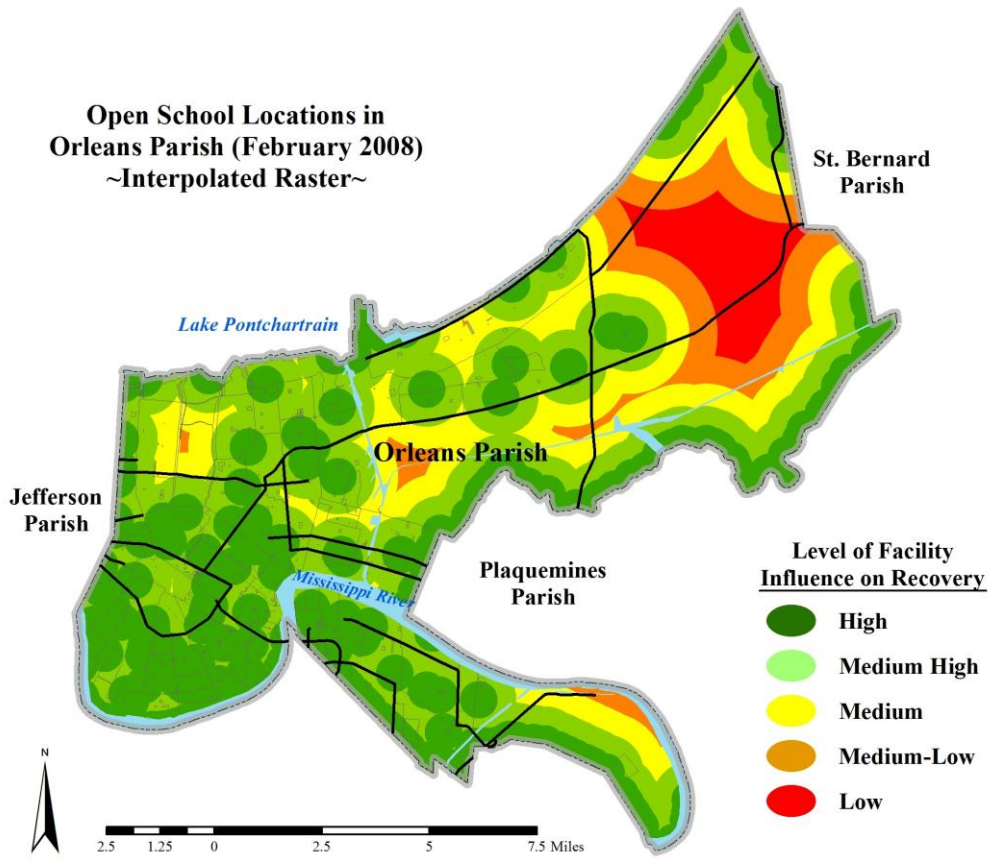
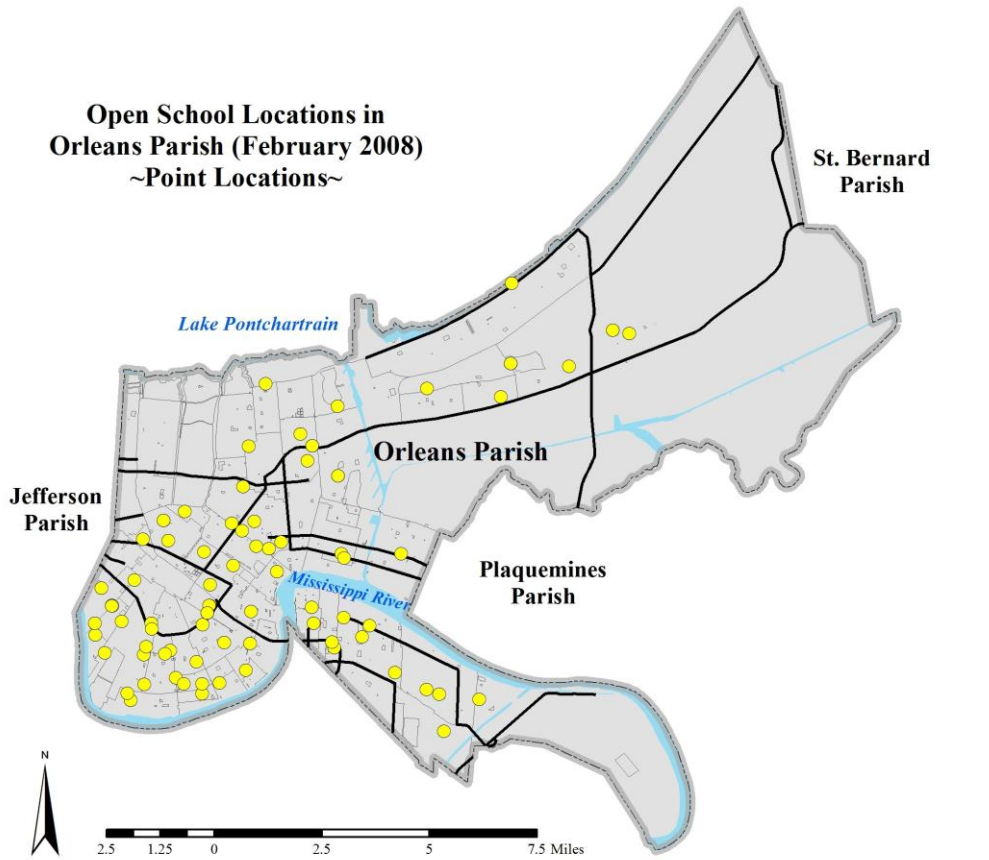
Once calculated, each of these CMUAs was input into the final model step in order to produce a raster file with values representing the SRI. This final SRI provides a visual representation of the distribution of recovery across the entire city based on traditional indicators of recovery (RI) combined with spatial vulnerability (VI). While it is not expected that the results of these CMUAs will accurately depict real world conditions within every discrete cell in the final raster output, it is believed that each of these CMUAs will provide planners with an enhanced perspective of recovery throughout the city. Furthermore, the CMUAs will also allow planners to identify those areas of the city that have yielded unconventional results, and in turn, require more in-depth qualitative analysis to understand the dynamics driving recovery.

In order to advance the usefulness of this study beyond ESDA and visual analysis, spatial analysis techniques were applied to describe the spatial distribution of the recovery from Katrina in the study area. Due to the scale of this study, local statistics were a more appropriate choice than global statistics owing to the latter's tendency to mask subtle spatial relationships and patterns (Fotheringham et al., 2000). The study began with a generalized assessment of the significance of recovery index patterns through spatial autocorrelation (Moran's I) and hot spot analysis (Getis Ord  $G_i^*$ ). In accordance with this assessment, Local Moran's I, and Getis Ord  $G_i^*$  were calculated to identify the hot spots/cold spots of the RI, VI, and SRI outputs. Moreover, Geographically Weighted Regression (GWR) analyses were conducted on the RI, VI, and SRI results to explore the relationship between the input variables and the indices. While it is common in more generalized studies to utilize Spearman's Rank Correlation Coefficient to assess the relationship between variables and results when datasets are not assumed to be linear and are measured on an ordinal scale, this approach fails to take into account the spatial vagaries of these relationships. Utilizing GWR is more appropriate than traditional Global Regression analyses as it has the ability to account for heterogeneous relationships between variables and results as they are distributed across the entire city (Fotheringham et al., 2002). In addition, the use of GWR permits easy visualization of the regression coefficients. The use of GWR was vital to determine the variance in recovery explained by the model (coefficient of determination) as well as the relative Influence of each parameter on the final SRI value. Although each input variable is receiving a rank based on Euclidean distance and natural breaks in the data, there is still subjectivity in this approach and as a result, the index cannot be assumed to be an interval level of measurement.

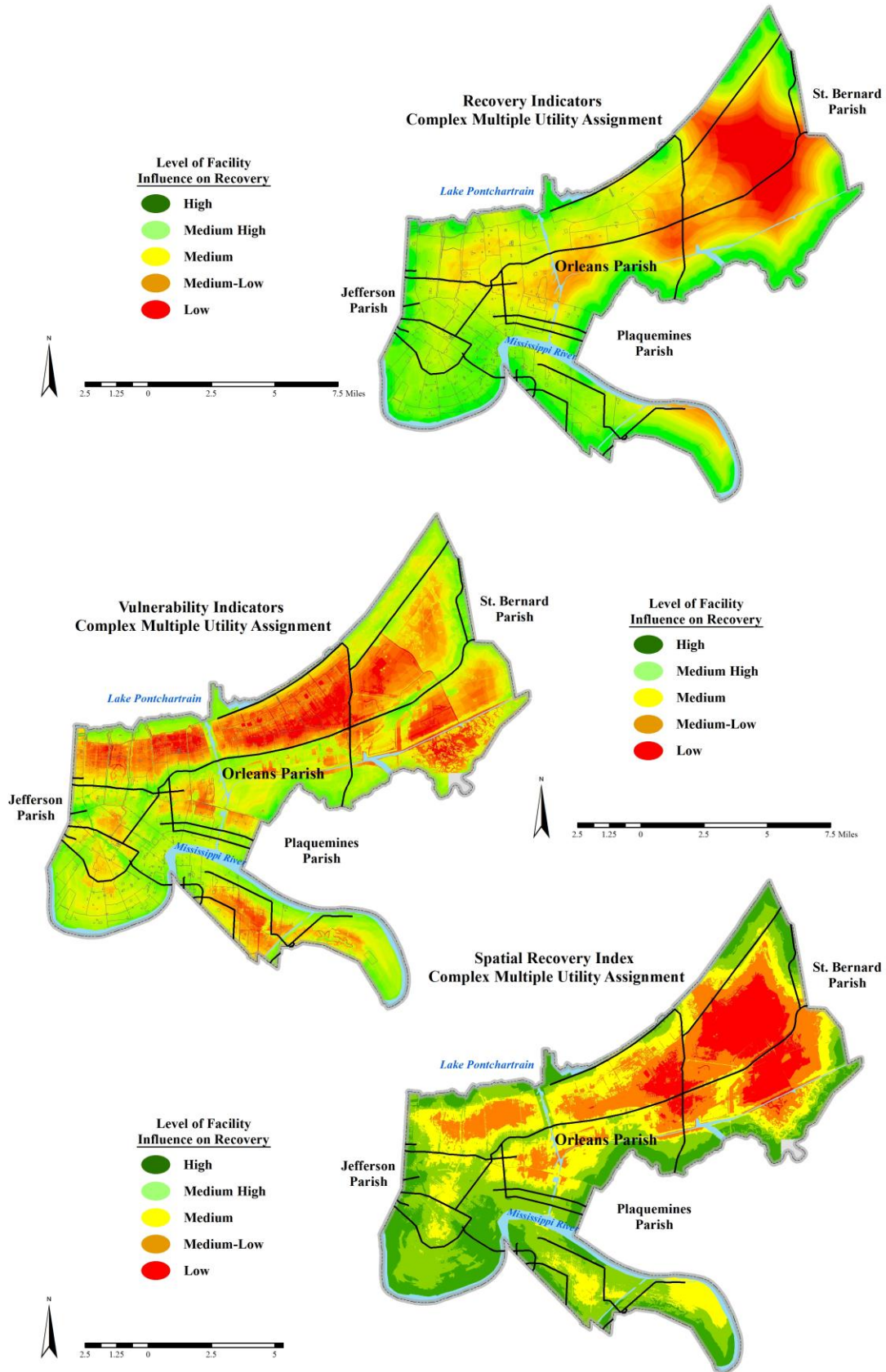
To facilitate increasing the value and interpretability of the model, a zonal analysis of the study area at the neighborhood, zip code, and planning district levels was conducted. This portion of the study collapsed the detail of the initial model results into statistics that were tied to specific study areas. The new output correlated the statistics of the model input and results to each study area and identified the diversity of limiting factors, median and mean of the suitability index, as well as a number of other exploratory aspects of the data. These results were visualized in cartographic and tabular format for ease of interpretation. The final results of the zonal analyses can be used to assess the most appropriate scale at which recovery should be studied. It was important that the results of this study were produced and analyzed at the same scale management decisions are being made (Carreno et al., 2007; Wilbanks & Kates, 1999; Clark et al., 2000; Cash & Moser, 2000). Analyzing this data at different geographic divisions also helped determine if recovery trends appear to project themselves on surrounding areas (Cutter, 2001).

## **2.5 Results**

Analysis of the Recovery Indicators portion of the model indicates that the highest level of recovery in the city has been achieved in the areas surrounding the Broadmoor and Audubon neighborhoods in a concentric pattern. These neighborhoods are located in the south central portion of the city and experienced varied levels of flooding. Broadmoor sits at a considerably lower elevation than Audubon and experienced low to moderate flood depths while Audubon increases in elevation as it approaches the river to the south. As a result it only experienced flooding on the extreme northern end of the neighborhood. The recovery of these areas may result from a combination of higher elevation, low flood levels, and proximity to the increased financial stability of the Central Business District and French Quarter.



**Figure 2.2: Orleans Parish Schools Open as of February 2008 – Represented as Point Data and Interpolated Raster**



**Figure 2.3: Results of Recovery Indicator (RI), Vulnerability Indicator (VI), and Spatial Recovery Index (SRI)**



These results are consistent with the VI outputs for the most extreme portions of the southwestern part of the parish but diverge from the vulnerability data to the north central and southeastern portions of the parish. The lowest level of recovery appears to be consistent with a highly vulnerable swath that runs from the extreme northeastern portion of the parish just south of the lake to the western border. Some discrepancy is seen in this pattern toward the Lake View and Fillmore areas in the extreme northwestern end of the parish. These neighborhoods are highly vulnerable according to the VI analysis but are experiencing moderate to high levels of recovery. Some might argue that the high level of damage in these areas coupled with the higher number of insured homeowners is offering a greater opportunity for recovery to flourish. Further analysis will have to be conducted in order to support this argument. In general there seems to be an inverse consistency between the RI and VI outputs, while the combined SRI output depicts a city with a large area undergoing moderate to slow recovery interrupted by isolated areas of high and low recovery. Figure 2.3 shows the results of all three CMUAs visualized using a red to green color ramp representing low to high levels of recovery or recovery suitability, respectively.

### **2.5.1 Recovery**

A more detailed analysis of the results produced constructive conclusions. Even with each variable being considered equally during the initial study, the statistical analysis of the RI, VI, and SRI CMUAs still provided significant results. The Local Moran's I calculated for the spatial recovery output variable indicated highly significant clustering of data at a 95% confidence interval with a Moran's I Index value of 0.28 and Z Score of 16.9. Furthermore, the results of the Getis Ord  $G_i^*$  Hot Spot analysis indicate moderate to highly significant hot-spots or clustering of high spatial recovery values across the city with a General G Index of .000181 and Z score of 2.13 at the 95% confidence interval. Figure 2.4 demonstrates the recovery pattern associated with the results of the P-Values from the hot spot analysis. This figure demonstrates a significant pattern associated with the recovery indicator results extending from the extreme northwestern portion of the parish through the southeastern edge of the parish. These results appear to suggest that there is an uneven distribution of recovery occurring across the city. While not groundbreaking in nature, these results provide an easily interpreted visual representation of recovery throughout the city. This visualization also presents planners and government officials with a new instrument for identifying those areas that do not follow recovery projections or trends. This ability will, in turn, justify the implementation of comprehensive studies of these locales in order to identify those factors driving recovery in these discrete settings.

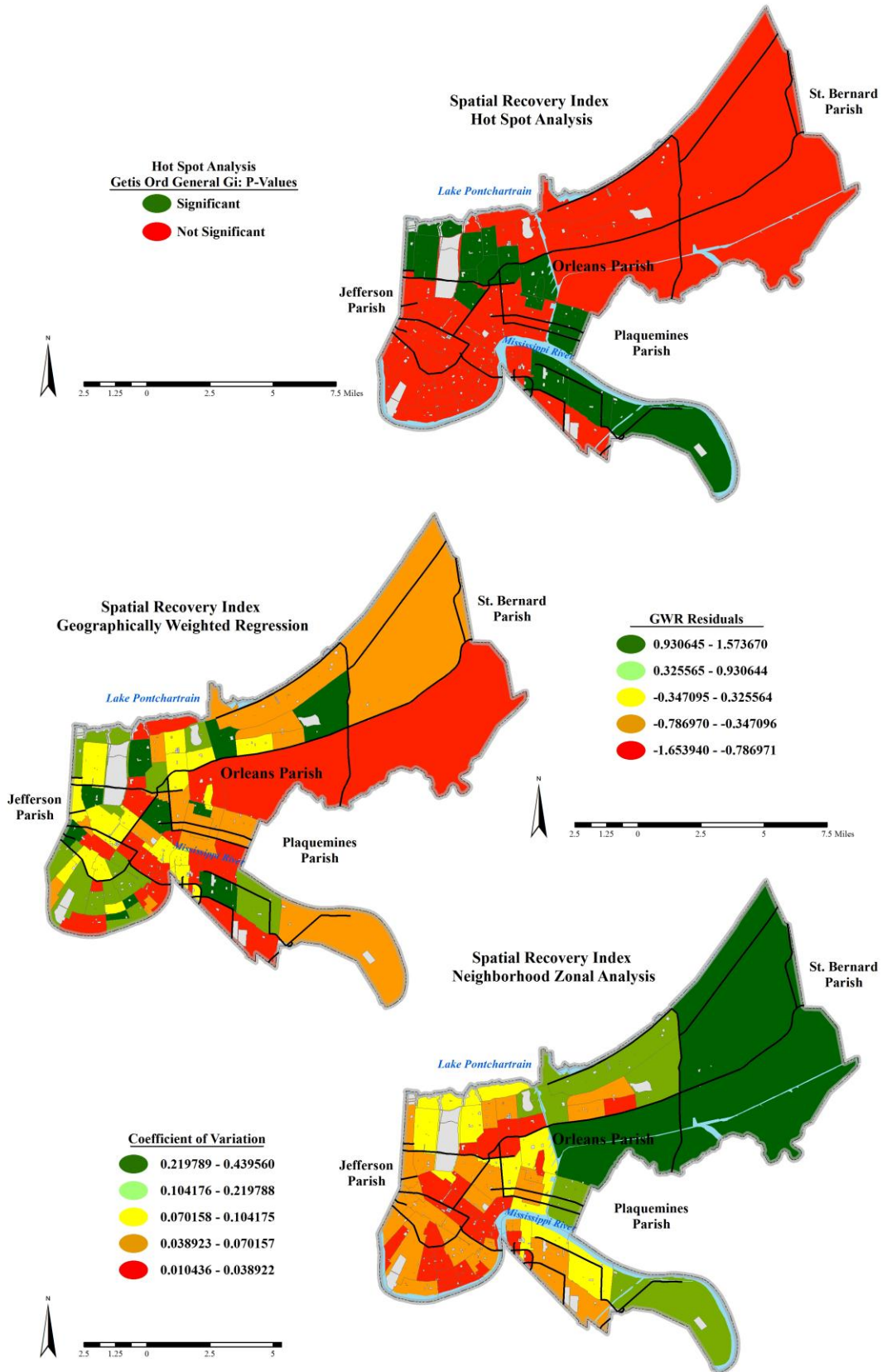
In order to determine the salient factors and spatial variation contributing to this heterogeneous distribution of recovery, a GWR analysis was conducted. Initial results of this analysis are limited in value due to an apparent over estimation of the significance by both the global and local models. There is some indication of low to moderate significance in spatial variation of recovery across the city, as well as evidence of limited influence on the model by a number of the MUAs. The GWR results also indicate that the level of variance in recovery explained by the local GWR model diverges only slightly from the global model, with the coefficients of determination falling in the 99% range for each. This finding could be attributed to the limited number of input variables being considered at this time. Despite this slight discrepancy, the decrease in the Akaike Information Criterion (AKC) from 633.31 in the Global Model to 631.9 in the local GWR, in spite of the varied degrees of freedom, suggests that the local GWR analysis offers an improvement over the results of the global model. The Analysis of Variance

(ANOVA) results from the same procedure coincide with these conclusions, offering an F-Value from the GWR Residuals of 2.314, demonstrating only slightly significant improvement from the global model. Figure 2.4 visualizes the spatial distribution of the standardized residuals from the GWR analysis.

Both the global and local models resulted in high coefficients of determination (99% range), suggesting that both approaches offer a significant explanation of the variance in recovery across the city. A coefficient of determination this high was unexpected and may also be an indicator of the need for more data in the model or the result of issues associated with multicollinearity. It is believed that this high level of inference will be reduced as more consequential datasets become available in the future. In addition, spatial indicators began to emerge from the GWR results. The Monte Carlo significance test was utilized to assess the significance in spatial variation associated with each input variable. This portion of the GWR analysis indicates proximity to education facilities, social institutions, and municipal structures as primary indicators of recovery. The P-Values associated with each of these variables were .87, .62, and .75, correspondingly. Additionally, proximity to education facilities and social institutions were identified as significant contributors to spatial recovery values by a linear regression analysis. These factors had R-Squared values of .88 and .86 respectively when using the SRI values as the dependent variable. No single variable positively correlated with recovery stands out significantly above the rest, but the results of this initial study do suggest that the availability of education facilities and social institutions lend themselves to increased recovery in post disaster situations. This result may indicate a need to include more variables in the model or investigate multicollinearity effects. At this stage of research, the variance in recovery associated with other factors such as economic, municipal, and health services appear to be occurring more by chance. This trend seems to be indifferent to the level of damage or depth of flooding during the storm, though an explicit analysis to determine this relationship was not conducted. Consequently, these results also suggest that the socio-economic status and race of an area prior to a disaster event may have less impact on that area's ability to recover than previously thought. This impression is supported by the similar level of overall recovery seen in the Lakeview area when compared to areas of lower income and greater racial variation (e.g., the Desire and Pines Village areas near the eastern edge of the parish).

### **2.5.2 Scale**

In order to assess the influence of scale on the interpretation of recovery throughout the city, a zonal analysis was conducted. The first portion of the zonal analysis of this study was based on the neighborhood level. Due to a lack of data collected at the census tract and block level, this study did not subdivide the city at a smaller scale. Future research will seek to address the best way to approach this task. By aggregating the data from the SRI CMUA to the neighborhood level, one gets a better sense of the broader geographic influences on recovery than the previous discussion focused on individual parameters. While not as detailed as the GWR results in terms of identifying primary variables contributing to recovery, the results of the zonal analysis do demonstrate the overall trends in recovery seen throughout the city. The coefficient of variation associated with the zonal analysis at the neighborhood levels is illustrated in Figure 2.4. This map demonstrates a high level of variance in results for the eastern side of the parish while little variation is seen in those areas demonstrating high levels of recovery in the central and southern



**Figure 2.4: Results of Hot Spot, Geographically Weighted Regression, and Zonal Analyses on SRI Results**

southwestern portions of the parish. This analysis suggests that recovery can be better understood when interpreted over a larger area. The ability to compare generalized recovery estimates from neighborhood to neighborhood over a larger region offers city planners a generalized view spatial of variations in recovery across the city. In turn, this can lead to valuable understanding of the scale at which management decisions should be made throughout the recovery process. This trend also supports the idea that there may be subtle issues associated with multicollinearity of parameters being used in this study. Viewing the results of this study at the neighborhood level reveals a direct relationship between high level of recovery and proximity to undisturbed/flooded parishes and proximity to the river levees. Proximity to internal levees subdividing the city appears to have limited influence on recovery patterns, regardless of their integrity throughout the storm event. As the zonal analysis is conducted with larger and more stochastic delineations at the zip code and planning district level, one begins to see an overgeneralization of the recovery process. Trends seen at the five meter grid and neighborhood level appear to be lost at these scales. In general, overall recovery of the city appears to be at a much higher level when viewed at these scales. This variation in results further demonstrates the problems associated with artificial masking of data through variations in scale, in addition to the importance of conducting these studies at the local level. A SPAC analysis of all three zone studies demonstrates moderately significant clustering at the neighborhood level with low significance at the zip code and planning district level. The data at these scales are too homogeneous in nature to draw any significant conclusions. Further analysis will seek to assess the progression of recovery at varying scales, most importantly the delineations of leveed areas utilized by the United States Army Corps of Engineers (USACE) and Federal Emergency Management Agency (FEMA) to conduct hydrologic studies and manage policy development in New Orleans.

### **2.5.3 Sensitivity**

The results of this study offer support to the hypothesized program evaluation benefits of a Spatial Recovery Index. The results of the SRI confirm mild significance in the variability of the recovery process and spatial vulnerability at the neighborhood level while also offering insight into those factors which influence recovery rates as well as the ability of an area to recover. These results would certainly lend value to a program evaluation as well as program development if used appropriately. These are not stand alone decision-making tools and should be used in conjunction with qualitative assessments and subjective evidence. Nevertheless, this study offers planners and policy makers the ability to see quantitative measures of recovery at the same scales that management decisions are being made. By using a zonal analysis to aggregate the data based on any jurisdictional delineation throughout the city, planners have the ability to make more informed decisions about resource allocation, mitigations measures, and policy decisions. Of equal importance may also be the application of this type of analysis to pre-disaster planning and vulnerability analysis. Simple modification of this analysis would allow for a proactive assessment of spatial vulnerability and recovery potential distributed across at-risk populations. The ability to quantify the recovery potential of a discrete area has indisputable value in the planning and resource allocation stages of local emergency operation and mitigation centers.

### **2.6 Conclusion and Recommendations**

In general the model development and geoprocessing procedures incorporated in this study were successful and required little editing given the user friendly work environment provided by

ESRI's® model builder application. One issue that will have to be addressed in future studies is associated with edge effects. The City of New Orleans spans multiple parishes and those individuals living on the extreme edge of Orleans Parish undoubtedly utilize facilities and infrastructure located in neighboring parishes. In order to account for these, it may be necessary to buffer the study area and include data within a larger region during the SUA, MUA, and CMUA development phase. The analyses could then be conducted on just Orleans Parish to facilitate accounting for these neighboring influences. Simple visual ESDA of the results of the RI CMUA, VI CMUA, and SRI CMUA demonstrate consistency between model results and did not draw any attention due to overly skewed data or potential outliers. It is projected that the general distribution of recovery throughout the city will see variation with the incorporation of future datasets.

The GNOCDC has indicated that the United States Postal Service (USPS) activity data may be the best indicator of long term population available in the City of New Orleans. Once available, this data will be used to assess the quality of the model results as well as act as a baseline for model calibration. It is believed that a population approaching pre-Katrina numbers will not be reached in New Orleans in the near future. As a result, it is not appropriate to utilize pre-storm population numbers as a measure of the accuracy of this model in assessing recovery.

Given the multi-layered nature of most spatial modeling techniques, it has been reasonable to make use of GIS technology to aid in the development of a recovery index for the City of New Orleans (O'Brien et al., 2004; ESRI, 2006). Utilizing a modeling based approach to this study has allowed for easy adaptability and assessment of recovery in Orleans Parish, regardless of the heterogeneity and nonstationarity of the recovery process as it is dispersed throughout the city (Lloyd, 2007). While many researchers will point out that quantitatively based indices suffer from a variety of fallacies and are victims of poor science and subjectivity, most literature suggests that this approach is still a relevant and acceptable spatial analysis technique (Wilson & Crouch, 1987; Freudenburg, 1988; Weinberg, 1985). Recovery datasets generally have important temporal and spatial dimensions. This means that the collection time and scale are very important in assessing data suitability. This limiting factor means that a GIS based approach is limited to the obtainable data rather than the best data (Cutter, 2001). "Fuzzy Sets" should be coupled with change detection in order to justify the quantitative assessment of qualitative parameters (Carreno et al., 2007).

Recovery from hazards is not only social in nature. GIS and geotechnologies have opened the door to a new chapter in hazards geography that will unquestionably improve upon existing theories and understanding of the spatial aspects of hazards and disasters. This type of study can only improve as data are collected at a finer resolution, in a timelier manner, and more comprehensively. Orleans Parish has not only been guided by the traditional social and economic indicators long thought of as the main contributors to recovery. The results of the early portions of this study appear to suggest that geography does in fact play a role in post disaster recovery. Furthermore, it is important to consider these spatial factors in future management practices and policy decisions as this tool offers leaders another instrument to assess the success of recovery programs. Currently, the recovery program in New Orleans is not working homogeneously. This lack of homogeneity indicates that management decisions regarding recovery in the city are not being addressed at the proper scale. Proactive application and exposure to the results of this type of study may help guide decision makers in a different direction. Every future recovery initiative

is a unique entity that will reveal new issues and trends that were not previously predicted. This study demonstrates that allocation of resources and management focus in post-disaster urban settings should operate within an integrated context of spatial and social variables in order to achieve optimum understanding of the erratic nature of the recovery process.

## **CHAPTER 3: VALIDATING A SPATIAL RECOVERY INDEX: QUANTIFYING RECOVERY AT THE NEIGHBORHOOD LEVEL IN NEW ORLEANS, LOUISIANA**

*It has become common in scientific as well as popular literature to consider floods as great natural adversaries which man seeks persistently to overpower. . . . This simple and prevailing view neglects in large measure the possible feasibility of other forms of adjustment.*

-- Gilbert F. White, 1945

### **3.0 Introduction**

In an attempt to bridge the gap between research and policy, hazards geographers have begun to develop and utilize spatial modeling techniques in order to simulate the real world conditions associated with disaster events. The intent is to develop models which can be used as decision making tools for planners and policy makers. Beginning with the terrorist attacks of September 11, 2001 and the 2002 Tsunami impacting Southeast Asia, the first decade of the twenty-first century has been underscored by an increased frequency of disaster events. This trend was punctuated in 2005 by the impacts of Hurricane Katrina on the Gulf Coast of the United States. While the impacts of other events were often more pervasive in nature, it was the dramatic juxtaposition of Katrina's impacts and the perceived resilience of the United States which captivated the world (Mabrey, 2009). New Orleans in turn, became a living laboratory for hazards and disasters researchers seeking to gain a better understanding of the relational nuances between research, policy, and community resilience. The post Hurricane Katrina archetype offers researchers an unprecedented opportunity to validate existing models, as well as develop and evaluate the performance of new and old indices and modeling techniques. By utilizing current data in spatial models; researchers can assess the quality of new measurement techniques with predictive capabilities that are both scientifically sound and administratively practical (Carter et al., 2004). It is these applied research tools that will guide understanding, management, and response related to disasters in the future (Rodríguez et al., 2006).

The current proliferation of Geographic Information Systems (GIS) software has resulted in a notable growth in the application of spatial indices and geospatial technology applications in hazards and disasters analysis (Gaile & Willmott, 2003). Due to this propagation of software development and research, the task of developing and building spatial models of this nature is technically achievable with little knowledge of spatial theory or hazards. With this being said, it is the validation or performance evaluation of the modeling process which is often overlooked by users. Until a model has been validated and refined, it is negligent to suggest that its results are representative of real world conditions. While research has suggested that no model can be completely validated, the value of predictive science within disaster management should not be overlooked (Villa et al., 2003).

This paper summarizes a performance evaluation of the recently developed Spatial Recovery Index (SRI) (Ward et al., 2009a). That is, how well do the index and its individual components represent the resilience of the study area in which it was tested? Research identifies a variety of validation and evaluation techniques for refining scientific models. These techniques vary based on the accessibility of data, the question the model is trying to answer, scale of the analysis, parametric variables used in the index construction, and the availability of historical points of reference (Schmidtlein et al., 2008; Rygel et al., 2006). As detailed in earlier research by the

authors, there exists a lack of studies focusing on resilience modeling by Hazards Geographers (Ward et al., 2009a). Due to the lack of an accepted metric assessing the resilience of a community to disaster events, it is difficult to verify the reliability of the results of the SRI analysis. This lack of baseline information on the recovery process presented the authors with a number of challenges throughout this work. Consequently, a variety of alternative measures for repopulation and community resilience were utilized to answer three core research objectives associated with this work. The primary objective was to determine if the SRI results concurred with other resilience metrics. The second objective focused on the individual recovery and vulnerability components of the SRI in order to identify complications associated with data aggregation, while the final objective was to determine if these comparative analyses revealed any subtle relationships between social and spatial vulnerability.

### **3.1 Context**

In the spring of 2008 Ward et al. (2009a) initiated a study to assess the evolution of the recovery process in the Greater New Orleans area. The paucity in research associated with the recovery portion of the hazards life cycle was cited as the primary motive behind the study. Second to this was a desire to gain a better understanding of spatial components and indicators of recovery. Accordingly, a SRI was created to quantify resilience at the neighborhood scale across the city. For the purpose of this study, the term resilience is seen approached from a socio-ecological perspective and is defined as the ability of a community to recover from the impacts of a disaster (Adger et al., 2005). The selection of the neighborhood resolution was related to the idea that previous indices associated with resilience were developed at too coarse of a scale to assist with policy decisions. It was posited that the ability of a model to produce results that could be aggregated at finer scales, would better serve communities in the development of policy and distribution of mitigation funds. At the time, the city was more than two years removed from the landfall of Hurricane Katrina. While the city was and still is considered to be in the recovery process, this was a sufficient time period for measurable and significant recovery to occur.

The SRI application in New Orleans utilized a raster based linear overlay technique based on a five meter grid cell array consistent with the elevation data for the study area. The choice of a raster based analysis as opposed to a vector based investigation allowed for a better representation of the influence of specific data points over the entire community. Converting all of the datasets to a raster based format with the same grid cell distribution also homogenized the various data sources and allowed the model to produce results which were more representative of real world conditions and not limited to the discrete results associated with vector based approaches (DeMers, 2002). The SRI is based on the theory of distance decay and utilizes Euclidean distance to interpolate raster surfaces from vector files. Due to the lack of academic knowledge or a justifiable reason for weighting, all variables in this model are considered equally. As a result, no weighting parameters have been applied to any of the parametric datasets used for this performance evaluation. The model was developed using Environmental Systems Research Institute's (ESRI's) ArcGIS 9.3 platform and is executed through the model builder component of this software. The final result of the model is a five meter grid layer with index scores for each unit in the cell array. This rating can be used to categorize the level of resilience of a particular area based on the recovery indicators.

Prior to the development of the SRI, a great deal of research was conducted on the use of spatial analysis in the study of hazards and disasters, as well as the overall academic focus on



vulnerability and sociological factors associated with disaster events (Ward et al., 2009a). This background analysis revealed a number of themes which ultimately guided the development of the SRI. Most prominent was the conspicuous lack of academic research focusing on the recovery process within the hazards cycle (Ward et al., 2009a). Despite the well documented fact that societies around the world fail to effectively recover from disasters of this magnitude, most research has been concentrated on the subject of vulnerability (Ward et al., 2009a; Cutter, 2001). This tendency was of no surprise given that the epistemic modal for disaster science distinctly separates vulnerability and recovery in the hazards cycle. The documented relationship between vulnerability and recovery referenced during the development of the SRI suggests that vulnerability cannot be measured effectively without accounting for a community's resilience (Ward et al., 2009a; Cutter, 2001). Cutter and Emrich (2006) also noted that social vulnerability is in fact a measure of resilience or ability to recover. While Cutter and Emrich's (2006) research focused on the interactions between the built environment and social networks, it can be postulated that this idea applies to recovery based on those portions of the built environment which allow social networks to flourish (i.e. schools, churches, etc.).

Consequently, this premise led to the question of scale. Vulnerability indices around the globe are conducted at a very coarse resolution (Gall, 2007; Cutter et al., 2008). Current research has pointed to the fallacy behind the use of global/national scales to address local issues (Gall, 2007). While this preference of macro scale research has been cited previously as a popular trend in hazards science over the past few decades, it is probable that this evolutionary direction of the science has arisen for other reasons (Gaile & Wilmott, 2003). Schmidtlein et al. (2008) have pointed to the lack of quality data collected at sub-national scales as one reason why research has been limited to national or regional scales. Additionally, the fact that hazard events generally influence large geographic regions in turn, results in vulnerability indices and hazards research studies that are coincident in scale with these impacted areas. While many case studies have included the application of these indices at a finer resolution, few of these modeling procedures were designed at a scale comparable to a single county or parish in the United States, much less a city. Ward et al. (2009a) identified this flaw in modeling vulnerability as one of the most limiting factors in the application of research findings in policy development. This idea is maintained in current research which suggests that the quantification of recovery may suffer even more than vulnerability from lack of translation into applied concepts (Gall, 2007; Berry, 1980). Recovery and vulnerability start at the local level first, therefore the results of any recovery metric should be delivered at the same scale policy decisions are being made (White, 1973). Cutter lent support to this thought when she implemented a tract level application of her well established social vulnerability index (SOVI) in the city of New Orleans after Hurricane Katrina (Finch et al., 2010). The SoVI index was originally designed to assess social vulnerability at the county level utilizing pre-event data extracted from census information. While U.S. census data appear to be the most obvious source of information when conducting a neighborhood/tract level analysis, there is some concern as to the applicability of this information in post-disaster urban settings (Plyer, 2008). Using alternative population data sources such as the American Community Survey (ACS) is also prohibitive due to the fact that many are collected at a county level. Plyer (2008) has also suggested that the "lag time" between the release of official census data sets coupled with the uncertainty of extrapolations between releases, limits the effectiveness of census information in post disaster and recovery studies. A sensitivity analysis of SoVI results based on census data suggested that changes in scale had little effect on the overall outcome of the index (Schmidtlein et al., 2008). Taking this into consideration when validating the results of

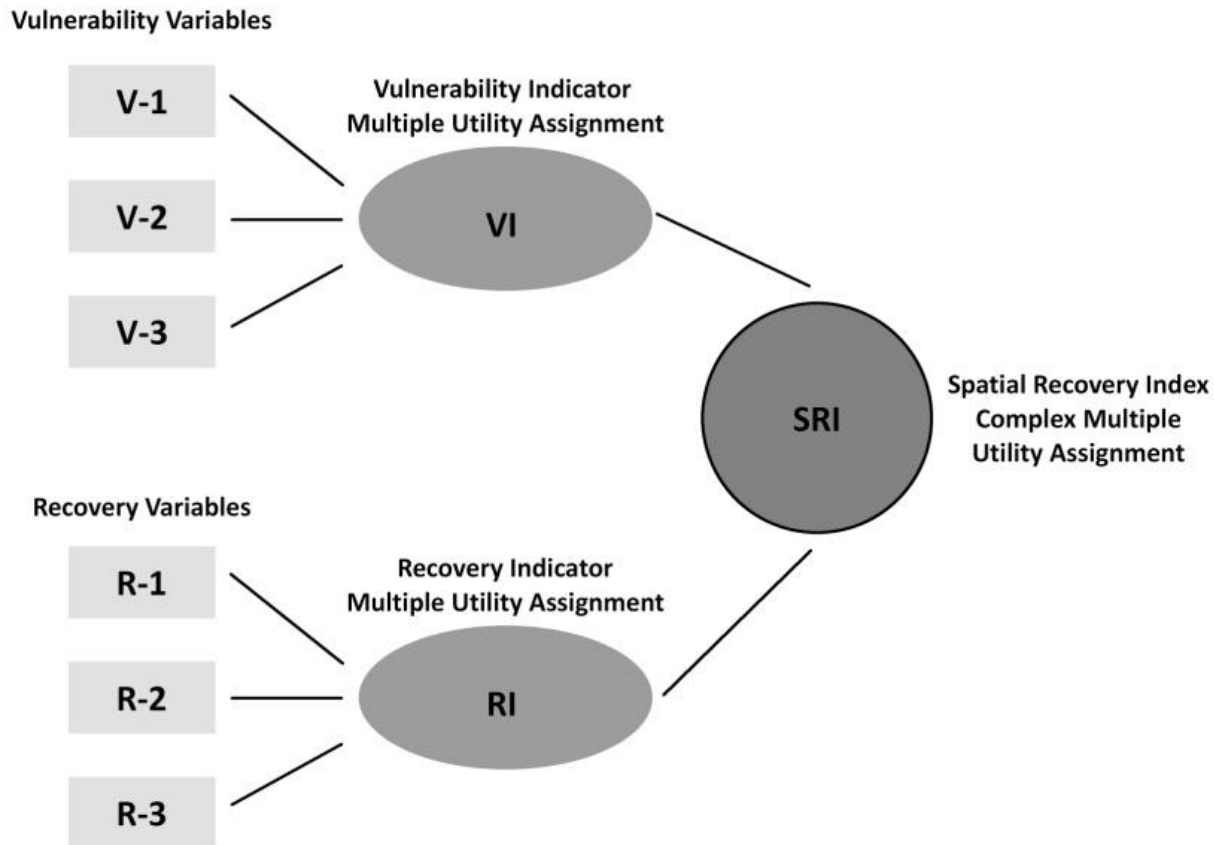
the SRI, it was hypothesized that the index in question could quantify recovery at the neighborhood scale effectively.

### 3.2 Spatial Recovery Index: Components

The SRI model is divided into two parts, the recovery indicators (RI) and vulnerability indicators (VI) portions of the model (Figure 3.1). The RI parameters identified by the authors for this study are portions of the built environment which may influence community resilience by providing a locale for social networks to flourish. Examples of these indicators are included in Table 3.1. For example, the presence of a church in a community will aid in post disaster recovery by offering residents a central location for support, information, cultural preservation, and social interaction. This in turn will result in a higher level of resilience when compared to an equally impacted community without a house of worship. The VI parameters represent data from the natural and engineered landscape, which act as indicators of physical vulnerability based on proximity. These include mitigation structures, protective measures, and potential hazard flash points which act as force multipliers for hazard events (Table 3.1). An individual’s proximity to these locations can have a negative or positive impact on their level of protection or risk from a particular hazards event. In the case of New Orleans, proximity to internal canals that pose a risk of overtopping during flood events presents a potential negative VI. Both the RI and VI parameters are causal in nature, with true impacts to a community not realized until after a disaster event has occurred. In an attempt to account for the relationship between recovery and vulnerability, the model first measures each component individually and then combines these two components into a final output representing overall spatial recovery potential or resilience of the study region. By avoiding demographics data and census information, the SRI presents a different approach to assessing resilience in a community by quantifying the potential for recovery based on an areas physical vulnerability, in conjunction with recovery factors within the built environment.

**Table 3.1: Spatial Recovery Index Variables**

<b>Recovery Indicators</b>	<b>Vulnerability Indicators</b>
Hospitals	Flood Depth
Elder Care Facilities	Roads
Health Clinics	Evacuation Routes
Schools	Levees
Child Care Facilities	Canals
After Care Facilities	Pump Stations
Libraries	Water Bodies
Banks	Elevation
Grocery Stores	
Fire Stations	
Post Offices	
Worship Facilities	
Recreation Facilities	



**Figure 3.1: Spatial Recovery Index**

This output should not be misinterpreted as an actual recovery level but as a guide to the varying levels of resilience throughout the city. Comparing this recovery potential to established metrics of recovery/vulnerability will assist in validating the efficacy of this model for producing mitigation guidance and in turn determine if the neighborhood scale of the post processing zonal analysis is suitable.

### 3.3 Spatial Recovery Index: Results

The SRI was executed and run on data in Orleans Parish as of February 2008. The initial analysis of the results of the SRI produced significant statistical clustering in the VI and RI components of the SRI, suggesting that the index could be used to measure resilience at varying levels throughout the city. These results demonstrate an uneven distribution of recovery across the city with significant clustering of areas experiencing high levels of recovery or exhibiting high levels of resilience. The model output depicts a city with a large area undergoing slow to moderate levels of recovery punctuated by isolated areas of rapid recuperation, as well as pockets of little to no progress. The model isolated the Audubon and Broadmoor areas as having the highest level of revitalization. Table 3.2 lists the neighborhoods with the highest and lowest SRI, RI, and VI component scores as produced by the SRI.

When broken down into the individual RI and VI components, the results of the model appear to be more conclusive and significant than those produced by the composite SRI. The RI and VI components tend to have an inverse relationship and indicate the slowest area of recovery to be

coincident with a highly vulnerable locale that extends from the extreme northeastern portion of Orleans Parish just south of Lake Pontchartrain to the western border of Orleans Parish (Figure 3.2). Figure 3.2 illustrates the results of the composite SRI which offer an overview of the capacity for recovery as predicted by this model. The 2008 Community and Regional Resilience Report (Cutter et al., 2008) indicates that variations in demographics and number of insured properties may be resulting in the skewed appearance of these neighborhoods. In other words, these neighborhoods do not contain an even distribution of homeowners, income, or flood insurance coverage.

A Geographically Weighted Regression (GWR) analysis was used in this initial study to help identify the specific factors contributing to the anisotropic distribution of recovery across the city (Ward et al., 2009a). The results of this analysis offered limited conclusions which were attributed to the lack of data input into the model. These limited results did suggest that the largest level of influence on community resilience was associated with the education facilities, social institutions (i.e. churches), and municipal establishments input into the model. Of particular interest was the relative importance demonstrated by churches and religious institutions under the “social institution” multiple utility assignment in the model. While difficult to quantify, it appears as if the presence of an active church/worship center in the community offers greater benefit to the recovery process than any other single portion of the built environment incorporated into the SRI (Ward et al., 2009a). While this concept offers innumerable questions and research opportunity, it must be noted that the SRI results did not offer any explanation beyond recovery potential in relation to proximity to these establishments.

Variation in recovery associated with economic and health services data appear to be more random in nature, and did not demonstrate any significant relationship to flood depth or damage levels. This result was of particular note as it suggested that pre-event socio-economic status may have less impact on resilience within a community than previously thought. While an interesting topic worth further examination, Ward et al. (2009a) stopped short of declaring an explicit conclusion on this relationship based on the SRI output. They in turn recommend a higher level of analysis to determine if this correlation actually exists.

Subsequent analysis was conducted to examine the effects of varying scales on the results of the SRI. Based on the outcome of varying zonal analyses it appears as if the greatest level of detail regarding recovery potential can be extracted from the neighborhood level analysis. Grouping the SRI data at increasingly coarse resolutions tended to result in problems associated with data visualization and ecological fallacy within model results (Schmidtlein et al., 2008).

While not overwhelmingly significant, the results of the first iteration of the SRI in New Orleans, Louisiana, were positive enough to indicate a need for further study. In order to enhance the SRI, it was necessary to evaluate the models performance by comparing it to existing metrics and proxies which are used to assess recovery. Upon completion, the model can be refined and modified based on the results of the validation process. Gall (2007) provides a thorough methodology for comparing spatial models and validating results in her analysis of global vulnerability indices. This comprehensive study will act as a point of reference for the evaluation of the SRI. While there is a paucity of existing quantitative metrics focusing on recovery, it is believed that an adequate performance evaluation can be conducted on the SRI by utilizing an approach which integrates both qualitative studies as well as quantitative proxy measurements for recovery.

**Table 3.2a: Lowest Rated Neighborhoods Based on USPS, RI, VI, SRI, SoVI, and NOI Data**

<b>VI</b>	<b>SRI</b>	<b>SoVI</b>	<b>NOI</b>
Read Blvd East	French Quarter	Viavant	Holy Cross
Milneburg	Viavant	Mid-City	Lower 9th Ward
West Lake Forest	Garden District	Marigny	Little Woods
Read Blvd West	Lake Terrace & Oaks	Bywater	Pines Village
St. Anthony	West End	Holy Cross	Plum Orchard
Florida Dev	City Park	B.W. Cooper	Read Boulevard East
Plum Orchard	Audubon	Central City	Read Boulevard West
Fillmore	St. Roch	Gert-Town	West Lake Forest
Florida Area	Little Woods	Tulane-Gravier	Dillard
Lakeview	Mcdonogh	Black Pearl	Gentilly

**Table 3.2b: Highest Rated Neighborhoods Based on USPS, RI, VI, SRI, SoVI, and NOI Data**

<b>VI</b>	<b>SRI</b>	<b>SoVI</b>	<b>NOI</b>
Black Pearl	Desire Dev	Central Business District	Central Business District
Mcdonogh	Milan	Read Blvd. West	French Quarter
Irish Channel	Pontchartrain Park	Village De L'est	Algiers Point
Leonidas	Touro	Lower Garden District	Behrman
Iberville	Gentilly Woods	Lakewood	Whitney
Lower Garden District	Village De L'est	Pines Village	McDonogh
St. Thomas Dev	Mid-City	Read Blvd. East	Old Aurora
Lakewood	Dixon	West Lake Forest	Fischer
Central Business District	Tall Timbers - Brechtel	Lake Terrace	Tall Timbers - Brechtel
Treme - Lafitte	West Lake Forest	Lakeshore	English Turn

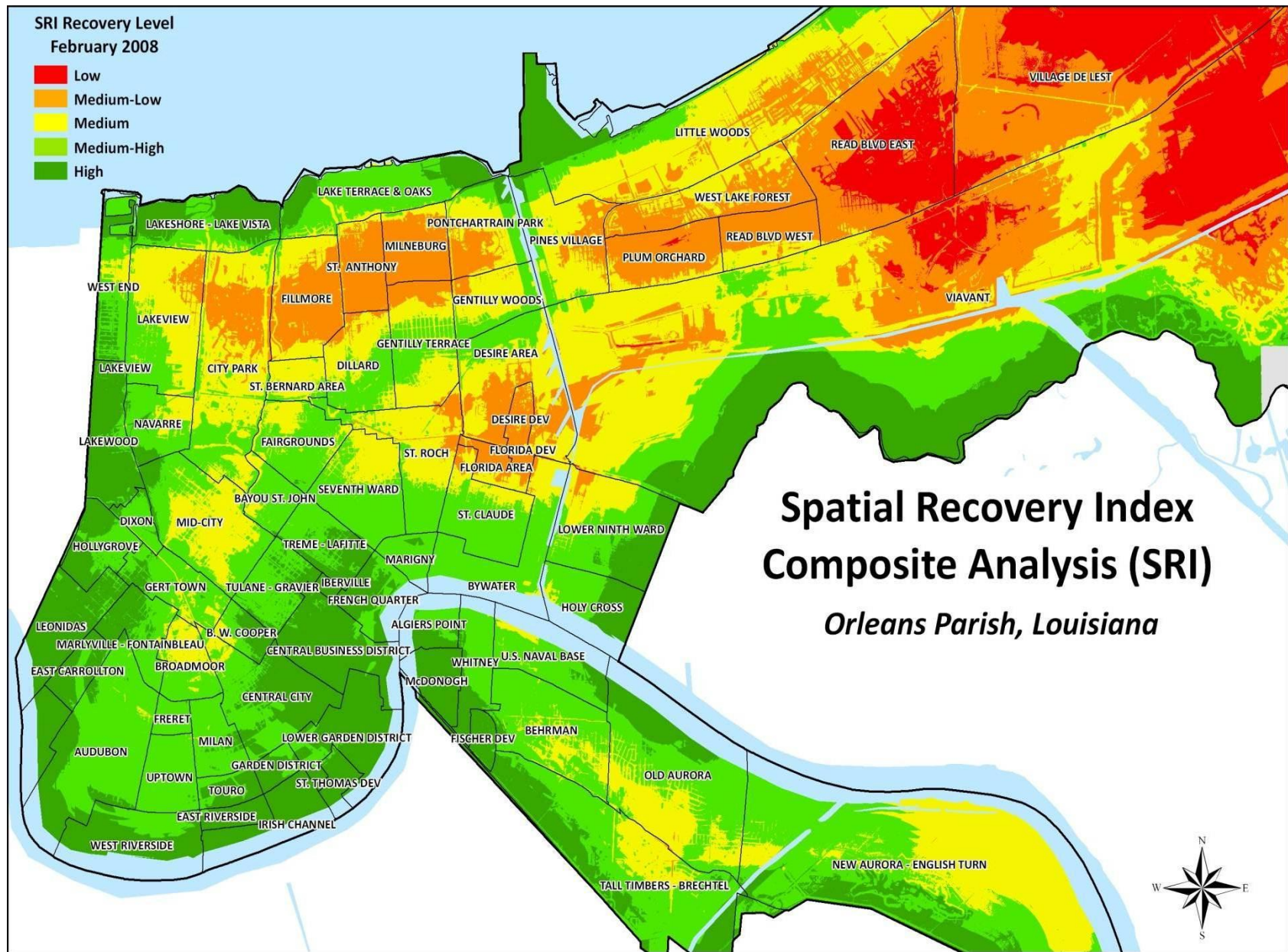


Figure 3.2: Spatial Recovery Index Composite Analysis Output

### 3.4 Evaluation

A model's value in an applied environment is directly linked to its ability to be evaluated, verified, and/or calibrated. Until these quality control steps have been implemented, a model or index will be restricted to the research environment (Gall, 2007). While many academically based models never evolve beyond research and into the applied community, this constraint acts as a contradictory note to the very reason a model should be developed. The purpose of a model is to offer users a predictive and guidance capacity for analysis of real world conditions. In turn, these results can be used to guide policy, decisions, and actions (Villa et al., 2003; Carter et al., 2004). Predictive science has begun to demonstrate efficacy in bridging the gap between traditional and applied research. In turn, the need for validation of prognostic modeling techniques is only going to increase over the next decade (Villa et al., 2003). Despite its obvious significance, basic research demonstrates that this portion of the model/index development process seems to be one of the most misunderstood across scientific disciplines. Of greatest importance is the understanding that no model can be categorically verified, validated, or calibrated with one hundred percent certainty (Oreskes et al., 1994; Carter et al., 2004). The results of a model should never be seen as more than a simulation or representation of real world conditions. The stochastic and varied nature of natural and human systems makes it too complex to predict with complete certainty.

In regard to the SRI, the authors have selected an evaluation process over verification or calibration. Oreskes et al. (1994) states that the process of verification is one that seeks to establish "truth" in its outcome. She goes on to state that this "truth" is impossible to find in modeling practices due to the uncertainty of input parameters leading to the development of models within an open system (Oreskes et al., 1994). Only those techniques produced in a closed system with complete understanding of all variables can lead to "truth" in the verification process (Oreskes et al., 1994). Regarding calibration, it is noted that a model cannot be "calibrated" without a historical backlog of the observations and data as well as sufficient information about existing conditions (Clarke et al., 1996; Oreskes et al., 1994; Carter et al., 2004; Willekens, 1983). It is this backlog of information that will be used to refine the independent variables utilized in the model to produce an outcome reflective of real world conditions. Carter et al. (2004) states that the only way to generate predictive capacity in a model is to calibrate it with historic data. In the case of the SRI, the lack of quality data associated with recovery makes calibration a difficult notion. On the contrary, the concept of evaluation is simply one that is seeking to define legitimacy in the results of a model (Oreskes et al., 1994; Gall, 2007). While the evaluation process is not used to determine absolute truth or fine tune the particulars of a model, it can be used to determine whether or not the model offers users a logical and consistent depiction of the system it is meant to explore. A valid model in no way elicits causality or certainty, but offers a vigorous guide for decision making and further investigation.

When evaluating a spatial model, a variation in errors with the model can be identified. All models suffer from at least one type of error. These problems and assumptions can only be improved through iterative development and time (Clarke et al., 1996). The first and most well documented type of error is associated with the completeness, scale, temporal resolution, and availability of input data or parameters (Clarke et al., 1996; Fotheringham et al., 2002; Schmidtlein et al., 2008; Oreskes et al., 1994). Additionally, models are often subject to inaccuracy related to model development/structure or aggregation of variables (Schmidtlein et

al., 2008; Fotheringham & Wegener, 1999). It is hypothesized that the modular approach of the SRI may be susceptible to this type of error due to the iterative levels of aggregation and reclassification seen throughout the modeling process.

Finally, the scale of a model may also be considered one of its greatest sources of error (Carter et al., 2004; Longley et al., 2005; Schmidtlein et al., 2008). This is not restricted to the overall scale of the area being studied, but also the scale of each parametric variable included in the analysis. Lastly, it must be noted that a supplementary source of error in the assessment of spatial models may arise in conjunction with the metrics used to determine the sensitivity of the model (Gall, 2007). While the use of proxies for evaluation of a model is often the only viable approach, Gall (2007) has documented variations in the effectiveness of this approach when comparing results between indices and within indices. Nevertheless, in the absence of an established measurement of resilience, the SRI will have to be evaluated using alternative metrics for resilience.

The very act of assessing sensitivity is not a simple and established process with a single academically accepted method. Due to the exploratory nature of the SRI, the authors have considered a variety of approaches. Willekens (1983) offers a robust and statistically complex validation process which relies heavily on the use of modified models and techniques from other scientific disciplines. While drawing comprehensive and complex conclusions from this type of evaluation is easy, the qualitative nature of some of the SRI input variables makes the Willekens (1983) approach inappropriate and overstated for this study. When considering the variation in input data sources and quality, the authors decided that a combined qualitative and quantitative approach to performance evaluation would be the most appropriate method to employ. While research indicates that quantitative analysis has been the norm in validation of spatial models over the past three decades, one cannot overlook the burgeoning community of researchers utilizing evaluation techniques that are not empirically based (Liang et al., 2005). Both Gall (2007) and Cutter et al. (2008) have cited the value of qualitative techniques in validation of scientific measures as well as assessment of community resilience. Clarke et al. (1996) and Gaydos et al. (1995) have also noted the importance of qualitative visualization and animation of model results in order to garner more focus from the applied community. As such, the authors have elected to compare the results of the SRI qualitatively to the “2009 New Orleans Index” report for the first stage of evaluation. Subsequent analysis will use alternative metrics for repopulation to gauge the value of the SRI results, as the repopulation of a community is being considered as a proxy measure for resilience in this work. These metrics include the United States Postal Service (USPS) activity/count data as well as the total number of Louisiana “Road Home” Grant awardees in Orleans Parish. In addition, the results of the SRI will be compared to the census tract level analysis of the Social Vulnerability Index (SoVI) in New Orleans (Finch et al., 2010).

### **3.4.1 Evaluation: New Orleans Index**

The New Orleans Index (NOI) (GNOCDC, 2009) is a semiannual publication produced by the Brookings Institute in conjunction with the Greater New Orleans Community Data Center (GNOCDC). In December of 2005 the index was released in its first format to offer researchers and community leaders a qualitative overview of recovery in the city of New Orleans. Using a variety of recovery indicators, the report focuses on the assessment of social and economic recovery throughout the city and is produced every six months. The decision by the authors to utilize the first 2009 release of the NOI is tied to the scale of the reports results. Prior to this



release, the research findings have been released at a generalized scale, offering only an overview of the city as a whole with occasional highlights of specific communities. The first release of 2009 saw the data and recovery broken down into neighborhoods and reported at the planning district level, thus making it a more appropriate tool for the evaluation of the SRI output. The report aggregates recovery into population, job recovery, residential housing status, road home funding, and rebuilding categories with specific details associated with education, labor force, and finances considered under each specific category. For the purpose of this evaluation, exploratory spatial data analysis will be used to compare the recovery indicator findings of the GNOCDC (2009) report to the results of the VI, RI, and final components of the SRI.

The NOI reports that more than half of rebuilt neighborhoods in New Orleans as of November 2008 are in those areas which experienced the least amount of flooding, indicating that the most vulnerable areas in the city are not recovering at the same rate as portions of the city which did not flood. While generally consistent with both the VI and RI components, these findings tend to vary slightly with the combined final output of the SRI. Neighborhoods such as Broadmoor, Leonidas, and Holly Grove experienced significant flooding after Katrina as well as subsequent flooding during Hurricane Rita one month later. Despite this, these areas are considered by the SRI to have some of the highest potential for recovery and are reported to be experiencing significant recovery by the media and the GNOCDC (GNOCDC, 2009). In addition, the total number of housing permits issued in these areas also seems to be coincident with this neighborhood recovery, indicating an increase in new development in these neighborhoods as opposed to renovation of damaged homes. The SRI output also indicates that the southern portion of the Ninth Ward and the Seventh Ward should be experiencing moderate returns due to the social capital in place in these neighborhoods. This is not substantiated by the NOI or any other source of information at this time. There are a number of reasons for this discrepancy, including the notion that flood depth and intensity superseded the resilience of the area, but little certainty can be drawn until a more detailed study of these areas is conducted. In regard to the rebuilding of neighborhoods, it appears as if there is increased consistency between the VI and RI components of model, while the composite SRI values offer only moderate correlation with the NOI summary. The total number of unoccupied addresses observed by the NOI is very consistent with the vulnerable swath of neighborhoods identified by the VI and RI components of the SRI. This area extends from Lakeview in the west to Village De l'est in the east. The only discrepancies identified when comparing the NOI unoccupied housing results with the VI and SRI appear to be in the Holy Cross and Lower Ninth Ward neighborhoods. These neighborhoods have SRI results which signify they are more resilient than the NOI indicates.

The NOI also reports that the greatest increase in the job sector in New Orleans has been seen in the fields of education and health. The demonstrated growth in the education field is mimicked in the SRI results, as it indicated the education variable had one of the most significant influences on resilience. The issue of healthcare was of particular interest to the authors. Although the influence of healthcare facilities on recovery illustrated by the SRI study does not reflect the significant growth seen in this sector by the NOI, the authors feel this is easily explained by looking at the SRI input variables. The SRI only considered major hospitals, elder care facilities, and subsidized health clinics in its health care variable. This data availability issue meant that a large number of general practice, family medicine, and specialized surgery, outpatient, after hours, and rehabilitation facilities were left out of consideration. These facilities undoubtedly

offer a large number of employment opportunities and had they been included in the SRI analysis, healthcare would have increased significantly in relative importance to the model results.

Turning to the economic sector, the NOI suggests that the greatest concentration of job recovery is located in the Central Business District, Warehouse District, and French Quarter, Black Pearl, and Tulane/Gravier neighborhoods in the southwestern portion of the city. Both the RI and SRI components of the model lend considerable support to these findings while the VI suggests that the vulnerability within this planning district would limit these neighborhoods' ability to recover. One would expect this area to recover at a higher rate than others due to the influx of money available from large corporations, casinos, and government agencies concentrated in this locale. In addition, the French Quarter acts as the anchor of the large tourist industry upon which New Orleans relies heavily, which in turn makes this area a focal point for recovery.

Neighborhoods in New Orleans East such as Read Boulevard, Plum Orchard, Pines Village, Little Woods, and Village De l'est still contain large numbers of blighted and heavily damaged homes with little sign of progress or recovery (GNOCDC, 2009). This data is supported by all three components of the spatial recovery index with exceptions in the Pines Village and Little Woods area for the RI component. According to the RI scores, these two neighborhoods should have a higher capacity for recovery and in turn have seen more progress in the housing sector.

When assessing recovery of an area by summarizing the number of homes awarded Louisiana Road Home funding, the NOI highlights the Bayou St. John and Pines Village areas of the city as having the highest concentrations of award recipients. This finding is very unusual given the dichotomous split between the VI, RI, and SRI scores in these two areas. Based solely on the SRI analysis, the Bayou St. John region is much better suited for recovery than the Pines Village neighborhood. One would suspect that these two areas would have significant differences in the number of applicants seeking recovery funding from the state despite the similarities in flood depth and duration in these neighborhoods. Also of interest is the fact that the NOI highlights the Fillmore, St. Anthony, and Milneburg neighborhoods as having the highest number of houses sold to the state by homeowners. These neighborhoods sit directly in between the Bayou St. John and Pines Village area and when viewed as a whole offer researchers an interesting area for study. Why do these communities seem to have a higher concentration of participation in government sponsored recovery programs than anywhere else in the city? These areas are largely middle class Caucasian communities which experienced significant flooding with reduced opportunity for recovery based on the RI and SRI data. Are these communities the source of population growth in the faster growing communities of Mid-City, Broadmoor, and Irish Channel? With a little more data, these questions can only be answered in a speculative manner, though the authors believe that a more thorough study of the education and socio-economic demographics of this area might clarify this phenomenon. Determining whether this issue is symptomatic of the level and duration of flooding associated with Katrina or is the result of a more complex social dynamic is not possible with the NOI or SRI data alone.

In summary, the NOI report on recovery at the neighborhood level has offered the authors a number of very interesting findings regarding the SRI, but only at a qualitative level. Based solely on the NOI data, it appears as if all components of the model in question offer at a minimum, limited potential for assessing resilience of a community. With this being said, the RI and SRI components tend to offer more agreement with the NOI data than the VI component

does. The authors felt as if this was expected given that the VI component is focused on spatial vulnerability in relation to physical geography, while the NOI findings were heavily focused on the recovery of the built environment and social/economic networks related to it. As an added benefit, the results of the SRI also offer researchers with a number of unique questions when compared to the NOI findings. It is the answers to these types of questions and subsequent analyses that will lead to an improved version of the SRI in the future.

### **3.4.2 Evaluation: United States Postal Service Data**

While a variety of metrics exist for assessing recovery, the SRI was based on those identified in the 2005 United Nations Tsunami Recovery Report (UN, 2005). This report excluded the measurement of population as an indicator of recovery. While many researchers will suggest that measuring population is the most straightforward approach to assessing recovery, Ward et al. (2009a) excluded the measurement for a number of reasons. In addition to substantial discrepancies in population numbers given for the New Orleans area after Katrina, Ward et al. (2009a) cited the importance of distinguishing between the short term or “opportunistic population” and the permanent population, which would be the actual driving force behind long term recovery. In addition, the work of Takeda (2003) has highlighted the fallacy in using population as a direct measure of recovery due to the inability to quantify “life recovery” within a population estimate. Of all these issues surrounding the use of population, the greatest shortcoming in past disaster events of this magnitude has been disagreement over accurate estimates without a comprehensive door to door census (UNOP, 2007).

In 2006, Plyer (2008) initiated a study to address this issue and determine if a subsequent measure could be used to estimate population following a disaster. Her findings determined that the postal activity count data kept by the USPS could be used with reasonable confidence as a measure of population activity. Plyer (2008) noted that the establishment of a permanent residential address where mail can be perceived is an indicator of an individual who is contributing to the long term recovery of the New Orleans area. While not a discrete population count, this level of activity can provide researchers with an idea of population activity at the neighborhood level within a city. Although the original USPS data are kept at the postal route level, the GNOCDC has established a workflow to aggregate the counts at the neighborhood level and has been making them available to researchers since early 2008. In the absence of any other academically verified population estimate, this dataset represents an appropriate proxy for population, and in turn offers an important substantiation measure for the SRI (Valassis, 2009).

The original USPS data were delivered in percent change in postal activity by census block from August 2005 to February 2008. Using a “dissolve and summary statistic” geoprocessing technique, the data were aggregated at the neighborhood level for comparative analysis. The datasets were then statistically compared using adjusted Z-scores for the VI, RI, SRI, and USPS data. Using the adjusted Z-scores, T-tests demonstrated that there was no significant difference in the VI, RI, and SRI scores when compared to the USPS data at the neighborhood level ( $p = .50$  for VI, RI, and SRI). Further analysis revealed a significant negative correlation between the VI component of the index ( $r = -.61, p < .05$ ) when compared to the USPS data. Of interest to the authors is that this negative correlation between the VI and USPS data is consistent with the trends found by Finch et al. (2010) regarding flood depth and recovery. Both studies suggest empirically that as flood depth or spatial vulnerability increase, the amount of recovery potential

decreases. As flood depth was a primary variable in the VI component of the SRI, it is constructive to see consistency between the results of the two studies.

In addition to the strong correlation between the VI and USPS data, there also appears to be a significant positive relationship between the RI component of the SRI and the USPS data (index ( $r = .58, p < .05$ )). This relationship further supports the supposition that the RI component of the SRI model is capable of predicting recovery levels. The relationship suggests that the population level (as measured by USPS activity) within the city is coincident with the spatial density of recovery indicators throughout the built environment.

When viewed as a whole the composite output of the SRI does not perform as well as the individual VI and RI components. The insignificant correlation which exists between the composite SRI and USPS data ( $r = -.14, p > .01$ ) suggests limited utility in the SRI as a predictor of recovery potential. This finding is consistent with the aforesaid analysis of the NOI as well as earlier attempts to assess the model's performance (Ward et al., 2009a). The fact that the combination of the VI and RI variables detracts from the performance of the overall index suggests uncertainty regarding the previously hypothesized relationship between community vulnerability and resilience (Ward et al., 2009a).

### **3.4.3 Evaluation: Social Vulnerability Index**

The SoVI was first developed as a county level analysis to assess the level of influence of various social variables on overall population vulnerability (Schmidtlein et al., 2008). It has since evolved into a robust tool capable of quantifying social vulnerability at varying spatial and temporal scales across multiple geographies (Schmidtlein et al., 2008). The exhaustive literature review, application, analytical scrutiny, and peer review associated with the development of the SoVI make it an ideal candidate for assessing the performance of an index in the infancy of its development, such as the SRI. Although SoVI is not purported to be a measure of recovery, the cited links between vulnerability and community resilience suggest that it can be used to assess the performance of a recovery index (Ward et al., 2009a). Considering this relationship between vulnerability and resilience, it is hypothesized that areas exhibiting high levels of vulnerability according to SoVI will demonstrate lower levels of recovery according to the SRI. In contrast, those areas with low SoVI values will reveal higher levels of recovery based on the perceived level of resilience associated with low social vulnerability.

Finch et al. (2010) utilized SoVI at the tract level to examine disparities in social vulnerability across New Orleans. The study had mixed findings and suggested that preexisting social vulnerability conditions do have an influence over recovery after a flood event, although, flood height appears to be a more valuable metric for assessing recovery. As the flood depth was one of the variables input into the VI component of the SRI, it is not appropriate to assess the performance of the SRI with this factor. The study also identified some alarming trends in recovery patterns which point to a burgeoning inequality between social classes, as well as conclude that recovery on the census tract level is occurring more rapidly in those areas considered by SoVI to be less vulnerable and is stifled in areas with medium to high social vulnerability. These findings suggest a need for a way to assess social vulnerability and physical vulnerability concurrently to quantify community resilience more accurately. Final conclusions of the study point to a new recovery trend heavily dependent upon individual wealth and financial stability as a driving force behind recovery as opposed to pre-event status.

The SoVI values for each tract were then mapped using a standard deviation (SD) approach. Low vulnerability areas were delineated by those tracts whose SoVI score was less than -0.5 SD from the mean and high vulnerability areas were those with scores greater than 0.5 SD from the mean (Finch et al., 2010). Medium vulnerability was denoted as all areas in between (Finch et al., 2010). To gain a better understanding of the association between the SoVI results and those of the SRI and its components, the raw VI, RI, and SRI data values were calculated at the tract level using a zonal analysis. These values were then standardized using the same SD scale as the SoVI analysis. This process enabled both the SoVI and SRI data to be compared spatially through the use of a bivariate mapping technique commonly used by the Hazards and Vulnerability Research Institute (University of South Carolina) to visualize the relationship SoVI shares with additional environmental factors. Figure 3.3 illustrates the results of the bivariate mapping of SoVI-SRI, SoVI-RI, and SoVI-VI respectively. In view of the theorized inverse relationship between vulnerability associated with SoVI and recovery levels associated with the SRI, the performance of the SRI was evaluated based on the density of census tracts displaying the High SoVI/Low SRI (red) or Low SoVI/High (red) SRI relationships. The same analysis was conducted on the RI and VI components of the SRI to identify any latent relationships between individual recovery indicators and vulnerability indicators that might be masked by the aggregation of the SRI values.

Of the 181 census tracts in Orleans Parish, only 14 fell within these two categories for the composite SRI Analysis (18 for the RI and 14 for the VI), suggesting a limited or constant correlation between the results of the SRI and SoVI analyses. The lack of correlation does not suggest that the SRI performed well as a measure of resilience. While there appears to be minimal relationship between SoVI and the SRI, the bivariate mapping procedure did exemplify a high level of consistency between the RI, VI, and SRI outputs when compared to SoVI. A statistical comparison of adjusted Z-scores similar to that conducted for the USPS-SRI analysis supports the findings of the bivariate mapping technique, offering very weak to no correlation between the VI, RI, and SRI variables when compared to the SoVI data ( $r = .14, .01, .10; , p > .01$ ).

The lack of significance in correlation between these two metrics could be the symptomatic of limitations of SoVI at the tract level cited by Finch et al. (2010) in the New Orleans study. Finch et al. (2010) suggested that SoVI could be used as a metric for the extreme ends of the resilience spectrum, while it had restricted capability for representing middle class behavior. The complexity of issues facing the wide ranging middle class population in urban areas is reflected poorly by SoVI analyses (Finch et al., 2010). It is posited that this understudied limitation of the SoVI may be contributing to the lack of correlation between the SoVI and the SRI data. This deficiency is not considered an indictment of the efficacy of either index as it relates to their ability to assess community resilience. Much to the contrary, it suggests a need for improved research associated with the use of spatial and socioeconomic indices to quantify vulnerability/resilience in this marginal population group. While the SoVI study suggests overall that the SRI performed poorly as an indicator of recovery potential, it does generate a significant amount of interest on the part of the authors.

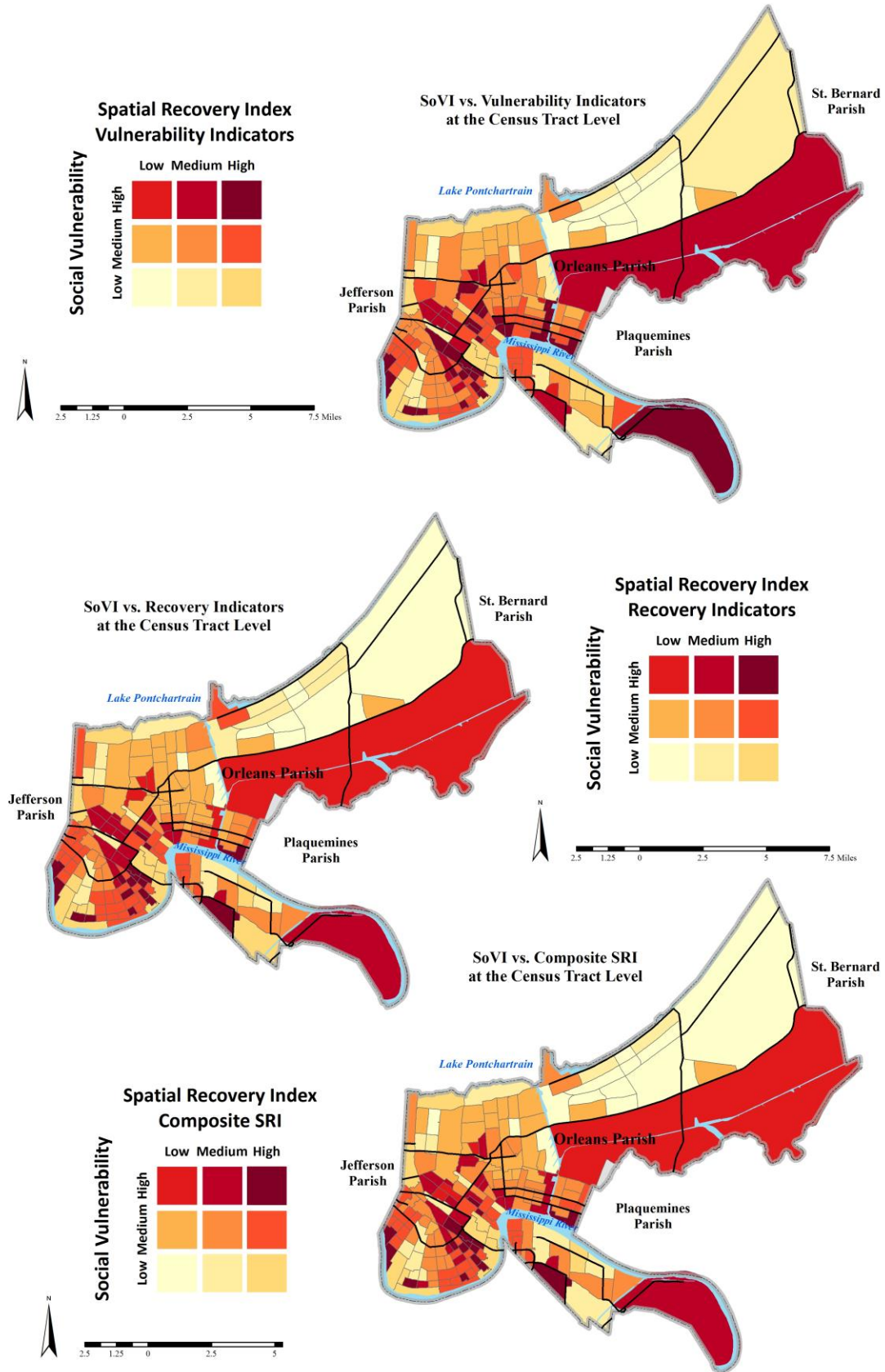


Figure 3.3: SoVI and SRI Bivariate Analysis

The links between vulnerability and resilience have been hypothesized by the authors as having a strong inverse relationship, one capable of offering predictive capabilities if measured accurately. The glaring lack of relationship between the vulnerability and resilience metrics in this analysis suggest a far more complex and intricate relationship between these two factors, one which may not be able to be defined.

### **3.5 Results & Discussion**

From a qualitative perspective it appears as if a significant number of neighborhoods classified by the SRI as highly resilient are recovering better than neighborhoods that were determined to have limited recovery potential. On the surface this appears to be an encouraging corollary for the SRI model, but one must be careful not to assume that low vulnerability is always equal to a high level of resilience. The SRI model cannot be used to determine the amount of damage which will occur in an area and in turn cannot account for one area having greater opportunity for recovery based on increased damage levels (the tool assumes an equal distribution of damage across the city). It appears that neighborhoods not significantly damaged by the storm may be popular locales for returning population due to the fact that infrastructure and facilities are already in place. This is of particular interest in those areas that lie on the margin between middle and low income as a significant influx of differing socio-economic populations will have distinct long term impacts on the traditional make-up of these resilient neighborhoods. In some cases the results may be beneficial while others will see an increased potential for negative effects on home value, increased crime rates, etc. Long-term monitoring of this situation may see shifts in traditional neighborhood boundaries in New Orleans, as the original delineations were loosely based upon race, culture, economic status, and land use (GNOCDC, 2009).

Upon completion of the performance evaluation for the SRI, there appears to be a consistent theme with the data being analyzed. When looking in detail at the index make up, one can easily identify minor issues with scale, data consistency, and temporal resolution. These were hypothesized by the authors to be the most obvious issues with the index. In contrast, the evaluation process indicates that an error in component aggregation appears to be the most significant limiting factor to the index. The statistical comparisons of the SRI components to the qualitative NOI and quantitative USPS data both demonstrate clearly that the two main modules of the SRI offer better predictive value than the combined SRI output. Overall, the RI portion of the model appears to produce the most justifiable results when compared to the proxy measures used in this evaluation. While not as robust as the entire SRI is intended to be, this finding does cast a positive light on the direction of this research.

Based on the cited links between vulnerability and recovery, it seems that a combination of the spatial recovery indicators and spatial vulnerability indicators throughout the city would produce a legitimate depiction of resilience at a scale appropriate for policy application (neighborhood level). While the comparison to the NOI was not as evident in this regard, it also demonstrated differences in the relationship of component results when compared to a qualitative assessment of recovery. Based on these results one is led to believe that resilience or the ability to recover can be considered separately from vulnerability despite their documented correlation. This trend was further evidenced by the comparison of the SRI analysis to a SoVI analysis similar in spatial and temporal scale. As a measure of population vulnerability, it was assumed that the SoVI results would demonstrate a strong negative correlation with the SRI data, rather than the limited low correlation presented by the analysis. These results offered little in the way of evaluation of

the SRI, but offered a substantial amount of material for future research into the relationship between vulnerability and resilience at varying socio-economic levels.

While the results of this validation process were not as successful as hypothesized by the authors, it is clear that a modification in model structure may ultimately produce the desired outcome. It must also be noted that data limitations in both modules may also be contributing to a lack of conclusiveness in the final output. Future emergence of other datasets acting as metrics or indicators of resilience may also lead to further refinement of the SRI. Of particular interest to the authors is the evidence identified by Finch et al. (2010) that suggests that a disaster intensity threshold exists for each specific event. Once this level of impact has been surpassed, the pre-event resilience or vulnerability of an area is superseded by the damages inflicted. While only briefly discussed by Finch et al. (2010), the idea that disaster intensity trumps pre-event conditions when assessing resilience has a potentially significant impact on the development of the SRI model. Is there a specific flood depth or duration that is reached which renders pre-event resilience obsolete? Is this threshold geographically specific based on local building patterns and techniques? Does the existence of such a threshold render resilience and vulnerability modeling ineffectual?

The SRI suffers from the parts being better than the whole, and in turn needs to have its aggregation classes reevaluated. The limitations of model construction have been well documented in past research and do not represent an insurmountable problem. While the SRI components appear to portray what is occurring at the neighborhood level in New Orleans legitimately, the issues behind the loss in predictive value when combined into a single output need to be investigated. Failing to account for this issue will define this tool as ineffective in the eyes of government practitioners and leave policy makers with limited support when developing mitigation guidelines. As previously stated, current indices looking at vulnerability and resilience are either too community specific in nature, or developed at a scale that is too coarse for application at the city level. Therefore, it is prudent for researchers to continue moving forward with the development of a recovery index that is applied efficiently and easily across communities and producing results at a practical scale. Subsequent phases of this research will see the SRI modified based on this evaluation and proactively applied to a community conducting a hazard mitigation and risk assessment. It is anticipated that comparing the results of this proactive application to the evaluation of the community by expert stakeholders will further justify the use of recovery indices in hazards management and planning.



## CHAPTER 4: AUGMENTING AUSTRIAN FLOOD MANAGEMENT PRACTICES THROUGH GEOSPATIAL PREDICTIVE ANALYTICS: A STUDY IN CARINTHIA

*The broad problem of flood-loss reduction is that the rate at which flood losses are being eliminated by construction of engineering or land-treatment works is of about the same magnitude as the rate at which new property is being subjected to damage...The construction of new flood-protection works frequently has been the signal for accelerated movement into the floodplain.*

-- Gilbert F. White, 1960

### 4.0 Introduction

While flooding has long signified one of the most ubiquitous hazard risks throughout Austria, one can argue that the catastrophic flood event in August of 2002 represents a seminal moment in flood risk management for the central European nation (European Commission, 2002). The last comparable event to impact this Alpine region occurred in 1899, far surpassing the memory of even its eldest citizens. Without this a posteriori knowledge, it is difficult to imagine flood mitigation being at the forefront of modern Austrian political agendas. On the surface, this statement appears to be an appropriate depiction of the reason behind the devastation in 2002, but a closer look at flood history and flood management in Austria reveals a different story. Dating back to as early as 1954, the Austrian portions of the Lower Danube River Basin have been subjected to intense flood events resulting in significant economic damages and loss of life (Arellano et al., 2007). Although none of these events have equaled the 2002 flood, their frequency and intensity have steadily increased, with the first decade of the millennium realizing the most concentrated period of flooding in modern history (Frei et al., 2006; Caspary, 2004). Coincident with the steady rise in flood events throughout the country since the mid-twentieth century has been a maturation of flood mitigation strategy (Arellano et al., 2007). When considering the fact that Austrian authorities have frequently enhanced flood mitigation efforts over the last 60 years, it is reasonable to question why flooding since the 2002 event has continued to result in such negative impacts throughout the country.

To shed light upon this inquiry, the authors have expanded upon flood recovery modeling research initiated in 2009 in the Province of Carinthia. Utilizing a spatial recovery index as a proxy for flood resilience in the region, the 2009 study sought to define local flood risk in a context different from the typical engineering based analyses (Ward et al., 2009ab). The results of this analysis relied upon the application of a recently developed geospatially based model for identifying flood recovery potential. With the application of this model at the core, the intent of the 2009 study was to:

1. Determine if a geospatially based model developed for an urban area in the United States could be applied to other regions throughout the world.
2. Identify what factors might limit the effectiveness of model execution and value of results.
3. Provide a tool by which planners in the Carinthia region could assess vulnerability to flooding.

While reviewing literature and exploring the results of this analysis, the authors were able to not only answer the aforementioned questions, but also identify a number of subtleties underlying the subject of flood risk within the study region in southern Austria. More revealing than the spatial distribution of recovery potential was the lack of research and information focused on the socio-cultural aspects of flooding. When considered in conjunction with the structural and engineering focus of current literature on flooding in the region, it becomes clear that an alternative approach to assessing flood risk is necessary. It is speculated that many flooding problems in Austria stem from anthropogenic alterations to rivers and streams (Arellano et al., 2007). Over-managing these features has led to a false sense of security, stimulated development in hazard zones, and exaggerated the intersection between vulnerable populations and the physical elements which put them at risk. Continuing to rely on flood mitigation strategies based primarily on the engineering and physical factors driving risk may be inadvertently increasing public apathy toward flooding. Moving forward, it is important that officials charged with flood control began to adopt a more investigative approach to assessing risk.

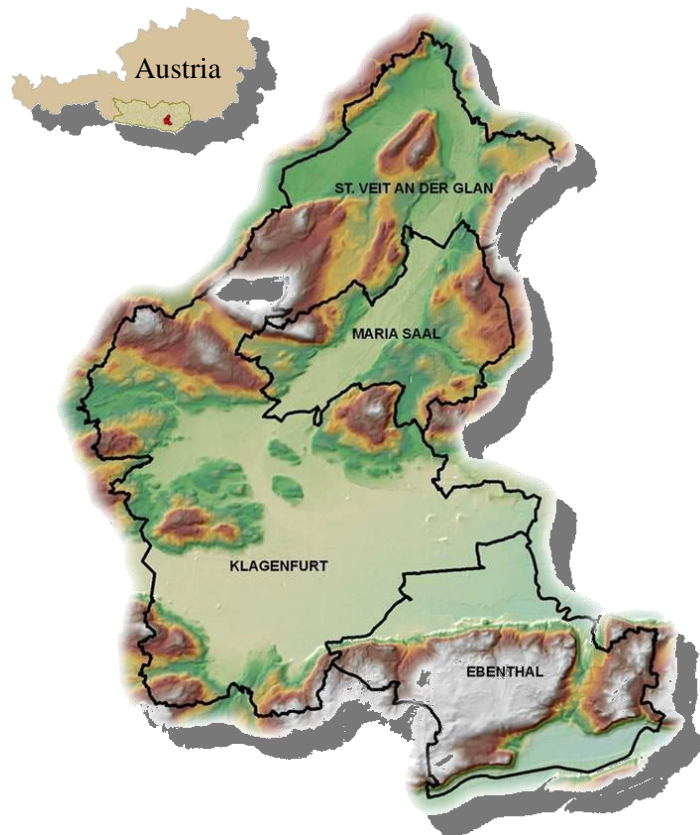
#### **4.1 Flood History and Study Region**

Central Europe has long been at significant risk from flood related hazards, especially those areas lying within the Danube Basin (Zischg, 2011). Extended periods of rain and flash flood events associated with the tributaries of the Danube have been characterized as the most important hazard impacting Austrian communities, yet, the hazardscape of many portions of the country remain largely misunderstood (Gaume et al., 2009). Exasperating the impact of this risk is the fact that over 70% of the Austrian landscape is covered by mountainous terrain (Keiler et al., 2010; Staffler et al., 2008). This rugged topography limits developable land and in turn has led to unsustainable development patterns and dense population distribution (Embleton-Hamann, 1997; Url & Sinabell, 2008). When one considers this in conjunction with the fact that over 7.5 million inhabitants live within the 96% of Austrian territory drained by the Danube; the grave nature of this risk is quite humbling (Schönerklee, 2008). An analysis of the 2002 flood event reinforced this threat, suggesting that over 40% of the flooded areas were heavily developed based on legal land use planning ordinances (Paulus et al., 2004). An Embleton-Hamann (1997) study also advises that 9%-12% of structures in Austria are considered to be at extreme risk to floods.

To state that the 2002 flood event did not result in a renewed interest in limiting the impacts of hazards would be misleading. Austrian authorities have taken significant steps to understand the driving factors behind floods, quantify their risk, and communicate this risk to planners and citizens. Furthermore, the need for increasingly sophisticated understanding of flood risks has not gone unnoticed by the European Union (EU) (Paulus et al., 2004). The EU Flood Directive developed in 2006 has called for a reduction in flood related risks to health, property, and infrastructure (Paulus et al., 2004). Leading up to the establishment of this directive, the nations impacted by the 2002 event gathered at a workshop hosted in Vienna. Experts in numerous flood related fields worked to develop a series of recommendations related to flood risk reduction strategies (Nachtnebel, 2007). The fatal flaw in this workshop, as pointed out by Nachtnebel (2007), was the fact that the shortcomings to flood risk management identified in Vienna were no different than those identified following floods a half century prior. To this end, Nachtnebel (2007) has suggested that insufficient implementation and coordination are the primary limiting factors to improved flood risk management in Central Europe.

This lack of re-assessment on flood mitigation planning is not as pervasive as Nachtnebel (2007) might suggest. Varying levels of action can be seen across the Central European countries represented at the 2003 Vienna workshop, and in turn, several regions of Austria have seen a proactive movement toward improved flood management. Of particular interest is the federal state of Carinthia. Following the 2002 floods, the Hydrologic Department of Carinthia developed a database-driven software system to house flood and water related data for retrieval and analysis. The system offers users the capability to conduct flood impact assessments and a platform for information exchange between experts and scientists in the region. Coincident with the development of this application was the initiation of the Natural Hazards in Carinthia project. This project incorporated many of the EU Flood Directive requirements and is widely considered to be one of the first interdisciplinary studies focused on hazards and risk management in the region (Paulus et al., 2004). This integrated approach to risk management in Carinthia is consistent with a trend in Austria which has seen the management of natural hazards transition from dealing with individual hazards to an all-hazards perspective (Zischg et al., 2011). At a national level, the Hochwasserrisikozonierung Austria (HORA) was launched in late 2002 by the Federal Ministry of Agriculture, Forestry, Environment, and Water Management (BMLFUW, 2006). By 2006, the program released its first maps depicting nationwide flood risk at the 30, 100, and 300 year return periods via an online version of HORA (eHORA) (Zischg et al., 2011). Prior to the eHORA release, flood damages and management processes were handled differently by each federal province (Faber, 2006). The eHORA platform depicts flood zones in much the same way as the Digital Flood Insurance Rate Maps prepared by the Federal Emergency Management Agency in the United States. As informative as the eHORA platform proved to be, the analysis used to generate its data was limited to a steady state model which does not consider discharge, impacted structures, impacted population, or any other details. For this reason, the maps usefulness is restricted to basic development decisions.

Despite these efforts, recent studies have described the administrative areas within southern Austria as having the highest level of flood risk in the country (Embleton-Hamann, 1997). Coupled with the significant risk of torrent hazards, Carinthia represents a particularly vulnerable region in southern Austria. Carinthia offers a unique blend of both mountainous terrain and relatively flat valleys populated with well-established urban,



**Figure 4.1: Study Area in Carinthia Austria**

suburban, and rural communities intersected by numerous rivers and streams (Kosar et al., 2010). Bearing these characteristics in mind, Carinthia presented itself as an ideal candidate for this study. Based on data availability, the municipalities of Klagenfurt, Ebenthal, Maria Saal, and St. Veit an der Glan were selected for analysis (Figure 4.1). These areas were determined to be representative of both the physical and human geography of Carinthia, allowing for broader conclusions to be drawn from the results of the analysis. The primary rivers dividing the study region are the river Glan and the river Gurk. The confluence of these two features is in the Ebenthal region in the southern portion of the study area.

The analysis and data collection phase of this study was initiated in June of 2009 at the Carinthia University of Applied Sciences (CUAS) to the west of the study region in Villach, Austria. Complementary research on Natural Hazards in Carinthia was being conducted at the University during the same timeframe, offering a healthy academic environment for this research. Data for this study was largely provided by KAGIS, Corine Land Cover (CLC) and the government of Carinthia. The initial stages of the work were presented at the 2009 GI-Forum in Salzburg and a companion study was conducted at CUAS in 2010 (Kosar et al., 2011). While research can often be conducted from remote locations, centering it in Carinthia provided invaluable insight into the at-risk geography and communities being studied.

#### **4.2 Spatial Recovery Index: Methods and Results**

The Spatial Recovery Index (SRI) was initially developed as a rapid means of assessing post disaster recovery based upon the spatial distribution of undamaged critical infrastructure (Ward et al., 2009b). An evaluation of the results of the SRI demonstrated variations in the models fidelity based on the structure of input parameters as well as scale. Further research has demonstrated that the index has potential benefit as a metric for resilience when applied to pre-event conditions (Ward et al., 2009b). In consideration of this probable value and the narrow flood management scope identified in current literature, the SRI was used to assess flood risk in the study region. Offering an alternative measure of flood risk across the community provides the initial shift away from engineering centric flood management strategies called for in recent work (Gaume et al., 2009; Faber, 2006; Ganoulis, 2009). Url and Sinabell (2008) have also called for policy, insurance, and social consideration to drive a new integrated approach to flood management in Austria. The SRI also answers the call of Paulus et al. (2004) and Szabó (2007), who have independently cited the need for an increased application of geospatial technology for hazards and disasters management in the region.

Based upon the results of their prior research, the authors have posited that flood resilience can be measured rapidly in the absence of social or even flood-related data by using the spatial proximity of structures. This can be realized because of the fact that structures are not one-dimensional when considered in the recovery context. Buildings and their intended purpose are facilitators of social networks (i.e. schools, churches, community centers, and athletic clubs). For instance, the negative consequences associated with an individual residence impacted by a flood will generally be isolated to a single family. On the other hand, buildings which house critical infrastructure or social capital have the ability to impact a much larger portion of the population, as multiple families rely on them as part of their social network. The SRI model is based on the notion that buildings which provide services to the entire community have more importance to the resilience of that community than any single family dwelling (Ward et al., 2009b). This can be evidenced in the case of a water treatment facility being damaged by a flood, restricting the

entire communities' access to potable water, regardless of whether the flood impacted the community itself. By identifying the spatial location of structures housing the key components of social networks within a community, one can begin to create a spatial network or sphere of influence each structure contributes to the public. When combined with the “spheres” of all other components, a surface depicting resilience or recovery potential can be created. This overall range of influence is captured by the SRI and can be run pre-event or even post-event based on damaged facilities. Because all of this analysis is conducted using the geoprocessing capabilities of GIS software, the data can then be analyzed to identify characteristics about the distribution of resilience across the study region, or compared to engineering studies to offer decision makers a more comprehensive view of risk.

### 4.3 Carinthia Case Study

In the case of Carinthia, three variants of the SRI were conducted based on varying input parameters, model structure, and scale. The multiple iterations were necessary to understand what modifications were necessary to employ the model properly. The SRI was originally developed to operate in the urban environment of a medium-sized city in the US (e.g. New Orleans, LA), and it was suspected that running an unmodified version may produce misleading results. A variety of input variables are divided into recovery indicators (i.e. structures) and vulnerability indicators (i.e. flood zones). The influence of each of these variables on the community is based on distance-decay theory and represented using a Euclidean distance conversion to a raster dataset with the same cell size as the elevation DEM. These two categories are then combined in the model using an additive raster calculation to produce a final SRI value. From this output, the data can be resampled, divided into administrative units with a zonal analysis, or analyzed for patterns and relationships.

#### 4.3.1 SRI 2009

The first model runs were conducted using the exact framework as the original SRI detailed in the 2009 study in New Orleans (Ward et al., 2009b). Every available dataset for the study region which was part of the original SRI data structure was clipped and incorporated into the analysis.

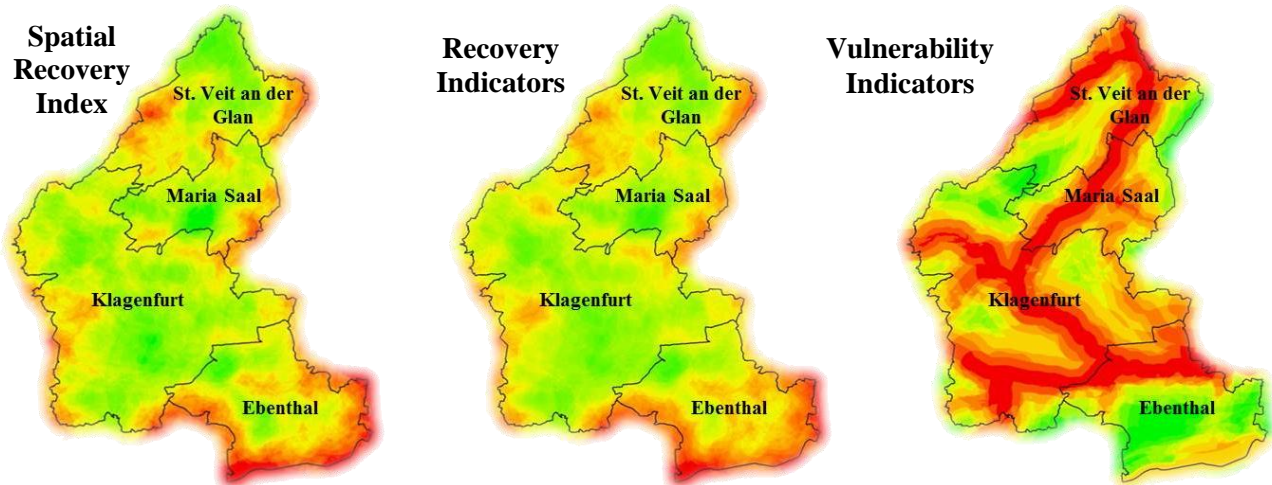


Figure 4.2: Three Components of 2009 SRI Analysis

These datasets included railroads, power lines, churches, schools, healthcare facilities, roads, flood zones, elevation, fire brigades, police stations, gas terminals, rivers, and water stations. The output from this scenario was intriguing, as it demonstrated a higher level of resilience and less variance than expected (Figure 4.2). The same trend was present when the model was executed with just the recovery indicators (Figure 4.2). The vulnerability indicators associated with elevation, slope, flood zones, and other natural features revealed a normal distribution of vulnerability in relation to rivers in the region when run on their own (Figure 4.2). The color symbology in Figure 4.2 depicts high recovery potential in green, decreasing on a color gradient from yellow to orange and finally to red, which is indicative of the least resilient areas of the region.

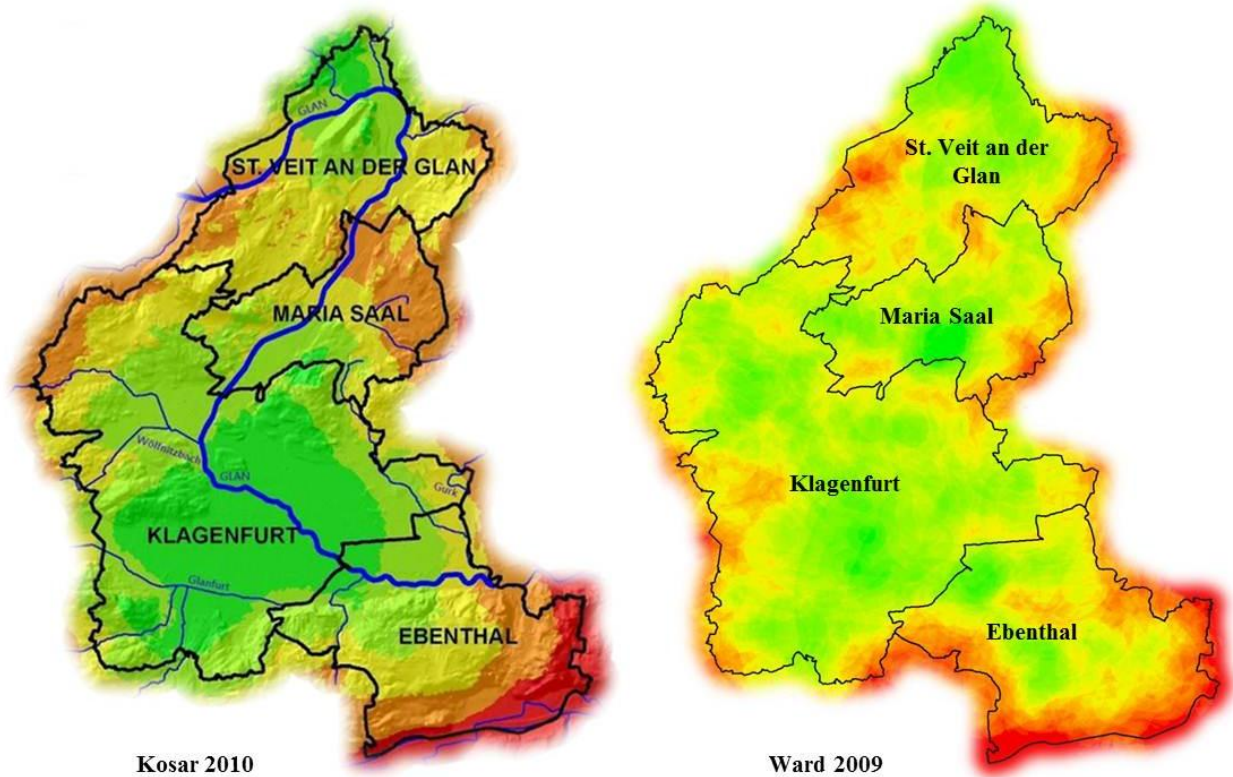
The lack of variation in the output of this initial SRI analysis suggests a flaw in model inputs or the structure. Segregating the components of the model into individual variables shows that the number of buildings included in the recovery indicators far exceeded the total number of variables ever run in the model, artificially enhancing the value of these input variables and homogenizing the model output. This high number of records was symptomatic of the large study area, a higher quality data set and the pre-event status of the scenario. However, the results of this first model run did demonstrate that the necessary data were available to run the model and produce results which had some spatial commonality with the flood zones from eHORA.

#### **4.3.2 SRI 2010**

With the intention of improving upon these results, Kosar et al. (2011) ran a second iteration of the SRI in the same study region. It was the intention of this analysis to modify the construct of the model to account for the large study region and an inordinate amount of input data. The 2010 study determined that many of the recovery indicators classified in the original study under specific categories were redundant and incorrect (Kosar et al., 2011). Being more familiar with the local datasets and colloquialisms of their attribution, Kosar et al. (2011) were able to build a recovery data model more representative of real world conditions. This improved version of the model was driven by only the most important variables gleaned from the much larger regional datasets, dividing the data into five variable categories: including care institutions, cultural resources, infrastructure, economy, and municipal buildings. This new model structure better represented the structure data available for this study, and removed the duplicative information which was not of importance to the model. In addition, this reiteration of the SRI was conducted at a finer resolution. All of the analysis was conducted using a cell array consisting of 9 meters as opposed to 25 meters. This improved resolution provided an increased level of detail in the final output of the model, allowing for more subtle trends to be identified throughout the study region. In addition to the modification in cell size for the analysis, the relative weight of recovery indicators and vulnerability indicators were considered. Kosar et al. (2011) speculated that in addition to the aforesaid faults with the recovery data, the vulnerability indicators were also contributing to the limited detail in the model output. To account for this proposed flaw, the vulnerability indicators were weighted 40 percent less than the recovery indicators in the final SRI output.

At a cursory glance, the Kosar et al. (2011) SRI analysis produced varying results from the original SRI analysis in 2009. Figure 4.3 compares the original SRI output to the modified version using the same color symbology to represent recovery potential as that used in Figure 4.2. When comparing the two assessments, the overall recovery potential for the study region is

fairly consistent with the exception of a few areas. The rural corridor between St. Veit an der Glan and Maria Saal, the areas of Ebenthal to the southeast of Klagenfurt and the region to the northwest of Klagenfurt all have a reduced capacity for recovery based on Kosar’s SRI methodology. A review of the individual data components in these regions unveils similarities in their physical geography which may be leading to the consistency in their low level of recovery potential (Kosar et al., 2011). Kosar also suggests that the large number of structures supporting social networks within the cities has a high level of influence on the high SRI scores in these areas. While a distinct change in output exists between these two models, it is unclear based on



**Figure 4.3: 2010 Kosar SRI compared to 2009 Ward SRI**

the work by Kosar et al. (2011) what is driving this dynamic. By altering the structure, input variables, weighting scheme, and grid cell size in a single model run, it is impossible to determine if a single modification or a combination of adjustments have led to the variance in model output. The 2010 analysis was also restricted by the fact that it did not analyze the data using administrative units smaller than the municipality. While areas such as Klagenfurt appear to be largely immune when viewed at the municipal or regional scale, analyzing the results from these areas at varying administrative units (i.e. postal codes, neighborhoods, land use, etc.) may tell a different story. Kosar et al. (2011) attempted to address this issue by executing the model for Maria Saal by itself, demonstrating that varying the scale has significant influence on the model output. Unfortunately, this single model run at the municipal scale is inadequate when attempting to draw conclusions on component influence and city-wide recovery potential. Although these limitations may restrict the model from being an effective decision support tool, the revised methodology employed in the 2010 study did produce results which were more easily

interpreted and more consistent with the distribution of population across the landscape. This improvement was further confirmed when the output was compared to the flood risk zones depicted on eHORA. While the extent of the eHORA delineated risk zones is not as expansive as the high risk areas identified by the SRI, the general trend of risk transitioning from low to high potential for recovery from Klagenfurt throughout the rest of the study area is represented.

### 4.3.3 SRI 2011

In late 2011, the topic of recovery in the same region of Carinthia was revisited once more in an attempt to further refine the SRI methodology. Prior to this analysis, Zischg et al. (2011) approached the assessment of risk to natural hazards in Carinthia as a function of climate change. This European study took a very similar approach to the original SRI analysis which considered structures as key elements of vulnerability. Just as Ward et al. (2009b) postulated in the New Orleans study, Zischg et al. (2011) identified a list of at-risk elements exposed to hazards. These elements were largely structural in nature and grouped into three categories, including: buildings (e.g. buildings, schools, and domiciles), infrastructure (e.g. roads, power lines, bridges, gas lines, and railways), and agriculture (e.g. farmland, grassland, and forest). These categories were derived from the European Water Framework Directive and the Guidelines for cost-benefit analyses in hydraulic engineering (BMLFUW, 2006 & 2008). These categories were reviewed by a team of local administrators in Carinthia to adjust for native conditions. Prior to the Zischg et al. (2011) study, the SRI had been used in Austria with little variation in the methodology or recovery features included in the model. With the intent to modify the index to be more reflective of Austrian ideology, the SRI analysis was conducted in 2012 using these new at-risk elements to replace the original recovery indicator components.

When considering these categories in the context of the SRI methodology, there are two very interesting variances. The first is the heavy focus on domiciles (single family and multi-family), while the second is the lack of any cultural or commercial facilities. No churches, banks, pharmacies, grocery stores, or elder care facilities were included in the at-risk elements classification used in the Zischg et al. (2011) study, indicating a possible variation in Austrian risk perception when compared to that identified in New Orleans. While Zischg et al. (2011) progress to an increasingly complex assessment and estimation of impacted population based on

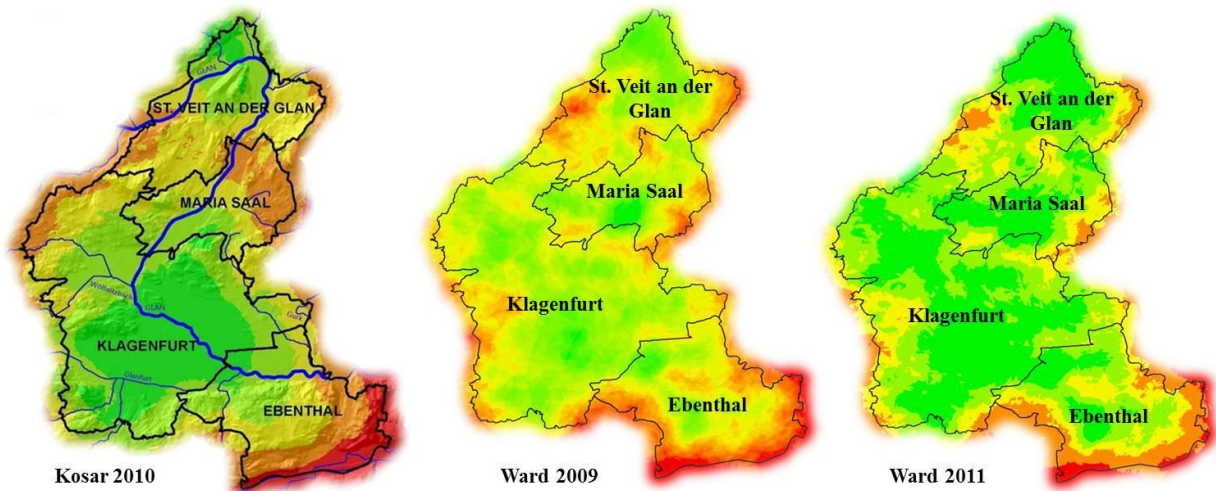
**Table 4.1: Recovery and Vulnerability Elements included in the 2012 Austrian SRI**

<b>Recovery Buildings</b>	<b>Recovery Infrastructure</b>	<b>Vulnerability Elevation</b>	<b>Vulnerability Hazards</b>
Schools	Roads	Elevation	Hydrology
Hospitals	Bridges	Slope	Flood Zones
Fire Stations	Railways		Flood Control Structures
Police	Power Lines		Major Roads
Industrial	Gas Lines		
	Water Stations		
	Electric Stations		
	Industrial Areas		



the conflation of various datasets focused on these at-risk elements, the SRI adopted a less intricate approach. It was important for the SRI analysis on these new classes to stay true to its original intent and only consider these elements from a spatial perspective. The final SRI run using the Austrian at-risk elements included the data layers detailed in Table 4.1.

This input data represented a significant reduction in the number of datasets used to calculate the SRI when compared to the aforementioned versions of the analysis. This decrease in input variables was welcomed as the overwhelming volume of data used in the 2009 study was suspected of reducing the quality of the model output. The data layers were each converted to a raster format using the geoprocessing procedures outlined in the 2009 SRI study in New Orleans (Ward et al., 2009b). These raster files represented each at-risk element's potential level of influence on recovery based on Euclidean distance. The level of influence on recovery for each element was inversely related to the distance between structures. These rasters were summed using a raster calculation to create a single layer representing recovery potential for the entire study region. The output of this SRI analysis is compared to the 2009 and 2010 indices in Figure 4.4.

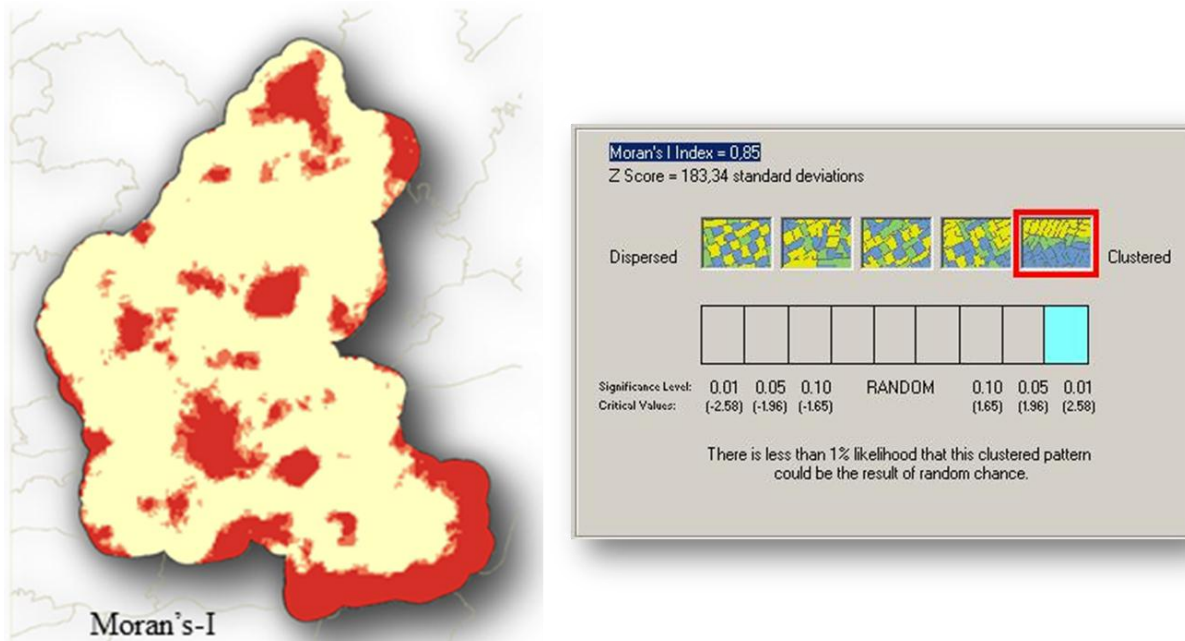


**Figure 4.4: Comparison of 2009, 2010, and 2011 SRI Results**

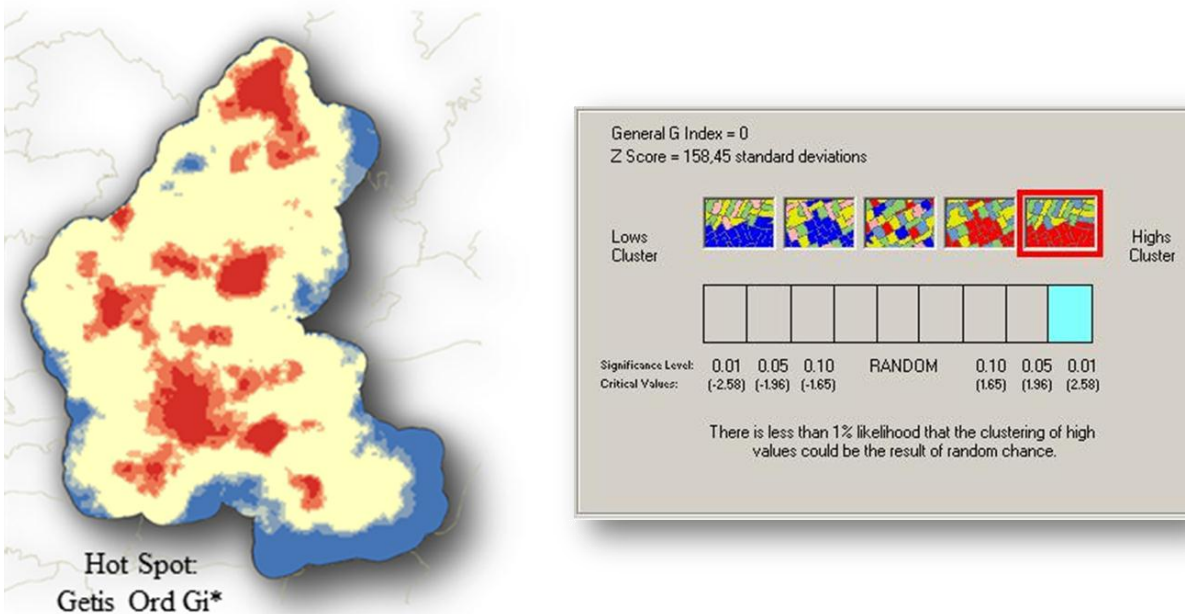
Visual inspection of the 2012 SRI results illustrates a balance between the data rich 2009 study and the heavily manipulated 2010 analysis. The primary distribution of recovery potential across the study area is very similar using all three methods, but further analysis of the 2012 data revealed significant patterns which were not present in the 2009 and 2010 studies. Using a global spatial autocorrelation (Moran's I) tool in the spatial statistics extension in ArcGIS, the results of the 2012 study were analyzed. The Moran's I analysis demonstrated significant clustering of recovery potential throughout the study region (Figure 4.5) with a Moran's I index value of .85 and a p-value of .00187. Having not seen a significant level of clustering in the output of the 2009 and 2010 iterations of the SRI, it was important to gain an understanding of the nature of the general trend identified in the 2012 study.

Significant areas of high and low clustering or "hot/cold spots" were examined using a local Getis Ord  $G_i^*$  analysis. This statistical method assigned a z-score and a p-value to each cell in

the final output raster and identified significant areas of high and low clustering of recovery potential. Areas with a high z-score and significantly low p-value represent significant hot spots (red) where high recovery values are clustered, while areas with low negative z-scores and significantly small p-values indicate significant cold spots (blue) where low recovery values are clustered (Figure 4.6). All other cells in the output raster have z-scores near zero which indicate no apparent clustering of recovery values.



**Figure 4.5: Global Spatial Autocorrelation – Moran's I Results**



**Figure 4.6: Local Spatial Autocorrelation – Hot Spot Analysis (Getis Ord Gi\*)**

Reviewing both the global and local statistics reveals the highest clustering of recovery potential in the urban areas of Klagenfurt, Maria Saal, and St. Veit an der Glan. These urban centers are obvious choices for high recovery potential due to their density of at-risk elements and structures. Of greater interest to emergency managers in the region may be the smaller clusters of high recovery potential northwest and southwest of Klagenfurt as well as the clusters of low recovery potential in Ebenthal and to the east and west of St. Veit an der Glan. The lack of at-risk elements in these regions provides limited options within the built environment for recovery. These clusters represent latent areas of vulnerability which may exacerbate the management and mitigation of floods in the region. To put these findings into perspective, one must imagine the entire state of Carinthia or country of Austria riddled with these dormant pockets of low recovery potential, creating a network of vulnerability to floods which cannot be ameliorated by means of structural flood control alone.

#### **4.4 Risk Perception in Austria**

Though the results of this third iteration of the SRI proved to be far more promising than the early efforts by Ward et al. (2009b) and Kosar et al. (2011), the fact that the benefit came at the expense of the cultural component of recovery indicators was stimulating. This was exaggerated further when considering the importance of churches and education facilities in the New Orleans study, leading to the conclusion that the application of the SRI in Austria may be suffering from risk perception issues. Without a thorough understanding of risk perception values within the Austrian culture and adequate documentation of local recovery from large flood events, appropriate input variables are difficult to identify. Including too many variables may dilute the results of the study (see Ward et al., 2009b) while excluding important variables will overgeneralize the results (see Kosar et al., 2011). This indefiniteness of input variables highlighted the underlying cultural context which is important to consider when assessing risk and vulnerability. Zischg et al. (2011) began to touch on this in the discussion of his analysis by suggesting that disaster management in Austria is experiencing a shift to a more integrated approach. This approach will call for more responsibility to be placed on the individual for damages incurred from flooding, but can only be accomplished with improved communication and comprehensive risk perception (Zischg et al., 2011).

The notion of culturally-driven risk perception having influence on the application of the SRI is not implausible when cultural theory is considered. Citing a scarcity of literature on the cultural variances of risk perception, Gierlach et al. (2010) investigated this phenomenon with interesting results. They found that risk perception across cultures has little to do with exposure to a disaster and more to do with an optimistic bias or “not in my backyard” mentality generated by social construct (Emerging Health Threats, 2008). The idea that hazards play more of a global risk than a local risk is pervasive across cultures and often results in imprecise valuation of risk, vulnerability, and preparedness (Emerging Health Threats, 2008). In light of this, personal experience and socio-cultural factors will often be superseded by ideologies created by groups within the community (Emerging Health Threats, 2008). For instance, individual members of a congregation at a church may undervalue individual risk based on the fact that as a group they are more resilient.

In Austria, it has been stated that this type of risk perception varies across the country based on expectancy-value theory (Thomas, 1981; Hobfoll, 2001). In other words, what benefit do I gain

or lose from taking steps to prepare for a flood event? Answering this question can be problematic for the public official who has to balance highly technical risk and vulnerability assessments with public risk perception requiring practicality and benefit (Renn, 1998). In light of this predicament, the application of methods used to assess vulnerability or recovery potential should be applied with cultural values in mind, whether they are a social metric or not. As such, the SRI as a standalone quantification of recovery potential will hold little value with the general public. In order to improve perception with assessment tools such as the SRI, the analysis must be conducted from the appropriate cultural perspective and presented in conjunction with additional factors (Fleischhauer, 2012). These factors can be referred to as “soft facts” which underscore the “hard facts” or results of technical assessments (Schmidt, 2004). A better understanding of the “soft facts” influencing risk perception in Austria will lead to an improved SRI model based on a refined set of at-risk elements.

As previously stated, current risk and vulnerability assessments in Austria are based primarily on management of river systems and structural control measures (Faber, 2006). This trend is symptomatic of water resources managers who are disconnected from impacted populations. This disconnect in Austria is highlighted in the European Social Survey (ESS) data over the last decade (European Social Survey, 2011). The ESS is a comprehensive biennial survey conducted across Europe to assess general social sentiment and includes political, social, moral, demographic, health, and well-being variables. Over the course of the last decade, hundreds of survey responses have focused on floods and natural disasters across Europe, with only a single response in this category coming from Austria in 2002 (European Social Survey, 2011). Previously cited literature suggests that the government is spending a significant volume of money on adapting flood management and policy to new norms. With this being said why is the risk of flooding receiving so little recognition from the Austrian public? The answer is undoubtedly multi-faceted and not attributable to a single cause, but may be highlighted in the same survey. When reviewing all of the Austrian data collected as part of the ESS, the topics of political performance and trust come up on a recurring basis (European Social Survey, 2011). This lack of trust toward government officials is expounded upon by the Austrian Academy of Sciences (Gazsó, 2008) who characterize the Austrian public as one that is slow to adopt change in regard to new technology and policy. This study also suggests that tight political regulations and little tradition of public debates among relatively old population also contribute to a passive view toward change, whether that be policy, technology, building standards, etc. (Gazsó, 2008). When formulating risk perception toward natural hazards, this detached mentality to policy change and political communication can have dire consequences, as its fault may only be recognized following a disaster. In order to improve upon risk communication between the government and the public, credibility of risk assessment tools must be established through improved risk communication (Reid, 1999). This will in turn lead to a better understanding of how the public perceives risk, what mechanisms of the social network are at greatest risk and finally, which structures within the built environment are necessary to sustain these social mechanisms (Fleischhauer, 2012). With this information in hand, the SRI can be applied using empirical recovery indicators which are correlated with public risk perception.

## 4.5 Discussion

By examining the role of predictive spatial analytics in flood management and mitigation, this study has expanded upon the aforementioned evolution of risk management in Austria. Although the initial phase and scope of the study was to apply the SRI in Carinthia, the use of this technology also led to a complementary summary of cultural influence on risk perception and recovery potential. The two crucial questions behind this investigation focused on the transferability of an urban index developed in the United States to a regional level in Austria, and the influence of culture on the assessment of potential for community recovery. In short, the answer to these is that the SRI can be utilized to assess recovery potential in Austria, but only with significant consideration given to the cultural setting it is being applied in. With this being said, it must be noted that this assessment was written from an American perspective based on observed data and research in the study region. As such, the information associated with this study does not lend itself to extrapolation across the rest of the state or country, but does offer a practical framework to build from.

Through three iterations of the SRI model, this study was able to identify that the variables input into the model had more influence on its outcome than the model structure, resolution, or weighting scheme. The results of the analysis indicate that although the corridor between Maria Saal and Klagenfurt may be one of the most vulnerable to floods in all of Austria, the density of recovery indicators in the Klagenfurt area may be able to offset the impacts of a widespread flood. More isolated and localized flooding in the region may result in problematic recovery for areas in Ebenthal and north of Klagenfurt which do not have the combination of recovery elements to facilitate social stability. The analysis could benefit from detailed post flood data in the region which would allow for the most influential at-risk elements to be identified. Moving forward, it would also be beneficial to run different components of the SRI at varying scales. Isolating the urban areas and rural areas into separate model runs may begin to offer more detail on the variance explained by each indicator used in the analysis. It would also help eliminate some of the overwhelming volume of data used in the first iteration of the study. In addition, adapting the land cover class developed by Zischg et al. (2011) to account for agricultural lands versus non-agricultural lands may reveal a nuance in recovery potential undetected in the scenarios used in this study. It should also be stated that floods do not present the only hazards in this Alpine region. Torrents, avalanches and landslides represent a few of the other hazards in this region of Carinthia. Couple any one of these events with a large flood event and predicting recovery becomes considerably more complex.

The nuances in recovery potential across this regional setting represent a critical missing component in current flood management practices in Austria. At present, individual structures are not viewed as enablers of social networks, and as such, their function and the people they house are placed in a secondary tier of flood management in Austria. One-dimensional flood management and reduced risk communication have created a culture with a skewed perception of resilience, risk, and vulnerability. In addition, personal responsibility for flood damages are dwindling and an obligation for rapid and thorough recovery has been left largely in the hands of government (Zischg et al., 2011; Fuchs, 2009). Zischg et al. (2011) recognized this complication in their loss estimation study, and called for new tools to assess the various components of disasters in Austria. In order to be effective, these tools had to be able to identify vulnerable hot

spots, distinguish between factors driving vulnerability and risk, and be easily updated with new data and information (Zischg et al., 2011). The results of this study suggest that with limited refinement, the SRI will meet all of these criteria in a simple and adaptable spatial decision support tool. Combining the SRI's prediction of recovery with other non-structural measures of vulnerability could place Carinthia at the forefront of flood management practices in Europe.

The integration of cultural values into non-social metrics in disaster science is not a new idea, but has been relatively dormant in the literature for some time. The recent increase in hazard intensity and frequency across the globe has resulted in a renewed interest in the intersection between these two subjects. This condition was recently illustrated in Austria by Kulmesch (2010) who faced numerous challenges when trying to transition Hazards US (HAZUS) loss estimation models to Austrian communities. In addition, the Federal Emergency Management Agency (FEMA) has only just initiated the RiskMap program which features the opportunity to combine cultural, social, and non-engineering based vulnerability assessments with ancillary flood map products (FEMA, 2008). These emerging trends are blurring the lines between risk perception, technologically driven risk assessment, and communication in a manner which provides a new perspective for managing flood hazards. This new viewpoint is a necessity for proactive management of hazards as human environments are increasingly overlapping hazardous geographies around the globe. In a community where the most hazardous geographies are already populated and developed, it does no good to "help" people by delineating flood zones on a map. Communities must find ways to mitigate flood risk retroactively by quantifying and defining recovery potential across these zones, better focusing mitigation dollars, and enhancing risk awareness and communication.

## CHAPTER 5: RESEARCH BASED DECISION SUPPORT IN HAZARD MITIGATION: LOUISIANA NORTHSORE FLOOD AND HURRICANE PROTECTION

*One effect of benefit-cost analysis is to give any respectable engineer or economist a means for justifying almost any kind of project the national government wants to justify. . . . Exclusive reliance on benefit-cost analysis has been one of the greatest threats to wise decisions in water development.*

-- Gilbert F. White, 1971

### 5.0 Introduction

As recovery from Hurricanes Katrina, Rita, Ike, Gustav, and Isaac begins to transition into strategic rebuilding and development aimed at enhancing coastal resilience; the Louisiana Coastal Protection and Restoration Authority (CPRA) has identified non-infrastructure related mitigation as a burgeoning component in its restoration planning model (CPRA, 2012). As demonstrated in the seminal 2012 document, *Louisiana's Comprehensive Master Plan for a Sustainable Coast*; there continues to be growing interest in the role of non-structural mitigation in community resilience. While the primary impetus of the Master Plan was to offer a blueprint for how the state of Louisiana will achieve flood risk reduction and limit coastal erosion; the CPRA also revealed a significant amount of maturation in overall understanding of resilience by documenting social and cultural influences on coastal protection. This is evidenced further when compared to the document's precursor published in 2007, which was heavily focused on the building of flood control structures and management of natural systems (CPRA, 2007). Although the acknowledgement of these non-traditional vulnerability metrics and resilience planning tools is an indicator of a more refined understanding of vulnerability, the CPRA fails to detail how it will implement non-structural mitigation as part of its long term coastal resilience program. Instead, it opts to maintain its focus on engineering-based mitigation strategies. Unfortunately, this inability to effectively put into practice the social elements of the Master Plan is not unique to the CPRA. While many opponents to the CPRA may marginalize this shortcoming as political imprudence, the difficulty in transitioning research based techniques or social science into policy is a well-documented issue which is pervasive throughout all levels of government (Rosenthal & Kouzmin, 1997; Dunning & Durden, 2008).

Bearing in mind that many non-structural mitigation strategies are based on social sciences and inexact models, it is much more difficult to elicit public approval of policy which does not result in tangible outputs with clear benefit to the community (e.g. levees, pump stations, weirs, etc.). The continuous focus on structural mitigation by policy makers in Louisiana is further aggravated by the recentness of Hurricanes Katrina, Rita, Ike, Gustav, and Isaac. Extreme events such as these storms tend to intensify the belief that damage to homes and property can only be remedied by building stronger and larger flood control structures; when in fact, vulnerability can never be engineered into extinction (Emrich, 2011). This reactive approach to mitigation is reflected heavily in both Master Plan documents (CPRA, 2007 & 2012) and helps to explain some of the current difficulty in embracing alternative mitigation strategies in the State of Louisiana (Exworthy & Halford, 1998; Ackroyd et al., 2007; Tummers, 2010).

The reluctant adoption of non-structural mitigation strategies is not novel to the state of Louisiana, having been recognized across the western world as early as the 1940s by Gilbert White (White, 1945; MacDonald et al., 2011). White spent a significant portion of his career researching how humans could coexist more harmoniously with the environment; with particular attention paid to floods (MacDonald et al., 2011). It was during this research that he first opined the notion of “adjustments” to flood recovery and response as a means of improved mitigation (White, 1945; MacDonald et al., 2011). These adjustments included elevating, flood abatement, new policy, land-use changes, insurance, engineering, and temporary flood control measures (MacDonald et al., 2011). Consistent with the intent of this study, White frequently called for populations to adapt and accommodate to flood risk, as he knew that construction of large scale flood control measures was not a permanent solution (Murphy, 2008). As early as 1936, White was beginning to identify a need for cost benefit analyses which incorporated social and environmental factors when prioritizing flood control projects (White, 1936). Realizing that the consideration of multiple adjustments could lead to an overwhelming volume of information for decision makers, White called for parsimony in the assessment of flood control strategies (Murphy, 2008). He felt that it was only necessary to include sufficient detail for the intended analysis and discouraged the over-analysis of data and inclusion of hollow information (Wescoat, 2006; Murphy, 2008).

Considering the above context, the authors propose a new vision for the “multiple lines of defense” mitigation approach currently used by CPRA. In 2010 the Northshore Hurricane and Flood Protection Plan was funded by the CPRA based on a scope of work developed by the authors. This project represented the first attempt to implement non-structural approaches into a regional mitigation study in Louisiana. While this project cannot be considered a direct link between science and policy, it is a positive step forward in the application of participatory science techniques within a regulatory environment. This adaptation in how vulnerability is utilized for mitigation planning represents a small portion of the critical paradigm shift identified by Rubin (2000) and Mileti (1999) as a logical and necessary progression toward improved disaster management. Furthermore, the approval of this study characterizes a significant maturation phase by the CPRA as they began to understand the importance of managing hazards and vulnerability as opposed to trying to eliminate them (Wisner et al., 2004; McEntire, 2004). Past research has clearly demonstrated that disasters are events grounded in social constructs, as they are often quantified by impacts on the health or fiscal aspects of human life (Weichselgartner, 2001). It must be asked, then, why mitigation is so often approached with little regard given to the social and organizational vulnerability entrenched in the population being protected? When considering this question in conjunction with the fact that no structural mitigation measure can ever remove risk entirely, the authors put forward an alternative approach to vulnerability assessment. By combining elements such as economic loss estimation, repetitive loss analysis, and social vulnerability valuations into the overall vulnerability assessment of the region, a new dimension of mitigation planning has been revealed (Weichselgartner, 2001; McEntire et al., 2002; McEntire, 2004).

This paper highlights the methodological aspect of the recently completed Northshore Hurricane and Flood Protection study as well as the connections between methods and decision making. The results of this study are currently being utilized by decision makers, engineers, and planners within communities throughout the Northshore to gain a better understanding of the vulnerability



they are attempting to mitigate with infrastructure development. By having a more comprehensive understanding of the spatial variations in vulnerability, as well as the relationships between the economic, social, and physical factors which drive vulnerability; these individuals are now basing their decisions on an understanding of susceptibility which extends beyond recent physical exposure, and an understanding of mitigation that extends beyond constructing a levee in the last place to be impacted by a flood.

## **5.1 Translating Research to Practice**

Current literature focusing on the research of flood vulnerability and mitigation is undergoing a transition based on the realization that flood risk is unavoidable. (Association of State Floodplain Managers - ASFPM, 2007). Historically, much of this research has been focused on reducing flood damages through structural project implementation. As the impact of flooding across the United States continues to intensify in both magnitude and frequency, many in the academic community are adopting a more management intensive focus when considering flood mitigation (Emrich et al., 2011). Better understanding of the social and political factors driving vulnerability to floods has led to an acceptance of flood risk as a perpetual threat incapable of being completely alleviated (Dunning & Durden, 2011). These social and political factors are not unlike the “adjustments” to flood management called for by White and others since the early part of the twentieth century (White, 1945). Consequently, the notion of managing flood risk has seen a dramatic increase in popularity. As is often the case with new research, this altered approach to flood vulnerability has remained largely in the academic realm. While similarities can be drawn between this new paradigm and the European practice of managing flood vulnerability through calculated losses and dedicated flood retention areas, even this innovative technique fails to consider the unique interactions between flooding and socioeconomic/demographic conditions (Hartmann, 2011). Taking these multidisciplinary factors into consideration, this study relied on both quantitative and qualitative research techniques. This blended approach to vulnerability and mitigation research is becoming an increasingly popular technique for evidence-based planning, and is consistent with the complex nature of flood vulnerability within the study area (Reed et al., 2005).

Difficulties in bridging the gap between research and practice cannot be attributed to any single cause, but a significant volume of literature has been dedicated to this very issue (Bowen & Zwi, 2005; Weichselgartner & Kasperson, 2010). The less quantitative nature of some vulnerability and disaster research may further intensify this trend (Hammond et al., 1992). Furthermore, the role of government and policy makers has often been overlooked in disaster related research, a trend which has widened the gap between the two ends of the disaster spectrum (Rosenthal & Kouzmin, 1997). However challenging, the solution to this problem lies firmly within the grasp of both researchers and policy makers; the former need to focus on conducting research within an applied context, and the latter need to lean on science more than public opinion (Weichselgartner & Kasperson, 2010). Historically, most research has occurred within an academic vacuum, with the benefit of knowledge being one of the only tangible outcomes (O’Connor et al., 2009). This stove-piped approach to research must be widened in order to reach practitioners. Conducting pragmatic research with the intent of transitioning findings into applications and decision support tools is one step toward consilience (O’Connor et al., 2009). The fact that disaster management is a politically charged arena in which cost-benefit ratios justify spending does not relieve public officials of the responsibility to ground decisions in

sound scientific methods (O'Connor et al., 2009). Emery and Giauque (2003) indicate that hyper-focus on economics of policy implementation has had a negative influence on the implementation of new policy and programs. It will be nearly impossible for any public official to consider new approaches to disaster mitigation without first divesting oneself from these traditional fiscal measures of policy implementation (Emery & Giauque, 2003). Hammond et al. (1992) also suggest that utilizing locally generated research to drive policy decisions may be one of the most promising approaches to successful collaboration between science and public administration. The application of this local knowledge in research will be much more palatable to policy makers, as it will warrant a dynamic inquiry process which will engage the community and change as local conditions evolve (Reed et al., 2005; Carruthers & Tinning, 2003).

Using native research to drive policy was the original intent of the authors conducting this study. A companion article to this work highlighted the development of a Spatial Recovery Index (SRI) in the city of New Orleans following Hurricane Katrina (Ward et al., 2009a). This index was considered to be an alternative to a measure of resilience and was intended to offer public officials a rapid assessment tool for identifying areas with the greatest ability to rebound from flood impacts (Ward et al. 2009). Although the SRI demonstrated positive results which warrant further research, its infancy does not lend itself to application on the Northshore. This is one of the greatest challenges to scientists seeking to conduct functional research involving social conditions (Hammond et al., 1992). However scrutinized a measure of resilience or vulnerability is no mechanism exists to quantify the ambiguity in its output (Hammond et al., 1992). It is this uncertainty which causes inquiry in disaster research to often be interpreted as an indefinite belief instead of systematic evidence. Hammond et al. (1992) support this notion by stating that failure to manage the vagueness inherent in science will lead to an inability to distinguish between fact and opinion. This will in turn dilute the value of the science and lead to the misuse or waste of meaningful data (Hammond et al., 1992).

Achieving this necessary shift in research and management practice is currently inhibited by a number of political and ideological hurdles within the disaster research and management community. First, researchers and decision makers are often focused on what has happened, rather than what can happen (Rosenthal & Kouzmin, 1997). This reactive mentality leads to political pandering toward previously impacted communities and research focused on explaining why existing policy allowed the impacts to occur. Fairweather & Tornatzky (1977) pointed out the need for a more dynamic social role for both researchers and public officials. Distinguishing these social elements within disaster related policy is the pathway for redefining how decision makers approach mitigation (Rosenthal & Kouzmin, 1997; Winner, 1972; Lagadec, 1982). Rosenthal & Kouzmin (1997) have observed that public officials are often one-dimensional in their approach to disaster management, seeking only to identify a single cause to the problem. With the intention of remedying this inclination, Rosenthal & Kouzmin (1997) identify the importance of understanding the multi-faceted complexities of social and political interactions prior to defining disaster related policy. This enhanced social awareness will allow evidence generated by research to bridge the gap between scientific methods and informed policy, leading to a more ideal scientifically-based decision-making process (Bowen & Zwi, 2005; Nutley et al., 2003).

The effective transmission of research into practice has been characterized as a tiered process which should demonstrate constraint (Kerner, 2008). Both scientific and administrative impediments exist when attempting to use evidence-based decisions in the mitigation process. In order to minimize the impacts of these impediments, it is necessary to engage public officials within the participatory science process. To do so, researchers must contextualize their investigation rather than force it upon administration (Tummers, 2010). Bowen & Zwi (2005) have further underscored the importance of defining research context in evidence-based decision making by simplifying the process to a three-tiered system. This process pathway is referred to as “adopt, adapt, and act” and engages public officials from the onset of research to ensure adoption or acceptance. Scientific evidence can then be acted upon by policy makers, who through participation in the entire process have gained an appreciation of the significance of scientific judgment and evidence (Hammond et al., 1992; Kerner, 2008; Bowen & Zwi, 2005). Critical factors to successful implementation of this translational process are establishing the relationship between researcher and policy maker, instituting a communally agreed upon vocabulary, and most importantly, defining the connotation of the evidence generated from the research (Kerner, 2008).

The Northshore region of Louisiana which serves as the focus of this study is not immune to these issues; there is a significant disconnect between emergency managers, engineers, and public works officials driving mitigation. The authors identified this divide early in the scoping phase of the study and took actions to include these decision-makers in the early stages of development through a number of round table discussions. These stakeholders became involved in the research study design and in turn were able to assist in the definition of both the research and policy goals, two of the most critical factors in evidence-based planning (Hammond et al., 1992; Committee on Science, Technology, and Congress, 1991). This process has empowered engineering and emergency management officials with the knowledge necessary to make political decisions grounded in scientific judgment while limiting public questions regarding the reason behind their actions. (Quarantelli, 1978; Schwenk, 1988).

## **5.2 Study Area and Geography**

The term “Northshore” refers to the area north of Lake Pontchartrain. Usage varies with respect to the geographic extent of this area. It always includes St. Tammany Parish, often additionally includes Tangipahoa and Washington Parishes, and sometimes additionally includes St. Helena and Livingston Parishes. The term is used in this study to describe the parishes of St. Tammany and Tangipahoa, which is appropriate because these two parishes encompass the geographic dimensions of the north shoreline of the lake, with St. Tammany accounting for most of the area (Figure 5.1).

The indefiniteness of the term is in large part a result of the fact that it developed as a relational term from the perspective of the residents of New Orleans, rather than a designation by the residents of the north shore of the lake (Hastings, 2009). During summers in the 1800s, the New Orleans newspapers were filled with steamboat advertisements for the “watering places,” which referred to the bathing areas and springs on the north shore of Lake Pontchartrain (particularly the southern part of St. Tammany Parish) that enabled New Orleans residents to escape from the heat and disease threats in the city (Gilbert, 1988). Recreation on the Northshore continued to be important for New Orleans residents during the 1900s and early 2000s and was supplemented by

population movements out of New Orleans to the Northshore (Ellis, 1981; Gardner, 1988). With the growth of the area, including indigenous development as well as movement out of New Orleans, a sense of regional integrity has become more prominent as the Northshore has established its economic and cultural independence from New Orleans proper (Gilbert, 1988; Hastings, 2009).

The characterization of St. Tammany as a bedroom community for New Orleans should not be taken to mean that a majority of the parish’s employed persons work in New Orleans. Numbers related to this issue are uncertain. Plyer et al. (2010) indicate that in 2008 there were 77,327 workers living in St. Tammany Parish but only 62,096 jobs in the parish, producing 15,231 net



**Figure 5.1: Northshore Study Area**

out-commuters. Transamerica’s draft “Strategic Plan for Economic Development in St. Tammany Parish” (St. Tammany Parish Government, 2003) indicates that half of the parish’s wage income is derived from commuters. Commuter destinations are not identified in either study, although both suggest that the non-commuting residents have always been much larger in number than the commuting residents, so it is improper to consider the Northshore as a dependent of New Orleans.

### 5.2.1 Population

Considerable disagreement exists concerning the effects of Hurricane Katrina on the population of St. Tammany Parish during August of 2005. The United States Census Bureau (Census) provides an estimate for July 1, 2009, of 231,495, which would constitute a 21.0 percent increase over 2000 (April 1). On the other hand, the Greater New Orleans Regional Economic Alliance provides estimates on its website of 220,295 for 2005, 239,132 for 2008, and 275,901 for 2013.

The Alliance estimates for 2008 and 2013 are derived from analysis by data specialists at the Environmental Systems Research Institute (ESRI). The 2008 estimate is significantly larger than the Census estimate of 228,456. In addition, a 2006 study by Policy Development and Research estimates a St. Tammany population of 248,000 in 2006 (compared to a Census estimate of 223,863) resulting from an influx of Katrina evacuees from St. Bernard and Plaquemines Parishes. For the purposes of this study we utilize the US Census 2000 and ACS 2005-2009 total population values of 291,856 and 339,762 respectively for the area. No single population data source can be considered 100 percent accurate due to the tendency of these estimates to rely on a combination of households, census counts, and symptomatic data such as population growth trends; the combined analysis of these sources support the general notion that there are approximately 340,000 people living in the project study area. The Northshore region is relatively homogeneous in regard to race when compared to the rest of the state of Louisiana. Over 80% of the population is white with a high school education. The dominant minorities are African-American and Hispanic, representing approximately 16% of the region's population. Nearly 50% of the overall population is below the age of 35 with an average annual income of \$60,866, nearly \$20,000 over the state average.

### 5.3 Methodology

The methodology for the Northshore study was carefully developed within the aforementioned flood management context. The initial scoping phase of this study was anchored around meetings with key stakeholders in the region which sought to detail study goals and methods. These individuals included engineers, parish leaders, biologists, and community leaders. Early participation by these entities was critical to the **“adoption”** phase of the study. Once agreed upon, a preliminary background investigation of available data and study limitations was conducted. This inquiry culminated in an additional round of stakeholder meetings where the proposed methodology was **“adapted”** based on data restrictions and limitations. The details of this adapted methodology follow this paragraph and offered the stakeholders the information necessary to **“act”** when considering new mitigation strategies for the region.

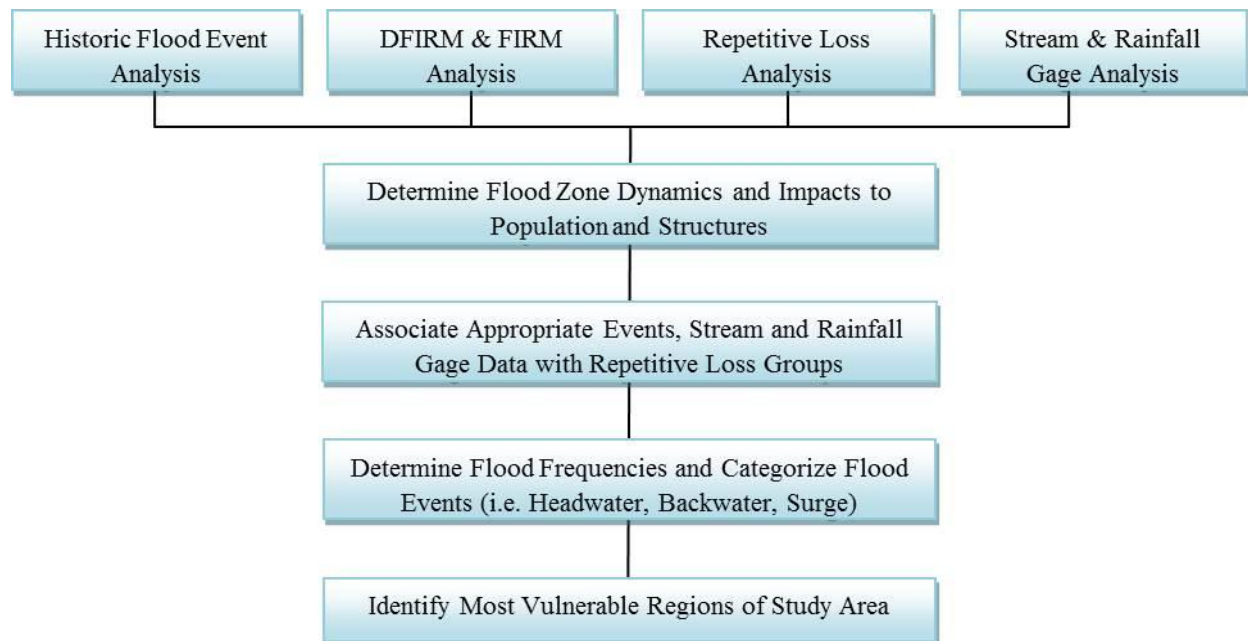
In order to assess flood vulnerability across the study region more accurately, three components were analyzed and combined in a qualitative decision support matrix. These variables included a flood exposure analysis, an economic loss estimation analysis, and a social vulnerability (SoVI) analysis. The exposure analysis was first used to identify the geographic areas with the highest intensity of flood impacts, as well as the source of these impacts. Once identified, the SoVI and loss estimation techniques were then applied in order to characterize vulnerability to flooding within these highly exposed areas further. Since each of these analytical procedures produces results with varying levels of measurement on a variety of scales, it was necessary to identify a simple process whereby each could be considered in the assessment phase of the study. To accommodate this need, each of these factors was integrated into a qualitative decision support matrix based on geographic location and tied to specific structural mitigation projects. The use of this matrix allowed for more informed, evidence-based decisions to be made by policy leader's seeking to maximize their mitigation dollars. The final outcome of this matrix was not intended to rank or prioritize areas based on vulnerability, but instead refine the general understanding of vulnerability across the region and delineate the factors driving it in these high exposure areas. By identifying the driving factors behind vulnerability in these areas, the authors presented the

necessary information for decision-makers to determine if building flood reduction infrastructure was truly the most appropriate solution for a given area.

### 5.3.1 Flood Exposure Analysis

The initial phase of this analysis was the documentation of extreme flooding events over the last half century. Historical flood event data from FEMA flood impact studies, local hazard mitigation plans, and the National Oceanic and Atmospheric Administration (NOAA) were all used to document the most extreme events over the last half century. This flood event data was used to identify those areas of the study region which have experienced the most flooding, the source of this flooding, and the general character of flooding over the entire region. Enhancing this data mining exercise was the analysis of the current effective Flood Rate Insurance Maps (FIRMs) and proposed Digital Flood Insurance Rate Maps (DFIRMs).

Claims made to the National Flood Insurance Program (NFIP) were examined using a point pattern analysis to gain a more highly resolved understanding of historical flood impacts. The primary means by which recurring flood damages may be evaluated for a region is by examining the Repetitive Loss (RL) properties. This information was gleaned from the FEMA Region VI Repetitive Loss and Severe Repetitive Loss database and used to further refine the identification of those areas most vulnerable to flooding. A RL property is any insurable building for which two or more flood-related claims of more than \$1,000 were paid by the NFIP within any rolling 10-year period, since 1978 (FEMA, 2012b). A SRL property is defined as any structure participating in the NFIP which files at least four claims inside a ten year period which are over \$5,000 a piece or, two separate claims within ten years which cumulatively total more than the fair market value of the structure (FEMA, 2012b). The purpose of this analysis was to categorize the areas within the parishes which exhibit significant flooding in order to identify the causes of flood event claims for each region.



**Figure 5.2: Flood Vulnerability Analysis Process Path**

All of the flood vulnerability data is then overlaid on a map in order to identify those areas which are most exposed to flooding based on geography, documented impacts to population/structures, historic flood events, and engineering studies. This common GIS analysis and data management approach serves as the link to the economic loss estimation and social vulnerability analyses also used in this study. Figure 5.2 details the flood vulnerability analysis process path used in this study.

While identifying where flooding will occur in order to assess vulnerability is important, it is equally important to understand the potential future impact that flooding will impose on a growing community. The level of economic losses resulting from flood events can vary tremendously across a study region. This variance justifies an increased consideration of impacts, Costs, and benefits when distributing mitigation dollars. Understanding potential economic losses is critical for public officials attempting to maximize return on every mitigation dollar invested in the community.

### **5.3.2 Flood Loss Estimation**

At present, the two most commonly used methodologies for assessing flood vulnerability from an impact perspective are the United States Corps of Engineers (USACE) Flood Damage Assessment (FDA) process and FEMA's Hazards-United States (HAZUS) model. This study used the USACE Hydrologic Engineering Center's Flood Impact Analysis Model (HEC-FIA), which combines the two other techniques. This new application is an efficient, robust and standardized method for estimating flood impact to communities and offers the ability to utilize HAZUS data within a Corps FDA environment. Reports can be generated for a number of potential impacts including, but not limited to, structures, structure contents, vehicles, population, and agriculture, which are the focus of this study. Within HEC-FIA, these four factors are aggregated according to the "structure inventory." While HEC-FIA is capable of utilizing several different data sources as the foundation of the structure inventory, the HAZUS general building stock (GBS) database was used for this study. Because the HAZUS GBS is based on 2000 Census data, valuations of structures, structure contents, and vehicles were increased by 31 percent to account for inflation to 2011 figures. This inflation percentage was developed by the Bureau of Labor Statistics and is the standard utilized by the USACE for economic analysis (US Bureau of Labor Statistics, 2011).

The 2008 storm surge depth data produced as a result of the joint FEMA and USACE Louisiana Mapping Project Advanced Circulation (ADCIRC) Model runs was used as the physical event input into the model. This set of depth grids represent the best available depiction of potential storm surge in the region. These surge data are the result of the average output from over 200 storm simulations conducted by the USACE in Vicksburg, Mississippi; and includes maximum inundation limits of surge for multiple return periods. It must be noted that HEC-FIA currently has no variable to account for velocity of surge. Thus, the results of this study should be considered to be those associated with a steady state model. Despite this limitation, HEC-FIA has proven to be an accurate and valuable tool for the assessment of economic vulnerability when compared to other assessment metrics utilized by FEMA and the USACE.

For the Northshore study, depth-to-damage functions were applied to each building for the structure, contents, and vehicles. The depth-to-damage functions are unique to each occupancy type and are generated by the USACE and FEMA. Each depth-to-damage function states that for a given depth of flooding, a certain percentage of a particular asset will be damaged. Once each building in the structure inventory was compared to the depth grids, the level of inundation was used to calculate damages based on the damage functions. Upon completion of the loss estimation model runs, the reports on structure, contents, and vehicle damages were summarized and compared across census blocks and impact areas for 50, 100, and 500-year return periods.

### **5.3.3 Social Vulnerability Analysis**

At the core of any disaster is an impacted population. The ability to quantify or assess risk to this population was first measured as vulnerability nearly 40 years ago and has since seen numerous derivations in hazards research. While a variety of interpretations exist throughout literature today, the application of vulnerability as a means to describe the interaction between the human and physical environments still acts as a foundational component of disaster science. The original intent of many vulnerability metrics was to define the adverse impacts to environments and natural systems and their subsequent ability to return to normal conditions following a disaster. As research into disasters evolved, it became clear that these bearings were not limited to natural conditions and had an equally significant effect upon society. This understanding gave rise to the notion of social vulnerability or the susceptibility of populations to disaster related impacts. The Social Vulnerability Index (SoVI) was developed by Cutter in 2003 and used extensively by the Hazards and Vulnerability Research Institute at the University of South Carolina. While SoVI has been used extensively within the research community, it is only recently being applied in the policy and public administration arena, an area of practice where it may very well impart the most value.

The concept of vulnerability, or the potential for harm, provides a means for understanding the social and natural systems that interact to produce disasters (O'Keefe et al., 1976). Vulnerability is widely used in the hazards, disasters, and human dimensions of global change literature to describe the differential impacts of environmental threats to people and the places where they live and work (Cutter et al., 2003; Pelling, 2003; Wisner et al., 2004; Adger, 2006; Birkmann, 2006; National Research Council, 2006; Eakin & Luer, 2006). Characterizing the vulnerability of places requires two interlocking concepts: exposure and sensitivity. While exposure relates to the areal extent, frequency, and severity of a particular hazard, sensitivity (social vulnerability) is defined by those social, economic, and demographic characteristics that influence a community's ability to withstand environmental hazards in general (Cutter, 1996). Social vulnerability is, thus, a pre-existing condition within a place and can be utilized in tandem with an "all-hazards" emergency management approach.

SoVI's ability to incorporate socioeconomic and demographic data in order to draw conclusions regarding community resilience and flexibility to hazards is of the utmost importance to the planning community. Prior to its implementation, it was very important to ensure that stakeholders within the region understood what SoVI was measuring, and more importantly, what it was not measuring. While this study is focused on flood vulnerability, it was vital to note



that social vulnerability is unbiased in regard to hazard as it is a means of displaying an existing condition, which is always present within a community. The index combines socioeconomic and demographic variables known to influence vulnerability (Heinz Center, 2002) using a principal components analysis (PCA) to describe multiple dimensions of vulnerability. These output dimensions, or components, are equally weighted and summed to produce an overall SoVI score for each particular spatial unit (e.g., county, block group) of interest (Cutter et al., 2003; Schmidtlein et al., 2008). As a scalable, place-based metric, SoVI is readily adaptable to an array of study areas and local planning and emergency management applications.

The original index developed by Cutter was intended to capture the influences of the built environment as well as those purely social in nature. In order to capture just the social capacity to environmental hazards more accurately the index was modified for this study to only include social and demographic variables which influence overall community welfare. For this study, two separate block-group level SoVIs are constructed to examine changes in social vulnerability across the Northshore region. The first of these uses Census 2000 data to describe vulnerability, while the second uses data from the 2005-2009 American Community Survey. While the 2010 Census would provide the most current data for SoVI, the decennial census no longer includes a long-form questionnaire—the primary source for information relevant to social vulnerability (Weinberg, 2011). Therefore, this study uses data from the American Community Survey (ACS), which includes questions similar to the old long-form census questionnaire. The number of input variables was also reduced in formulating a Northshore SoVI from 42 social and built environment variables (Cutter et al., 2003) to 27 social variables common to both datasets. Despite reducing the number of variables, this formulation of SoVI incorporates unique dimensions of vulnerability including vehicle accessibility, family structure, and language barriers. The block group level of geography is selected not only because it is the finest resolution of data available from both the decadal Census and the ACS. This degree of geographic specificity also permits the pairing of fine-scale flood hazard data with SoVI to enable neighborhood-level decision-making. As identified by Ward et al. (2009a), the importance of analyzing vulnerability at a neighborhood level scale is critical for decision-makers looking to mitigate flooding throughout a community. The census block not only represented the most discrete geography with the necessary data available to quantify social vulnerability at this scale, but also offers the ability to be scaled up to larger study units if needed. By assessing social vulnerability of the 165 census blocks within the study region, the results of the analysis would offer community leaders more flexibility and fidelity when compared to real world conditions.

#### **5.4 Flood Exposure Analysis Results**

Across the study area, tropical storms and hurricanes produce coastal and inland flooding as well as storm surges from the lake. These surges have the capacity to produce waves greater than 15 feet that inundate the extensive low-lying coastal areas and the lower portions of the Pearl River floodplain (FEMA, 2012a). In addition to storm surges, flooding is caused by heavy rains from tropical storms, hurricanes, thunderstorms, prolonged rain, and dam or levee failure. Flooding occurs on the floodplains of the streams that comprise the seven major drainage basins in the parish (St. Tammany Parish Government, 2009). While the smaller watersheds flood more quickly, the larger Pearl River watershed responds more slowly to runoff, and the duration of its flooding tends to be much longer. Water tends to pond in the flat areas of the parish with very

measured runoff, often resulting in localized flooding conditions (FEMA, 2012a). Natural drainage ways have been disrupted in developed areas, and impervious surfaces increase the runoff. All of these conditions are aggravated by channel obstructions. These watershed conditions mean that the parish is faced by longer-lasting overbank flooding from the larger rivers and quick or “flash” stormwater flooding in areas where the runoff overloads the drainage system (St. Tammany Parish Government, 2009). The first occurs primarily because of rain falling upstream in the watershed, and the second occurs by rain falling in the affected area.

According to FEMA’s flood impact study and the parish mitigation plans, flooding in the Northshore region needs to be understood in the context of two different geographic areas. Within five miles of Lake Pontchartrain, flooding occurs as a result of intense rainfall, abnormally high tides in the lake, hurricanes or lesser tropical storms, or any combination of these events. In the areas not adjacent to the lake, flooding occurs from periodic intense rainfall, causing overflow of rivers and streams. Historic data indicate that the majority of flood events in the region are associated with heavy rainfalls as opposed to more isolated extreme events. Table 5.1 offers a summary of major flood events that have impacted the Northshore region over the last 50 years.

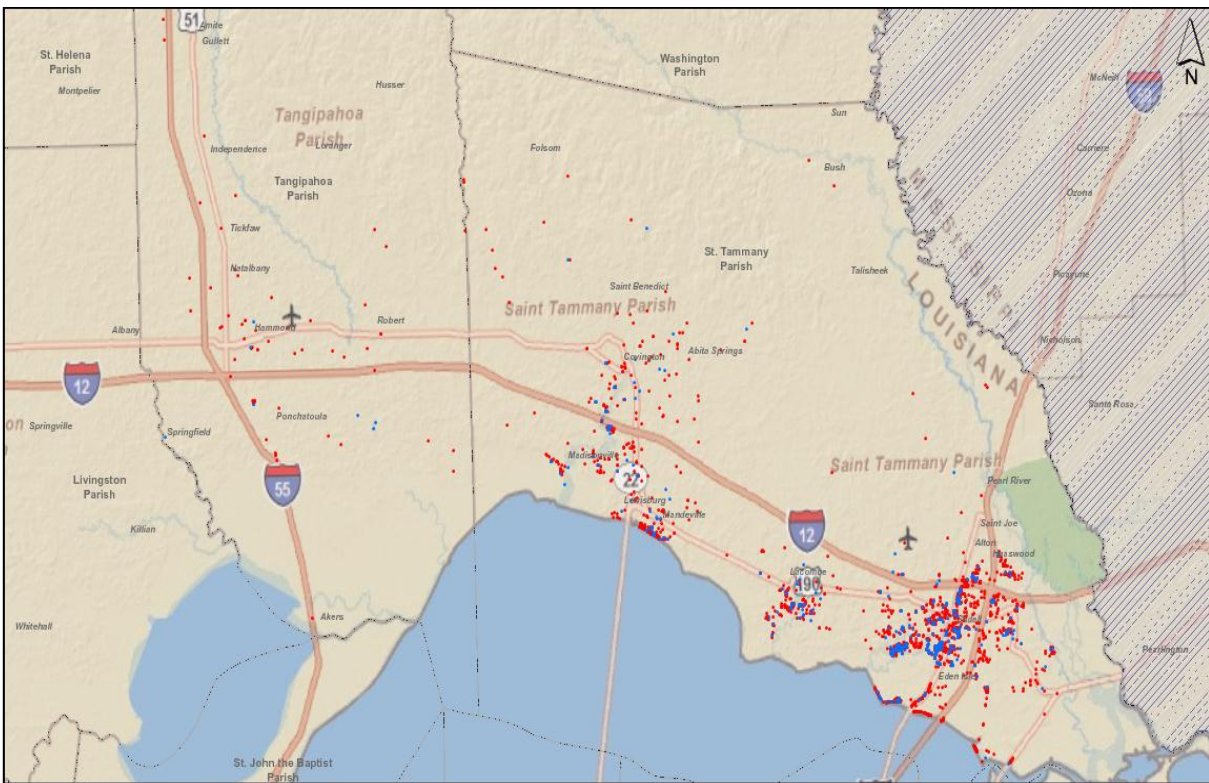
**Table 5.1: Summary of Major Flood Events (Data from FEMA and NOAA records)**

<b>Northshore Flood Events</b>			
<b>Date</b>	<b>Event</b>	<b>Date</b>	<b>Event</b>
Aug-69	Hurricane Camille	Sep-98	Tropical Storm Frances
Apr-79	Heavy Rainfall	Sep-98	Hurricane Georges
Apr-80	Heavy Rainfall	Jun-01	Heavy Rainfall
Dec-82	Heavy Rainfall	Jun-01	Tropical Storm Allison
Jan-83	Heavy Rainfall	Aug-02	Tropical Storm Bertha
Mar-83	Heavy Rainfall	Sep-02	Tropical Storm Isidore
Apr-83	Heavy Rainfall	Oct-02	Hurricane Lili
Aug-85	Hurricane Danny	Sep-04	Hurricane Ivan
Nov-85	Hurricane Juan	Aug-05	Hurricane Katrina
Feb-88	Heavy Rainfall	Jan-06	Heavy Rainfall
Apr-88	Heavy Rainfall	Oct-07	Heavy Rainfall
Jun-89	Heavy Rainfall	May-08	Heavy Rainfall
May-91	Heavy Rainfall	Aug-08	Tropical Storm Fay
Aug-92	Hurricane Andrew	Sep-08	Hurricane Ike
Apr-95	Heavy Rainfall	Sep-08	Hurricane Gustav
May-95	Heavy Rainfall	Apr-09	Heavy Rainfall
Oct-95	Hurricane Opal	Oct-09	Heavy Rainfall
Aug-96	Heavy Rainfall	Nov-09	Heavy Rainfall
Oct-96	Coastal Flooding	Nov-09	Tropical Storm Ida
Jan-98	Heavy Rainfall	Dec-09	Heavy Rainfall
Mar-98	Heavy Rainfall	Aug-12	Hurricane Isaac

A review of FEMA FIRM and DFIRM data indicates a significant amount of change in total area delineated as flood zones when comparing the FIRMs to the DFIRMs. While the net gain in Special Flood Hazard Area (SFHA) acreage in the region is substantial, a more detailed analysis using current aerial photography demonstrates that the increase in impacted structures was negligible. St. Tammany Parish will see a net gain in SFHA of approximately 30,538 acres with approximately 11,357 new structures (structures previously not within SFHAs) impacted by these areas with a net gain of 58 structures once all buildings no longer in SFHA are removed. The new data in Tangipahoa Parish demonstrates a net gain of 4,260 acres of SFHA and 1,709 (net gain of 65) structures impacted by the new SFHA designations.

### 5.4.1 Repetitive Loss Analysis

Repetitive Loss (RL) and Severe Repetitive Loss (SRL) information was collected from FEMA for both St. Tammany and Tangipahoa Parishes. Over 2,500 and 110 RL occurrences were identified for St. Tammany and Tangipahoa Parishes respectively (Figure 5.3). The majority of the data was geocoded using GIS software with a small percentage requiring manual completion or scrubbing of the data. Table 5.2, which is derived from two tables in the St. Tammany Parish Hazards Mitigation Plan, shows flood insurance claims paid by FEMA from 1978 through June 2008 in St. Tammany Parish. The unincorporated areas accounted for 63 percent of the claims paid and 69 percent of total payments. Of the 14,407 claims paid in the unincorporated areas, 8,851 resulted from Katrina. The City of Slidell accounted for 31 percent of the claims paid and 28 percent of total payments. Together, the unincorporated areas and Slidell accounted for 94



**Figure 5.3: Northshore Repetitive Loss and Severe Repetitive Loss Claims**

percent of the claims paid and 97 percent of total payments. This information indicates that flood exposure in the parish is largely concentrated in the incorporated areas of Slidell, Mandeville, Covington, and Madisonville, as well as the Lacombe/Oaklawn area and lakefront communities south of Slidell.

The RL and SRL data act as one of most accurate proxies for historic impacts, making it a useful dataset for identifying significant clustering of claim locations. This data must be considered with caution as the largest number of insured properties exists within these high exposure areas, causing the results to appear to be biased toward these locales. Due to this, a high level of significance in clustering of the RL data was found when running a nearest neighbor analysis. As expected, a subsequent Hot-Spot analysis proved to be of little value as the data was clustered around the largest cities with the most claims associated with them. While these spatial statistics did not assist in the identification of unknown clusters, it did confirm which areas should be focused on for the subsequent stages of the flood vulnerability analysis.

In order to expand upon the point pattern analysis of the RL data, engineering experts (Jacques Bagur, Jonathan Puhls, and George Hudson) from Gulf Engineers and Consultants assisted in the determination of what type of flood event caused each claim. In order to do so, the date associated with each claim was compared to flood events using historic stream and rainfall data. By doing so, it was possible to identify which types of events were responsible for the most frequent flooding as well as what type of flooding resulted in the most impact. Due to the

**Table 5.2: Total Flood Insurance Claims, January 1, 1978 – June 30, 2008**

<b>Community</b>	<b>Total Claims Paid</b>	<b>Total Payments</b>	<b>Substantial Damage Payments</b>	<b>Repetitive Loss Claims</b>
<b>Abita Springs</b>	49	\$619,715	6	5
<b>Covington</b>	353	\$5,819,919	35	58
<b>Folsom</b>	6	\$77,829	0	0
<b>Madisonville</b>	118	\$4,246,030	30	11
<b>Mandeville</b>	905	\$31,437,422	176	100
<b>Pearl River</b>	17	\$280,989	0	2
<b>Slidell</b>	7,114	\$422,000,922	3,029	837
<b>Uninc. Areas</b>	14,407	\$1,036,166,213	5,470	1,448
<b>Total</b>	22,969	\$1,500,648,948	8,745	2,460

timeframe covered by the RL dataset, events prior to May 1978 were not considered. Although large or infrequent storm events were not excluded from the evaluation, the relative frequency of the event which led to the occurrence of a RL claim was considered throughout the evaluation.

Stream gage data (Table 5.3) from the United States Geological Survey (USGS) were obtained in order to determine if the flooding associated with each repetitive loss location was potentially caused by backwater or headwater events from nearby rivers or streams, localized drainage issues, or storm surge. However, stream gage data were limited, and were not available for the entire RL dataset. The repetitive losses examined occurred from May 1978 to February 2010. Stream gage data were examined for the dates which corresponded with the appropriate RL data.

In order to augment the stream data, daily rainfall data (Table 5.4) were obtained from the National Oceanic and Atmospheric Administration (NOAA) in order to determine the type and magnitude of storm events associated with each RL claim. While rainfall data were also not available for the entire RL dataset, the combination of both stream gage and rainfall data enabled nearly every claim in the significantly clustered RL areas to be assessed.

**Table 5.3: USGS Stream Gages**

<b>USGS Stream Gage</b>	<b>Location</b>	<b>Dates of Available Data</b>
<b>02492600</b>	Pearl River at Pearl River, LA	10/1/94 to 2/22/10
<b>07375105</b>	Bogue Falaya River near Camp Covington, LA	1/6/98 to 2/22/10
<b>07375175</b>	Bogue Falaya River at Boston St. in Covington, LA	12/31/07 to 11/17/10

**Table 5.4: NOAA Precipitation Gages**

<b>NOAA Rain Station</b>	<b>Description</b>	<b>Dates of Available Data</b>
<b>160016</b>	Abita Springs	9/1/97 to 12/31/10
<b>162151</b>	Covington 4 NNW	5/7/71 to 12/29/1983
<b>164030</b>	Hammond 5 E	1/1/81 to 12/31/10
<b>167161</b>	Pearl River Lock 1	1/1/78 to 3/29/85
<b>168539</b>	Slidell	8/1/74 to 7/31/10
<b>168543</b>	Slidell Airport	9/1/88 to 12/31/10

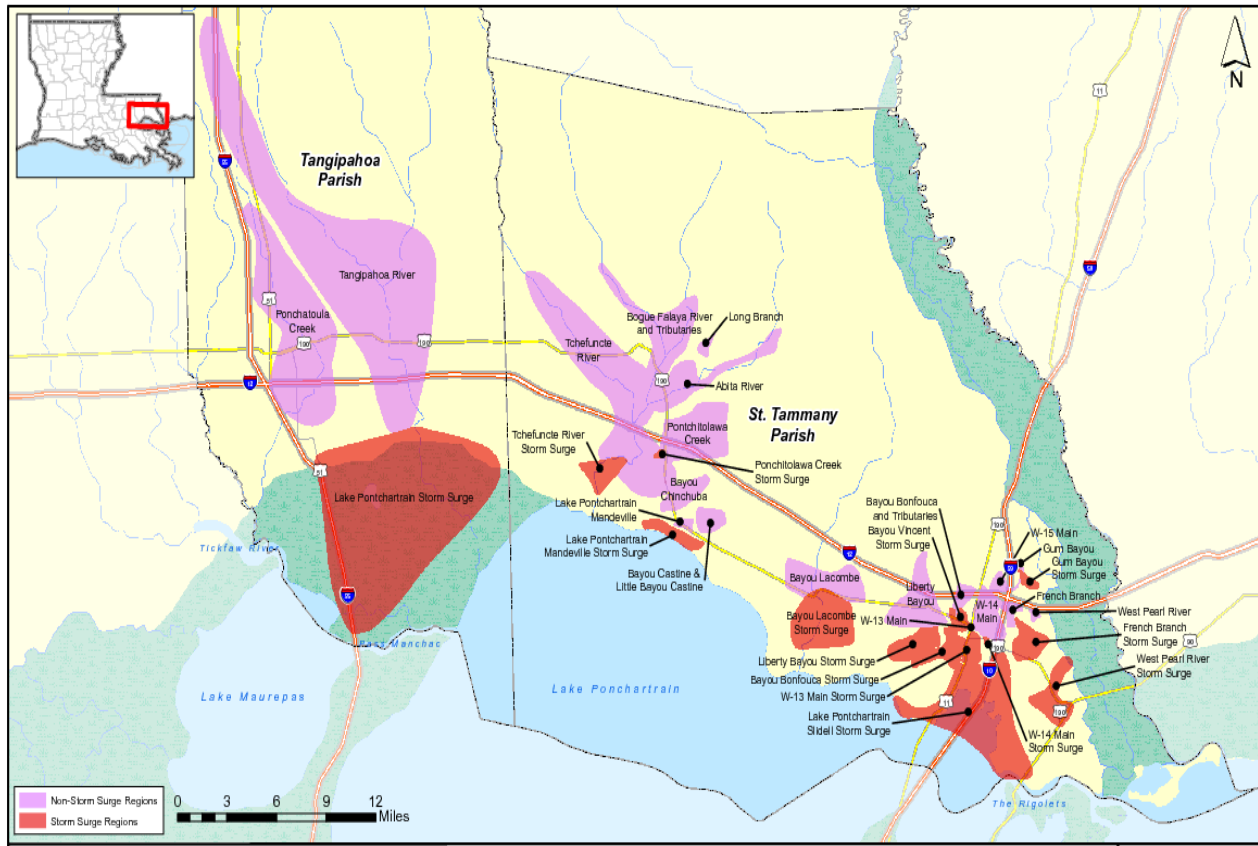
The area in both parishes south of Interstate 10 is susceptible to the impacts of wave action and storm surge from hurricanes and tropical storms. Repetitive loss claims resulting from storm surge were also identified as a subset of the larger FEMA dataset by identifying those claims associated with Hurricane and Tropical storm dates which also resided within the surge zone. The output of ADCIRC for the coastal regions of both parishes was used to delineate surge zones within the study region. This model enabled an approximation of the 100-year storm surge zone region to be identified. Within recent years, Hurricanes Juan (1985), Andrew (1992), George (1998), Hermine, (1998), Isidore (2002), Katrina (2005), and Gustav (2008) have impacted St. Tammany and Tangipahoa Parishes. While it is commonly accepted that Hurricane Rita (2005) also generated surge in this region, due to its close proximity to Katrina it is nearly impossible to distinguish between damages associated with the two events. As such, Hurricane Rita has been excluded from this assessment as Katrina proved to be the more significant event in this region.

After characterizing the nature of flooding associated with each RL claim, storm frequency was estimated for the large or infrequent events by utilizing the U.S. Department of Commerce Technical Papers Number 40 and 49 (U.S. Department of Commerce, 1961 & 1964). The TP-40 and TP-49 document maps depict storm frequency, by rainfall, for regions throughout the country. For a sense of scale, according to TP40 and TP49, the rainfall associated with the 1-, 2- and 4-day precipitation totals for this area during a 100 year event are approximately 12.5, 14, and 16 inches, respectively. The storm frequency was estimated by comparing these maps to the precipitation data associated with each event. The relationship between flooding and storm frequency was assessed by comparing the storm frequency data and flood damage data provided by the RL dataset. The regions which incurred the most structural damages from less frequent storm events, as opposed those areas with damages resulting from more frequent events, were identified using the flooding and storm frequency relationship. This enabled the regions, which are most susceptible to flood damages from more frequent events, to be identified.

When considered with historic flood events, SFHA delineations and total number of potentially impacted structures; the flood frequency and source information associated with the clustered RL data begins to sharpen the view of flood vulnerability in the study region. Using watersheds as a rough guideline, the areas identified as having the highest level of vulnerability to floods based on analysis of these past conditions have been delineated in Figure 5.4.

## **5.5 Flood Loss Estimation Results**

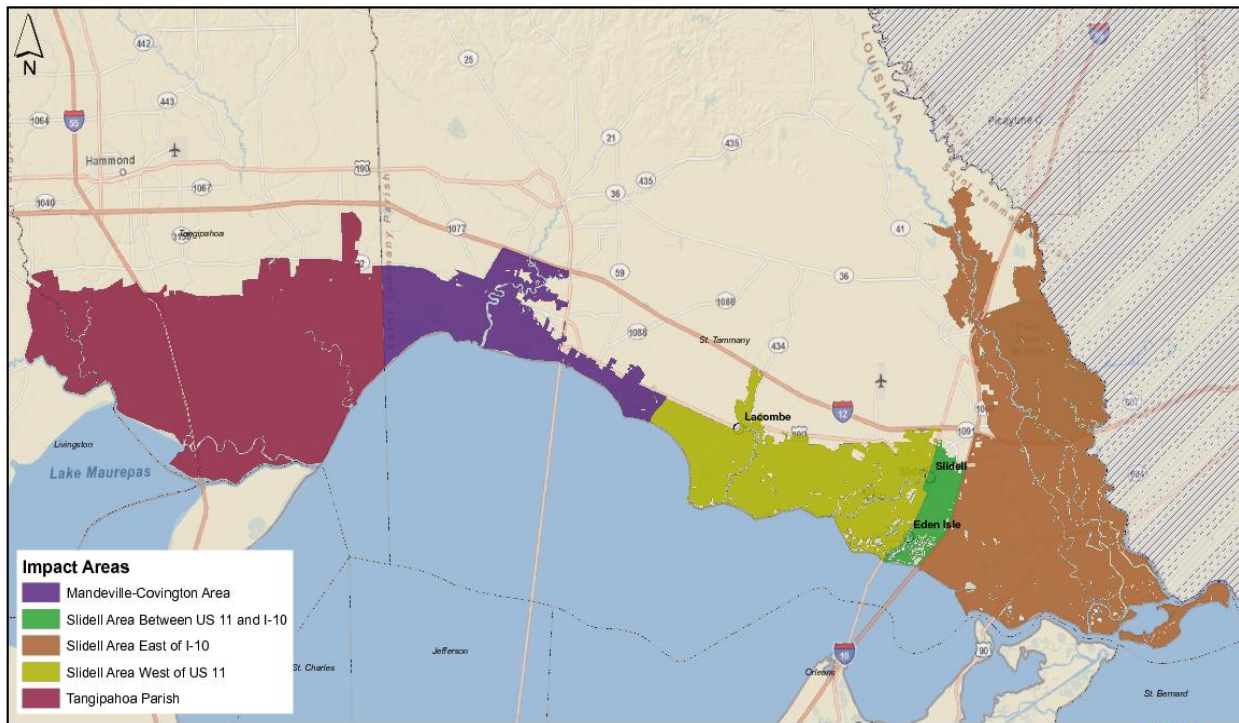
Due to data limitations, the HEC-FIA analysis was conducted for the surge zone of the Northshore for 50, 100 and 500 year flood events. Flood depth related data were incomplete or nonexistent for the northern reaches of the study area making it impossible to conduct a loss estimation using HEC-FIA. Nevertheless, due to the high concentration of total population and development within the surge zone, the results of the analysis were determined to be of value when assessing overall vulnerability to flooding. The results of the HEC-FIA analysis were in many ways consistent with the distribution of the high vulnerability areas identified in the flood analysis. The significance of these economic loss estimations is the ability to further refine the understanding of vulnerability in these regions. Each vulnerable region may be comprised of a variety of flood conditions generated by different sources. Identifying the distribution of economic losses across this flood-prone area will allow decision-makers to identify how to minimize damages by targeting those areas with the highest potential for economic losses.



#### 5.4 Northshore High Flood Vulnerability Areas

The HEC-FIA analysis was first executed by dividing the Northshore Region into five impact areas. These impact areas were delineated in a west to east fashion using easily identifiable break points between community highways, canals, etc. Dividing the region into five impact areas presents results which are easily interpreted and reduces the processing time when running the analysis. One impact area covered Tangipahoa Parish. Another covered the Mandeville and Covington area, and the final three impact areas covered adjacent sections of the Slidell area (Figure 5.5).

These impact regions were ingested by HEC-FIA along with the HAZUS GBS data, depth grids, and output parameters to generate a Rapid Consequences Assessment model. Damage curves were calculated for 50-year, 100-year, and 500-year frequency flood events within each impact area. For each impact area and each return period, reports on structure damage, content damage, vehicle damage, and population affected were generated. The life-loss function within FIA was not used in these runs and is typically not done for rapid consequence assessments due to the lack of detail associated with flood duration and extent in steady-state analyses.



**Figure 5.5: HEC-FIA Impact Areas**

The model identified that primary losses associated with flooding in this region were associated with building contents, with structure damage and vehicle losses accounting for less than half of the overall loss within each impact area. This can be attributed to the fact that many of the impacted buildings within the surge zone are constructed with periodic flooding in mind. This breakdown in contribution to losses would most likely shift in favor of structural losses if HEC-FIA had the capability to account for surge velocity and wave action on these structures, but the overall ratio of damage from one impact area to another would likely remain the same. Within the HAZUS GBS, the content costs are set as a percentage of the structure’s replacement cost and are determined by the occupancy type (FEMA, 2011). The occupancy type and foundation height proved to be the most influential variables in the overall analysis of loss estimation, suggesting that a more detailed user defined approach with accurate foundation heights would generate a far more accurate estimate of potential damages.

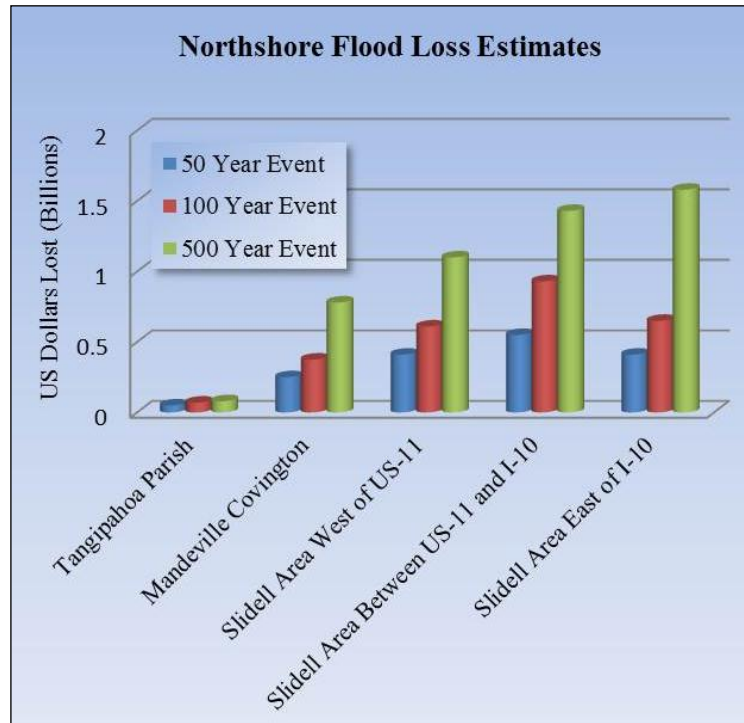
Overall, the loss estimation results show that the highest level of damages and impacted population are concentrated in the Slidell area for surge related flooding, with Mandeville/Covington and Tangipahoa Parish following respectively. The lack of population and development in the southern portions of Tangipahoa has once again limited its potential economic impacts from surge events. While it was no surprise that Slidell (the largest community in the region) would retain the highest potential for economic losses, it is interesting to note that the central and western areas of the city are much more susceptible to losses from higher flood events than the eastern portion of the city. As the frequency of an event decreases the economic losses tend to shift toward the eastern portion of the city and top one and a half



billion dollars during a 500-year event (Figure 5.6). Going back to the previous flood vulnerability analysis demonstrates that this dynamic variation in economic impacts is a result of the inland reach of flooding associated with each flood event coupled with the offset of development from the lakeshore.

### 5.6 Social Vulnerability Analysis Results

Based upon the original SoVI methodology, 32 distinct variables were incorporated into the SoVI<sup>NS</sup> analysis. Due to limitations associated with the 2010 Census data, the 2000 Census information was used to generate these variables. To offer an update to this information similar to the



**Figure 5.6: HEC-FIA Derived Economic Loss Estimates**

economic inflation factor applied to the HAZUS GBS, American Community Survey (ACS) data was used to adjust the 2000 Census data to 2009 figures. By comparing the SoVI analysis generated from 2000 Census data and 2009 adjusted Census data trends social vulnerability dynamics were identified throughout the study region. Because a one-to-one relationship does not exist between every variable in the Census information and the ACS data, modifications in method and data proxies had to be identified to create a seamless group of input variables. The 2000 SoVI<sup>NS</sup> PCA produced seven components responsible for 72.5% of the variance in the model. These components and their composite variables represent the driving forces behind social vulnerability in the Northshore region and include gender, race, and class; wealth; urbanization; age; special needs populations; ethnicity; and language barriers. In contrast, the 2009 SoVI<sup>NS</sup> PCA produced eight components that explained slightly less variance (67%) in the model. The most notable changes in influential components from 2000 to 2009 were associated with in-migration of a new Hispanic working class and an increase in both the number of people per housing unit and the number of block groups with lower average per capita incomes. Table 5.5 summarizes the component influences on model variance for both the 2000 and 2009 SoVI<sup>NS</sup> analysis.

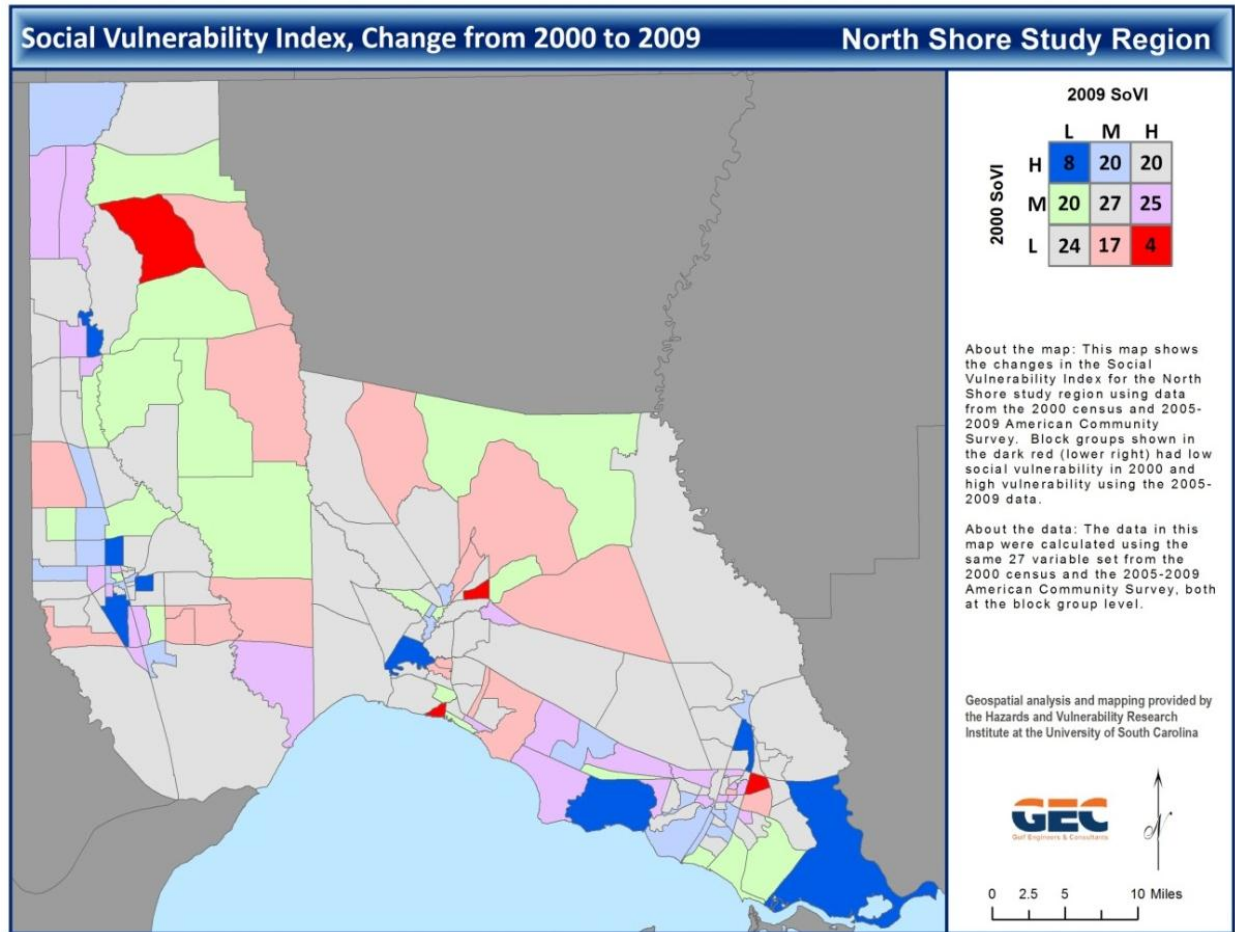
While the 2000 and 2009 SoVI<sup>NS</sup> models identify impoverished and black residents as defining characteristics of the first component, they are not necessarily the most important drivers of social vulnerability in each block group on the Northshore. When interpreting and applying SoVI results, it is necessary to consider all significant input variables and the combination of influential output components as opposed to any single output component. The final SoVI score for each spatial unit is a reflection of the dynamic interaction between these variables and components.

SoVI scores indicate that southern Slidell and southeastern Hammond are the most socially vulnerable while northeastern Slidell, western Hammond, and Covington residents are the least vulnerable. Interestingly, large-scale population movements into the area between 2000 and 2009, partially due to Hurricane Katrina, are modifying the social landscape of the Northshore. The Northshore SoVI scores indicate that southern Slidell and southeastern Hammond are the most socially vulnerable while northeastern Slidell, western Hammond, and Covington residents are the least vulnerable. Interestingly, large-scale population movements into the area between 2000 and 2009, partially due to Hurricane Katrina, are modifying the social landscape of the Northshore. Comparing the SoVI<sup>NS</sup> input data from 2000 to 2009 suggests that the Northshore population is becoming increasingly reliant on government programs, is experiencing more unemployment, is increasing in age, has more single mothers and service industry employees, and is seeing an increase in minority populations. While each of these factors (alone) can lead to

**Table 5.5: SoVI<sup>NS</sup> 2000 and 2009 Components**

<b>SoVI Northshore 2000</b>		
<b>Component</b>	<b>Name</b>	<b>% Variance Explained</b>
<b>1</b>	Gender, Race (Black), Poverty	31.2
<b>2</b>	Wealth	12.45
<b>3</b>	High Density Urban	9.98
<b>4</b>	Age (Elderly)	5.85
<b>5</b>	Special Needs, Gender	4.99
<b>6</b>	Native American	4.22
<b>7</b>	Language Barrier	3.81
<b>Total</b>	~	<b>72.5</b>
<b>SoVI Northshore 2009</b>		
<b>Component</b>	<b>Name</b>	<b>% Variance Explained</b>
<b>1</b>	Class, Race (Black)	21.6
<b>2</b>	Gender	9.78
<b>3</b>	Age (Elderly)	9.15
<b>4</b>	Wealth	7.04
<b>5</b>	High Density Urban	5.81
<b>6</b>	Underprivileged Families	4.73
<b>7</b>	Hispanic	4.34
<b>8</b>	Native American	4.23
<b>Total</b>	~	<b>66.68</b>

an increase in overall vulnerability, the fact that the Northshore as a whole simultaneously became more educated, has fewer mobile homes per capita, a lower percentage of Native American residents and fewer people per unit has resulted in a reduction in overall social vulnerability. These dynamic shifts in underlying population characteristics have also led to geographic changes in social vulnerability from 2000 to 2009. While social vulnerability across the entire study region is trending upward, there are distinct clusters of sharp vulnerability intensifications in central Slidell, Lacombe, and the northern fringe of Covington. Using a bivariate mapping scheme developed by the Hazards and Vulnerability Research Institute for displaying SoVI data clearly demonstrates this shift in social vulnerability (Figure 5.7).



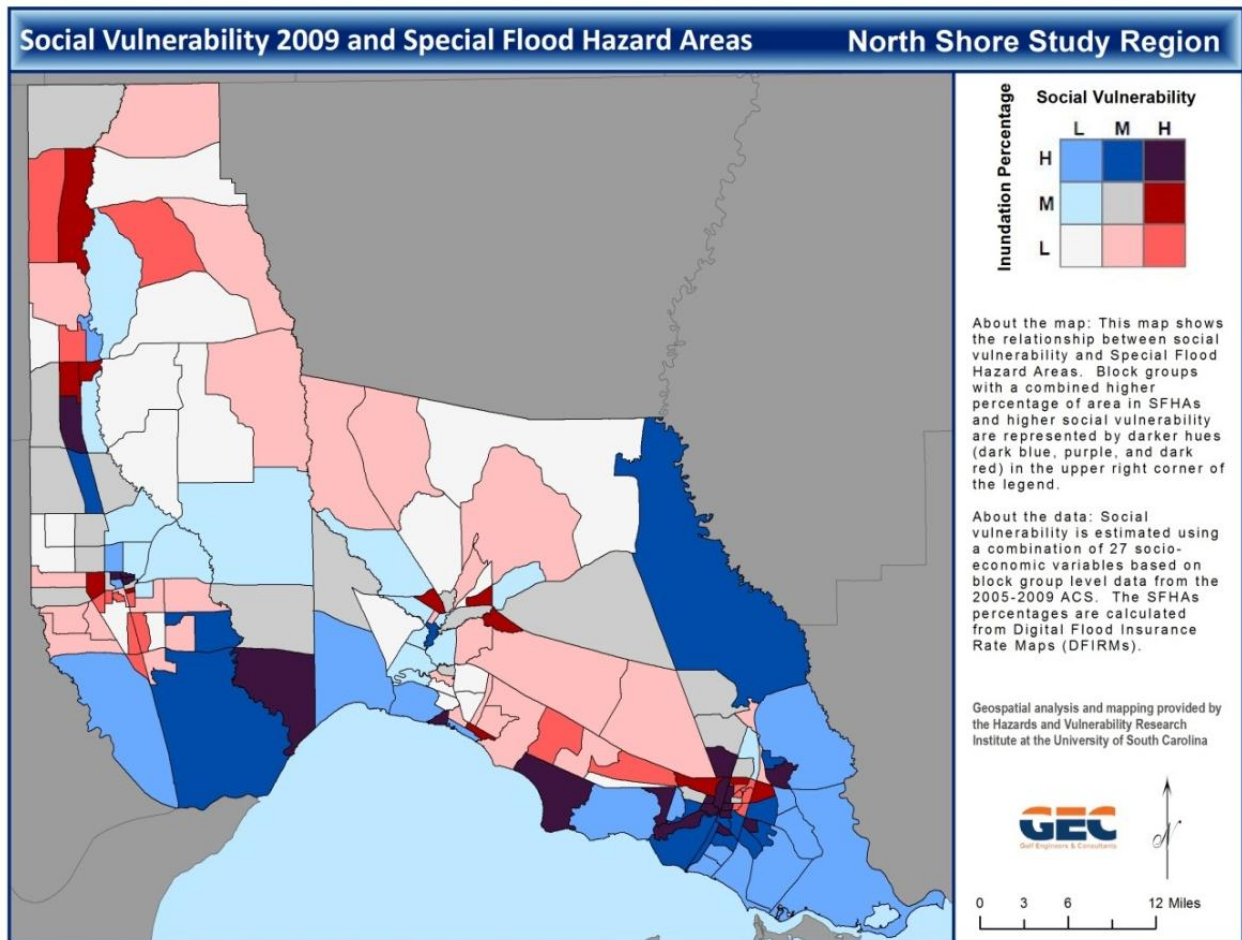
**Figure 5.7: SoVI<sup>NS</sup> Change from 2000 to 2009**

In addition to those areas experiencing the most significant increase (shaded dark red) or reduction (shaded dark blue) in social vulnerability, those areas indicated as experiencing moderate increases (light pink and light purple) should be identified as areas of concern that public officials should monitor for possible increases in social vulnerability as the population changes.

Use of the same bivariate mapping technique provides additional insight into the relationship between social vulnerability and potential exposure to flooding (Figure 5.8). The total percentage of land categorized by FEMA as a Special Flood Hazard Area within each block group was

acquired from FEMA’s National Flood Risk Report and categorized based on standard deviations. The social vulnerability data for each block was classified into three classes based on standard deviation to generate block group vulnerability ratings.

Care should be taken when drawing conclusions about places based on Census-derived information displayed using this bivariate scheme. Mapping a single value across block groups, which vary in size can lead to the assumption of an even population distribution. This, in turn, may draw focus to large rural census block groups exhibiting extremely low or high SoVI scores. In reality, the sizes of these block groups are related to total population, where larger enumeration units have lower population densities and smaller units have more people per square



**Figure 5.8: SoVI<sup>NS</sup> Related to SFHAs**

mile. Populations within each of these block groups are generally clustered together because of the location of developable, dry land, access to resources and transportation, and/or housing availability.

### 5.7 Combined Analysis

To explore the results of each tier of this analysis as a single consideration of vulnerability, it was necessary to combine the results of each phase. The challenge in doing this was two-fold, first dealing with the mix of qualitative and quantitative results from each phase and second was

reducing the volume of information into an easily transferable product. When considered as a whole, this study represented a systematic process by which the flood vulnerability of the region was defined at a coarse regional scale (FIRMs and DFIRMs) and then refined based on historic flood data, flood source data, analysis of repetitive losses, potential for economic losses, and finally vulnerability of the potentially impacted population. As one combines these data sources into a single picture, variations in the intensity of flood vulnerability begin to emerge. These variations and the driving factors behind them should be the consideration of policy makers in the region prior to dedicating mitigation funds.

To accomplish this goal, the flood prone regions identified in the first phase of this study were used to design a decision support matrix. This required the quantitative variables associated with flood losses and social vulnerability to be backed into a nominal level of measurement, as the flood vulnerability data could not be quantified. By intersecting these areas with the flood loss estimation and social vulnerability data within the GIS, attributes associated with each vulnerability component were added to the matrix based on geography. Once this matrix was completely populated, public officials were presented a brief, easily understood tool grounded in analytics and a significant volume of data (Appendix A).

In addition to summarizing details of each vulnerability component, recommended “treatments” were proposed for each of the vulnerable locations highlighted in the matrix. These treatment options were driven largely by the nature of flooding in a given area, distribution of vulnerable structure, and the volume of impacted populations. The assignment of a particular treatment to a specific social or economic vulnerability level was avoided at the request of officials in the community who wanted to avoid the assumption of “socially driven solutions.” As such, these two components were considered in a secondary nature when prescribing treatments. These proposed treatments are not final recommendations and should only be considered as an example of what review of the matrix can produce. Prior to implementation in any area, it is recommended that the detailed data behind the matrix be reviewed.

The final decision support matrix identified southern and central Slidell, Liberty Bayou, Gum Bayou, and French Branch as the communities most vulnerable to flooding based on flood exposure, economic loss estimation, and social vulnerability. Because the nature of flooding in each of these areas is documented in the matrix, it was easy for decision makers to consider what flood control measures would bring the maximum return on investment. As stated in the introduction of this document, the majority of traditional mitigation strategies in Louisiana focus on the implementation of structural flood control measures. The intention of this study was not to replace these, but to utilize non-structural input to prioritize implementation, with the long-term goal of augmenting the overall mitigation process. This return can be measured in number of citizens protected, number of structures protected, potential losses alleviated, livelihoods improved, or number claims reduced. Currently, the administration in St. Tammany Parish is incorporating these findings into their mitigation plans.

## **5.8 Discussion**

When viewed in its entirety, this study has collected, summarized, and analyzed a large volume of data associated with three key components of flood vulnerability in the Northshore region. As one of the first studies of its kind in Louisiana, it was imperative to generate enough empirical

evidence to demonstrate the value of utilizing research based methodology in applied environments. Understanding flood damage, and reducing the economic ramifications associated with flooding, remains a vital priority for both St. Tammany and Tangipahoa Parishes. The potential damages incurred by flood events take a toll on the social and economic vitality of the region, and may limit the potential for future growth. While hurricane protection plays a significant role in the reduction of flooding issues within the southern portion of the parishes, high-intensity rain events, seasonal fluctuations in rivers and streams, and manmade impacts may also exacerbate flood-related damages within all regions of the parishes.

While the primary flood control problems appear to be geographically isolated in areas closest in proximity to Lake Pontchartrain; research of historic flood events and analysis of social vulnerability and potential economic losses indicates that this phenomenon can be attributed more to the concentration of development and populations in these areas than the exposure to periodic storm surge. Historic economic development trends suggest that this movement will only continue to intensify as growth in the region occurs in those desirable geographies nearest to the lake and interstates. With this being said, one must ask why most mitigation in the region focuses on reducing storm surge as opposed to managing flood risk through changes in development patterns and guidelines. It is also important to note that the last decade has seen significant changes in the social vulnerability of the region, particularly in those areas in and around Slidell and Hammond. This shift in population dynamics will continue to contribute to the amplification of flood vulnerability in these communities. Concurrent with this will be a rise in the potential for economic losses as vulnerable populations are forced to live in less desirable, inexpensive, and more flood prone areas of the region. With all of this being said, it can be stated that flood vulnerability in the Northshore area is associated more with smaller rainfall events than extreme but less frequent tropical storms and hurricanes.

As an additional advantage, the engineering department from the Parish has been successful in utilizing the nonstructural information generated from this study to assist in cost/benefit justifications when applying for new mitigation funding. This new approach to analysis of mitigation has also assisted in enhancing the lines of communication between divisions throughout the Parish. Opposition from the public to this plan has also been less passionate due to the fact that stakeholders from the community were involved from the onset.

The results of this study have demonstrated the benefits of integrating current and emerging research methods within the policy realm. By establishing the value of approaching flood control from the social and economic as well as the engineering and structural perspective, public officials in the region are now addressing flood mitigation with a new level of insight. While it is clear that non-structural measures of vulnerability can lend value to the selection of mitigation projects, it is unclear from this study as to whether they can be used in the complete absence of engineering data. With this being said, this analysis has also demonstrated that vulnerability metrics such as SoVI do have a role within the “multiple lines of defense” strategy to flood protection currently employed in Louisiana. One could argue that non-structural techniques such as SoVI and flood loss estimation are in fact the mortar which binds each line of structural defense together in this approach to flood control. Ignoring their value will result in a disjointed and broken solution which may not be the most effective use of mitigation budgets. In the case of the Northshore Flood Control Plan, clear lines of communication from the onset of the study

acted as the primary vehicle for the integration of participative science into study methodology. While this novel approach proved to be difficult for administrators to understand and often clouded the scope of work, in the end its importance for both flood control and cost benefit justifications was sincerely valued by public officials.

## CHAPTER 6: CONCLUSION

*We flirt shamelessly with risk today, constructing city skylines in hurricane alleys and neighborhoods on top of fault lines...But as we build better buildings and airplanes, we do less and less to build better survivors.*  
-- Amanda Ripley, 2008

### 6.0 Summary of Results

Each of the research questions posited in Chapter 1 of this document have been addressed based on the series of essays presented in this study. The questions generally span the entire series of essays with no single chapter offering a definitive answer to each. In contrast, it would be safe to state that the iterations of the SRI analysis and application of alternative vulnerability assessments produced results which helped focus these questions and generate a path for future research.

As with any scientific inquiry, challenges were encountered throughout the course of the study, requiring interim adjustments to the proposed course of action. The majority of these adjustments were minor in detail, resulting generally in less ambiguity in the focus of each essay. Without a doubt, data availability and quality presented the most challenges throughout the dissertation. As stated in the introduction, data conditions are often the drivers of geospatial modeling, resulting in models which are not based on the most ideal set of information. The lack of historic recovery data was particularly difficult to overcome, as it made validation of the model impossible. As an alternative, the essay in Chapter 3 summarizes the use of proxy measurements of recovery for evaluation of the SRI. This lack of historic data also restricted the ability to apply a weighting scheme to the variables input into the model. With no historic context to reference, each variable had to be considered with an equal level of importance in the model. Overall, the adjustments made as a result of these issues only resulted in minor deviance from the original proposed course of study, allowing for each research question to be addressed with empirical data as a point of reference.

**Question 1:** Can a spatially based index be developed to quantify the ability of a community to recover from disaster?

The results of this analysis provide positive support to the idea that recovery can be measured from a spatial perspective, but not necessarily as hypothesized. It was originally posited that recovery could be considered separate from social factors, with critical infrastructure having to be established in order for population to return. What was crafted as an inquiry into separating the social components of recovery from physical and spatial components exposed an interesting notion. What the SRI is actually measuring is the ability of a community to experience “life recovery” based on those portions of the built environment which promote social capital. In this sense, a building is no longer just a building and cannot be valued on bricks and mortar alone. The recovery that is occurring following a disaster is social in nature and firmly tied to locations which hold meaning to the individuals residing there. The fact that churches and education centers coincided with positive recovery levels is reflective of the strong religious values held by



many of the communities in New Orleans, a fact that was not considered prior to the SRI but should have been. On the contrary, the church does not play the same roles in Austria as it does in inner city New Orleans, making its inclusion in the 2009 and 2010 SRI studies in Carinthia unnecessary. It is safe to presume that the influence on social networks of each of these locations diminishes as distance from them increases, but the ratio of influence to distance cannot be gathered from the SRI. Identifying what these locations are is critical to measuring recovery using the SRI. This limiting factor can be remedied with proper research into the culture and social network of the community being studied but restricts the SRI from one region to be compared to the SRI from another.

**Question 2:** Are there external factors influencing the ability to quantify the spatial distribution of recovery?

Although it is difficult to identify the exact amount of variance represented by each external component in the final outcome of the SRI, it is obvious that the influence of scale, model structure, and local culture is quite significant. The scale factor was brought to light in the first essay and arose once again in the Austrian study. Careful consideration of scale is imperative for the proper execution of this model, consideration of input data, as well as interpretation of the results.

The application of the SRI in Austria was intended to offer an environment completely different from New Orleans in order to test applicability of the model. It was hypothesized that applying the model in a location closer in proximity to New Orleans (e.g. Mobile, AL or Biloxi, MS) would not provide the necessary variance in locale to distinguish any difference in model output. However, the fundamental cultural influence on assessing recovery capabilities presented by the Austrian study suggests that this may not be the case. This cultural influence has a direct bearing on model structure, as it requires the identification of which at-risk elements within the built environment are most critical to sustaining social networks within the community. These elements are undoubtedly influenced by local traditions, values, culture and demographics, making it difficult to state that potential for recovery can be measured independent of social factors.

**Question 3:** Are tools such as a spatial recovery index capable of being used and acknowledged in an applied environment?

Initially, the planned approach to this study was to develop, vet, and deploy the SRI in both a research and an applied setting. This ambitious plan may have been shortsighted given current budgetary limitations related to exploratory studies. In addition, the SRI proved to be a difficult concept for many to grasp and did not produce significant enough results to justify its application. Presently, more rigorous research and validation of the tool are required in order to be confident in its use outside of a research environment.

With this being said, the opportunity to apply research based analytics to a study on the Northshore presented an opportunity to utilize similar research based methodologies in an applied environment. The final Northshore study was presented to the CPRA in the spring of 2012 as a 300 page document detailing the results of the analysis as well as the benefits these

results offered. In short, the Northshore essay highlights a successful application of three research based or exploratory vulnerability assessment techniques for long term mitigation planning. Unfortunately, the methods used in this study were viewed with great skepticism throughout its duration, resulting in a negative impact on the participatory process. Nevertheless, the final outcome was well received with the RL/SRL and SoVI portions of the analysis generating the most interest.

### 6.1 Significance

Hurricane Katrina compellingly demonstrated a deficiency in how American society comprehends disasters, and in turn how much it needs to learn. The American public lives in a complacent vacuum when it comes to understanding disasters (Flynn, 2007). This complacency is driven by the reactive measures employed by government officials and a tendency to assess risk through the eyes of the media. This misguided and unabashed disregard for proactive disaster management is firmly embedded at the highest level of American government and filters all the way down to local officials, resulting in a public that is often unaware of the totality of the risk they face. The events that unfolded in New Orleans after Hurricane Katrina can be considered a slow onset disaster or municipal perversity. Neither the public nor the government has accepted responsibility in initiating or fueling the internal collapse of the city after the disaster. This lack of liability has acted as a lingering wound which has contaminated the recovery process from day one. In addition to causing new wounds, Katrina also shed new light on a number of historic issues which have plagued the city for decades. Preexisting political, social, and racial divides in the city acted as the architecture for the inequity in response efforts. The disaster showcased by Katrina had in essence already occurred, Katrina only exposed it.

The decision to focus the research of this dissertation on the recovery component of disasters was undeniably inspired by the inadequacies highlighted in the previous paragraph. It was not the intent of this research to chart the political, social, or physical path which initiated this situation, but more importantly to move forward from it. Progress has proven to be one of the single greatest challenges to the disaster management field, as there is often a misguided belief that preparing for the last event will prevent the next. The tendency to retreat to the same techniques and lessons for guidance is even reflected in the basic disaster life cycle diagram used by nearly all practitioners in the United States (Figure 6.1). While variations exist, almost every form of this cycle presents the: “disaster causes response which leads to recovery where we mitigate and become more prepared” sequence. Understanding this process path is critical for an emergency manager to gain an

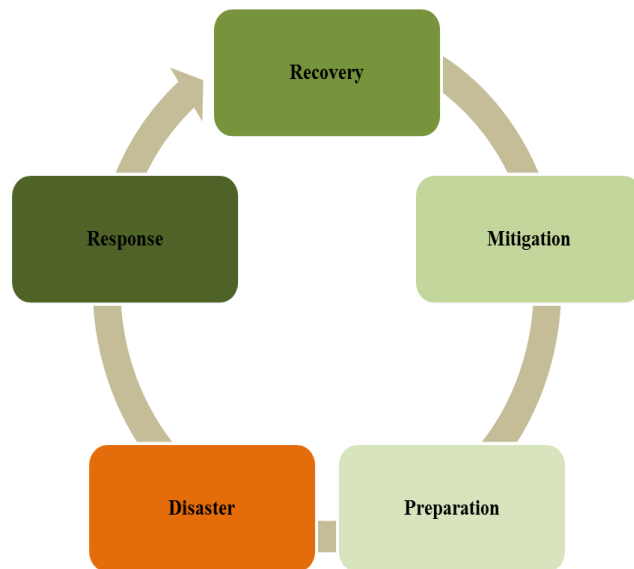


Figure 6.1. Disaster Life Cycle

overview of disaster events, but has more recently become a crutch in a field which is under political and fiscal pressure to move through the process. As a result, the life cycle has become a de facto doctrine for emergency managers who are increasingly reluctant to adjust the process. These adjustments may be as simple as using new tools to assess vulnerability and resilience, or as drastic as removing mitigation from the cycle and adding it as a complimentary standalone element. This criticism is not to suggest there is no value in utilizing past events as a source for moving forward, only that practitioners need to be careful that past experience does not create barriers which impede progress.

Every now and then a crack appears in this cycle, causing it to move forward instead of churning in place. These cracks are being increasingly exploited by a variety of resources as the field of disaster management extends its reach into various disciplines. Geographers have long held a place in this cycle, and now have an opportunity to promote its growth through the combined application of geospatial technology and social science. This study represents an adjustment to traditional disaster management techniques waiting to capitalize on one of the aforesaid fractures in this cycle. Regardless of whether it is the SRI, SoVI, or some other tool which improves the ability to both live with and mitigate disasters, progress in disaster management will not be realized without blending traditional practice with novel and innovative techniques. Establishing a bridge between research and practice will provide stakeholders in the emergency management field with a vehicle for transitioning new science into applied environments.

## **6.2 Path Forward**

In 1957 Wernher Von Braun stated that “*Basic research is what I am doing when I don’t know what I am doing*”. While this quote may now be considered trite and overused as a means of making light of the role of academics, its value lies in its underlying message. The true benefit to a great deal of research resides in the questions it generates rather than the answers it provides. Accepting these questions as results may be one the most perplexing aspects of scientific research. At present, there is a void in the research acumen in the field of disaster science. This deficiency is undoubtedly tied to the complexity of the ever-changing relationship between humans and the environment within which they chose to live. Understanding the issue of recovery is only one minor component of this disaster research puzzle and in this study has presented new directions as research in this arena moves forward.

The most interesting of these questions arose as a result of the evaluation of the SRI in Chapter 3. After reviewing the data, alternative measures of recovery, and conducting qualitative reviews of media reports, it became apparent that portions of the city were not recovering the way that any of the datasets suggested they should. Digging further into these isolated areas revealed extensive levels of damage, far beyond that witnessed in most areas of the city. These profound damages were the result of extreme flood depth and duration as well as water velocity and fires. These data suggested that there may be a threshold of disaster intensity that drives recovery. Once crossed, the impacted areas will experience extreme difficulty in recovering, despite preexisting socio-economic conditions, mitigation efforts, or returning population. Determining what this threshold is could be an improvement on existing baselines used to determine levels of flood protection built in communities. Is there a specific flood intensity level (duration or depth) which supplants any preexisting resilience?

Additionally, the understanding of cultural influences on recovery which were highlighted in Austria offers numerous opportunities for expanding this research. Do variations in the most important at-risk elements exist across cultures? Can the variation in risk perception be tied to the size of the geographic area in which it is measured? Does nationality have more of a role in risk perception than race and class? A better understanding the relationship between recovery and culture could ease the burden of identifying appropriate input variables for the model when applied across varying locales.

Moreover, the results of the initial SRI development caused a shift in how it was interpreted. Further investigation of the theory that buildings act as measurable anchors of social networks would also benefit future versions of the SRI. Does the structure itself hold value to the social network it serves, or is the presence of that element of the social network more important than location? In other words, if religious services took place in a deli rather than a church, would that element of the social network carry as much weight as one which was located in a more traditional setting?

In the end, the most important take away from this study is that understanding how recovery may be distributed across an impacted landscape is a valuable management tool for the practitioner. Regardless of whether recovery is measured spatially, socially, or with some combination of the two is of no matter. As long as researchers and practitioners are taking steps to expand upon this knowledge base and make it possible for the science to evolve, progress is being made.

## REFERENCES

- Ackroyd, S., Kirkpatrick, I., & Walker, R. M. (2007). Public management reform in the UK and its consequences for professional organizations: A comparative analysis. *Public Administration*, 85(1), 9-26.
- Adger, W.N., Hughes, T.P., Folke, C., Carpenter, S.R., & Rockström, J. (2005). Socio-ecological resilience to coastal disasters. *Science*, 209(5737), 1036-1039.
- Adger, W. N. (2006). Vulnerability. *Global Environmental Change*, 16, 268-281.
- Anthes, R.A., Corell, R.W., Holland, G., Hurrell, J.W., MacCracken, M., & Trenberth, K.E. (2006). Hurricanes and global warming - potential linkages and consequences. *Bulletin of the American Meteorological Society*, 87, 623-628.
- Arellano, A.L., Vetere, A. de Roo, & Nordvik, J.P. (2007). Reflections on the challenges of EU policy-making with view to flood risk management: actors, processes and the *acquis communautaire*. In Selina Begum, Marcel J.F. Stive, & Jim W. Hall (Eds): *Flood risk management in Europe*. (Section V) New York, NY: Springer Press.
- Association of State Floodplain Managers [ASFPM]. (2007). *Floodplain management 2050*. A Report of the 2007 Assembly of the Gilbert F. White National Flood Policy Forum. Washington, D.C.: Author. Retrieved from [http://www.asfpmfoundation.org/forum/GFW\\_Forum\\_Report%20205.pdf](http://www.asfpmfoundation.org/forum/GFW_Forum_Report%20205.pdf)
- Barroca, B., Bernardara, P., Mouchel, J.M., & Hubert, G. (2006). Indicators for identification of urban flooding vulnerability. *Natural Hazards and Earth System Sciences*, 6, 553-561.
- Birkmann, J. (Ed.). (2006). *Measuring vulnerability to Natural Hazards: Towards Disaster Resilient Societies*. Tokyo, Japan: United Nations University Press.
- Berry, B. (1980). Creating future geographies. *Annals of the Association of American Geographers*, 70 (4), 449-458.
- BMLFUW. (2006). Richtlinien für die wirtschaftlichkeitsuntersuchung und priorisierung von maßnahrender wildbach- und lawinenverbauung gemäß § 3 Abs. 2 Z 3 Wasserbautenförderungs-gesetz 1985. Teil I: Kosten-Nutzen-Untersuchung (KNU) und standardisierte Nutzenuntersuchung. Teil II: Leitfaden Prioritätenreihung. Wien.
- BMLFUW. (2008). Kosten-Nutzenuntersuchungen im Schutzwasserbau. Richtlinie, Wien.
- Bogard, W.C. (1988). Bringing social theory to hazards research: conditions and consequences of the mitigation of environmental hazards. In S. Cutter (Ed.), *Environmental Risks and Hazards (124-135)*. Upper Saddle River, NJ: Prentice-Hall Inc.

- Boruff, B.J., Emrich, C., & Cutter, S. (2005). Hazard vulnerability of U.S. counties. *Journal of Coastal Research*, 21(5), 932-942.
- Bowen, S., & Zwi, A.B. (2005). Pathways to evidence-informed policy and practice: A framework for action. *PLoS Med*, 2(7), e166.
- Cannon, T., Twigg, J., & Rowell, J. (2003). Social vulnerability, sustainable livelihoods and disasters. Report to DFID – Conflict and Humanitarian Assistance Department (CHAD) and Sustainable Livelihoods Support Office.
- Caspary, H.J. (2004). “Zunahme ‘kritischer’ wetterlagen als ursache fu¨r die entstehung extremer hochwasser in su¨dwestdeutschland.” In: KLIWA (Ed.) Klimaveränderung und Konsequenzen für die Wasserwirtschaft-Fachvorträge beim KLIWA-Symposium am 3. und 4.5.2004 in Würzburg, 135–151.
- Carr, Margaret H. & Zwick, Paul D. (2007). *Smart Land-use Analysis: The LUCIS model*. Redlands, CA: ESRI Press.
- Carreno, M.L., Cardona, O.D., & Barbat, A.H. (2007). A disaster risk management performance index. *Natural Hazards*, 41(1), 1-20.
- Carruthers, G., & G. Tinning. (2003). Where, and how, do monitoring and sustainability indicators fit into environmental management systems? *Australian Journal of Experimental Agriculture*, 43, 307-323.
- Carter, J.N., Ballester, P.J., Tavassoli, Z., & King, P.R. (2004). Our calibrated model has no predictive value: An example from the petroleum industry. *Proceedings of the Fourth International Conference on Sensitivity Analysis of Model Output*. Santa Fe, New Mexico: SAMO-04.
- Cash, D., & Moser, S.C. (2000). Linking global and local scales: Designing dynamic assessment and management processes. *Global Environmental Change*, 10, 109-120.
- Clark, G., Moser, S., Ratick, S., Dow, K., Meyer, W., Emani, S., Jin, W., Kasperson, J., Kasperson, R., Schwarz, H.E. (1998) Assessing the vulnerability of coastal communities to extreme storms: The case of Revere, MA., USA. *Mitigation and Adaptation Strategies for Global Change*, 3, 59-82.

- Clark, W., Jaeger, J., Corell, R.W., Kasperson, R.F., McCarthy, J.J., et al. (2000). Assessing vulnerability to global environmental risks. *Discussion Paper 200-2012, Environmental Natural Resource Program*, Belfer Center for Science and International Affairs, Cambridge, MA: Kennedy School of Government Harvard University.
- Clarke K.C., Hoppen, S., & Gaydos, L. (1996). Methods and techniques for rigorous calibration of a cellular automaton model of urban growth. *3<sup>rd</sup> International Conference/Workshop on Integrating GIS and Environmental Modeling*, Santa Fe, New Mexico.
- Committee on Science, Technology, and Congress. (1991). *Science, Technology, and Congress: Expert Advice and the Decision-making Process*, New York, NY: Carnegie Commission on Science, Technology, and Government.
- Covello, V.T. & Mumpower, J. (1985). Risk analysis and risk management: An Historical Perspective”, In S. Cutter (Ed.), *Environmental Risks and Hazards (33-54)*. Upper Saddle River, NJ: Prentice-Hall Inc.
- Coastal Protection and Restoration Authority (CPRA). (2012). *Louisiana’s Comprehensive Master Plan for a Sustainable Coast*. Retrieved from <http://www.coastalmasterplan.la.gov/>
- Coastal Protection and Restoration Authority (CPRA). (2007). *Integrated Ecosystem Restoration and Hurricane Protection: Louisiana’s Comprehensive Master Plan for a Sustainable Coast*. Retrieved from <http://www.coastalmasterplan.louisiana.gov/>
- Cutter, S. (Ed.) (1994). *Environmental Risks and Hazards*. Upper Saddle River, NJ: Prentice-Hall Inc.
- Cutter, S., Holm, D., & Clark, L. (1996). The role of geographic scale in monitoring environmental justice. *Risk Analysis*, 16(4), 517-526.
- Cutter, S. (1996). Vulnerability to environmental hazards. *Progress in Human Geography*, 20, 529-539.
- Cutter, S. (Ed.) (2001). *American Hazardscapes*. Washington D.C.: Joseph Henry Press.
- Cutter, S., Boruff, B.J., & Shirley, W.L. (2003). Social vulnerability to environmental hazards. *Social Science Quarterly*, 84(2), 242-261.

- Cutter, S. & Emrich, C. (2006). Moral hazard, social catastrophe: The changing face of vulnerability along the hurricane coasts. *The Annals of the American Academy of Political and Social Science*, 604, 102-112.
- Cutter, S. (2007). The social vulnerability index: A county-level assessment of communities and implications for preparedness planning. *First Annual DHS University Network Summit on Research and Education*.
- Cutter, S., Barnes, L., Berry, M., Burton, C., Evans, E., Tate, E., & Webb, J. (2008). *Community and Regional Resilience Initiative: Perspectives from Hazards, Disasters, and Emergency Management*. CARRI Research Report 1, Oak Ridge, TN: Oak Ridge National Laboratory.
- DeMers, M.N. (2002). *GIS Modeling in Raster*. Toronto: John Wiley & Sons, Ltd.
- Dunning, M. & Durden, S.E. (2008). *Handbook on applying "other social effects" factors in Corps of Engineers water resources planning*. Institute for Water Resources Technical Report, US Army Corps of Engineers, Retrieved from [www.iwr.usace.army.mil/docs/iwrreports/09R4.pdf](http://www.iwr.usace.army.mil/docs/iwrreports/09R4.pdf).
- Dunning, M.C. & Durden, S.E. (2011). *Social Vulnerability Analysis Methods for Corps Planning - USACE Campaign Plan, Goal 2: Systems approach*. Final Report by the Institute for Water Resources for the US Army Corps of Engineers, Retrieved from <http://www.iwr.usace.army.mil/docs/iwrreports/2011-R-07.pdf>.
- Eakin, H. & Luer, A.L. (2006). Assessing the vulnerability of social-environmental systems. *Annual Review of Environment and Resources*, 31, 365-394.
- Ellis, Frederick S. (1981). *St. Tammany Parish: L'Autre Cote Du Lac*. Gretna, LA: Pelican Publishing Co.
- Embleton-Hamann, C. (1997). Austria. In Embleton C. & Embleton-Hamann C. (Eds.), *Geomorphological Hazards of Europe (PP. 1-30)*. Amsterdam: Elsevier.
- Emerging Health Threats Forum. (2008). *Culture sways views of disaster risk*. Retrieved from [http://anitamakri.com/wp-content/uploads/2007/12/EHTF10.08.13\\_anitamakri.com\\_.pdf](http://anitamakri.com/wp-content/uploads/2007/12/EHTF10.08.13_anitamakri.com_.pdf).
- Emery, Y., & Giauque, D. (2003). Emergence of contradictory injunctions in Swiss NPM projects. *International Journal of Public Sector Management*, 16(6), 468-481.
- Emrich, C. T., Cutter, S. L., Ash, K. & R. Schumann. (2011). Flood risk management: integration of the social vulnerability index in multiple lines of defense mitigation. Technical Report submitted to GEC, Inc. Columbia, SC: *University of South Carolina, Hazards and Vulnerability Research Institute*.



- Eriksen, S.H., & Kelly, P.M. (2007). Developing credible vulnerability indicators for climate adaptation policy assessment. *Mitigation and Adaptation Strategies for Global Change*, 12, 495-524.
- ESRI Staff. (2006). GIS and emergency management in Indian Ocean earthquake/tsunami disaster. *ESRI White Paper*, 1-40.
- European Commission. (2002). *Communication from the Commission to the European Parliament and the Council, the European Community Response to the Flooding in Austria, Germany and Several Applicant Countries – A Solidarity-Based Initiative*. Brussels, Belgium: COM(2002) 481. Retrieved from <http://eur-lex.europa.eu/>.
- European Social Survey (ESS). (2011). <http://www.europeansocialsurvey.org/index.php>.
- Exworthy, M., & Halford, S. (Eds.). (1998). *Professionals and the New Managerialism in the Public Sector*. Maidenhead, UK: Open University Press.
- Faber, R. (2006). *Flood risk analysis: Residual Risks and Uncertainties in an Austrian Context*. (Doctoral Dissertation). Available from University of Natural Resources and Applied Life Sciences, Vienna.
- Fairweather, G.W., & L.G. Tornatzky. (1977). *Experimental Methods for Social Policy Research*. Elmsford, New York: Pergamon Press.
- Federal Emergency Management Agency (FEMA). (2008). *FEMA's Risk MAP Strategy – Integrating Mapping, Assessment, and Mitigation Planning*. Retrieved from [http://www.fema.gov/pdf/plan/risk\\_map\\_strategy\\_02202008.pdf](http://www.fema.gov/pdf/plan/risk_map_strategy_02202008.pdf)
- Federal Emergency Management Agency (FEMA). (2010). *Flood Insurance Study: Tangipahoa Parish, Louisiana, and Incorporated Areas*. Denton, TX: FEMA Region XI.
- Federal Emergency Management Agency (FEMA). (2011). *HAZUS 2.0 Technical and User's Manuals*. Retrieved from <http://www.fema.gov/library/viewRecord.do?id=4713>
- Federal Emergency Management Agency (FEMA). (2012a). *Flood Insurance Study: St. Tammany Parish, Louisiana, and Incorporated Areas - Draft*. Denton, TX: FEMA Region XI.
- Federal Emergency Management Agency (FEMA). (2012b). *Severe Repetitive Loss Program*. Retrieved from <http://www.fema.gov/severe-repetitive-loss-program>
- Finch, C., Emrich, C.T. & Cutter, S.L. (2010). Disaster disparities and differential recovery in New Orleans. *Population and Environment*, DOI 10.1007/s11111-009-0099-8.

- Fleischhauer, M., Greiving, S., Flex, F., Scheibel, M., Stickler, T., Sereinig, N., Koboltschnig, G., Malvati, P., Vitale, V., Grifoni, P., & Firus K. (2012). Improving the active involvement of stakeholders and the public in flood risk management – Tools of an involvement strategy and case study results from Austria, Germany and Italy. *Natural Hazards and Earth System Sciences* 12, 2785-2798.
- Flynn, S. (2007). *The Edge of Disaster*. New York, NY: Random House Press.
- Fotheringham, A.S., & Wegener, M. (1999). *Spatial Models and GIS: New Potential and New Models*. New York, NY: CRC Press.
- Fotheringham, A.S., Bunsdon, C., & Charlton, M. (2000). *Quantitative Geography: Perspectives on Spatial Data Analysis*. London, England: Sage Publications Ltd.
- Fotheringham, A.S., Bunsdon, C., & Charlton, M. (2002). *Geographically Weighted Regression: The Analysis of Spatially Varying Relationships*. Chichester, England: John Wiley and Sons, Ltd.
- Francis, R.L., McGinnis L.F. & White, J.A. (1992). *Facility Layout and Location: An Analytical Approach*. Cliffs, NJ: Prentice Hall Englewood.
- Frei C., Scholl, R., Fukutome, S., Schmidli, J., & Vidale, P.L. (2006). Future change of precipitation extremes in Europe: Intercomparison of scenarios from regional climate models. *Journal of Geophysical Research*, 111, D06105.
- Freudenburg, W.R. (1988). Perceived risk, real risk: Social science and the art of probabilistic risk assessment. In S. Cutter (Ed.), *Environmental Risks and Hazards* (244-256). Upper Saddle River, NJ: Prentice-Hall Inc.
- Fuchs, S. (2009). Susceptibility versus resilience to mountain hazards in Austria: Paradigms of vulnerability revisited. *Natural Hazards and Earth System Sciences*, 9(2), 337–352.
- Gaile, G. L. & Willmott, C. J. (Eds.) (2003). *Geography in America at the Dawn of the 21<sup>st</sup> Century*. Oxford, England: Oxford University Press.
- Gall, M. (2007). *Indices of Social Vulnerability to Natural Hazards: A Comparative Evaluation*. (Doctoral Dissertation). Available from University of South Carolina.
- Ganoulis, J. (2009). An integrated approach for flood risk management. In I. Linkov, Elizabeth Ferguson, & Victor S. Magar (Eds.), *Real-Time and Deliberative Decision Making* NATO Science for Peace and Security Series C: Environmental Security. Netherlands: Springer.
- Gardner, J. (1988). *The Florida Parishes: An Overview, Louisiana's Living Traditions*. Retrieved from [http://www.louisianafolklife.org/LT/Virtual\\_Books/FL\\_Parishes/.html](http://www.louisianafolklife.org/LT/Virtual_Books/FL_Parishes/.html)

- Gaume, E., Bain, V., Bernardara, P., Newinger, O. (2009). A compilation of data on European flash floods. *Journal of Hydrology*, 367(1–2), 70-78.
- Gaydos, L., Acevedo, W. & Bell, C. (1995). Using animated cartography to illustrate global change. *Proceedings of the International Cartographic Association Conference*, Barcelona, Spain: International Cartographic Association, 1174-1178.
- Gazsó, A. (2008). *The Austrian Experience – Project Nanotrust*. Presentation given at the OECD Working Party on Nanotechnology Workshop on Public Engagement with Nanotechnology, Delft, Netherlands.
- Gierlach, E., Belsher, B.E., & Beutler, L.E. (2010). Cross-cultural differences in risk perceptions of disasters. *Risk Analysis*, 30(10), 1539-1549.
- Gilbert, Janice D., (1988). *The Northshore: St. Tammany Parish - Louisiana's Living Traditions*. Retrieved from [http://www.louisianafolklife.org/LT/Virtual\\_Books/Fla\\_Parishes/](http://www.louisianafolklife.org/LT/Virtual_Books/Fla_Parishes/)
- Gillet, V. (2007). *A Multiobjective Approach to Combinatorial Library Design*. Retrieved from <http://daylight.daylight.com/meetings/emug01/Gillet/img0.htm>
- Greater New Orleans Community Data Center, (GNOCDC). (2009). *The New Orleans Index: Tracking Recovery of New Orleans and the Metro Area*. Product of the Greater New Orleans Community Data Center for the Brookings Institute. Retrieved from [http://www.gnocdc.org/NOLAIndex/NOLA\\_Index/ESNOLAIndex.pdf](http://www.gnocdc.org/NOLAIndex/NOLA_Index/ESNOLAIndex.pdf)
- Greater New Orleans Community Data Center, (GNOCDC). (2007). Retrieved from <http://www.gnocdc.org/>
- Günter B., Merz, R., Parajka, J., Salinas, J., & Viglione. A. (2012). Floods in Austria. In Z.W. Kundzewicz (Ed.), *Changes in Flood Risk in Europe*, Wallingford, Oxfordshire: IAHS Special Publication 10.
- Hammond, K. R., Harvey L.O., & Hastie, R. (1992). Making better use of scientific knowledge: Separating truth from justice. *Psychological Science*, 3(2), 80-87.
- Hartmann, T. (2011). *Clumsy Floodplains: Responsive Land Policy for Extreme Floods*. Farnham, England: Ashgate.
- Haining, R. (2003). *Spatial Data Analysis: Theory and Practice*. Cambridge, England: Cambridge University Press.

- Hastings, R.W., (2009). *The Lakes of Pontchartrain: Their History and Environments*. Jackson, MS: University Press of Mississippi.
- Heinz Center. (2002). *Human links to coastal disasters*. Washington D.C.: The H. John Heinz III Center for Science, Economics and the Environment.
- Hobfoll, S.E. (2001). The influence of culture, community, and the nested-self in the stress process: Advancing conservation of resources theory. *Applied Psychology* 50, 337–421.
- Johnston, R.J., & Sidaway, J.D. (1979). *Geography and Geographers*. New York, NY: Arnold Press.
- Kasperson, R.E., Ortwin, R., Slovic, P., Brown, H.S., Emel, J., Goble, R., Kasperson, J.X., & Ratick, S. (1988). The social amplification of risk: A conceptual framework. In S. Cutter (Ed.), *Environmental Risks and Hazards (112-123)*. Upper Saddle River, NJ: Prentice-Hall Inc.
- Kates R.W. (1971). Natural hazards in human ecological perspective hypotheses and models. In S. Cutter (Ed.), *Environmental Risks and Hazards (78-93)*. Upper Saddle River, NJ: Prentice-Hall Inc.
- Keiler M., Knight, J., & Harrison, S. (2010). Climate change and geomorphological hazards in the eastern European Alps. *Philosophical Transactions of the Royal Society*, 368, 2461-2479.
- Kerner, J.F. (2008). Integrating research, practice, and policy: What we see depends on where we stand. *Journal of Public Health Management and Practice*, 14(2), 193-198.
- King, D. (2007). Organizations in disaster. *Natural Hazards*, 40(3), 657-665.
- Kosar, B., Gröchenig, S., Leitner, M., Paulus, G., & Ward, S. (2011). The application of geospatial technology in hazards and disaster research: Developing and evaluating spatial recovery indices to assess flood hazard zones and community resilience in Austrian communities. In J. Strobl, T. Blaschke, & G. Griesebner (Eds), *GI-Forum 2011* Heidelberg. Germany: Herbert Wichmann Verlag.
- Kulmesch, S. (2010). *Evaluation of the HAZUS-MH Loss Estimation Methodology for a Natural Risk Management Case Study in Carinthia, Austria*. Austrian Marshall Plan Foundation Scholarship Publications. Retrieved from <http://www.marshallplan.at/2011/>
- Lagadec, P. (1982). *Major Technological Risk: An Assessment of Industrial Disasters*. Elmsford, New York: Pergamon Press.

- Landsea, C.W., Harper, B.A., Hoarau, K., & Knaff, J.A. (2006). Can we detect trends in extreme tropical cyclones? *Science*, 313, 452-454.
- Liang, L., Chen, S., Chen X., Nafiz, O., Adams, A.D., Macklin, M., & Ebenezer, J. (2005). *Student Understanding of Scientific Inquiry (SUSI): Development and Validation of An Assessment Instrument*. Leeds, UK: Eighth International History, Philosophy, Sociology & Science Teaching Conference (IHPST).
- Lin, G. (2002). *A GIS Method to Assess Distance Effects on Hospitalizations*. Research Paper #2002-15. West Virginia University Regional Research Institute Working Papers. Retrieved from <http://www.rri.wvu.edu/pdffiles/linwp2002-15.pdf>
- Liverman, D.M. (1990). Vulnerability to global environmental change. In S. Cutter (Ed.), *Environmental Risks and Hazards* (326-342). Upper Saddle River, NJ: Prentice-Hall Inc.
- Lloyd, C. D. (2007). *Local Models for Spatial Analysis*. Boca Raton, FL: CRC Press.
- Longley P.A., Goodchild, M.F., Maguire, D.J., & Rhind, D.W. (2005). *Geographic Information Systems and Science*, (2<sup>nd</sup> ed.). Chichester, England: John Wiley.
- Mabrey III, P. E. (2009). Hurricane Katrina and the third world: A cluster analysis of the “third world” label in the mass media coverage of Hurricane Katrina. *Communication Theses*. Paper 55. Retrieved from [http://digitalarchive.gsu.edu/communication\\_theses/55](http://digitalarchive.gsu.edu/communication_theses/55)
- Macdonald, N. Chester, D., Sangster, H., Todd, B., & Hooke, J. (2011). The significance of Gilbert F. White’s 1945 paper ‘human adjustment to floods’ in the development of risk and hazard management. *Progress in Physical Geography*, 36, 125-133.
- McCarthy, K., Peterson, D.J., Sastry, N., & Pollard, M. (2006). *The Repopulation of New Orleans After Hurricane Katrina*. RAND Corporation. ISBN: 0-8339-3940-7.
- McEntire, D. A. (2004). Tenets of vulnerability: An assessment of a fundamental disaster concept. *Journal of Emergency Management*, 2(2), 23-29.
- McEntire, D. A., Fuller, C., Johnson, C., & Weber, R. (2002). A comparison of disaster paradigms: The search for a holistic policy guide. *Public Administration Review*, 62(3), 267-281.
- Mileti, D.S. (1980). Human adjustment to the risk of environmental extremes. In S. Cutter (Ed.), *Environmental Risks and Hazards* (178-193). Upper Saddle River, NJ: Prentice-Hall Inc.
- Mileti, D. S. (1999). *Disasters by Design: A reassessment of Natural Hazards in the United States*. Washington, D.C.: Joseph Henry Press.

- Mitchell, J.K., Devine, N., & Jagger, K. (1989). A contextual model of natural hazards. In S. Cutter (Ed.), *Environmental Risks and Hazards (97-111)*. Upper Saddle River, NJ: Prentice-Hall Inc.
- Mitchell, J. K. (2008). Perspectives on alternatives: Differentiation and integration in pursuit of a better fit between society and nature. *Progress in Human Geography*, 32(3), 451.
- Muller, I., Smith, T., Mellor, S., Rare, L., & Genton, B. (1998). The effect of distance from home on attendance at a small rural health centre in Papua New Guinea. *International Journal of Epidemiology*, 27, 878-884.
- Murphy, A.B. (2008.) Makers of modern human geography: The extraordinary career of Gilbert White. *Progress in Human Geography*, 32(3), 445-461.
- Nachtnebel, H.P. (2007). Revised strategies for flood risk management: lessons from the 2002 flood in Europe. In O.F. Vasiliev, P.H.A.J.M. van Gelder, E.J. Plate, & M.V. Bolgov (Eds.), *Extreme Hydrological Events: New Concepts for Security*. Netherlands: Springer.
- National Research Council, (2006). *Facing Hazards and Disasters: Understanding Human Dimensions*. Washington D. C.: National Academies Press.
- Natural Hazards Center, CU. (2005). Holistic disaster recovery: Ideas for building local sustainability after a natural disaster. *Natural Hazards Center: University of Colorado; Boulder, CO*.
- NDMA (2007). Terminology of disaster risk reduction. India: National Disaster Management Authority. Retrieved from <http://ndma.gov.pk/publications.html>
- Niemeijer, D. (2002). Developing indicators for environmental policy: Data-driven and theory-driven approaches examined by example. *Environmental Science and Policy*, 5, 91-103.
- Nutley, S., Walter, I., & Davies, H. (2003). From knowing to doing. *Evaluation*, 9, 125–148.
- O'Brien, K., Leichenko, R., Kelker, U., Venema, H., & Aandahl, G. (2004). Mapping vulnerability to multiple stressors: Climate change and globalization in India. *Global Environmental Change*, 14, 303-313.
- O'Connor, M.C., Cooper, J.A.G. & McKenna, J. (2009). Integrating science into shoreline management practice, an Irish perspective. *Journal of Coastal Research*, SI 56, 1267-1270.

- O'Keefe, P., Westgate, K., & Wisner, B. (1976). Taking the naturalness out of natural disasters. In S. Cutter (Ed.), *Environmental Risks and Hazards (94-96)*. Upper Saddle River, NJ: Prentice-Hall Inc.
- Oreskes, N., Shrader-Frechette, K., & Belitz, K. (1994). Verification, validation, and confirmation of numerical models in the Earth sciences. *Science*, 263, 641-646.
- Paulus, G., Bäk, R., Flaschberger, G., Gruber, K., Piechl, T., Sereinig, N., & Seymann, C. (2004). Interoperability and geohazards : A conceptual framework for natural risk management in Carinthia, Austria.. In P. Prastacos, U. Cortes, U. Diaz de Leon, J.L. & M. Murillo (Eds.), *e-Environment : Progress and Challenge, Research on Computing Science (219-226)*.
- Perry, R.W. (1979). Evacuation decision-making in natural disasters. In S. Cutter (Ed.), *Environmental Risks and Hazards (208-221)*. Upper Saddle River, NJ: Prentice-Hall Inc.
- Pelling, M.(2003). *The Vulnerability of Cities: Natural Disasters and Social Resilience*. London: Earthscan.
- Plyer, A. (2008). An analysis of administrative data for measuring population displacement and resettlement following a catastrophic event. (Doctoral Dissertation). Available from Tulane University. New Orleans, LA.
- Plyer, Allison, Ortiz, E. & Petit, K. (2010). Post-Katrina commuter patterns. *Metropolitan Transportation Plan, St. Tammany Urbanized Areas, Fiscal Years 2011 – 2040*. New Orleans, LA: Greater New Orleans Community Data Center.
- Policy Development and Research. (2006). *New Orleans-Metairie & Kenner, Louisiana Metropolitan Statistical Area: Economic and Housing Market Conditions Pre- and Post-Katrina and Rita*. Washington D.C.: U.S. Department of Housing and Urban Development.
- Quarantelli, E. L. (Ed.). (1978). *Disasters: Theory and Research*. Beverly Hills, CA: Sage.
- Quarantelli, E. L. (1988). Disaster studies: An analysis of the social historical factors affecting the development of research in the area. In S. Cutter (Ed.), *Environmental Risks and Hazards (18-32)*. Upper Saddle River, NJ: Prentice-Hall Inc.
- Reed, M., E. D. G. Fraser, S. Morse, & A. J. Dougill. (2005). Integrating methods for developing sustainability indicators to facilitate learning and action. *Ecology and Society*, 10(1), r3.
- Reed, D., Preuss, J., Park, J. (2006a). Assessing vulnerability of social environmental systems. *Annual Review of Environmental Resources*, 31, 365-394.

- Reed, D., Preuss, J., Park, J. (2006b). The influence of context on lifeline behavior: Local policies under wind storm and earthquake scenarios. *Natural Hazards*, 39(2), 289-307.
- Reid, S. G. (1999). Perception and communication of risk, and the importance of Dependability. *Structural Safety*, 21(4), 373-384.
- Renn, O. (1998). The role of risk perception for risk management. *Reliability Engineering and System Safety*, 59(1), 49-62.
- Rosenthal, U. & Kouzmin, A. (1997). Crises and crisis management: Toward comprehensive government decision making. *Journal of Public Administration Research and Theory*, 7(2), 277-304.
- Rodríguez, H., Diaz, W. Santos, J., & Aguirre, B. (2006). Communicating Risk and uncertainty: science, technology, and disasters at the crossroads. In H. Rodriguez, E.L. Quarantelli, E.L., and R. Dynes, R. (Eds.), *Handbook of Disaster Research*. New York: Springer.
- Rygel, L., O'Sullivan, D., & Yarnal, B. (2006). A method for constructing a social vulnerability index: An application to hurricane storm surges in a developed country. *Mitigation and Adaptation Strategies for Global Change*, 11, 741-64.
- Rubin, C.B. (2000). Emergency management in the 21st century: Coping with Bill Gates, Osama bin-Laden, and Hurricane Mitch. *Natural Hazards Working Paper #104*, Institute of Behavioral Science, Natural Hazards Research and Applications Information Center, University of Colorado: Boulder, Co.
- Schmidt M. (2004). Investigating risk perception: A short introduction. In M. Schmidt *Loss of Agro-Biodiversity in Vavilov Centers, with a Special Focus on the Risks of Genetically Modified Organisms (GMOs)*, (Chapter 3). (Doctoral Dissertation). Available from University of Natural Resources and Applied Life Sciences, Vienna.
- Schmidtlein, M., Deutsch, R., Piegorsch, W., & Cutter, S. (2008). A sensitivity analysis of the social vulnerability index. *Risk Analysis*, 28(4), 1099-1114.
- Schönerklee, M. (2008). Advances in Managing Austria's water resources. In I. Gönenç, A. Vadineanu, J. P. Wolflin, & C. Russo (Eds.), *Sustainable Use and Development of Watersheds*. NATO Science for Peace and Security Series C: Environmental Security. Netherlands: Springer.
- Schwenk, C.R. (1988). The cognitive perspective on strategic decision making. *Journal of Management Studies*, 25(1), 41-56.



- Scott, M. & Cutter, S. (1996). *GIS and Environmental Equity: An Analysis of the Assumptions*. Santa Barbara, CA: National Center for Geographic Information and Analysis (NCGIA). Retrieved from <http://www.geo.wvu.edu/i19/papers/position.html>
- Slovic, P. (1987). Perception of Risk”, In S. Cutter (Ed.), *Environmental Risks and Hazards (155-165)*. Upper Saddle River, NJ: Prentice-Hall Inc.
- SOPAC. (2005). *Building Resilience in SIDS: The Environmental Vulnerability Index*. South Pacific Applied Geoscience Commission & United Nations Environment Programme. Retrieved from [http://www.vulnerabilityindex.net/evi\\_2005.htm](http://www.vulnerabilityindex.net/evi_2005.htm)
- Staffler H., Pollinger, R., Zischg, A., & Mani., P. (2008). Spatial variability and potential impacts of climate change on flood and debris flow hazard zone mapping and implications for risk management. *Natural Hazards and Earth System Sciences*, 8, 539–558.
- St. Tammany Parish Government. (2003). *Future Directions for St. Tammany Parish, Louisiana: A Strategic Plan for Economic Development*. St. Tammany Parish, LA. Retrieved from <http://www.stpgov.org/pdf/1179351369.pdf>
- St. Tammany Parish Government. (2009). *Natural Hazards Mitigation Plan – 2009 Update*. St. Tammany Parish, LA. Retrieved from <http://www.stpgov.org/pdf/1239205136.pdf>
- Stubbs, W.C. (1895). *A Hand-book of Louisiana, Giving Geographical and Agricultural Features*. New Orleans, LA: New Orleans Picayune, New Orleans.
- Swaroop, D.R. (2000). Factors influencing the incorporation of hazard mitigation during recovery from disasters. *Natural Hazards*, 22(2), 185-201.
- Szabó, J.A. (2007). Decision supporting hydrological model for river basin flood control. In J. Robert & J. Gyozo (Eds.), *Digital Terrain Modeling*, Heidelberg, Germany: Springer.
- Takeda, J., Tamura, K., & Tatsuki, S. (2003). Life Recovery of 1995 Kobe earthquake survivors in Nishinomiya city: A total-quality-management-based assessment of disadvantaged populations. *Natural Hazards*, 29, 565-583.
- Thomas, K. (1981). Comparative risk perception: How the public perceives the risks and benefits of energy systems. *Proceedings of the Royal Society of London*, 376, 35-50.
- Tummers, L. (2010). *Explaining Willingness of Public Professionals to Implement New Policies: A Policy Alienation Framework*. Presented at the ISPRM Conference - Track 12: Organizing Professionalism Panel. Bern, Switzerland.

- Unified New Orleans Plan (UNOP). (2007). Unified New Orleans plan. Retrieved from <http://unifiedneworleansplan.com/home3/>.
- United States Department of Commerce (USDOC). (2006). *United States Department of Commerce Service Assessment: Hurricane Katrina*. Retrieved from <http://www.weather.gov/om/assessments/pdfs/Katrina.pdf>.
- United Nations (UN). (2005). *Tsunami Recovery Status Report Summary*. Document prepared for the United Nations Information Management Service and Reconstruction Agency for Aceh and Nias. Retrieved from. <http://www.humanitarianinfo.org/sumatra/reference/indicators/docs/>
- U.S. Bureau of Labor Statistics. (2011). *Producer Price Index*. Retrieved from <http://www.bls.gov/ppi/home.htm>.
- U.S. Census Bureau. (2011a). *St. Tammany Parish Quick Facts*. Retrieved from <http://quickfacts.census.gov/qfd/states/22/22103.html>.
- U.S. Census Bureau. (2011b). *Tangipahoa Parish Quick Facts*. Retrieved from <http://quickfacts.census.gov/qfd/states/22/22105.html>.
- U.S. Department of Commerce. (1964). *Technical Paper No. 49: Two To Ten Day Precipitation for Return Periods of 2 to 100 Years in the Contiguous United States*. Washington D.C.: Weather Bureau.
- U.S. Department of Commerce. (1961). *Technical Paper No. 40: Rainfall Frequency Atlas of The United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years* Washington D.C.: Weather Bureau.
- Url, T., & Sinabell, F. (2008). Flood risk exposure in Austria – Options for bearing risk efficiently. *Journal of Applied Social Sciences*, 128(4), 593-614.
- Valassis. (2009). *Data Driven by Valassis Lists: From a Compilation by the Greater New Orleans Community Data Center*. Retrieved from <http://www.gnocdc.org>.
- Villa F., Voinov A., Fitz C., & Costanza R. (2003). Calibration of large spatial models: A multistage, multiobjective optimization technique. In R. Costanza & A. Voinov (Eds.), *Landscape Simulation Modeling*. New York, NY: Springer-Verlag.
- Ward, S., Leitner, M., & Pine, J. (2009a). Investigating recovery patterns in post disaster urban settings: Utilizing geotechnology to understand post-Hurricane Katrina recovery in New Orleans, Louisiana. In P. Showalter & Y. Lu (Eds.), *Geotechnical Contributions to Urban Hazard and Disaster Analysis*, New York, NY: Springer.

- Ward, S., Leitner, M., & Paulus, G. (2009b). Utilizing GIS technology in hazards research: Applying a spatial recovery index to assess vulnerability and community resilience in Carinthia, Austria. In J. Strobl, T. Blaschke & G. Griesebner (Eds), *Geospatial Crossroads @ GI\_Forum '09*, Heidelberg, Germany: Wichmann Verlag.
- Webster, P.J., Holland, G.J., Curry, J.A., & Chang, H.R. (2005). Changes in tropical cyclone number, duration, and intensity in a warming environment. *Science*, 309, 1844-1846.
- Weichselgartner, J., & Kasperson, R. (2010). Barriers in the science policy-practice interface: Toward a knowledge-action-system in global environmental change research. *Global Environmental Change*, 20(2), 266-277.
- Weichselgartner, J. (2001). Disaster mitigation: The concept of vulnerability revisited. *Disaster Prevention and Management*, 10(2), 85-95.
- Weinberg, A.M. (1985). Science and its limits: The regulators dilemma. In S. Cutter (Ed.), *Environmental Risks and Hazards (257-268)*. Upper Saddle River, NJ: Prentice-Hall Inc.
- Weinberg, D.H. (2011). *Management Challenges of the 2010 U.S. Census*. Retrieved from <http://www.copafs.org/userfiles/file/managingthe2010uscensus28jul11.pdf>
- Wescoat, J.L. (2006). Gilbert Fowler White (1911–2006), Wisdom in environmental geography. *Geographical Review*, 96, 700–710.
- White, G.F. (1936). The limit of economic justification for flood protection. *The Journal of Land and Public Utility Economics*, 12, 133–148.
- White, G.F. (1945). *Human Adjustment to Floods*. Research Paper 29. Department of Geography, University of Chicago.
- White, G. F. (1973). Natural Hazards Research. In S. Cutter (Ed.), *Environmental Risks and Hazards (5-17)*. Upper Saddle River, NJ: Prentice-Hall Inc.
- White, G.F. (1983). Interdisciplinary Research, A Plan for Research on Floods and Their Mitigation in the United States. In S. A. Changnon (Ed.), Champaign, Illinois: State Water Survey.
- White, G. F. (1988). Paths to risk analysis. In S. Cutter (Ed.), *Environmental Risks and Hazards (69-74)*. Upper Saddle River, NJ: Prentice-Hall Inc.
- Wilbanks, T.J., & Kates, R.W. (1999). Global change in local places : How scale matters. *Climate Change*, 43, 601-628.
- Willekens, F.J. (1983). Specification and calibration of spatial interaction models: A contingency-table perspective and an application to intra-urban migration in Rotterdam. *Tijdschrift voor Econ. en Geografie*, 74(4).

Wilson, R., & Crouch, E.A.C. (1987). Risk assessment and comparisons: An introduction In S. Cutter (Ed.), *Environmental Risks and Hazards (236.243)*. Upper Saddle River, NJ: Prentice-Hall Inc.

Winner, L. (1972). On criticizing technology. *Public Policy*. 20, 35-59.

Wisner, B., Blaikie, P., Cannon, T. & Davis, I. (2004). *At Risk: Natural Hazards, People's Vulnerability and Disasters*. New York, NY: Routledge.

Wu, S.Y., Yarnal, B., & Fisher, A. (2002). Vulnerability of coastal communities to sea-level rise: A case study of Cape May County, New Jersey, USA. *Climate Research*, 22, 255-270.

Zischg, A., Schober, S., Sereinig, N., Rauter, M., Seymann, C., Goldschmidt, F., Bäk, R., & Schleicher, E. (2011). Monitoring the temporal development of natural hazard risks as a basis indicator for climate change adaptation. *Natural Hazards*, Netherlands: Springer.

**APPENDIX A: FLOOD VULNERABILITY DECISION SUPPORT MATRIX**

<b>Area</b>	<b>Causes</b>	<b>Type of Flood Event</b>	<b>Social Vulnerability</b>	<b>Economic Vulnerability</b>	<b>Treatment</b>
<b>Abita River</b>	Large Rain Events	Headwater	Low to Medium	Low	Elevate Relocate
<b>Bayou Bonfouca Storm Surge</b>	Hurricanes	Storm Surge	High	Low	Elevate Relocate
<b>Bayou Bonfouca and Tributaries</b>	Large Rain Events	Headwater Backwater	High	Low	Elevate Relocate
<b>Bayou Castine/Little Bayou Castine</b>	Large Rain Events	Headwater	High	Low	Elevate Relocate
<b>Bayou Chinchuba</b>	Large Rain Events	Headwater	Low	Low	Elevate Relocate Drainage
<b>Bayou Lacombe Storm Surge</b>	N/A	Storm surge	High	Low	Elevate Relocate
<b>Bayou Lacombe</b>	Large Rain Events	Headwater	High	Low	Elevate Relocate
<b>Bayou Vincent Storm Surge</b>	N/A	Storm Surge	Low	Low	Elevate Relocate
<b>Bogue Falaya River</b>	Large Rain Events	Headwater Backwater	Low	Low	Elevate Relocate

<b>Area</b>	<b>Causes</b>	<b>Type of Flood Event</b>	<b>Social Vulnerability</b>	<b>Economic Vulnerability</b>	<b>Treatment</b>
<b>French Branch Storm Surge</b>	Large Rain Events	Storm Surge	High	High	Elevate Relocate
<b>French Branch</b>	Large Rain Events	Headwater Backwater	High	High	Elevate Relocate Drainage
<b>Gum Bayou Storm Surge</b>	N/A	Storm Surge	High	High	Elevate Relocate
<b>Gum Bayou</b>	Large Rain Events	Headwater Backwater	High	High	Drainage
<b>Liberty Bayou Storm Surge</b>	N/A	Storm Surge	High	High	Elevate Relocate
<b>Liberty Bayou</b>	Large Rain Events	Headwater Backwater	High	High	Elevate Relocate
<b>Long Branch</b>	Large Rain Events	Headwater	Low	Low	Elevate Relocate
<b>Mandeville Storm Surge</b>	N/A	Storm Surge	Low	Low	Elevate Relocate
<b>Mandeville</b>	Large Rain Events	Headwater	Low	Low	Elevate Relocate
<b>Slidell Storm Surge</b>	N/A	Storm Surge	High	High	Elevate

<b>Area</b>	<b>Causes</b>	<b>Type of Flood Event</b>	<b>Social Vulnerability</b>	<b>Economic Vulnerability</b>	<b>Treatment</b>
					Relocate
<b>Ponchitolawa Creek Storm Surge</b>	N/A	Storm Surge	Low	Low	Elevate Relocate
<b>Ponchitolawa Creek</b>	Large Rain Events	Headwater	Low	Low	Elevate Relocate Drainage
<b>Tchefuncte River Storm Surge</b>	N/A	Storm Surge	Low	Low	Elevate Relocate
<b>Tchefuncte River</b>	Large Rain Events	Headwater	Low	Low	Elevate Relocate Drainage
<b>Bayou Vincent Storm Surge</b>	N/A	Storm Surge	Low	Low	Elevate Relocate
<b>W-13 Main Canal</b>	Drainage System	Headwater	Low	Low	Drainage
<b>W-14 Main Canal Storm Surge</b>	N/A	Storm Surge	High	Low	Elevate Relocate
<b>W-14 Main Canal</b>	Drainage System	Headwater	High	Low	Drainage
<b>W-15 Main</b>	Drainage	Headwater	Low	Low	Drainage

<b>Area</b>	<b>Causes</b>	<b>Type of Flood Event</b>	<b>Social Vulnerability</b>	<b>Economic Vulnerability</b>	<b>Treatment</b>
	System				
<b>West Pearl River Storm Surge</b>	N/A	Storm Surge	Low	High	Elevate Relocate
<b>West Pearl River</b>	Large Rain Events	Headwater Backwater	Low	High	Elevate Relocate
<b>Ponchatoula River</b>	Large Rain Events	Headwater Backwater	Low	Low	Elevate Relocate
<b>Tangipahoa River</b>	Large Rain Events	Headwater Backwater	Low	Low	Elevate Relocate



## APPENDIX B: PERMISSIONS

Dear Sir,

With reference to your request (copy herewith) to reprint material on which Springer Science and Business Media controls the copyright, our permission is granted, free of charge, for the use indicated in your enquiry.

This permission

- allows you non-exclusive reproduction rights throughout the World.
- permission includes use in an electronic form, provided that content
  - \* is password protected;
  - \* at intranet;
  - \* not separately downloadable
  
- excludes use in any other electronic form. Should you have a specific project in mind, please reapply for permission
  
- requires a full credit (Springer/Kluwer Academic Publishers book/journal title, volume, year of publication, page, chapter/article title, name(s) of author(s), figure number(s), original copyright notice) to the publication in which the material was originally published, by adding: with kind permission of Springer Science and Business Media.

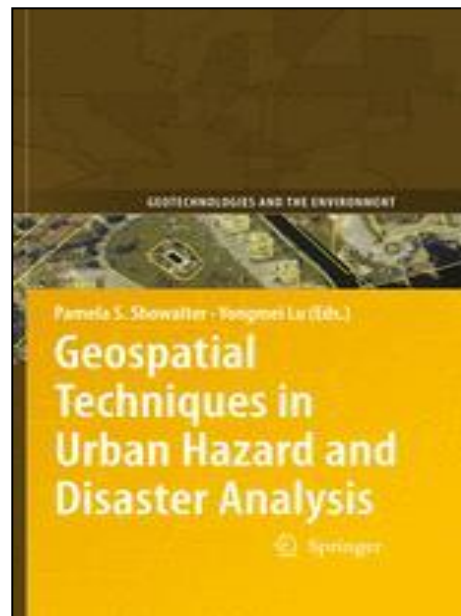
The material can only be used for the purpose of defending your dissertation, and with a maximum of 100 extra copies in paper.

Permission free of charge on this occasion does not prejudice any rights we might have to charge for reproduction of our copyrighted material in the future.

Kind regards,

Nel van der Werf (Ms)  
Rights and Permissions/Springer

Van Godewijkstraat 30 | P.O. Box 17  
3300 AA Dordrecht | The Netherlands  
tel +31 (0) 78 6576 298  
fax +31 (0)78 65 76-377



Nel.vanderwerf @springer.com  
www.springer.com

-----Ursprüngliche Nachricht-----

Von: SpringerAlerts@springeronline.com [mailto:SpringerAlerts@springeronline.com]

Gesendet: Montag, 15. Oktober 2012 15:18

An: authorhelpdesk

Betreff: Permission to use Springer articles/ chapters

INTERNAL NAME - Your Question about Rights & Permissions ORIGINAL URL -  
<http://www.springer.com/authors/book+authors/contact?SGWID=5-1725113-12-807911-0>

-----  
Additional information

-----  
form\_of\_address - Mr.

first\_name - Steven

last\_name - Ward

EMAIL RETYPE - steven.matthew.ward@gmail.com title - Geospatial Techniques in Urban Hazard and  
Disaster Analysis - ISBN: 978-90-481-2237-0 question - To whom it may concern,

I was a contributing author in this book with a chapter titled "Investigating Recovery Patterns in Post  
Disaster Urban Settings: Utilizing Geotechnology to Understand Post-Hurricane Katrina Recovery in  
New Orleans, Louisiana" (pages 355-372). I am currently approaching my dissertation defense as part of  
my PhD studies which included the research in this chapter. I would like to include it as a chapter in my  
dissertation and per LSU graduate school guidelines require permission from Springer to reprint it. Can  
you please advise on this process and provide proof of permission for me to include with the final  
document. Thanks in advance for your time and consideration on this matter.

Kind regards,  
Steven

## VITA

Steven Ward received a Bachelor's of Science in Environmental Management Systems with a minor in Chemistry from Louisiana State University in the spring of 1999. Having spent his undergraduate career working in various labs around the Agronomy department, Steven stayed at LSU to complete a Master's of Science in Agronomy with a special focus on the application of geospatial technology in land use planning and trafficability assessments as part of the US Army Integrated Training Area Management Program. Following graduation Mr. Ward worked as a Geospatial Specialist for the Louisiana Office of Mineral Resources as well as Coastal Environments, Inc. before spending seven years as a GIS project and program manager at GEC, Inc. in Baton Rouge, LA.

Mr. Ward is currently employed as a Senior Geospatial Scientist with GeoEye Analytics. He is responsible for predictive analytics, geospatial intelligence, spatial statistics, advanced cartography, project management, proposal development, GIS database development, training course development and instruction, analyses, map and report production for complex research, planning, and impact assessment projects conducted by GeoEye scientists. His academic credentials in Agronomy, Environmental Management Systems, Hydrology and Hazards Geography enable him to effectively participate in a variety of project, research and field investigations.

In addition to being a certified GIS professional, Mr. Ward is currently a member of a number of national and local emergency management organizations and working toward an international certification in emergency management and disaster science. Regular attendance at local and national hazards and disasters workshops/conferences, as well as completing training at FEMA's Emergency Management Institute and online independent study programs has provided Steven with a strong background of conducting GIS work within the structure of ICS, NIMS, and the National Response Framework.

At the professional level Mr. Ward has successfully completed/worked on projects involving disaster relief, risk assessment, vulnerability modeling, temporary housing, public outreach, DFIRM production and adoption, public works in disasters, and mitigation. He has lectured on the integration and use of geospatial technology in all aspects of emergency management and counter terrorism at Louisiana State University's geography department as part of the Disaster Science and Management curriculum; as well as the university of Salzburg, and Carinthia University of Applied Sciences. Mr. Ward's current research and development related projects include work on multiple spatial modeling and disaster related studies; including predictive analytics for hazards and vulnerability modeling, social vulnerability modeling, cultural landscapes, hazards and recovery research, evacuation modeling, sustainable development research and predictability modeling, habitat/ environmental suitability models, and application of statistical procedures to assess spatial autocorrelation in environmental and disaster related studies.