MEASURING LONG-TERM POST-DISASTER COMMUNITY RECOVERY

by

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ABSTRACT

Long-term post-disaster community recovery is a complex process that can define the character of affected communities for years to come. Currently, however, no comprehensive, well accepted method of measuring recovery at the community scale exists, impeding efforts to fully understand it.

This thesis is part of a larger effort to develop a quantitative measure of post-disaster community recovery, and makes three primary contributions towards that goal. First, it introduces a systematic process by which a measure of post-disaster community recovery can be designed, identifying the important issues in designing a recovery measure, enumerating the ways they may be addressed, and discussing how one might choose among those alternative approaches. Second, the process is applied to develop a prototype measure of post-disaster community recovery for the housing sector specifically (with the idea that it could later be extended to other sectors). The housing measure includes three dimensions: (1) *Degree of recovery*, which captures the speed of recovery; (2) *Sustainability of recovery*, which represents the extent to which the recovery builds sustainability into the community for the future; and (3) *Extent of change*, which identifies permanent changes in the community as a result of a disaster and the subsequent recovery. By repeating the assessments at multiple time steps, one can track the recovery over time. The use of supporting data and an assessment of data quality are also addressed.

Finally, the thesis presents a case study of housing recovery in Punta Gorda, Florida following Hurricane Charley (2004). The housing recovery is described in detail drawing on multiple sources of data, including remote sensing and aerial imagery, building permits, U.S. census data, and interviews with local officials. The strengths and weaknesses of different data sources are evaluated, and the housing recovery measure is then applied to demonstrate how it summarizes recovery for this case study.

CHAPTER 1 - INTRODUCTION

This chapter provides an introduction to the content of the thesis. Section 1.1 introduces the idea of measuring long-term post-disaster community recovery and provides the background for the project. Section 1.2 discusses the objectives and scope. Section 1.3 provides an outline for the remainder of the thesis.

1.1 Measuring Post-Disaster Community Recovery

Long-term post-disaster community recovery is a complex physical, social, economic, environmental, and political process. It can last years, require enormous financial and other resources, and define the character of the affected communities for years to come. Nevertheless, recovery is often cited as the most poorly understood phase of the disaster cycle (e.g., Haas et al. 1977, Mileti 1999, Olshansky 2005).

The first step in understanding disaster recovery is to define and measure it. Explicit, quantitative definitions of the concept can provide a consistent basis for discussion and enable systematic, transparent determination of the extent to which and ways in which a community has recovered, and how that assessment changes over time. Such a measure of community recovery could then be used to help address important questions, such as:

- In a particular event, is a community recovering quickly or slowly? What is good or bad about how it is recovering?
- In what ways do different communities recover differently, and why?
- What can be done to improve the speed and quality of recovery in future events?
- For a disaster that has just occurred, over what timeframe and in what ways is recovery likely to unfold?
- How are the speed and character of a community's post-disaster recovery related to various pre- and post-disaster decisions and actions?

Unfortunately, no such comprehensive, well accepted method of measuring recovery at the community scale currently exists, perhaps in part because of the many substantial challenges involved in creating such a method. First, there is no widely accepted definition of when the recovery process is complete. Some literature suggests recovery ends when the community has returned to its original state or to a level where it would have been without the disaster (e.g., Schwab et al. 1998). Other literature advocates a definition of recovery in which the community achieves a stable state which may or may not be the same as the pre-disaster state (e.g., Quarantelli 1999). It is difficult to determine how far along a recovery has progressed when there is no established definition of the end goal. Another challenge is the expansive, multi-dimensional nature of community recovery. The recovery process involves almost every aspect of community life, including the built environment, natural environment, economy, education, and health care. It also does not typically proceed uniformly across geographic regions or population groups within a community. As such, community recovery is not easily captured by a few, readily available metrics. The desire for a measure to be applicable across many communities and a relatively long time frame, and perhaps across a large geographic region and different disaster types introduces challenges as well. Many types of data are not available in a consistent form and at consistent levels of reliability across jurisdictions and time frames.

1.2 Objectives and Scope

The research presented in this thesis is part of a larger National Science Foundation (NSF)-funded project that includes five co-Principal Investigators—Ronald Eguchi (PI, ImageCat, Inc.), Beverley Adams (co-PI, ImageCat, Inc.), Stephanie Chang (co-PI, School of Community and Regional Planning and Institute for Resources, Environment, and Sustainability, University of British Columbia), Rachel Davidson (co-PI, Department of Civil and Environmental Engineering, and Disaster Research Center, University of Delaware), and Arleen Hill (co-PI, Department of Earth Sciences, University of Memphis). The larger NSF project has the following two main objectives:

- **Develop a quantitative measure of post-disaster community recovery**. The development of the measure will be based on the theory of recovery, input from potential future users, and consideration of a full spectrum of data sources including remote sensing and aerial imagery; street-view GPS-referenced photographs and video collected using the VIEWS field data collection system; interviews with key decision makers and participants in the recovery process; census and other secondary statistical sources. The measure is focused on community-level recovery (as opposed to household or business recovery, for example).

- **Demonstrate the new measure through application to two case study areas**. The new measure is being applied to Hurricane Charley in Punta Gorda, FL and to an area affected by Hurricane Katrina. To ground the measure development in real examples, ensure the required data are available, and demonstrate how the measure can potentially be used; it is being applied to these two different case study areas.

The research presented in this thesis has the following objectives, which are related to the two above, but somewhat reduced in scope:

- **Develop a systematic process by which a quantitative measure of post-disaster community recovery can be designed and applied**. Identify the important issues in designing a recovery measure, the many ways they may be addressed, and how one can think through the decisions to choose among those alternative approaches.
- **Develop a prototype community-level measure of post-disaster housing recovery**. Apply the process developed in the first objective to develop a measure for only the housing sector of a community.

- **Apply the housing measure for Punta Gorda, Florida**. Demonstrate the housing measure for Punta Gorda, the largest city in and county seat of Charlotte County, Florida.

1.3 Outline of Thesis

This first chapter of the thesis provides an introduction, including the motivation and objectives both of this thesis and the overall project of which it is part. Chapter 2 presents a review of the existing literature related to the field of disaster recovery. The literature review describes the overall theories and framework, including the definition and scope of recovery; introduces the sectors of recovery which have been established in the literature, including housing; discusses previous attempts to measure recovery using indicators and other approaches; and presents case studies related to disaster recovery. The final section discusses general case studies related to disaster recovery as well as a section on the many case studies related to Hurricane Katrina.

Chapter 3 introduces the new process by which a measure of post-disaster community recovery can be designed and applied. Development of a recovery measure depends on identifying the features it should have, then balancing the desire to include those features while recognizing the limited data available to evaluate it. Identifying the features that specify the design of a recovery measure involves numerous decisions. Those decisions are presented, along with guidance as to how to make them. The many indicators that may potentially be used in a recovery measure are enumerated and discussed as well. Finally, a prototype measure of the housing sector only is developed using this new approach.

The fourth chapter describes how the community housing recovery measure developed in Chapter 3 can be applied, using the experience of Punta Gorda, Florida after Hurricane Charley as a case study. The many sources of potentially useful data that were collected are presented and compared. The recovery of the housing in Punta Gorda following the August 13, 2004 Category 4 hurricane is described in detail, and the new housing recovery measure is applied to show how it summarizes the progress and character of the recovery in that event.

The final chapter of the thesis summarizes the key conclusions and discusses future work that can improve and extend the effort to better measure and monitor post-disaster community recovery.

CHAPTER 2 - LITERATURE REVIEW

Chapter 2 summarizes the literature in the field of long-term post-disaster recovery. This thesis attempts to build on the literature to create a comprehensive measure of the disaster recovery process. Section 2.1 discusses overall theories and frameworks of disaster recovery. Section 2.2 introduces the various sectors of the community that must be considered. Information from the literature about measuring recovery is summarized in Section 2.3. Finally, Section 2.4 discusses specific cases studies.

2.1 Overall Theories and Frameworks

Each year, thousands of lives are affected by disaster events. Mileti (1999) suggests that humans adjust to these disaster events through a continuous disaster cycle which has four stages: mitigation, preparedness, response, and recovery. Mitigation consists of policies and activities designed to reduce a community's vulnerability to future disasters. The mitigation stage can include, for example, strengthening buildings, moving houses out of flood plains, and building levees. Preparedness involves developing an emergency response and management capability prior to a disaster to produce an effective response when a disaster occurs or is imminent. This stage includes setting up a warning system and training emergency personnel. Response consists of the emergency measures taken at the time of the disaster to save lives and minimize damage. The response stage involves evacuations, shelter, and emergency medical care. Recovery can begin while the response stage is still occurring and includes both short-term activities to restore vital systems and long-term activities to restore the community (Mileti 1999). The recovery stage is extremely important, but it is also the least understood part of the emergency management process.

2.1.1 Definition of Recovery

One reason disaster recovery is not well understood may be that it is a relatively new concept. According to Comerio (2005), the formal disaster recovery process was not officially recognized until 1900 when the United States Congress granted the American Red Cross a charter which allowed them to perform peacetime efforts to bring people relief from suffering after disasters, such as floods and fires. Government assistance was only provided when the scale of the disaster outweighed the American Red Cross's capacities. The American Red Cross handled all disasters, both national and international, until the creation of the Federal Emergency Management Agency (FEMA) in 1979. FEMA then began employing the previously mentioned emergency management process (Comerio 2005).

Fully understanding the recovery process is difficult in part because there is no set definition of disaster recovery. Chang (2009) references three different ways to define recovery: (1) returning to pre-disaster conditions, (2) attaining what would have occurred without the disaster, or (3) reaching a new stable state. According to the first definition, a community has recovered when it returns to the way it was before the disaster. This form of recovery may be the easiest to measure, but it may never actually be achieved. Further, it may not be an appropriate goal if returning to the pre-disaster level would leave the community vulnerable to future disasters (Schwab et al. 1998). Comerio (2005) questions why any community would want to return buildings, bridges, or infrastructure to their hazardous pre-event conditions, which would likely fail again in another event. Currently though, the U.S. government assigns federal funds based on this definition of recovery where a community returns to its pre-event conditions (Comerio 2005). The next definition of recovery is to attain the state that would have occurred if the disaster had not happened. This definition involves projecting community growth based on aspects such as population and the economy and then attempting to reach these projected levels. Alesch et al. (2009, p.39) make a strong case for the third definition and suggest that "recovery has happened when the community repairs or develops social, political, and economic processes, institutions, and relationships that enable it to function in the new context within which it finds itself." They point out that communities change from year-to-year anyway, so it would not make sense to return to past levels. The majority of the literature seems to agree with the third definition of recovery and offer similar ideas.

The literature also discusses the complex balance that must be maintained between the speed and quality of recovery. A successful recovery should occur in a reasonable period of time while also including sustainability. Gardoni and Murphy (2008) are advocates for the third definition of recovery and also express the need for sustainability. They explain that a sustainable recovery process would not just recreate pre-event conditions, but would instead aim to ensure a decent quality of life for members of the disaster-stricken communities in both the short and long-term. A sustainable recovery aims to ensure that future generations are not undermined by the recovery efforts. The recovery implementation should leave room for changes such as technological improvements and increased information about a hazard. The Natural Hazards Center (2005) offers a guide on how to build sustainability into a community during the post-disaster recovery period. They suggest that a community be divided into three spheres: (1) a social sphere which includes human interactions, (2) an environmental sphere which involves the natural, physical setting of the community, and (3) an economic sphere which consists of everything related to producing and exchanging goods and services. In order to achieve a sustainable and holistic disaster recovery, the community must maintain the balance and integration of its three spheres (Natural Hazards Center 2005).

Gardoni and Murphy (2008) also recognize the importance of finding a balance between this long-term sustainable recovery and the needs of a disaster-stricken community to return to normal as soon as possible. As Olshansky and Chang (in press) point out, the tension between speed and quality is always a key challenge in evaluating recovery.

2.1.2 Scope of Recovery

The recovery process is also complicated because it involves a large number of organizations with various responsibilities. Governmental agencies, non-governmental organizations (NGOs), and private industry may all play a role in the disaster recovery process. While many of the ideas and methods discussed in this thesis can be applied internationally, it will focus primarily on U.S. disasters and recovery processes. In the U.S., governmental agencies, such as FEMA or the U.S. Army Corps of Engineers, are major participants in helping a community recover after a disaster. NGOs are also very involved, including the American Red Cross and the United Way. Governmental agencies and NGOs are often involved at the national, state, and local levels. The federal government might work along with state representatives and local officials to represent the government. NGOs can range from the national chapter of a program, to a state coalition, to a local church.

Finally, recovery must encompass many aspects of a community. Recovery has to include repairing and reconstructing houses, businesses, public buildings, lifelines, and infrastructure; organizing and dealing with volunteers and donated goods; delivering disaster relief; restoring and coordinating vital community services; expediting permitting procedures; and coordinating activities among governments (Mileti 1999). Section 2.2 talks more about the various aspects of the community which must be addressed.

2.2 Sectors of Recovery

Recovery is a complex process which must consider the community as a whole and recognize that all aspects (e.g. housing, population, economy) are interconnected and have to develop together (Alesch et al. 2009). In the literature, the aspects of the community that are included in the recovery are referred to by various names. Hereafter, these various aspects of the community will be referred to by the term *sectors*. The literature has identified many sectors that must be considered in disaster recovery. In this thesis, the community is organized into eight sectors: demographics, housing, critical infrastructure, natural environment, economy, education, health and well-being, and community identity. This thesis focuses on housing recovery and, therefore, the housing sector is discussed in more detail in Section 2.2.1.

2.2.1 Housing

Housing is an important sector of disaster recovery. According to Comerio (1997), housing can be considered the single greatest component of all losses in terms of both economic value and building damage. In fact, the strongest similarity between both U.S. disasters and international disasters is their substantial impact on housing which, in turn, leads to huge economic loss (Comerio 1997).

Quarantelli (1982) proposes that the recovery of households after a disaster occurs in four stages: (1) emergency shelter, (2) temporary shelter, (3) temporary housing, and (4) permanent housing. The first stage, emergency shelter, consists of the locations sought out during the disaster to provide protection from the elements. The next stage is temporary shelter, which may include staying with friends or relatives, commercial lodging, or mass care facilities such as schools and gymnasiums. Next is the temporary housing stage, which allows community members to reestablish household routines, but in a temporary location or structure. An example of the temporary housing stage includes the trailers that are provided to disaster-stricken communities by FEMA. The final stage is when community members are able to move into permanent houses, whether repaired versions of their pre-disaster homes or newly built homes after the disaster (Quarantelli 1982).

Levine et al. (2007) take a more in depth look at the idea of temporary housing. The most common forms of temporary housing in the U.S. are mobile homes or smaller travel trailers, such as those provided by FEMA, and vacant rental units near the disaster stricken community. Along with temporary housing though, come the concerns of vulnerability, housing availability, and land development. Depending on the quality and location, temporary housing may leave disaster victims susceptible to future hazards, such as the next hurricane season. According to Tony Palermo, a senior planner for Lee County, Florida, 10,000 people displaced by Hurricane Charley in 2004 were still living in temporary housing when the 2005 hurricane season began (Palermo 2005). Providing large numbers of temporary houses also creates problems with housing availability and often drives up the price of housing in surrounding areas (Levine et al. 2007). Land development may also become an issue due to the need for a large area where the temporary housing can be placed.

In the literature, housing is studied in various ways. Miles and Chang (2007) suggest the use of fragility curves to model the effects that disasters have on housing. These fragility curves can be used to calculate damage and injury after disasters. They also discuss the importance of looking at the impacts of disasters on individual households within the housing sector. They suggest that household recovery is not just a function of housing damage, but also depends on socio-economic attributes, business recovery, and the loss and restoration of critical infrastructure. This idea is reflected in the variables they choose to include in their disaster models. Miles and Chang (2007) suggest two different types of models that forecast community recovery: a co-event model and a post-event model. The co-event model simulates variables related to conditions before, during, and immediately after a disaster. This model for households includes variables such as building damage, injury to building occupants, and whether or not a household had insurance. The post-event model simulates variables related to conditions that exist over time as the community recovers after the disaster. This model for households includes residential reconstruction, household health recovery, estimation of debt levels due to the disaster, and whether each household will stay or leave after the disaster. Miles and Chang (2007) apply their model to the 1994 Northridge earthquake to evaluate and calibrate it. Previous versions of the model also exist and are applied to a fictional city (Chang and Miles 2004) and the Kobe earthquake (Miles and Chang 2006).

Lindell and Prater (2003) support the idea that household recovery is influenced by socio-economic attributes. They discuss the problems that are often faced by lower income households during disaster recovery. These households are more likely to experience damage because they tend to be more vulnerable prior to the disaster. They also note that these lower income households are disproportionately headed by females and racial/ethnic minorities (Lindell and Prater 2003). Levine et al. (2007) add that large households and households with elderly residents may also be more vulnerable. This suggests that demographics of a community may also need to be considered in a measure of community disaster recovery.

Comerio (1993) analyzes the way different types of housing are valued according to different attributes. She shows that the Loma Prieta earthquake highlighted the struggles associated with the repair and reconstruction of multi-family and affordable housing. Single-family homes are valued based on three main attributes: the shelter they provide, their location, and the wealth potential they provide. The long-term value of a single-family home depends on its condition, so homeowners are more inclined to maintain their homes and rebuild them after a disaster (Comerio 1993). With multi-family homes, investors may only maintain their properties to the extent that the maintenance increases cash flow. Therefore, multi-family homes are less likely to be rebuilt after a disaster (Comerio 1993). This can lead to an inadequate amount of affordable housing after a disaster. Comerio (1997) discusses the difference between single-family detached homes and multi-family units in more detail. She particularly analyzes the breakdown of the two different types of housing as they relate to the Northridge earthquake and then compares these results to other U.S. disasters in urban areas and international disasters. Comerio (1997) argues that the numbers of housing units affected or people displaced are not the best ways to gauge the need for recovery aid. We need to focus instead on the concentration of housing losses to a particular section of the housing market. For example, damage to a large number of well-insured, single-family homes will not necessarily cause a recovery crisis. Recent disasters, both in U.S. urban areas and internationally, have shown the need to look at the impact of disasters in relation to existing housing resources and conditions in the housing market. In reality, there may be as many multi-family housing units as there are single-family detached homes, and the difficulties that they face after disasters must be considered (Comerio 1997).

In order to strengthen the community against future disasters, mitigation can be incorporated into the recovery process. Housing is a sector of recovery where the idea of mitigation becomes a large focus. Some states, such as Florida, have begun providing incentives for strengthening existing structures and encouraging adoption of mitigation measures (Levine et al. 2007). After Hurricane Andrew in 1992, Florida implemented special requirements addressing hurricane resistance into the state building codes. These upgraded building codes have been applied in much of the state and have been more strictly enforced than previous codes. Florida also began dedicating funds to assisting homeowners with mitigation measures, such as installing storm shutters (Levine et al. 2007).

Wu and Lindell (2004) suggest that having a pre-disaster community recovery plan will increase the speed of housing reconstruction. A valuable pre-disaster recovery plan should establish a location for temporary housing and discuss essential tasks such as damage assessments, debris removal, and permitting. It should also acknowledge the importance of licensing and monitoring contractors and retail price (Wu and Lindell 2004). Wu and Lindell (2004) demonstrate the effectiveness of a pre-disaster recovery plan by studying two recent earthquakes which struck comparable communities: the 1994 Northridge earthquake in southern California and the 1999 Chi-Chi earthquake in Taiwan. Wu and Lindell (2004) explain that Los Angeles had a recovery plan in place prior to the Northridge earthquake which specified the local government actions required, identified the roles of federal and state officials, and introduced mitigation into the recovery process. Taiwan had no such plan in place prior to the Chi-Chi earthquake. For this study, the speed of housing reconstruction was primarily measured by the number of building permits issued at certain time periods after the disaster. Wu and Lindell (2004) found that having a pre-disaster recovery plan speeds up the housing reconstruction process and also increases the extent to which risk mitigation can be incorporated into the recovery process. Lindell and Whitney (2000) also express the importance of pre-disaster actions to the recovery process. They suggest making hazard adjustments which would leave households less vulnerable to disasters and, therefore, cause fewer casualties, less property damage, and less economic disruption. Their definition of hazard adjustment incorporates mitigation and emergency preparedness. Taking actions, such as reinforcing a house against disasters, will obviously expedite the recovery process after that disaster (Lindell and Whitney 2000).

2.3 Measuring Recovery

The literature discusses various ideas that should be considered when measuring recovery. Comerio (2005) suggests that the success of measuring recovery will depend on three main concepts: the geographic scale on which recovery is measured, the time frame in which recovery is measured, and the perspective of the evaluator. The geographic scale of recovery can include individuals or households, neighborhoods or communities, and cities or regions. The time frame can range from days and months after the event, to years after the event, to decades after the event. The recovery measure should also consider the perspective of the evaluator. The evaluator could be an individual recipient of assistance, a local community, a funding provider, or an independent evaluator. A successful evaluation of recovery should measure the sectors of recovery on different geographic scales, in different time frames, and from different social and economic perspectives. To truly measure recovery, one must also include multiple assessments and recognize that all aspects of the community must be considered (Comerio 2005).

2.3.1 Indicators

Many previous studies suggest using *indicators* to measure the sectors of recovery (e.g., Chang 2009, Comerio 2005). Indicators are quantitative metrics, such as number of deaths, damage to private property, and per capita income (Chang 2009). A good example of an indicator is looking at the number of permits issued at various time intervals after a disaster in order to measure the recovery of the housing sector, as in the French et al. (1984) study of the Coalinga earthquake.

Chang (2009) suggests that indicators can be used to make comparisons across disasters if they meet at least three criteria:

1. The definition should be universal (i.e., meaningful and consistent across countries, cultures, and historic time periods).
2. Data should be readily available (i.e., routinely collected and published as consistent time series, at least annually).
3. The measurement should be standardized (i.e., allow meaningful comparisons across space and time).

Indicators can also be useful for making comparisons within one specific disaster, such as comparing the recovery process in two communities struck by the same disaster (Chang 2009).

Some researchers may try to weight indicators based on importance, but most of the literature suggests that all indicators should be treated equally (e.g., Chang 2009, The Sphere Project 2004). Alesch et al. (2009) does, however, suggest that certain aspects need to be addressed first, such as electricity, sewer, and water, but the other parts should develop together. Based on the literature, it appears that indicators are an effective method for measuring the various aspects of community recovery. Indicators are beneficial for developing a knowledge base, testing hypotheses, validating models, and informing policy (Chang 2009).

Indicators should be used together with other forms of qualitative and quantitative information to develop better understandings of recovery outcomes, trajectories, and processes (Chang 2009). Previous research has looked at recovery in terms of households and economics, but very little research has examined recovery at different scales of intervention, over different time frames, or using different finance mechanisms (Comerio 2005).

One resource that successfully utilizes indicators is a handbook produced by The Sphere Project (2004). The Sphere Project was launched in 1997 to improve the quality of assistance for people affected by disasters and enhance the disaster response efforts of the humanitarian system. In the Sphere Project’s handbook, indicators are introduced as ‘signals’ to show whether or not certain standards have been met during the disaster response. The handbook suggests that indicators can provide a basis for establishing priorities, following trends, gauging the effectiveness of the response, and suggesting revisions to their programs (The Sphere Project 2004).

2.3.2 Additional Approaches

Gardoni and Murphy (2009) suggest a capabilities-based approach to measure recovery which would also account for the societal impacts of disaster. In this approach, capabilities refer to what an individual is able or unable to do, such as being adequately nourished. Indicators still need to be identified in this approach to measure the impact a disaster has on the selected capabilities, because capabilities are not directly measurable. An advantage to this approach is that it captures the overall impacts of a disaster, including both potential benefits and losses, whereas most approaches can only measure monetary and utilitarian amounts of loss (Gardoni and Murphy 2009). The capabilities-based approach can also be applied in mitigation and disaster planning (Murphy and Gardoni 2007). Comerio (2005) also identifies the need for indicators that can measure societal impacts. Social vulnerability can have a large effect on the recovery process, especially in developing countries, which may not have support or basic needs such as food and shelter (Comerio 2005). Lindell and Prater (2003) discuss the idea of an impact ratio, which would compare the amount of damage caused by a disaster versus the amount of resources available to the community. Gardoni and Murphy (2008) also suggest that indicators should be updated over time to account for the impact of technological social changes.

Olshansky and Chang (in press) suggest two main approaches for measuring recovery. In the first approach, an urban systems model is developed that can anticipate and explain the pace, characteristic, and success of recovery with post-disaster indicators. In the second approach, one studies the institutions, planning processes, and management approaches for guiding recovery actions by both public and private branches (Olshansky and Chang, in press).

Chang (2009) suggests the need for a systematic framework that can be used to measure disaster recovery at the community scale. The systematic framework should be able to provide guidance for the use of statistical data, such as information gathered from the U.S. Census. It should also be able to acknowledge the possibility of structural change for when post-disaster conditions of normality differ from pre-disaster conditions. Finally, the framework should recognize that aggregate trends may mask important disparities in recovery (Chang 2009).

Gardoni and Murphy (2008) introduce the idea to measure recovery using the Disaster Impact Index (DII) and the Disaster Recovery Index (DRI) method. This method again focuses on the societal aspect of community recovery. The method uses a DII to measure the change in well-being of a community after a disaster. The DII can be computed by determining the DRI, which measures the current level of individuals' capabilities. This computation is written as $\text{DII}(t) = \text{DRI}(0) - \text{DRI}(t)$, where DRI(0) represents the level of well-being of the community prior to the disaster and DRI(t) represents the level of well-being at some time t after the disaster. The DII can be computed at various time intervals after the disaster to determine the progress of the recovery from a societal perspective. This method is also beneficial because the DRI can either be compared against a benchmark of ideal societal functioning, or to DRI values in other areas or from other disasters (Gardoni and Murphy 2008). Any measure of disaster recovery will benefit from having the ability to make these three comparisons.

2.4 Case Studies

Many case studies exist which can provide insight into what has been done previously to understand disaster recovery. Section 2.4.1 discusses case studies of disaster recovery after various disaster events, and Section 2.4.2 presents case studies of Hurricane Katrina in particular.

2.4.1 Disaster Recovery Case Studies

The first study that attempted a comprehensive look at the recovery process was Haas et al. (1977). The study aimed to determine the forces that affect community recovery by examining four disasters: the 1972 Rapid City flood, the 1972 Managua, Nicaragua earthquake, the 1964 Alaska earthquake, and the 1906 San Francisco earthquake. These researchers recommend that decisions regarding recovery be made as soon as possible to avoid uncertainty among private decision makers. They also suggest that a community have plans and policies in place before the disaster. This idea of a disaster recovery plan is mentioned repeatedly in the recovery literature. Another important aspect of the Haas et al. (1977) study is their idea of overlapping recovery phases. This is an important concept that has been repeated throughout the literature.

The study suggests that the recovery process consists of four phases: an emergency period, a restoration period, a replacement period, and a period of commemorative, betterment, and developmental reconstruction. The emergency period is the phase involving tasks such as search and rescue and emergency housing. This period normally occurs within the first few days or weeks after the disaster. The second phase is the restoration period. This is the phase that includes repairing infrastructure and returning to relatively normal activities, which normally lasts for several months after the disaster. The next phase is the replacement period which consists of rebuilding capital stock to pre-disaster levels. The replacement period can take up to two years. The final phase is the period of commemorative, betterment, and developmental reconstruction. This phase involves large projects and can take up to ten years. The four phases can overlap each other, so the recovery process should be able to transition smoothly through the phases until they are all complete (Haas et al. 1977).

Comerio (2005) uses a case study of the Hurricane Andrew to support the third definition of recovery discussed in Section 2.1, where recovery means reaching a stable state of community functioning that may or may not be the pre-event state. Comerio explains that some recent disasters have led to the need for a new definition of recovery because their scenarios did not warrant returning the community to its pre-disaster state. After Hurricane Andrew, for example, Homestead, Florida needed a recovery in which it could attain a new stable state without the Homestead Air Force Base. In this scenario, it did not make sense to restore the air base because it had already been scheduled to be closed by the federal government prior to Hurricane Andrew (Comerio 2005).

An earlier case study was performed by Comerio in 1998. In this study, Comerio (1998) compared the recovery processes after Hurricane Hugo, Hurricane Andrew, the Loma Prieta earthquake, the Northridge earthquake, the 1993 Mississippi River floods, the 1985 Mexico City earthquake, and the Kobe earthquake. Laituri and Kodrich (2008) use the 2004 Indian Ocean tsunami and Hurricane Katrina as case studies to discuss the integration of key geospatial technologies such as remote sensing, geographic information systems (GIS), and global positioning systems (GPS) into the disaster recovery process. Advances are being made in using these technologies, but researchers are still trying to develop the best methods for utilizing the technologies for disaster management. For the technologies to be effective, they must be in place before the disaster and continue through the recovery process (Laituri and Kodrich 2008).

Other case studies include the Kobe earthquake (Chang 2009), and Hurricane Floyd (Maiolo et al. 2001). Chang (2009) examines the Kobe earthquake to test for empirical patterns of urban disaster recovery by using indicators. Maiolo et al. (2001) use Hurricane Floyd to examine the effectiveness of the recovery along the coastal plains. Kweit and Kweit (2004) is a case study which compares the recovery in Grand Forks, North Dakota to that in East Grand Forks, Minnesota after they experienced a large flood in April 1997. They discuss the impact of citizen participation and how it expedited the recovery process. Rubin and Barbee (1985) also discuss the importance of cooperation in the recovery process. They express the importance of local officials working together with emergency management personnel at the state and federal levels, to ensure the most effective recovery.

Some case studies focus on particular sectors of recovery, such as the economy. Belasen and Polachek (2009) examine the effects that various hurricanes in Florida, including Hurricane Charley, have had on the local labor markets. They discuss the Generalized Difference in Difference (GDD) technique and its application for comparing economic effects of hurricanes. Zhang et al. (2009) discuss five major issues related to the vulnerability of businesses after disaster. They mention the ways businesses are subjected to the impacts of disasters, the factors that determine the magnitude of those impacts, how and when businesses have recovered, measures that can be taken to reduce the risks to businesses, and the need for public policy to reduce business vulnerability.

Other case studies have examined the varying impacts that disasters have on different members of society. These case studies relate to the demographics sector of community recovery. Cupples (2007) explores the importance of gender in disaster events. The study uses Hurricane Mitch to explain how women are more vulnerable in a disaster and also how their unique capabilities as community leaders or natural resource managers are often overlooked during the recovery process. Moore et al. (2004) look at Hurricane Floyd to analyze the social impacts from disaster preparedness and recovery. Pais and Elliott (2008) look at major hurricanes such as Hurricane Andrew and Hurricane Opal. They discuss how social inequalities can lead to an uneven transformation of local neighborhoods across regions. Using Hurricane Andrew as a case study, Smith and McCarty (1996) discuss the overall demographic effects of disasters. The Sphere Project also acknowledges that specific factors, such as gender, age, and disabilities, can affect vulnerability and influence the ability of particular groups to cope and survive in a post-disaster context (2004).

Another common idea discussed in case studies is implementing mitigation and creating a sustainable community. Ozcevik et al. (2009) discuss using a sustainable urban regeneration approach to assist in the ongoing disaster recovery process from the 1999 Marmara earthquake in Turkey. Shaw and Goda (2004) use the Kobe earthquake to demonstrate the importance of sustainable recovery and how it is influenced by the involvement of the society in the recovery process. Reddy (2000) discusses the implementation of mitigation measures during the long-term recovery process and looks particularly at the recovery process after Hurricane Hugo.

Overall, these case studies provide important insights into post-disaster recovery. The information gained from these case studies established a good foundation for the NSF project.

2.4.2 Hurricane Katrina Case Studies

The total damage caused by Hurricane Katrina was more than $200 million and it created a National Disaster Declaration area of 90,000 miles (Levine et al. 2007). It is, by far, the most expensive disaster in American history and, therefore, it is one of the most studied disaster events. In the NSF project, of which this study is part, the measure of disaster recovery will be applied to Hurricane Katrina. Therefore, it is important for us to look at the research that has already been done on this subject.

The immensity of Hurricane Katrina makes it a good benchmark against which other disasters can be compared. Gotham and Greenburg (2008) use it to compare the post-disaster recovery in New Orleans to the recovery efforts in New York City after September 11, 2001. Hori et al. (2009) compare the displacement of population in Southern Louisiana from one year after Hurricane Katrina to that from one year after Hurricane Rita. In Baade et al. (2007) Hurricane Katrina is used as a benchmark for the study of economic impacts caused by various natural and social disasters. Kates et al. (2006) analyze the reconstruction of New Orleans after Hurricane Katrina and discuss the conflicting goals of rapid recovery, safety, betterment, and equity which arise as a common issue of concern in all disasters. Hurricane Katrina can also be used to show how different neighborhoods affected by the same storm can have very different recovery experiences. Green et al. (2007) look at the progress made with regards to the recovery efforts in New Orleans' Upper Ninth Ward to those in the Lower Ninth Ward. This case study showed how low-income neighborhoods, such as the Lower Ninth Ward, often have a more difficult time and take longer to recover from disasters (Green et al. 2007).

Hurricane Katrina also led to much controversy during the recovery process regarding the impacts faced by different demographic groups. Dass-Brailsford (2008) explains the importance of recognizing the racial, socioeconomic, language, and religious differences of survivors in the wake of a disaster. She discusses the importance of a multicultural approach to recovery from the perspective of a trauma psychologist who volunteered after Hurricane Katrina. Elliott and Pais (2006) examine the effect of race and class on both human and institutional responses to disaster events. They interviewed over 1,200 Hurricane Katrina victims and analyzed their findings. In Masozera et al. (2007) Hurricane Katrina is used to examine the impact that disasters have on various income groups. Boettke et al. (2007) analyze the political, economic, and social aspects of Hurricane Katrina. They discuss the findings of a research team assembled by the Mercatus Center at George Mason University that studied those various aspects of the recovery process. Hurricane Katrina is used by Zottarelli (2008) to analyze its effect on employment one month and one year after the storm. She determines that the ethnicity of employees and the location of businesses are important factors that influence the recovery of employment. Finally, Myers et al. (2008) look at Hurricane Katrina to explore the relationship between place-based social vulnerability and post-disaster migration throughout the U.S. Gulf Coast region.

The need for a beneficial disaster recovery plan is an important lesson that can be taken from Hurricane Katrina. Mitchell (2006) uses Hurricane Katrina as a case study to illustrate the need for a new national disaster recovery policy. He suggests that a main focus in the new policy should be the partnership between various stakeholders. Olshansky et al. (2008) discuss the key planning challenges faced in New Orleans after Hurricane Katrina and the subsequent flooding. They suggest the need for a disaster recovery plan, citizen involvement, strong communication between planners, and external resources. Berke and Campanella (2006) discuss the importance of resiliency in the disaster recovery process. They use Hurricane Katrina as an example of how the recovery process can be used to strengthen a community against future disasters.

In fact, Hurricane Katrina has shown a lot of ways in which a community can benefit from the recovery process after a disaster. Varda et al. (2009) examine how disasters, such as Hurricane Katrina, cause changes in the social network of a community and how those changes, such as shifts in demographics, may assist in the recovery process. Waugh and Smith (2006) discuss how disasters can sometimes be used as opportunities to redevelop the economic bases of damaged communities. For example, Louisiana and Mississippi can use the opportunities created by Hurricane Katrina to redevelop neighborhoods and whole communities which were damaged by the storm. It is important to note that even such catastrophic disasters as Hurricane Katrina can be used to teach us valuable lessons for the future.

CHAPTER 3 - DEVELOPING A MEASURE OF COMMUNITY RECOVERY

Systematically and quantitatively defining and measuring long-term post-disaster community recovery is an important first step in understanding and ultimately improving it. As yet, no such comprehensive, well accepted measure exists. This chapter first presents an approach for developing an overall measure of post-disaster community recovery, and then introduces a prototype measure for the housing sector of recovery that was developed using that approach.

Many decisions are made in the process of defining a recovery measure, and it is best to make those explicitly and deliberately so that they are consistent and result in a measure that is as useful as possible. Section 3.1 enumerates the decisions that must be made in defining a measure. For each decision, alternatives are listed and compared, and a choice among them is made for purposes of this project.

Ultimately, design of a recovery measure depends both on the desired features, as summarized in Section 3.1, and the data available to apply it. Section 3.2 summarizes the types of data that may be available to capture the different aspects of recovery. Focusing on the housing sector of recovery only, Section 3.3 presents a prototype measure and discusses its key features, strengths, and limitations.

3.1 Process to Develop a Recovery Measure

Any measure of community recovery should be grounded in the theory discussed in Chapter 2, but beyond that there are myriad ways to define a measure. It is important therefore, to explicitly list the features one would like the measure to have for a specified purpose, then design the measure so as to reflect those preferences as well as possible. In this research, a systematic process is introduced by which a measure can be designed: (1) list all the decisions that must be made, (2) for each decision, brainstorm the possible alternatives, and (3) for each decision, select the desired alternative(s).

Tables 3.1 to 3.3 summarize the many decisions that must be made—implicitly or explicitly—in the process of designing a community recovery measure. Similar to strategy tables used in decision analysis (Howard 1988), these tables provide a useful tool to understand and systematically consider the many interrelated decisions involved in designing a recovery measure. Table 3.1 presents the decisions associated with specifying the intended users, uses, and applicability of a measure; Table 3.2 focuses on definition of the concept of post-disaster community recovery; and Table 3.3 includes decisions that together define the how recovery will be measured.

For each decision in Tables 3.1 to 3.3, one or more alternatives are selected, such that together those choices define the main features of the recovery measure. In making these selections, it is important to recognize that the decisions are often interrelated, so some combinations will not make sense. As a simple example, a *composite index* for type of measure is not compatible with a scale precision of *infinite* (Table 3.3). It is also necessary to iterate between these decisions and the data likely to be available to evaluate a measure. One may identify desirable features, realize the required data is not available to evaluate it, then modify accordingly.

In Sections 3.1.1 to 3.1.3, each decision and the associated alternatives are discussed briefly. The superscripts in Tables 3.1 to 3.3 indicate the alternative(s) chosen for use in the remainder of this thesis (^{1}) and those intended for use in the larger NSF project (^{2}). Note that it would be valid to make different choices depending on how one intends that the measure will be used, and these same tables can be used by others interested in designing different recovery measures. The alternative(s) chosen for this thesis (^{1}) are explained in Section 3.1.4 and used to develop the housing recovery measure in Section 3.3.

3.1.1 Intended Users, Uses, and Applicability

The decisions listed in Table 3.1 relate to the intended users and uses of the recovery measure. These are the most fundamental decisions that should be made. To some extent, the decisions about the other attributes will follow from these.

Table 3.1: Key Features of a Community Recovery Measure: Intended Users/Uses and Applicability

Decision	Alternatives	Comments
Intended users	Federal government[1,2]	Agencies that fund, support recovery
	State/local government[1,2]	Government agencies in disaster region
	Community organizations[1,2]	Groups that implement recovery
	International aid organizations	Agencies that fund, support recovery
	Researchers[1,2]	
Intended uses	Determine recovery progress[1,2]	
	Compare recovery across sectors[1,2]	e.g., housing vs. economy
	Compare recovery across geographic areas within an event[1,2]	
	Compare recovery from different events[1,2]	
	Evaluate how well recovery is progressing	
	Evaluate effectiveness of specific recovery decisions	
General approach	Descriptive[1,2]	Describe recovery as it actually happens
	Normative	Describe ideal of how recovery "should" happen
Intended timing of use	During recovery[1,2]	Apply as recovery is progressing
	After recovery[1,2]	Apply only after recovery is complete
Geographic scope measure is applicable to	Region within U.S.	e.g., Southeast, West
	United States only[1,2]	
	Industrialized nations only	
	International	
Disaster types measure is applicable to	Only hurricanes[1,2]	
	All natural disasters	e.g., earthquakes, tornados, floods
	All disasters	e.g., including technological accidents, terrorist attacks
Disaster severities measure is applicable to	All severities[1,2]	
	Only extreme events	
	Only "typical" events	

[1] Indicates choice for this thesis.

[2] Indicates choice planned for NSF project.

3.1.1.1 Intended Users

While a single measure may ultimately be used by multiple people and organizations, the intended uses, definition of recovery, resources available for collecting data, geographic jurisdiction, and therefore, the most appropriate measure design may vary by user. General categories of intended users with fundamentally different perspectives can be defined based on the extent of their jurisdiction (international, federal, local) and primary role (groups that help fund, manage, or study recovery).

3.1.1.2 Intended Uses

The way that a measure will be used is critical in guiding how it should be designed. For example, to use a measure for comparison—across sectors (e.g., housing, economy), geographic regions, or events—requires only a relative measure (A is faster or better than B), although separate assessments must be made for each item to be compared (e.g., each neighborhood or sector). To assess whether a recovery is complete or to what extent it has progressed requires an absolute measure. Evaluation of a recovery (i.e., providing a value judgment about it) requires some concept of what is considered ideal recovery. Assessing the relative effectiveness of or encouraging specific recovery decisions (e.g., setting up temporary housing in a particular location, expediting building permit issuance, incorporating mitigation in the recovery) is easiest if those decisions are explicitly represented in the measure.

3.1.1.3 General Approach

A measure may be descriptive or normative, describing how the recovery is actually unfolding or how it "should" be occurring according to some ideal.

3.1.1.4 Intended Timing of Use

If a measure is intended to be used to monitor a recovery as it is evolving, it cannot rely on knowledge of what the final state will be. For example, the *percentage of reconstructed houses that are complete* will only be known after the recovery is over and the total number of rebuilt houses is known. One could use the metric *percentage of destroyed houses that have been rebuilt*, recognizing that it may never reach a value of 100%.

3.1.1.5 Geographic Scope

The geographic area in which a measure will be applied will help determine, for example, what key issues must be included, what data it can rely on, and the range of values it might cover. If the measure is intended to be used only in the United States, for example, it can rely on census and other statistical data that are consistently available for all jurisdictions in the country. If it is intended for use in developing countries as well, that type of data may not be available in consistent forms across countries. Another example is if the disaster is only inland, the measure does not need to consider surge-related issues.

3.1.1.6 Disaster Type Applicability

While some aspects of disaster recovery are common across disaster types, some are not. The pattern of impact to the population and built and natural environment, and therefore, the timing and difficulty in doing repairs and reconstruction will differ by hazard. A measure for just hurricanes may be more focused than one that is intended to be applicable to all natural disasters, technological disasters, and terrorist attacks.

3.1.1.7 Disaster Severity Applicability

Again, the pattern of damage and demands of a recovery will differ between minor events and true regional catastrophes. For example, the issue of a large number of evacuees never returning to the community may be not be important for a small event, but may require consideration in an event like Hurricane Katrina.

3.1.2 Definition of the Concept of Recovery

In the past, researchers were unable to develop a satisfactory measure of post-disaster community recovery. One of the reasons for this is the difficulty and lack of agreement in defining what is meant by the term “recovery.” This section provides a set of decisions related to how the concept of recovery is defined (Table 3.2).

Table 3.2: Key Features of a Community Recovery Measure: Definition of Concept of Recovery

Decision	Alternatives	Comments
Place/people	Recovery of place[1,2]	Focus on the place affected, allowing people to come and go
	Recovery of people	Follow people affected, even if they leave the physical place
Disaster phase represented	Response[1,2]	SAR, damage assessment, etc.
	Short-term recovery[1,2]	Restoring functions, including workarounds
	Long-term recovery[1,2]	Rebuilding and restoring structures, institutions, etc.
Recovery endpoint	Achieve pre-disaster levels	Recovery is complete when situation is as it was pre-disaster
	Achieve without-disaster levels	Recovery is complete when situation is as if disaster had not occurred
	Attain new stable state[1,2]	
Sectors	Demographics[2]	
	Housing[1,2]	
	Critical infrastructure[2]	
	Natural environment[2]	
	Economy[2]	
	Education[2]	
	Health and well-being [2]	
	Community identity[2]	
Emphasis	Degree of recovery[1,2]	How much has the community recovered?
	Sustainability of recovery[1,2]	Quality of recovery, based on sustainability principles
	Changes as a result of recovery[1,2]	To what extent have structural changes occurred as part of recovery?
Functional vs. physical	Functional[1,2]	Recovery of community functions
	Physical[1,2]	Recovery of physical facilities that support functions

[1] Indicates choice for this thesis.

[2] Indicates choice planned for NSF project.

3.1.2.1 Place vs. People

A recovery measure can focus on a community affected by an event or the people who are part of that community at the time of an event. Of course the two are related. Since recovery extends over months or years, and people move to and from communities all the time, however, the concepts can diverge. If people leave a community following an event, it would be important to follow them and their circumstances for a people-focused measure, but not for a place-focused measure.

3.1.2.2 Disaster Phases

Since the term “recovery” is not always used consistently, it is worth clarifying whether a measure is intended to apply to the immediate post-disaster response, short-term recovery period, and/or long-term recovery period. The first phase includes, for example, search and rescue and damage assessment, the second includes restoration of basic functions (electric power, water supply) and establishing temporary housing, and the third includes repairing and rebuilding damaged buildings.

3.1.2.3 Recovery Endpoint

A critical issue in defining recovery is specifying when a recovery is complete. Section 2.1 introduced three possible endpoints that have been defined in the literature, which are illustrated in Figure 3.1: (1) achieving the pre-disaster situation (e.g., in terms of population, economic output, or other aspects of community functioning), (2) achieving the situation that would have existed had the disaster not occurred, and (3) attaining a new stable state. The first option is perhaps the most straightforward, but it assumes that a community will eventually return to the way it was, which experience shows may or may not happen. The second option acknowledges that a community is not static, but is on some trajectory before a disaster, perhaps growing, shrinking, or changing in some way. The third option recognizes that a community may change in some way as the result of a disaster such that it never returns to the pre-disaster state or trajectory. A new stable state could be defined in terms of reaching a constant level (of population, for example) or a constant rate of change. It is less straightforward to operationalize this definition because, while a recovery is unfolding, it is difficult to estimate how far along the recovery is if the level associated with the endpoint is not known ahead of time.

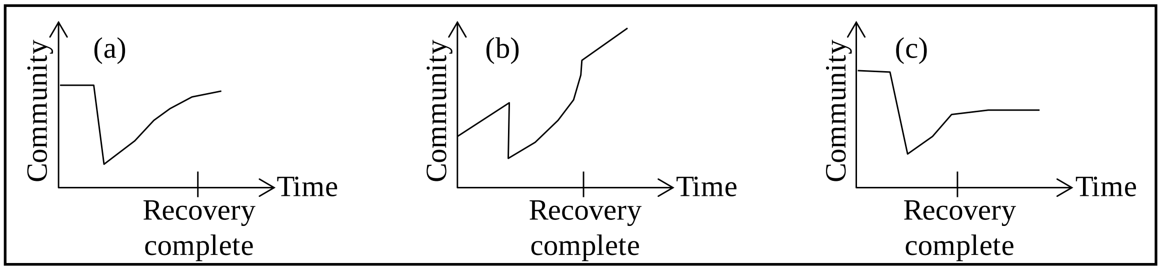


Figure 3.1: Schematic Representation of Possible Recovery Endpoint Definitions: (a) Achieving pre-disaster situation, (b) Achieving the situation that would have existed had the disaster not occurred, and (c) Attaining a new stable state

3.1.2.4 Sectors

Several distinct sectors of a community have been identified that may recover in different ways at different speeds: (1) demographics, (2) housing, (3) critical infrastructure, (4) natural environment, (5) economy, (6) education, (7) health and well-being, and (8) community identity. A measure of recovery may attempt to capture the recovery of all or some subset of these sectors.

3.1.2.5 Emphasis

One might consider three different aspects of recovery that may be of interest: (1) degree, (2) sustainability, and (3) resulting change. The most commonly discussed aspect of recovery is the degree of recovery (i.e., to what extent has a community recovered? How much of the building damage has been repaired? How many of the jobs have been restored? How many of the students are back in school?). The time required to increase the degree of recovery defines the speed of the recovery. The second issue that is frequently discussed is how well a community is recovering. The quality of the recovery may be defined in terms of the extent to which it is improving the community's sustainability, as described according to the six principles described in Mileti (1999) and Natural Hazards Center (2005): uses a participatory process, enhances quality of life, builds local economic vitality, promotes social and intergenerational equity, protects environmental quality, and improves disaster resilience. The third aspect of recovery that may be measured is the extent to which a recovery results in permanent changes to the community, such as, shifts in the relative importance of different industries or changes in the demographic composition. These three aspects will not necessarily be correlated and thus may have to be measured on different scales.

3.1.2.6 Functional vs. Physical

Recovery of community functions and physical infrastructure are related but not necessarily perfectly correlated either. For example, by holding classes at different times or in temporary locations, the function of educating students may be restored before damaged schools are physically repaired. If a household returns to its home, which is damaged but habitable, one could say that it has achieved a level of functional recovery (having shelter) but not complete recovery, which would only occur when the function and physical recovery had both taken place (i.e., the household has shelter and the home is repaired to a permanent state). Data may be more readily available to measure physical recovery, but functioning may be of more interest.

One might conceptualize functional and physical recovery as taking place on different axes, or as different levels along the same axis. The order of which takes place first (functional or physical recovery) may not always be the same. For instance, in the household example above, one would say that the function takes place first then the physical recovery, but they are both part of a single path to recovery. One could imagine another example in which a store is physically repaired, but the business is still slow because customers are not buying or supplies are not available. In that case, the business would be physically but not functionally recovered.

3.1.3 Definition of a Measure of Recovery

Once it is clear what is being measured and for what purpose, the many questions of exactly what form that measure should take can be addressed. This section lists the decisions associated with designing the specific format of a recovery measure (Table 3.3).

Table 3.3: Key Features of a Community Recovery Measure: Definition of Measure of Recovery

Decision	Alternatives	Comments
Geographic resolution (area unit of measure)	Smaller than a neighborhood	
	Neighborhood	
	City[1,2]	
	Local region[2]	County, metropolitan area
	State	
Temporal resolution (time unit of measure)	Monthly	
	Every 3 months[1,2]	
	Every 6 months[1,2]	
	Yearly	
Sectoral resolution	None	Aggregate for community only
	General[1,2]	e.g., housing, economy, education
	Specific	e.g., sectors of economy, population groups
Accounting for heterogeneity	Measure then aggregate	Define a measure for each group separately, then aggregate
	Aggregate then measure[1,2]	Separately measure (a) total degree of recovery and (b) degree of change across groups
Accounting for trajectory of recovery	Trajectory	Consider progress along trajectory of recovery
	Endpoint[1,2]	Consider percentage who have reached recovery endpoint
Absolute/relative	Absolute measure[1,2]	Can evaluate recovery of a single community
	Relative to other geographic areas/events	Final measure describes recovery only compared to another region or event
	Relative to hypothetical "ideal" recovery	Final measure describes recovery only compared to an ideal
Type of measure	Set of natural scale indicators[1,2]	e.g., number of houses rebuilt, number of children in school
	Composite index	Mathematical combination of indicators
	Constructed scale[1,2]	e.g., on a scale of 1~10, where each level has a defined meaning

Table 3.3: Key Features of a Community Recovery Measure: Definition of Measure of Recovery(cont'd)

Decisions	Alternatives	Comments
Normalization	Not normalized[2]	raw counts
	To pre-disaster levels	e.g., % of pre-disaster housing that is habitable
	To initial loss[1,2]	e.g. % of damaged housing that is rebuilt
	To larger spatial unit	e.g. account for trends at county, state, regional scale, remove non-disaster influences
	To size of event	e.g., account for intensity of hazard
Scale precision	A few levels[1,2]	approximately up to 10
	Many levels	approximately 11 to 20
	Infinite	Real numbers
Language of scale	Numbers[1,2]	
	Words[1,2]	
	Images	
Bounds (if numerical)	Bounded[1,2]	e.g., 0 to 10
	Semi-infinite	i.e., 0 to infinity
	Unbounded	Real numbers
Data sources	Remote sensing/aerial imagery[1,2]	
	Raw data[1,2]	Collected by secondary source
	Summary data[1,2]	From available reports
	Field observations[1,2]	Primary/local data
	Subjective assessments by interviews[1,2]	Primary/local data
	Subjective assessments by surveys	Primary/local data
Data requirements	Requires specified data	Cannot be evaluated without specified data
	Flexible[1,2]	Can be evaluated with different types/quality of data

[1] Indicates choice for this thesis.

[2] Indicates choice planned for NSF project.

3.1.3.1 Geographic Resolution

A single assessment of recovery will be available for each area unit. A smaller area unit allows a measure to capture more heterogeneity within the community, but requires more and higher resolution data. Possibilities include an area smaller than a neighborhood (e.g., census tract, zip code, city block, building, or grid cell), neighborhood, city, county, or metropolitan area. The area unit for which a recovery measure is evaluated depends primarily on the intended uses of the measure, data availability, and consistency of the area unit. For example, if the measure is intended to be used for allocating resources among neighborhoods in a community, one would need separate assessments at the neighborhood level. If the measure will be applied in different countries, a definition that applies internationally will be necessary (e.g., not U.S. census tracts).

3.1.3.2 Temporal Resolution

Similarly, the temporal resolution decision is primarily a balance between a smaller time step that captures the trends over time more precisely and a larger time step that requires less data. Again, it depends largely on the intended uses and data availability. If the time steps are two small, the required data may not be available and there may be too much variability. If the time steps are too large, important fluctuations could be missed. Data should be used at its best resolution, which is likely to be between one and six months.

3.1.3.3 Sectoral Resolution

One may attempt to measure recovery for a community as a whole, for sectors defined as in Section 3.1.2 (e.g., housing, economy, education), or for more precisely defined sectors. For housing, more specific sectors might include, for example, single-family housing, multi-family housing, affordable housing, vacation housing, or rental housing. For the economy, specific sectors might be different industries (e.g., retail, manufacturing).

3.1.3.4 Accounting for Heterogeneity

If there is a desire to capture the heterogeneity in a community recovery, that may be done in two different ways. One might measure the recovery for each of many smaller area units, specific sectors, or population groups, then aggregate them, so as to end up with information about how the recovery differs across those smaller units. Alternatively, one might separately assess the total degree of community recovery and the degree of heterogeneity within the community. Compared to the latter, the former approach is more straightforward and would result in more detailed output, but requires more data, and thus may be more difficult to implement.

3.1.3.5 Accounting for Trajectory of Recovery

Community recovery is complicated both because of the heterogeneity that may exist within the community (different households or neighborhoods within a community may recovery differently) and because each may follow a different trajectory to get to the endpoint of “recovered”. Figures 3.2a and 3.2b, for example, use event trees to illustrate possible trajectories that a displaced household and damaged building may follow, respectively. Each can be read chronologically from left to right. Figure 3.2b, for example, shows that a damaged building may be repaired or demolished; it may be repaired to the same state it was in pre-disaster or differently. At the site of a building that has been demolished, a building may then be rebuilt the same, differently, or not rebuilt at all.

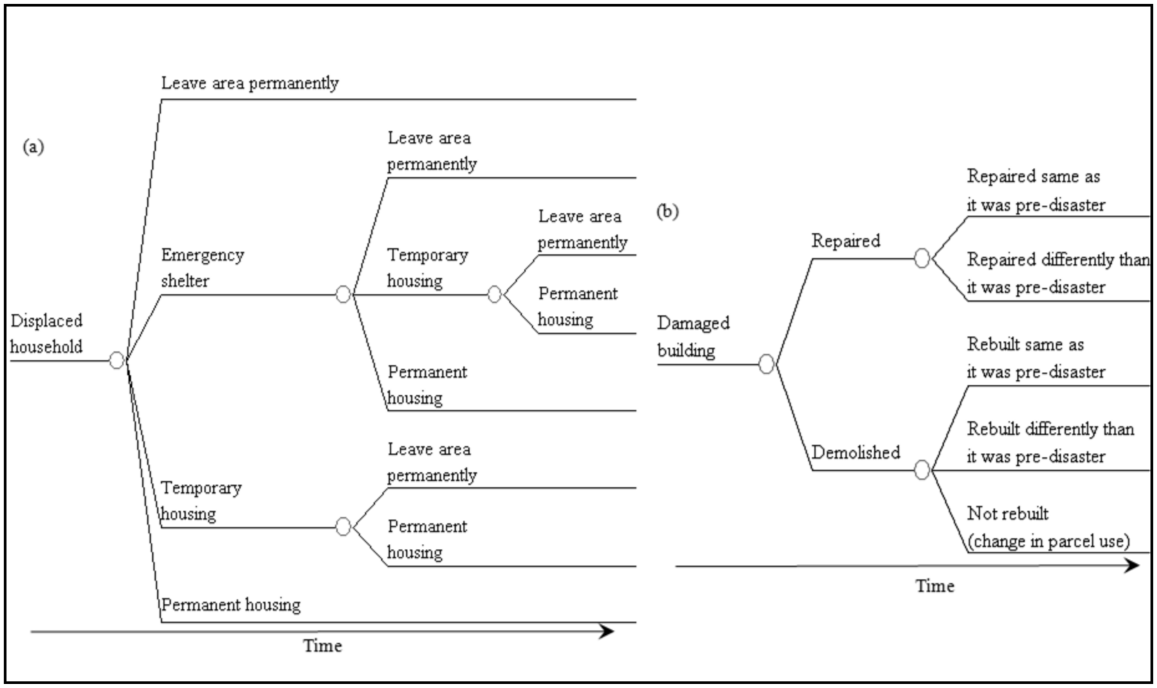


Figure 3.2: Schematic Representations of Possible Trajectories: (a) Displaced household and (b) Damaged building

A measure may be concerned only with when a household or building achieves its final state, or it may try to capture any progress along the trajectory, distinguishing, for example, a situation in which all displaced households are in emergency shelters from one in which all are in temporary housing. In both cases, none are in the their final "recovered" state, either having left the community or being in permanent housing, but one might consider the recovery to be farther along in the latter case.

3.1.3.6 Absolute/Relative

Directly related to the intended uses of a measure, it may be that a measure need only provide an assessment of recovery relative to some standard. A relative measure may be more intuitive by putting an assessment in context if there is a basis for comparison that users would have an intuitive feel for, but it may not be if no such entity exists.

3.1.3.7 Type of Measure

Possibilities for the overall format of the measure include a set of indicators, composite index, or constructed scale. A natural scale is one that already exists and that people use widely and have an intuition for, such as, dollars, miles per gallon, or number of houses. The final measure of recovery could be in terms of a collection of carefully chosen natural scale indicators, such as number of damaged houses, average per capita income, and number of children in school. Another alternative is to combine such indicators mathematically into a single composite index using a linear combination or other function. A third option is to develop a constructed scale of community recovery in which a relatively small number of discrete levels of recovery are defined. The Modified Mercalli Intensity (MMI) scale of earthquake intensity is an example of a constructed scale.

A set of indicators has the advantage of requiring only quantitative data to apply, no judgment, but it does not tell the user anything about the relative importance of the indicators or how they should be integrated to give an overall assessment of community recovery. A composite index aggregates the many indicators for the user, but it requires sometimes difficult assumptions about the functional form of the index, and scaling and relative weights of the different indicators. While a constructed scale allows relatively coarse distinctions since it would have only several possible values and it may be difficult to define well, it has the advantage of potentially being able to capture a complex concept such as recovery more completely than relatively specific, focused indicators.

3.1.3.8 Normalization

To help interpret metric values, it may help to normalize the values using pre-disaster levels, initial loss, a larger spatial unit, or the size of the event. Normalization to pre-disaster levels or initial loss puts the metric in context. To understand if construction of ten new buildings is a lot or a little, for example, one might want to express it as a percentage of the number of buildings that existed before the disaster or as a percentage of the number of buildings completely destroyed in the disaster that have to be rebuilt. Normalizing metrics to a larger spatial unit, such as that state, may help explain whether a trend is the result of the disaster event or just a larger trend, such as an economic downturn that affected the whole state. Finally, a community recovery will depend to some extent on the intensity of the event itself. One may be interested in understanding the speed of a recovery controlling for (or normalizing to) the initial impact.

3.1.3.9 Scale Precision

Related to the type of measure chosen, the precision of the scale may be just a few levels, many levels, or an infinite number.

3.1.3.10 Language of Scale

The possible levels of a recovery scale may be described in terms of numbers, words, and/or images.

3.1.3.11 Bounds

If numerical, a recovery measure may be bounded (e.g., having possible values 1 to 10), semi-infinite, (e.g., 0 to infinity), or unbounded (e.g., all real numbers). The bounds may be important for how values of the measure are interpreted.

3.1.3.12 Data Sources

A recovery measure may draw on many different types of data, including remote sensing/aerial imagery, raw statistical data (e.g., individual building permits issued), summary data analyzed by someone else (e.g., from available reports and secondary sources), field observations, or subjective assessments elicited through field interviews or surveys. Each type of data has different strengths and weaknesses in its availability, quality, and ability to capture important aspects of the recovery concept.

3.1.3.13 Data Requirements

One may design a recovery measure so that it cannot be applied without the availability of certain data, or so that it is flexible in the specific datasets it requires. This is an important issue for a measure of community recovery that could potentially be applied in communities all over the country or world requiring data at multiple time steps.

3.1.4 Features of the Recovery Measure Selected for this Thesis

To make the many decisions described in Tables 3.1 to 3.3, one might identify the intended users and then ask representatives of that group for their input on the other decisions. As part of the larger NSF project, of which this study is one component, a survey instrument has been prepared and will be administered to community, state, and federal officials involved in managing and funding community recovery to get their input. When that study is complete, the decisions represented by the superscripts (^{2}) in Tables 3.1 to 3.3 may be modified to reflect that input.

The study presented in this thesis is based on the decisions represented by the superscripts (^{1}) in Table 3.1 to 3.3. Specifically, the goal is to develop a measure of community recovery that will be useful for government agencies and community organizations involved in funding and managing recovery to help them determine the level of recovery, compare recovery across sectors and geographic areas within an event, and across events. The measure is intended to be descriptive, and applicable for hurricanes of all severities in the United States. The measure focuses on recovery of place, considering all phases from emergency response through long-term recovery, and assuming recovery is complete when a new stable state is achieved. Although the prototype measure presented in Section 3.3 focuses on the housing sector only, it is designed with the intention of ultimately being extended to all sectors of a community (e.g., economy, education). The measure considers the *Degree of recovery*, *Sustainability of recovery*, and *Extent of change as a result of the recovery* (accounted for as three separate measures). It considers recovery of both community functions and physical infrastructure. The area unit is a city and the temporal unit is every three months. The trajectory along which a recovery proceeds is not emphasized, just the extent to which a community has reached the endpoint. The measure is an absolute constructed scale from 1 to 7, with each level of the scale described in words and is linked to values of indicator data that may be available. The aim is to make use of all types of available data, but at the same time capture the complexity of recovery more comprehensively than a set of specific indicators can and not require that specific datasets are available for all communities at all time steps to be able to apply the measure.

3.2 Possible Recovery Indicators and Data Sources

Design of a recovery measure depends both on the desired features, as summarized in Section 3.1, and the data available to apply it. This section summarizes the types of indicators — quantitative, scalar variables — that may be available to capture the recovery of the different sectors of a community and possible data sources for each. The lists provided in Tables 3.4 to 3.11 are not intended to be exhaustive, but rather, to offer examples of indicators that may be useful in representing the main features of the speed or quality of community recovery and that may be available with reasonable effort. They were developed based on a review of previous recovery studies (Section 2.3.1), and an understanding of the important features of recovery. The indicators are organized by the sector of the community that they represent: demographics, housing, critical infrastructure, natural environment, economy, education, health and well-being, and community identity (Section 3.1.2.4).

Table 3.4 provides examples of indicators and possible data sources for the demographics sector. These data sources should provide statistical information about the community at different points in time after the disaster.

Table 3.4: Demographics Indicators and Data Sources

Indicator	Possible Data Sources
Population	(Florida) Demographic Database
Educational attainment by residents	Decennial U.S. Census and American Community Survey
Average age of residents	Decennial U.S. Census and American Community Survey
Percentage of male vs. female residents	Decennial U.S. Census and American Community Survey
Ethnicity of residents	Decennial U.S. Census and American Community Survey
Length of time residents have lived in the community	Decennial U.S. Census and American Community Survey
Crime rates for before and after the disaster	Decennial U.S. Census and American Community Survey
Divorce rate among residents at various time intervals after the disaster	Decennial U.S. Census and American Community Survey

Table 3.5 shows possible indicators and data sources for measuring the recovery of the housing sector. Local building departments can be valuable in providing data such as building permits and damage assessments. It is important to collect as much data as possible to achieve a comprehensive idea of how the housing sector progressed. Analysis of the various data sources should support one another and illustrate the trends of the housing recovery. More information about housing indicators and those utilized for this project can be found in Chapter 4.

Table 3.5: Housing Indicators and Data Sources

Indicator	Possible Data Sources
Number of damaged housing units	Damage assessment
Number of damaged housing units that have been repaired	Building permit data
Number of housing units demolished after the disaster	Building permit data
Number of new housing units constructed	Building permit data
Number of destroyed housing units reconstructed	Building permit data
Number of homeowner insurance claims (total and those that have been settled)	Data from insurance agencies
Value of homeowner insurance claims (total and those that have been settled)	Data from insurance agencies
Number of unoccupied housing units	Decennial U.S. Census Bureau: General Housing Characteristics
Number of occupied mobile homes/trailers	Decennial U.S. Census Bureau: General Housing Characteristics
Number of owner-occupied housing units	Decennial U.S. Census Bureau: General Housing Characteristics
Number of renter-occupied housing units	Decennial U.S. Census Bureau: General Housing Characteristics
Number of vacant housing units	Decennial U.S. Census Bureau: General Housing Characteristics
Average home value	Decennial U.S. Census Bureau
Average cost of rent for renter-occupied housing	Decennial U.S. Census Bureau
Number of people per household	Decennial U.S. Census Bureau
Number of FEMA green, yellow, red-tagged buildings	Damage assessment
Number of people living in temporary shelters	FEMA housing records
Number of FEMA trailers being provided	FEMA housing records
Number of structures recovered	Repeat photography, VIEWS*
Number of blue tarps installed to cover structures	USACE ESF #3 Temporary Roofing Mission Analysis

*VIEWS (Visualizing Impacts of Earthquake with Satellites) is a system developed by ImageCat, Inc. that integrates satellite imagery with real-time GPS readings and map layers in conjunction with a digital camera and video recorder.

Table 3.6 provides examples of indicators and possible data sources that might be used to measure the recovery of the critical infrastructure sector. This is often one of the first sectors addressed after a disaster; therefore, it is essential that data is collected at frequent time intervals in order to fully capture the progress.

Table 3.6: Critical Infrastructure Indicators and Data Sources

Indicator	Possible Data Sources
Number of electricity, water, wastewater, communications, and gas services restored after the disaster	Local utility companies
Police department capacity (number of depts. open, officers, etc.)	Local police departments
Fire department capacity (number of stations, engines, etc.)	Local fire departments
Number of public transportation lines in operation	Department of Transportation
Number of customers without power	Local electric company public utility commission
Number of customers without potable water	Local water company
Number of customers without communication service	Local telephone company
Number of customers without wastewater service	Local sewer company
Number of customers without gas service	Local gas company
Number of electricity, water, wastewater, communications, and gas services restored after the disaster	Local utility companies
Amount of utility consumption in terms of MW, gallons, etc. (not customers)	Local utility companies
Damage to electric power system (e.g., number of outages, number of poles/transformers damaged, length of line down)	Impact assessments, computer models, aerial views
Damage to water supply system (e.g., number of pipe breaks/leaks, number of tanks/pump stations/other facilities damaged)	Impact assessments, computer models, aerial views
Damage to communications system (e.g., number of outages, number of poles down, length of line down)	Impact assessments, computer models, aerial views
Amount of debris in the area	Aerial views, damage assessments
Police department capacity (in terms of number of depts. open, officers)	Local police departments
Fire department capacity (in terms of number of stations open, fire fighters, engines)	Local fire departments
Local government capacity (in terms of number of depts. open, employees)	Local government officials
Length of roadways opened	Department of Transportation
Number of public transportation lines (e.g., bus routes, train lines) in operation	Department of Transportation
Number of bridges damaged, repaired, or demolished	Department of Transportation
Length of sidewalks repaired	Department of Transportation
Average resident commute time	Department of Transportation
Total average daily traffic	Department of Transportation
Number of railroad lines opened after disaster	Department of Transportation
Number of airports opened after the disaster	Department of Transportation

The indicators and data sources shown in Table 3.7 are examples that could be used to understand recovery for the natural environment sector. These indicators illustrate how the recovery of the natural environment has progressed at various time intervals.

Table 3.7: Natural Environment Indicators and Data Sources

Indicator	Possible Data Sources
Number of beaches in good condition	Aerial views of the coastline
Quality of various water parameters	Water sampling stations
Effect of sediment-laden water entering a basin	Water samples from research vessels
Obstructions along sea floor	Hydro surveys
Area of vegetation damaged	Aerial views of the vegetation
Area of parks repaired after the disaster	Aerial views of the parks
Changes in the natural coastline	Aerial views of coastline

Table 3.8 provides possible indicators and data sources for the economy sector. These indicators and data sources should show how the recovery of the economy is progressing over time. It is also important to note factors other than the disaster which may affect the economy, such as recessions.

Table 3.8: Economy Indicators and Data Sources

Indicator	Possible Data Sources
Number of tourists visiting the area	Tourism department
Number of available and number of vacant rental properties	Tourism department
Number of businesses closed due to disaster	Surveys of local business owners
Number of businesses closed due to disaster that have reopened	Surveys of local business owners
Number of businesses reopened, based on cars in parking lots	Aerial views of businesses
Number of newly established businesses	Surveys of local business owners
Number of business owners willing to expand	Surveys of local business owners

Table 3.8: Economy Indicators and Data Sources (cont'd)

Indicator	Possible Data Sources
Local business revenue	Office of Economic and Demographic Research
Gross Domestic Product	U.S Bureau of Economic Analysis
Differences in sectoral (primary, secondary and tertiary) contribution to GDP/Local Businesses revenue	Office of Economic and Demographic Research
Changes in (consumers) price level	Data from economic consulting firms
Economic rise due to improvements after a disaster	Data from economic consulting firms
Average annual employment by industry	Office of Economic and Demographic Research
Local number of unemployed people or unemployment rate	U.S. Department of Labor
Average income for community residents	Office of Economic and Demographic Research
Number of residents living below poverty level	Decennial U.S. Census and American Community Survey
Number of bankruptcies	Office of Economic and Demographic Research
Loan defaults	Local banks
Business payroll taxes	Office of Economic and Demographic Research
Amount of cargo that goes through the local airport	Local revenue offices
Amount of cargo that has been shipped by rail	Local revenue offices
Number of job vacancies and the time it took to fill them	Surveys of local business owners
Adequacy of finance	Local banks
Number of sources for local business loans	Office of Economic and Demographic Research
Local government revenue	Office of Economic and Demographic Research
Degree of debt of the local government	Office of Economic and Demographic Research
Number of business insurance claims (total and those that have been settled)	Insurance agencies, state insurance commission
Value of business insurance claims (total and those that have been settled)	Insurance agencies, state insurance commission
Percentage of business insurance claims that have been settled	Surveys of local business owners
Percentage of business insurance claims that have been settled	Surveys of local business owners

Examples of indicators and possible data sources to measure recovery of the education sector are shown Table 3.9. These indicators should include structural aspects, such as the number of usable school buildings, as well as academic aspects such as graduation and dropout rates.

Table 3.9: Education Indicators and Data Sources

Indicator	Possible Data Sources
Number of schools opened	Local Board of Education
Number of students taking classes at a school other than their permanent one	Local Board of Education
Number of students taking classes in modular buildings at their original campus	Local Board of Education
Number of students enrolled in school	Local Board of Education
Average GPA of students	Local Board of Education
Average dropout rate	Local Board of Education
Graduation rate	Local Board of Education

Table 3.10 offers possible indicators and data sources for the health and well-being sector of the community. These indicators should capture the progress of both the physical and psychological recovery of the community members.

Table 3.10: Health and Well-Being Indicators and Data Sources

Indicator	Possible Data Sources
Number of hospitals opened	Local hospitals
Number of hospital beds available	Local hospitals
Number of residents satisfied with the help received from various organizations	Surveys of local residents
Number of residents who feel the recovery levels are satisfactory	Surveys of local residents
Level of recovery residents feel has been achieved	Surveys of local residents
Number of suicides	Local hospitals

The indicators and possible data sources in Table 3.11 can be used to measure the recovery of the community identity sector. Many of these indicators require interacting with community members and understanding their perspectives of the recovery progress.

Table 3.11: Community Identity Indicators and Data Sources

Indicator	Possible Data Sources
Community participation in recovery efforts	Surveys of local residents
Participation of residents in other community events	Surveys of local residents
Residents' sense of attachment to community	Surveys of local residents
Local support for the recovery as a process	Surveys of local residents
Residents' sense of place	Surveys of local residents
Community's sense of place	Surveys of local residents
Changed awareness	Surveys of local residents
Absence of conflicts/the way conflicts are being resolved	Local police departments
Intergroup cooperation	Local organizations
Extent to which the disadvantaged perceive their needs	Local organizations
Number of people that have returned to the disaster struck community	Population records

There are several issues to note about the way the indicators are defined. Some of the indicators listed describe damage and disruption; some describe recovery. While the focus here is on recovery, both types of indicators are relevant because recovery can be considered a measure of how damage and disruption decrease over time. All indicators are for a particular time, and the idea is that they would be measured at different points in time before and after the event to monitor recovery. The tables do not specify spatial dimensions for the indicators. Many can be mapped or disaggregated to give a value for each area unit within the community. Most indicators that are expressed as “Number of…” could also be translated into a rate, “Number per unit time”. The indicators are defined in raw form, but they could be normalized by total in whole area, number in state, or some other quantity. Many indicators can be defined in terms of number or percentage that are damaged or nonfunctioning, or in terms of the number or percentage that are functioning (i.e., have been repaired, reopened, or restored). For consistency, one may want to take the same approach for all indicators. The data available to evaluate these indicators may vary in geographic and temporal resolution and coverage (all or some sample). Some provide data for each individual household or building, for example; some give one value for the entire community. Some will be available for every household or building; some for only a sample, and the samples used may be different for different indicators. It would be useful to keep these issues in mind when defining, selecting, or finding data for indicators to use in any community recovery measure.

3.3 Proposed Post-Disaster Community Housing Sector Recovery Measure

The proposed post-disaster community recovery measure for the housing sector has six main sections: (1) Overview, (2) degree of recovery, (3) sustainability of recovery, (4) extent of change as a result of the recovery, (5) supporting data, and (6) data quality. The complete measure is presented in Section 3.3.1, and each of its six main sections is described in turn in Sections 3.3.2 to 3.3.7.

3.3.1 Measure

This section presents the actual measure, which would be used to evaluate post-disaster recovery for a community. The evaluator would use the collected resources to fill out the measure and assign the overall scores to the community's housing recovery.

POST-DISASTER COMMUNITY HOUSING RECOVERY MEASURE OVERVIEW

For a community and hurricane of interest, the community can be evaluated on each of three different dimensions—*Degree of recovery*, *Sustainability of recovery*, and *Extent of change as a result of the recovery*—at each time step. The number of assessments for each dimension will depend on the intended use of the measure and the available data. One may wish to assess *Degree of recovery* over time, for example, but the other two dimensions only after the recovery has been determined to be completed. If one or more dimensions are assessed at multiple time steps, then by tracking those assessments over time, one can monitor the community's recovery in a systematic, comprehensive way. Each assessment can be accompanied by an assessment of the quality of the data supporting the assessment using the *Data quality* measure.

Assessments made over time can be presented as a graph showing the dimension vs. time (e.g., Figure M1a). At a single point in time, assessments of the three dimensions can be summarized on a spider plot (e.g., Figure M1b).

Table M1. Schematic example of summary of all community recovery assessments

	Degree of recovery											Sustainability of recovery	Extent of change
Time (months post-event)	0	6	12	18	24	30	36	42	48	54	60	60	60
Recovery assessment	I	I	II	III	V	VI	VI	VII	VII	VII	VII	IV	II
Data quality assessment	B	B	B	B	B	B	B	B	B	B	B	C	C

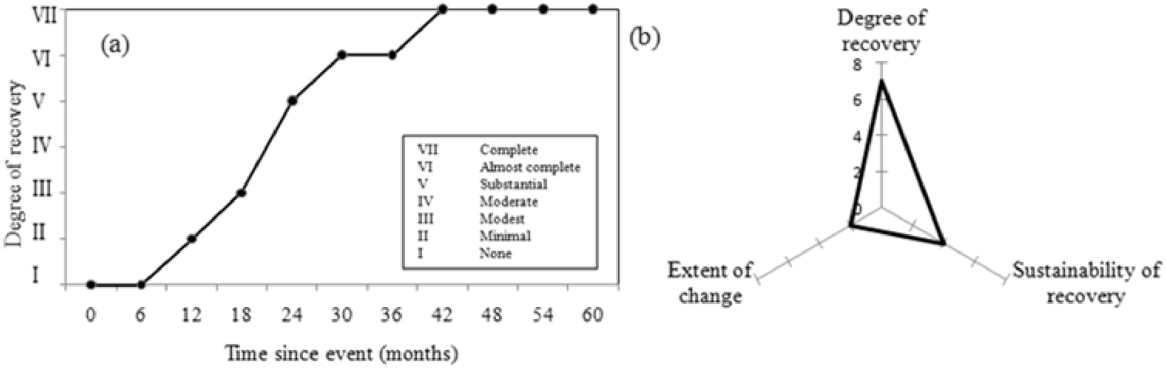


Figure M1. Schematic examples of (a) assessments over time for one dimension of recovery and (b) assessments of three dimensions of recovery at one time

DEGREE OF HOUSING RECOVERY

Definition and scale

This measure describes the extent to which households seeking permanent shelter as a result of the hurricane have obtained permanent shelter in good physical condition (i.e., without damage that has not been repaired).

I	**None**. 1 in 10 households seeking permanent shelter as a result of the hurricane have obtained permanent shelter in good physical condition
II	**Minimal**. 2 to 3 in 10 households seeking permanent shelter as a result of the hurricane have obtained permanent shelter in good physical condition
III	**Modest**. 4 to 5 in 10 households seeking permanent shelter as a result of the hurricane have obtained permanent shelter in good physical condition
IV	**Moderate**. 6 to 7 in 10 households seeking permanent shelter as a result of the hurricane have obtained permanent shelter in good physical condition
V	**Substantial**. 8 in 10 households seeking permanent shelter as a result of the hurricane have obtained permanent shelter in good physical condition
VI	**Almost complete**. 9 in 10 households seeking permanent shelter as a result of the hurricane have obtained permanent shelter in good physical condition
VII	**Complete**. All households seeking permanent shelter as a result of the hurricane have obtained permanent shelter in good physical condition, or the number has been stable for 2 years

Application of the measure

The *Supporting data* section offers some key types of data that may be available and useful to support determination of the *Degree of housing recovery* value that best reflects a community's situation at a point in time. As many of these types of data as possible should be collected, and the assessment should be based on the picture they collectively produce.

SUSTAINABILITY OF HOUSING RECOVERY

Definition and scale

This measure describes the extent to which housing recovery has occurred in a way that reflects the six principles of sustainability: uses a participatory process, enhances quality of life, builds local economic vitality, promotes social and intergenerational equity, protects environmental quality, and improves disaster resilience (Mileti 1999, NHC 2005).

I	**None**. Sum of component scores = 0 or 1
II	**Very low**. Sum of component scores = 2 or 3
III	**Low**. Sum of component scores = 4 or 5
IV	**Moderate**. Sum of component scores = 6
V	**High**. Sum of component scores = 7 or 8
VI	**Very high**. Sum of component scores = 9 or 10
VII	**Superior**. Sum of component scores = 11 or 12

Application of the measure

For each of the six components of a sustainable community recovery, 0 to 2 points are available, based on the scales below. The component scores should be added to produce an assessment for the overall sustainability measure. The assessment should refer to the activities that have taken place just since the last time at which it was assessed, rather than through the entire course of the recovery (i.e., it is not cumulative).

Uses a participatory process. A participatory process seeks wide participation from all individuals who have a stake in the outcome of a decision. It involves identifying concerns and issues, allowing the generation of ideas for potential solutions, and facilitating consensus on decisions and actions (NHC 2005, p.1-3).

0	**Low**. One or two stakeholder groups dominated the recovery decision making
1	**Moderate**. Multiple stakeholder groups involved in the recovery decision making, but some key groups did not participate meaningfully.
2	**High**. Most stakeholder groups meaningfully participated in process

Stakeholders may include real estate groups, homeowners associations, civic organizations, business and environmental groups, individual residents, and any other people or groups with an interest in the recovery.

SUSTAINABILITY OF HOUSING RECOVERY (CONT'D)

Enhances quality of life. Improve mobility, recreation, public safety, affordability, civic engagement and other characteristics that affect livability and that are not directly captured in the other components of sustainability.

0	**Low**. Little or no effort made to improve quality of life through housing recovery
1	**Moderate**. Some effort made to improve quality of life through housing recovery
2	**High**. Multiple or significant efforts to improve quality of life through housing recovery

Examples of ways to improve community quality of life through housing recovery:

- Provide more affordable housing
- Ensure mobility
- Maintain safe/healthy environs
- Buyout housing with history of abandonment and tax delinquency
- Encourage energy efficient buildings
- Buyout homes in known hazardous areas and use for public spaces instead
- Provide temporary housing, and rebuild and repair housing so as to maintain social networks

Builds local economic vitality. Improve job opportunities, attractive business climate, and stable tax base.

0	**Low**. Little or no effort made to improve economic vitality through housing recovery
1	**Moderate**. Some effort made to improve economic vitality through housing recovery
2	**High**. Multiple or significant efforts to improve economic vitality through housing recovery

Examples of ways to improve local economic vitality through housing recovery:

- Create new housing to support area redevelopment or neighborhood-serving businesses
- Establish housing near job centers to attract/retain businesses
- Attract/retain work force by building housing to alleviate housing shortages

SUSTAINABILITY OF HOUSING RECOVERY (CONT'D)

Promotes social and intergenerational equity. Requires that housing is repaired and rebuilt at similar speeds and to similar quality for all groups of residents.

0	**Low**. Little or no effort made to promote social and intergenerational equity through housing recovery
1	**Moderate**. Some effort made to promote social and intergenerational equity through housing recovery
2	**High**. Multiple or significant efforts made to promote social and intergenerational equity through housing recovery

Examples of ways in which equity may be improved as part of post-disaster housing recovery:

- Fair distribution of resources across a community's population
- No groups at increased risk by living in structures that are more vulnerable
- No groups at increased risk by living in structures with higher exposure to natural hazards

Protects environmental quality. Improve the quality and protection of the natural environment, including wetlands, rivers, beaches, forests, parks, open spaces, wildlife habitats, and other components of the natural environment.

0	**Low**. Little or no effort made to protect the environment through housing recovery
1	**Moderate**. Some effort made to protect the environment through housing recovery
2	**High**. Multiple or significant efforts to protect the environment through housing recovery

Examples of ways to improve natural environment through housing recovery:

- Preserve natural resources
- Protect open space
- Manage stormwater runoff
- Prevent/remediate pollution

Improves disaster resilience. Reduce damage, disruption, casualties, and other negative impacts of future hazard events.

0	**Low**. Little or no effort made to improve disaster resilience through housing recovery
1	**Moderate**. Some effort made to improve disaster resilience through housing recovery
2	**High**. Multiple or significant efforts to improve disaster resilience through housing recovery

Examples of ways to improve disaster resilience through housing recovery:

- Relocate or buyout housing in hazardous areas
- Avoid building new housing in hazardous areas
- Reduce vulnerability of housing by upgrading the building code, improving enforcement, or including mitigation efforts as part of repair and reconstruction
- Promote purchase of appropriate disaster insurance for housing

EXTENT OF CHANGE AS A RESULT OF HOUSING RECOVERY

Definition and scale

This measure describes the extent to which permanent changes have occurred in the character of the community's housing sector as a result of the disaster event and subsequent recovery process.

I	**No change**. Largest change in the percentage of one type of housing unit < 5%
II	**Very little change**. Largest change in the percentage of one type of housing unit = 5% to 10%
III	**Little change**. Largest change in the percentage of one type of housing unit = 10% to 15%
IV	**Moderate change**. Largest change in the percentage of one type of housing unit = 15% to 20%
V	**Substantial change**. Largest change in the percentage of one type of housing unit = 20% to 25%
VI	**Very substantial change**. Largest change in the percentage of one type of housing unit > 25%
VII	**Extensive change**. Multiple types of housing units have change > 25%

* Type of housing unit is all units with a certain characteristic, such as, single-family dwellings or seasonal homes.

Application of the measure

The housing stock can be divided based on various characteristics, such as the following:

- ***Units-in-structure***. Single-family dwelling, multi-family dwelling (apartment), mobile home.
- ***Primary residence vs. seasonal home***.
- ***Tenure***. Rental vs. owner-occupied.
- ***Value***. Value of owner-occupied housing unit or rent for renter-occupied homes, perhaps using definitions of economy, average, custom, luxury homes from RS Means (2006), or perhaps defined in affordable or unaffordable.
- ***Size***. Floor area and/or number of stories.

For each characteristic, the percentage of housing units in each category (e.g., rental vs. owner-occupied) can be tracked to see if it has changed substantially as a result of the disaster or recovery process.

SUPPORTING DATA

For each data type, a brief description is provided, together with possible sources and how it may be mapped to the housing recovery measure.

Structural surveys. Structural surveys may be conducted by individual researchers, engineering companies, insurance companies, building departments or other government agencies, or others to assess the number, locations, and types of housing units damaged, and the magnitude and character of the damage.

Remote sensing/aerial imagery analysis. Satellite and/or aerial images can be used to evaluate individual buildings to determine the extent of initial damage and the degree of recovery at different points in time using the following scale. The number of damaged buildings that have transitioned from an initial damage state to an intermediate recovery state or final recovered state at a point in time can provide information about the degree of recovery. Examination of the number of buildings repaired or rebuilt differently than before may be useful in assessing the *Sustainability of recovery* or *Extent of change*.

Building damage and recovery scale based on remote sensing and aerial imagery

Initial damage states
0. Undamaged or unchanged
1. Minor damage, less then 15% of roof failure
2. Moderate damage, between 15% and 50% of roof failure
3. Severe damage, more then 50% of roof failure
4. Catastrophic damage, building collapsed or completely destroyed roof
Intermediate recovery states
5. Demolished building, after the event[a]
6. Under repair/construction, incomplete building
7. Blue tarpaulin present on the roof
Final recovered states
8. Repaired building, with the same ground footprint
9. Repaired building, with different footprint
10. Rebuilt building, with the same footprint
11. Rebuilt building, with different footprint.

[a] Note that demolished could be an intermediate state if the building is subsequently rebuilt, or a final state if not.

SUPPORTING DATA (CONT'D)

Building permits. Many types of building permits may be relevant, and the classifications may vary by jurisdiction and hazard type. Permit types that may be relevant include those required for building demolition, remodeling, roof repair, mobile home construction, and new construction, and any others directly related to repair of building components likely to have been damaged in the hurricane or likely to be part of a hurricane mitigation effort (e.g., screen enclosures or hurricane shutters).

Plots of the number of permits versus time may indicate the times at which a peak associated with the event starts and ends. Developing these plots as a recovery is unfolding, however, will not indicate how far along the recovery has progressed, because the end point will not yet be apparent. To use permit data to assess degree of recovery as the recovery is still unfolding, it can be linked to an initial damage assessment based on a structural survey or remote sensing analysis. In that way, a database can be created showing, for each damaged building, the permits issued for it over time. By assuming that the issuance of a permit reflects a degree of recovery, this type of analysis can help indicate the extent of recovery over time. Ideally, the time work is complete would be recorded and used in the analysis, but it may be that only the application or issue date for a permit, indicating the start time for construction, is available.

Permit data may be available from the local building department.

Temporary housing. The number of units of temporary housing being used may include mobile homes, travel trailers, tents, or other facilities set up for the purpose of providing temporary shelter to people who are unable to occupy their pre-event permanent housing. Since different agencies provide temporary housing and people seek it in different places, it may be difficult to find a total amount, but data from some primary providers may offer information about the trend.

Temporary housing data may be available from the Federal Emergency Management Agency, U.S. Army Corp of Engineers, or other agencies providing temporary housing.

Temporary roofing (blue tarps). Blue tarps are often installed on roofs of damaged homes as a temporary repair measure. FEMA has a program to provide assistance with this task. Under the FEMA program, which may be implemented by the U.S. Army Corps of Engineers, roofs that are more than 50% damaged, have tree debris on the roof, and metal, tile or flat roofs do not qualify for temporary roofing. Commercial businesses, including apartments, are also ineligible for assistance. Installation of a blue tarp indicates a certain degree of recovery, since it may make a house temporarily habitable, though not permanently repaired and still vulnerable. Removal of a blue tarp for permanent roof repair or replacement can indicate another higher level of recovery.

Temporary roofing data may be available from FEMA, U.S. Army Corp of Engineers, or other agencies providing temporary roofing support.

U.S. Census, American Community Survey. Data on the breakdown by units in structure, number of rooms, year built, tenure, value of owner-occupied units, gross rent for renter-occupied units, and other characteristics are available annually for geographic areas with a population of 65,000 or more and every 3 years for geographic areas with a population of 20,000 or more (U.S. Census Bureau 2008). This data may be useful in assessing the *Extent of change*.

Property appraisal data. Property tax assessor's data typically includes information for each building in the county, on the location, occupancy type (e.g., single-family, commercial), value, number of stories, and other building attributes. The property appraisal data should be available yearly. This data may be useful in categorizing houses to determine if the distribution changed during the course of the post-disaster recovery. This would be directly useful in assessing the *Extent of change* measure. It can also be useful in identifying which buildings in an aerial image are residential.

Property appraisal data may be available from the county property tax assessor's office.

Interviews. Community stakeholders may be interviewed to elicit subjective assessments about the three dimensions of housing recovery. These stakeholders may include building department officials, city planners, builders, FEMA representatives, and other community members involved with the housing recovery process. They may be asked to assess the dimensions of recovery at different points in time using the scales provided in the measure. Asking the interviewees to explain the basis of their assessments as well can help in interpreting the assessments and merging them assessments from other data sources.

DATA QUALITY

Definition and scale

This measure describes the quality of the data on which the *Degree of recovery*, *Sustainability of recovery*, and *Extent of change as a result of the recovery* assessments are based.

A	**High**. Sum of component scores = 5 to 6
B	**Medium**. Sum of component scores = 2 to 4
C	**Low**. Sum of component scores = 0 to 1

Application of the measure

An assessment of data quality can be made for each dimension of recovery at each point in time that it is evaluated. In making a data quality assessment, all data used to assess the particular dimension at that time should be considered. For each of the three components of data quality, 0 to 2 points are available, based on the scales below. The component scores should be added to produce an assessment for the overall data quality measure.

Completeness. Extent to which there is sufficient data of sufficient spatial, temporal, and thematic precision and without known bias to capture the concept being measured and no important data is missing.

0	**Low**. Insufficient data to capture all aspects of the concept being measured or important data is missing.
1	**Medium**. Captures most of concept but may be indirect measure. Some pieces of data may be missing.
2	**High**. Sufficient data to offer clear assessment of the concept being measured and no important data is missing.

Accuracy. Extent to which data reflects the real-world phenomenon or concept of interest and lacks spatial, temporal, thematic, or other errors.

0	**Low**. Many known errors that might affect the final level of recovery assessed.
1	**Medium**. Some errors, but unlikely to affect the final level of recovery assessed by more than +/- one level.
2	**High**. Any errors are very unlikely to affect the final level of recovery assessed.

Consistency. Extent to which data from different sources suggest the same conclusions. Absence of apparent contradictions. Internal validity.

0	**Low**. Data from more than one independent source suggest conflicting assessments of recovery.
1	**Medium**. Data from only a single source.
2	**High**. Data from more than one independent source suggests the same assessment of recovery.

3.3.2 Measure Overview

The proposed post-disaster community recovery measure for the housing sector includes three different dimensions—*Degree of recovery*, *Sustainability of recovery*, and *Extent of change as a result of the recovery*. The *Degree of recovery* dimension captures the speed of recovery, how quickly it gets to a state in which the effect of the event is no longer substantially felt. The *Sustainability of recovery* captures the extent to which the recovery is conducted so as to build sustainability into the community for the future as defined by Mileti (1999) and NHC (2005). In some cases a community experiences permanent changes in character as a result of a disaster and the subsequent recovery so that it may never return to its pre-disaster state, and the *Extent of change* dimension aims to capture the extent to which that occurs.

The housing recovery measure is divided into these three dimensions because they capture fundamentally different aspects of recovery, all of which are important, but that are not necessarily correlated and are not naturally measured along a single axis. A community's recovery may, for example, proceed quickly but not in a sustainable fashion. Two communities may recovery equally quickly but one ends up very similar to how it was pre-event, whereas the other has experienced a significant and permanent change in its demographic composition or the key industries contributing to its economy have changed. The three dimensions of the measure are discussed in turn in Sections 3.3.3 to 3.3.5. For each of the three dimensions, the measure includes: (1) definition of the concept being measured and the scale (I to VII) proposed to measure it, and (2) the way in which it should be applied. Each measure can be used to assess post-disaster recovery of a community at a point in time. By repeating the assessments at multiple time steps post-event, one can track the recovery over time. The number of assessments done for each dimension will depend on the intended use of the measure in that application (e.g., if it is intended to support midcourse corrections as a recovery unfolds, or understand a recovery after it is complete) and the available data. The assessments may be presented in a variety of graphical forms (Figure M1) depending on whether the intent is to show trends over time or compare recovery across dimensions.

3.3.3 Degree of Recovery

The *Degree of recovery* measure describes the extent to which households seeking permanent shelter as a result of the hurricane have obtained permanent shelter in good physical condition. There are a few issues to note about this definition and the measure used to capture it. First, this measure is intended to capture the speed of recovery for the community overall, so it does not capture *how* the community recovers and it does not capture spatial or other variability across the community. Those are intended to be represented by the *Sustainability of recovery* and *Extent of change* measures, respectively.

Second, the focus of this measure is on the recovery of place, not the recovery of people (Section 3.1.2). That is, it focuses on the community itself rather than the people who are part of the community at the time of the disaster event. As a result, the measure addresses "households seeking permanent shelter," so that if someone leaves the community permanently following the event and does not intend to return, that person is considered to be “recovered” in the sense that his situation does not have to change any more as part of furthering the community’s recovery.

Third, in related assumptions, when using housing units as a proxy for people, the measure normalizes housing unit recovery by the number of units damaged or destroyed in the event, and assumes that the recovery is complete when either all those units have been repaired or rebuilt, or when a new stable level has been reached. The reason for this is to acknowledge the fact that the community may never return to its pre-event situation in terms of number of households or housing units, but at the same time be able to assess how far along the community is in the recovery process as it is still unfolding (i.e., possibly before it is clear what the end state will be).

Fourth, by focusing on people seeking shelter, as opposed to physical housing units repaired or rebuilt, the measure emphasizes recovery of functionality over physical recovery. The measure assumes that functionality generally occurs before physical recovery for the housing sector but that both must take place for a full housing recovery to be accomplished. This means that being in a temporary mobile home, while it achieves the housing function of protecting people from the elements, is not considered full recovery. Similarly, if a household is living in its own home, but the roof or other parts of the building are still damaged, that would not constitute complete recovery either. Having said this, housing sector data that is likely to be available tends to focus on physical recovery (e.g., repair of building damage), and thus, physical recovery will likely be used as a proxy for functional recovery. Finally, while it would be useful to capture a household’s trajectory of recovery (Section 3.1.3), the proposed measure considers only the endpoint for each household, i.e., when it either has permanent shelter in good physical condition or left the community permanently.

3.3.4 Sustainability of Recovery

The *Sustainability of recovery* measure describes the extent to which housing recovery has occurred in a way that reflects the six principles of sustainability: uses a participatory process, enhances quality of life, builds local economic vitality, promotes social and intergenerational equity, protects environmental quality, and improves disaster resilience (Mileti 1999, NHC 2005). Recovery is evaluated according to each of the six principles individually. The component scores are then added to produce an assessment for the overall sustainability measure. The assessment should refer to the activities that have taken place just since the last time at which it was assessed, rather than through the entire course of the recovery (i.e., it is not cumulative). Mileti (1999) and NHC (2005) are the basis for the concept of sustainability of recovery and therefore, are the source for most of the information in this section.

A *participatory process* seeks wide participation from all individuals who have a stake in the outcome of a decision. It involves identifying concerns and issues, allowing the generation of ideas for potential solutions, and facilitating consensus on decisions and actions (NHC 2005, p.1-3). Potential benefits of a participatory process include: (1) Mutual learning between participants and local staff and officials, (2) more creative ideas and solutions emerge, (3) higher levels of credibility and support, and (4) faster and more sustainable recovery. A high quality participatory process involves many participants from the full range of stakeholder groups, including organized and unorganized groups of people. It includes demonstrated political and financial commitment, and a commitment by local policy makers to let the process influence their decisions. Concerted efforts to encourage participation should be on-going, perhaps using one or more of the following methods: public meetings, issue presentations, panel discussions, workshops, community visits, call-in radio, and/or distribution of publications. Since a participatory process does not guarantee successful outcomes, the measure is based on the efforts made rather than outcomes.

Since *quality of life* is a very broad concept that overlaps with the other principles, in this context, the focus of the quality of life assessment is on those aspects of community life that are not captured by the other components, such as mobility, recreation, public safety, affordability, and civic engagement. A few examples of ways in which quality of life may be improved as part of post-disaster housing recovery are provided in the measure (Section 3.3.1).

Improving *economic vitality* includes improving job opportunities, making the business climate more attractive and ensuring a stable tax base. The role of housing in economic vitality relates to the need for housing for both the workers and customers that businesses rely on, and to the tax base that housing provides a community. Examples of ways in which economic vitality may be improved as part of post-disaster housing recovery are provided in the measure (Section 3.3.1).

Promotion of *social and intergenerational equity* during housing recovery requires that housing is repaired and rebuilt at similar speeds and to similar quality for all groups of residents. Examples of ways in which equity may be improved as part of post-disaster housing recovery are provided in the measure (Section 3.3.1).

There are many aspects of the natural *environment* that may be considered part of a community's well-being, including wetlands, rivers, beaches, forests, parks, open spaces, recreational areas, and wildlife habitats. Examples of ways in which environmental protection may be improved as part of post-disaster housing recovery are provided in the measure (Section 3.3.1).

Perhaps the most important aspect of the sustainability housing recovery relates to the extent to which it improves *disaster resilience* for the future. Important efforts to reduce the vulnerability of the housing stock may include not rebuilding damaged housing in flood-prone areas, adding hurricane shutters to houses as they are repaired, and repairing and rebuilding houses to stricter building standards.

3.3.5 Extent of Change as a Result of the Recovery

The *Extent of change as a result of the recovery* measure is intended to capture any permanent changes in the character of the community's housing sector as a result of the disaster event and subsequent recovery process. The character of the housing stock is described based on the breakdown for each of the following key characteristics:

- ***Units in structure***. Single-family dwelling, multi-family dwelling (apartment), mobile home.
- ***Primary residence vs. seasonal home***. Year-round residence vs. seasonal residence.
- ***Tenure***. Rental vs. owner-occupied.

- ***Value/amount of affordable housing***. Value of owner-occupied housing unit or rent for renter-occupied homes.
- ***Size***. Floor area and/or number of stories.

For example, for a specified community at a specified time, a large percentage of the housing units may be multi-family units or mobile homes; whereas, in another community or at another time, it may be almost all single-family dwellings. These characteristics were selected because they are features of the housing sector that could change as the result of a disaster and are relatively easily measured.

For each characteristic, the percentage of housing units in each category (e.g., rental vs. owner-occupied) can be tracked to see if it has changed substantially as a result of the disaster or recovery process.

3.3.6 Supporting Data

The post-disaster community housing recovery measure includes a section that suggests types of data that might be collected and used to support assessment of a value for a community at a particular point in time. For each data type, it provides a brief description, possible sources of that data, and how it may be mapped to the housing recovery measure. As many of these types of data as possible should be collected, and the assessment should be based on the conclusion they collectively suggest. Additional types of data may be used as well, and perhaps as the measure is applied to more communities and events, the list can grow. This scheme was developed as an attempt to balance two key objectives. First, because it is likely that there will be considerable variability in the types and quality of data available across communities and events, it is desirable to have a measure that can be applied even if one particular type of data is missing. Second, it is desirable to take full advantage of the great deal of useful, quantitative, replicable data that will exist in at least some cases. Some types of data may not have been collected for this purpose, so it is likely that all data sources will have limits, but together they can produce a reasonably clear picture of a community's post-disaster housing recovery. In defining each of the scales used in this suite of community recovery measures, an effort was made to define them so that they require little judgment to apply so that multiple people would make the same assessment for the same community.

3.3.7 Data Quality

The data quality section of the measure introduces a method for making an explicit assessment of the quality of data used to support assessment of each dimension of recovery at each time step. Such an assessment of data quality can be important because, especially given the large scope of post-disaster community recovery, data availability and quality are likely to vary considerably across applications of the recovery measure. Some communities will have more available background data and be easier places to collect post-event data. Some events may garner more attention and therefore may have more high quality data available. Some aspects of recovery are more specific and easier to capture with a few simple indicators than others. A data quality measure can be useful both to help users determine appropriate ways to use a recovery measure and to identify areas in which data collection can be improved for future disaster events.

A great deal of literature exists about what constitutes data quality and how to measure it (e.g., Pipino et al. 2002), ranging from classical statistical measures of data quality (e.g., mean error, root mean square error, inference tests, and confidence limits) to qualitative multi-dimensional frameworks. For this purpose, with dual aims to capture the key issues likely to affect data quality in this context and to avoid undue complexity, three main components were identified: completeness, accuracy, and consistency. *Completeness* refers to the extent to which there is sufficient data of adequate spatial, temporal, and thematic precision and without known bias to capture the concept being measured and no important data is missing. *Accuracy* reflects the extent to which data reflects the real-world phenomenon or concept of interest and lacks spatial, temporal, thematic, or other errors. Finally, *Consistency* refers to the extent to which data from different sources suggest the same conclusions. It describes the absence of apparent contradictions, or internal validity.

An assessment of data quality can be made for each recovery assessment that is made. In making a data quality assessment, all data used to assess the particular dimension at that time should be considered.

CHAPTER 4 - HOUSING RECOVERY CASE STUDY

This chapter discusses the case study conducted to help develop the post-disaster community recovery measure. Section 4.1 provides background information about the case study area (Punta Gorda, Florida) and event (Hurricane Charley in 2004). Section 4.2 discusses the relevant data collected and Section 4.3 provides background information about the housing sector before Hurricane Charley. The initial damage to the housing sector and the subsequent recovery process are discussed in Sections 4.4 and 4.5, respectively. Section 4.6 compares the strengths and limitations of the data sources used in the analysis. Finally, Section 4.7 utilizes the data and background information to apply the prototype housing recovery measure proposed in Section 3.3 to the case study area.

4.1 Case Study Area and Event

Punta Gorda was chosen as the case study area mainly because Hurricane Charley was a recent event with results typical of a hurricane disaster. Selecting Punta Gorda was also beneficial because ImageCat, Inc. had high resolution aerial images from before Hurricane Charley and VIEWS data from directly after the disaster. Furthermore, the recovery in Punta Gorda was already well-advanced so many data resources were readily available and the community members seemed interested in the project and, therefore, more likely to be helpful in the project.

4.1.1 Charlotte County and Punta Gorda Background

Charlotte County was established in 1921. It was originally a portion of Manatee County and then became part of DeSoto County in 1887. The county was named for the bordering Charlotte Harbor, Florida's second-largest estuarine system. In the 1970s, Charlotte County was one of Florida's fastest growing counties. It is a charter county with Punta Gorda as its only incorporated area (Enterprise Florida, Inc. 2010). Charlotte County adopted its charter in 1986. As a charter county, Charlotte County governs itself through the elected Charlotte County Board of County Commissioners (Florida Association of Counties 2008).

According to the Charlotte County Chamber of Commerce, Punta Gorda was incorporated in 1887 and is the only incorporated city in Charlotte County, meaning it is established as a municipality and has its own governing body (Charlotte County Chamber of Commerce 2008). Ponce De Leon landed on Punta Gorda's Pine Island in 1513 and Hernando DeSoto landed at Live Oak Point on the Peace River in 1539. The conquistadors named the town Punta Gorda, which means "Broad Point" in Spanish. After these landings, the Spanish attempted to colonize the area, but were stopped by the native Calusa Indian tribes. Punta Gorda was eventually settled by the English. In 1885, Colonel Isaac Trabue from Kentucky bought the land from British investors and founded the town of Trabue. The name was not well accepted though and upon incorporation, the town returned to its original Spanish name (Charlotte County Chamber of Commerce 2008). Punta Gorda features three elementary schools, one middle school, one high school, and one hospital. The Charlotte County Chamber of Commerce boasts that Punta

Gorda is undergoing major revitalization and beautification efforts. It has also achieved State Historical District status and is emphasizing historic preservation as a priority. The historic atmosphere is enhanced by brick lanes, street lamps, benches, brick planters, flowers, and shade trees (Figure 4.1). Unique shops and restaurants also add to the charm of this historic waterfront town (Charlotte County Chamber of Commerce 2008).

Figure 4.1: Photograph of Downtown Punta Gorda (Punta Gorda Chamber of Commerce 2010)

4.1.1.1 Location

Charlotte County is located in southwest Florida along the Gulf Coast (Figure 4.2). The county is bordered by the Gulf of Mexico, Sarasota County, DeSoto County, Glades County, and Lee County. Charlotte County is 96 miles south of Tampa, 132 miles southwest of Orlando, and 167 miles northwest of Miami. Punta Gorda is located in central Charlotte County along Charlotte Harbor (Figure 4.2) (Florida Netlink 2010).

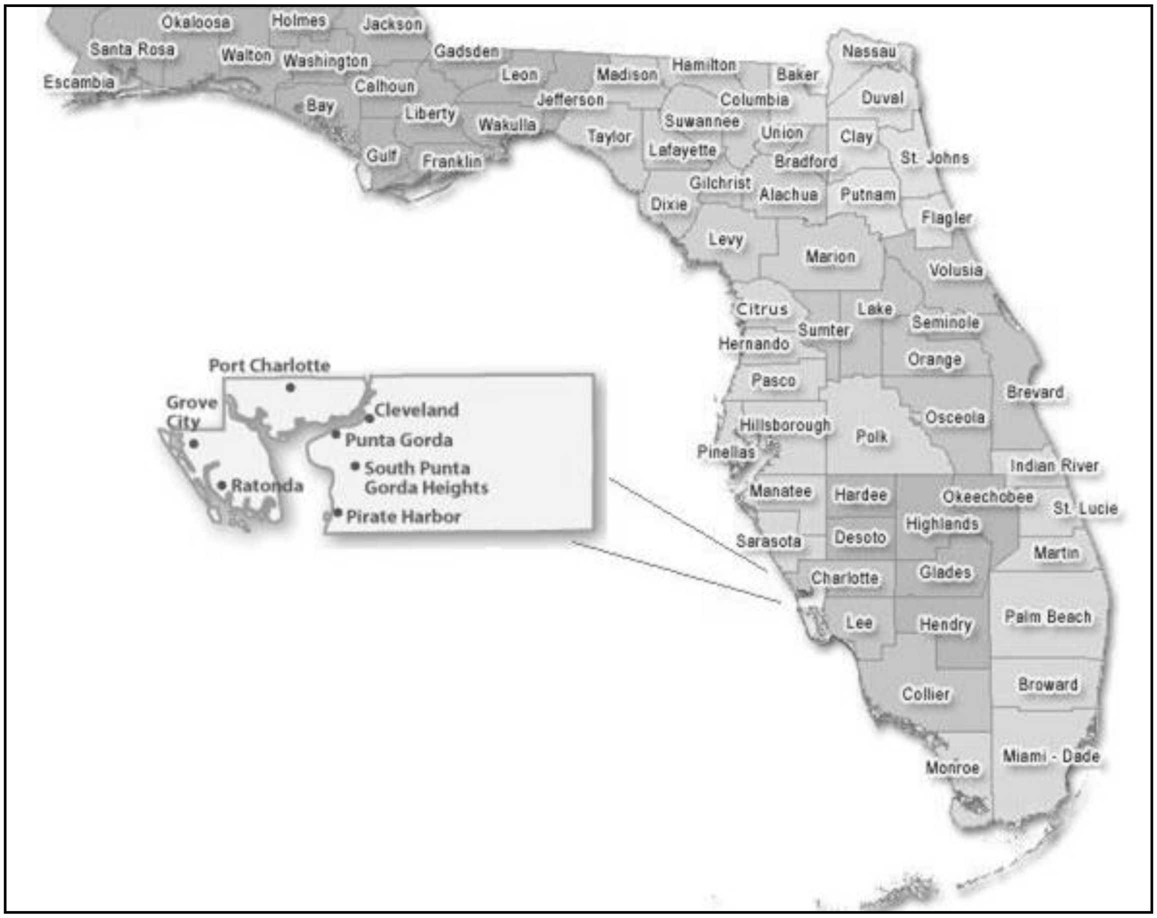


Figure 4.2: Location of Charlotte County and Punta Gorda (Enterprise Florida, Inc. 2010)

4.1.1.2 Climate

Charlotte County features a humid and subtropical climate. It experiences warm temperatures and large amounts of rainfall. A majority of the annual precipitation occurs between the months of June and September. On average, Charlotte County experiences 112 rain days in a year. The average daily low temperature in January is 53°F and the average high daily temperature in July is 91°F. Charlotte County also has prevailing easterly winds coming off the Gulf of Mexico (Enterprise Florida, Inc. 2010).

4.1.1.3 Demographics

According to the 2000 U.S. Census, the State of Florida has the second oldest population in the country with a median age of 38.7 years. The median age in Charlotte County is 54.8 years, so it has quite an old population. Punta Gorda has an even older population with a median age of 63.6 years. Figure 4.3 provides a breakdown of the population in Punta Gorda, Charlotte County, and the state of Florida by age. In Punta Gorda, 58% of the population is 60 years old and over (U.S. Census Bureau 2000).

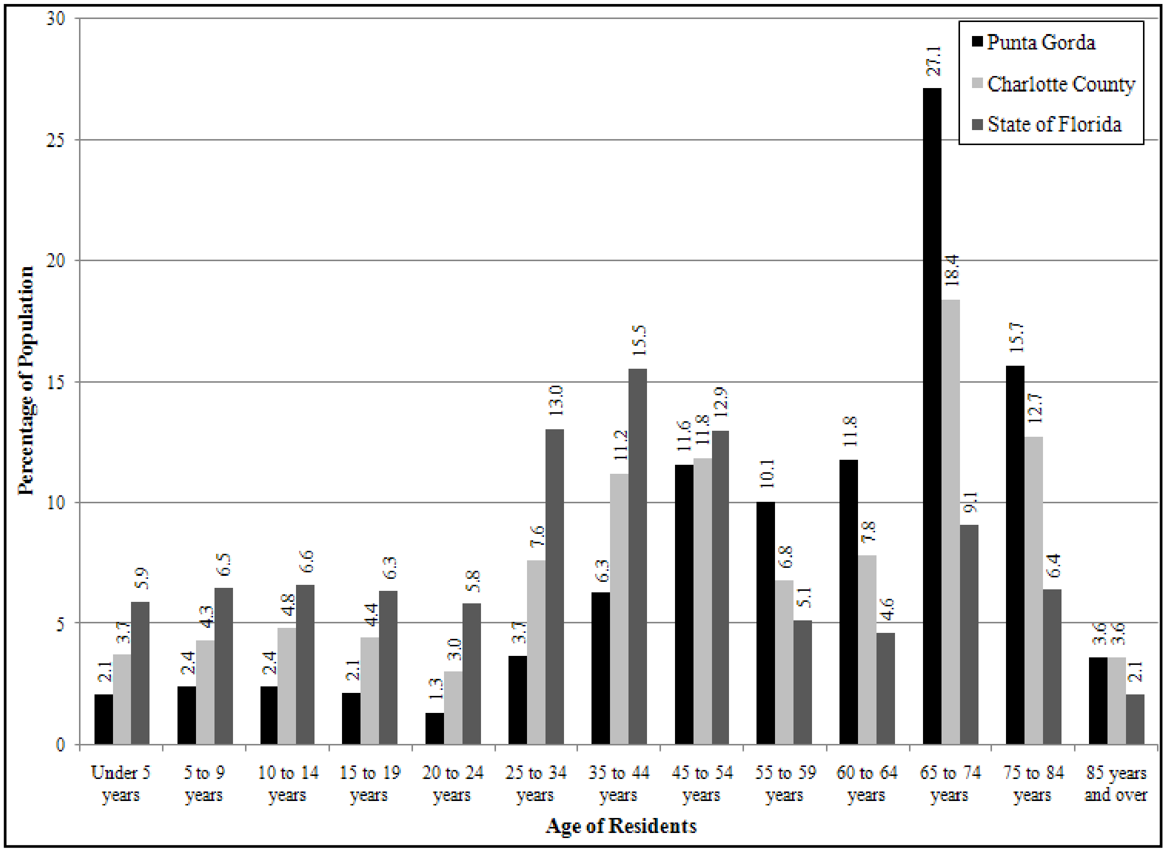


Figure 4.3: Breakdown of Population by Age

The majority of the population in Charlotte County is comprised of Caucasian citizens. Figure 4.4 shows a breakdown of the most common races in Punta Gorda, Charlotte County, and the state of Florida. The chart shows that the three most common races in both Punta Gorda and Charlotte County are Caucasians, followed by African Americans, and then Hispanics. The Caucasians account for approximately 90% of the population in Charlotte County and almost 95% in Punta Gorda. In the state of Florida Caucasians are still the majority, but represent only 67% of the total population (U.S. Census Bureau 2000).

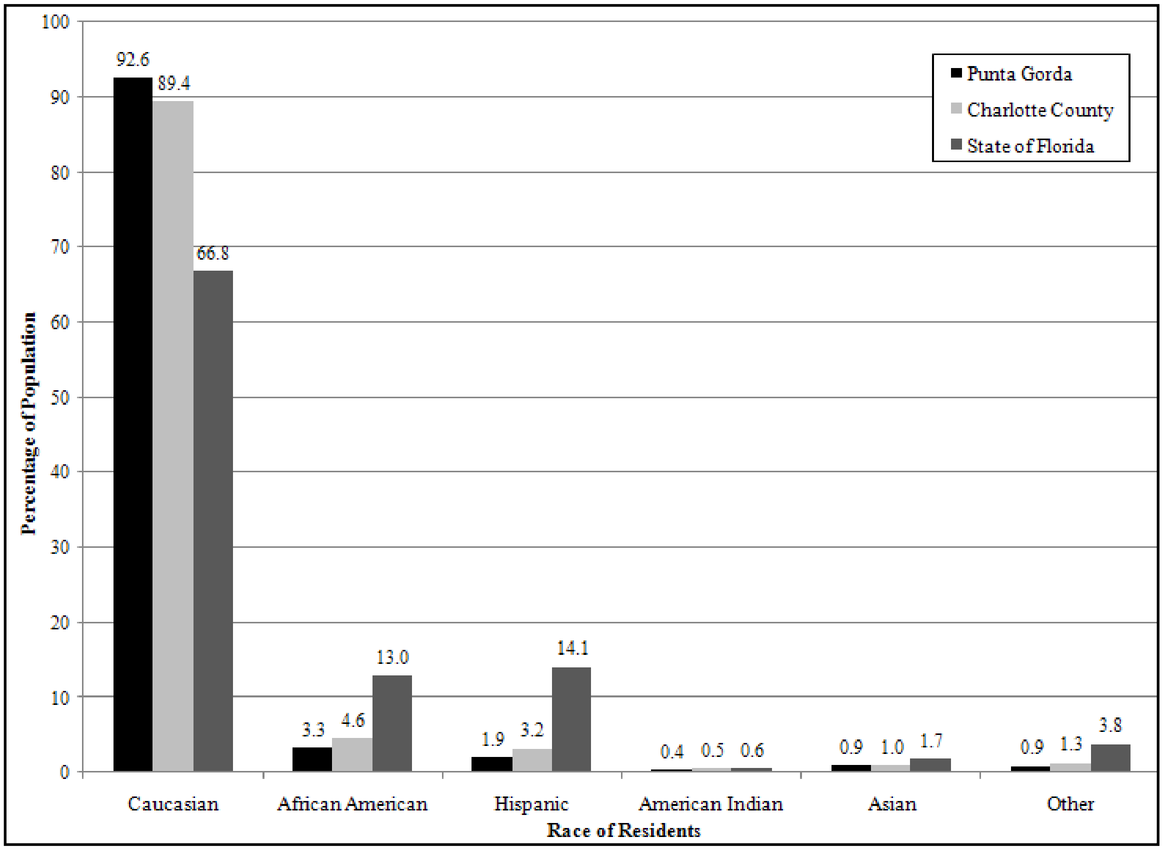


Figure 4.4: Breakdown of Population by Race

The majority of the population speaks English at home. Figure 4.5 below shows a breakdown of the most common languages spoken at home in Punta Gorda, Charlotte County, and the state of Florida. The table shows that over 90% of the population in Punta Gorda and Charlotte County speak English at home. In Charlotte County, Spanish is spoken in almost 3% of homes and the other Indo-European languages combine for less than 5% of the population (U.S. Census Bureau 2000).

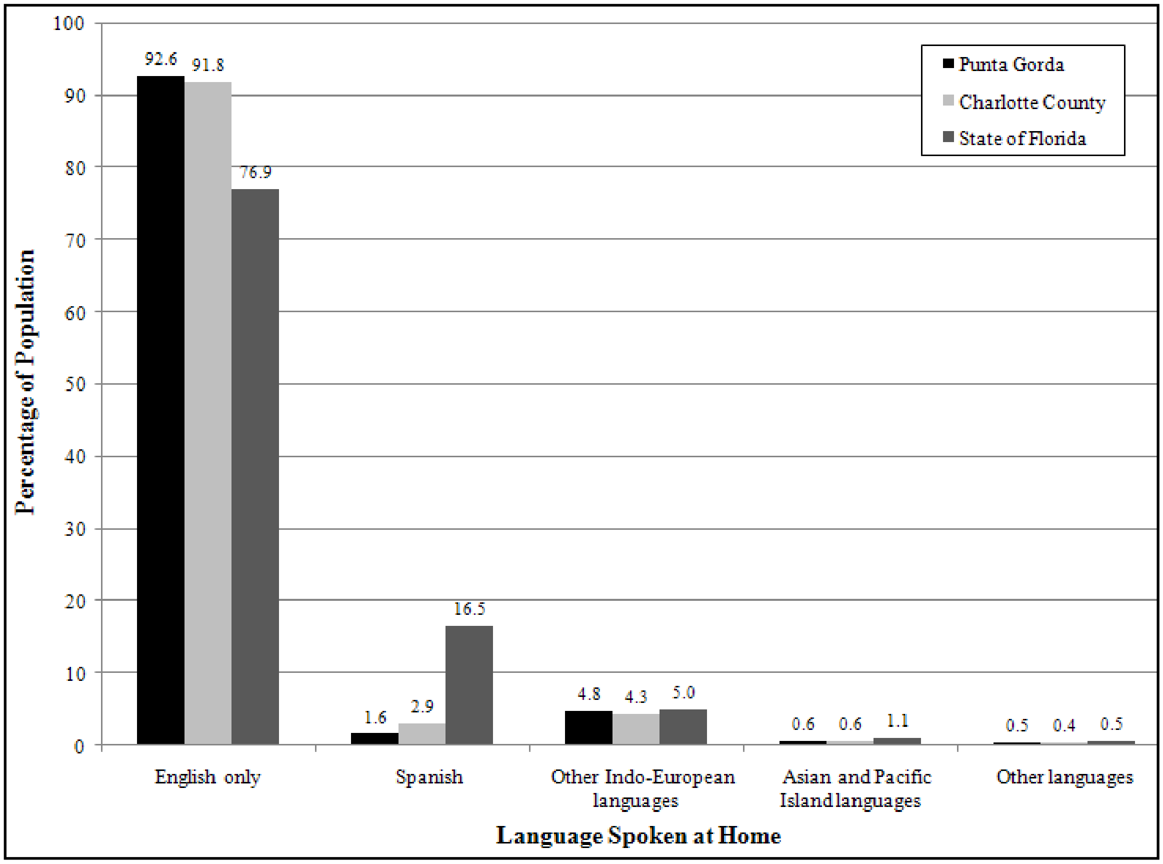


Figure 4.5: Breakdown of Population by Language Spoken at Home

The majority of the population in Punta Gorda, Charlotte County, and the state of Florida were reported as married in the 2000 U.S. Census. Figure 4.6 provides a breakdown of the marital status of the populations. The chart shows that over half of the population in Charlotte County is married and almost 75% of Punta Gorda's population is married. Those who have never been married make up the second highest percentage of population in Charlotte County. In Punta Gorda, the second highest percentage is comprised of widows, which is consistent with the trend of an older population (U.S. Census Bureau 2000).

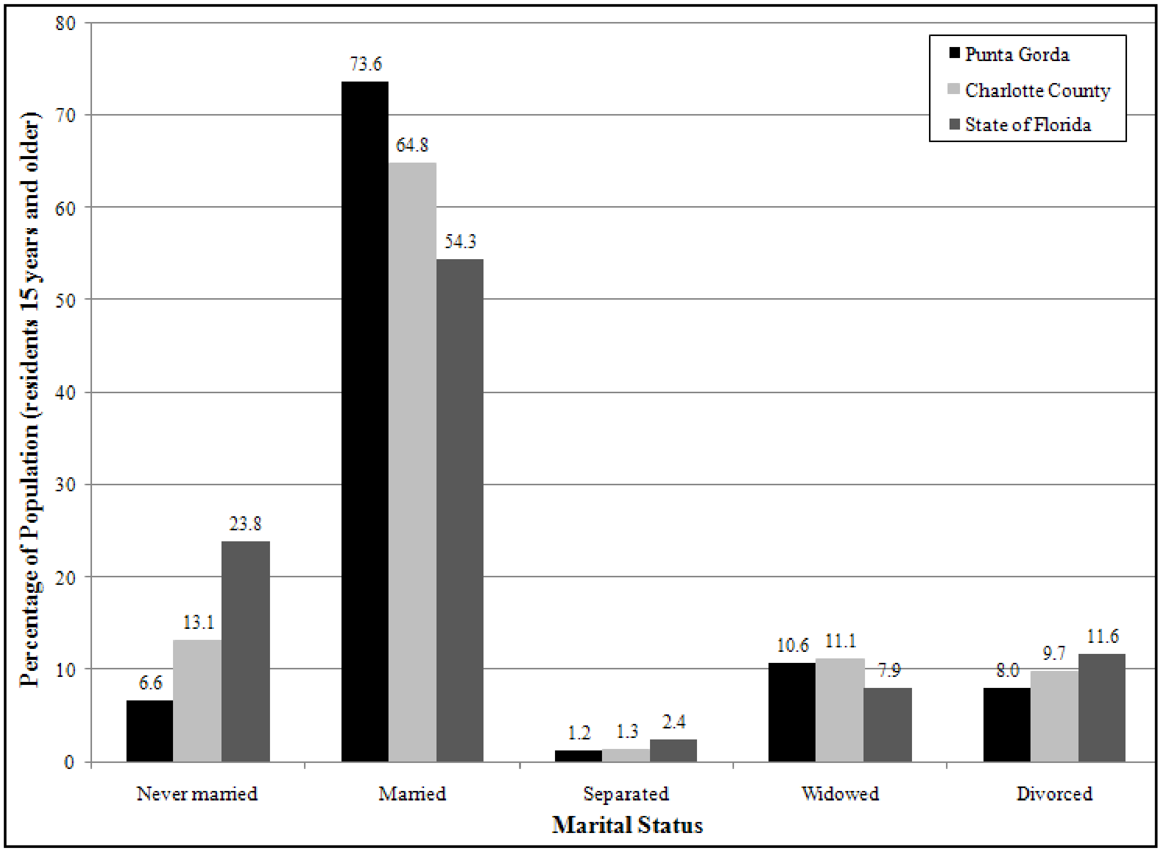


Figure 4.6: Breakdown of Population by Marital Status

The U.S. Census shows that over 80% of the population in Charlotte County has a high school diploma or higher degree. In Punta Gorda, approximately 90% of the population has graduated high school or some level of higher education. Figure 4.7 provides a breakdown of the levels of educational attainment in Punta Gorda, Charlotte

County, and the state of Florida. In Charlotte County, 23.5% of the population has earned some form of college degree. In Punta Gorda, 32.2% of the population has earned a Bachelor's degree or higher (U.S. Census Bureau 2000).

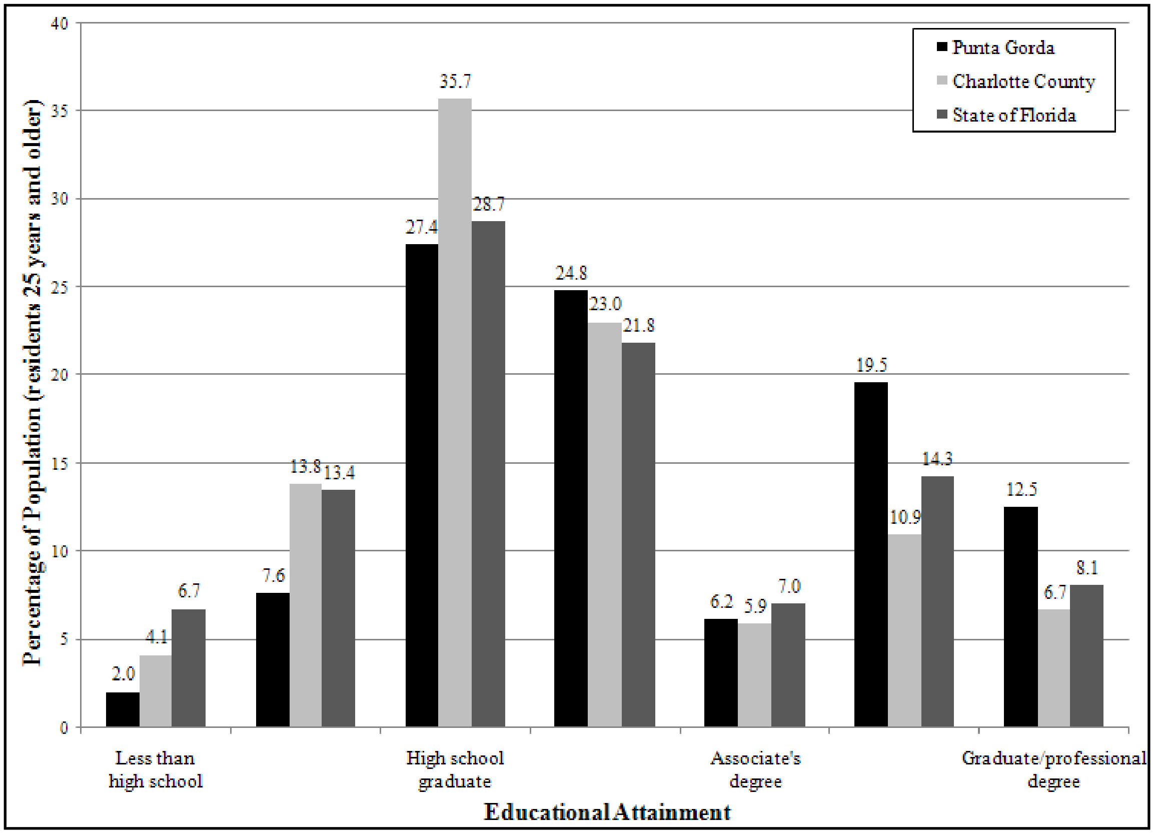


Figure 4.7: Breakdown of Population by Educational Attainment

In summary, the 2000 Census data shows that Punta Gorda is a very Caucasian, older, and well-educated community when compared to Charlotte County and, especially, to the state of Florida. Over half the residents (58%) in Punta Gorda are 60 or older and almost 95% are Caucasian. Less than 10% of the residents did not earn a high school diploma and over 38% have earned at least some level of college degree (U.S. Census Bureau 2000).

4.1.1.4 Economy

According to the Office of Economic and Demographic Research, the most common industries for workers in Charlotte County in 2007 were (Figure 4.8), in order: trade, transportation, and utilities (23%); education and health services (18%); and leisure and hospitality (12%) (Florida Legislature 2007).

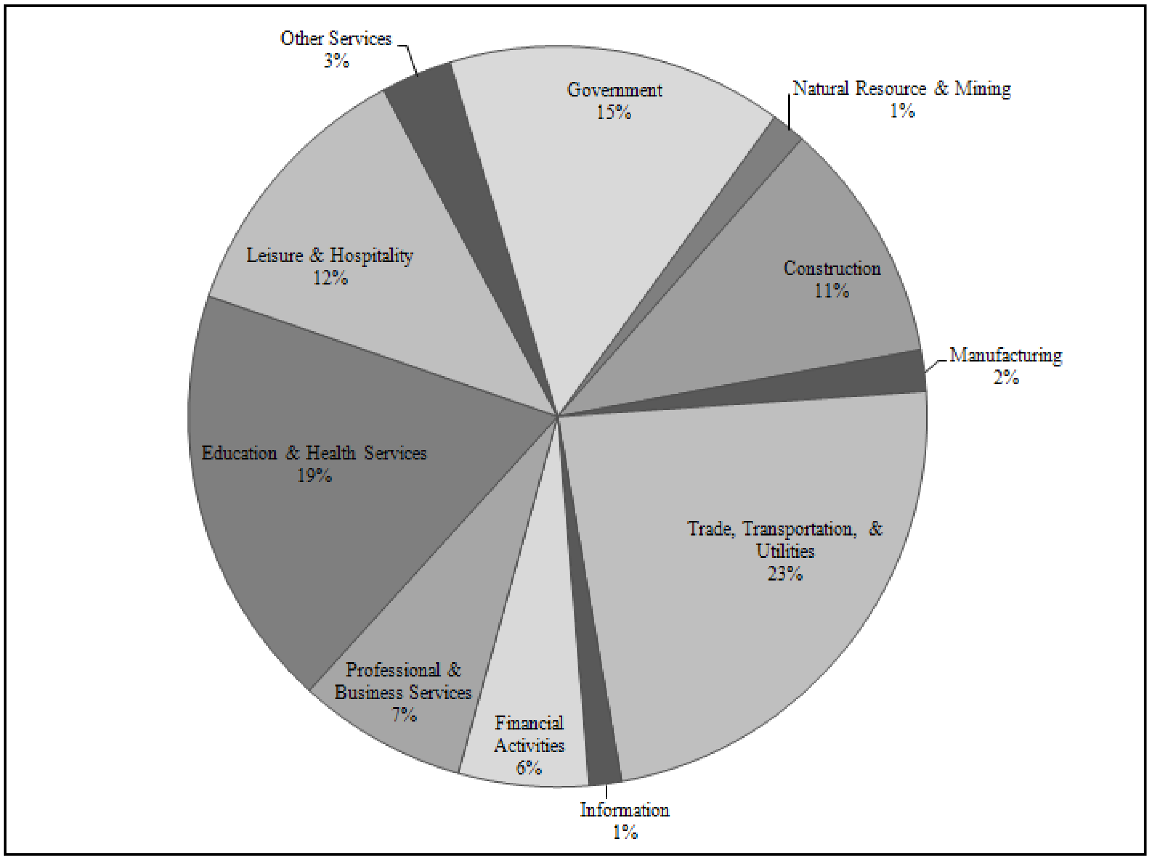
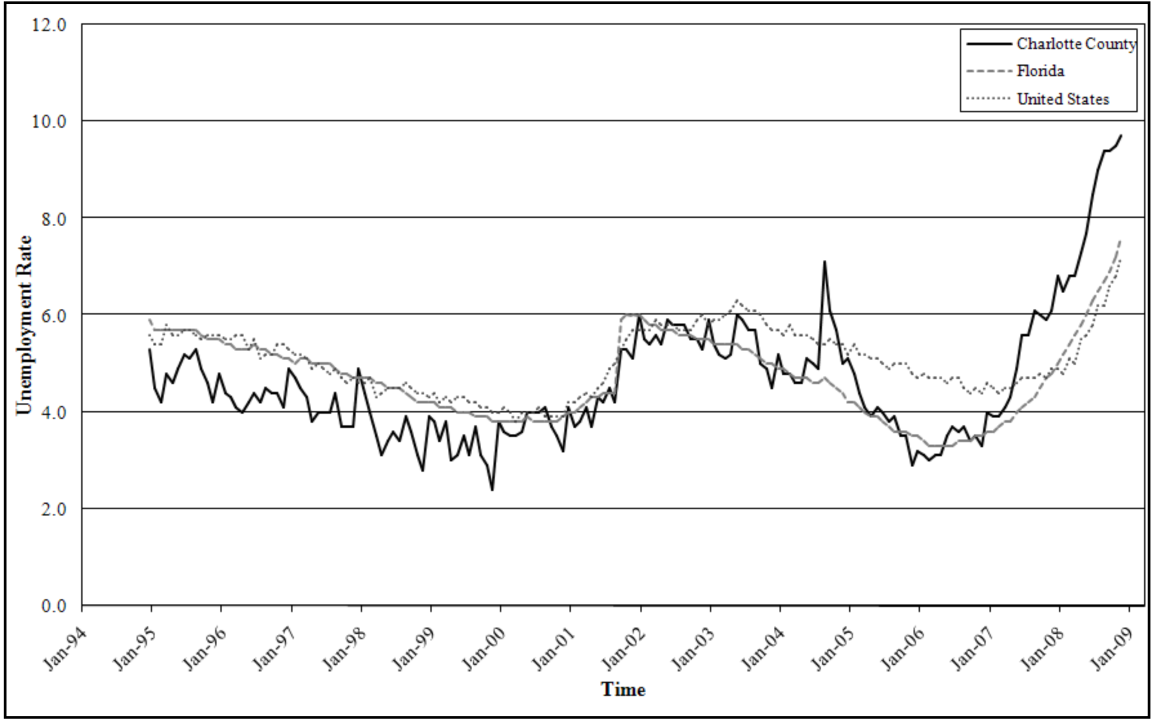


Figure 4.8: Breakdown of Labor Force by Industry

According to the U.S. Department of Labor, the average unemployment rate in Charlotte County between 1995 and 2008 was 4.6%. This rate is very similar to the average unemployment rate of 4.7% for the state of Florida and slightly below the rate of 5.1% for the United States (U.S. Bureau of Labor Statistics 2009). Figure 4.9, shows the monthly unemployment rates for Charlotte County, the state of Florida, and the United States from January 1995 through December 2008. The unemployment rates for Charlotte County, the state of Florida, and the United States appear to follow similar trends. Although, the unemployment rate in Charlotte County does fluctuate more throughout the year due to the smaller sample size. Charlotte County also shows a spike in the unemployment rate from mid-2004 through 2005 during the recovery from Hurricane Charley. The rise in unemployment for all areas at the right side of the chart is a reflection of the current recession, which officially began in December 2007 (U.S. Bureau of Labor Statistics 2009).

Figure 4.9: Unemployment Rates from January 1995 through December 2008



Based on income levels provided by the 2000 U.S. Census, Punta Gorda was relatively well off in 1999 (Figure 4.10). In Punta Gorda, the average per capita income in 1999 was $32,460, almost 50% higher than Charlotte County ($21,806), the state of Florida ($21,557), and the United States ($21,587) (U.S. Census Bureau 2000).

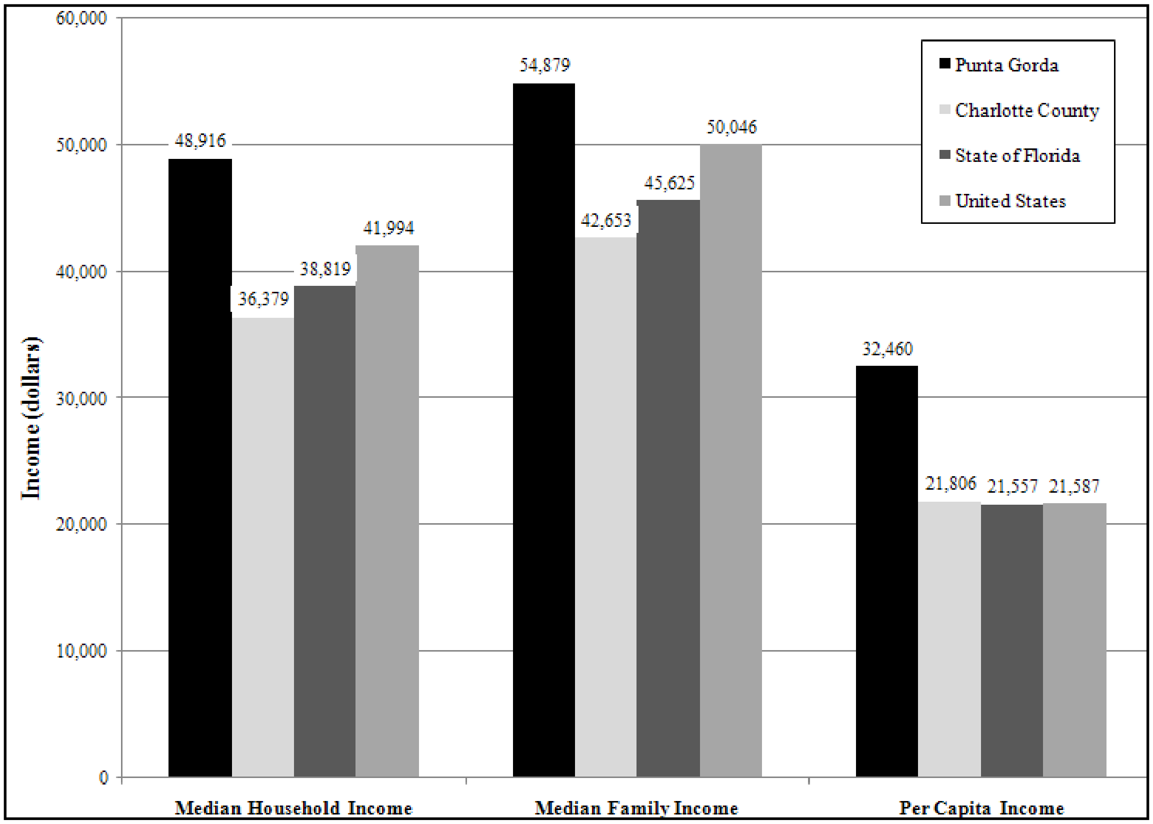


Figure 4.10: Income Levels for Punta Gorda, Charlotte County, Florida, and U.S.

4.1.2 Hurricane Charley

According to the Tropical Cyclone Report produced by the National Hurricane Center, Hurricane Charley began as a tropical wave off the western coast of Africa on August 4, 2004 (Pasch et al. 2005). It formed a tropical depression on August 9 and strengthened to Tropical Storm Charley on August 10 in the Caribbean Sea (Figure 4.11).

The storm reached hurricane strength on August 11 near Jamaica. On August 12, Charley became a Category 2 hurricane near the Grand Cayman Islands. Hurricane Charley strengthened to a Category 3 just before hitting the south coast of western Cuba at 0030 Eastern Daylight Time (EDT) on Friday, August 13, 2004 with maximum winds of 120 mph. By 0200 EDT, Hurricane Charley emerged from the north coast of Cuba and slightly weakened to a Category 2 over the lower Straits of Florida. It turned northward around 0800 EDT and passed over the Dry Tortugas with maximum winds of 108 miles per hour. Hurricane Charley then came under the influence of an unseasonably strong mid-tropospheric trough which caused it to intensify and turn north-northeastward. By 1000 EDT, the Hurricane had strengthened to 125 mph winds and was headed to the southwest coast of Florida. It strengthened to 142 mph winds by 1300 EDT and became a Category 4 hurricane. Moving north-northeastward at 20 mph with sustained winds near 150 mph, Hurricane Charley made landfall on the southwest coast of Florida around 1545 EDT just north of Captiva Island. The eye of the Category 4 hurricane passed over Punta Gorda, Florida around 1645 EDT and continued across the central Florida Peninsula leaving a trail of destruction. The interactions with land caused Hurricane Charley to lose strength and it moved off the northeast coast of Florida around 2430 EDT with maximum sustained winds of 80 miles per hour. On August 14, 2004, Hurricane Charley came ashore again near Cape Romain, South Carolina around 1000 EDT as a Category 1 hurricane with maximum winds still at 80 mph. Charley made one more landfall near Myrtle Beach, South Carolina around 1200 EDT with winds down to 75 mph. Hurricane Charley then weakened to a tropical storm off the coast of North

Carolina. By 2000 EDT on August 14, the tropical storm became embedded in a frontal zone. This interaction created an extra-tropical storm that moved back out into the Atlantic Ocean (Pasch et al. 2005).

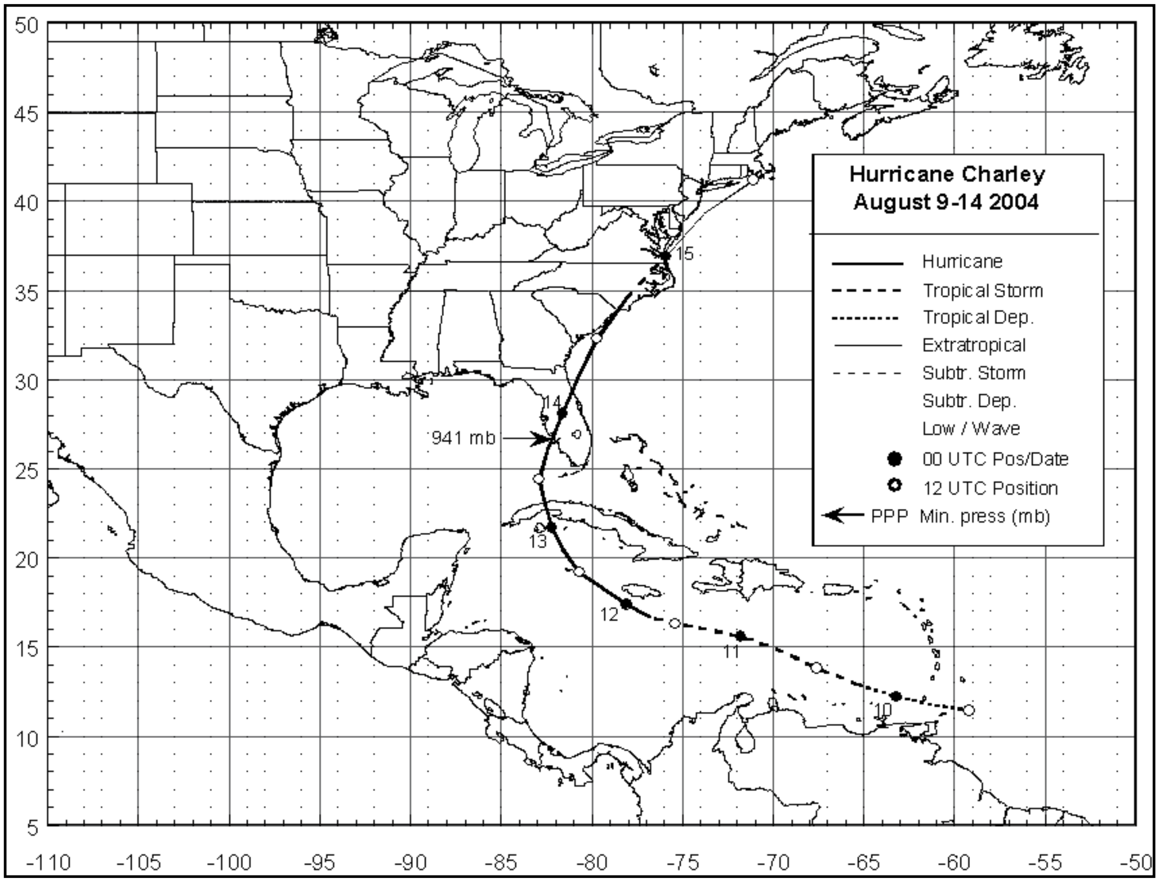


Figure 4.11: Track Positions for Hurricane Charley (Pasch et al. 2005)

Hurricane Charley struck Punta Gorda at approximately 1645 EDT on Friday, August 13, 2004. The eye of the Category 4 hurricane passed directly over Punta Gorda and continued across the Florida Peninsula at approximately 20 mph. The maximum sustained winds were 150 mph as Hurricane Charley devastated Punta Gorda. Hurricane Charley was a very strong storm, but did not cover a large geographic area when it made landfall. The maximum winds and storm surge were located only 6 to 7 miles from the center of the storm. This helped to minimize the extent and amplitude of the storm surge, which did not exceed 7 feet. Rainfall amounts were also modest with less than 8 inches falling. The violent winds though, did enough damage to make Hurricane Charley the second costliest U.S. hurricane at that time, with damage estimated to be around $15 billion (Pasch et al. 2005). Hurricane Charley also produced 16 tornadoes throughout Florida, North Carolina, and Virginia, including one in Port Charlotte, Florida. The hurricane was directly responsible for 10 deaths in the United States as well as 4 deaths in Cuba and 1 in Jamaica (National Hurricane Center 2005). Hurricane Charley was especially devastating to Punta Gorda, Florida because its interaction with the mid-tropospheric trough caused its projected path to alter just prior to landfall. Residents of the Punta Gorda area expected Hurricane Charley would make landfall near Tampa, Florida as a Category 2 hurricane. Instead, the trough caused Hurricane Charley to increase to a Category 4 hurricane and its path moved it directly up the Charlotte Harbor to Punta Gorda (Pasch et al. 2005).

When considering recovery, it is important to note that Hurricane Charley was the first of four major storms to make landfall in or near Florida during the 2004 hurricane season (Figure 4.12, Table 4.1). The second 2004 storm, Hurricane Frances, made landfall on the east coast of Florida near Stuart, Florida just after midnight on September 5, 2004. Hurricane Frances made landfall as a Category 2 hurricane with 105 mile per hour maximum winds and weakened as it crossed the Florida Peninsula. Hurricane Ivan was the third storm of the 2004 hurricane season. Ivan made landfall near Gulf Shores, Alabama on September 16, 2004 as a Category 3 storm with maximum winds near 120 miles per hour. The last major storm of the 2004 hurricane season was Hurricane Jeanne. The category 3 storm with 120 miles per hour winds made landfall on September 26, 2004 near Stuart, Florida at almost the exact location where Frances had struck 3 weeks earlier. Hurricane Jeanne weakened as it moved across the Florida Peninsula and became a tropical storm near Tampa, Florida (National Hurricane Center 2005).

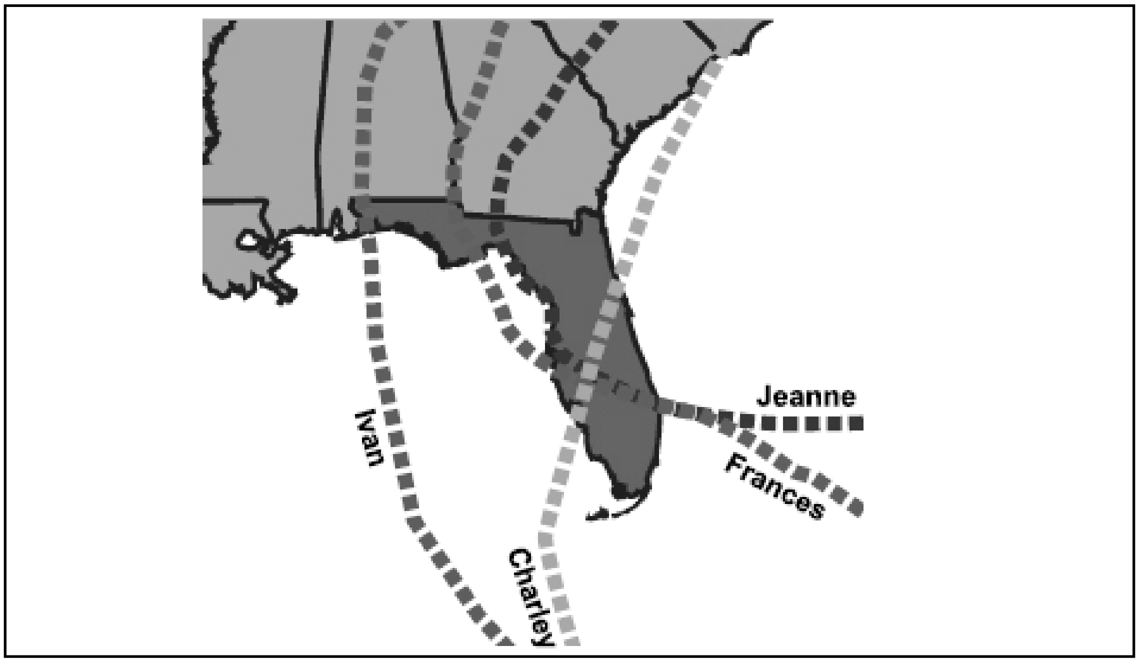


Figure 4.12: Tracks of Major 2004 Hurricanes (Jacobitz 2005)

Table 4.1 provides information about the four major 2004 hurricanes including their date and location of landfall. It also shows their hurricane category and maximum sustained winds at landfall.

Table 4.1: Information about Hurricane Landfalls for 2004 Hurricane Season

Hurricane Name	Date	Landfall Location	Category	Max. Sustained Winds (mph)
Charley	August 13	Punta Gorda, Florida	4	150
Frances	September 5	Stuart, Florida	2	105
Ivan	September 16	Gulf Shores, Alabama	3	120
Jeanne	September 26	Stuart, Florida	3	120

4.2 Data Collection

The collection of data related to the damage and recovery of Punta Gorda, Florida following Hurricane Charley proceeded with two goals in mind: (1) to use the data directly in applying the prototype housing measure, and (2) to demonstrate the amount, type, and quality of data available for a typical event to which the measure might be applied, and therefore, that the measure could reasonably expect to utilize. With these goals, as much data as possible was collected from multiple sources on all aspects of community recovery (not just housing). The data used for the Hurricane Charley/Punta Gorda case study include: (1) summary reports and data, (2) raw data, (3) interviews, (4) memory wall, and (5) remote sensing and aerial imagery. These data sources are described below. The remainder of this chapter focuses on damage to and the recovery of the housing sector only, not for example, the economy, environment, or health care.

Summary Reports and Data include available analyses and data in summary form from the agencies that conducted post-Hurricane Charley investigations, the U.S. Census, the Department of Labor, and other agencies.

Raw Data refers to datasets, such as damage assessments of individual buildings and collections of individual building permits that are disaggregated to the extent where they are highly amenable to further analysis as part of this research project.

Interviews can also be a useful data source. Members of the larger NSF project team conducted two field deployments to Punta Gorda in Charlotte County. One deployment in August 2009 and another in January 2010, during which they met with key participants in the recovery process, such as building department officials, and city and county officials. Table 4.2 provides more details about the field deployment meetings, including a list of the agencies with which the team met.

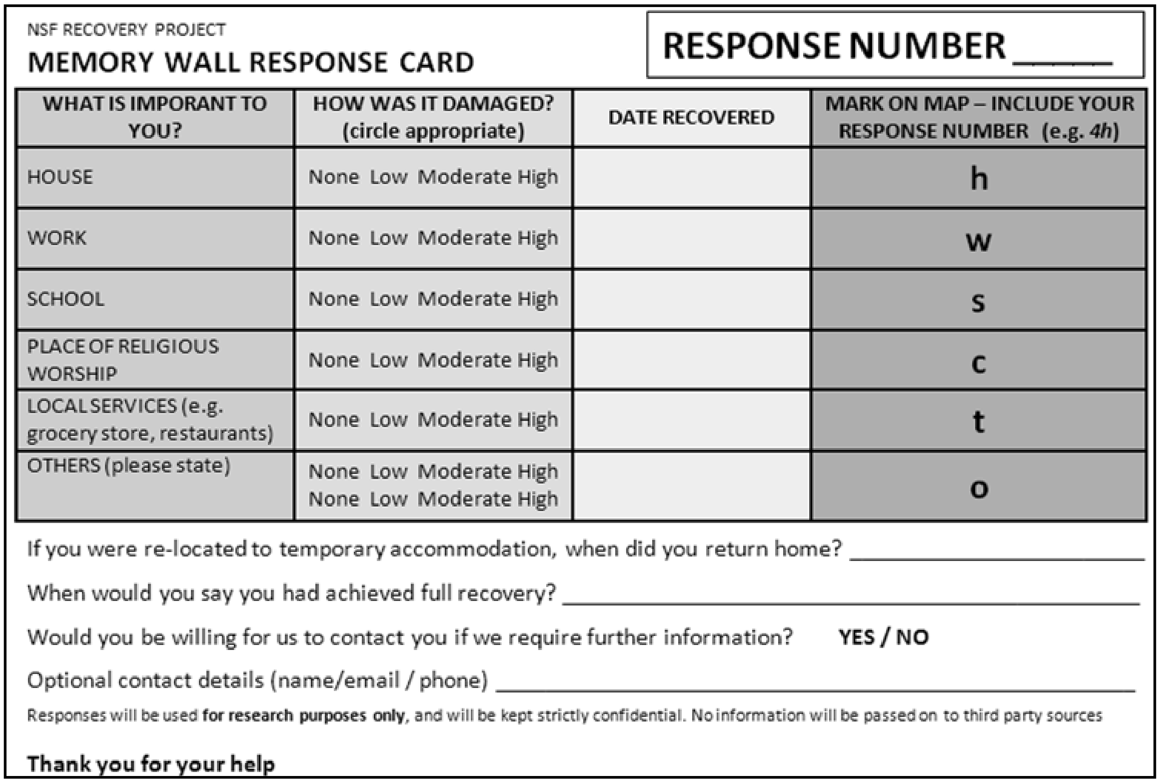
Table 4.2: Meeting Details from August 2009 and January 2010 Punta Gorda Field Deployments

Agency	Contacts at Meeting	Meeting Date
City of Punta Gorda	Director of Growth Management Assistant City Manager	August 13, 2009
Charlotte County Public Schools	Superintendent	August 14, 2009
Punta Gorda Public Works	Director Executive Assistant Facilities Supervisor Right-of-Way Supervisor Canal Maintenance Supervisor Sanitation Supervisor Parks and Grounds Crew Chief	January 5, 2010
Charlotte County Natural Resources Division	Natural Resources Manager Marine Extension Agent	January 6, 2010
Charlotte County Building Construction Services	Deputy Building Official	January 6, 2010
Charlotte County Economic Development Office	Business Development Specialist Research Analyst	January 6, 2010
Punta Gorda Building Department	Plans Examiner	January 7, 2010
Charlotte County GIS Department	IS/GIS Coordinator	January 7, 2010
Charlotte County Public Schools	Superintendent Assistant Superintendent Director of Maintenance Chief Financial Officer	January 7, 2010
Eagle Point Mobile Home Park	Site Manager Resident	January 8, 2010
Park Hill Mobile Home Park	Site Manager Residents	January 8, 2010
Maple Leaf Golf and Country Club	General Manager	January 8, 2010

The August 2009 field deployment was scheduled to coincide with a public event held on the 5th anniversary of Hurricane Charley. "Punta Gorda's Five Year Xtreme Makeover Celebration" was held in Punta Gorda, Florida on August 15, 2009 to celebrate the community's achievements since the disaster. Team members organized a booth at the event to solicit input from the public. At the booth they presented a "memory wall," to invite interested passersby to share their experiences. The "memory wall" was a poster displaying a 2008 aerial photograph of Punta Gorda and surrounding areas. Figure 4.13 shows the "memory wall" zoomed to the Punta Gorda portion of the map.

Figure 4.13: Memory Wall from Punta Gorda's Five Year Xtreme Makeover Celebration

The team members also supplied response cards (Figure 4.14) featuring a short questionnaire where community members could share information about their households, schools, places of business, and other significant locations. Participants provided information related to the timing and extent of recovery in each of these locations. Each response card had a unique response number so participants could mark their corresponding locations on the "memory wall" poster.



NSF RECOVERY PROJECT

MEMORY WALL RESPONSE CARD

RESPONSE NUMBER _____

WHAT IS IMPORANT TO YOU?	HOW WAS IT DAMAGED? (circle appropriate)	DATE RECOVERED	MARK ON MAP – INCLUDE YOUR RESPONSE NUMBER (e.g. *4h*)
HOUSE	None Low Moderate High		h
WORK	None Low Moderate High		w
SCHOOL	None Low Moderate High		s
PLACE OF RELIGIOUS WORSHIP	None Low Moderate High		c
LOCAL SERVICES (e.g. grocery store, restaurants)	None Low Moderate High		t
OTHERS (please state)	None Low Moderate High None Low Moderate High		o

If you were re-located to temporary accommodation, when did you return home? ______________________

When would you say you had achieved full recovery? ____

Would you be willing for us to contact you if we require further information? **YES / NO**

Optional contact details (name/email / phone) ____

Responses will be used **for research purposes only**, and will be kept strictly confidential. No information will be passed on to third party sources

Thank you for your help

Figure 4.14: Response Cards from Punta Gorda's Five Year Xtreme Makeover Celebration

The final types of data sources used in the Punta Gorda case study were remote sensing and aerial imagery analyses from the ImageCat, Inc. team members. ImageCat, Inc. collected images of Punta Gorda at seven different time steps. Quickbird satellite images were collected on March 23, 2004 (four months before Hurricane Charley), August 14, 2004 (one day after Hurricane Charley), and August 19, 2004 (six days after Hurricane Charley). Aerial images were supplied by Southwest Florida Water Management District for February 2004 (six months before Hurricane Charley), January 2005 (five months after Hurricane Charley), January 2006 (17 months after Hurricane Charley), January 2007 (29 months after Hurricane Charley), and January 2008 (41 months after Hurricane Charley). The ImageCat, Inc. team members superimposed these images with 154 equal grids of 500 square meters (Figure 4.15) to simplify the analysis.

Figure 4.15: Analysis Grid Superimposed on Punta Gorda Image for Remote Sensing Analysis

ImageCat, Inc. team members looked at each grid separately and performed a visual assessment on each building within that grid. This assessment was performed at each of the eight time steps. For buildings that appeared to change (e.g., built a different size, moved to a new location on property) after Hurricane Charley, an additional polygon analysis was conducted. The polygon analysis captured changes in a building by drawing its footprint on both the 2004 and 2008 aerial images. Overall, the remote sensing analysis performed by the ImageCat, Inc. team members is able to show the status of buildings prior to the disaster, the initial damage to those building, and the status of the buildings at different time steps during the recovery process.

4.3 Housing Sector Background

The 2000 U.S. Census provides a reasonable picture of the housing sector in Punta Gorda and Charlotte County before Hurricane Charley. In 2000, Punta Gorda had a population of 14,433 making up 8,907 households. There were 8,944 housing units, 80.4% of which were occupied. Of the occupied housing units, 86% were owner-occupied, a somewhat higher percentage than the state overall (70%). The homeowner and rental vacancy rates were 1.9% and 13.5%, respectively. About 67% of the housing units were single-family, 24% were multi-family (two or more units in structure), and 8% were mobile homes. The housing is relatively new in Punta Gorda, with 87% of structures built after 1970 and 93% of households having moved into their unit since 1980. Only small percentages of occupied housing units lack a vehicle (4.5%), plumbing facilities (0.1%), kitchen facilities (0.4%), or telephone service (0.8%). The median value of owner-occupied housing units was $204,400 and the median gross rent for renter-occupied units was $569 (U.S. Census Bureau 2000).

To better understand the damage sustained in Hurricane Charley, it would be useful to know the structural features typical of the housing as well. Unfortunately, that type of data is not systematically collected. However, a few available studies offer some indication of the construction typical in the 2000 housing stock in Punta Gorda. The Florida Public Hurricane Loss Projection Model estimates that in Central Florida, where Punta Gorda is located, 42% of structures are one-story buildings with concrete block exterior walls and a shingle or tile gable roof, 22% are one-story buildings with concrete block exterior walls and a shingle or tile hip roof, and 12% are one-story wood frame buildings with a shingle or tile gable roof. The other 24% of houses fall into other small categories (FCHLPM 2007).

As part of a post-Hurricane Charley damage survey done at the University of Florida, Gurley (2006) conducted detailed surveys of 126 single-family homes in Charlotte County. Of these 126 houses, 86 had Punta Gorda addresses. The Gurley (2006) data shows that 74% of the Punta Gorda houses had hip roofs, while 5% had gable roofs, and 18% had some combination of these roof types. Plywood sheathing was used on 79% of the roofs and the vast majority had either shingle (54%) or tile (32%) roof covering.

Based on a random sample of 121 homes in Burnt Store Isles, a subdivision of residential homes in southern Punta Gorda, PartnerRe (2004) estimated about 80% hip roofs and 20% gable roofs; all tile roofs; and about 82% plywood roof sheathing.

A few key dates are important to understanding the state of the housing stock at the time of Hurricane Charley: 1965, 1995, and 2001 (PartnerRe 2004, IBHS 2004).

From about 1950 to 1965 a transition occurred in home construction in southern Florida. Before that time, roof decks were primarily made of dimensional lumber or tongue and groove boards and roof trusses or joists were connected to the walls with nails. After that time, roof decks were constructed with plywood or oriented strand board (OSB), and metal connectors were used for roof-to-wall connections (PartnerRe 2004). The first change generally reduced the wind resistance; the latter increased it. Motivated by Hurricane Andrew in 1992, coastal areas of Florida, including Charlotte County, began to use high wind design provisions for residential housing in 1995 (IBHS 2004). At that time, the County adopted the SBCCI's Standard for Hurricane Resistant Construction SSTD-10 (SBCCI 1999). In 2001, the State adopted a statewide building code for the first time, the Florida Building Code (FBC). The 2001 FBC included substantial changes to improve the hurricane performance of new homes (PartnerRe 2004). Requirements for roof cover attachments and materials were improved; wind load provisions became more stringent; and requirements were added so that either internal building pressure must be accounted for explicitly or all openings must be protected with approved shutters. Figure 4.16 provides a breakdown of when houses in Punta Gorda were built to suggest how many houses were built to each of the discussed codes. The data is based on the 2000 U.S. Census and therefore only shows houses built through 2000. According to the Census, only 12% of houses in Punta Gorda were built before 1970 and correspond to the older building codes. The majority (71%) of houses were built between 1970 and 1995 and would relate to designs with plywood or OSB roof decks and metal roof-to-wall connections. In 2000, 12% of houses had been constructed since the SBCCI's Standard for Hurricane Resistant Construction was implemented (U.S. Census Bureau 2000). Houses constructed since the 2000 Census, and not shown in this table, should comply with the 2001 Florida Building Code.

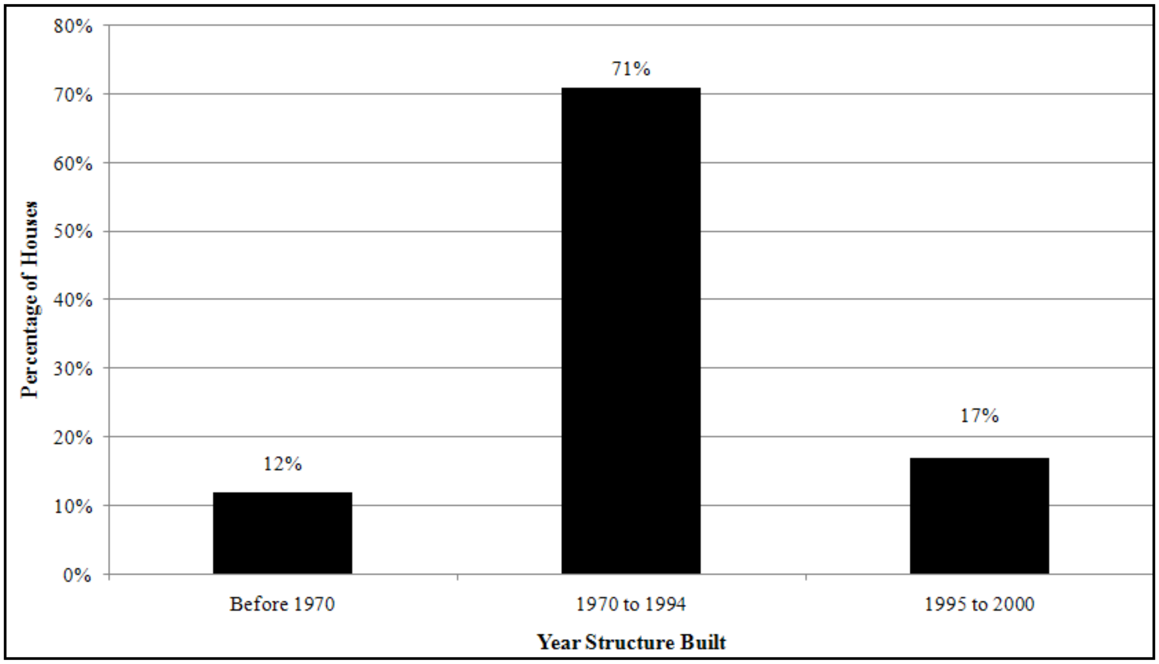


Figure 4.16: Year Punta Gorda Houses were Built Related to Building Codes

In summary, the Loss Projection Model (FCHLPM 2007), University of Florida report (Gurley 2006), and PartnerRe (2004) study provide an overview of the types of housing in Punta Gorda. These three sources suggest that many of the houses in Punta Gorda are one-story buildings with concrete block exterior walls. The data also suggests that the majority of houses have hip or gable roofs with plywood sheathing. The 2000 U.S Census data implies that most of the houses in Punta Gorda were built between 1970 and 1994, meaning they did not comply with the stricter building codes implemented in 1995 and 2001.

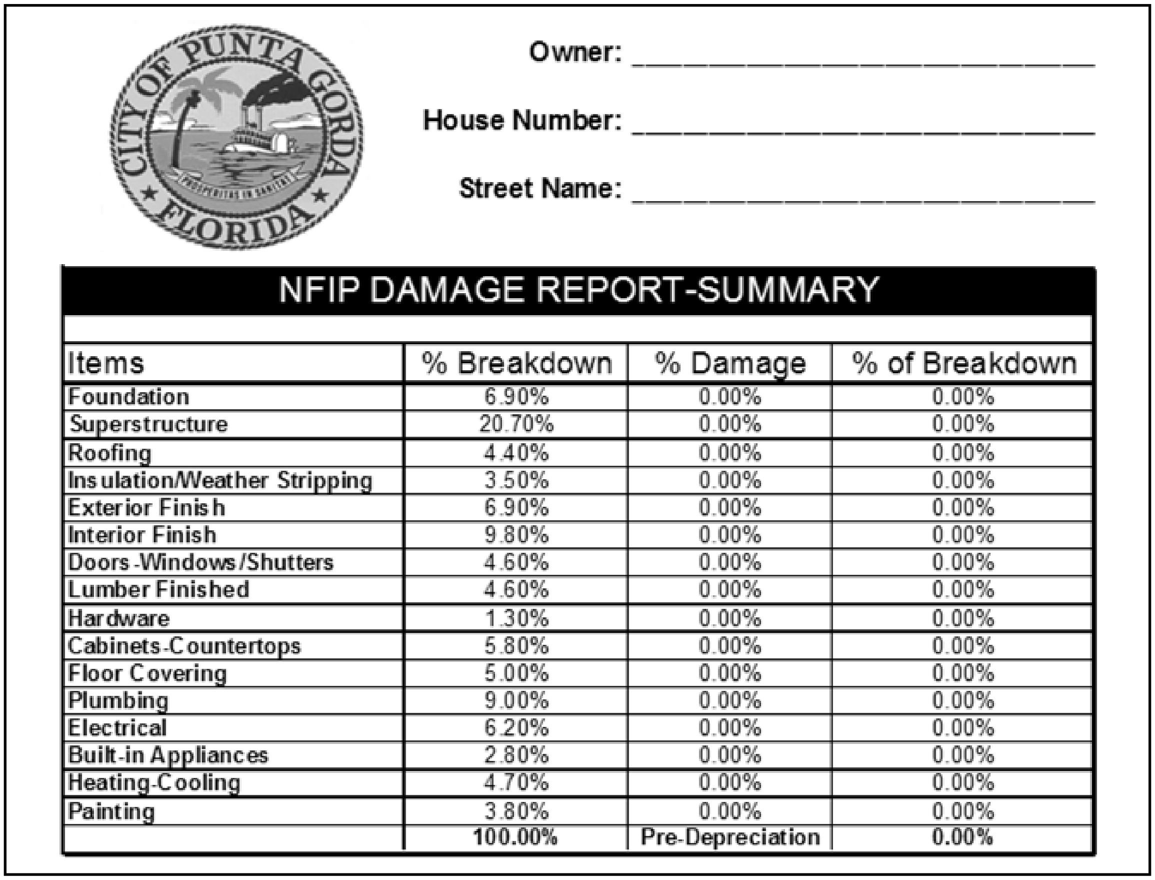
4.4 Damage to Housing

In order to measure the housing recovery process, it is important to first understand the amount of initial building damage caused by the hurricane. Many resources can provide background information about the damage to the housing sector. This section discusses the damage to housing in Punta Gorda after Hurricane Charley and the various resources that were collected to assess that damage. Those resources include damage assessments from the Punta Gorda Building Department (Section 4.4.1) and the University of Florida (Section 4.4.2), remote sensing analysis from ImageCat, Inc. (Section 4.4.3), and additional information from other damage reports (Section 4.4.4). The data from these various sources is then summarized and compared to show the overall trends of housing damage (Section 4.4.5).

4.4.1 Punta Gorda Building Department Damage Assessments

Damage assessments for many houses in Punta Gorda were obtained from the Punta Gorda Building Department. Immediately after Hurricane Charley, the Punta Gorda Building Department performed visual inspections to approximate the overall damage to buildings throughout Punta Gorda. Within 72 hours, the Building Department began performing preliminary damage assessments to comply with FEMA requirements and recorded the amount of damage to each house in terms of repair cost in dollars. Soon after, the Building Department started receiving applications for building permits to address Hurricane Charley damage. The value of the house requesting a permit (based on Property Appraiser data or State Certified Appraisal provided by the property owner) was then compared to the estimated value of the damage. If the cost to repair the damage exceeded 35% of the value of the house, the Punta Gorda Building Department required a thorough damage assessment to determine the actual percentage of damage to the house. These damage assessments were performed by City staff using a FEMA software program called the 'Residential Substantial Damage Estimator (RSDE)' (John Smith, personal communication, January 7, 2010).

The RSDE program determines the percentage of damage to a structure in accordance with the National Flood Insurance Program (NFIP) regulations. The NFIP breaks the house into its components (e.g., foundation, superstructure) and assigns a percent value of building attributable to that component. The percentage of damage to each component is recorded on an RSDE damage inspection worksheet during the field inspection then entered into the RSDE program. The software considers the percentage of damage to each component and calculates the overall percentage of damage to the house. The Punta Gorda Building Department maintained records of these damage assessments for each house in forms (e.g., Figure 4.17) that show the percentage of damage to each component, weight of each component, and overall percentage of damage caused by Hurricane Charley. If the overall percentage of damage to a house was found to be more than 50% the structure was classified as "substantially damaged." In that case, the Building Department had to send a formal letter to the owner instructing them to either demolish the house or improve the entire structure to meet all applicable codes. The Punta Gorda Building Department also conducted RSDE damage assessments at the request of the homeowner (in most cases to comply with that individual's insurance company). These records were also supplied to our team and account for the structures with less than 35% damage.



Owner: ____________________________

House Number: ____________________________

Street Name: ____________________________

NFIP DAMAGE REPORT-SUMMARY

Items	% Breakdown	% Damage	% of Breakdown
Foundation	6.90%	0.00%	0.00%
Superstructure	20.70%	0.00%	0.00%
Roofing	4.40%	0.00%	0.00%
Insulation/Weather Stripping	3.50%	0.00%	0.00%
Exterior Finish	6.90%	0.00%	0.00%
Interior Finish	9.80%	0.00%	0.00%
Doors-Windows/Shutters	4.60%	0.00%	0.00%
Lumber Finished	4.60%	0.00%	0.00%
Hardware	1.30%	0.00%	0.00%
Cabinets-Countertops	5.80%	0.00%	0.00%
Floor Covering	5.00%	0.00%	0.00%
Plumbing	9.00%	0.00%	0.00%
Electrical	6.20%	0.00%	0.00%
Built-in Appliances	2.80%	0.00%	0.00%
Heating-Cooling	4.70%	0.00%	0.00%
Painting	3.80%	0.00%	0.00%
	100.00%	Pre-Depreciation	**0.00%**

Figure 4.17: Example of Building Department Damage Assessment Form

The Punta Gorda Building Department collected 426 damage assessments for buildings after Hurricane Charley. These buildings are not a random sample though, and do not provide a representative overview for the City of Punta Gorda. The damage assessments also include all types of buildings in Punta Gorda and do not focus on just residential structures. The damage assessments for these buildings however, can be used in conjunction with other resources and provide an idea of the most prevalent types of damage caused by Hurricane Charley.

Table 4.3 shows the breakdown of the initial damage to buildings after Hurricane Charley according to the Punta Gorda Building Department. The buildings were divided into five categories based on the percentage of damage: undamaged (0%), minor (greater than 0% to 25%), moderate (greater than 25% to 50%), severe (greater than 50% to 75%), and catastrophic (greater than 75%). These five categories were chosen so the data could later be compared with building data from other sources which were categorized using the HAZUS damage scale shown in the next section (Table 4.5). The HAZUS damage scale also classifies buildings as undamaged, minor, moderate, severe, or catastrophic, but does so using qualitative damage descriptions. It was assumed, for purposes of this analysis, that the damage percentages used to classify the Punta Gorda Building Department damage assessment approximately corresponds with the qualitative levels used in the HAZUS scale.

Of the 426 buildings studied by the Punta Gorda damage assessments, the majority suffered either minor or moderate damage. A total of 24% of the studied houses had greater than 50% damage and required either demolition or improvements to comply with the stricter building codes.

Table 4.3: Initial Damage Assessments from Punta Gorda Building Department

Status	Damage State	Number	Percent
Undamaged	0% damaged	12	3%
Minor	>0% - 25% damaged	164	38%
Moderate	>25% - 50% damaged	146	34%
Severe	>50% - 75% damaged	85	20%
Catastrophic	>75% damaged	19	4%
Total Number of Assessed Houses		**426**	

The next analysis performed using the Punta Gorda Building Department damage assessments was to use a GIS program to determine the locations of buildings. The assessed buildings are shown on the map in Figure 4.18. The buildings are denoted by dots and color-coordinated from white to black to illustrate which damage state they represent. The goal of creating this map was to analyze the damage assessments spatially and determine if a relationship could be found between location and damage level. Looking at only the 426 houses with damage assessments from the Punta Gorda Building Department, no discernable trend was discovered.

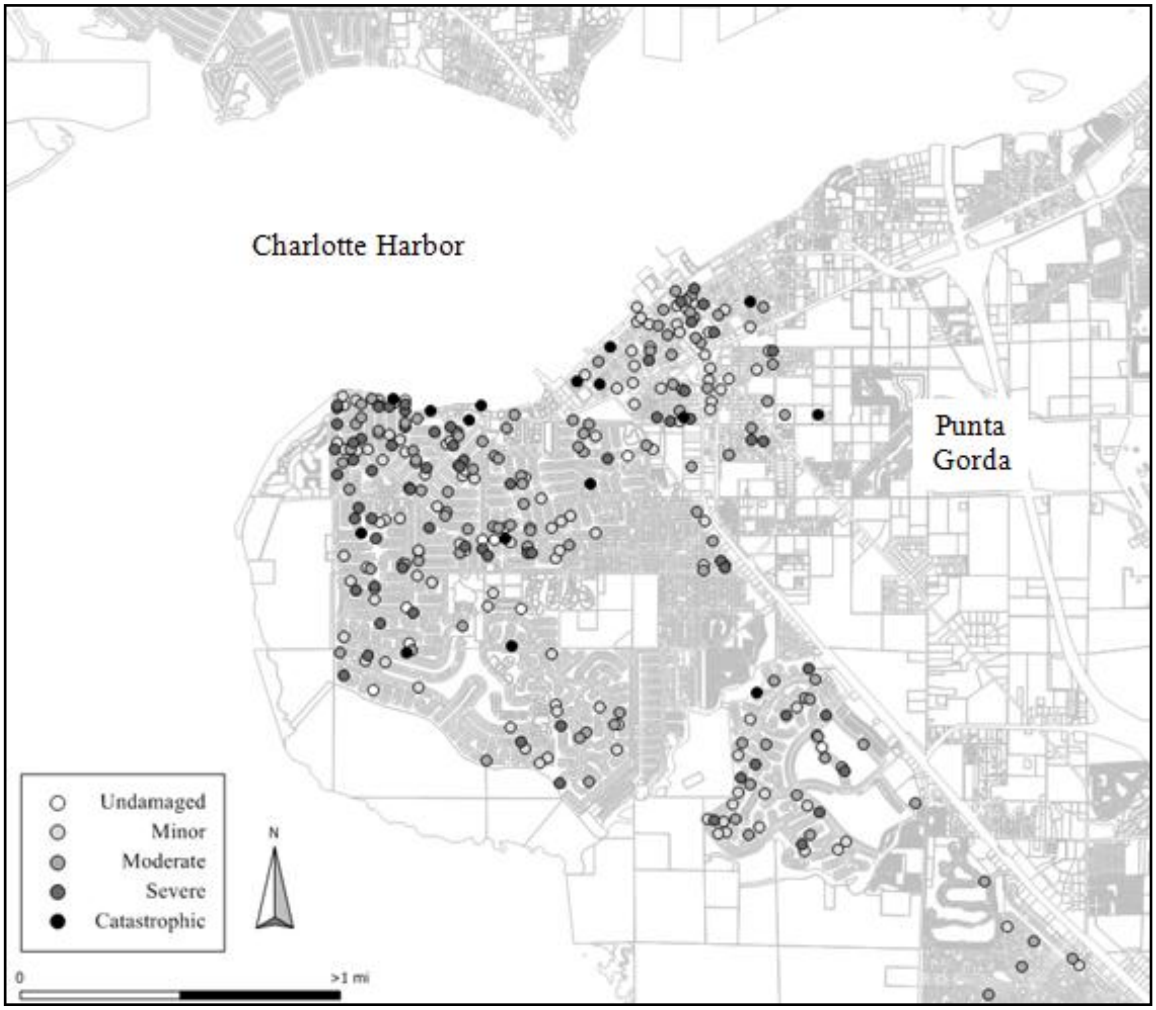


Figure 4.18: Location of Punta Gorda Building Department Damage Assessments in Punta Gorda

The Punta Gorda damage assessments are useful for determining the most frequently damaged building component due to Hurricane Charley. Table 4.4 provides a breakdown of the most common types of damage to the assessed buildings. Of the 426 buildings with Punta Gorda Building Department Damage Assessments, 93% experienced damage to the roof. After roof damage, the most common types of damage were: interior finish (90%); insulation and weather stripping (84%), and painting (83%). Doors, windows, and shutters were another component that frequently (80%) experienced damage.

Table 4.4: Most Frequently Damaged Building Components according to Damage Assessments

Type of Damage	Code	Number	Percent
Foundation	FND	66	15%
Superstructure	SS	221	52%
Roofing	ROOF	395	93%
Insulation/ Weather Stripping	I/WS	357	84%
Exterior Finish	EF	338	79%
Interior Finish	IF	382	90%
Doors/ Windows/ Shutters	D/W/S	339	80%
Lumber Finished	LF	101	24%
Hardware	HW	185	43%
Cabinets/ Countertops	C/C	259	61%
Floor Covering	FC	322	76%
Plumbing	PLMB	209	49%
Electrical	ELEC	332	78%
Built-in Appliances	BIA	165	39%
Heating/ Cooling	H/C	221	52%
Painting	PNT	353	83%
Undamaged	UND	12	3%
Total Number of Assessed Houses		**426**	

The chart in Figure 4.19 illustrates the types of building components that were the most frequently damaged according to the Punta Gorda Building Department damage assessments. The labels along the x-axis correspond to the codes presented in Table 4.4.

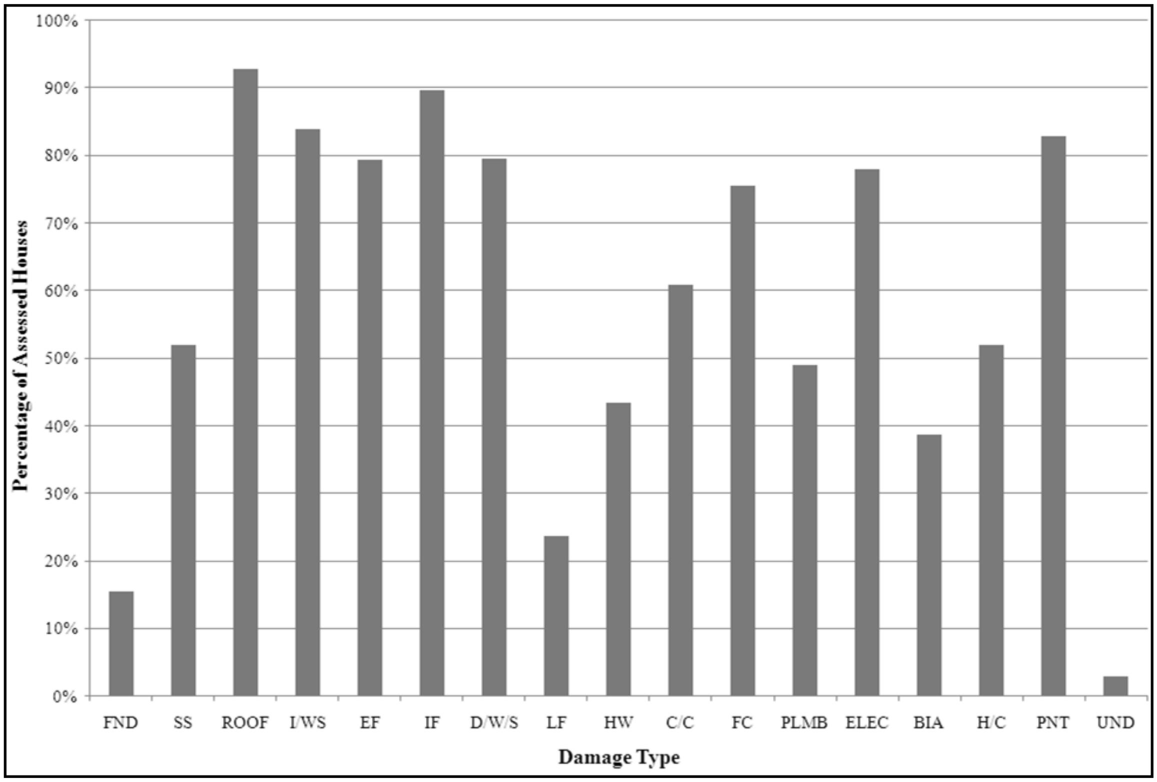


Figure 4.19: Most Frequently Damaged Building Component according to Damage Assessments (Codes as defined in Table 4.4)

The damage assessments from the Punta Gorda Building Department show that a large majority of the buildings in Punta Gorda were not 'substantially damaged' after Hurricane Charley. Most of the assessed buildings had either minor or moderate damages. The damage assessments also show that the most frequently damaged component of a building was the roof.

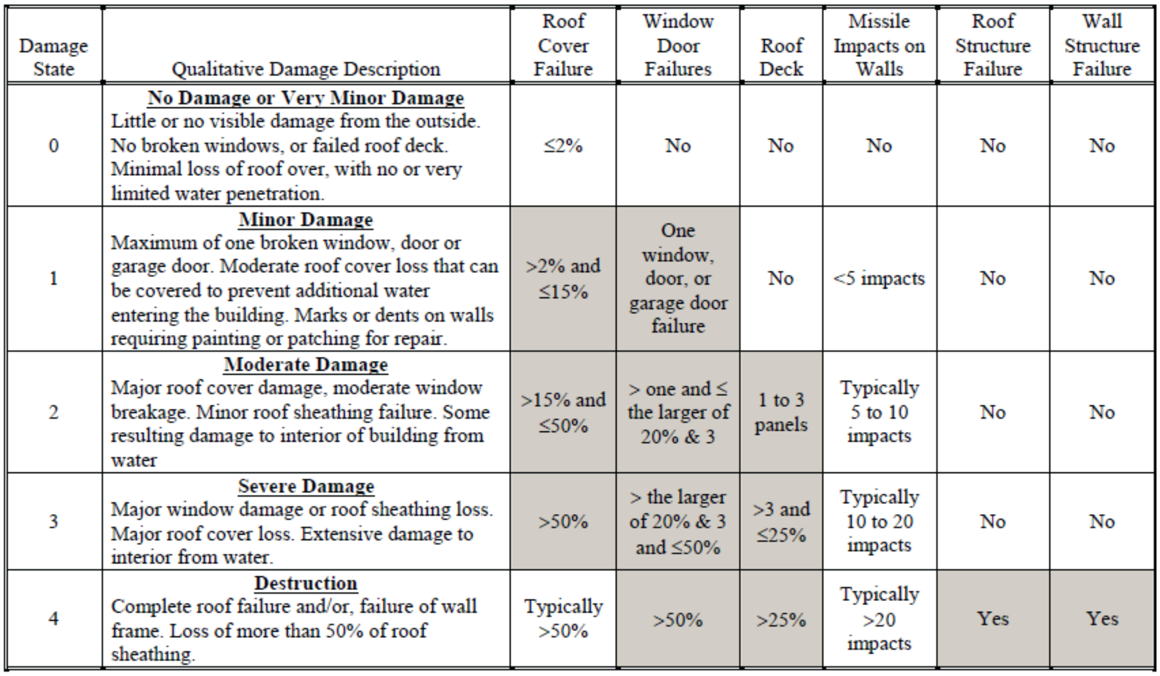
4.4.2 University of Florida Damage Assessments

The Department of Civil and Coastal Engineering at the University of Florida also conducted a damage assessment after Hurricane Charley between January and May 2005. Kurtis Gurley, an associate professor in the department, was the principal investigator for the study and provided our team with several datasets and reports from their assessment. The University of Florida damage assessments studied houses built between 1994 and 2001 compared to houses built after 2001. Houses built between 1994 and 2001 comply with the Standard Building Code and changes that went into effect after Hurricane Andrew in 1992. After 2001, houses were built to meet the 2001 Florida Building Code. The University of Florida study compares the performance of houses built to these two different codes.

The study systematically chose houses built between 1994 and 2004 in the areas that experienced the highest wind speeds during the 2004 hurricane season. The sampling strategy chose houses to survey based on their age of construction, construction details, and maximum wind exposure (Gurley 2006). For the analysis discussed in this thesis, only the 86 houses that were surveyed in Punta Gorda, Florida were examined. Key information was pulled out of this report to create charts and table that showed the damage severities and types and provided background information about the housing sector in Punta Gorda. Several of these charts and tables are presented in this section.

The University of Florida damage study was analyzed and the initial damage to houses in Punta Gorda after Hurricane Charley was determined. Houses were separated into five categories using the HAZUS damage scale as shown in Table 4.5. On this scale, buildings are assigned to a damage state based on six components: roof cover failure, window door failures, roof deck failure, missile impacts on walls, roof structure failure, and wall structure failure. The highest damage state assigned to any of these six components is the damage state assigned to the whole building.

Table 4.5: Damage States for Residential Construction (HAZUS)



Damage State	Qualitative Damage Description	Roof Cover Failure	Window Door Failures	Roof Deck	Missile Impacts on Walls	Roof Structure Failure	Wall Structure Failure
0	**No Damage or Very Minor Damage** Little or no visible damage from the outside. No broken windows, or failed roof deck. Minimal loss of roof over, with no or very limited water penetration.	≤2%	No	No	No	No	No
1	**Minor Damage** Maximum of one broken window, door or garage door. Moderate roof cover loss that can be covered to prevent additional water entering the building. Marks or dents on walls requiring painting or patching for repair.	>2% and ≤15%	One window, door, or garage door failure	No	<5 impacts	No	No
2	**Moderate Damage** Major roof cover damage, moderate window breakage. Minor roof sheathing failure. Some resulting damage to interior of building from water	>15% and ≤50%	> one and ≤ the larger of 20% & 3	1 to 3 panels	Typically 5 to 10 impacts	No	No
3	**Severe Damage** Major window damage or roof sheathing loss. Major roof cover loss. Extensive damage to interior from water.	>50%	> the larger of 20% & 3 and ≤50%	>3 and ≤25%	Typically 10 to 20 impacts	No	No
4	**Destruction** Complete roof failure and/or, failure of wall frame. Loss of more than 50% of roof sheathing.	Typically >50%	>50%	>25%	Typically >20 impacts	Yes	Yes

The Punta Gorda houses were broken into damage states (Table 4.6) depending on the percentage of roof cover damage, the number of roof sheathing panels lost, and the number of openings (windows, doors, and garage doors) damaged in Hurricane Charley. The houses from the University of Florida damage study are classified as undamaged, minor, moderate, severe, and catastrophic. As shown in Table 4.6, the majority (51%) of the houses in the University of Florida study were undamaged. The lack of damage is not surprising though, because the study only considers new houses built after 1994. In fact, the study found that none of the surveyed houses in Punta Gorda affected by Hurricane Charley experienced roof sheathing failure, wall failure, or roof-to-wall connection failure (Gurley 2006).

Table 4.6: Initial Damage Assessments from University of Florida Study

Status	Damage State	Number	Percent
Undamaged	0	44	51%
Minor	1	15	17%
Moderate	2	18	21%
Severe	3	9	11%
Catastrophic	4	0	0%
Total Number of Assessed Houses		**86**	

The main purpose of the University of Florida damage study was to compare houses built to the Standard Building Code with those built to the 2001 Florida Building Code. Table 4.7 breaks down the damage levels of the assessed houses by their corresponding building code. The table shows that the selection built to the 2001 Florida Building Code had almost 20% more undamaged houses and had an overall better performance.

Table 4.7: Impact of Building Codes on University of Florida Damage Assessments

Damage Level	Standard Building Code		2001 Florida Building Code		Combined	
	Number	Percent	Number	Percent	Number	Percent
Undamaged	26	45%	18	64%	44	51%
Minor	12	21%	3	11%	15	17%
Moderate	12	21%	6	21%	18	21%
Severe	8	14%	1	4%	9	10%
Catastrophic	0	0%	0	0%	0	0%
Total	**58**		**28**		**86**	

The next analysis performed using the University of Florida damage assessments was to use the GIS program to determine the locations of houses as was done with the Punta Gorda Building Department damage assessments. The assessed houses were shown on a map of Punta Gorda and denoted by color-coordinated dots to illustrate which damage state they represent. The map provided a spatial analysis of the damage assessment but, as with the Punta Gorda Building Department damage assessments, there was no discernable trend between location and damage level.

The University of Florida damage assessments provide an idea of which types of damage were most frequent after Hurricane Charley. Table 4.8 shows the breakdown of the most common types of damage found by the University of Florida study for 59 of the Punta Gorda houses. Roof damage was the most frequent type of damage experienced according to the data from the study. Of the 59 houses analyzed, 86% experienced some roof damage and 83% had soffit damage. The next most common damages were to attachments (64%) and exterior finish (61%).

Table 4.8: Most Common Types of Damage to Houses Assessed by University of Florida Study

Type of Damage	Number	Percent
Openings	18	31%
Soffit	49	83%
Roof	51	86%
Interior	31	53%
Exterior Finish	36	61%
Structural	1	2%
Attachments	38	64%
Unknown	1	2%
Total Damaged	**59**	

The chart in Figure 4.20 further illustrates the most common types of damage to the houses with University of Florida damage assessments.

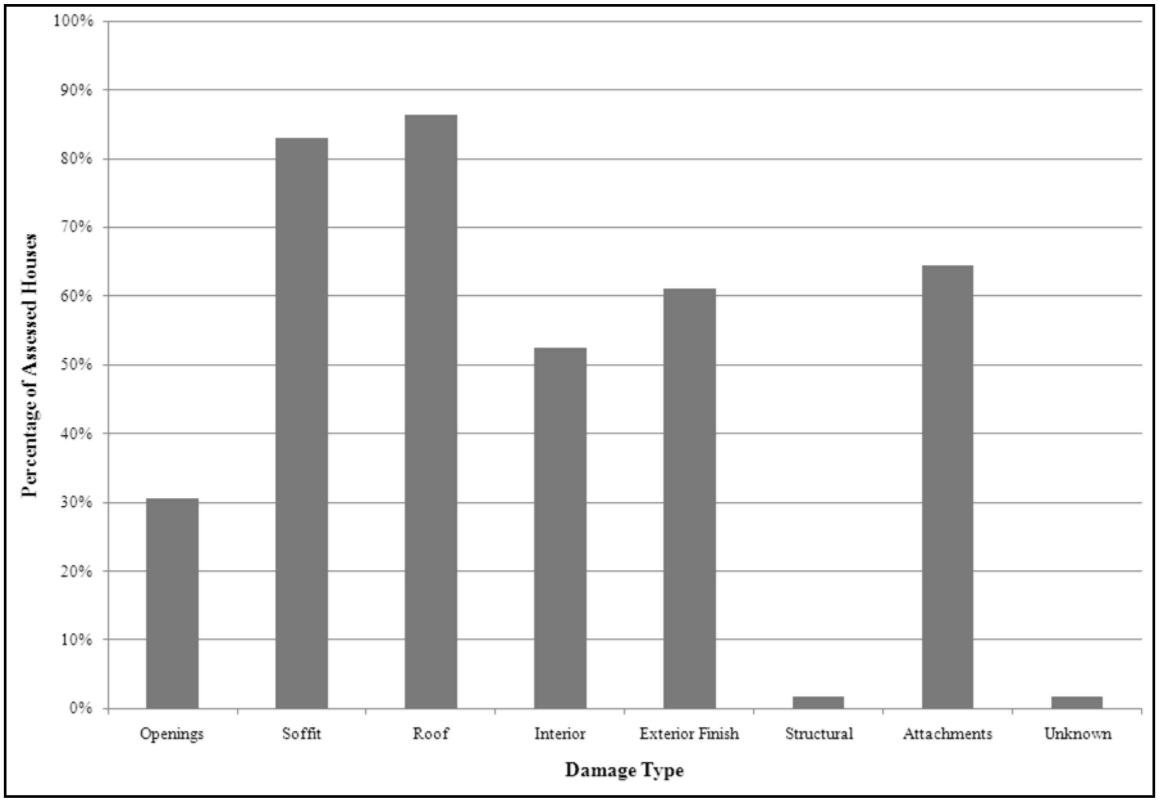


Figure 4.20: Most Common Types of Damage to Houses Assessed by University of Florida Study

The analysis of the damage assessments from the University of Florida also provides a breakdown of the building characteristics associated with more damage. For example, 17% of garages without windows had damage compared to 4% of garages with windows. The analysis also shows that 48 of the Punta Gorda houses include a total of 59 exterior attachments. Screen enclosures account for 45 of the exterior attachments and 62% of them were damaged by Hurricane Charley. Since roof damage was so prevalent, the University of Florida study identified the most frequent causes for roof damage. Wind accounts for 71% of the roof damage while wind borne debris cause 23% of the roof damage. The remaining roof damage can be attributed to damage from trees or other unknown causes. Another analysis considered if windows were protected and, if so, what types of protection were used. Of the 813 windows on the Punta Gorda houses, only 284 (35%) had window protection in 2004, but only 4 of these protected windows suffered damage. The study asked the 59 homeowners whether they planned to use window protection for future hurricane seasons and 88% said they did. Table 4.9 provides a breakdown of the window protection used by Punta Gorda homeowners during the 2004 hurricane season and the protection types homeowners said they planned to use in the future. The table shows that the majority of houses (51%) had no window protection in 2004, but 76% planned to install hurricane shutters before future hurricane seasons. This data suggests that mitigation was factored into the Hurricane Charley recovery.

Table 4.9: Types of Window Protection on Assessed Houses

Protection Type	2004 Season		Future Intent	
	Number	Percent	Number	Percent
Impact Glass	4	7%	1	2%
Plywood	2	3%	5	8%
Shutters	20	34%	45	76%
Tape	2	3%	0	0%
Window Film	1	2%	1	2%
None	30	51%	6	10%
Unknown	0	0%	1	2%
Total	**59**		**59**	

Analysis of the damage assessments from the University of Florida study show that the majority (51%) of the houses in Punta Gorda built between 1994 and 2004 were considered undamaged after Hurricane Charley. The most common type of damage was found to be roof damage. The analysis also suggests no relationship between the location of a house and the amount of damage it experienced for this sample. All the houses in this survey were built after 1994 and the majority performed well, but there was an improvement seen in the houses built after the 2001 Florida Building Code. The University of Florida damage assessments are accompanied by a report that discusses the methodology behind the study, analyzes the data, and comments on the results (Gurley 2006). The information from this study is also summarized by a University of Florida student in the Journal of Undergraduate Research (Brandt 2006).

4.4.3 ImageCat, Inc. Remote Sensing Damage Assessments

Members of the NSF project team work at ImageCat, Inc. and performed a remote sensing analysis of buildings in Punta Gorda. The remote sensing utilized satellite images of the affected area in 2004 both prior to the event and directly after Hurricane Charley. By analyzing the satellite images building by building, the ImageCat, Inc. team members were able to assign a damage state to each building. The HAZUS damage scale previously mentioned (Table 4.5) was also used for the remote sensing damage levels. A few extra categories though were added to account for additional possibilities, such as an inability to determine the damage state due to cloud cover. The Remote Sensing Damage and Recovery Scale will be further discussed in Section 4.5.4.1.

The remote sensing analysis was performed using satellite images from both one day and six days after Hurricane Charley. The original dataset provided by ImageCat, Inc. contained 9,631 records. For purposes of this thesis, buildings which were non-existent before Hurricane Charley were neglected. Buildings which were not assigned an initial damage state, many due to cloud cover, were also neglected. The dataset was reduced to a total of 8,725 buildings that existed prior to Hurricane Charley and were afterwards assigned a damage state of undamaged, minor, moderate, severe, or catastrophic. Table 4.10 provides a breakdown of the initial damage assessments using the remote sensing analysis. The breakdown shows that the largest percentage (34%) of buildings were undamaged, followed by buildings with minor (28%) or moderate (23%) damage. Only a small percentage (11%) of buildings had severe damage and even fewer (4%) sustained catastrophic damage.

Table 4.10: Initial Damage Assessments from Remote Sensing Analysis

Status	Damage State	Number	Percent
Undamaged	0	2,939	34%
Minor	1	2,467	28%
Moderate	2	2,007	23%
Severe	3	966	11%
Catastrophic	4	346	4%
Total Number of Assessed Houses		**8,725**	

As previously done using data from the Punta Gorda Building Department, the remote sensing data was next analyzed using a GIS program to determine the locations of damaged buildings. From the remote sensing dataset, only fifteen buildings did not have corresponding parcel numbers and, therefore, could not be analyzed using the GIS program. The remaining 8,710 assessed buildings are shown on the map in Figure 4.21. The buildings are shown as shaded dots to illustrate which damage state they represent. Undamaged buildings are represented with white dots, and then the dots become darker as the damage level increases until buildings with catastrophic damage are shown as black dots. This map analyzes the damage assessments spatially and determines the relationship between location and damage level. The map does not show any distinct trend of damaged buildings, although there are a few darker areas where clusters of buildings sustained more damage, such as in the south central portion of the map. These building clusters tend to represent the location of mobile home parks, as witnessed during the field deployments and seen on aerial maps.

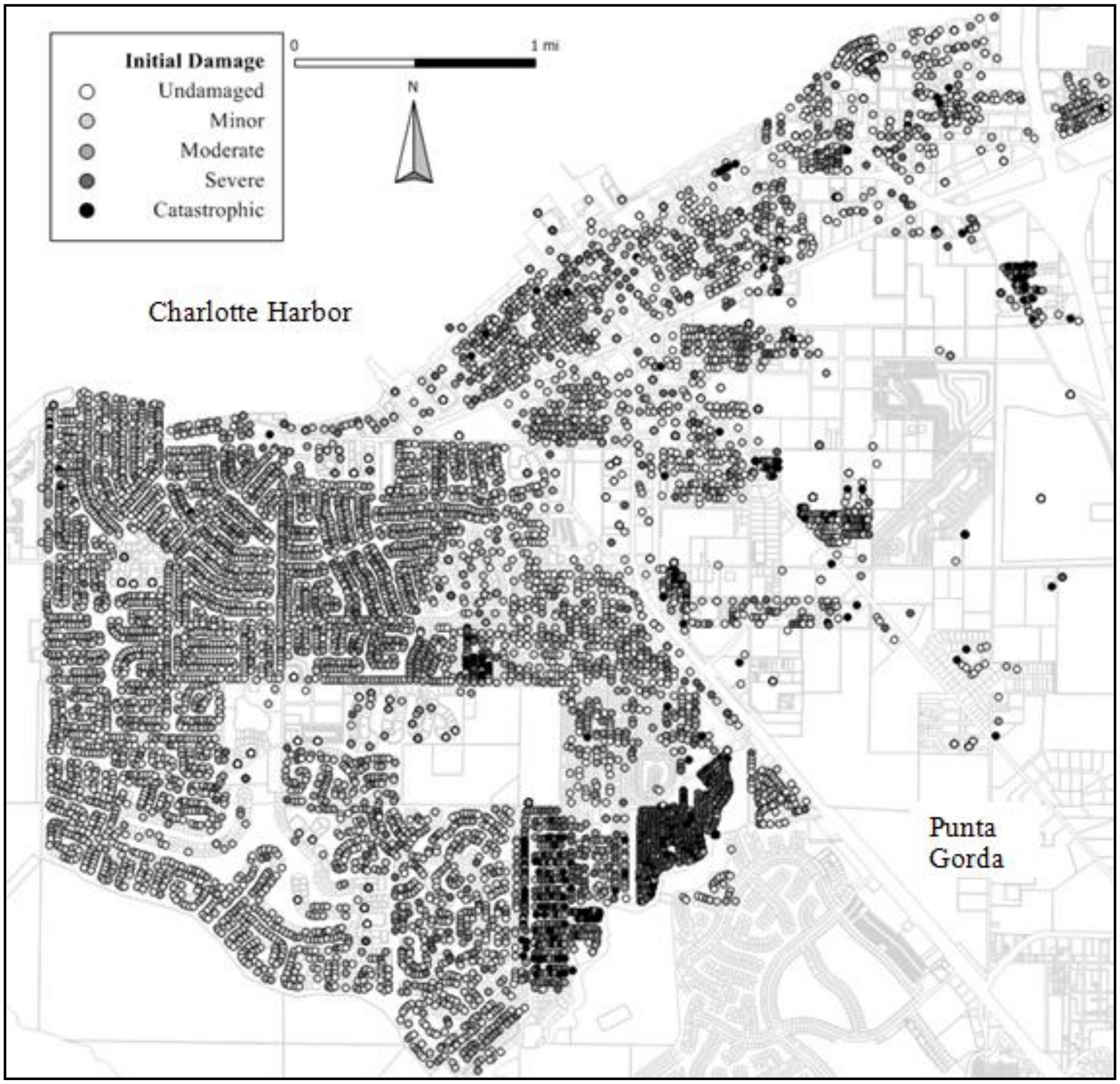


Figure 4.21: Location of Remote Sensing Damage Assessments in Punta Gorda

The remote sensing analysis shows that undamaged buildings were the most common damage state found in Punta Gorda after Hurricane Charley. The majority of the buildings (85%) were either undamaged or had only minor or moderate damages. Only 15% of buildings in Punta Gorda suffered severe or catastrophic damage. The remote sensing data also shows that the type of building (i.e., mobile homes) played a role in the amount of damage to a building, but the geographic location did not have a direct effect.

4.4.4 Additional Damage Studies

The Institute for Business and Home Safety (IBHS) conducted another study of damage from Hurricane Charley, using insurance claims data (IBHS 2004). The study used a manual process to review a sample of 270 claims to determine which building components failed in Hurricane Charley. The results are shown in Figure 4.22 and are similar to the results found in the other damage assessments. As with the damage assessments from the Punta Gorda Building Department and University of Florida, the IBHS (2004) study shows that the majority of damage after Hurricane Charley was to the roofs of houses.

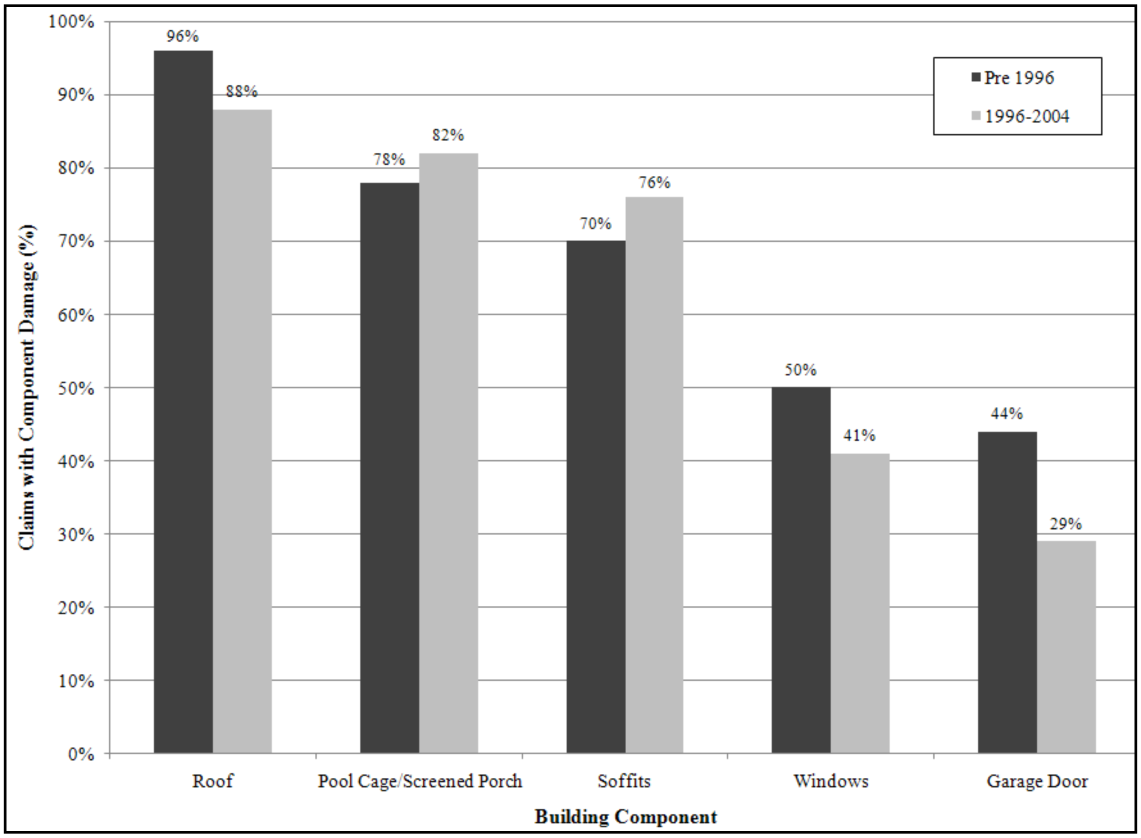


Figure 4.22: Frequency of Building Component Failure according to IBHS Study

The IBHS study also compared claims of houses built before Charlotte County began using high wind design provisions in 1995 to those built later to higher standards. Components on houses constructed after 1996 saw a reduction in both damage frequency and damage severity. Notably, 38% fewer houses had window damage after 1996, there were 32% fewer total garage door replacements, and total roof covering replacements were reduced by 44% (IBHS 2004). The IBHS conducted an additional damage study focused on the performance of garage doors. This study utilized the county's tax roll data, building construction dates, hurricane wind maps, and garage door building permits to analyze damage and repairs to garage doors after Hurricane Charley. Unfortunately though, Punta Gorda was not included in this study because it did not issue specific garage door permits (Reinhold et al. 2004).

Representatives from Wyndham Partners Consulting, Limited (WPC) collaborated with the IBHS in performing additional damage assessments in the days immediately after Hurricane Charley (2004). This study further proved the effectiveness of the 2001 Florida Building Code. It showed that houses built to this code performed well, especially in areas without a significant amount of debris from adjacent structures. The study also showed that mobile homes built after 1994 performed considerably better than all other mobile home groups. Nearly all mobile homes though, lost exterior attachments such as screen porches, pool covers, and carports (WPC 2004).

The Florida Commission on Hurricane Loss Projection Methodology (2007) discusses the insurance claims handled by two major companies after Hurricane Charley. The main goal of the study was to use a Monte Carlo simulation to estimate losses due to a theoretical hurricane. They support their findings with historical hurricane data and insurance claims.

The Multidisciplinary Center for Earthquake Engineering Research (MCEER) performed damage assessments using the VIEWS software mentioned in Chapter 3. The MCEER report discusses the ground surveys conducted during field deployments in August 2004. During the ground surveys, the VIEWS deployment team found that garage door damage and window failure were prevalent forms of damage. They also observed that wall failure was principally sustained by carports and pool covers (MCEER 2004).

Another informative damage study was conducted by PartnerRe (2004). This study assessed 385 single-family residences and 274 manufactured homes at three sites: two in Port Charlotte (Harbour Heights and Tamiami Trail) and one in Punta Gorda (Burnt Store Isles). Damage states in this damage assessment were assigned using the previously discussed HAZUS damage scale (Table 4.5). Figure 4.23 features histograms that compare the damages of single-family residences in those three areas. The Punta Gorda houses are shown as the dark gray column and the most frequent type of damage to those houses was found to be moderate.

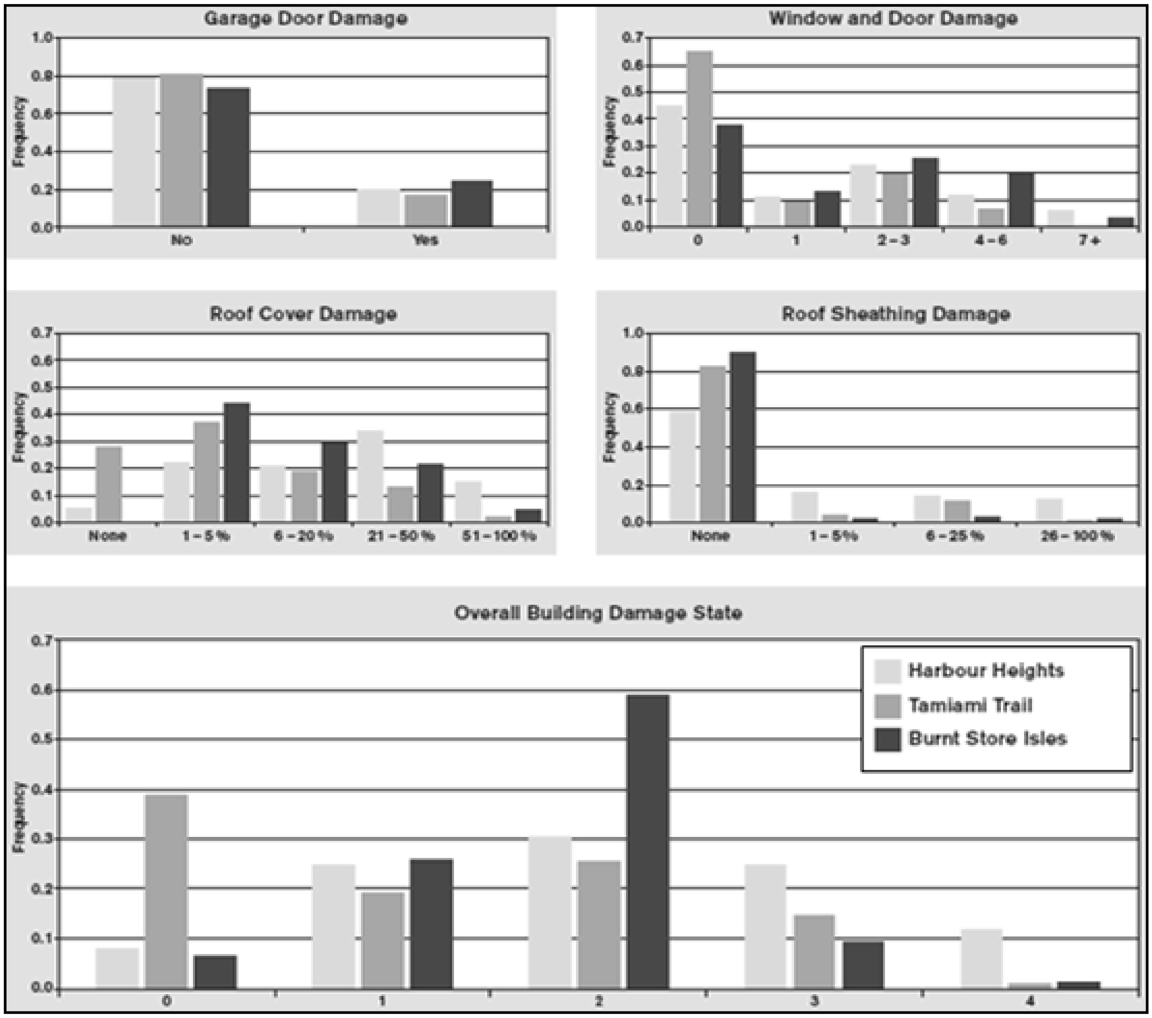


Figure 4.23: Damage Survey Results for Port Charlotte and Punta Gorda (PartnerRe 2004)

The PartnerRe (2004) study also examined the performance of manufactured housing at two mobile home parks in Punta Gorda: Emerald Lake and Ventura Lakes. The approximately 200 mobile homes in Emerald Lake were mostly built between 1986 and 1992. These homes were built to the 1976 HUD standards, not the stricter 1994 HUD wind loading requirements. In Ventura Lakes, construction of the almost 250 mobile homes began in 1999 and the mobile homes complied with the 1994 HUD wind loading requirements. The Emerald Lake homes also suffered higher winds with the strongest gusts estimated to be in the range of 141 to 147 mph compared to Ventura Lakes where the highest wind gusts were around 102 mph (PartnerRe 2004). As can be seen in Figure 4.24, the Ventura Lakes mobiles homes performed better than those in Emerald Lake. At Ventura Lakes, about three quarters of the mobile homes suffered minor damage or less. In contrast, only about one quarter of the units in Emerald Lake had minor damage or less. This damage survey showed that attached carports and screen-enclosed porches performed poorly. Over 80% of the carports at Emerald Lake and more than 50% at Ventura Lakes were either partially collapsed or completely destroyed. Emerald Lake units also had over 50% of screen enclosed porches suffer total construction while Ventura Lakes units had approximately 25% (PartnerRe 2004).

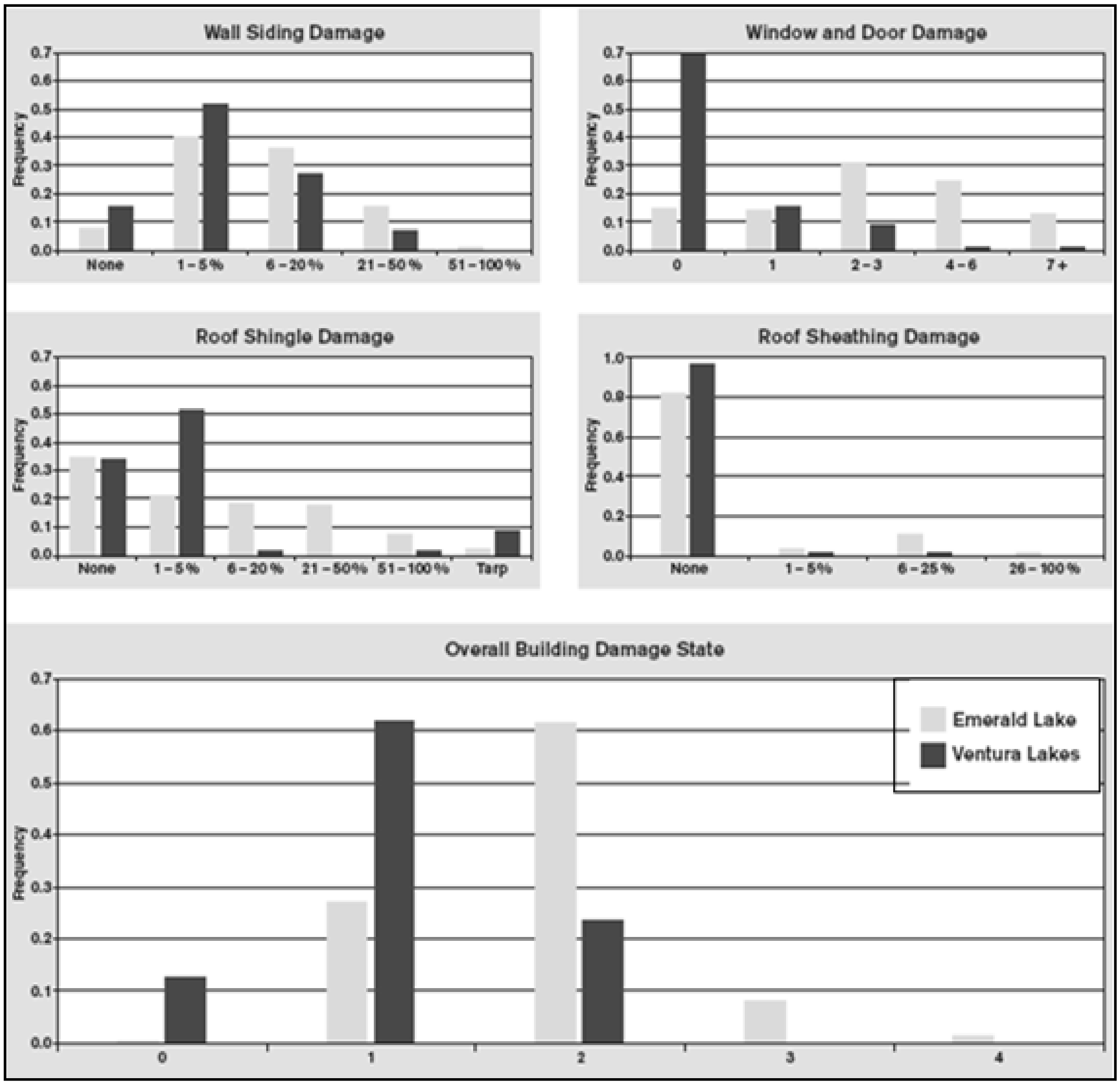


Figure 4.24: Damage Survey Results for Emerald Lake and Ventura Lakes (PartnerRe 2004)

Overall, the results from these additional damage studies seem to support the findings from the Punta Gorda Building Department, University of Florida, and ImageCat, Inc. remote sensing damage assessments. These studies suggest that the main damages were to roofs and exterior attachments. Many of these studies also support the findings that updated building codes have a significant impact on the amount of damages.

4.4.5 Summary of Housing Damage Data

The analysis of initial damage to Punta Gorda included datasets from three different resources: the Punta Gorda Building Department records, the University of Florida study, and the ImageCat, Inc. remote sensing analysis. The initial damage estimates from these sources are compared in Table 4.11. The Punta Gorda Building Department records show a much smaller percentage of undamaged buildings. This makes sense because the Building Department only performed damage assessments on buildings where the repair cost exceeded 35% of the value, unless an assessment was specifically requested by the property owner. Conversely, the University of Florida assessments suggest that over half the houses in Punta Gorda were undamaged. This high percentage of undamaged houses is explained because the study only looked at houses built between 1994 and 2004. The most accurate assessment of initial damage to buildings in Punta Gorda is provided by the remote sensing analysis. This analysis considers all buildings in Punta Gorda regardless of damage level, structural characteristics, or location. It shows the highest percentage of buildings as undamaged, followed by minor, moderate, severe, and then catastrophic. The variation in undamaged buildings between the three sources is understandable, and the distribution of the other damage states is relatively similar. Given that there is damage, minor and moderate damage make up the highest percentages of damaged buildings and are fairly equal. The severely damaged buildings equal approximately half those that have minor or moderate damage and the buildings with catastrophic damage account for only a small percentage of the total buildings.

Table 4.11: Comparison of Initial Damage Assessments

Initial Damage Status	Building Department		University of Florida		Remote Sensing	
	Number	Percent	Number	Percent	Number	Percent
Undamaged	12	3%	44	51%	2,939	34%
Minor	164	38%	15	17%	2,467	28%
Moderate	146	34%	18	21%	2,007	23%
Severe	85	20%	9	11%	966	11%
Catastrophic	19	4%	0	0%	346	4%
Total	**426**		**86**		**8,725**	

The additional damage studies (Section 4.4.4) can be used to support the results from these three main sources. They validate the explanation for the undamaged houses in the University of Florida study by further analyzing the impact of newer building codes on damage. These additional damage studies also provide more information about the specific housing components which were damaged as shown using the Building Department records in Section 4.4.1.

4.5 Recovery Process

The recovery process began almost immediately after Hurricane Charley and lasted for multiple years. A goal for this NSF project is to gauge the progress of the recovery process over time. To assess the recovery of housing after Hurricane Charley both qualitative and quantitative data from various resources were collected and analyzed. This section discusses those resources and analyzes the data provided. It looks at permit data from the Punta Gorda Building Department (Section 4.5.1), a temporary roofing analysis from the United States Army Corps (Section 4.5.2), temporary housing data from FEMA (Section 4.5.3), a remote sensing analysis provided by ImageCat, Inc. (Section 4.5.4), and data from the 2000 U.S. Census (Section 4.5.5). The analyses from these resources are then summarized and the results are compared (Section 4.5.6).

4.5.1 Punta Gorda Building Department Building Permits

A good measurement of how the housing sector is progressing can be determined by looking at the building permits issued after the disaster. The building permit process begins when the homeowner applies for a permit at the customer service desk at the Building Department. They next need to submit plans to the Punta Gorda Building Department to review. Once the plans are revised, the Building Department provides revisions and issues the building permit. After the building permit is issued, the homeowner can begin construction and the process concludes when the Punta Gorda Building Department performs an inspection of the completed job.

4.5.1.1 Categories of Building Permits

Building permit data was analyzed to understand what types of permits were issued and at what times the homeowners applied for permits. We received building permits for the six categories that are most likely related to hurricane damage: (1) addition and remodel, (2) demolition, (3) mobile homes and construction trailers, (4) new construction, (5) roof, and (6) miscellaneous. The Punta Gorda Building Department provided our team with all building permits issued in Punta Gorda from January 1, 2000 through December 31, 2009 for these six categories. Table 4.12 provides a breakdown of the number and value of each permit category issued by the Punta Building Permit. It shows that, for these six categories, 31,396 permits were issued between January 2000 and December 2009 and over half of them were miscellaneous permits. The table also shows that over one billion dollars was spent on permitted construction during the ten-year period. The code column provided in Table 4.12 provides an abbreviation for each permit category which will be used in the subsequent tables and charts throughout this section.

Table 4.12: Number and Value of Punta Gorda Building Permits Issued by Category

Code	Permit Category	Number	Percent	Value	Percent
AR	Additions and Remodels	2,135	6.8%	$88,658,137	8.6%
MISC	Miscellaneous	18,401	58.6%	$151,709,336	14.7%
DEM	Demolition	619	2.0%	$7,882,725	0.8%
MHCT	Mobile Home-Construction Trailer	279	0.9%	$1,366,954	0.1%
NEW	New Construction	1,766	5.6%	$629,887,611	61.0%
ROOF	Roof	8,196	26.1%	$153,753,189	14.9%
	Total	**31,396**		**$1,033,257,952**	

The chart in Figure 4.25 further illustrates the number and value of permits issued by the Punta Gorda Building Department for each permit category. In this chart, it is clear that the miscellaneous permits were the most frequently issued, but more than half of the costs were associated with new construction.

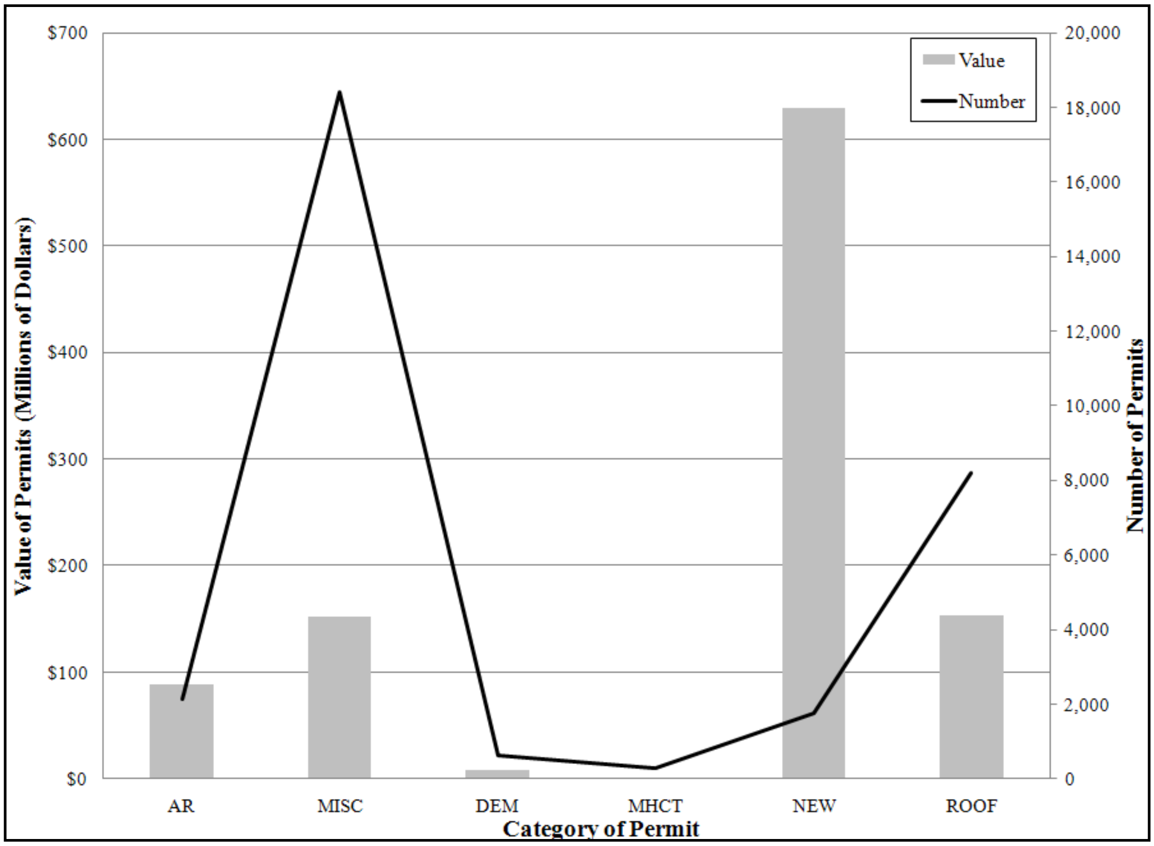


Figure 4.25: Number and Value of Punta Gorda Building Permits Issued by Category from 2000 through 2009 (Codes as defined in Table 4.12)

The building permit data from the Punta Gorda Building Department includes permits from January 2000 to December 2009. Roof permits though, only went through December 2005 and stopped after the Hurricane Charley recovery. Graphing the six building permits over this time period allowed our team to analyze how building permits issued after Hurricane Charley differed from those issued during routine times. Figure 4.26 shows the trend of when Punta Gorda residents applied for building permits during the ten year period broken up into three month periods. The permits do not mention if they were issued in relation to hurricane damage, but the peaks at the end of 2004 and beginning of 2005 show a drastic increase in building permits after Hurricane Charley.

Roof permits, mobile home and construction trailer permits, and demolition permits show the largest jump in the number of permits. Roof permits increase to repair the large amount of damage they sustained and demolition permits increase to allow severely damaged structures to be demolished. The mobile home and construction trailer permits are relevant because these permits include setting up trailers for both temporary housing and construction purposes. The only permit category that does not see a significant peak after Hurricane Charley is new construction, mostly because the housing industry is constantly growing and new construction cannot begin until damage assessments, demolitions, and inspections are complete.

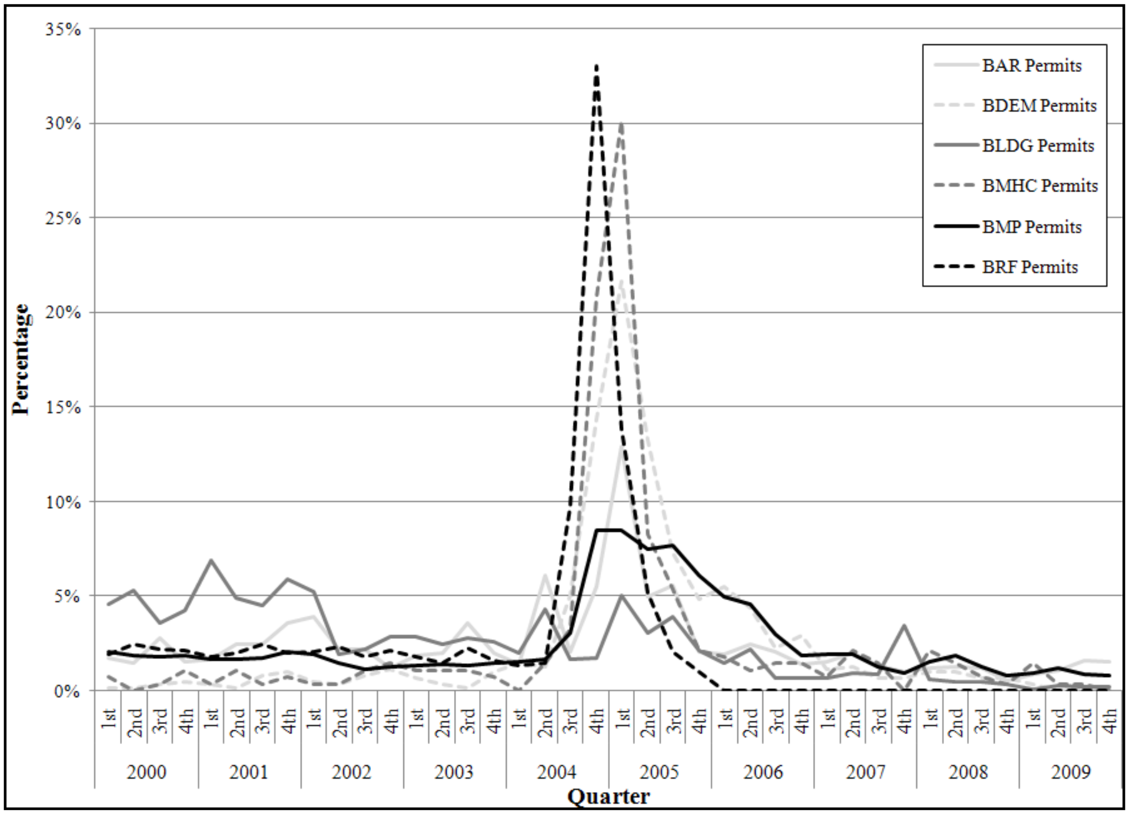


Figure 4.26: Percentage of Punta Gorda Building Permit Applications by Quarter (Codes as defined in Table 4.12)

In order to better illustrate the trend of building permits after Hurricane Charley, Figure 4.27 focuses only on the permits that were applied for during the recovery period. This graph shows the percentage of permit applications from each permit category starting in August 2004 (Initial) and then every three months after Hurricane Charley. Roof permits are shown to be the first type of permits to peak and then stop after one year. The Punta Gorda Building Department did not have any roof permits after 2005. Addition and remodel permits, trailer permits, and demolition permits all show large peaks in application in the first year and a half and then return to a relatively steady rate. Miscellaneous permits have somewhat less drastic peaks after Hurricane Charley and then gradually decline. Again, new construction permits follow a slightly different trend and show an increase later in the recovery around three years after Hurricane Charley. This could be because homeowners waited until the other types of permits died down before applying for new construction permits.

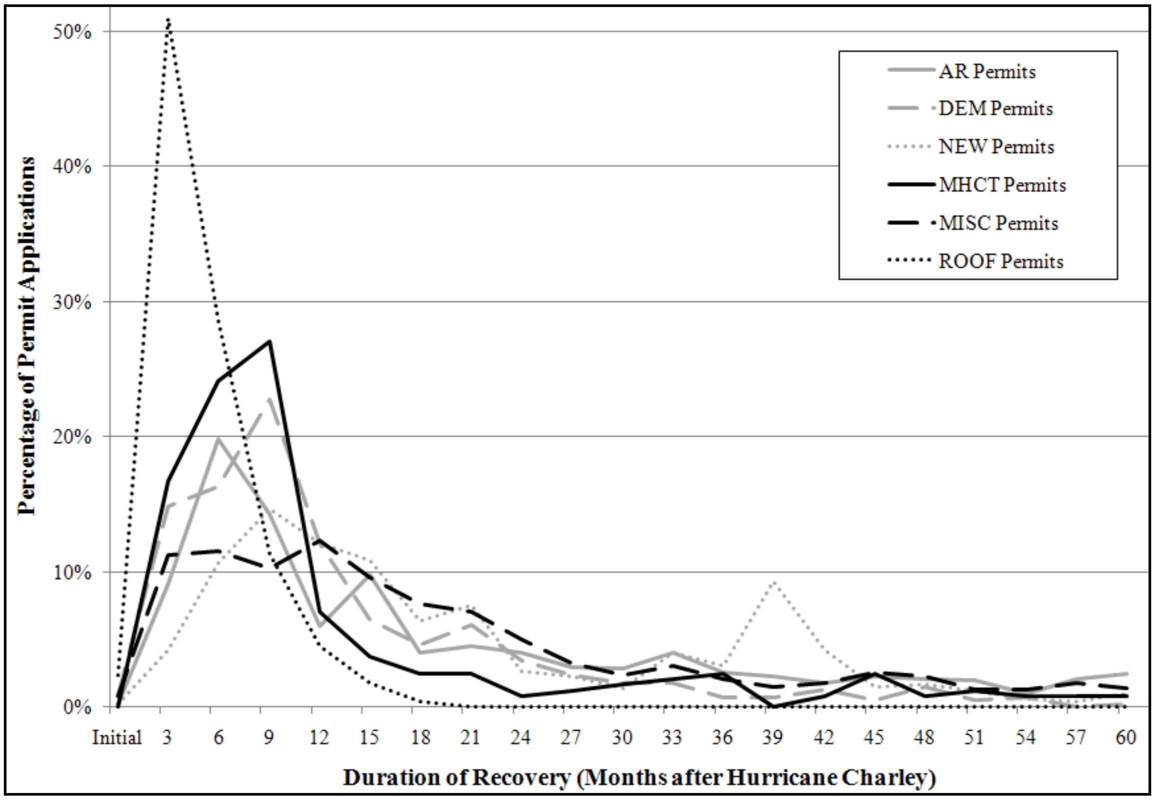


Figure 4.27: Percentage of Punta Gorda Building Permit Applications in 3 Month Intervals after Hurricane Charley (Codes as defined in Table 4.12)

The six categories of building permits received from the Punta Gorda Building Department (addition and remodel, demolition, mobile homes and trailers, new construction, roof, and miscellaneous) were selected because they represented types of permits that could be associated with hurricane damage. It was expected that roofs would make up a large percentage of the building permits because the damage assessments showed that roof damage was the most common type of damage sustained by buildings in Punta Gorda. Finding that miscellaneous permits accounted for over half of the total building permits though was not expected and prompted a closer analysis of what types of permits were considered in this category. Table 4.13 provides a breakdown of the most common types of permits issued as miscellaneous. The table shows that the two most common types of miscellaneous permits were screen enclosures and security/hurricane shutters. Screen enclosures account for almost 30% of the miscellaneous permits, which is consistent with the damage assessments that showed they sustained large amounts of damage. The security and hurricane shutter permits make up just over 20% of the miscellaneous permits and show that many residents considered mitigation as part of the recovery process.

Table 4.13: Number and Value of Miscellaneous Building Permits Issued

Type	Application Description	Number	Percent	Value	Percent
SCRN	Screen Enclosures	5,502	29.90%	$37,060,206	24.43%
SHS	Security/Hurricane Shutter	3,793	20.61%	$25,950,192	17.11%
NON	Non-Category	2,468	13.41%	$45,821,911	30.20%
LSP	Lawn Sprinklers	1,855	10.08%	$3,549,354	2.34%
FEN	Fence	836	4.54%	$2,598,972	1.71%
WIN	Windows	788	4.28%	$7,509,680	4.95%
CON	Concrete	632	3.43%	$15,080,513	9.94%
GOHD	Garage/Overhead Doors	574	3.12%	$972,425	0.64%
SSF	Siding/Soffit/Fascia	419	2.28%	$1,712,346	1.13%
POOL	Pool	415	2.26%	$1,045,514	0.69%
CRPT	Carport/Garage/U-Room/Screened Room/Patio	306	1.66%	$3,627,124	2.39%
SOL	Solar	249	1.35%	$630,735	0.42%
SHD	Sheds	139	0.76%	$429,099	0.28%
AWN	Awnings/Canopies	82	0.45%	$570,045	0.38%
GEN	Generator	57	0.31%	$786,806	0.52%
OTHER	Other	286	1.55%	$4,364,414	2.88%
	Total	**18,401**		**$151,709,336**	

The chart in Figure 4.28 shows the timeline of miscellaneous permits for screen enclosures, hurricane shutters, windows, and carports. These are the types of miscellaneous permits that would be expected to increase after a hurricane. Screen enclosures, windows, and carports are components that were commonly damaged after

Hurricane Charley as shown in Section 4.4. Hurricane shutters are a part of the mitigation that could be included in the recovery. The graph below shows these four types of miscellaneous permits peak during the recovery from Hurricane Charley.

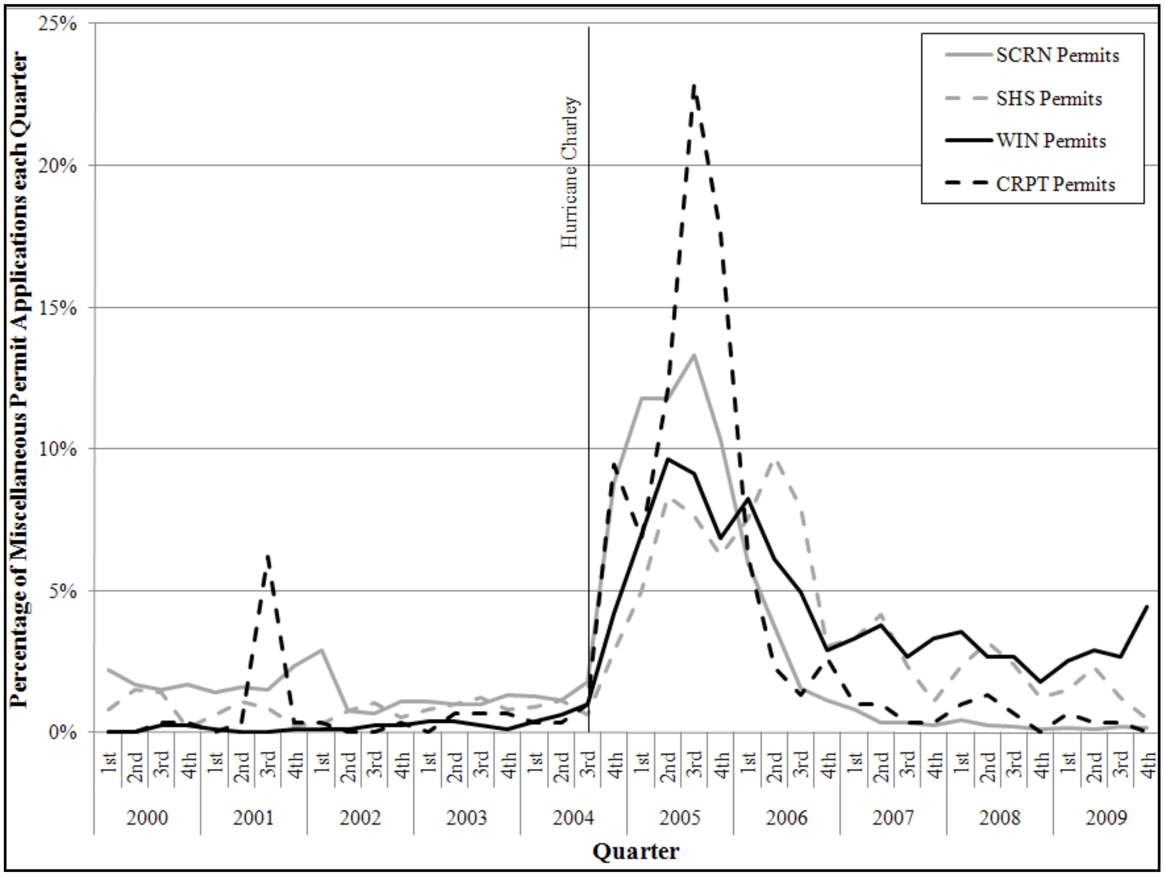


Figure 4.28: Percentage of Miscellaneous Building Permits in Punta Gorda by Quarter (Codes as defined in Table 4.13)

4.5.1.2 Recovery Categories Determined using Building Permits

When analyzing the building permits, it was observed that there are six different scenarios for an individual building depending largely on its initial damage state. For an undamaged structure, the options are either to leave it as is or it could still be modified with updates or mitigation. A damaged building could also be left unrepaired, or it could be repaired or demolished. If a structure is demolished, it then has the option to either be rebuilt or left demolished. Therefore, the six alternatives for housing recovery are (1) undamaged, (2) undamaged – modified, (3) damaged – not repaired, (4) damaged – repaired, (5) demolished – rebuilt, (6) demolished only. Figure 4.29 illustrates the possible processes that a building can go through to reach one of these six end recovery categories.

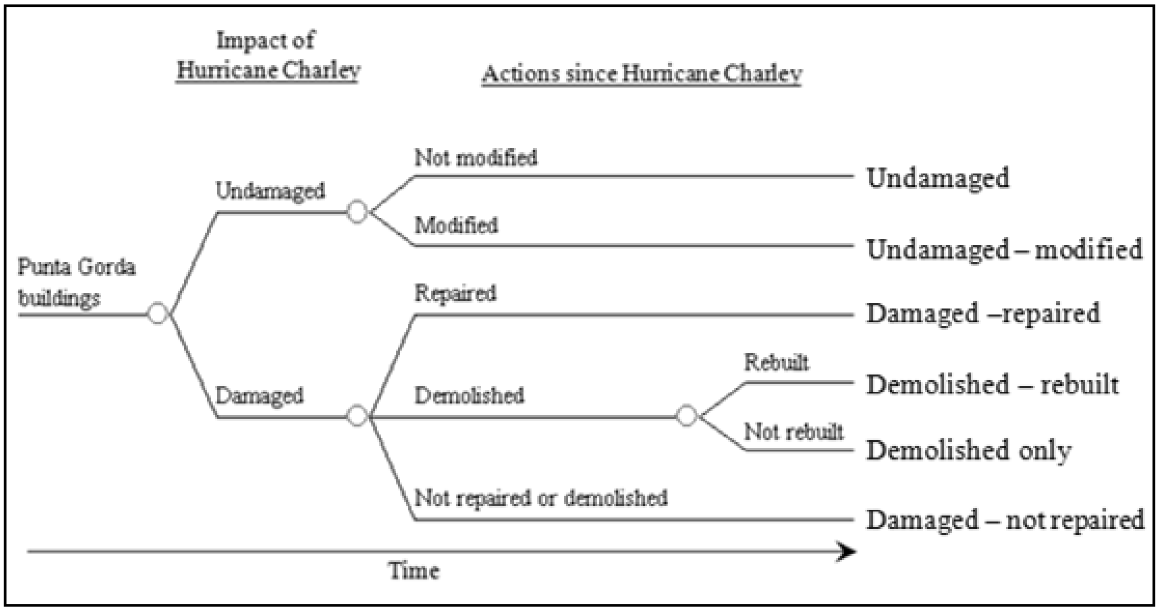


Figure 4.29: Possible End Recovery Categories for Punta Gorda Buildings

An analysis was performed by looking at the initial damage assessments from the Punta Gorda Building Department data, the University of Florida study, and the remote sensing analysis. The buildings from these damage assessments were then matched to the building permits data using their parcel numbers and were assigned to the appropriate recovery categories based on the categories of permits they were issued. For example, buildings with demolition permits were either demolished and rebuilt or demolished only, while damaged buildings with other types of permits were primarily repaired. Figure

4.30 represents what percentage of buildings fall into each of the recovery categories for these three data sources. From the Punta Gorda Building Department data, 336 buildings were found to have both damage assessments and building permits issued after Hurricane Charley. Building permits were also issued for 23 of the 86 Punta Gorda houses in the University of Florida study. The remote sensing data contains 4,530 buildings which have both a damage state from the remote sensing and building permits from the Punta Gorda Building Department. Since this third analysis only considers the remote sensing buildings that had permits, it does not have any results shown in Figure 4.30 for the undamaged or damaged – not repaired recovery categories.

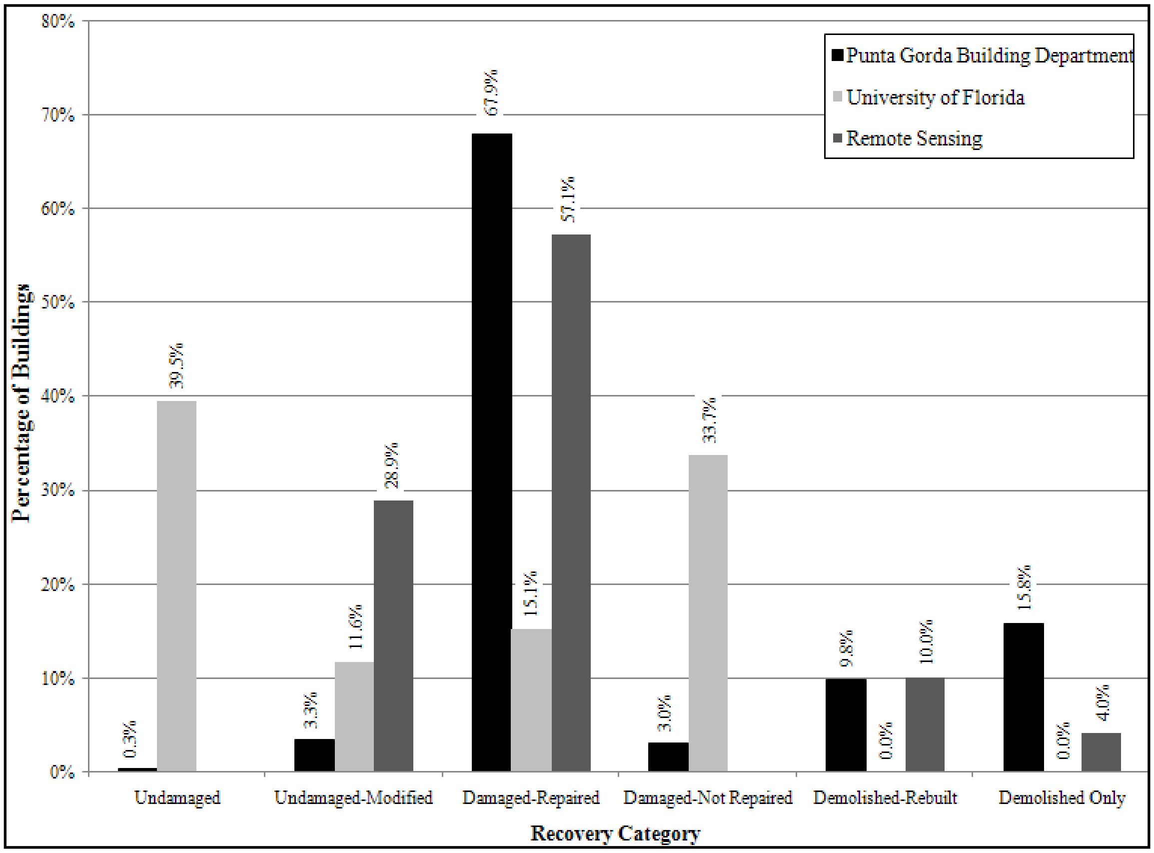


Figure 4.30: Percentage of Buildings in Each Recovery Category (Based on damage assessments with associated building permits)

Figure 4.30 above shows that the majority (67.9%) of buildings from the Punta Gorda Building Department data were initially damaged and then repaired. The houses in the University of Florida study were mostly (39.5%) undamaged. There were not many permits issued for houses from the University of Florida study, which can be explained by the fact that they were all newer houses (built after 1994) which did not suffer a lot of damage (Section 4.4.2). The remote sensing analysis considers the 8,710 buildings which had parcel numbers and, therefore, could be linked to the data from the Building Department using the GIS program. Only 4,530 of the 8,710 buildings (52%) with remote sensing damage assessments were linked to permit data from the Punta Gorda Building Department. Of the buildings without permits, 36% were undamaged and 64% were damaged. This high percentage of buildings that were damaged and did not have permits can be explained by three possible scenarios: (1) repairs were done to the building without the required permit, (2) the type of repair done did not require a permit (e.g., painting, stucco, other cosmetic repairs), (3) the building was damaged and never repaired. The first explanation, that repairs were done without permits, is most likely. This can be further explained because the Building Department was lenient with requiring permits during the time of disaster (John Smith, personal communication, June 7, 2010). Due to these unpredictable circumstances, the buildings that did not link to permits were not considered and the remote sensing analysis does not show any ‘undamaged’ or ‘damaged – not repaired’ buildings. This analysis assumes that the buildings that linked to permit data are a representative sample of the damaged buildings and that those buildings without permits were not disproportionately damaged. The remote sensing analysis corroborates the Building Department data and suggests that more than half the buildings in Punta Gorda were damaged and then repaired within the five year period.

4.5.1.3 Progress of Recovery over Time using Building Permits

A similar process was used to determine the status of a building at particular time intervals after the disaster. This analysis looked at the initial damage state and end recovery category as before, but also considered permit application dates to show how the recovery of a particular building progressed over time. The first analysis considered the 336 buildings that had both damage assessments and building permits from the Punta Gorda Building Department. Buildings in this analysis were first assigned an initial damage state based on the Punta Gorda Building Department damage assessments and only the damaged buildings were considered. The recovery period was then divided into three month intervals and considered for the five years after Hurricane Charley. In this analysis, the building was considered to be in its initial damage state until the first permit application associated with that structure. The building was then assigned a status based on the type of permit requested. Buildings with addition and remodel, mobile home and construction trailer, new construction, roof, and/or miscellaneous permits were considered “under construction”. After the last of these types of permits was applied for a building, the structure was then considered “repaired”. If a structure required a demolition permit, the building was then considered “demolished”. Buildings that had a demolition permit as the last type of permit remained demolished. Those that applied for a new construction permit after being demolished were considered “rebuilt”. These statuses were recorded for each of the assessed buildings at three month intervals and the results can be seen in Figure 4.31. The chart shows a discernable trend as one would expect to see as the recovery progressed. In the first few months, the buildings are primarily categorized by the amount of damage they sustained. The time steps between three months and 48 months show a lot of buildings under construction. The construction period starts during the first three month interval and accounts for many of the buildings in the first two years before gradually fading out around the four year anniversary. After five years, the Punta Gorda buildings are all considered demolished (12%), repaired (78%), or rebuilt (10%) with an overwhelming majority being repaired structures.

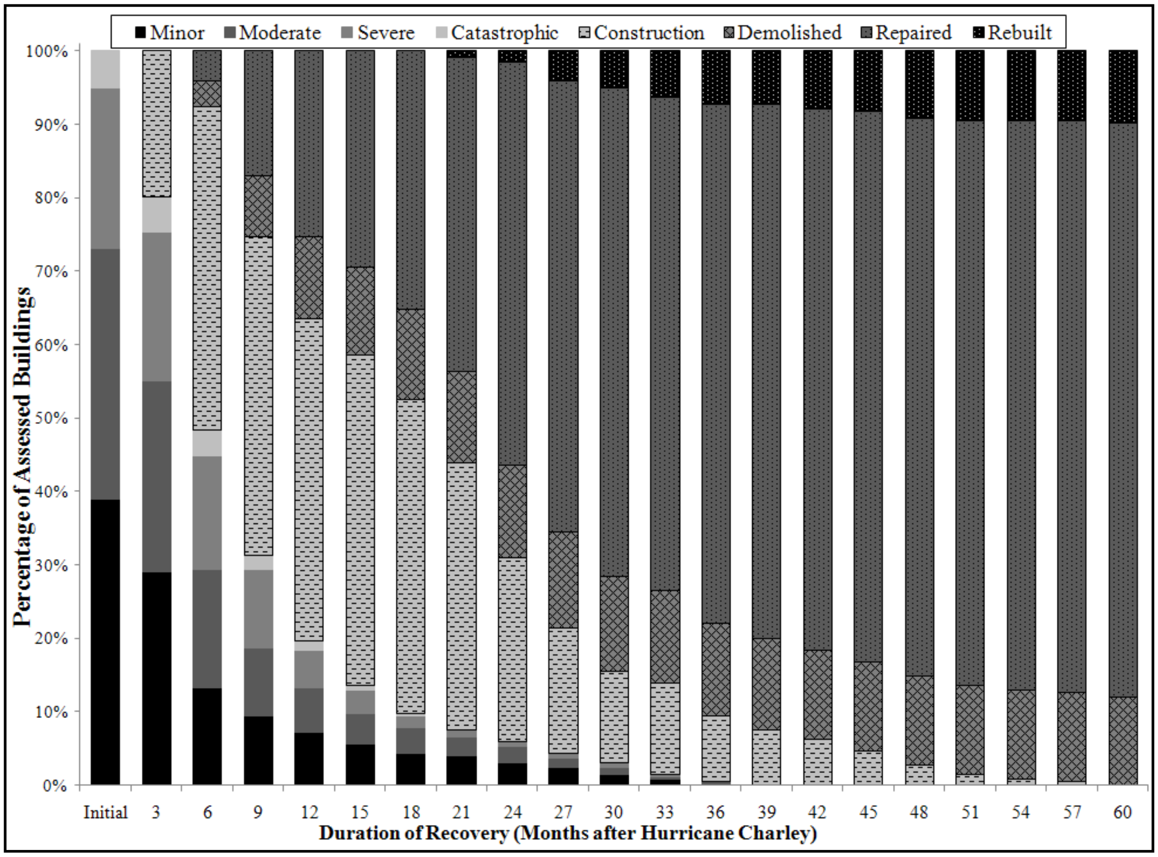


Figure 4.31: Status of Damaged Buildings during Recovery using Building Permits

The same analysis was next performed using the initial damage assessment provided by the ImageCat, Inc. remote sensing data. The analysis started with the 4,530 buildings that were previously linked to the building permit data and then focused on only the damaged buildings from that dataset. The chart for this analysis (Figure 4.32) shows a discernable trend similar to that seen from the Building Department data. The buildings are initially categorized by the amount of damage they sustained, then transition into a construction phase, and finally reach their end state. The construction period begins during the first three month interval gradually decreases to only a small percentage (2%) at the five year mark. After five years, the buildings are mostly considered demolished (5%), repaired (81%), or rebuilt (12%).

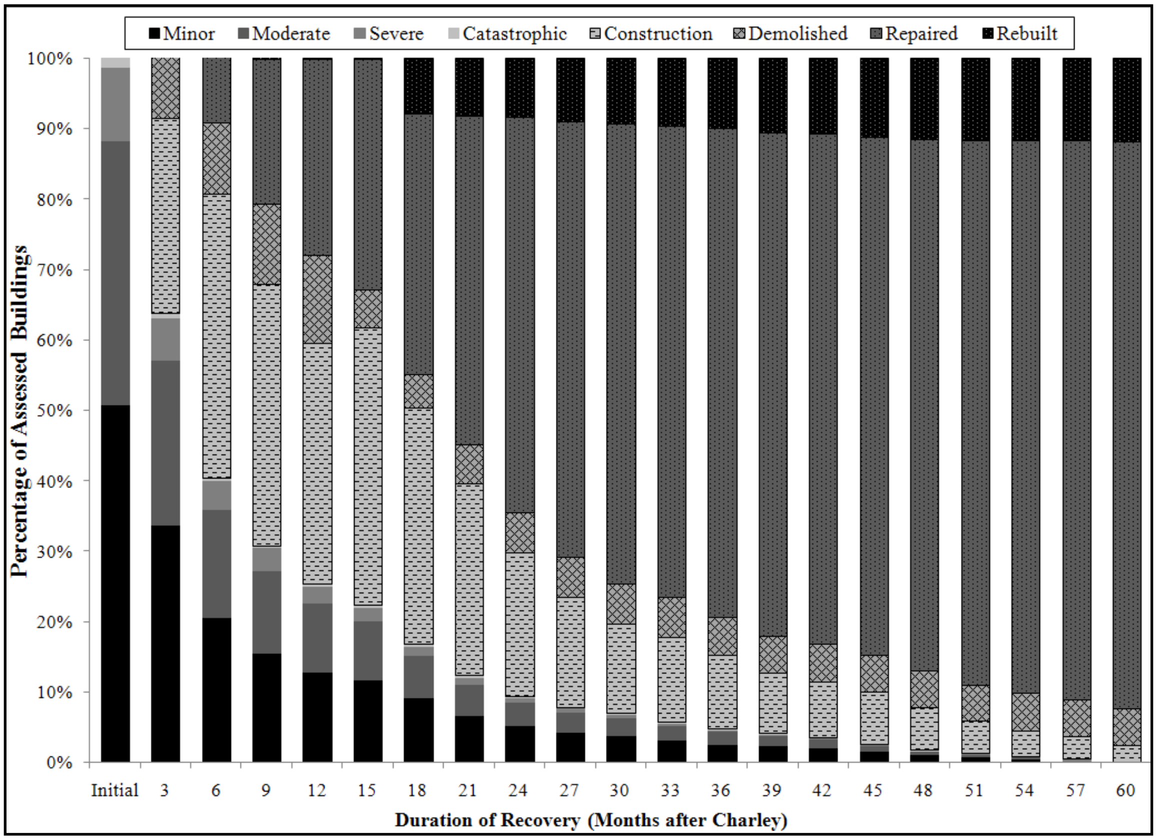


Figure 4.32: Status of Damaged Buildings Assessed by Remote Sensing using Building Permits

The chart using the Punta Gorda Building Department damage assessments (Figure 4.31) and the chart using the remote sensing damage assessments (Figure 4.32) show similar trends. Both suggest that construction began in the first three months and that the majority of buildings had been repaired by the five year anniversary. This analysis was not performed using the University of Florida damage assessments because almost 75% the houses in this study did not link to associated building permits.

4.5.2 United States Army Corps of Engineers Roof Analysis

During the recovery process, many structures require temporary roofing for protection from the elements while the house is damaged or undergoing repairs. The U.S. Army Corps of Engineers (USACE) assists in the temporary roofing process by installing blue tarps that have been provided through FEMA. The process is free for all homeowners, but they must sign a Right of Entry to allow the USACE crew to access their home. Only primary residences are eligible and blue tarps are only installed on houses where the roofs have less than 50% damage and have been deemed structurally sound (Jachimowicz 2009).

Analyzing the number of roofs with blue tarps at specific time intervals can provide an idea of how the recovery is progressing. Blue tarps can be observed from aerial images and were used in the ImageCat, Inc. analysis as mentioned in Section 4.5.4. The USACE also provided our team with a report analyzing the installation of blue tarps after Hurricane Charley. The report includes the number of temporary roofs that were installed daily for the 80 days following Hurricane Charley. This data is for all houses needing temporary roofing after Hurricane Charley and not just those in Punta Gorda.

Table 4.14 summarizes the data in the USACE report. This summary shows that the temporary roofing mission started 7 days after Hurricane Charley and took 73 days to complete. A total of 35,918 temporary roofs were installed and the maximum number of roofs installed in a single day was 1,613.

Table 4.14: Summary of USACE Temporary Roofing Analysis

Variables	Number
Total number of roofs installed	35,918
Maximum number of roof installed in one day	1,613
Days of production	73
Days between landfall and 1st installation	7

Figure 4.33 shows the trend of the number of temporary roofs that the USACE installed each day after Hurricane Charley. It illustrates the data from the table by showing that the first roofs were installed 7 days after the disaster. The chart shows that the mission lasted for 80 days after Hurricane Charley and consisted of 65 days of work. The 15 days of no production were interruptions during Hurricane Frances, Hurricane Ivan, and Hurricane Jeanne, which occurred 20 days, 30 days, and 42 days after Hurricane Charley, respectively.

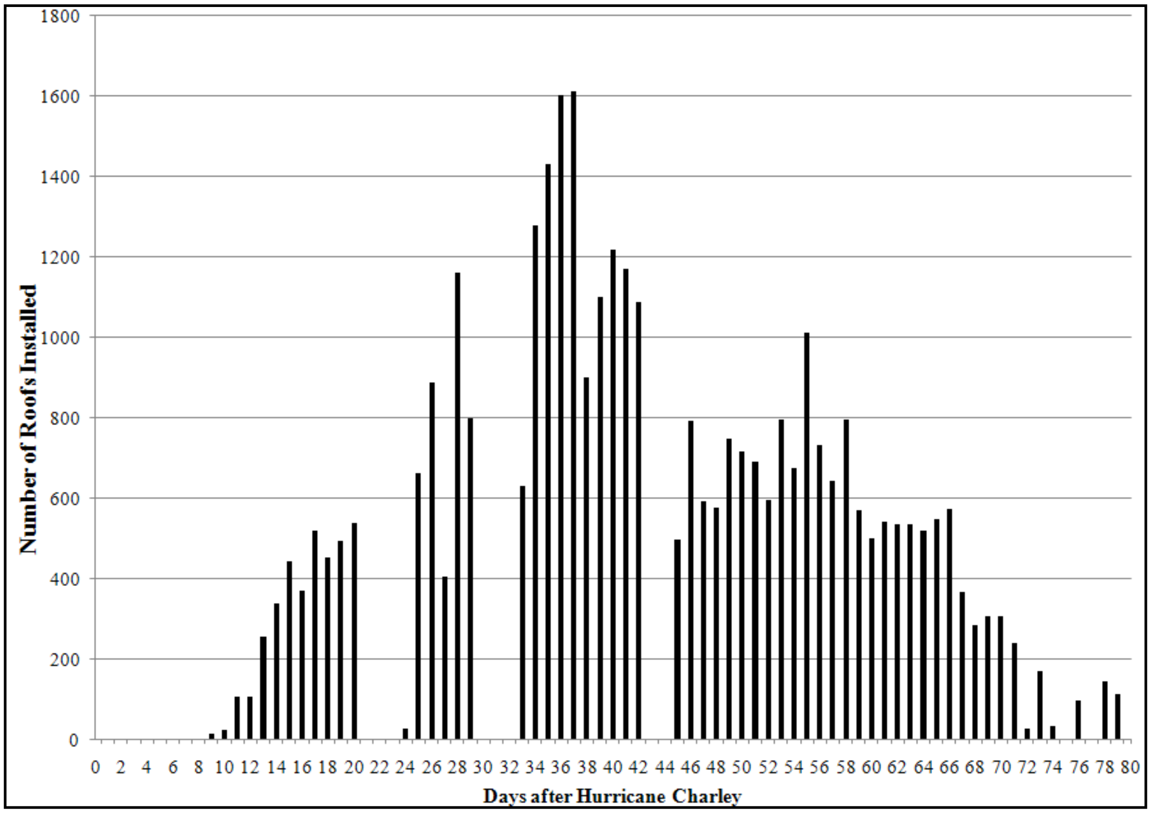


Figure 4.33: Daily Number of Roofs Installed by USACE after Hurricane Charley

4.5.3 Federal Emergency Management Agency Temporary Housing Data

The Federal Emergency Management Agency plays an important role in helping communities recover after disasters. An essential responsibility of FEMA is providing temporary shelter and temporary housing to residents who have been displaced by the disaster. FEMA maintains detailed records of the number of evacuees in shelters and how many shelters are in operation and issues news releases on this data (FEMA 2007). These news releases were collected and the information in them was extracted and compiled to provide an analysis of the temporary shelters. The number of shelters and evacuees can be useful in gauging the progress of recovery. As recovery progresses, the number of shelters and evacuees occupying them decreases. Table 4.15 summarizes the FEMA news releases to show the number of operational shelters in Florida during the 2004 hurricane season and the number of evacuees utilizing those shelters. There is a discernable trend that the largest number of shelters were in use directly after Hurricane Charley and then began to decrease immediately as time progressed. However, the 2004 hurricane season featured three other major hurricanes which complicated the recovery.

Table 4.15: Number of Shelters and Evacuees after Hurricane Charley

Date	Shelters	Evacuees
13-August-2004	**Charley**	
14-August-2004	228	50,000
22-August-2004	21	1,628
24-August-2004	19	1,397
26-August-2004	17	824
27-August-2004	14	557
28-August-2004	8	385
29-August-2004	8	286
31-August-2004	7	181
1-September-2004	4	159
5-September-2004	**Frances**	
9-September-2004	52	3,830
16-September-2004	**Ivan**	
20-September-2004	14	3,167
23-September-2004	9	1,000
26-September-2004	**Jeanne**	
28-September-2004	75	7,452
29-September-2004	55	3,963
30-September-2004	42	2,420

After living in temporary shelters, evacuees may need to find temporary housing before they can return to permanent homes. FEMA assists the community by providing mobile homes and travel trailers for residents to use as temporary housing. The first trailers were put into operation after Hurricane Charley on August 18, 2004. Table 4.16 provides data collected by FEMA that shows the number of active travel trailers and mobile homes at six month intervals after the disaster (FEMA 2007). This data demonstrates the trend of recovery by showing a large number of units in use after the disaster that steadily decreases as time passes. According to FEMA records the peak number of active units occurred in January 2005 and consisted of a total of 5,042 travel trailers and mobile homes.

Table 4.16: FEMA Travel Trailers and Mobiles Homes in use after Hurricane Charley

Date	Travel Trailers	Mobile Homes	Total
13-January-2005	3,820	1,222	5,042
13-July-2005	1,493	606	2,099
13-January-2006	903	772	1675
13-July-2006	297	369	3,774
1-November-2006	89	104	193
31-May-2007	39	0	39
1-November-2007	6	1	7
31-January-2008	3	0	3
31-January-2009	1	0	1

Figure 4.34 better illustrates the trends of travel trailers and mobile homes in use during the recovery period. It shows the number of active units in use at three month intervals after Hurricane Charley. The graph shows that the majority of units were no longer in use at the end of 2007.

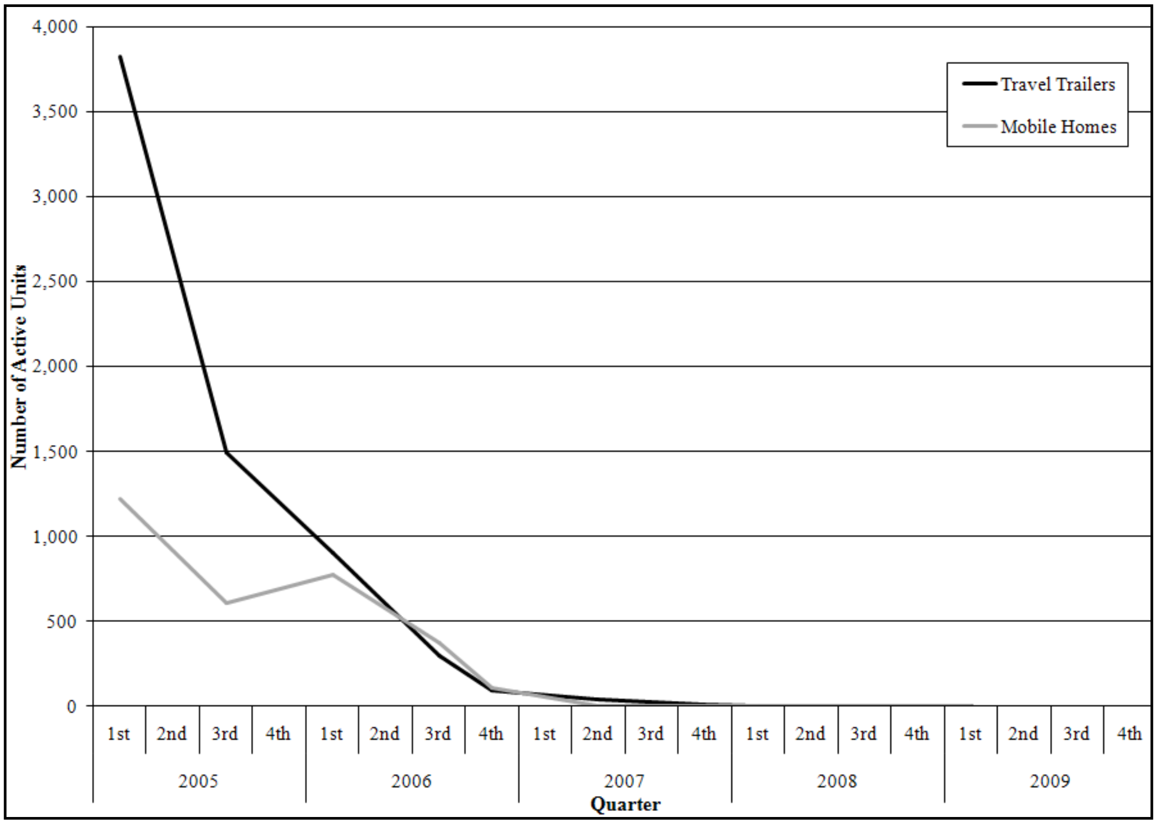


Figure 4.34: FEMA Travel Trailers and Mobile Homes in use after Hurricane Charley

4.5.4 ImageCat, Inc. Remote Sensing Analysis

The ImageCat, Inc. remote sensing analysis also provides an approach for analyzing the progress of recovery. ImageCat, Inc. had satellite and aerial images for Punta Gorda in 2004, both before and directly after Hurricane Charley, and obtained images for 2005, 2006, 2007, and 2008. The images were visually assessed at these eight time steps and each building was assigned a code from the Remote Sensing Damage and Recovery Scale (Table 4.17) developed by ImageCat, Inc. The analysis discussed in this section again uses the dataset of 8,725 buildings which existed prior to Hurricane Charley. These buildings are given an initial damage state after Hurricane Charley using the HAZUS damage scale (Table 4.5) as previously shown in Section 4.4.2. The buildings are then assigned a code for each subsequent time step. This analysis allows comparison of the status of buildings at different time steps to determine both the overall process that a building went through and the progress of recovery at over time.

Table 4.17: Remote Sensing Damage and Recovery Scale

Code	Status	Definition
-1	Non-Existent	A building exists in the location at a different time period, but is not present on this image date
0	Undamaged/Unchanged	No changes have occurred since the previous image date (also applies to buildings undamaged by hurricane)
1	Minor Damage	As described in HAZUS Damage Scale
2	Moderate Damage	As described in HAZUS Damage Scale
3	Severe Damage	As described in HAZUS Damage Scale
4	Catastrophic Damage	As described in HAZUS Damage Scale
5	Demolished	Building has purposely been demolished
6	Under Construction	Building is currently under repair/construction
7	Temporary Roofing	Blue tarp is installed on roof
8	Repaired	Building has been repaired on the same ground footprint
9	Repaired Differently	Building has been repaired with a different ground footprint than pre-disaster
10	Rebuilt	Building has been rebuilt with the same ground footprint
11	Rebuilt Differently	Building has been rebuilt with a different ground footprint than pre-disaster
12	New Construction	Building is currently under construction (previously non-existent building)
13	New Building	Completed construction (previously non-existent building)
99	Unknown	Status cannot be determined (e.g., due to cloud cover, obscuration, outside image extent)

4.5.4.1 Recovery Categories Determined using Remote Sensing

A similar analysis to the one done in Section 4.5.1.2 was performed using the remote sensing data. This analysis considered the 8,725 buildings from the remote sensing dataset that were existing prior to Hurricane Charley and then given an initial damage state after the storm. The analysis used the remote sensing codes assigned to the buildings at the different time steps to determine the overall process that each house went through during the recovery. It provides an overview of how the housing sector recovered by assigning each building to one of the six aforementioned recovery categories: (1) undamaged, (2) undamaged – modified, (3) damaged – not repaired, (4) damaged – repaired, (5) demolished – rebuilt, (6) demolished only. Figure 4.35 shows what percentage of buildings fall into each recovery category. The largest percentage (51%) of buildings in Punta Gorda were damaged by Hurricane Charley and then repaired. The next highest percentage (26%) of buildings were determined by the remote sensing analysis to be undamaged.

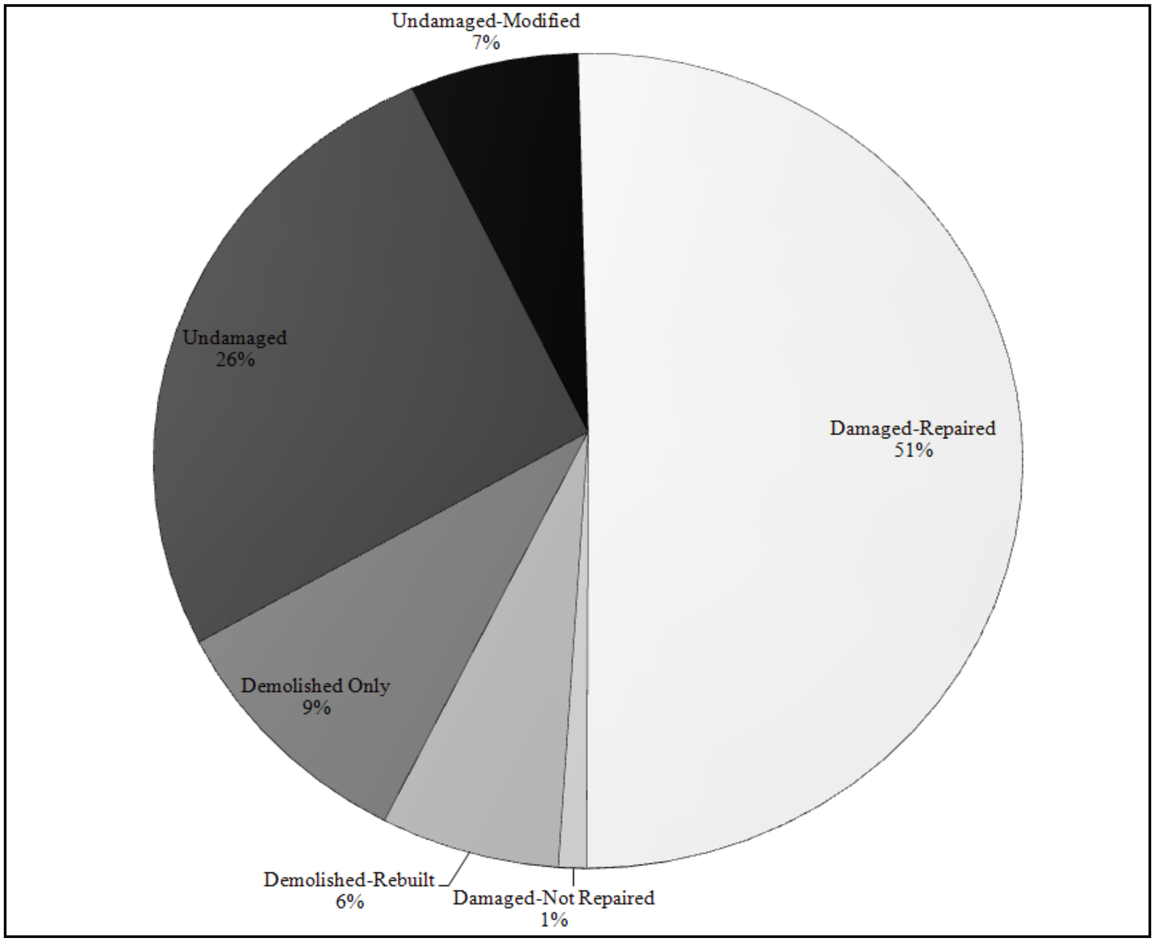


Figure 4.35: Percentage of Buildings in Each Recovery Categories using Remote Sensing

4.5.4.2 Progress of Recovery over Time using Remote Sensing

The remote sensing data was also analyzed at each time step to determine the status of the 5,786 damaged buildings as the recovery progressed, as previously done using building permits in Section 4.5.1.3. This analysis considered the initial damage state determined in the remote sensing analysis then assigned the buildings to a category at each time step based on their associated remote sensing code in January of 2005, 2006, 2007, and 2008. Each building in this analysis was first categorized by its initial damage state. Based on the remote sensing code assigned at the next time step, a building could either remain in its damage state or transition to construction or demolished. Buildings which were classified as construction either transitioned to repaired or remained under construction. Buildings which were demolished could either be rebuilt or remained demolished. The chart in Figure 4.36 shows the breakdown of buildings in each category at the different time steps. This chart shows that the majority (55%) of buildings were under construction after five months. At 17 and 29 month time steps, the construction had decreased and the majority of buildings were repaired. After 41 months, only a small percentage (2%) of buildings were still damaged or under construction and almost all buildings (98%) were either demolished, repaired, or rebuilt. This analysis further shows that after 41 months 75% of the damaged buildings were repaired, while 10% were demolished then rebuilt, and 13% remained demolished.

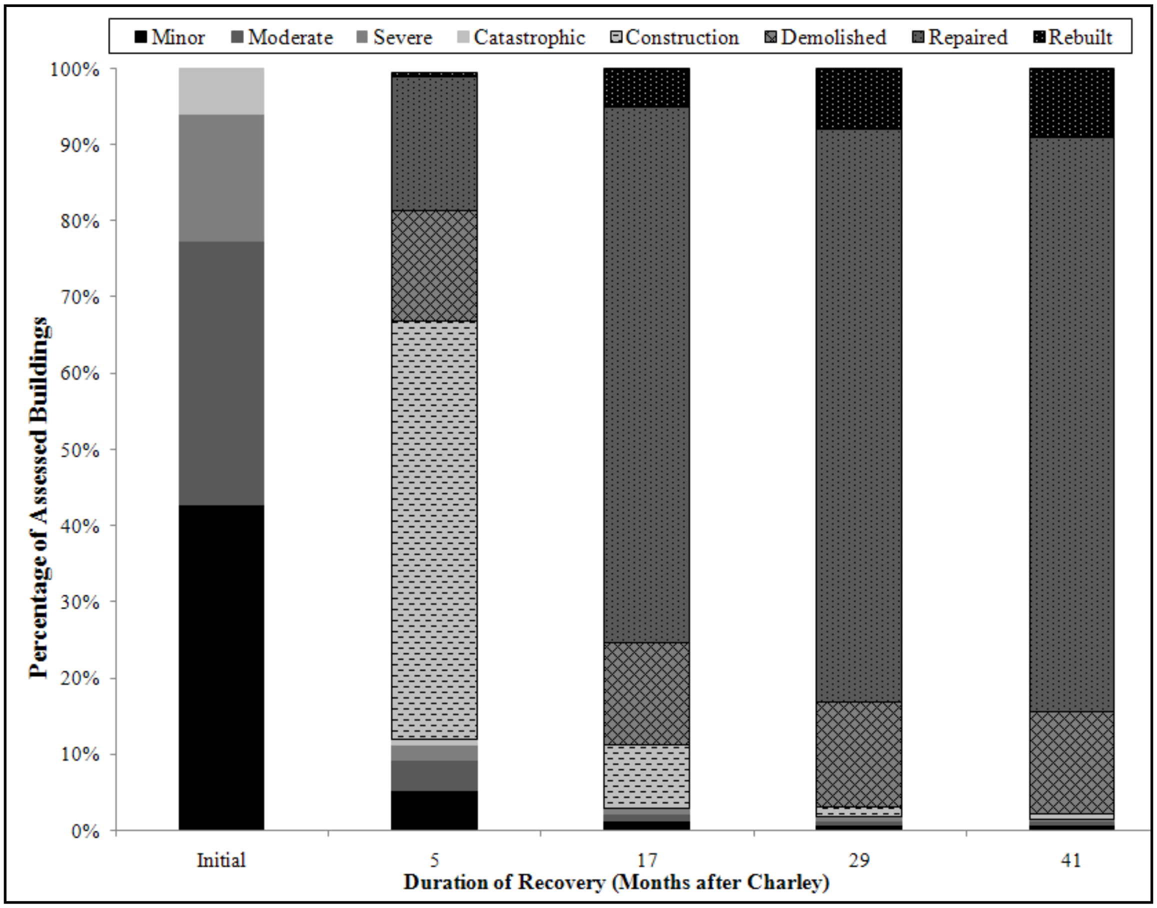


Figure 4.36: Status of Buildings during Hurricane Charley Recovery using Remote Sensing

4.5.5 Census Data for Housing Recovery

The United States census includes data about various characteristics of the housing stock that can potentially be useful in describing the post-disaster recovery of the housing sector, in particular the extent to which the character of the housing stock changes during the course of the recovery. The availability, and therefore the usefulness, of census data depends on which housing characteristics are of interest, and the size of the community. The decennial census has data for many small geographic areas but is only available once every 10 years.

Since 2005, the American Community Survey (ACS) has provided annual estimates for geographic areas with at least 65,000 people, three year estimates for areas with at least 20,000 people, and five-year estimates for areas with at least 20,000 people. The ACS was in its development phase 1996 to 2004, so the geographic coverage was limited during that time (U.S. Census Bureau 2008). While the ACS did not provide annual data from before Hurricane Charley, in future events, it should be useful in providing a full timeline from before and after the event.

For this study, data was collected from the 1990 and 2000 U.S. Decennial Censuses and from the American Community Survey for each year from 2005 to 2008. The attributes of interest that were collected were the occupancy rate, units in structure (e.g., single-family, multi-family), size in terms of number of rooms, tenure (owner- vs. renter-occupied), and percentage of affordable owner- and renter-occupied housing (Table 4.18). Since the data was not available for multiple years since the 2004 hurricane for the city of Punta Gorda, it was collected for Charlotte County, which is also known as the Punta Gorda Metropolitan Statistical Area.

Table 4.18: Selected Census Data for Punta Gorda MSA/Charlotte County, FL

	1990		2000		2005		2006		2007		2008	
HOUSING OCCUPANCY												
Occupied housing units	48,433	75%	63,864	80%	70,838	77%	71,026	74%	70,871	71%	73,937	73%
Vacant housing units	16,208	25%	15,894	20%	20,684	23%	25,034	26%	29,208	29%	27,244	27%
UNITS IN STRUCTURE												
1-unit, detached	41,686	64%	53,539	67%	63,308	69%	65,457	68%	67,521	67%	68,043	67%
1-unit, attached	1,178	2%	1,583	2%	1,421	2%	1,945	2%	2,600	3%	2,039	2%
2 units	1,424	2%	1,383	2%	2,245	2%	1,203	1%	1,910	2%	1,831	2%
3 or 4 units	1,946	3%	1,995	3%	2,755	3%	3,337	3%	3,264	3%	3,568	4%
5 to 9 units	2,898	4%	2,967	4%	4,038	4%	3,461	4%	4,295	4%	4,502	4%
10 to 19 units	2,360	4%	2,161	3%	2,681	3%	3,625	4%	3,642	4%	4,223	4%
20 or more units	2,610	4%	3,990	5%	3,706	4%	3,947	4%	5,319	5%	5,223	5%
Mobile home	10,195	16%	11,611	15%	11,368	12%	12,998	14%	11,528	12%	11,688	12%
Boat, RV, van, etc.	344	1%	529	1%	-	0%	87	0%	-	0%	64	0%
ROOMS												
1 room	569	1%	845	1%	634	1%	-	0%	66	0%	5,814	6%
2 rooms	1,381	2%	1,861	2%	1,195	1%	1,057	1%	1,301	1%	3,636	4%
3 rooms	4,310	7%	5,438	7%	4,295	5%	5,174	5%	3,548	4%	4,356	4%
4 rooms	16,824	26%	16,582	21%	23,948	26%	22,493	23%	23,000	23%	22,384	22%
5 rooms	19,373	30%	24,214	30%	27,510	30%	27,884	29%	30,341	30%	25,406	25%
6 rooms	13,137	20%	17,182	22%	20,374	22%	21,908	23%	25,805	26%	20,077	20%
7 rooms	6,227	10%	8,929	11%	8,452	9%	11,618	12%	10,991	11%	11,501	11%
8 rooms	1,904	3%	3,186	4%	3,301	4%	4,183	4%	3,459	3%	5,752	6%
9 rooms or more	916	1%	1,521	2%	1,813	2%	1,743	2%	1,568	2%	2,255	2%
Median (rooms)	N/A	N/A	5.1		5.1		5.2		5.2		5.1	
HOUSING TENURE												
Owner-occupied	38,559	80%	53,444	84%	60,269	85%	58,912	83%	58,457	82%	57,028	77%
Renter-occupied	9,874	20%	10,420	16%	10,569	15%	12,114	17%	12,414	18%	16,909	23%
UNAFFORDABLE HOUSING UNITS*												
Owner-occupied with mortgage	5,086	32%	8,723	35%	15,057	45%	17,692	51%	17,850	54%	16,961	50%
Owner-occupied without mortga	846	6%	1,535	9%	3,480	13%	3,876	16%	4,251	17%	3,580	16%
Renter-occupied	3,584	36%	3,951	38%	5,415	51%	5,695	47%	6,481	52%	8,430	50%

*Unaffordable means selected monthly owner costs or gross rent are 30% or more of household income.

This data does not suggest that any notable change occurred during the post-Hurricane Charley recovery in the breakdown of Punta Gorda housing units by occupancy, units-in-structure, size (in terms of number of rooms), or tenure (owner- vs. renter-occupied). There is some evidence that the amount of unaffordable housing (houses where selected monthly owner costs or gross rent are 30% or more of household income) may have may have increased following the hurricane (Figure 4.37), but without a longer time series it is difficult to tell if it is simply natural variability or a significant change. In any case, further analysis would be needed to assess whether any change could be attributed to the hurricane.

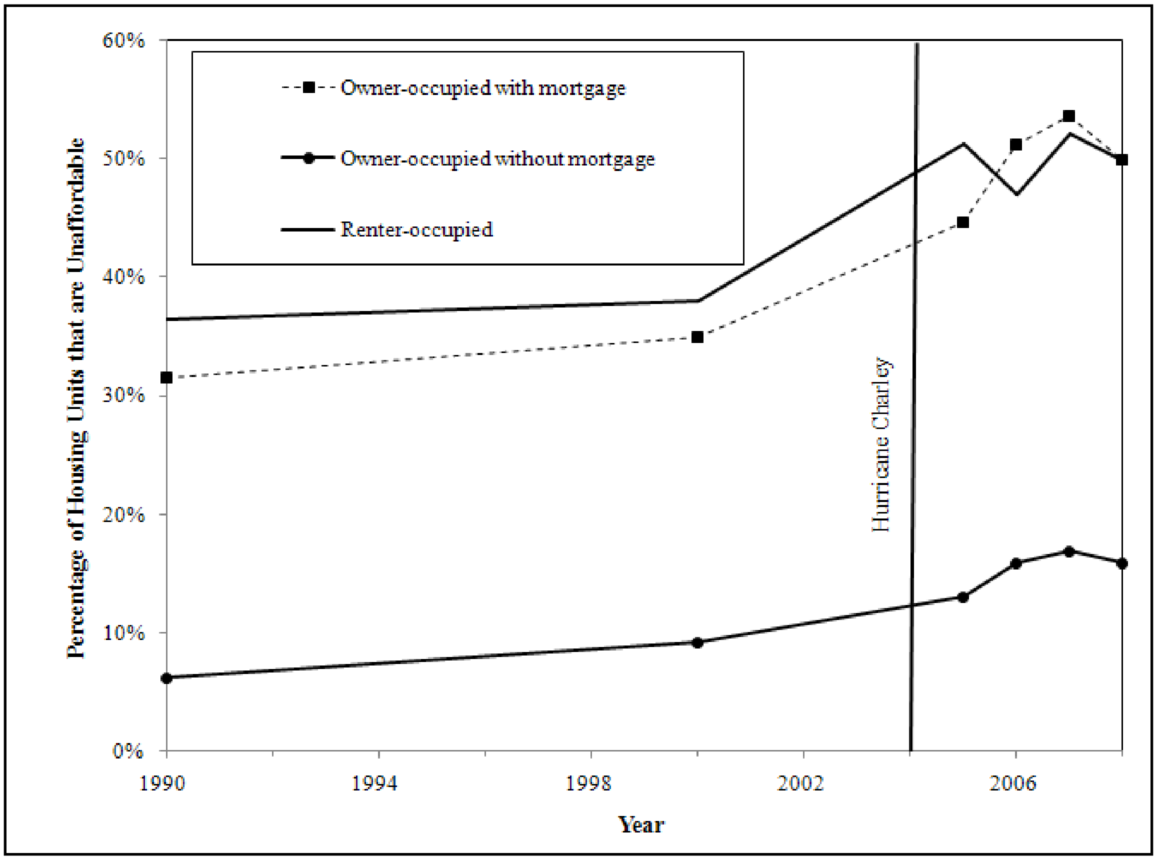


Figure 4.37: Change in Percentage of Unaffordable Housing Units in Punta Gorda MSA over Time

4.5.6 Summary of Housing Recovery Data

The Punta Gorda Building Department building permits provide a helpful overview of the recovery process. They can be used to illustrate the trend of housing as the recovery progressed over time and also show the different end categories of how a particular building could recover. The building permits were used to show the progress of recovery over time using both the Punta Gorda Building Department damage assessments and the remote sensing damage assessments (Section 4.5.1.3). The progress of recovery over time was also shown using the yearly remote sensing data (Section 4.5.4.2).

Figure 4.38 represents when the buildings in each of the three analyses reach their final state. These consist mainly of buildings that have been repaired or rebuilt. To account for those buildings that are demolished and intentionally left demolished, the assumption was made to also include half the demolished buildings at each time step as being in their final state. The solid block line represents the buildings with damage assessments from the Punta Gorda Building Department and building permits, the light gray dotted line represents the buildings with damage assessments from the remote sensing analysis linked to the building permits, and the dark gray dashed line represents the buildings analyzed using the remote sensing analysis. The assessments made using the building permits seem to follow very similar trends. The remote sensing assessment shows the recovery happening slightly faster. One reasonable assumption could be that this occurs because the remote sensing only assesses a house based on an aerial view and cannot see the repairs occurring at ground level. The trend of the remote sensing analysis more closely follows the trend shown by roof permits. As seen in Section 4.5.1, applications for roof permits stopped in 2005, which is consistent with the aerial images depicting a faster recovery. All three analyses though show that in 2007, approximately 85% to 90% of the buildings were in their recovered end state.

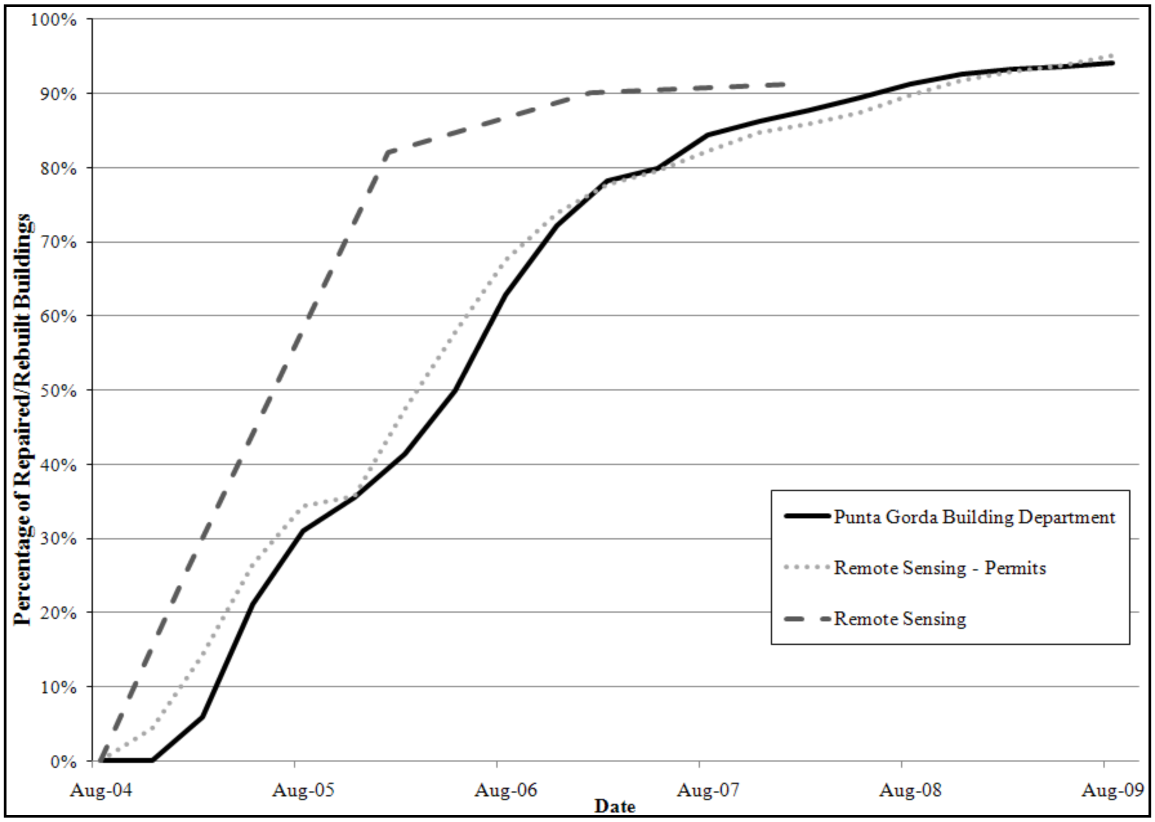


Figure 4.38: Percentage of Buildings in their Recovered State

The building permit data and remote sensing analysis can be used together with the other data sources to show a complete picture of recovery. As discussed in Section 2.2.1, Quarantelli (1982) suggests that recovery occurs in four stages: (1) emergency shelter, (2) temporary shelter, (3) temporary housing, and (4) permanent housing. The data collected for Punta Gorda supports this idea that recovery occurs in phases. The first phase of recovery was the emergency shelter that was used during Hurricane Charley. Information about emergency shelter was provided by FEMA news releases (Section 4.5.3). The next phases of recovery dealt with temporary shelter and housing. FEMA provided data about the travel trailers and mobile homes that they supplied after Hurricane Charley (Section 4.5.3). The blue tarps installed by the USACE to provide temporary roofing (Section 4.5.2) can also be included in the middle phases of recovery. The final stage of recovery is illustrated by the building permit data and remote sensing analysis, which show the processes of demolition, repairs, and new construction needed to get buildings to their permanent state. In Punta Gorda, the miscellaneous permits also included permits for hurricane shutters, which provided evidence of mitigation.

Figure 4.39 illustrates the overall recovery of buildings in Punta Gorda after Hurricane Charley according to the phases. Emergency shelter and temporary roofing installations are shown by short black bars, which represent that these phases occurred immediately after the storm and were over in a short amount of time. The black section of the temporary housing bar shows when 75% of the total number of FEMA travel trailers and mobile homes were in use. The dark gray section illustrates when the last 25% were still in use and the light gray section shows when only 10% of the total number were still in use. This shows that temporary housing was put into place immediately after Hurricane Charley and the majority of these units were no longer active by the beginning of 2006. The building permits were analyzed by looking at permit applications immediately after Hurricane Charley and then determining when the average number of permit applications returned to the same average as during normal activity prior to the disaster. The light gray sections of these bars represent the first and last 10% of permits, the dark gray sections illustrate up to 25% of permits, and the black sections show when the majority (50%) of permits in each phase were requested. Roof repairs occurred first and were finished in 2005. Mobile homes/trailers included both mobile homes where residents lived while their houses were under construction and construction trailers for crew and equipment. The majority of these permits were requested around the spring of 2005. Demolition and repair permits peaked during 2005 and trailed off by the end of 2007. Repair permits include any permits requested for additions and remodels to buildings. The minor repairs in this analysis include carports, windows, screen enclosures, and hurricane shutters. These peak after demolition and repair permits and represent both mitigation and smaller repairs that could be done after the building was in its permanent state. New construction is always occurring so it is harder to analyze. The black section of this bar though, does show that new construction permits peaked later and lasted longer than the demolition and repair permits. Overall, the Figure 4.39 again suggests that the recovery could be considered complete around 2007.

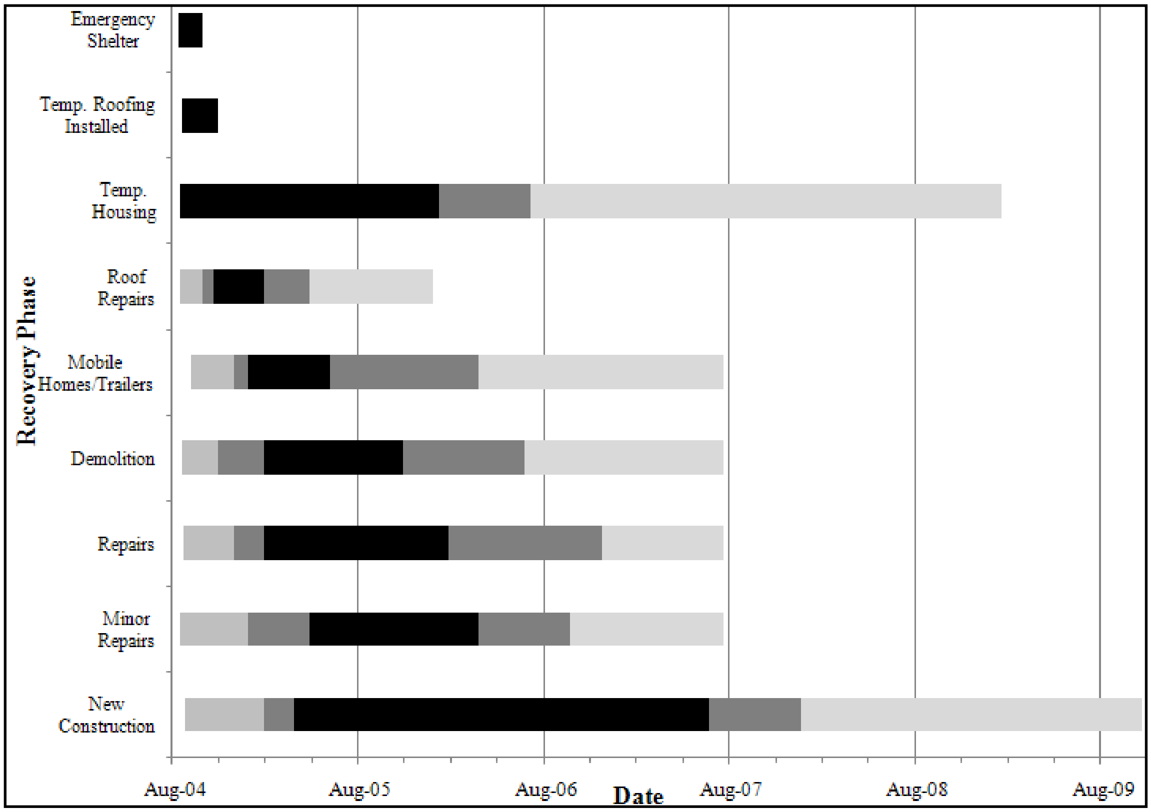


Figure 4.39: Timeline of Recovery Phases

The data suggests that the recovery of buildings was completed around 2007. This analysis is consistent with the information gathered through meetings with local building officials during the January 2010 field deployment to Punta Gorda. Our team conducted two key interviews related to the housing sector, one with the Punta Gorda Building Department and another with the Charlotte County Building Construction Services. These interviews provided personal insight from members of the community who were involved with the housing recovery.

John Smith, the plans examiner for the Punta Gorda Building Department, provided many of the datasets (damage assessments and building permits) discussed in this thesis and also met with team members to answer some of our questions. An important question that asked of John Smith was whether or not he would consider Punta Gorda recovered and, if so, when did he think the recovery ended. Mr. Smith explained that he did consider Punta Gorda to be recovered and felt that the recovery was over around the end of 2007. After that time, the Punta Gorda Building Department was no longer receiving plans for new projects coming into town and the rate of building permit applications was back to pre-disaster levels. Mr. Smith acknowledged that “everything coming down is down and everything being replaced has been replaced”. In his opinion, downtown Punta Gorda was a work in progress before Hurricane Charley and still is undergoing improvements, but looking around Punta Gorda he feels there is no longer evidence of the storm (John Smith, personal communication, January 7, 2010).

Our team also met with Vince LaPorta, the Deputy Building Official at the Charlotte County Building Construction Services. Mr. LaPorta was asked the same question about when and if he felt the community was recovered. Mr. LaPorta also answered that he felt the recovery had ended in late 2007. He explained that there was a feverish peak of construction in 2006 that finally leveled off in 2007. He gauged his idea of recovery by looking at the transformation of Punta Gorda, which was completely decimated after Hurricane Charley. Mr. LaPorta cited the completion of the Events Center in Punta Gorda as a key indication that the recovery had ended because it was such a large project. Both building officials also noted that the recession played a role in leveling off the recovery by not allowing additional new projects. Mr. LaPorta explained that there were “occasional struggles, but overall everything came together” (Vince LaPorta, personal communication, January 6, 2010).

4.6 Comparison of Data Sources and Future Suggestions

This section discusses the various data sources utilized in the Punta Gorda case study, the advantages and disadvantages of each source, and suggestions for collecting data in future case studies. Table 4.19 summarizes the comparison, and each data source is discussed in turn in the subsequent sections.

4.19: Comparison of Data Sources

Data Source	Data Type	Advantages	Disadvantages	Future Suggestions
Punta Gorda Building Department	Damage assessment	• Show severity of damage • Break down houses by components	• Not representative of all buildings • Not just residential	• Consider only residential buildings • Use together with remote sensing
Punta Gorda Building Department	Building permits	• Show types of construction required • Show trend of when construction was required	• Not all damaged buildings had permits • No construction end date • Not just residential	• Require final inspection date • Consider only residential buildings • Use together with remote sensing
ImageCat, Inc. Remote Sensing Analysis	Damage assessment	• Consider every building in Punta Gorda	• Only show aerial view • Not just residential	• Focus on only residential buildings • Use together with building permits
ImageCat, Inc. Remote Sensing Analysis	Yearly assessments	• Consider every building in Punta Gorda	• Time intervals too large • Only show aerial view • Not just residential	• Focus on only residential buildings • Use together with building permits
University of Florida	Damage assessment	• Provide housing background • Only residential	• Only newer houses	• Consider all houses • Use as supplemental data
U.S. Army Corps of Engineers	Temporary roofing analysis	• Show when temporary roofing was installed	• No removal date • Not just Punta Gorda	• Provide both installation and removal dates • Record locations
Federal Emergency Management Agency	Temporary housing data	• Show how long temporary housing was in place	• Not just Punta Gorda • Not just Hurricane Charley	• Track only the specific units of interest

4.6.1 Punta Gorda Building Department

The Punta Gorda Building Department supplied both initial damage assessments (Section 4.4.1) and building permit data (Section 4.5.1). The damage assessments were helpful in illustrating the types and severities of damaged buildings throughout Punta Gorda. An advantage of the damage assessment data is that it breaks down the damage to a building by its components. This provided information on which components of a building were most susceptible to hurricane damage. The disadvantage of this damage data though is that it is not a representative sample of all buildings. Damage assessments were only issued by the Punta Gorda Building Department for those buildings where the cost of damages exceeded 35% of the building value. A damage assessment could also be performed if the property owner specifically requested it. Therefore these damage assessments misrepresent the community as having more damaged buildings because it only records a small number of buildings which were undamaged. The Punta Gorda Building Department damage assessments can provide a general idea of the damage breakdown, but a more thorough source, such as remote sensing, should be used to represent all buildings in the community.

The building permits from the Punta Gorda Building Department played an essential role in developing and applying the housing recovery measure. These building permits were collected from January 2000 through December 2009. When plotted over time, the building permits showed a clear peak in the months following Hurricane Charley. This showed that building permits could be useful in estimating when the majority of the housing recovery occurred, although the percentages cannot be calculated until the recovery is complete and the total number of permits is determined. The building permits were also used in conjunction with damage assessments from both the Punta Gorda Building Department and the remote sensing analysis to show the status of buildings over time. The building permits provide information on the types of permits associated with each building. This information was used to determine the different recovery categories that were possible for the buildings (e.g., damaged – repaired, demolished – rebuilt). It was also used to show the status of the buildings at different time intervals. Building permits were the most useful resource for showing what was actually happening to buildings as the recovery progressed.

The building permit data did still have a few weaknesses though. In our analysis, building permits were linked to buildings from the damage assessments. The building permits associated with the damaged buildings were then assumed to be for construction related to the hurricane. This assumption is reasonable when looking at buildings with a lot of damage that had permits soon after Hurricane Charley. As the permit dates get further away from the disaster or the houses get less damaged though, it becomes more difficult to determine which permits are hurricane related and which are for routine changes in the housing sector. A suggestion for future data collection would be for the Building Department to make a note of the reason for a permit. This way there would be a clear collection of permits issued solely for addressing damages caused by the disaster.

Another disadvantage to the building permits is that they only show the dates when the property owner applied for the permits and when the Punta Gorda Building Department issued the permits. This is helpful in knowing when a permit was needed and when the construction began, but it does not provide any information on when the construction was completed. In the analysis for this thesis, the recovery period was broken into three month intervals and permitted construction was assumed to last during that interval and then finish by the next. This assumption created a recovery time frame that was reasonably close to the information gathered from interviews and other sources, but it has the potential to underestimate the length of the recovery process. During interviews with building officials, it was mentioned that the permit process is not complete until an inspection is performed by the Building Department to approve the new construction. It would be very beneficial if future permit reports could include this final inspection date. Then both the start and end date of construction could be considered and the analysis could depict a much more accurate timeline of the housing recovery.

An additional weakness with the datasets from the Punta Gorda Building Department is that they include all types of buildings. The analyses performed using the damage assessments and building permits did not distinguish which buildings were residential. In future analyses, it would be beneficial to narrow the dataset so that it only includes houses.

4.6.2 ImageCat, Inc. Remote Sensing Analysis

Team members from ImageCat, Inc. performed an analysis on buildings in Punta Gorda using remote sensing. This analysis provided an initial damage assessment (Section 4.4.3) as well as data for January 2005, 2006, 2007, and 2008 (Section 4.5.4). The remote sensing analysis involved a visual inspection of every building in Punta Gorda using either satellite or aerial imagery. The buildings were assigned an initial damage state using satellite images from both one day and six days after Hurricane Charley. This damage assessment provides the most comprehensive breakdown of the locations and severities of damaged buildings in Punta Gorda.

The remote sensing analysis also includes aerial images taken each January from 2005 through 2008. These yearly assessments illustrate the progress of each building after the disaster and can be used to determine the recovery categories to which each building belongs. Again, these assessments are advantageous because they consider every building in Punta Gorda, but the disadvantage is that the time intervals are too large. Only looking at a building once every year, allows for gaps in the recovery process data. The procedure of visually inspecting each building is very time consuming though, and it would not very difficult to perform this analysis at smaller time steps.

Another disadvantage to this remote sensing analysis is that it considers all buildings and does not distinguish which buildings are residential. For future analyses, the buildings can be linked to land usage data that can flesh out a dataset which only considers houses. The biggest weakness of the remote sensing analysis, though, is that it can only base the status of a building on what it is clearly visible from an aerial view. This perspective can sometimes misrepresent the amount of damage or repairs to a building. For this reason, the recovery progress analysis in Figure 4.38 illustrates that recovery progress tracked using remote sensing occurs faster than those using the permit analysis. The remote sensing data more closely resembles the timeline of when roof repairs were completed which shows the weakness of only gauging a building from an aerial view. Therefore, the remote sensing is a useful resource but should also be used in conjunction with other resources, such as building permit data.

4.6.3 University of Florida Damage Assessment

An additional damage assessment was performed by the University of Florida (Section 4.4.2). This damage assessment was very helpful because it provided background information about the housing sector in Punta Gorda. The study supplied a breakdown of housing characteristics such as the typical roof styles on Punta Gorda houses and the most common materials used for sheathing and roof cover. It also noted the number of garage doors, windows, carports, and other frequently damaged components found on Punta Gorda houses. This study did not, however, provide a complete picture of the housing sector in Punta Gorda because its main purpose was to compare the effectiveness of building codes. It looked at houses built between 1994 and 2001 which comply with the Standard Building Code and revisions made after Hurricane Andrew in 1992. It also looked at houses built between 2001 and 2004 that meet the 2001 Florida Building Code. Therefore, this study only considered houses built between 1994 and 2004. The study proved that these two building codes had a huge impact on reducing the amount of damage a house sustained and the results showed that over half of the assessed buildings were undamaged. So this study is not accurate in showing the percentage of damages in Punta Gorda because it only accounts for newer houses and misrepresents the breakdown of damages. Reports, such as the University of Florida study and others mentioned in Section 4.4.4, can be beneficial when used in conjunction with other damage assessments, but do not provide enough information to be used as a main resource.

4.6.4 United States Army Corps of Engineers Roof Analysis

The U.S. Army Corps of Engineers provided data about when blue tarps were installed to provide temporary roofing (Section 4.5.2). This data showed that temporary roofing installations began immediately after Hurricane Charley and were completed within three months. The timeline presented in this analysis is beneficial because it shows that temporary roofing is crucial to the recovery process, but the Army Corps data does not provide any information about when the blue tarps were removed. The roofing data would be much more helpful if it showed both when the blue tarps were installed and when they were removed. Then the analysis could clearly show when houses were transitioning from temporary roofs to permanent roof repairs. Another weakness of this analysis is that it encompasses all houses assisted by the Army Corps after Hurricane Charley and does not acknowledge how many of the blue tarps were installed in just Punta Gorda. It would also be helpful if the locations of these houses were recorded so they could be mapped and linked to the other datasets.

4.6.5 Federal Emergency Management Agency Temporary Housing Data

FEMA provided information about emergency shelters used during Hurricane Charley and the temporary housing they provided during the recovery period (Section 4.5.3). The information about emergency shelters was collected from several FEMA news releases issued after Hurricane Charley. Records of how many shelters were opened and how many evacuees were using them can be helpful in showing when the first phase of recovery ends. The weakness of the emergency shelter records though, is that they include all shelters operating during and after Hurricane Charley rather than those just in Punta Gorda. Another weakness is that the subsequent 2004 hurricanes (Frances, Ivan, and Jeanne) caused an unsteady trend in the decreasing number of evacuees still in shelters after Hurricane Charley.

FEMA also provided data on the number of temporary housing units that were active during the Hurricane Charley recovery. This data shows that the number of active units peaked at the beginning of 2005. It shows that most of the temporary units were no longer needed by 2007 and that only one remained active in January 2009. This temporary housing data is useful in showing the trend of when people were able to move out of temporary housing. Unfortunately, this data is again for all areas affected by Hurricane Charley and does not offer any numbers specifically for Punta Gorda. In future analyses it would also be nice to collect numbers that show when the temporary units became active rather than starting at the peak value.

4.6.6 Future Suggestions

Several data sources were used to create and apply the proposed measure of housing recovery. Overall, this data created a comprehensive analysis of the initial damage and recovery progress of buildings in Punta Gorda after Hurricane Charley. Comparing the various data sources, remote sensing analysis and building permits prove to be the most useful resources. Remote sensing analysis should be used to provide a complete damage assessment for all houses in Punta Gorda. Building permit data should then be used to determine the progress of the housing sector recovery over time.

In future analyses, it is suggested that both of these resources separate out residential buildings so the housing measure can be used considering only houses. It would also be very beneficial if the final inspection date on building permits could be used to determine when the recovery process ended. Other resources should then be used to supplement the analysis performed using the remote sensing and building permit data. This additional data can fill in missing pieces and also confirm the results of the primary analysis.

4.7 Application of Housing Recovery Measure to Punta Gorda, Florida

Based on the data collected, the proposed post-disaster community housing recovery measure was applied to assess the post-Hurricane Charley recovery of Punta Gorda, Florida. This section presents the overall results from that measure and then discusses the methods used to obtain those results.

4.7.1 Punta Gorda Housing Recovery Assessment using Proposed Measure

The Punta Gorda data was used to assess the three dimensions of recovery as presented in Section 3.3. The *Degree of recovery* measure was applied at three month intervals from the time of the hurricane to August 2009, five years (60 months) later. Due to insufficient data, the *Sustainability of recovery* and *Extent of change* measures were applied only after the recovery was deemed complete, in August 2009. Table 4.20

summarizes the assessments of the three dimensions of recovery. Figure 4.40a provides an illustration of the *Degree of recovery* dimension and Figure 4.40b provides a spider plot that shows the end states of the three dimensions together.

Table 4.20: Summary of Punta Gorda Community Housing Recovery Assessments

	Degree of Recovery											Sustainability of Recovery	Extent of Change
Time (months post-event)	0	6	12	18	24	30	36	42	48	54	60	60	60
Recovery assessment	I	II	III	III	IV	V	VII	VII	VII	VII	VII	V	II
Data quality assessment	A	A	A	A	A	A	A	A	A	A	A	B	C

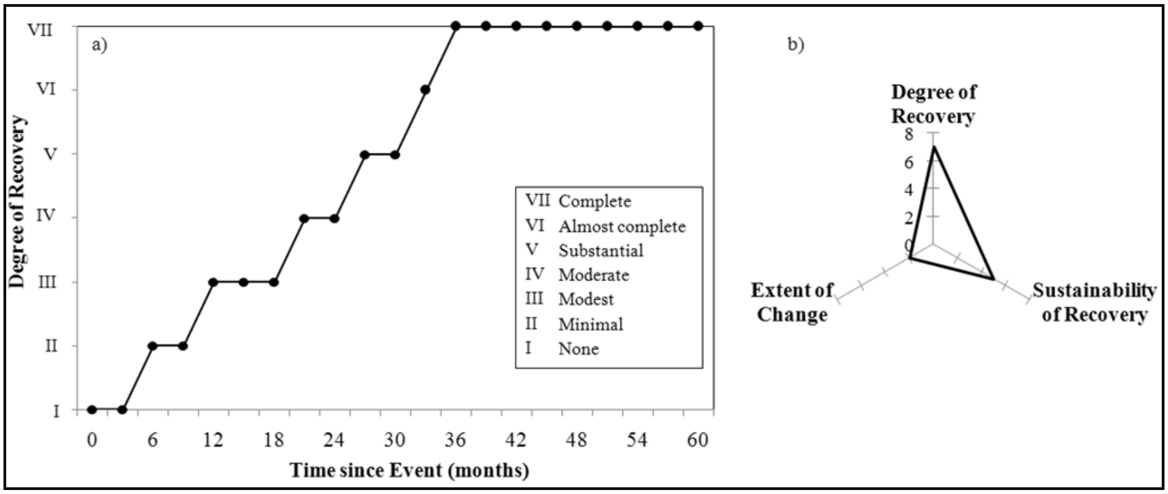


Figure 4.40: Assessments of Recovery in Punta Gorda: a) Degree of Recovery over Time, b) Three Dimensions of Recovery at 60 Months after Hurricane Charley

Figure 4.40a suggests that the housing recovery was complete 3 years (36 months) after the hurricane and that it proceeded steadily until that time. Note, however, that the way the *Degree of recovery* measure is defined is not linear, with more progress required to move from II to III than is required to increase from V to VI (Section 3.3.1). Figure 4.40b indicates that there was little long-term change in the character of the community’s housing as a result of the hurricane and subsequent recovery, and that the recovery was undertaken in a substantially sustainable way. While the measure is an absolute scale and thus should be interpretable on its own, the expectation is that if it were adopted and applied to multiple events and communities, over time, users would develop improved intuition for each level of the measure in each dimension (e.g., how good or bad is a IV in sustainability).

4.7.2 Supporting Data for Degree of Recovery Assessments

The *Degree of recovery* assessments in Section 4.7.1 were based primarily on the timeline of recovery developed using an initial damage assessment from the remote sensing analysis linked with the building permit data. The results of that analysis are summarized in the remote sensing-permits (dotted line) curve in Figure 4.38 and are shown again in Figure 4.41 for convenience.

That analysis integrated the most complete description of the initial damage state for the community as a whole with the most complete timeline of recovery from the building permits. It also maps most directly to the levels defined in the *Degree of recovery* measure. The ordinate at 12 months (August 2005), for example, is 34%, which corresponds directly to a *Degree of recovery* of Modest (III) (Section 3.3.1).

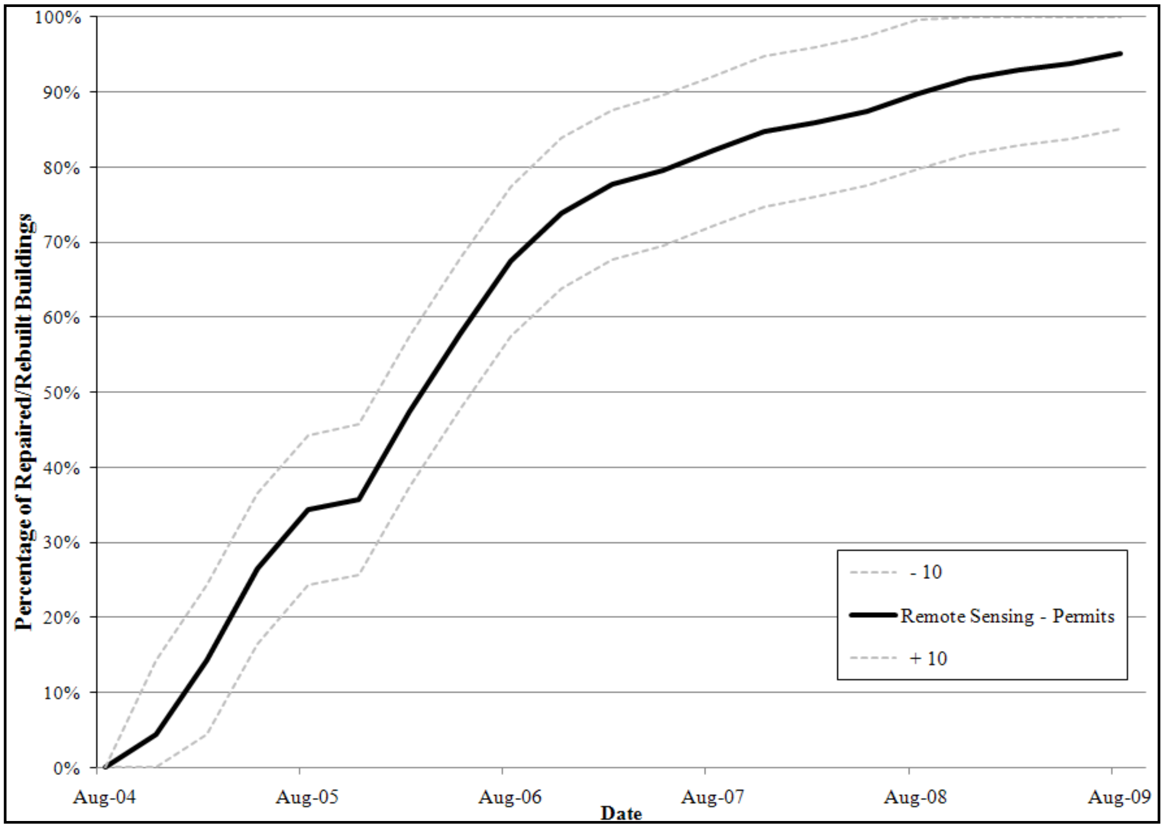


Figure 4.41: Percentage of Damaged Buildings Repaired/Rebuilt, with Approximate Error (+/- 10%)

The results of the remote sensing-permit analysis include various sources of uncertainty and the dashed gray lines in Figure 4.41 are included to highlight that point. As discussed in Section 4.6.1, key sources of error include uncertainty about (1) when the construction associated with a permit is actually complete (only the permit application and issue dates were available), (2) which demolition is intended to be a final state (i.e., the owner is intentionally not rebuilding on a site) versus an intermediate state on the way to reconstruction, and (3) which construction (and permits) are associated with normal, on-going construction versus hurricane-related recovery. The *Degree of recovery* assessments associated with time steps 0 through 33 months were taken directly from the solid line curve in Figure 4.41. For the assessments at 36 to 60 months, values at the higher dashed gray line were used so as to agree more closely with the conclusions drawn from analyses of the number of permits and number of temporary shelters in use vs. time. (Specifically, instead of remaining at Almost complete (VI) until 57 months, it is assumed that Complete (VII) recovery was achieved at 36 months). Figures 4.26, 4.27, and 4.28 suggest that the numbers of roof, mobile home/construction trailer, demolition, addition/remodel, and miscellaneous (screen enclosure, carport, window, and /hurricane shutter) permits peaked following Hurricane Charley, but were back at their pre-Hurricane levels by 36 months after the event. Figure 4.34 indicates that there were no FEMA-issued temporary shelters (travel trailers or mobile homes) still in use after 3 years. The assessment that the housing recovery was essentially complete after 3 years also agrees with subjective assessments made by officials at the Punta Gorda Building Department (John Smith, personal communication, January 6, 2010) and Charlotte County Building Construction Services (Vince LaPorta, personal communication, January 6, 2010). Given the multiple sources of data and the uncertainty in each, it is reasonable to assign a *Degree of recovery* of Complete (VII) at 36 months.

The *Data quality* assessments were made based on the assessors understanding of the data. It was assumed that all *Degree of recovery* measure assessments had the same data quality since they were all made using the same datasets and analyses. Table 4.21 shows the overall data quality for this assessment is determined to be an A.

Table 4.21: Data Quality Assessment for Degree of Recovery Dimension

Component of Data Quality	Assessed Points	Assessment
Completeness	2	High
Accuracy	1	Medium
Consistency	2	High
Overall Data Quality	**A**	**High**

4.7.3 Supporting Data for Sustainability of Recovery Assessments

Table 4.22 summarizes the intermediate assessments used to determine the final *Sustainability of recovery* assessment. An assessment was made using each of the six principles of sustainability and then these assessments were combined to determine the overall sustainability. The following table shows that the overall sustainability of the recovery in Punta Gorda, Florida was determined to be a level V, which corresponds to a substantially sustainable recovery. The data quality is graded as a B though, because much more information should be gathered to support the assessment of this dimension.

Table 4.22: Assessments of Sustainability of Recovery 60 months after Hurricane Charley

Principle of Sustainability	Assessment	Assessed Points	Data Quality Assessment
Participatory process	High	2	B
Quality of life	Moderate	1	C
Economic vitality	Moderate	1	C
Equity	Low	0	C
Environmental quality	High	2	B
Disaster resilience	High	2	A
Overall Sustainability	**Substantial**	**V**	**B**

Uses a participatory process. From meetings with local building officials and residents during the field deployments, it was learned that the community of Punta Gorda bonded together in the months after Hurricane Charley to expedite the immediate recovery. As the recovery progressed, certain groups became more involved in the planning process and others expressed that they felt left out of the decision making. Overall though, the attitude in Punta Gorda was that the community performed very well in their recovery efforts and the majority of people were involved in at least some way. Therefore, Punta Gorda was categorized as high (2). The data quality for this principle was assessed as a B, because interviewees provided opinions directly related to this idea but more information could be gathered to provide a better assessment.

Quality of life. Temporary housing was mentioned in many interviews during the field deployment. FEMA supplied adequate temporary housing through travel trailers and mobile homes. However, these temporary houses were set up in an area that was not convenient for the daily needs of the individuals occupying them. Affordable housing was also provided after Hurricane Charley, but there was not a significant change in the amount. Therefore, this principle is assigned as moderate (1), but much more data should be collected on the subject so it is assigned a C for data quality.

Builds local economic vitality. Punta Gorda has a thriving downtown area where many businesses are located and convenient to the surrounding residential areas. The planning process in Punta Gorda also mentioned the existence of live/work units. Therefore this principle is categorized as moderate (1), but given a C for the lack of information.

Promotes social and intergenerational equity. Meetings with local officials revealed that recovery was uneven between the East and West areas of Punta Gorda. The wealthier families tended to recover much faster. Therefore, this principle is assigned as low (0) and given a C for data quality since the assessment is based solely on interviews.

Protects environmental quality. According to local officials, plans were already in the works to improve parks before Hurricane Charley. After the disaster though, these projects were accelerated and parks in Punta Gorda have seen much improvement. Sonar was used to find debris in canals, so they may be clearer than before Hurricane Charley.

Punta Gorda already featured parks along Charlotte Harbor, where a bicycle/pedestrian trail is currently under construction that will connect the city's parks, neighborhoods, and commercial areas. This principle is assigned a high (2) and given a B for data quality.

Improves disaster resilience. Local building officials expressed that many changes were put in place after Hurricane Charley to strengthen the community against future disasters. Punta Gorda used this disaster as a learning experience and changes were especially significant for improving future recovery efforts. For example, back-up generators were installed in critical buildings, inspectors were provided laptops to reduce the time spent filling out paperwork, and GIS programs can now be used in conjunction with damage maps. Building officials also noted that mitigation was implanted on houses in the forms of impact windows and hurricane shutters. A statewide program called "My Safe Florida" provided grant money to encourage homeowners to mitigate their houses. City ordinances were even relaxed to allow stronger roofing materials, rather than requiring the more aesthetically pleasing tile shingles. Mitigation was also evident in the increase of building permits for installing hurricane shutters (Figure 4.28). Overall, significant efforts were made to improve disaster resilience so this principle is categorized as high (2) and the adequate information from building officials along with permit data earns it an A for data quality.

4.7.4 Supporting Data for Extent of Change as a Result of the Recovery Assessments

The *Extent of change as a result of the recovery* assessment at 60 months was based primarily on the census data discussed in Section 4.5.5, which suggested the possibility that there was a small change in the percentage of affordable housing. The remote sensing analysis also suggested some changes in the housing sector when considering the recovery endpoints discussed in Section 4.5.4.1. This analysis showed that 6% of buildings were demolished and then rebuilt. Using footprint analysis, ImageCat, Inc. determined that 67% of these were rebuilt differently. For the 50% of buildings that were damaged and repaired though, almost 98% were rebuilt the same. Therefore, the *Extent of change as a result of the recovery* in Punta Gorda is categorized as Minimal (II).

The *Data quality* assessments was made based on the completeness, accuracy, and consistency of the data. Table 4.23 shows the data quality for this assessment is considered a C because the data is for the county rather than Punta Gorda and because data before 2004 is missing.

Table 4.23: Data Quality Assessment for Extent of Change as a Result of the Recovery

Component of Data Quality	Assessed Points	Assessment
Completeness	0	Low
Accuracy	1	Low
Consistency	1	Medium
Overall Data Quality	**C**	**Low**

4.7.5 Discussion

This application of the proposed post-disaster housing recovery measure to Punta Gorda, Florida following Hurricane Charley provides a few lessons. It demonstrates that it is possible to gather the necessary data to apply the measure, and that the precision of the measure (seven levels) is reasonable given the data quality one could expect in a U.S. hurricane. Since the data collected for this event was arguably as good as one can reasonably expect and it still includes some uncertainty, it would be extremely difficult to obtain data of sufficient precision to indicate the degree of recovery with higher resolution.

To the extent that the proposed measure is applied to multiple events and communities and by multiple assessors, the measure itself, the data collection process, and interpretation of the measure will likely improve. Future applications could suggest modifications to the measure that were not apparent in Punta Gorda's experience in Hurricane Charley but that might be in another recovery. The data collection process could be streamlined and improved in subsequent applications as well. For example, the Punta Gorda case study suggests some additional questions that could be asked in interviews with building department officials, planners, or others, such as the extent to which the breakdown of housing by various characteristics changed. It also suggests the relative usefulness of different types of data, which could help prioritize data collection in the future. Finally, if the measure is applied repeatedly, users could gradually develop an intuition for what the levels of each dimension mean.

CHAPTER 5 - CONCLUSION

This chapter provides conclusions for the work presented in this thesis. Section 5.1 summarizes the main ideas of the thesis. Section 5.2 discusses future work and how the measure developed in this thesis can be applied to other sectors and case study areas.

5.1 Summary

This thesis focuses on long-term post-disaster community recovery, specifically how it might be quantitatively measured, and challenges associated with doing so. Section 1.2 in the introduction established three objectives for the thesis: (1) Develop a systematic process by which a quantitative measure of post-disaster community recovery can be designed and applied; (2) Develop a prototype community-level measure of post-disaster housing recovery; (3) Apply the housing recovery measure for Punta Gorda, Florida.

The first objective was addressed in Sections 3.1 and 3.3 in Chapter 3. A key contribution from these sections was the strategy table presented in Tables 3.1 through 3.3. This strategy table was used to identify the important issues in designing a recovery measure, the many options for how to address those issues, and how one can think through the decisions to choose among those options. A few of the key decisions presented in the strategy table included determining if the focus should be on physical or functional recovery, choosing which sectors of the community to measure, and deciding how to define when the recovery has ended. This section of the thesis also presented the specific choices that were made for the NSF project by using the strategy table. Furthermore, this section introduced the idea of using indicators (e.g., number of damaged houses) from various data sources to gauge the progress and quality of recovery.

The second objective for this thesis was discussed in Section 3.3. This section utilized the decisions made using the strategy table and the recovery indicators acquired from the data sources to develop a prototype community-level measure of post-disaster recovery. This measure was developed for only the housing sector, but the same framework can be applied to develop measures for the other sectors of the community. The housing recovery framework suggests that recovery be measured along three different dimensions: (1) *Degree of recovery*, (2) *Sustainability of recovery*, and (3) *Extent of change as a result of the recovery*. The *Degree of recovery* dimension should be measured at certain time intervals during the recovery process to gauge how much progress has been made since the disaster. The *Sustainability of recovery* and *Extent of change* dimensions can be measured at these time intervals if enough data has been collected, but they will likely be measured just once at the end.

Chapter 4 of the thesis provides information about Punta Gorda, Florida and applies the proposed housing measure for this area. Punta Gorda was chosen because it is the largest city in and the county seat of Charlotte County, and it was highly damaged by Hurricane Charley in 2004. First, information about Punta Gorda and the housing sector was collected to provide background information about the status of Punta Gorda before

Hurricane Charley. Data was then collected from several sources (e.g., Punta Gorda Building Department, ImageCat, Inc. remote sensing analysis) directly after the disaster and at various time intervals during the recovery process. This data was used to assess the proposed housing measure. The measure was modified slightly during the process to create a version that could be easily interpreted and applied using the available data. The results were presented in Section 4.7 and showed that the recovery of the housing sector in Punta Gorda was complete at approximately the end of 2007. It also showed that the recovery increased the sustainability of Punta Gorda and did not drastically change the characteristics of the community.

Along with addressing the objectives laid out in the introduction, this thesis also presented several key findings from the study. The phases of recovery were refined based on the timeline of the data used in our study. This thesis suggests that the post-hurricane housing recovery in Punta Gorda occurred in seven phases: (1) emergency shelter, (2) temporary roof installation, (3) temporary housing, (4) demolition, (5) new construction, (6) major repairs, and (7) minor repairs. These phases can be related back to the Quarantelli (1982) study which suggested that housing recovery consists of emergency shelter, temporary shelter, temporary housing, and finally permanent housing.

Another key finding in this thesis is that some data sources are more useful than others, but they should all be used in conjunction with each other. The most useful resources were found to be building permit data provided by the Punta Gorda Building Department and the remote sensing analysis performed by ImageCat, Inc. These are the most informative resources, especially when linked, but other data sources can be used to support their findings and provide supplemental materials.

Overall, this thesis showed that developing a measure of long-term, post-disaster, community recovery is a complex task, which requires many difficult decisions. The proposed recovery measure of the housing sector in this thesis may require further modification, but provides an extremely useful first iteration. The framework of this measure allows for a comprehensive analysis of the recovery process and will be easily applicable to the other sectors of the community. Punta Gorda's recovery from Hurricane Charley proved to be a valuable case study and supported the proposed measure.

5.2 Future Work

The proposed measure lends itself to many opportunities for future work. These opportunities for future work relate to both extending the measure and refining it. Future efforts towards extending the measure could suggest modifications to the proposed measure, which could then be used to refine it as necessary.

One essential modification to the proposed measure is extending it to account for the other sectors of the community (e.g., demographics, economy, environment) using the same framework. The concept of measuring the recovery according to three dimensions will be carried over to the other sectors. This extension may reveal revisions that need to be made to the proposed measure. After the revisions are implemented, the updated measure for the other community sectors should be applied to the Punta Gorda recovery. As with the housing measure, Punta Gorda will be used as the case study to test the effectiveness and usability of the measure for the other sectors of community recovery.

Once the proposed housing measure has been extended to the other sectors and has gone through several revisions, it can be applied to another community event. The NSF project discussed in this thesis chose Hurricane Katrina as the second case study for which the measure will be applied. Team members plan to conduct a field deployment to the Gulf Coast where they will collect similar data to that used in Punta Gorda. This data will then be used to apply the proposed measure and determine its usefulness.

If possible, the final measure will be further tested by having multiple individuals make independent assessments using the same data. The purpose of this test is to determine if the individuals apply the measure similarly resulting in the same overall assessments. This will show whether or not the measure is straightforward for users or if it needs more instructions on how to interpret the data and utilize the recovery scales.

Finally, the measure can be extended to account for a broader range of disaster events. The measure developed in this thesis considers only hurricane events and focuses primarily on disasters in the United States. Future efforts could extend the measure to enable it to evaluate the recovery process from other natural disasters (e.g., earthquakes, tornadoes, tsunamis) or man-made disasters (e.g., terrorist attacks, oil spills). The measure could also be used in the future to measure the recovery after international disasters.

The measure developed in this thesis provides a great method for measuring long-term post-disaster community recovery for the housing sector. The next steps will be to apply the proposed measure to the other sectors of the community, to other hurricanes in the U.S., to various types of disasters, and to international disasters. The long-term goal, though, is that this measure will be used to determine the best approaches to post-disaster recovery and help communities to recover stronger and faster after future events.

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