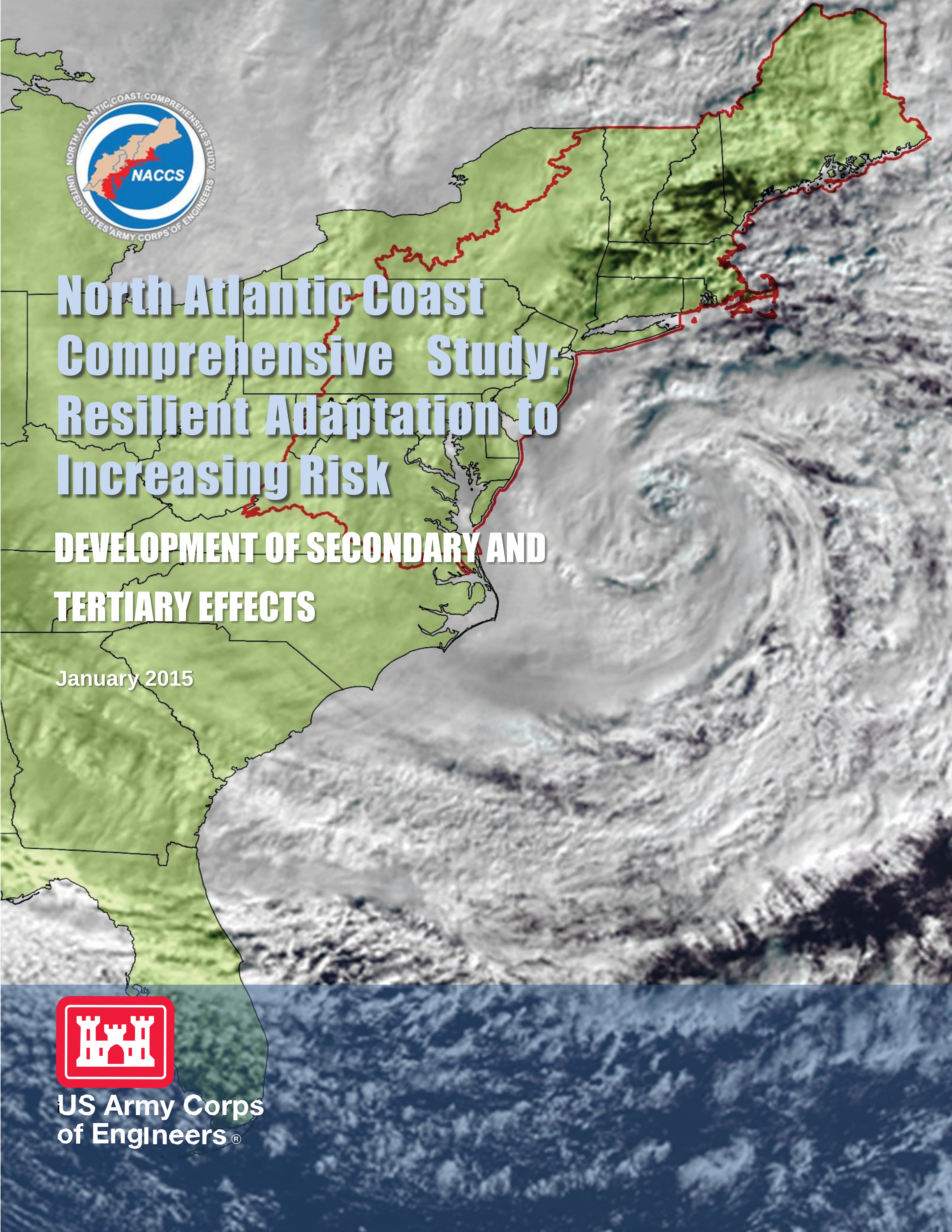

North Atlantic Coast Comprehensive Study: Resilient Adaptation to Increasing Risk

DEVELOPMENT OF SECONDARY AND TERTIARY EFFECTS

January 2015

US Army Corps of Engineers®

NACCS Economic Assessment
Development of Secondary and Tertiary Effects

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North Atlantic Coast Comprehensive Study
Secondary and Tertiary Effects

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1 Introduction

The U.S. Army Corps of Engineers (USACE), North Atlantic Division (NAD) is preparing the North Atlantic Coast Comprehensive Study (NACCS), which is a multi-agency effort to develop strategies that will reduce risk and increase resiliency for populations vulnerable to tidally influenced flooding and storm surge in areas within the boundaries of the USACE NAD.

The economic analysis performed for the NACCS consisted of two parallel efforts. The first effort was to develop a framework (referred to as the Coastal Storm Risk Management Framework) to characterize and compare the risk and vulnerability of coastal populations that is consistent with the direction of the Disaster Relief Appropriations Act, Public Law 113-2 (enacted January 29, 2013). The second effort was to incorporate information on Hurricane Sandy impacts into the procedures planners use to estimate the effects of future events. This study is part of the second effort.

1.1 Background

The economic justification for USACE Coastal Storm Risk Management (CSRM) projects is based on a benefit-cost analysis. The benefit-cost analysis generates the net benefits and benefit-cost ratio for each alternative, which are used to compare alternatives and to estimate the cost effectiveness of an alternative, respectively.

USACE classifies benefits into four accounts: National Economic Development (NED), Regional Economic Development (RED), Environmental Quality (EQ), and Other Social Effects (OSE). Although all of the accounts are taken into consideration when evaluating CSRM alternatives, only the NED benefits are considered when calculating whether an alternative is cost effective and economically justified. As dictated by the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (Water Resources Council 1983), “the Federal objective of water and related land use project planning is to contribute to NED, and such projects are to be formulated to alleviate problems and contribute to this objective.” The Principles and Guidelines defines NED as “increases in the net value of the national output of goods and services.”

When conducting economic evaluations of USACE CSRM alternatives, the primary NED benefits considered are damages avoided to structures, contents, automobiles, and infrastructure and avoided transportation delay costs, as they are relatively easy to measure and monetize. The evaluations sometimes include avoided emergency costs (e.g., debris cleanup, evacuation costs). However, the evaluations rarely include secondary and tertiary effects because they are difficult to measure.

Hurricane Sandy revealed that secondary and tertiary effects can be significant.

1.2 Objective and Purpose

Because they are difficult to measure, USACE economic evaluations rarely include secondary and tertiary effects, which results in an incomplete estimate of storm damages and the benefits of CSRM alternatives. Therefore, the overall goal of this study is to expand the use of secondary and tertiary effects in the NED evaluation of CSRM alternatives. The objective of this study is to develop a method to estimate the secondary and tertiary effects that could be considered for inclusion as part of an NED evaluation.

The purposes of this effort are to:

- Describe the lines of causation that result in secondary and tertiary effects;
- Describe the magnitude of selected secondary effects in terms of extent and intensity;
- Identify methods to quantify significant secondary effects, and
- Suggest approaches for the incorporation of secondary and tertiary effects into the economic evaluation of USACE projects.

1.3 Definition of Secondary and Tertiary Effects

Secondary and tertiary effects have been described in various ways, including:

- "Secondary effects are the changes in economic activity from subsequent rounds of re-spending of tourism dollars." USACE, Economic Impacts Glossary, http://corpslakes.usace.army.mil/employees/economic/glossary.cfm
- "Secondary economic impact is the effect resulting from subsequent rounds of (re-) expenditure of different sectors in the economy." Urban Securipedia, http://securipedia.eu/mediawiki/index.php/Secondary_economic_impact
- Tertiary – "Third in place, order, degree, or rank." The Free Dictionary, http://www.thefreedictionary.com/tertiary
- Secondary – "Of the second rank; not primary." The Free Dictionary, http://www.thefreedictionary.com/secondary

In general, the definitions typically refer to secondary effects as second in order, while tertiary effects are typically defined as third in order. For purposes of this study, a primary effect is an impact on things that the floodwater actually touches (e.g., homes, buildings, factories, roads, vehicles, electric power components); a secondary effect is an impact on things that the water did not touch, but were indirectly impacted as a result of the primary effect (e.g., factories closed due to lack of power or inability of workers to get to work, injuries from clearing debris); and a tertiary effect is an induced impact on things as a result of the secondary effects (e.g., an assembly plant in another State is closed because supplies could not be provided by a factory that was flooded).

As an example, consider a factory that produces specialty automotive parts is significantly damaged and cannot operate as a result of a costal storm event. The primary (direct) effect is the physical damage to the structure and its contents. The primary effects are measured by the cost to repair or replace the damaged components. Because the factory cannot operate, employees cannot work, products cannot be produced, and managerial staff must work with customers to make alternative arrangements. These are the secondary (indirect) effects, which are measured by the impact on the factory's employees and managerial staff. Because the specialty parts cannot be produced, operations at the customer's facilities may also cease even though those facilities received no damage from the event. These are the tertiary (induced) effects, which are measured by impacts on the customer's employees and managerial staff.

The concepts of secondary and tertiary effects can be difficult to understand and often overlap. Although this study is focused on measuring secondary effects, many of the effects that are presented can be considered as secondary or tertiary, depending on how they are realized. Therefore, this study does not always make a distinction between secondary and tertiary effects when estimating the impacts, but simply refers to them as indirect. This approach is consistent with the overall goal of this study to expand the use of secondary and tertiary effects that are not currently being included in NED analyses.

When considering secondary and tertiary effects in the context of NED impacts, USACE guidance requires that the damages must be lost and not simply postponed or transferred to other firms or entities. Following a coastal storm event, many of the damages from secondary and tertiary effects will occur because substitutions and transfers cannot be easily made, leading to a national loss. Therefore, the NED impacts would be expected primarily during the storm and initial response and recovery periods when substitutes are not available. The impacts would diminish during the recovery period as the substitutes are found and businesses become operational.

1.4 Use of this Study

As noted earlier, USACE studies rarely include secondary and tertiary effects in the economic evaluation of CSRM alternatives because of the difficulty in measuring them. Although this study explores ways to expand the use of secondary and tertiary effects by reviewing selected components, it does not provide a comprehensive approach to capture all secondary and tertiary effects. Therefore, this report and the findings should be seen as a step towards full integration of secondary and tertiary effects into NED analyses, not formal guidance that would be accepted through the review process. Until formal guidance is provided, including secondary and tertiary effects in feasibility studies or other decision documents should be discussed with HQUSACE-CECW-PD.

1.5 Study Area

NAD includes five civil works districts: New England, Baltimore, New York, Norfolk, and Philadelphia. This study focuses primarily on the coastal areas of New York and New Jersey that were most significantly impacted by Hurricane Sandy, which are within the geographic limits of the New York and Philadelphia Districts.

2 Overview of Hurricane Sandy Impacts

Hurricane Sandy was one of the deadliest and costliest hurricanes in U.S. history (Blake et al. 2013). Tropical storm winds extended over an area more than 1,000 miles in diameter, with 24 States experiencing a range of storm effects, including wind, rain, flood, coastal surge, and blizzards. Globally, 286 direct and indirect deaths are attributed to Hurricane Sandy, of which 159 were in the United States (Blake et al. 2013). Total property damages in the United States are estimated to be about $65 billion. Power outages caused by flooding or fallen trees impacted approximately 8.5 million customers (Blake et al. 2013).

Most of the damages from Hurricane Sandy occurred along the New York, New Jersey, and Connecticut coasts from wind, waves, and storm tide flooding and also to inland areas that experienced high storm tides and high water levels. For example, a storm surge of 9.4 feet above normal high tide occurred at the southern tip of Manhattan. The number of housing units damaged or destroyed in New York and New Jersey was about 305,000 and 346,000, respectively. Over 6.6 million households and businesses in New Jersey, New York, Pennsylvania, and Connecticut lost power during Hurricane Sandy, many for several weeks.

New York City metropolitan area hospitals were also severely impacted by Hurricane Sandy. Five acute care hospitals and one psychiatric hospital closed, requiring the emergency evacuation of nearly 2,000 patients. New York City hospitals incurred an estimated $1 billion in costs associated with emergency response measures and another $1 billion for repairs and mitigation. Hurricane Sandy also impacted 61 nursing homes and adult care facilities in New York City alone as a result of power outages and/or flooding.

There were also significant impacts on the Port of New York and New Jersey (Wakeman and Miller 2013). Many of the Port's facilities were severely damaged. Although the Port reopened to vessel traffic on November 4 (on the sixth day after the storm passed), numerous port facilities, including the container and oil terminals, did not resume full operations for several weeks because of facility damage and lack of electric power, costing the regional economy billions of dollars (Smith and Katz 2013).

Hurricane Sandy also triggered the worst sustained transportation disruption in U.S. history (Porcari 2013), with mass transit particularly impacted. This included Amtrak service along the Northeast corridor, mass transit systems and commuter lines in Washington, D.C, Baltimore, Philadelphia, New York City and Boston. Motorists experienced gridlock due to closures of bridges and tunnels and the limited mass transit availability. The most severely impacted areas were the New York City metropolitan area and New Jersey. There were also significant disruptions to the petroleum supply networks in the Northeast, which resulted in severe fuel shortages for several weeks.

Hurricane Sandy also triggered significant disruptions in economic activity, including a substantial adverse impact on the local labor market immediately after the storm made landfall. As shown in Figure 1, new claims for unemployment in New York and New Jersey combined had averaged around 35,000 per week prior to Hurricane Sandy. In the first week of November, they jumped above 100,000 per week and remained elevated for another 2 to 3 weeks. Overall, about 160,000 initial unemployment claims filed in the two States during the month of November were related to Hurricane Sandy. After 4 weeks, unemployment claims dropped back to pre-storm levels (Abel et al. 2013).

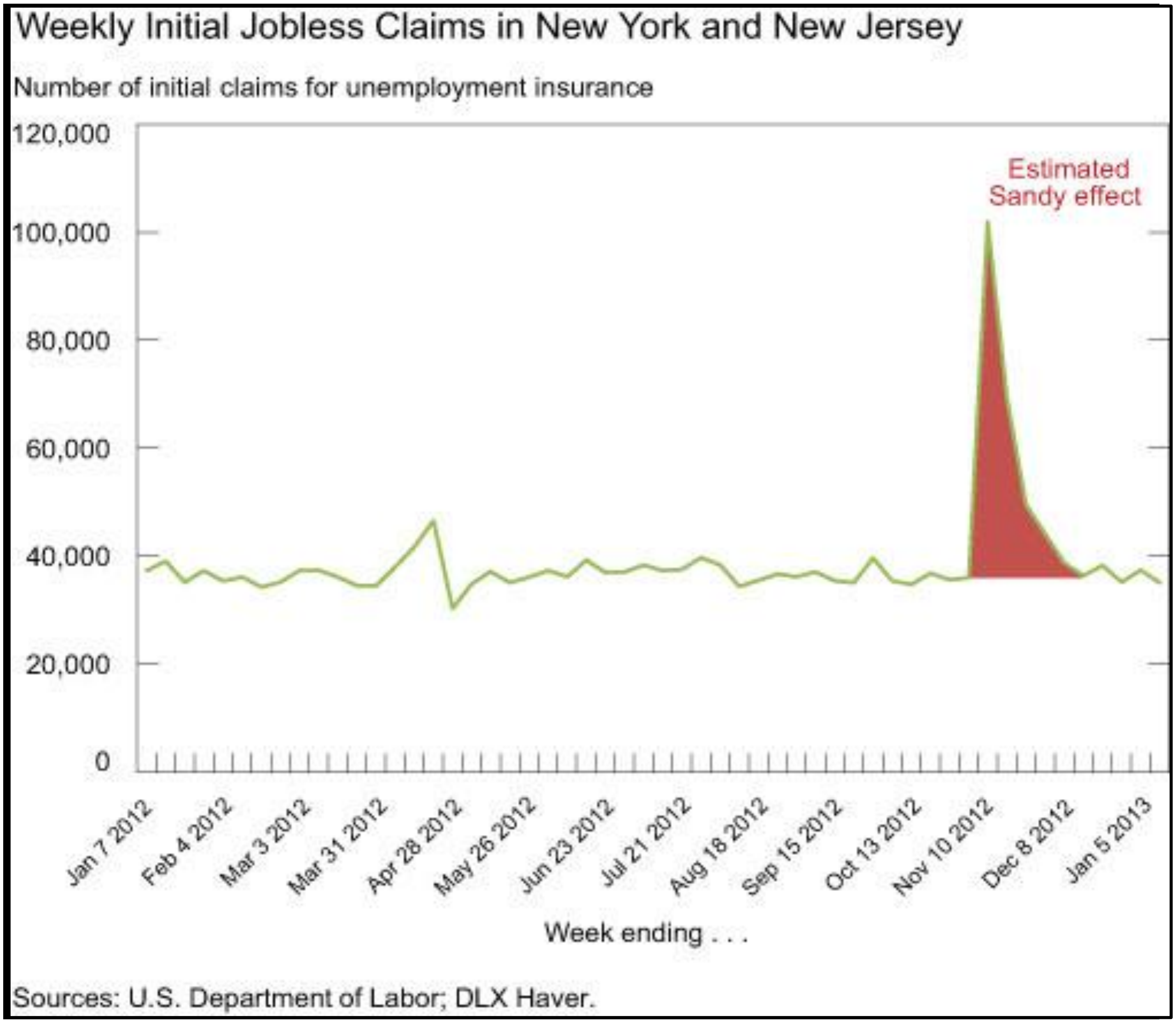

Figure 1. Weekly Initial Jobless Claims in New York and New Jersey (January 2012 to January 2013)

Figure 2 depicts the payroll employment numbers collected from a survey of firms during the second full week in November. The figure shows a loss of 32,000 jobs in the New York City metropolitan area—a significant number, though a good deal lower than suggested by the surge in unemployment claims. The discrepancy suggests that many of the people filing unemployment claims at the beginning of the month may have been back at their jobs, or in other jobs, by the time the payroll employment survey was conducted. Also, while many people suddenly found themselves out of work in the aftermath of Hurricane Sandy, others likely found work created as a consequence of the storm, a development that provided some offset to jobs lost in November (Abel et al. 2013).

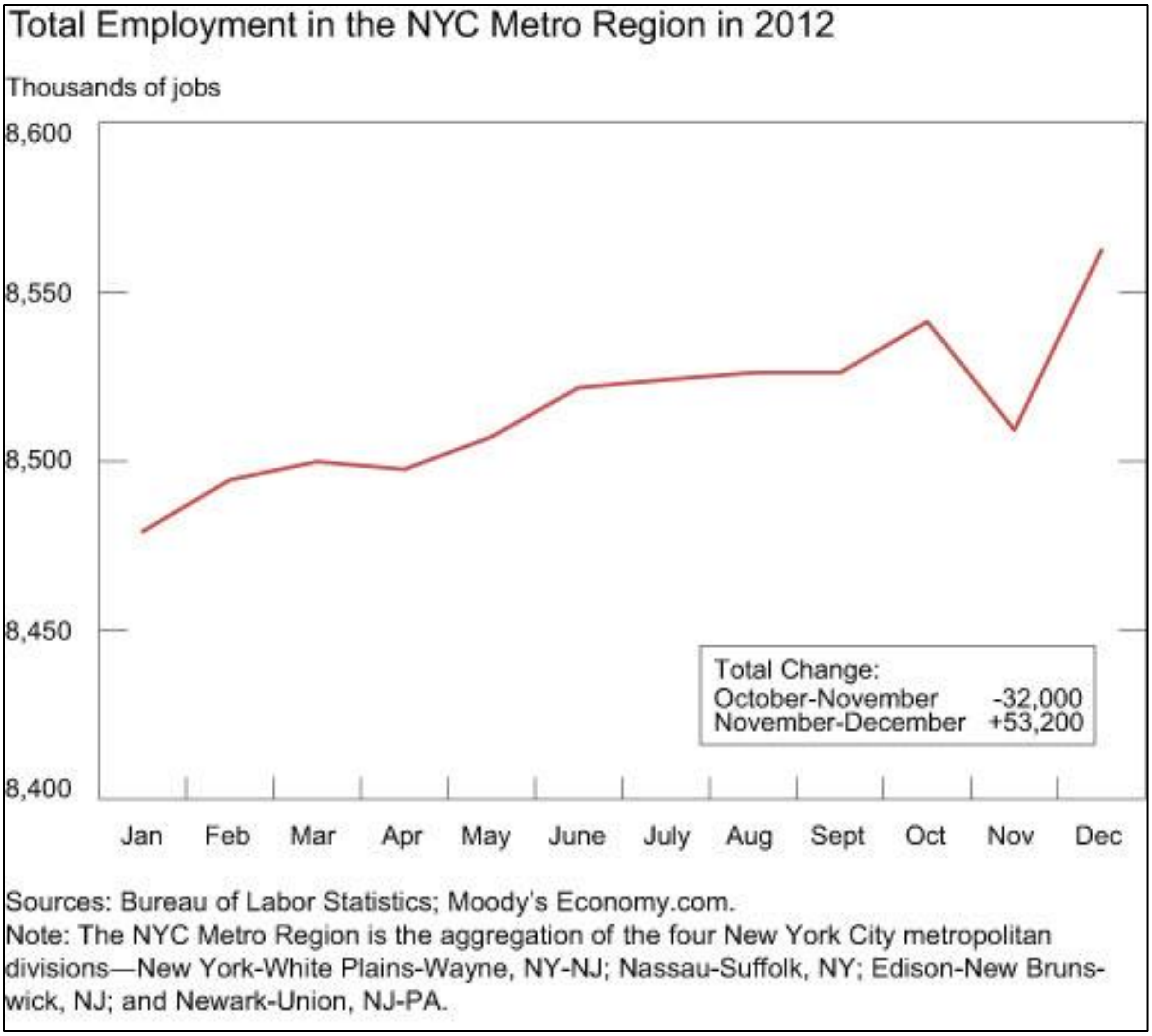

Figure 2. Total Employment in New York City Metropolitan Region (January 2012 to December 2012)

Manufacturing firms represented a sizable portion of the overall number of businesses that were forced to close as a result of the storm. Industrial companies most severely affected faced repairing structural damage, draining floodwater, removing debris, and waiting for power, phone, and Internet restoration. Such delays on the industrial supply chain affected productivity of distributors and storage facilities far from the damaged areas. An estimated 10,000 separate manufacturing facilities were directly affected by Hurricane Sandy. The period of time that facilities lost production varied (U.S. Department of Commerce 2013). Although increased production after the storm made up for some of the forced downtime, additional costs and the loss of labor due to the forced downtime can never be fully recovered.

An estimated 20 percent of the commercial trucking industry was stalled during the week after the storm, with losses of $140 million per day (Diesel Driving Academy News 2012). But the following week, the reductions in freight tonnage recovered and actually increased as demand for freight trucking increased with Hurricane Sandy–related rebuilding (Soloman 2013).

Following Hurricane Sandy, there were significant losses of economic activity in the commercial and recreational fishing industries in New York and New Jersey. The National Oceanic and Atmospheric Administration (2013) reported losses of $105 million in recreational fishing and almost $14 million to the commercial sector in New Jersey. In New York, damages to the recreational and commercial fishing sectors totaled $19 million and $15 million, respectively.

In New Jersey, nearly 19,000 small businesses sustained damages of $250,000 or more with total business losses estimated at $8.3 billion as a result of Hurricane Sandy, about 1.6 percent of New Jersey's Gross State Product in 2012. Although many small businesses were forced to close in the immediate aftermath of the storm, over 80 percent were closed for 2 weeks or less (U.S. Department of Commerce 2013).

One of the most significant economic impacts in New Jersey was to tourism, with an estimated $950 million loss in tourism spending in 2013 and reduced employment by over 11,000 workers (U.S. Department of Commerce 2013).

Mantell et al. (2013) point out that the

> economic pattern that typically accompanies severe natural disasters such as Hurricane Sandy consists of large immediate losses in output, income and employment. This occurs because the immense damage to public infrastructure and the stock of private capital (housing, business structures, and inventory) severely disrupts economic activity. Subsequently, over the next several years, there is a burst of economic growth due to large expenditures on reconstruction and restoration of this capital stock, although the loss in its value is usually never fully compensated by private insurance and public restoration spending.

Mantell et al. (2013) estimated economic losses in New Jersey (not including damages to physical structures) to be approximately $11.7 billion in State gross domestic product. Based on a forecasting model, the State economy is estimated to recover by 2015, assuming $25.1 billion is spent in recovery and reconstruction.

In summary, Hurricane Sandy caused significant direct damage to homes, medical facilities, and other buildings, and also to major infrastructure systems, such as power and mass transportation. This damage resulted in a significant drop in economic activity over large portions of the New York and New Jersey region and also contributed to secondary and tertiary economic effects that have been largely unmeasured.

3 Selection of Community Sectors

A coastal storm event can impact communities in many different ways, and these impacts are often difficult to differentiate between NED, RED, EQ, and OSE, as any given impact may affect multiple accounts. As discussed in Section 1, the objective of this effort was to develop a method to estimate the secondary and tertiary effects that could be included as part of the NED analysis of CSRM alternatives. To accomplish this, five community sectors representing broad aspects of a community were selected to provide a basis to frame the evaluation of the secondary and tertiary effects. Because the secondary and tertiary effects were not evaluated for all sectors, this study should be considered an initial step into the analysis of the NED impacts of secondary and tertiary effects.

3.1 Initial List of Community Sectors

An initial list of community sectors representing different aspects of the economy and community was developed through research on Hurricane Sandy as presented in news reports, academic or government research, and the *Operational Group Sandy Technical Progress Report* (U.S. Department of the Interior 2013), as well as discussions with local stakeholders and government officials.

The initial list of community sectors included:

- Labor market
- Health
- Mental health
- Tourism
- Tax revenue (local sales, income and property taxes)
- Recreation boating
- Rental housing market
- General recreation
- Education
- Commercial and recreational fishing (e.g., shell fish harvests)

3.2 Selected Community Sectors

Following review and discussions of the initial list among the NACCS team the list of community sectors was revised significantly. Although the revised list is not all inclusive, it provided a basis for selecting representative effects to study. The revised list comprised:

- Manufacturing

- Retail activity
- Tourism
- Commercial fishing / shell fishing
- Professional services
- Municipal Services
- Education
- General recreation
- Physical health
- Mental health
- Housing market

Initial assessments of the potential effects on these sectors led to the selection of the community sectors to be studied further. In addition to being relevant to NED, the NACCS team considered whether the effects would be relatively easy to define by experts and would represent a range of impacts. The intent was to identify the community sectors that might offer the greatest likelihood of yielding measurable secondary and tertiary effects. Table 1 identifies the five community sectors selected for further study and briefly describes the selection process.

Table 1. Selection of Community Sectors

Carried Forward	Sector	Notes
X	Manufacturing	Impacts described in literature, so basis for reference and comparison
X	Retail activity	Impacts described in literature, so basis for reference and comparison
	Tourism	Unlikely that a USACE CSRM alternative would provide many benefits or the perception of a loss by others
	Commercial fishing / shell fishing	Unlikely that a USACE CSRM alternative would provide many benefits
	Professional Services	Impacts not well described in literature, so little basis for reference or comparison
X	Municipal functions	Municipal functions can be defined by city managers, so impacts can be focused
	Education	Impacts are usually quickly mitigated through emergency measures, such as temporary classrooms
	General recreation	Can be difficult to define and separate from other municipal functions

Carried Forward	Sector	Notes
X	Physical health	Impacts described in literature, so basis for reference and comparison
X	Mental health	Impacts described in literature, so basis for reference and comparison
	Housing market	Impacts well defined, but may be difficult to separate from RED

Table 2 describes basic characteristics of the community sectors, examples of primary effects on the sector, and examples of how the secondary and tertiary effects of the sectors relate to NED. The NED Focus column is intended to focus the initial discussions with the experts.

Table 2. Description of Selected Community Sectors

Sector	Description	Primary Effect	Causation	NED Focus
Manufacturing	Impacts to manufacturing output in study area	Electrical system damaged, facilities damaged, roads damaged	Lack of power, employees unable to get to work, lack of supplies	Increased administrative costs, increased transportation costs
Retail Activity	Impacts to retail activity in study area	Electrical system damaged, facilities damaged, roads damaged	Lack of power, employees unable to get to work, unable to obtain supplies	Increased administrative costs, burden to public
Municipal Functions	Impacts to level of municipal service	Public facilities destroyed/damaged	No facilities available, employees work efforts redirected	Services not provided
Physical Health	Impacts to physical health	Health care facilities damaged/destroyed, roads damaged	Indirect storm injuries, patients unable to received regular treatment	Increased costs for medical treatment, reduced productivity
Mental Health	Impacts to mental health	Damage to treatment facilities, damage to homes	Anxiety of dealing with damages, fear of event recurring, disruption in daily patterns	Increased costs for medical treatment, reduced productivity

4 Data Collection

Data collection for this study consisted of a literature review and discussions with experts. One objective of the review and the discussions was to identify which observable variables might be used to measure secondary and tertiary effects.

4.1 Literature Review

A review of literature was conducted throughout the study to identify potential secondary and tertiary effects of the selected categories. The literature review involved reviewing news articles, journal articles, trade publications, and government reports. Pertinent information from the articles was recorded for use in describing the impacts for each of the categories.

Although extensive information was found on the impacts and damage caused by Hurricane Sandy, few research-based studies (e.g., journal articles) were available. These studies were still in the data collection phase and had not been published. In addition, much of the Hurricane Sandy literature provided only qualitative descriptions or broad-brush analyses of the impacts, not necessarily the data needed to quantify the impacts.

Literature on other hurricane events (e.g., Hurricane Katrina) was more complete. Results from these studies were used to inform the NACCS team of potential lines of causation of impacts and to assist in developing values.

The authors of relevant articles were contacted to determine whether they could provide additional information that may not have been included in the articles. These discussions often led to the authors providing the names of other people whom they felt were in a better position to assist in estimating the monetary damages related to secondary and tertiary effects.

Findings from the literature review are incorporated throughout the report.

4.2 Expert Interviews

This section defines and describes the methods used to identify potential experts to participate in the study.

4.2.1 Identification of Experts

To gather the necessary data to represent all five sectors, a list of potential experts was developed. The initial list of experts was compiled using news articles, studies, reports focusing on Hurricane Sandy, archival literature, scholarly journals, and references from knowledgeable professionals, technical societies, and governmental organizations. The target number of experts to interview for each sector was three.

Experts who best represented each sector were targeted for participation. Additional contacts for the sectors were solicited during initial calls and during interviews, as well as from contacts developed through other studies, such as the Emergency Cost study conducted as part of the

NACCS. The resulting selection was intended to maintain a balanced and broad spectrum of technical viewpoints, expertise, and organizational representation.

Once experts were identified, they were contacted via phone or email to solicit their participation in the study. If an expert agreed to move forward with the interview, an initial conference call was scheduled with NACCS team members. Contacts who did not agree to participate in the interview were asked whether they knew of another expert who might be willing to participate in the study.

4.2.2 Questionnaire Development

Because of the broad nature of the topic, a general list of questions was developed for each sector. The questions were primarily open-ended to encourage the experts to discuss a broad range of ideas and bring forward effects that may not have been identified previously.

4.2.3 Discussions with Experts

Discussions with the experts focused on:

- Determining the relationships between factors, pathways, and secondary and tertiary effects;
- Attributing costs from Hurricane Sandy to various causes;
- Determining how damage estimates can be evaluated and monetized;
    - Defining criteria to measure the impact being evaluated (e.g., population impacted, type of impact, duration of impact);
    - Determining metrics for evaluation of the criteria (e.g., $/person, $/facility, ratio based on total structure/content damages);
- Scaling the impacts and identifying a threshold for scaling (e.g., population impacted, number of facilities impacted); and
- Determining appropriateness of results for use in other areas.

Table 3 lists the experts who were interviewed. Appendix A provides a summary of the interviews, and findings are incorporated throughout the report.

Table 3. List of Experts Interviewed

Sector	Expert(s)	Date
Mental/Physical Health	Rachel Pruchno, PhD, Director of Research at the New Jersey Institute for Successful Aging, and Endowed Professor of Medicine at Rowan University's School of Osteopathic Medicine	18 Sep 2014
Mental/Physical Health	Dr. Emanuela Taioli and Dr. Rebecca Schwartz, North Shore Long Island Jewish Hospital, Principal Investigators, Project Light (Centers for Disease Control and Prevention funded)	22 Sep 2014
Mental/Physical Health	David Abramson, PhD, Deputy Director, Columbia University's National Center for Disaster Preparedness and Donna Van Alst, Director of the Office of Research and Evaluation at the Institute for Families, Rutgers School of Social Work	10 Oct 2014
Mental/Physical Health	Dr. Jeanne Hurlbert, Sociologist, Optinet Resources	16 Oct 2014
Municipal Functions	Dr. Tom Dallessio, Professor, New Jersey Institute of Technology (NJIT) and Deane Evans, Professor, NJIT	17 Oct 2014
Manufacturing/Retail Activity	Dr. Thomas Wakeman, Professor, Stevens Institute of Technology Dr. Jon Miller, Professor, Stevens Institute of Technology	23 Oct 2014
Manufacturing/Retail Activity	Jerry Von Dohlen, President, Port Newark Refrigerated Warehouses	24 Oct 2014
Manufacturing/Retail Activity	Alan Haveson, President, New Jersey Technology and Manufacturing Association and former owner and President, Lee Controls Inc., Piscataway, NJ	14 Nov 2014

5 Measurement of Secondary and Tertiary Effects

Components of NED impacts related to the community sectors identified in Section 3 were identified to assist in the overall measurement of the secondary and tertiary effects. Four general components were identified: increased costs, inefficient use of resources, loss of services, and losses to the labor market. These components capture different NED impacts and, depending on the nature of the secondary and tertiary effects in relation to the community sector, can be used together to estimate the full impact of the secondary and tertiary effects.

5.1 Increased costs

The increased costs component captures the treatment of indirect physical and mental health injuries and illnesses that would not be incurred if the direct damages from a storm event had not occurred. The indirect injuries resulting in increased costs include:

- Treatment costs for stress and anxiety;
- Medical expenses associated with injuries from debris clean-up;
- Increased treatment costs because of delays in providing care;
- Treatment for carbon monoxide poisoning; and
- Lack of availability of treatment for pre-existing conditions.

Indirect injuries are the result of dealing with the consequences of a storm event. Although direct injuries related to a storm event can be minimized through evacuation, the consequences of the storm event still need to be addressed, such as clearing debris and relocating your family. Addressing these consequences can result in physical or mental injuries. These indirect injuries may require treatment to resolve, which increases the overall cost of a storm. These costs are not currently captured in USACE studies, but they are an NED damage that could be reduced through CSRM projects. Although many of these injuries would be incurred and treated during the recovery process, some may have longer lasting effects.

The increased costs component was used to measure the secondary and tertiary effects of the physical health and mental health community sectors.

5.2 Inefficient use of resources

The inefficient use of resources component captures redirected labor and costs that would not be incurred if the direct damages from a storm event had not occurred. The labor and costs associated with inefficient use of resources include:

- Managerial efforts to rearrange shipments to customers;
- Managerial efforts to rearrange employee schedules; and
- Increased trucking costs to receive products from non-damaged suppliers.

Although direct damages to facilities are routinely captured as part of CSRM studies, the labor and costs for addressing the indirect impacts to the business are not estimated. The labor and costs are associated with maintaining client relations and ensuring that a business can continue to function when the facility/business is operational. Often, the role of maintaining this business continuity falls on the managerial staff and is in addition to their normal duties. These indirect costs (including labor) apply to facilities that were directly impacted by a storm and also their network of suppliers and customers. For example, if a facility is directly damaged and cannot provide products to a client, the client must expend effort to find a new supplier of the product, which may cost more because it is being transported from further away. These labor losses and costs would not have occurred if the storm event had not damaged a facility. Therefore, it is an inefficient use of resources and an NED impact.

The inefficient use of resources component was used for analysis of the manufacturing and retail activity community sectors.

5.3 Loss of Services

The loss of services component captures the indirect losses that were paid for, but are no longer available because of direct damage to a facility or institution. Indirect losses associated with loss of services include:

- A town government is not available because the town hall was damaged;
- City parks and recreational facilities are not available because town staff are redirected to clean-up efforts;
- Fire service is delayed because firefighter efforts are redirected;
- School is closed because of damage; and
- Library is closed because of damage.

The public services provided to residents of a community are primarily supported through property and income taxes. The taxes residents pay and the level of public services that they receive are typically controlled through elected city officials or voter initiatives, which underscores the strong correlation between taxes and the amount of services provided to residents. Therefore, residents make a conscious choice to accept paying higher taxes for an increased level of service, basically their willingness-to-pay for the level of service received. This willingness-to-pay for level of service concept is supported by Glaser and Hildreth (1999), who found that the willingness of citizens to pay taxes in order for a community to run sufficiently is linked to the citizens' view of the community; so, there is a direct correlation between performance assessments and willingness-to-pay. This is similar to USACE recreation studies that use willingness-to-pay as a method for estimating the benefits of a recreation measure.

Following a storm event, the level of public services that residents have elected for their community is reduced because facilities are damaged and/or municipal employees are redirected to recovery efforts. Therefore, residents have paid for services that they are not receiving. Their willingness-to-pay for services not received is an NED impact.

The loss of services component was used for analysis of the municipal services community sector.

5.4 Losses to the Labor Market

Losses to the labor market component capture the loss to the Nation of labor that is forced to be idle or required to perform less productive tasks. These losses are the result of people not being able to perform their jobs for any number of reasons, including:

- Facility is damaged and employees cannot work;
- Facility is closed because of loss of power;
- Facility is unable to operate due to lack of product or supplies;
- Employees are unable to get to work because transportation is not available;
- Employees are displaced from their homes;
- Employees must stay home to care for children care because schools and/or daycares are closed; and
- Employees' efforts are redirected to sub-optimal tasks.

The USACE adheres to the concept that in an open and competitive marketplace, goods and services can be freely traded and the loss of one provider would not change the value of the good or service because other providers are available (i.e., substitutes). However, because storm events occur relatively quickly and the extent of the resulting damages is not known, there is often not enough time to make adequate adjustments to continue the unimpeded provision of the goods and services. In addition, Hurricane Sandy revealed the interconnectedness and complexity of economic relations, which is the consequence of increasing levels of specialization and division of labor. Because of these factors, substitutes may not be immediately available, resulting in a reduction in productive labor immediately following a storm event.

Goods and services can be recouped over time, but not without considerable effort on the part of people impacted by the event and/or people located in other parts of the county. Therefore, losses to the labor market represent labor that is lost to the country and cannot be recovered, which is an NED impact.

The degree of the NED impacts for losses to the labor market increases with the degree of the consequences of the storm event (i.e., the more catastrophic the storm event, the greater the NED impacts for losses to the labor market in relation to the overall direct damages). This is a result of the interconnectedness of the economy (e.g., one company relies on the products of another company) and the greater the impacts to major infrastructure systems that would prevent movement of goods and employees. As the storm consequences increase, the further the impacts are felt from the area of direct damage because there is the potential for more suppliers, employees, and clients to be impacted. For example, a storm event that has relatively few consequences can still cause damages to infrastructure and companies, but the economy is better able to quickly recover or identify substitutes than would be the case in a larger storm event. Therefore, NED impacts for losses to the labor market are short-lived. Whereas, a storm event that has relatively large consequences causes greater damage to infrastructure and companies. In these situations, companies outside of the inundation area may be idle because suppliers and vendors are damaged and unable to deliver supplies or receive goods, employees' homes are damaged or they cannot get to work, or there is a lack of power to operate the facility. For a large storm event, it takes longer for the economy to absorb/recover, and the NED impacts are greater.

Losses to the labor market should be distinguished between employees that are forced to be idle (e.g., stay at home) and those who arrive at their place of employment but their efforts are redirected towards less productive tasks, such as debris cleanup. The effort for debris cleanup is captured in the USACE direct damage estimates, but the losses to the labor market would be the incremental value of labor between the redirected efforts and full productivity. In addition, people who stay home often perform other activities during the recovery phase of a storm, such as home repairs and clearing debris to ensure that essential needs are met (e.g., heat, food, water). Although they are working, the labor is a sub-optimal substitute for full production.

NED impacts associated with losses in the labor market are realized until the business operations are fully functioning again or the efforts transferred. Although the losses to the labor market may be significant following an event, these impacts diminish during the recovery period.

The losses to the labor market component were used for analysis of all of the community sectors considered for this study.

6 Analysis of Secondary and Tertiary Effects

One key to understanding secondary and tertiary effects for each community sector is to identify the impact pathways. This includes understanding the physical forces that cause impacts, the primary effects themselves, and the various pathways that cause the secondary and tertiary effects. Coastal storms, such as Hurricane Sandy, have been associated with the following physical forces: storm surge flooding, riverine flooding due to high rainfall, wave, shoreline erosion, and high winds. Some impacts may be associated with more than one physical force type. For instance, power may be lost as a result of storm surge damaging substations, erosion undermining distribution systems, or wind damage to distribution systems. CSRM planning must consider the interrelationship of these different storm physical forces and pathways. Pathway diagrams depict the relationships between the initial physical or environmental force through the primary effects to the secondary and tertiary effects for each of the selected community sectors.

The factors that contribute to secondary and tertiary effects for each of the selected community sectors are graphically displayed in the sections that follow with the connections between physical force type (storm surge flooding, riverine flooding, wave, shoreline erosion, and wind damage); the primary effects to major infrastructure systems (power, transportation, water, wastewater, telecommunications, etc.), buildings (homes businesses, factories, medical and government facilities, etc.), and vehicles (private, commercial, emergency, etc.); and direct impacts to people (injuries, evacuations, etc.). These factors lead to the secondary and tertiary effects as discussed in Section 5 that result in economic or social impacts. For example, people may be unable to work as a result of many direct impacts, such as the subway was not working (as a result of flooding or power loss), the place of business was closed (as a result of flooding or power loss), or the employee's residence was damaged (as a result of flooding), or as a result of secondary pathways, such as the schools or daycare being closed (because of damage or lack of staff). In addition to graphic pathways, the results are presented in a table format with discussion on how the factors were identified and any other qualitative information that may help in determining relationships between the factors.

The following sections provide a discussion of the five community sectors that were selected for analysis. For each community sector, pathway diagrams illustrate the impacts and identify the NED impact components. The nature of the NED impact components are described and methods for estimating the economic effects are presented.

6.1 Physical Health

Impacts to physical health occur when health care facilities are not able to operate or operate at a reduced capacity because of the impacts of a storm event.

6.1.1 Literature Review and Discussion of Pathways

Figure 3 shows the breakdown of causes of death for the 109 deaths in the New York City metropolitan area attributed to Hurricane Sandy (Daniel 2012). The majority of deaths occurred as a result of drowning in homes and cars, followed by trees falling and falls, which were mostly to senior citizens, that were associated with lack of light due to power outages. Nine deaths were due to carbon monoxide poisoning after people left their generators running indoors. The "other" deaths resulted from electrocution, debris crashing into people, and not receiving medical aid fast enough to prevent loss of blood or oxygen.

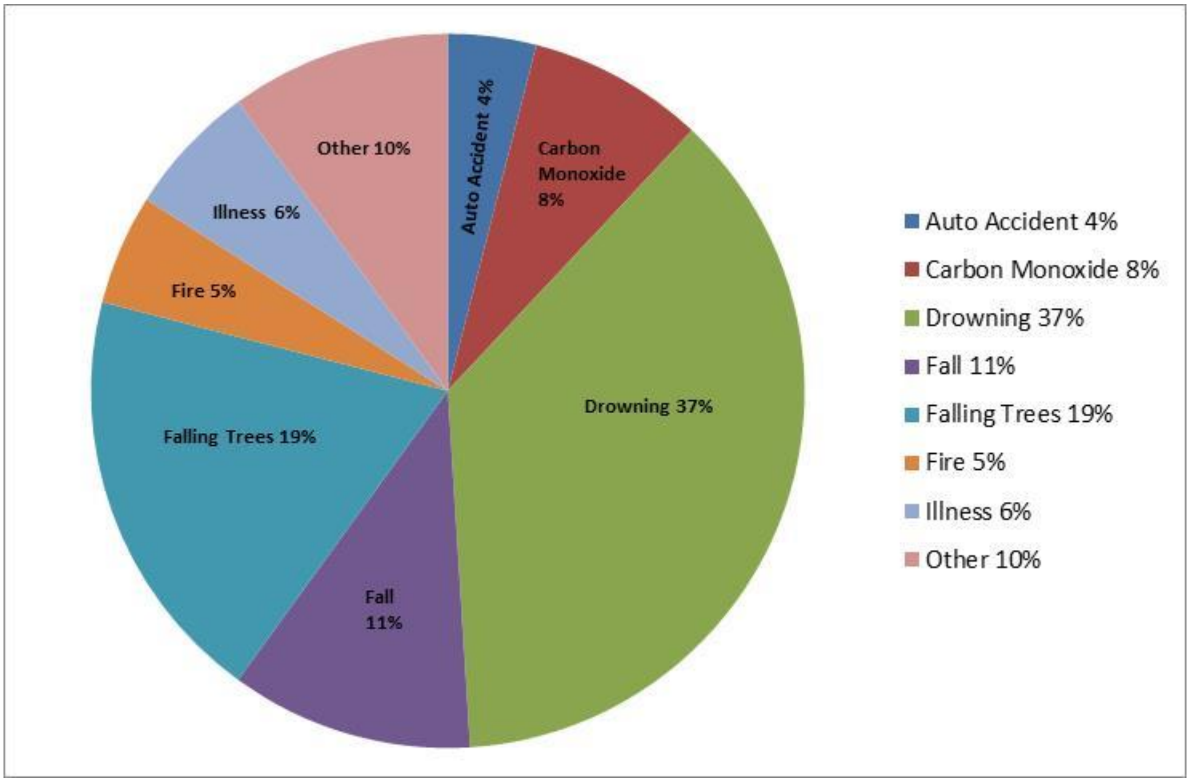

Figure 3. Causes of Deaths during Hurricane Sandy

About 45 percent of the deaths occurred to seniors over 65. Although complete data is not available for injuries, there were likely numerous non-fatal indirect injuries in similar categories, as well as other indirect injuries associated with cleanup activities (e.g., chainsaw accidents). For example, researchers at the New York City Poison Control Center identified a spike of 437 cases of suspected carbon monoxide poisoning reported in emergency rooms of the City's hospitals during the 2 weeks following Hurricane Sandy. Other secondary and tertiary effects associated with damage to infrastructure systems, such as power and transportation, resulted in injuries (e.g., falls) and difficulty or delays for people with pre-existing conditions to receive needed treatments (e.g., dialysis) and prescriptions and other medical necessities. Indirect physical health effects were also experienced by people who were forced to evacuate their homes and medical facilities, such as Coney Island Hospital and NYU Medical Center, because of flood damage and loss of power and heat. Brackbill et al. (2014) surveyed a cohort of persons affected by events related to the WTC disaster in New York City and found that 10.4 percent of respondents who lived in an inundation zone sustained an injury in the first week after Hurricane Sandy. For respondents living in areas that were not inundated, 3.4 percent reported injuries. These results are similar to reports regarding earlier hurricanes (e.g., Hurricanes Andrew, Katrina, and Irene) which found the most reported injuries occurred after the hurricane passed and were associated with clean-up and repair activities (CDC 2005). Norris and Sherrieb (2010) investigated the extent to which Hurricane Ike contributed to disaster-related illness and injury, distress, disability, and perceived needs for care in Galveston and Chambers Counties. They estimated that about 7,700 adults (4 percent of population) were injured and about 31,500 adults (16 percent) experienced household-level illness. Risk of injury/illness increased with area damage and decreased with evacuation. Illness or injury, or both, were associated with stress, post-traumatic stress, dysfunction, days of disability, and perceived need for care.

The NACCS team interviewed several investigators who are studying the physical and mental impacts associated with Hurricane Sandy (Table 3 and Appendix A). Because most of the studies were only recently initiated, only limited Hurricane Sandy data are available. When completed, these studies will provide important data and possible metrics with regard to quantifying the physical health secondary and tertiary effects. For example, the Sandy Child and Family Health study, being undertaken by Columbia University's National Center for Disaster Preparedness and the Rutgers University School of Social Work, is evaluating the health and well-being of children and adults who were impacted by Hurricane Sandy, the ongoing needs of affected residents, and how well people and households are recovering. The study focuses primarily on six topics: 1) children and family issues, 2) health and health care, 3) vulnerable populations, 4) economic and legal issues, 5) community and social issues, and 6) housing (Appendix A).

Dr. Rachel Pruchno of Rowan University has a 5-year study underway that is looking at the impacts on the mental and physical health of senior populations in nine New Jersey counties that were most impacted by Hurricane Sandy (Appendix A). Dr. Taioli and Dr. Schwartz, who are affiliated with the North Shore Long Island Jewish Health System, have a 2-year study underway that is focusing on psychological and mental impacts of Hurricane Sandy on Long Island residents (Appendix A).

However, data from several studies following Hurricane Katrina and other natural disasters suggest the likelihood of similar impacts as a result of Hurricane Sandy. Abramson and Garfield (2006) reported that children displaced from homes during Hurricane Katrina suffered high rates of chronic health conditions and generally poor access to medical care. They found that 34 percent of the children living in Federal Emergency Management Agency–subsidized community settings have at least one diagnosed chronic medical condition, such as asthma, developmental delay, and learning disabilities, a rate one-third higher than that of the general pediatric population in the United States. About 14 percent of children were unable to receive needed prescription medicine, and 61 percent were unable to receive specialized medical equipment, such as nebulizers. In addition, the displaced lost stability, income, and security. On average, displaced households moved 3.5 times, and only 45 percent had a salaried wage earner after the hurricane, as compared to about 65 percent prior to the storm. Rhodes et al. (2010) also found a correlation between disasters and physical illness.

Other studies have found negative physical health issues are associated with disasters, such as hypertension, diabetes, lymphoma and leukemia, spontaneous abortion, arthritic flares, gastrointestinal disturbances, fatigue, memory lapses, confusion, and general sluggishness (Lutgendorf et al. 1995). There are also higher mortality rates, especially with cancer patients. Health issues thought to be related to the endocrine system and immunity are suspected to be affected by disasters. Further, direct injuries could occur in preparation for a hurricane, during, or even after when physically strenuous cleanup and recovery occur.

Findings on the long-term health and mental health consequences of disasters are mixed. Whereas some studies have noted enduring effects, most find that problems are relatively short lived, with survivors recovering from the initial shock and trauma within a matter of weeks or months of the event. Individual resilience is also an important factor in the face of loss and trauma, with several personality factors (e.g., tendency toward self-enhancement and positive emotions) and also demographic and contextual factors associated with resilient functions.

To help quantify the physical injuries sustained during a major hurricane event, Kim Knowlton published an article in *Health Affairs* (2011), in which she examined the health costs of six climate change–related events that occurred in the United States, including hurricanes, between 2000 and 2009. In total, Knowlton estimated that the climate change–related events accounted for about $14 billion in prematurely lost lives and health costs. Table 4 illustrates the total impact assessment of the 2004 Florida hurricane season.

Table 4. Physical Health Effects of 2004 Florida Hurricane

Premature Death	Hospitalization	Emergency Department Visit	Outpatient Visit	Estimated Number of People Exposed
144	2,197	2,633	160,387	17,375,259

Table 5 illustrates the total health impact cost assessment based on the 2004 Florida hurricane season.

Table 5. Economic Effects of 2004 Florida Hurricane

Premature Death ($ thousands)	Hospitalization ($ thousands)	Emergency Department Visit ($ thousands)	Outpatient Visit ($ thousands)	Total Health Cost ($ thousands)
$1,137,600	$18,321	$4,365	$232,547	$1,392,833

Source: Knowlton (2011)

From the findings, Figure 4 was developed to show the pathways from the physical forces associated with storms through each of the primary and secondary effects on physical health that have potential unmeasured NED impacts. The secondary physical health effects include indirect injuries/illnesses such as carbon monoxide poisoning, chainsaw accidents, falls, auto accidents, fire, fallen trees, and exposure, and also secondary physical health effects from inability or delays in obtaining treatment or prescriptions as a result of medical facilities/pharmacies being closed, lack of transportation, and delays in emergency response services. There are also secondary physical health effects associated with being forced to evacuate from one's home, which often results in the inability or a delay in obtaining treatment and medical needs being unmet. These secondary physical health effects result in currently unmeasured NED impacts. These NED impacts include increased costs for medical care as result of the secondary and tertiary effects and losses to the labor market due to the loss of work days for both those experiencing storm-related health effects and family caregivers who miss work to care for sick or injured family members.

For clarity, Figure 4.1 shows the pathways resulting from the primary effect of injuries, evacuations, and damage to homes/vehicles, while Figure 4.2 shows the pathways resulting from impacts to major systems, such as medical facilities, transportation, electric power, telecommunications, water supply, and waste water. Based on the literature review and discussion with experts, the secondary and tertiary physical health effects are expected to be greatest among the elderly and those who suffered significant damage and were displaced or evacuated from their homes.

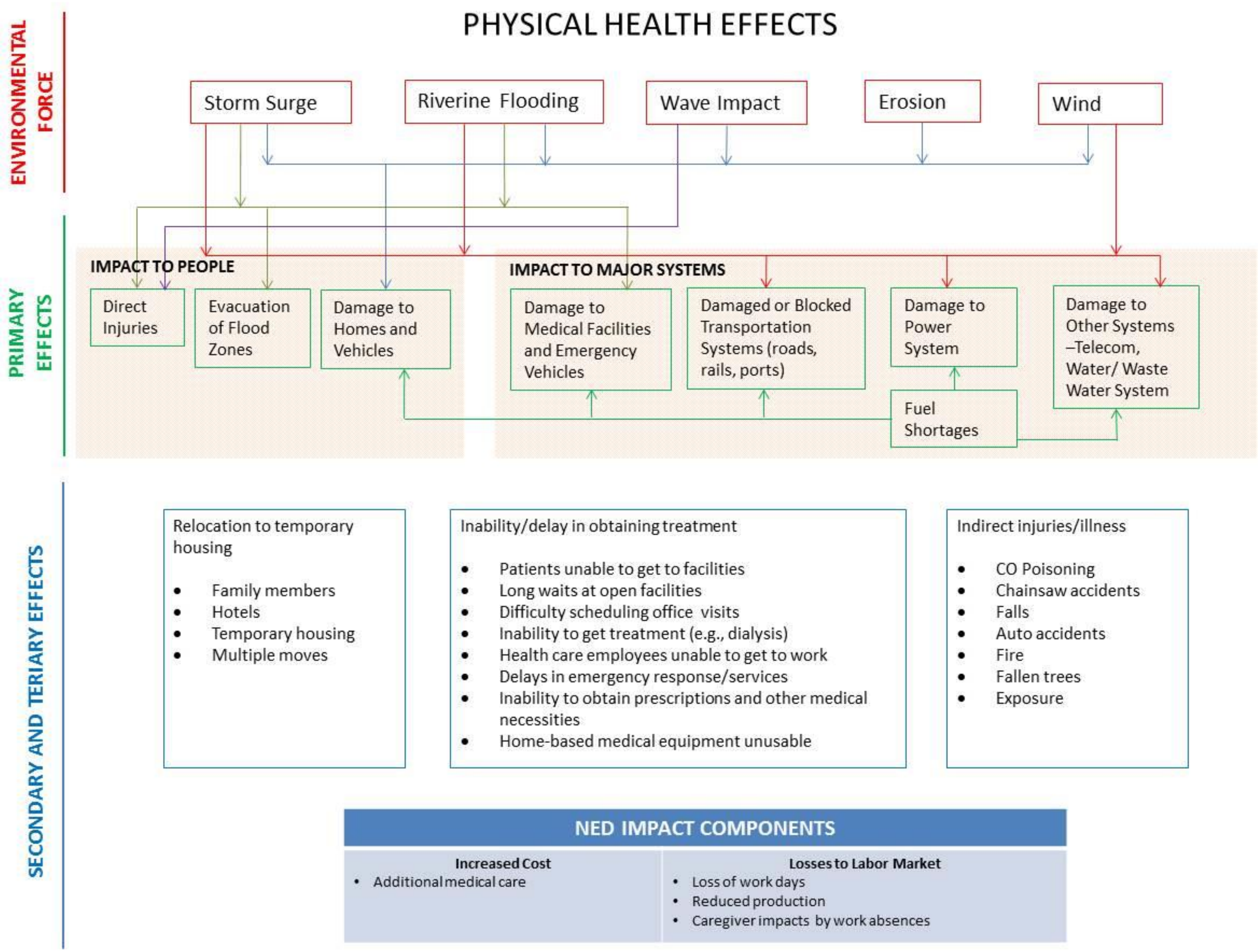

Figure 4. Physical Health Effects Pathway

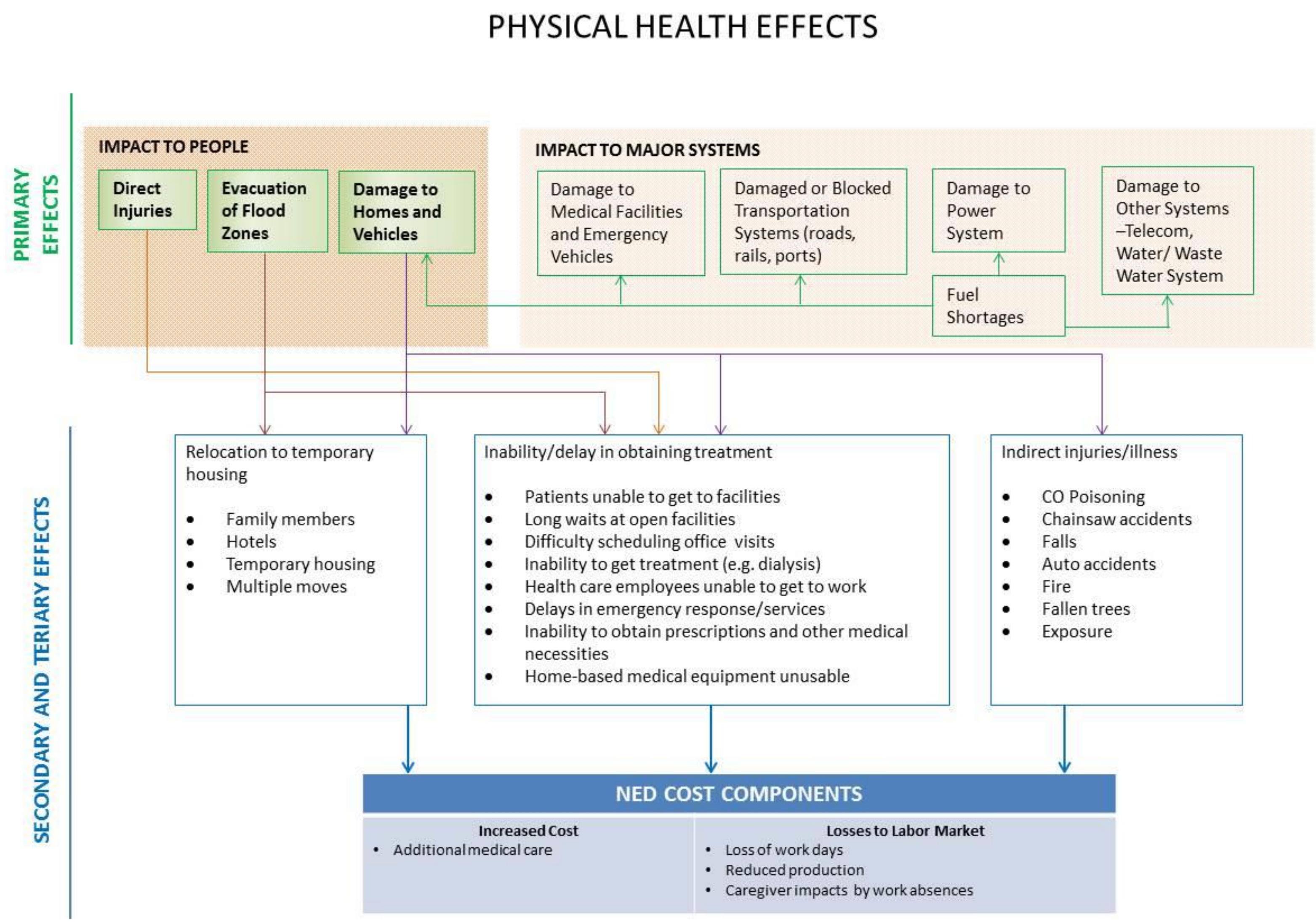

Figure 4.1. Physical Health Effects Pathway – Impact to People

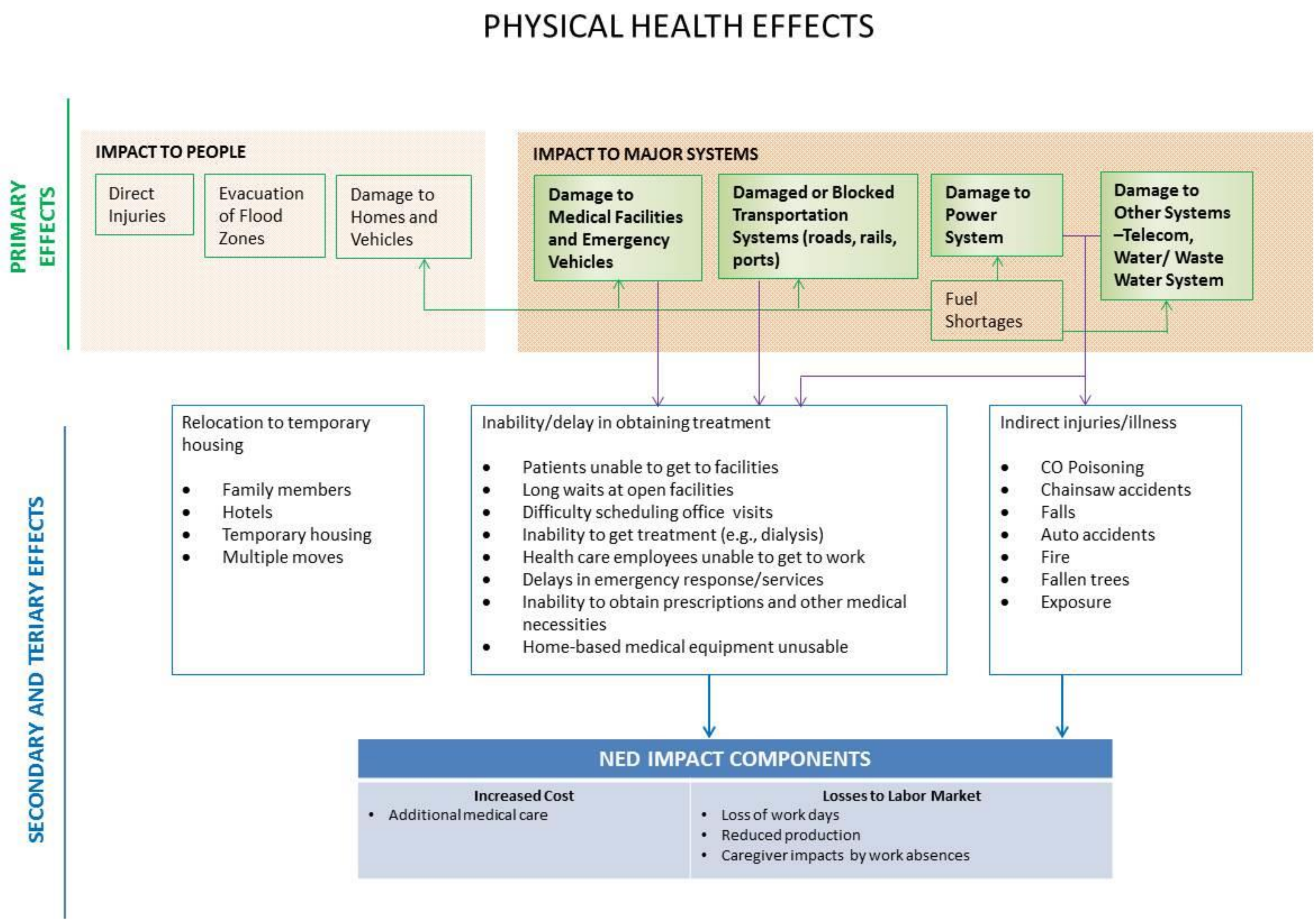

Figure 4.2. Physical Health Effects Pathway – Impact to Major Systems

6.1.2 NED Impact Components

As identified on the pathway diagrams, the secondary and tertiary effects components evaluated for the physical health community sector were as follows:

Increased costs – the treatment of indirect injuries and illnesses related to a storm event. The NED impacts include hospital and non-hospital health care costs attributed to the event, as well as the incremental health care needs resulting from the inability to obtain necessary treatments for pre-existing medical conditions. Impacts would be expected primarily during the storm and during the initial response and recovery periods, but they may last longer, particularly for those displaced from their homes for extended periods of time.

Losses to the labor market – lost labor and production due to storm-related injuries and illnesses, and also lost labor and production by family members who provide care for storm-related injuries and illnesses. The NED impacts would be expected primarily during the storm and initial response and recovery periods when substitutes cannot be found and individuals are operating at reduced capacity.

6.1.3 Measurement

The following lists present potential ways to capture NED impacts associated with each component of the secondary and tertiary effects.

Increased cost

- Estimate the increased rate of injuries by type due to the storm event;
- Estimate the percentage of injuries requiring treatment and hospital stays;
- Estimate treatment costs for each type of injury;
- Estimate incremental treatment costs for patients dealing with pre-existing conditions; and
- Estimate increased travel expenses for patients needing to travel further to receive treatment.

Losses to the labor market

- Estimate the number of days of work that would be lost for each type of injury;
- Estimate the number of days of work that family caregivers would provide for each type of injury; and
- Estimate NED impacts (loss of labor) for time prior to when substitutions could be implemented.

Measuring the NED impacts associated with increased costs and losses to the labor market involves examining several different components of the impacts of physical health as a result of a coastal storm event. While Knowlton (2011) provided a broad overview of the costs, specific information on the costs of physical injuries was not available. However, a study by Brackbill et al. (2014) provides a starting point for estimating the costs.

To estimate the increased rate of physical health issues due to a storm event, Brackbill et al. (2014) studied the occurrence of physical injuries by level of flooding from Hurricane Sandy. The study was based on survey data that included questions on physical injuries that occurred following Hurricane Sandy. The study asked respondents to identify the type and number of injuries that they received within 1 week of Hurricane Sandy. The overall findings indicated:

- Injuries were reported almost exclusively by those engaged in clean-up activities;
- Respondents in inundated areas had a much higher chance of being injured than those who did not flood;
- The number of injuries were greater for those who had more than 3 feet of flooding compared to those who had less flooding; and
- Whether a person evacuated did not appear to be a large contributor to injuries.

Of the residents living in areas inundated by flooding, 10.4 percent reported receiving at least one injury within 1 week following Hurricane Sandy. Of the injuries, 25.1 percent of the respondents reported receiving treatment at a hospital emergency department or doctor's office. The percentage of injured persons seeking treatment at an emergency department or doctor's office increased with income, indicating that those with lower incomes may not have had the means to seek treatment.

Table 6 illustrates the correlation between the level of flooding inside the home after Hurricane Sandy and the number of types of physical injuries sustained by individuals 1 week after Hurricane Sandy. Of the respondents who reported injuries, the number of injuries increased with the depth of flooding.

Table 6. Number of Injuries at Different Flood Depths.

Number of Injuries	Less than 3 feet of flooding	3 feet or more of flooding
1 injury	25 %	18%
2 injuries	17%	16%
3 or more injuries	58%	66%
Total	**100%**	**100%**

Source: unpublished WTC Health Registry data obtained via personal communication with R. Brackbill December 2014

The Brackbill et al. (2014) study only included injuries for three categories: arm/hand cut, back strain, and leg cut. It did not evaluate the severity of the injury or include other physical injuries, such as carbon monoxide poisoning or electrocution. Therefore, the findings can be considered a low estimate of the actual secondary and tertiary physical health issues that could occur following a coastal storm event.

Building on the findings from Brackbill et al. (2014), the average cost per injury treated at a hospital emergency department was estimated using information from the Centers for Disease Control and Prevention (CDC). The CDC maintains an interactive, online database called WISQARS (http://www.cdc.gov/injury/wisqars/index.html). WISQARS provides injury-related data, which includes the average treatment and lost work costs for the injuries. Table 7 provides an example of the information provided from WISQARS for non-intentional injuries that received treatment at an emergency department.

Table 7. Example of Data from WISQARS

Injury Mechanism	Cost Category	Average Cost
Cut/Pierce	Medical	$1,564
	Work Loss	$1,910
	Combined	$3,474
Fall	Medical	$2,552
	Work Loss	$3,764
	Combined	$6,316
Total	Medical	$2,349
	Work Loss	$3,383
	Combined Cost	$5,731

Source: WISQARS, CDC

If 10 percent of the population that is inundated is injured during a flood event, of which 25 percent of those seek treatment at a hospital emergency department (from Brackbill et. al 2014), and the treatment costs from the CDC are representative, then the average secondary and tertiary effect for these relatively minor injuries is $143 per person[1] within the area of inundation. However, this estimate is conservative because it does not include other injuries related to an event, and it does not include injuries occurring for the remainder or the recovery period.

6.2 Mental Health

Impacts to mental health occur when treatment facilities are not able to operate or operate at a reduced capacity because of the impacts of a storm event.

[1] For example, if 1,000 people are inundated x 10% injured x 25% seeking treatment x $5,731 combined cost = $143,275 total cost, which equals $143 per person.

6.2.1 Literature Review and Discussion of Pathways

Decreased mental health may be a result of mental stress and post-traumatic stress disorder (PTSD) associated with exposure to the disaster, including stress associated with evacuations, losing a home and possessions, physical injuries, and illnesses to family and friends. Mental stress can also be a secondary response to other direct impacts, such as being displaced from home and community, loss of electricity and heat in the home for extended periods of time, inability to receive regular counseling or treatment as a result of closure or lack of transportation, or inability to obtain needed medication. Figure 5 shows the pathways from the physical forces associated with storms through each of the primary and secondary effects on mental health that have potential associated NED impacts. For clarity, Figure 5.1 shows the pathways resulting from primary effects from injuries and trauma related exposure to the storm and being evacuated from home and how these lead to NED impacts, while Figure 5.2 shows the pathways resulting from impacts to major systems, such as medical facilities, transportation, power, telecommunications, water, and waste water, and the pathways to NED impacts.

As mentioned in the previous section on physical health, the NACCS team interviewed several investigators who are studying the physical and mental impacts associated with Hurricane Sandy (Table 3 and Appendix A). Because most of the studies were only recently initiated, little specific Hurricane Sandy data are available. However, Taioli and Schwartz (personal interview 2014) provided preliminary results of their Project Light Study, which is evaluating the psychological impacts of Hurricane Sandy on affected individuals in Long Island and New York City. They estimate that approximately 25 percent of their sample population exhibits PTSD symptoms, as compared with under 5 percent of the general population.

Data from several studies following Hurricane Katrina and other natural disasters suggest the likelihood of similar impacts as a result of Hurricane Sandy. A rapid-needs assessment completed by the Centers for Disease Control and Prevention in October of 2005 after Hurricane Katrina concluded that over 50 percent of low-income patients in New Orleans showed signs of needing mental health treatment, with many experiencing psychological stress from the threatened or actual loss of health, social, or economic resources (Rhodes et al. 2010). A number of hurricane-related stressors taken from the K6 scale, which is a scale of nonspecific psychological distress, can be used within 30 days of a stressful event to asses mood, anxiety, andPTSD. Rhodes et al. 2010 found that mental and physical illness rose and remained elevated for a 1-year period after Hurricane Katrina, and 13.8 percent had probable serious mental illness and 47.7 percent had probable PTSD. Pre-Hurricane Katrina studies indicate that the rate of probable serious mental illness was 6.9 percent for the general population. Another study found that 19.2 percent of Tulane University faculty, staff, and administrators showed symptoms of PTSD following Hurricane Katrina (DeSalvo et al. 2007). Hurricane-related stressors were found to be comparable across sociodemographic samples, indicating that the problem needs to be addressed for the population as a whole and not specific sociodemographics (Galea et al. 2007). Galea et al. note that avoiding stressors would greatly reduce the adverse mental health effects of disasters. In a study of changes in mental and physical health among low-income parents exposed to Hurricane Katrina, Rhodes et al. (2010) found that probable serious mental illness doubled among respondents, and nearly half exhibited probable PTSD. Higher levels of hurricane-related loss and stressors were generally associated with worse health outcomes.

LaJoie et al. (2010) reported that over one-half of the 101 adults evaluated who had evacuated to Louisville, KY, met the criteria for PTSD, and a majority suffered from depression and anxiety. Similarly, Rhodes et al. (2010) determined that the prevalence of serious mental illness doubled among 392 low-income mothers exposed to Hurricane Katrina and nearly half exhibited probable PTSD. The adverse health consequences persisted for a year or more and were most severe for those experiencing the most stressors and loss. Abramson and Garfield (2006) reported that displaced children in 665 randomly selected households at trailer communities and hotels suffered from high rates of behavior problems and learning disabilities. Hurlbert (personal interview 2014) also found that the depression index[2] for adults almost doubled from 1.06 prior to Hurricane Katrina to 1.74 in Jefferson Parish and to 1.89 in Orleans Parish following the storm.

A study published by the World Health Organization examined the impact of Hurricane Katrina on mental illness and suicidality by comparing results of a post-Katrina survey with those of a pre-Katrina survey. Results found that the post-Katrina survey had significantly higher estimated prevalence of serious mental illness (SMI) in respondents, 11.3 percent compared to 6.1 percent in the pre-Katrina survey . Additionally, 19.9 percent of the post-Katrina respondents reported mild to moderate mental illness compared to 9.7 percent for pre-Katrina respondents (Kessler et al. 2006).

The economic impact of mental illness can be significant. In 2006, mental disorders were one of the five most costly conditions in the United States with estimated expenditures at $57.5 billion compared to $35.2 billion in 1996 (AHRQ 2009).

A study conducted by the National Institute of Mental Health estimated the 2002 total costs of SMI, which is considered to be severely debilitating and affect about 6 percent of the adult population. Conservative estimates using data from the Substance Abuse and Mental Health Services Administration as well as the Social Security Administration determined annual total direct and indirect costs of SMI to be $317.6 billion, with $24.3 billion allocated to disability benefits such as social security income and social security disability insurance, $100.1 billion allocated for health care expenditures, and $193.2 billion allocated for loss of earnings (NIH 2008). These statistics only include data for those who sought treatment and reported suffering from a mental illness. Currently, of 8.9 million adults who suffer from any mental illness and a substance use disorder, only 44 percent received substance use treatment or mental health treatment in the past year, while 13.5 percent received both mental health treatment and substance use treatment. An estimated 37.6 percent did not receive any treatment (SAMHSA 2014).

[2] The depression index was determined using the Beck Depression Inventory (BDI) test, a 21 question, self-report assessment composed of topics related to characteristics of depression including both emotional and physical symptoms.

The American Psychological Association (APA) (2008) reported on a study from the American Journal of Psychiatry that each year SMI costs Americans $193 billion in lost earnings, which is consistent with the findings from the National Institute of Health. The APA also reported on the 2003 average earnings of healthy respondents versus those with SMI and found that the average annual earning of healthy respondents was $38,851 versus only $22,545 for respondents with SMI. Healthy men had an average earning of $54,505, while men with SMI had an average earning of $28,070. Healthy women had an average earning of $28,026, while women with SMI had an average earning of $18,700.

The New York State Office of Mental Health received an $8.2 million, 60-day initial services grant to provide mental health services to individuals and communities impacted by Hurricane Sandy. A second award for continued services was granted and raised the total amount awarded to $50 million over a 16-month period (Sederer 2014).

From the findings, Figure 5 was developed to show the pathways from the physical forces associated with storms through each of the primary and secondary effects on mental health that have potential unmeasured NED impacts. The secondary mental health effects include increased stress and related disorders, such as PTSD, lack of sleep, and increase in drug and alcohol abuse, and also secondary mental health effects from inability or delays in obtaining treatment or obtaining prescriptions for pre-existing mental health issues. Researchers have also identified significant mental health effects associated with being forced to evacuate from one's home. Mental health issues such as depression, PTSD, and difficulty in sleeping can also lead to secondary and tertiary effects such as increases in auto accidents, drug and alcohol abuse, and increases in crime. These secondary mental health effects result in currently unmeasured NED impacts. These NED impacts include increased costs for medical care as result of the secondary and tertiary effects, and also include losses to the labor market due to the loss of work days from both those experiencing storm related health effects and caregivers who miss work to care for sick or injured family members.

For clarity, Figure 5.1 shows the pathways resulting from primary effects resulting from injuries, evacuations, and damage to homes/vehicles, while Figure 5.2 shows the pathways resulting from impacts to major systems, such as medical facilities, transportation, electric power, telecommunications, water supply, and waste water. Based on the literature review and discussion with experts, the secondary and tertiary mental health effects are expected to be greatest among the elderly and those who suffered significant damage and were displaced or evacuated from their homes.

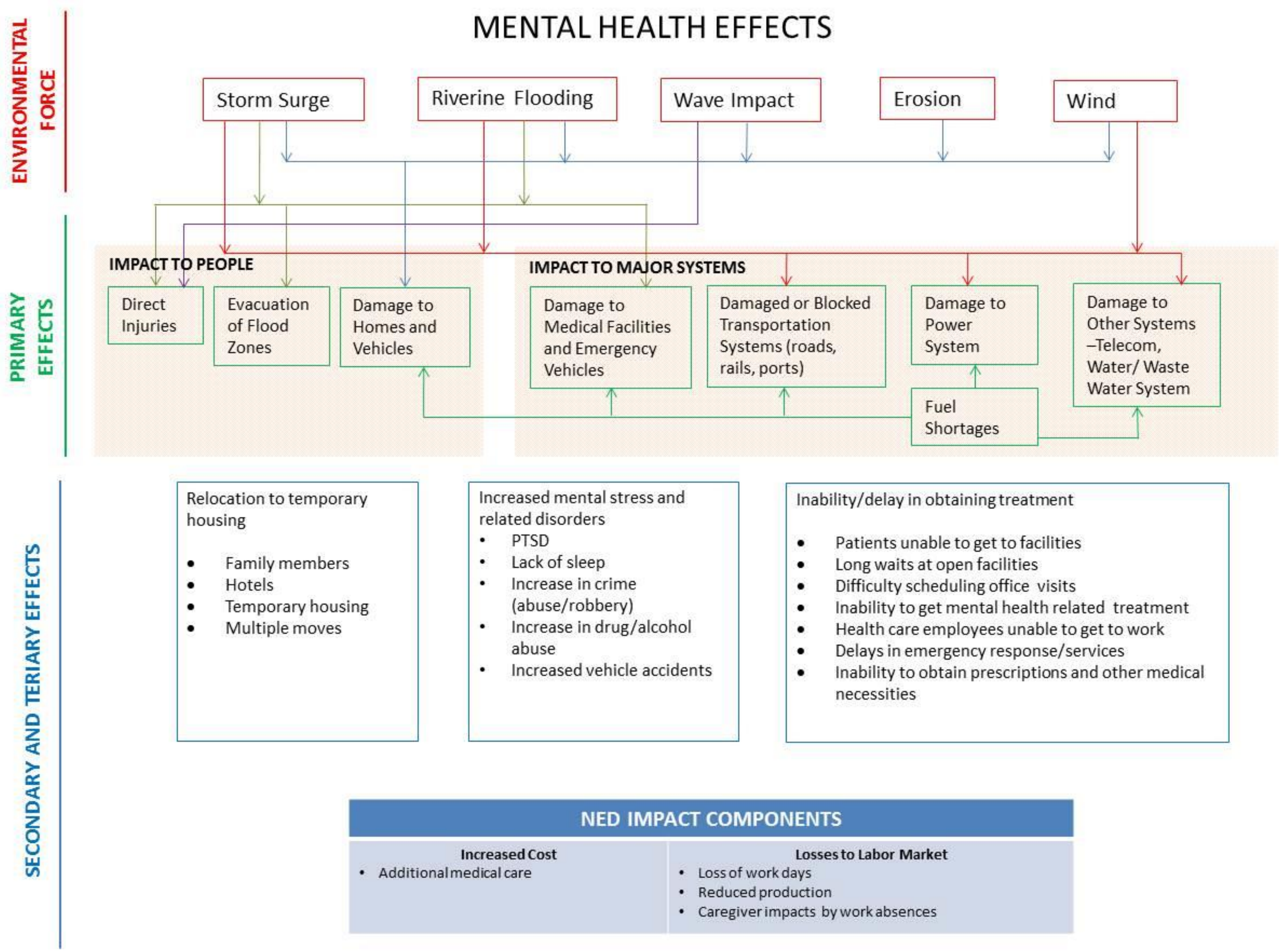

Figure 5. Mental Health Effects Pathway

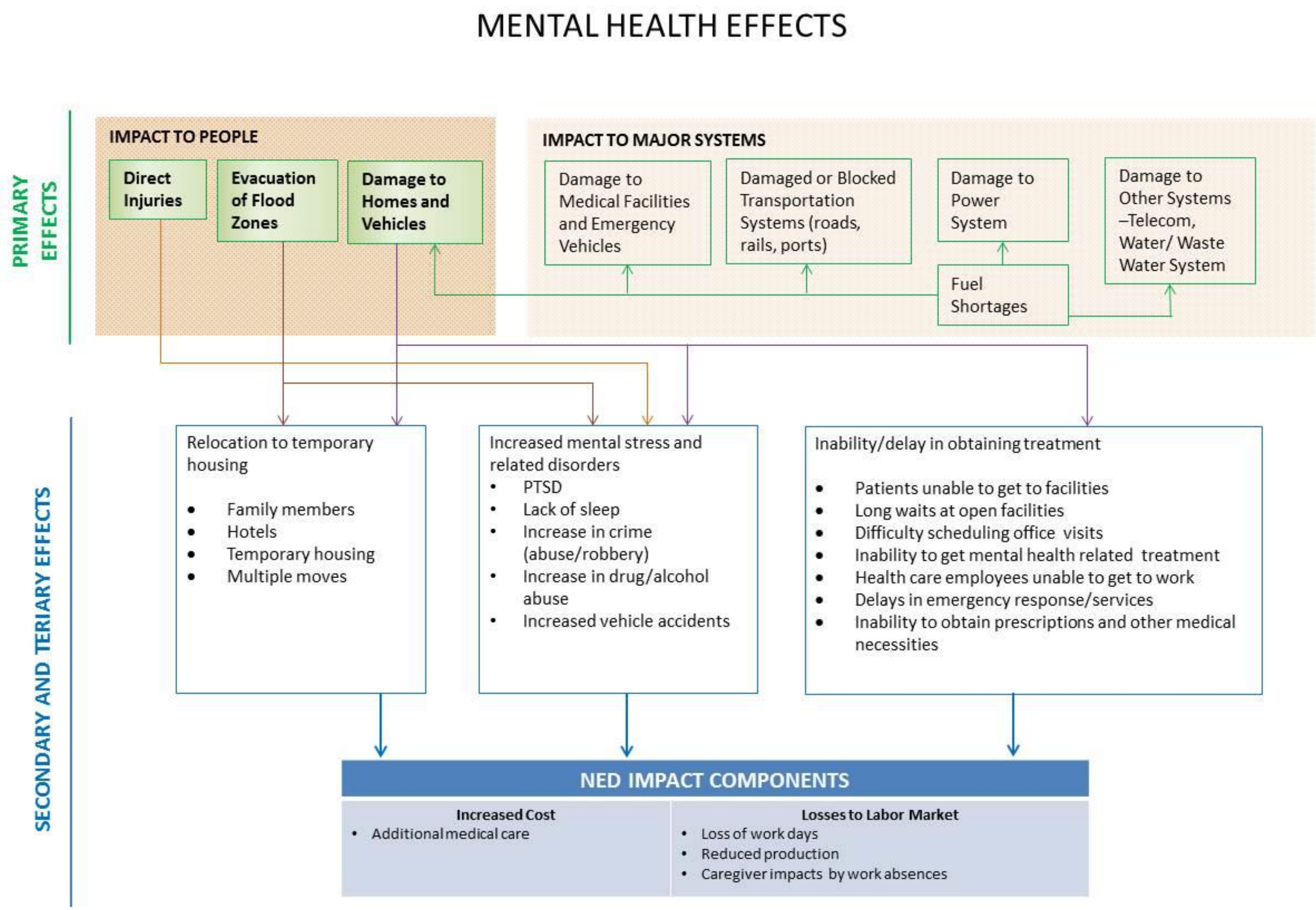

Figure 5.1. Mental Health Effects Pathway – Impact to People

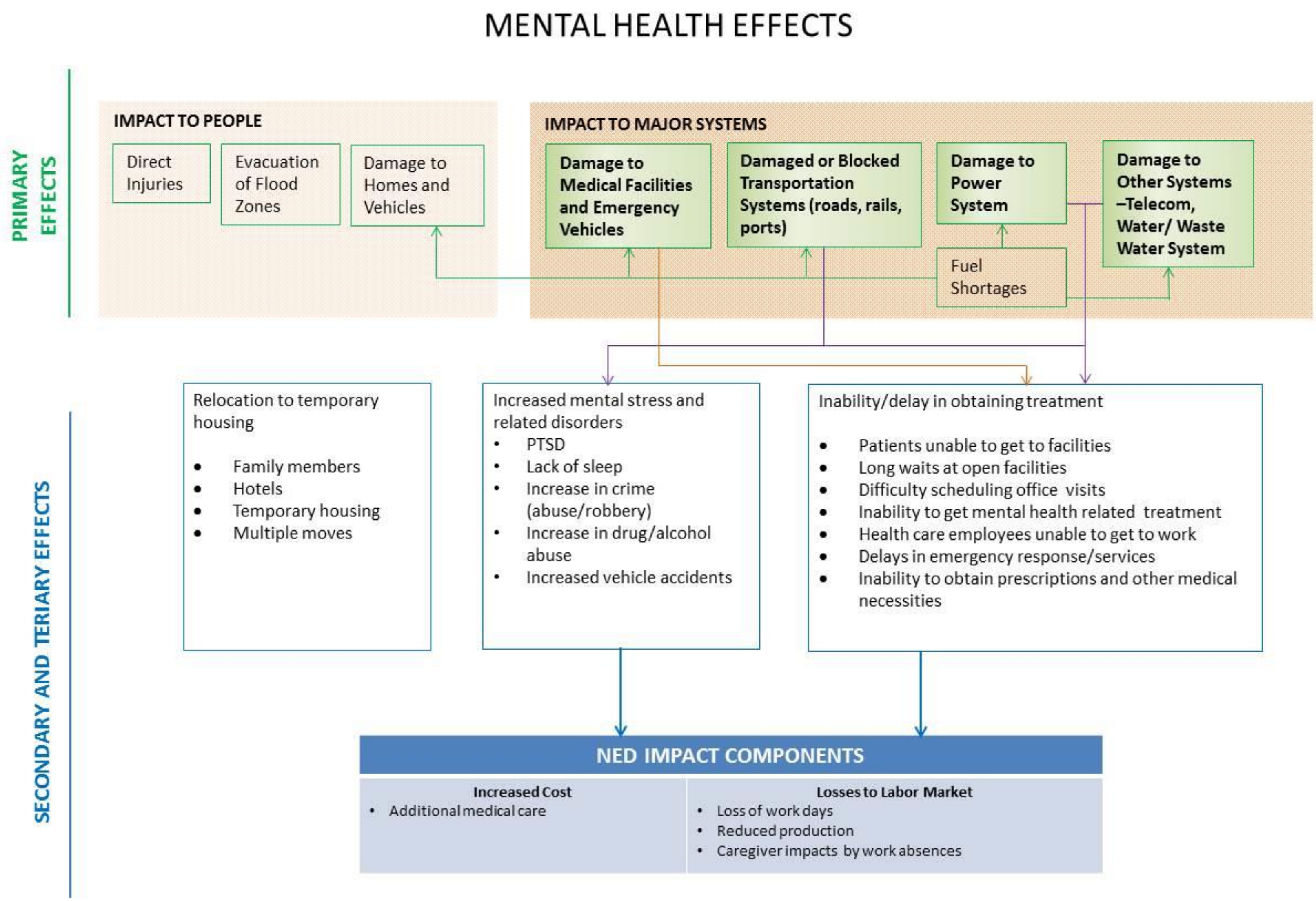

Figure 5.2. Mental Health Effects Pathway – Impact to Major Systems

6.2.2 NED Impact Components

As identified on the pathway diagrams, the secondary and tertiary effects components evaluated for the mental health community sector were as follows:

Increased costs – the treatment of mental health injuries related to a storm event. The NED impacts include hospital and non-hospital treatment costs attributed to the event, such as depression and PTSD. NED impacts also include the incremental treatment costs resulting from the inability to obtain necessary treatments for pre-existing conditions. It also includes deteriorated health due to stress, depression, and other storm-induced mental health issues, such as sleep disorders and drug/alcohol abuse. Increased costs as a result of mental illness are also associated with an increase in chronic diseases, including cardiovascular disease, diabetes, asthma, epilepsy, diabetes, and cancer (CDC 2011). Impacts extend from the initial response and recovery period to several years after the storm event, particularly for people who were displaced for extended periods of time.

Untreated depression and PTSD can lead to sleep disorders, drug/alcohol abuse, and inability to work and can last for many years following an event.

Losses to the labor market – lost labor and production due to storm-related mental health issues. It also includes lost labor and production by those who provide care to affected family members. The NED impacts would be expected primarily during the storm and initial response and recovery period when substitutes cannot be found and individuals are operating at reduced capacity.

6.2.3 Measurement

The following lists present potential ways to capture NED impacts associated with each component of the secondary and tertiary effects.

Increased costs

- Estimate the increased rate of mental health issues, by severity, due to the storm event;
- Estimate treatment costs for each level of severity;
- Estimate incremental treatment costs for patients dealing with pre-existing conditions; and
- Estimate increased travel expenses for patients needing to travel further to receive treatment.

Losses to the labor market

- Estimate the number of days of work that would be lost for each level of severity;
- Estimate the number of days of work that family caregivers would provide for level of severity; and

- Estimate NED impacts (loss of labor) for time prior to when substitutions could be implemented.

As seen in the literature research previously examined, measuring the NED impacts associated with increased costs and losses to the labor market involves examining several different components of the impacts of mental illness as a result of a natural disaster.

Based on services that are provided to individuals in need of medical assistance, Dr. Michael Schoenbaum of the National Institute of Mental Health developed a recommended intervention model for adults in an "urban/affected" area. Table 8 outlines the estimated unit costs of various treatment services, including those related to mental health illnesses (Schoenbaum 2009).

Table 8. Recommended Intervention Components (Adult, Urban/Affected Area)

		Mild/moderate, 1st course		Mild/moderate, Refractory / previously severe		Severe, 1st course		Severe, Refractory	
Type of Service	Unit cost*	#	% who receive	#	% who receive	#	% who receive	#	% who receive
Screening			100%				100%		
In-person	$25	1	100%			1	100%		
Telephone	$25	0	--			0	--		
Assessment**			100%				100%		
In-person I Mix of masters & nurse/MD in primary care	$100	1	65%			1	65%		
Telephone I Masters Level	$75	1	35%			1	35%		
Therapy***			70.0%		85.0%		100%		100%
In-person I Masters Level Provider (one-on-one)	$90	12	8.6%	12	10.5%	0	--	0	----
In-person I Masters Level Provider (group)*	$210	12	15.9%	12	19.5%	0	--	0	--
In-person I PhD Level Provider (one-on-one)	$135	12	3.7%	12	4.4%	12	100%	12	100%
In-person I PhD Level Provider (group)*	$245	12	6.8%	12	8.1%	0	--	0	--
Telephone I Masters Level Provider	$47	12	24.5%	12	30.0%	0	--	0	--
Telephone I PhD Level Provider	$67	12	10.5%	12	12.5%	0	--	6	-
Medication management***			50.0%		85.0%		100%		100%
In-person I MD Provider in primary care	$80	6	30.0%	6	47.0%	0	--	0	--
In-person I NP Provider in primary care	$60	6	5.0%	6	8.0%	0	--	0	--
In-person I Psychiatrist Provider	$96	6	15.0%	6	30.0%	6	100%	6	100%
Telephone I Master's Level, meds reminders	$50	0	--	0	--	0	--	0	--
Phone consults to PCP by psychiatrist***	$70	2	5.3%	2	80%	0	--	0	--
Inpatient care (hospital nights)***	$900	0	--	0	--	5	20%	5	40%
Rx (months)***	$40	6	50.0%	9	85.0%	9	100%	12	100%

Source: Schoenbaum (2009)

Dr. Schoenbaum also examined Hurricane Katrina and Hurricane Rita as case studies to estimate costs and outcomes of an enhanced mental health response to large-scale disasters. The study developed an intervention model that could be implemented post-disaster to identify people with substantial mental health problems and provide them with evidence-based treatment. It used a multi-period decision analysis model to illustrate the potential costs and benefits of implementing the proposed interventions, at different levels of intensity, in the population affected. Treatment components included initial screenings, clinical assessments, both Masters and PhD level therapy sessions, primary care visits, and psychiatric-related hospital stays. Table 9 lists the costs of implementing the recommended model under 100 percent implementation (vs. 0 percent treatment) overall and by type of service and time period.

Table 9. Estimated Costs for 1000 Population per Intervention Component

Intervention component	7-12 months	13-18 months	19-24 months	TOTAL
Screening	$20,930	$834	$64	**$21,828**
Assessment	$50,534	$5,883	$1,144	**$57,561**
Therapy	$218,664	$172,091	$102,511	**$493,266**
Medication management*	$101,479	$91,120	$54,581	**$247,180**
Hospital nights	$36,998	$50,046	$39,282	**$126,326**
Prescription drugs	$56,611	$78,297	$51,768	**$186,676**
TOTAL	**$485,217**	**$398,270**	**$249,350**	**$1,132,837**

* **NOTE**: Includes office visits to primary care providers, nurse practitioners, and psychiatrists, plus provider-to-provider telephone consultation by psychiatrists to primary care providers, and telephone care management by masters-level providers.

Source: Schoenbaum (2009)

Based on the information presented in Table 9, the estimated cost per 1,000-person inundated sample size for those receiving treatment would be $1,132,837. Thus, full coverage of the intervention model would cost $1,133 per capita over a 7- to 24-month recovery period. Therefore, to estimate the financial costs required to treat a real-world population suffering from hurricane-related mental health disorders, one would multiply the $1,133 value by the affected population size.

The findings from Schoenbaum (2009) have also been used by the Federal Emergency Management Agency (FEMA), which has recently released guidance (FEMA 2014) for estimating the social damages related to natural disasters. The guidance provides monetary values for treatment of mental health issues and lost productivity for people impacted by an event. The methods used in the guidance can be reviewed to assist in estimating the damages for an event; however, the monetary values are not recommended to be used until they are independently verified.

6.3 Manufacturing

Impacts to manufacturing occur when a facility is not able to operate or operates at a reduced capacity because of the impacts of a storm event.

6.3.1 Literature Review and Pathways

IHS Global Insight (2012) estimated macroeconomic impacts of $25 billion as a result of the virtual shutdown of business activity along key parts of the East Coast following Hurricane Sandy. This represents losses equivalent to about 1.0 percent of the gross regional product for the States impacted. On a national scale, these losses represent about 0.2 percent of nominal gross domestic product. Mantell et al. (2013) estimated a loss of $11.66 billion in economic activity in the State of New Jersey during the fourth quarter of 2012.

For an individual facility, the losses from down time can account for 80 percent of the total losses (Ericsson 1997). The down time is from direct damage to the manufacturing equipment or site as well as supply chain disruptions caused by the disaster. These disruptions directly affect the manufacturer supplying components or the ability of delivery services to deliver components, because of blockage of routes, lack of fuel or energy, public safety–related edicts regarding traffic, or some combination of those factors. The risk of disruptions are increased with current manufacturing practices, which utilize global sourcing, increasingly rely on outsourcing and partnering or single-sourcing, and follow the trend of reducing inventory (Hendricks and Singhal 2005).

Decreased manufacturing may be a result of either direct damages to the facility and to equipment or may be a secondary response to many other direct impacts. These include the loss of power that prevents the facility from operating, damaged or blocked transportation that prevents employees and supplies from reaching the plant, and loss of telecommunications. Figure 6 shows the pathways from the physical forces associated with a storm that impact the operation of the manufacturing facility because of direct damage to the facility, lack of power, or inability of employees to get to work due to lack of transportation or being injured or displaced from home. The secondary and tertiary effects include decreased productivity due to the shutdown of the plant, which also impacts both the manufacture's suppliers and customers. Additional secondary effects include the increased cleanup effort to get the facility in operating condition and maintaining communication with both customers and suppliers to ensure continuity once facility is back in operation.

The NACCS team had several discussions with manufacturing facilities located throughout the study area. Many of the facilities stated that they experienced significant secondary effects from the storm. A mortar manufacturer had two dozen employees working for a month to clean the facility before operations could resume. While the facility was not operating, the products were produced at overseas facilities. Another manufacturer stated that they spent considerable time assisting clients to obtain products that they could not provide because of damage to the facility. Another small company spent considerable time obtaining loans to provide them with the resources to re-open their facility. Another company did not anticipate the severity of the extended impact that Hurricane Sandy had on the entire economy. Rather than laying off employees during the slow period following the storm, the owners used their own savings to keep the employees on payroll. However, when business slowed down and customers stopped paying, they had to lay off four of nine employees.

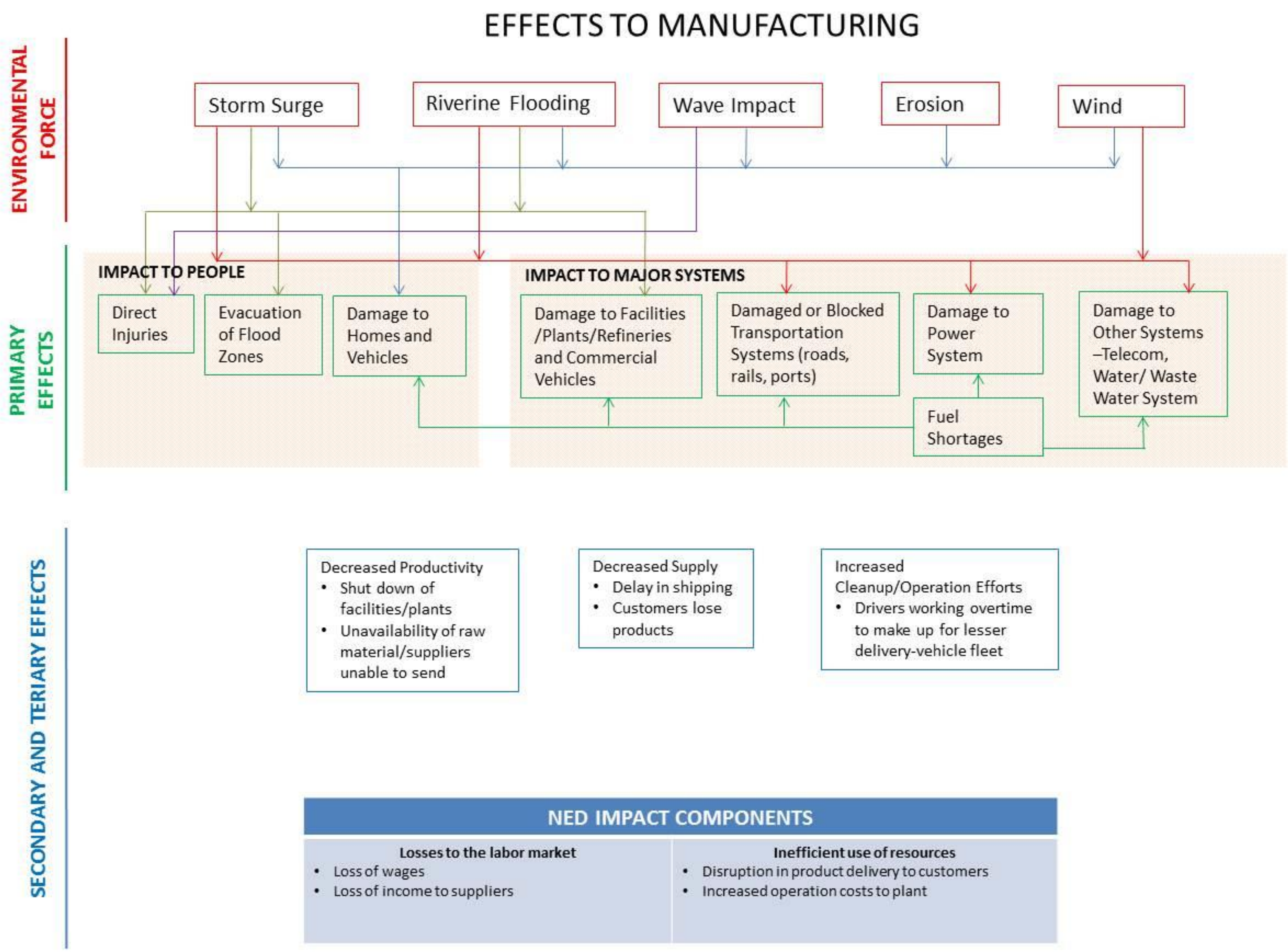

Figure 6. Manufacturing Effects Pathway

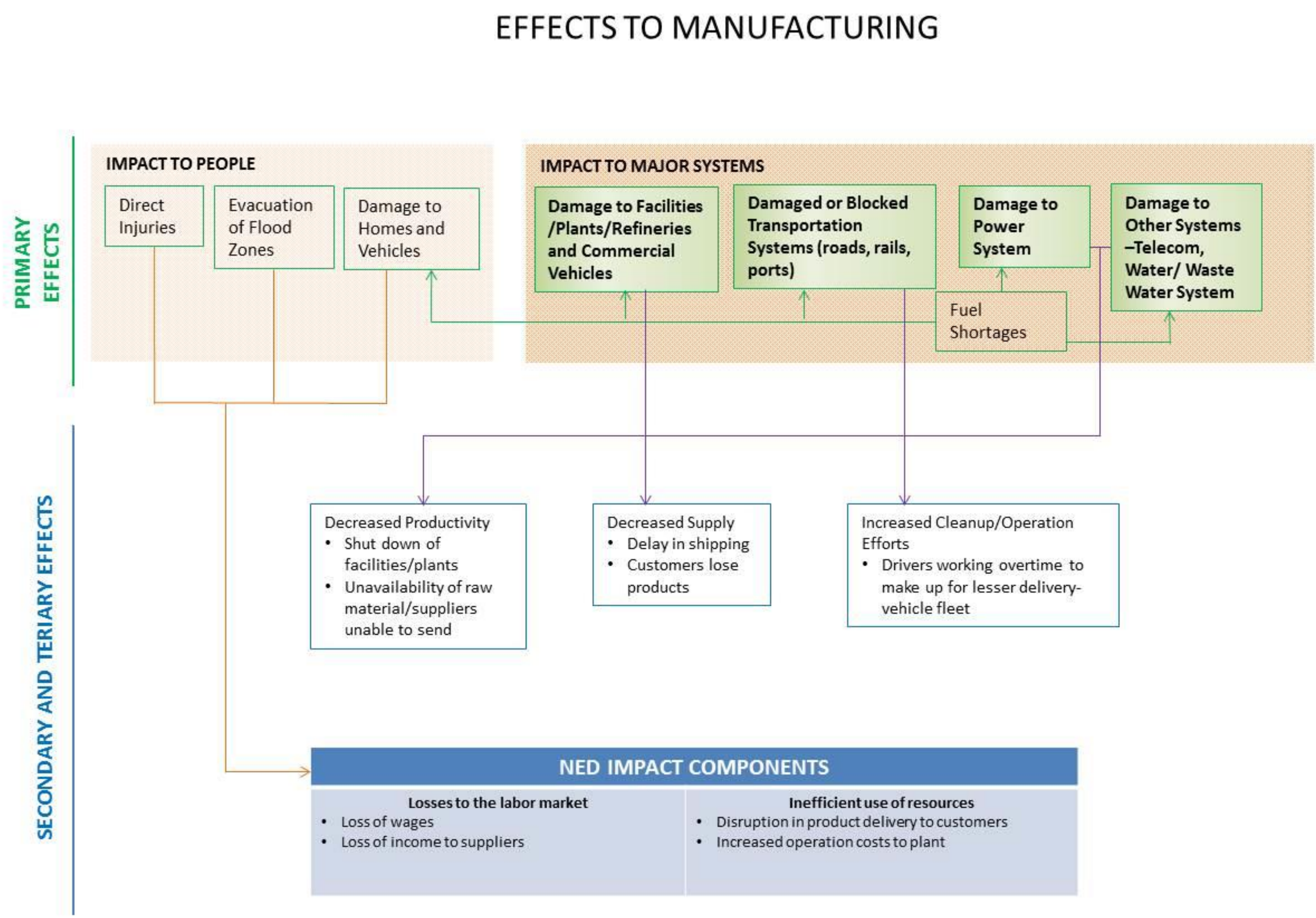

Figure 6.1. Manufacturing Effects Pathway – Impact to People and Major Systems

6.3.2 NED Impact Components

As identified on the pathway diagrams, the secondary and tertiary effects components evaluated for the manufacturing community sector were as follows:

Inefficient use of resources – the inefficient use of resources resulting from the inability to receive or provide a good because of a storm event. The NED impacts include administration time to rearrange orders and identify new suppliers or raw material, as well as increased trucking costs for delivery of goods. These are not the direct damages to a facility, but the incremental actions/expenditures that are needed to ensure that the needs of clients are addressed.

Losses to the labor market – lost productivity due to storm-related shut downs when employees cannot be put into the production of a good. The NED impacts would be expected primarily during the storm and the initial response and recovery period when substitutes could not be found and individuals are idle or not operating at full potential.

6.3.3 Measurement

The following lists present potential ways and tools to capture NED impacts associated with each component of the secondary and tertiary effects.

Inefficient use of resources

- Develop a basic list of manufacturing categories (e.g., size, type) that are present in the study area;
- Estimate the number of manufacturing facilities by category that would be directly damaged by a storm event and those that would be indirectly impacted;
- Estimate the incremental amount of administrative time that would be spent per facility for addressing client related issues (e.g., rearranging shipments);
- Estimate the incremental amount of administrative time that would be spent per facility for addressing employee-related issues (e.g., rearranging work schedules);
- Multiply the incremental amount of administrative time by the average labor rate for administrative staff to estimate the labor impacts;
- Estimate the incremental distance of transportation of shipments that would need to be delivered from another location;
- Multiply the incremental distance by the average trucking cost to estimate the increased shipping costs; and
- Estimate the number of days that costs would be incurred at a facility.

Losses to the labor market

- Estimate the average number of employees that work at each type of facility;

- If a facility is closed as a result of flooding, estimate the number of days that it would take before substitutes could be realized;
- Multiply the average number of employees by the average number of days by the average wage to estimate the loss to the labor market at closed facilities;
- If facility is not directly damaged from flooding, but closed or operating at reduced capacity, estimate the percentage of employees who would be impacted;
- Estimate the number of days that it would take before substitutes could be realized;
- Multiply the average number of employees by the average number of days by the average wage to estimate the loss to the labor market at these facilities; and
- Estimate NED impacts (loss of labor) for time prior to when substitutions could be implemented by adding the damages for facilities that are directly damaged and those that are not.

Several tools are available to estimate the indirect economic effects to manufacturing. Mantell et al. (2013) utilized the R/RECON model to estimate the economic and fiscal impacts of Hurricane Sandy. The first step in this process was making key assessments as to the negative effects of the storm and integrating those into the model for the purpose of simulating the extent and time path of the losses to the State's economy. Assumptions included:

- Loss of 1 week's output for two-thirds of the State's gross domestic product. Half the loss was assumed to be restored week two, and the other half in week three, with full output by week four.
- Payroll employees continued to be paid, but contract, hourly, and self-employed workers were not paid during the storm and its immediate aftermath. Based on this assumption, income and employment losses were substantially less than the output loss.
- User-tax losses (sales, gas, and alcohol) occurred immediately during the storm period, but ended as people returned to work in early November 2012.

The NACCS team worked with the Alward Institute for Collaborative Science to explore potential methods of measuring storm impacts to the national economy. A discussion of a potential method to estimate secondary and tertiary effects based on economic impacts is provided in Appendix B. The discussion includes an illustrative example that is based on two sectors of the economy: agriculture and manufacturing.

6.4 Retail Activity

Impacts to retail activity occur when a business is not able to operate or operates at a reduced capacity because of the impacts of a storm event.

6.4.1 Literature Review and Pathways

The secondary and tertiary effects on retail from disruptions to the transportation system have been well documented in literature. During public transit strikes in cities that rely heavily on public transit for work and pleasure, social and leisure trips are canceled or decreased, which relates to retail activity losses (Van Exel and Rietveld 2001). Although many of the purchases can be put off, the labor power of the retail persons is gone forever. The May 1981 strike in Hague, Netherlands, led to a decrease in downtown store sales by 10 to 15 percent, and 40 percent of planned leisure trips that relied on public transportation were canceled. The 1966 New York City subway strike caused a decrease in retail activity of 20 to 25 percent and even led to a 6-month post-strike loss of riders for retail of 2.6 percent. A bus strike in Knoxville in 1977 decreased downtown merchant business ridership by 7 to 16 percent. These strikes also affected the ability of the employees to get to the retail establishments. In Pittsburgh during the strike in 1976, one-quarter of the public transportation users stayed home on the first day of the strike because they did not own a car and had not planned on needing to find alternate transportation. This would be similar to a post-disaster setting where if public transportation is shut down, then most likely personal transportation may not be reasonable either. Long-term retail activity may decrease as well because customers may not return even after the business reopens if they find a satisfactory alternative (Webb et al. 2002). Although many retailers suffered a 100 percent loss of business for a few days and a slowdown thereafter, others benefitted from increased sales during the recovery and reconstruction period (McClain 2012).

Overall, the impact of Hurricane Sandy on retail appears to be mixed, with short-term impacts on sales followed by a strong rebound during the recovery. Decreased retail activity may be a result of either direct damages to a business or may be a secondary response to many other direct impacts. These other direct impacts include loss of power that prevents the store from operating, damaged or blocked transportation that prevents employees and supplies from reaching the store, and also loss of telecommunications. Figure 7 shows the pathways from the physical forces associated with a storm that impact the operation of the retail facility because of direct damage to the facility, lack of power, or inability of employees to get to work as a result of a lack of transportation or being injured or displaced from home. The secondary and tertiary effects include decreased productivity due to the shutdown of the plant, which also impacts both the retail facility's suppliers and customers. Additional secondary effects include the increased cleanup effort to get the retail facility in operation and maintaining communication with both customers and suppliers to ensure continuity once the facility is back in operation. Impacts expected primarily during the storm and the initial response period include:

- Loss of work days - includes lost labor and lost productivity due to store closure and/or the inability of employees to get to work.
- Disruption to customers – includes increased transportation and other costs for customers to obtain food and other necessities. Impacts expected primarily during the storm and the initial response period.

- Loss of labor to suppliers – includes interruption/delays in delivery by suppliers to stores. Impacts expected primarily during the storm and the initial response period.
- Operation costs to store – includes overtime for management and employees during the recovery period while repairs are underway and also for maintaining contact with customers and suppliers.

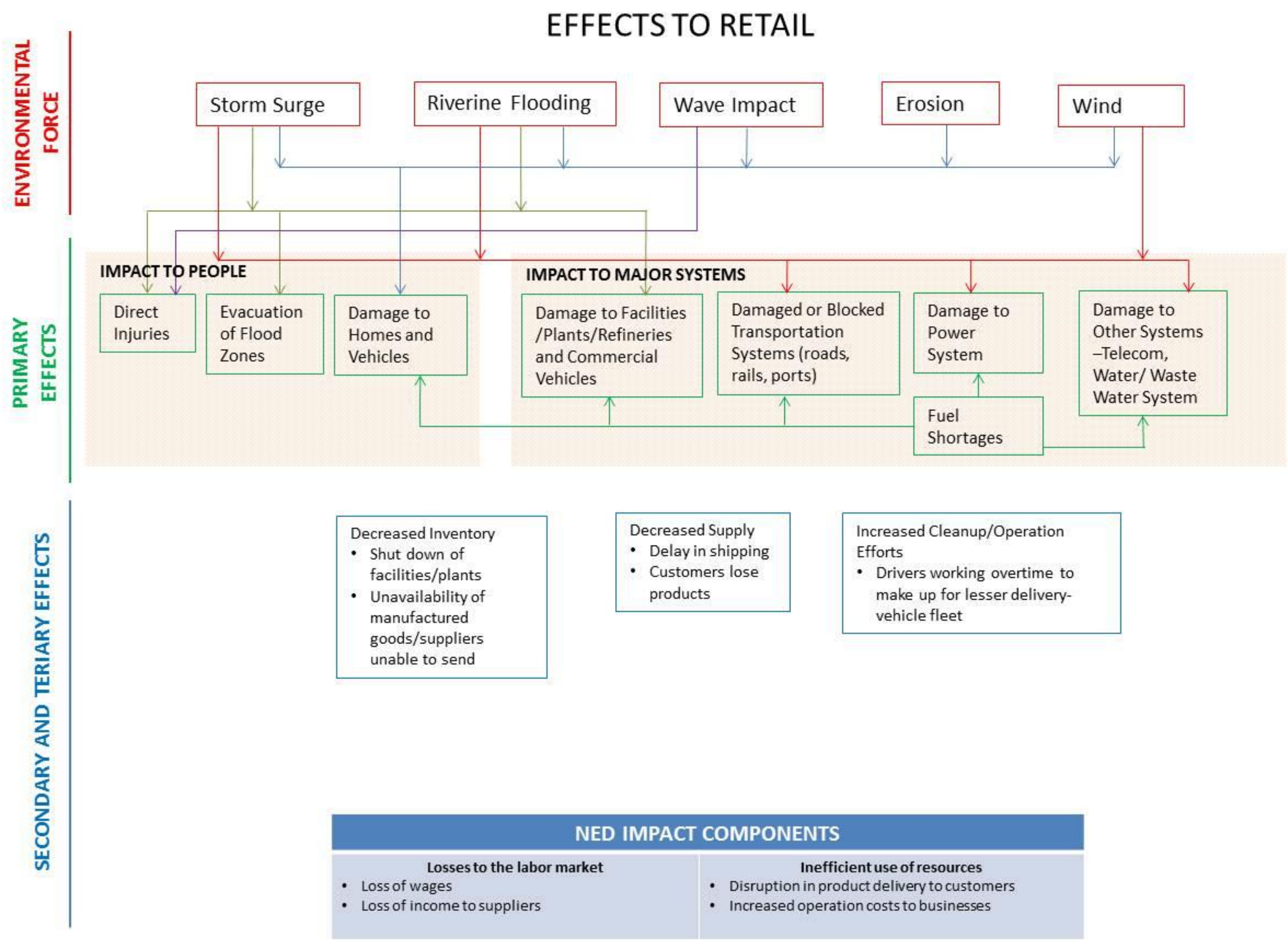

Figure 7. Retail Effects Pathway

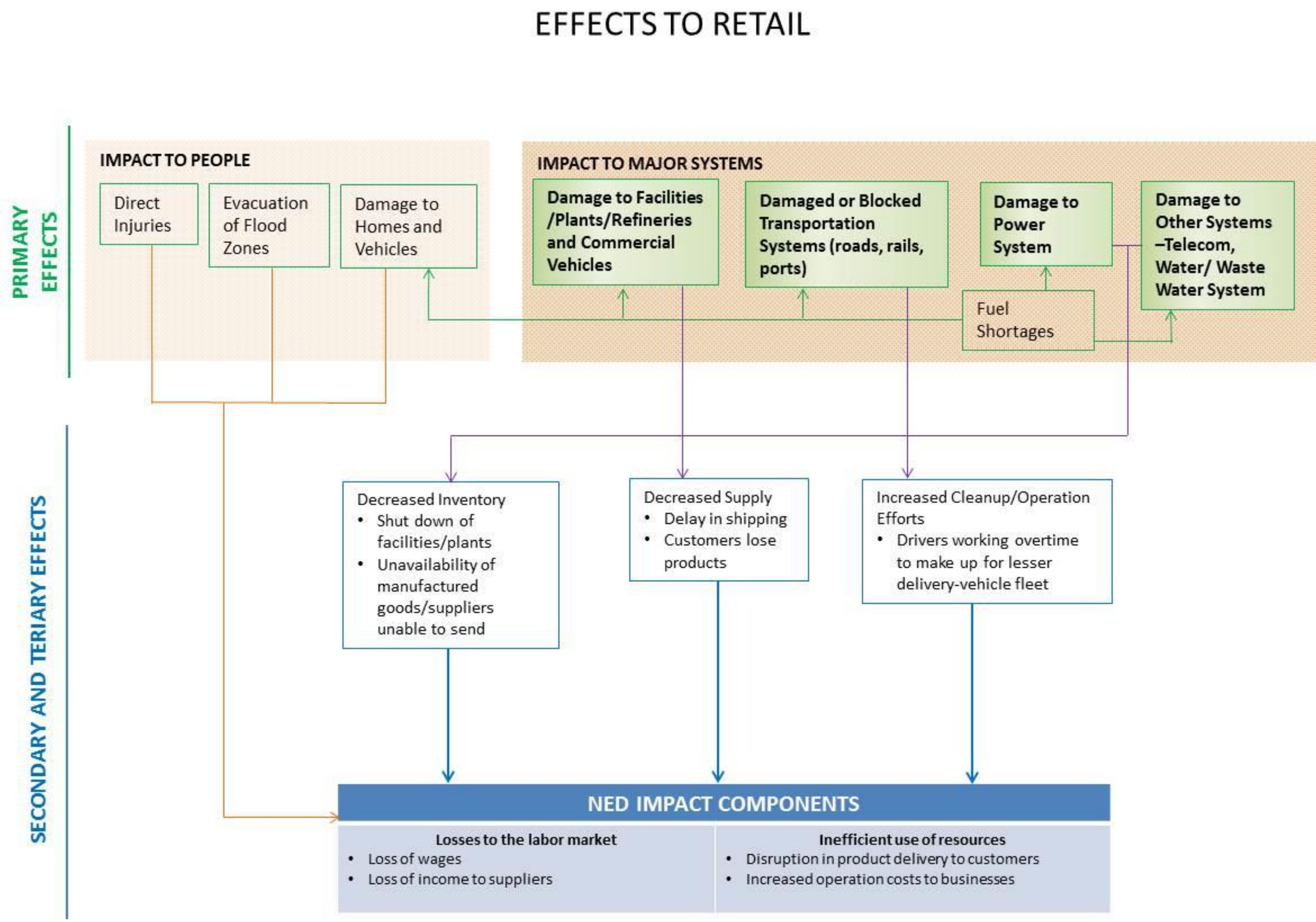

Figure 7.1. Retail Effects Pathway – Impacts to People and Major Systems

6.4.2 NED Impact Components

As identified on the pathway diagrams, the secondary and tertiary effects components evaluated for the retail activity community sector were as follows:

Inefficient use of resources – the inefficient use of resources resulting from the inability to receive or provide a good or service because of a storm event. The NED impacts include administration time to rearrange orders and identify new suppliers or raw material, as well as increased trucking costs for delivery of goods. These are not the direct damages to a business, but the incremental actions/expenditures that are needed to ensure that the needs of clients are addressed.

Losses to the labor market – lost productivity due to storm-related shut downs when employees cannot be put into the production of a good or service. The NED impacts would be expected primarily during the storm and the initial response and recovery period when substitutes cannot be found and individuals are idle or not operating at full potential.

6.4.3 Measurement

The following lists present potential ways and tools to capture NED impacts associated with each component of the secondary and tertiary effects.

Inefficient use of resources

- Develop a basic list of retail categories (e.g., size, type) that are present in the study area;
- Estimate the number of retail establishments by category that would be directly damaged by a storm event and those that would be indirectly impacted;
- Estimate the incremental amount of administrative time that would be spent per establishment for addressing client-related issues (e.g., rearranging shipments);
- Estimate the incremental amount of administrative time that would be spent per establishment for addressing employee-related issues (e.g., rearranging work schedules);
- Multiply the incremental amount of administrative time by the average labor rate for administrative staff to estimate the labor impacts;
- Estimate the incremental distance of transportation of shipments that would need to be delivered from another location;
- Multiply the incremental distance by the average trucking cost to estimate the increased shipping costs; and
- Estimate the number of days that costs would be incurred at a facility.

Losses to the labor market

- Estimate the average number of employees that work at each type of establishment;

- If an establishment is closed as a result of flooding, estimate the number of days that it would take before substitutes could be realized;
- Multiply the average number of employees by the average number of days by the average wage to estimate the loss to the labor market at closed establishments;
- If an establishment is not directly damaged from flooding, but closed or operating at reduced capacity, estimate the percentage of employees who would be impacted;
- Estimate the number of days that it would take before substitutes could be realized;
- Multiply the average number of employees by the average number of days by the average wage to estimate the loss to the labor market at these establishments; and
- Estimate NED impacts (loss of labor) for time prior to when substitutions could be implemented by adding the damages for establishments that are directly damaged and those that are not.

Similar to the manufacturing sector, the NED impact components primarily include "inefficient use of resources" and "loss of labor." As such, the tools discussed for the indirect effects to manufacturing are expected to also apply to the indirect economic effects to retail.

6.5 Municipal Services

Impacts to municipal services occur when a municipality is not able to operate or operates at a reduced capacity, leading to a decreased level of service to residents.

6.5.1 Literature Review and Discussion of Pathways

The willingness of citizens to pay taxes in order for a community to be able to run sufficiently is linked to the citizens' view of the community; there is a direct correlation between performance assessments and willingness to pay (Glaser and Bartley 1999).

Power infrastructure is often affected during a disaster, resulting in approximately $2.99 per customer per outage hour loss, plus distribution pole repair of $2,500 each, and transmission support structure repair of $0.4 million each (Ouyang and Dueñas-Osorio 2014). The average restoration times for hurricanes by Category of the Saffir-Simpson Hurricane Wind Scale are 8.9 days for Category 1, 2.3 weeks for Category 2, 3.4 weeks for Category 3, 4.9 weeks for Category 4, and 6.7 weeks for Category 5. Economic resilience can be estimated with respect to mitigating these outages because the efficiency of the restoration sequences impacts the economic loss.

Decreased municipal services may be a result of either direct damages to the municipal facilities and equipment or may be a secondary response to many other direct impacts. These include loss of power that prevents the municipal facility from operating or the diversion of normal municipal services, such as police, fire, and sanitation, to perform disaster response and recovery activities. In addition, there can also be long-term impacts to municipal services due to both diversion of funding to pay for response and recovery activities and loss of property tax revenues as a result of damaged or destroyed rateables (Mantell et al. 2103). Figure 8 shows the pathways from the physical forces associated with a storm through each of the primary effects that resulted in decreased municipal services. It also shows the pathway from each of the primary effects associated with the storm that includes damages to municipal buildings, schools, homes/businesses, transportation systems, power, water and waste water, and telecommunications resulting from the storm.

The indirect decreased municipal services identified on the pathway diagrams include the following:

- Loss of school days for students – includes school closures due to either direct damage to schools, the inability of teachers to get to school, or loss of power. Impacts are generally mitigated by the school year being extended.
- Loss of work days – includes lost labor and lost productivity due to parents of children providing child care while schools are closed.
- Loss of police, fire, sanitation services
- Loss of recreational opportunities
- Lack of potable water
- Untreated sewage

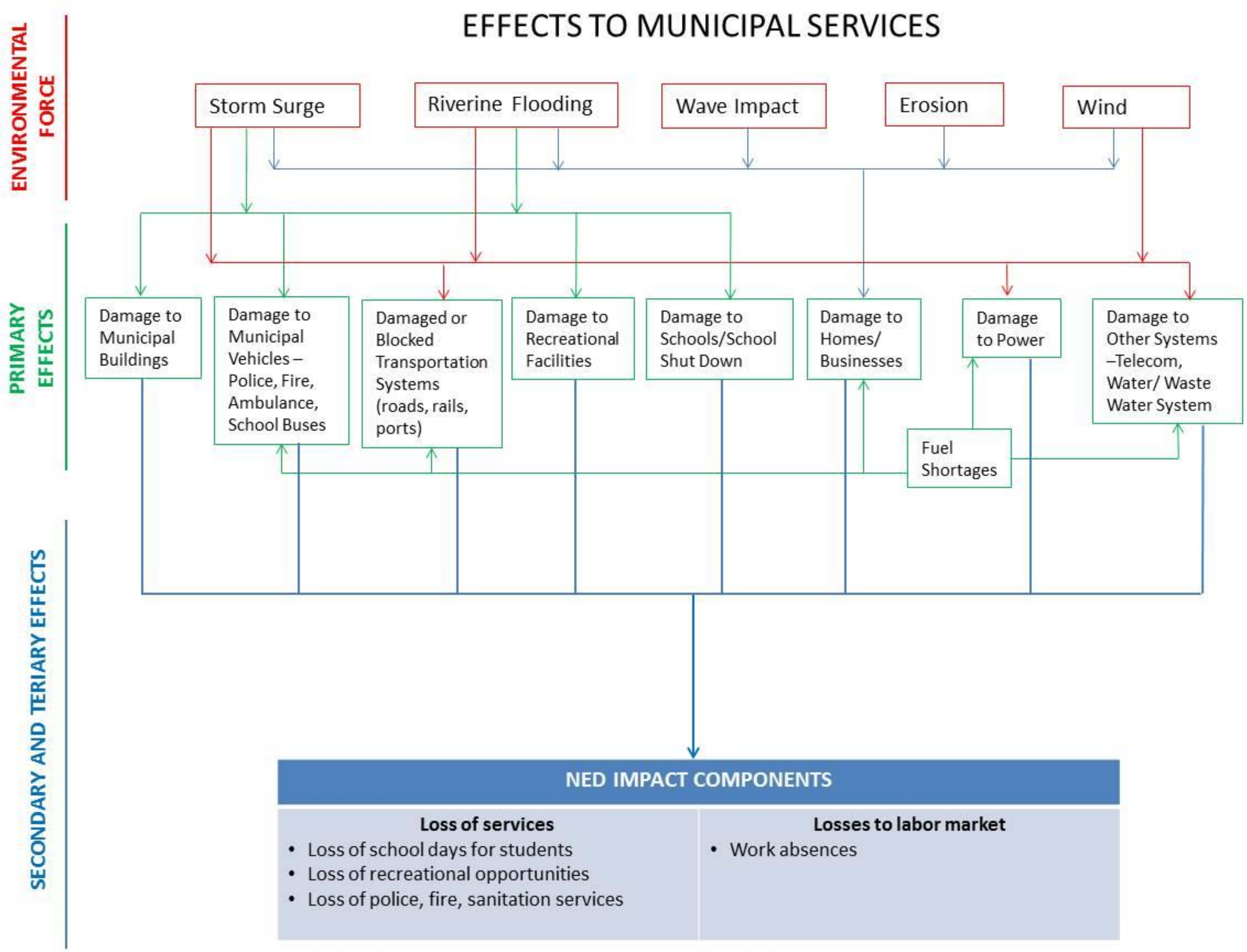

Figure 8. Effects to Municipal Services Pathway

6.5.2 NED Impact Components

As identified on the pathway diagrams, the secondary and tertiary effects components evaluated for the municipal services community sector were as follows:

Loss of services – the loss of municipal town functions and facilities (e.g., libraries, parks, town offices, police) that are not available as a result of a storm event. The NED impacts include the willingness to pay for a given level of service by town residents and the effects of the loss of a particular function.

Losses to the labor market – lost productivity due to a storm when residents cannot be put into the production of a good or service because of the loss of a municipal service, such as when a school is closed and parents must stay home. The NED impacts would be expected primarily during the storm and the initial response and recovery period when substitutes cannot be found and individuals are idle or not operating at full potential.

6.5.3 Measurement

The following lists present potential ways to capture NED impacts associated with each component of the secondary and tertiary effects.

Loss of services

- Determine the municipal tax revenue used to support the community;
- Estimate the services that would be lost as a result of a storm event;
- Using the operating cost as a proxy, determine the value that residents place on that service;
- Estimate the number of days that service would not be available or the number of days before a substitute could be implemented; and
- Multiply the number of days the service would not be available by the willingness-to-pay value to estimate the NED impacts.

Losses to the labor market

- Estimate the impact of the loss of services on the community;
- Estimate the number of residents that would be impacted by the loss of the services;
- Estimate the number of days that it would take before substitutes could be realized;
- Multiply the number of residents by the average number of days by the average wage to estimate the loss to the labor market throughout the community; and
- Estimate NED impacts (loss of labor) for the time prior to when substitutions could be implemented.

7 Next Steps

This study of secondary and tertiary effects was an initial effort to quantify the impacts of secondary and tertiary effects for inclusion in NED evaluations. As such, this study was intended to provide an enhanced understanding of how storms create secondary and tertiary effects, how potential CSRM projects could reduce these effects, and how the impacts can be quantified for consideration in future NED evaluations of CSRM alternatives.

The evaluation of secondary and tertiary effects can be used for planning purposes to better define the costs of storm-related damages. The damage pathways developed in this study will be used to improve the analyses and communication of the benefits associated with flood and storm risk management alternatives being considered for project planning areas.

The overall goal of this study was to expand the use of secondary and tertiary effects in the NED evaluation of CSRM alternatives. Because the range of secondary and tertiary effects can be expansive, only selected community sectors were evaluated. Although these sectors are representative, they are not inclusive of all the secondary and tertiary effects that could occur. Therefore, follow-on studies should conduct assessments of additional community sectors to provide a more comprehensive analysis of the secondary and tertiary effects.

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Appendix A: Interview Notes

1. Interview Notes - Rachel Pruchno, Ph.D.

Date – September 18, 2014

Interview Technique – Conference Call

Conference call attendees

Interviewee:	Rachel Pruchno, Ph.D.
URS Participants:	Jason Weiss Michael Cannon Bill Slezak Molly Curtiss Stacy Mulrain Pritpal Bamhrah

Rachel Pruchno, Ph.D. is Director of Research at the New Jersey Institute for Successful Aging, and Endowed Professor of Medicine at Rowan University's School of Osteopathic Medicine. She directs the ORANJ BOWL project. (*Source - http://www.rowan.edu/som/njisa/behavioral-research/)*

Dr. Pruchno was introduced to the project and was asked to provide input on the likely impacts on the mental and physical health of senior populations which she is discovering and analyzing as a part of her research. We also asked for her general thoughts and advice on how the storm the storm affected people (flooding, power loss, fuel loss, social relationships) and how to capture those effects.

Dr. Pruchno explained that one of the problems with post-disaster research is that a good pre-disaster baseline is rarely available. As a result, it is impossible to tell what proportion of the problems measured after the disaster was pre-existing. It is interesting to note that in 2006, Dr. Pruchno cultivated a large representative sample of NJ residents aged 50 – 74 for a long-term study on aging (approx. 6000 people). Using this baseline sample, she is conducting two post-disaster studies. The first study, sponsored by the NIA, investigates the effects of Hurricane Sandy on the functional limitations of older people. Preliminary results will not be available until spring 2015. The second study, funded by ASPR and the CDC will attempt to identify which aspects of social connectedness promote resilience in older people that were exposed to Hurricane Sandy over a five-year period. Due to the term of this study, results will not be available in the near future.

In her work, Dr. Pruchno attempts to measure:

- Physical health
- Functional ability (walking, climbing steps)

- Depression
- Post-Traumatic Stress Disorder

She also explained that these indicators are not combined into one index, but are kept separate. The relationships between them are examined (for example, the effect of physical health on emotional well-being). Dr. Pruchno confirmed that there are costs associated with treating disaster-related anxiety, and that one of the goals of her work is to understand the prevalence of post-disaster anxiety and Post-Traumatic Stress Disorder. She also stated that a number of her interviewers mentioned that many people were concerned about the loss of electricity during Sandy and the possibility that it would happen again. She also mentioned that a significant source of anxiety might be fear of direct impacts to family members.

According to Dr. Pruchno, most post-Sandy research is still in process, and results will not be forthcoming for some time. In the absence of solid data, she suggested we look into:

- Mortality rates for counties that were hit by Sandy
- Hospital usage rates (particularly ER visits)
- Nursing home applications
- Cost of providing care for elderly at nursing homes as compared to within the communities
- Anecdotal accounts
- Katrina research
- Metrics that the Department of Health uses

When asked if she thinks the cost associated with other storms, specifically the ones in Gulf Coast, can be translated to North East, she suggested that we compare the costs by looking at similar services – cost of seeing a psychologist in Florida versus in NJ, as an example.

As with all disasters, the effects of Hurricane Sandy are ongoing, and long-term impacts will not be discernable for 3 – 5 years.

She shared contact information for Marci Wright, who has access to data related to grants issued for various research related to Hurricane Sandy. She also provided contact information for David Abramson of Columbia University. She is the second person that has pointed us toward Dr. Abramson.

2. Interview Notes - Emanuela Taioli, Ph. D. and Rebecca Schwartz, Ph. D.

Date – September 22, 2014

Interview Technique – Conference Call

Conference call attendees

Interviewee:	Emanuela Taioli, Ph. D. Rebecca Schwartz, Ph. D.
URS Participants:	Jason Weiss Bill Slezak Molly Curtiss Stacy Mulrain Pritpal Bamhrah

Interviewees were Dr. Emanuela Taioli and Dr. Rebecca Schwartz, principal investigators of a CDC-funded study called Project Light aiming to study the psychological impact of Hurricane Sandy on affected individuals throughout Long Island and New York City. Dr. Taioli is an epidemiologist, and Dr. Schwartz is a psychologist. Both are affiliated with the North Shore-LIJ Health System (NSLIJHS).

Project Light is a two year study (2013-2015) aiming at learning the psychological and mental impacts of Hurricane Sandy on the population living in the geographic area that is served by NSLIJHS. The approach involves a 25-question survey and a review NSLIJHS's own hospital records throughout the area. The bulk of the data has already been collected, but since the study is ahead of schedule, the study team intends to collect more survey data before a final analysis is conducted in March 2015.

Surveys were conducted in person by study team members deployed to the field. Targeted locations generally consisted of health-fairs, job-fairs, recreation centers, and senior centers. The sample chosen for survey was selected on a voluntary basis. The investigators recognize that the resulting sample is not necessarily random, but one of convenience. They understand that they may have oversampled the hardest-hit areas. However, the team did make efforts to mimic the demographic of the counties in which they conducted the surveys.

Surveys related to Hurricane Katrina were used as baseline to develop the survey questionnaire. Questions focused mostly on property loss, personal loss, displacement, perceived stress, anxiety, depression, PTSD, substance abuse, and preexisting medical and psychological conditions. Most questions pertained to the immediate impact of the storm, although there were some follow-up questions on categories like displacement and power loss. The study team contacted approximately 500 people. Interviews were conducted based on willingness to participate.

Through NSLIJHS, the study team has access to emergency room admissions records for all 16 emergency rooms in the health system. Analysis will compare admission records before Hurricane Sandy, during the storm, and after 2012 records will be compared with records from other years to determine changes in pattern. Regular hospital admissions will also be studied for the same time period, as the investigators expect that during catastrophic events, people may not be able to access hospital services in the traditional manner.

Using this information, investigators will develop profiles of the affected populations; i.e., vulnerability groups, and subgroups within each cohort. An example could be that elderly people who live alone, and who have a major comorbidity, are more vulnerable to mental health damage than other populations. Profile characteristics can be geographic, as well. For people who fit a given profile, the investigators may recommend a specific course of treatment during disasters. For example, they may recommend that solitary, elderly people with a major comorbidity be treated ahead of the other groups.

Their final analysis will not be available until after the NACCS deadline. However, Drs. Taioli and Schwartz are able to tell us which variables they have, and how that information was collected. The data can be quantified by severity and degree of exposure. They would be able to run analyses for us with their data based on the aims and goals of the NACCS study. This method would help to avoid confidentiality problems. However, since their study is not yet published, a memorandum of understanding regarding the use of the data would be required.

Jason asked some specific questions about PTSD and anxiety. Dr. Schwartz stated that all results are very preliminary at this time, but she estimated that approximately 25 percent of the sample population exhibited the symptomatology of PTSD. Less than 5 percent of the people in the general population fall into this category. Anxiety varied a lot by subgroup and geography. Dr. Schwartz also stated that it would be difficult to disentangle flood damage from wind damage, but an attempt could be made.

3. Interview Notes - David Abramson, PhD MPH and Donna Van Alst, Ph.D.

Date – October 10, 2014

Interview Technique – Conference Call

Conference call attendees

Interviewees:	David Abramson, PhD MPH Donna Van Alst, Ph.D.
URS Participants:	Jason Weiss Bill Slezak Stacy Mulrain

Interview was primarily with Dr. Abramson.

David Abramson, PhD, Deputy Director, Columbia University's National Center for Disaster Preparedness and Donna Van Alst, Director of the Office of Research and Evaluation at the Institute for Families, Rutgers School of Social Work are co-leads for the Sandy Child and Family Health Study which is being funded by the State of New Jersey in order to understand the effects of Hurricane Sandy on the health and wellbeing of children and adults, the ongoing needs of affected residents, and how well people and households are recovering. A phone interview with Dr. Abramson and Dr. Van Alt was conducted on October 10, 2014. Dr. Abramson explained that the research was initiated in July 2014 and will include field interviews with 1,000 randomly selected households from the nine most affected counties in the state. The interviews will focuses on six topics: 1) children and family issues, 2) health and health care, 3) vulnerable populations, 4) economic and legal issues, 5) community and social issues, and 6), housing. Detailed information about the study can be found: at http://ncdp.columbia.edu/microsite-page/sandy-child-and-family-health-study/s-cafh-home/).

Dr. Abramson indicated that many of the specific issues to be addressed in the study are particular relevant to the current Development of secondary and tertiary effects study that include:

Children and Family Issues:

- Behavioral issues and challenges among children and youth;
- Lack of social and economic support for parents resulting in additional parental challenges and familial conflicts;
- Increased reports of domestic violence;
- Some schools have been unable to adequately support affected children and youth (due to lack of resources, lack of knowledge regarding post-disaster curriculum; etc.).

Health and Health Care:

- Emergent mental health issues, even almost two years after the storm;
- Perceived rise in drug use and/or alcohol abuse post-storm.

Vulnerable Populations:

- Particularly vulnerable groups in the response and recovery: the elderly; children and adults with disabilities or special health care needs; undocumented persons; methadone users; the poor; renters; single mothers; and others.
- Amplified vulnerability among these groups was often attributed to stigma, pre-existing marginalization; and lack of awareness of or access to necessary services.

Economic and Legal Issues:

- Job loss due to the hurricane;
- Lack of access (in some areas) to legal aid.

Community and Social Issues:

- Buy-back programs, including those from previous hurricanes, may change the character of communities in multiple ways;
- Uneven recovery rates in neighborhoods.

Housing:

- Lack of affordable housing, a challenge exacerbated after the storm;
- Need for more short- and long-term rentals.

Dr. Abramson indicated that he expects to have data with preliminary findings in about a year. While Dr. Abramson was not able to provide any specific metrics or cost estimates for estimating the secondary and tertiary effects of a coastal storm on health care, he did share several helpful perspectives with regard to considering the secondary and tertiary effects associated with decreased health. In particular he mentioned that the medical care system comprises three components, each of which impact medical care in distinct ways which reduce its capacity to function. These include the infrastructure (e.g., buildings, electricity, water, telecommunications), the supply chain, and the work force. Since each of the components have a different throttling effect, the overall medical system depends on each functioning as a single integrated system. Dr. Abramson also pointed out that the Medical system is also dependent on the regional infrastructure. One consideration is whether there is sufficient surge capacity to handle increased health care during natural disasters. Short term impacts, such as injury or immediate illness, are instantly apparent. But some impacts, such as impacts to mental health, are only revealed over time. As a result of the delay in manifestation, these are very difficult to tie to changes in infrastructure. Although mental health disturbances are clearly defined through medical outcome studies, Dr. Abramson is not sure how best to monetize an effect like mental health. He suggested that we attempt to define excesses in morbidity, mortality, and health care costs above and beyond ordinary, and use that as a metric. He expects that it will be difficult to account for a moving population. Following Hurricane Katrina, 400,000 people left the impacted area. The baseline population did not return, and the current population is different from the previous population. One way to measure displacement might be through a meta-analysis of home destruction and post-disaster housing.

Dr. Abramson suggested an investigation of possible relationships between health and reconstruction (does mental health decrease the longer reconstruction is delayed?), and that we attempt to relate aggregate storm surge data in a small area to excess health care costs in the same area.

The scale of a disaster changes response to the disaster. A large scale disaster affects a regional system through displacement, local government, and pressure on the region.

Social scientists tend to think about population impact as an outcome.

Prior to the interview, Dr. Abramson reviewed the preliminary pathway diagrams prepared by URS. He observed that the indirect impacts contained a combination of outcomes, mediators, and health impacts and that an attempt be made to distinguish between them. Outcomes are things like increased health care costs, increased hospital stays, decreased mental and physical function, and death. Mediators are things that lead to poor health. Health Indicators predict economic impact. These include loss of work days and reduced productivity.

4. Interview Notes - Thomas G. Dallessio and Deane M. Evans

Date – October 17, 2014

Interview Technique – Conference Call

Conference call attendees

Interviewee:	Thomas G. Dallessio Deane M. Evans
URS Participants:	Jason Weiss Bill Slezak Pritpal Bamhrah

Interviewees were Thomas G. Dallessio, Director Center for Resilient Design at NJIT and Deane M. Evans, Executive Director for Center for Building Knowledge at NJIT. They discussed about their effort of reaching out to three towns which they had worked earlier with to get an insight about post Sandy impacts. These three towns were Perth Amboy in Middlesex County, Long Branch and Sea Bright in Monmouth County.

Further Hoboken, Greenwich Township (Cumberland County) and Union Beach were also approached. These conversations were not a part of any formal study, but led to about two dozen design studios at NJIT.

As a specific example of loss of municipal service, it was mentioned that Sea Bright town had no funds for debris removal, hence bonded entire years' budget for the cause, leading to unavailability of any budget to provide/improve other municipal services.

Tourism was impacted as most places lost customers, but some places like Asbury Park saw a return in customers.

It was suggested that tax rolls can be looked as a gross indicator and may be a parameter that can be used as a metric. They also suggested exploring NJ Resiliency Network which is a post-Sandy initiative that studies municipal recovery and resiliency needs. Contact information for Debbie van Opstal, Executive Director of US Resiliency Project was also provided by Thomas Dallessio to help us move further.

5. Interview Notes - Jeanne Hurlbert, PhD

Date – October 16, 2014

Interview Technique – Conference Call

Conference call attendees

Interviewees:	Jeanne Hurlbert, PhD
URS Participants:	Jason Weiss Bill Slezak

Prior to the interview, Dr. Hurlbert reviewed the preliminary mental health pathway diagrams prepared by URS, which helped guide the interview.

Dr. Jeanne Hurlbert explained that most of her work involved studying depression" in populations in Orleans and Jefferson Counties that were impacted by post Katrina. Dr. Hurlbert actually started her studies prior to Katrina, and was therefore able to compare pre and post Katrina depression symptoms. She found that the depression index almost doubled from 1.06 to 1.74 in Jefferson Parish and to 1.89 in Orleans Parish. She found that a mitigation factor in vulnerability to depression was the extent of social network – church, family, friends, and neighbors. She pointed out that depression caused by stress due to destruction of homes and being displaced made everyday tasks (e.g., grocery shopping, mail, doctor visits, work, school) even much more difficult. She also pointed out that increased depression leads to:

- Sleep disorder
- Drug/alcohol abuse
- Increased stress
- Vehicle accidents
- Crime
- Incarceration.

Dr. Hurlbert pointed out that this also leads to additional demands and costs to voluntary organizations, medical treatment centers and government social services. Lack of capacity or failure to treat ultimately becomes a societal cost.

6. Interview Notes - Thomas Wakeman and Jon Miller

Date – October 23, 2014

Interview Technique – In-Person Interview

Interview attendees

Interviewee:	Thomas Wakeman Jon Miller
URS Participants:	Bill Slezak Stacy Mulrain

Interview was primarily with Dr. Wakeman. Dr. Miller arrived towards the end of the interview.

Dr. Wakeman observed that the Coast Guard restored the Port of New York and New Jersey to operation relatively early after Sandy hit, but the supply chain on the landside remained in disrepair for a much longer time. It was clear that the Port side benefitted from an emergency plan and a well-structured chain of command. But equally important to its recovery were the myriad ad-hoc collaborations between Port stakeholders that drew upon shared relationships and experience. Dr. Wakeman identified human factors as among the most influential in disaster recovery. Unfortunately, this powerfully beneficial dynamic can also be the most vulnerable.

On the landside, stakeholders could not achieve the same degree of focused effort as their counterparts on the Port side. Resiliency in the supply chain was undermined by arguments between political leaders and competition between businesses. It is evident from post-Sandy experience that an operable port is of little value if inventory cannot move. To avoid system failure, physical and social (organizational) infrastructure must align and work together, and this effort must bridge election cycles.

During the interview, Dr. Wakeman reviewed the preliminary pathway diagrams prepared by URS. His recommendations were as follows:

- To generate the best estimates pathways need to be site-specific and decision-making needs to be uniform. The charts can help to ensure that both of these needs are met. Once good estimates are generated, scenarios can be modelled.
- Avoid attempting to solve everyone's problems. Allow stakeholders to work their own way through the chart. Individual stakeholder charts can be superimposed onto each other to reveal the needs of a community. This will enable policy makers to make thoughtful decisions.
- Make sure the target audience recognizes the public agency value system, and whether they are in it or out of it.
- The chart can inform the trigger levels.

Dr. Wakeman stressed the importance of consistency in decision making, and the simultaneous need for a framework that can accommodate the uncertainty of a global marketplace as well as unintended consequences. The assumption that impacts will always be specific and local can harm the recovery process. He gave an example of the unforeseen consequences of Governor Christie's prioritization of electricity after Hurricane Sandy. The governor prioritized as follows:

1. Hospitals
2. Electricity to homes
3. Industry

Placing industry last on the list resulted in cascading failures across multiple sectors. Refineries and tank farms were unable to get online. The subsequent lack of fuel caused sanitation problems at water utilities, created massive delays at the gas pumps, and strangled transportation. Water supply and transportation have been identified by the National Research Council as "lifeline sectors" due to their critical position in the support structure of today's standard of living.[3] These, it was argued, were crippled as a result of prioritizing industry after homes.

Dr. Wakeman discussed the fiercely competitive nature of Port business and its impact on the cooperation and coordination of multiple stakeholders during post-disaster circumstances. Businesses are constantly contemplating and implementing new strategies to stay ahead of their competition. A crisis can often bestow a much-needed opportunity. Dr. Wakeman gave the example of Nokia's succession over Ericsson as an industry leader in electronics following a fire in a microchip plant. Nokia's speedy response to the fire ensured that its outstanding orders at the damaged facility were fulfilled through alternate manufacturers and warehouses. As a result, Nokia's profits soared and its market share increased to 30 percent. Ericsson, which did not take any actions following the plant fire, experienced order fulfillment delays upwards of six weeks, undershot annual earnings projections by hundreds of millions of dollars, lost 3 percent of its market share, and had to lay-off thousands of employees.[4]

This type of competition can be a huge detriment to the recovery process following a disaster. Partnership is critical, but businesses are reluctant. Customers are very agile, and businesses face a high risk of losing them to competitors during recovery time. Businesses have great incentive develop their own disaster-response playbooks at the expense of other competitors, and this can negatively affect the region at large by depriving it of important resources. Partnership needs to be safe for businesses. Dr. Wakeman feels there needs to be a charter in place that states that efforts will make cargo move at normal velocity, but not beyond that.

[3] UTRC Final Report Lessons from Hurricane Sandy for Port Resilience, p29

[4] The Fire that Changed an Industry, FT Press, 2008

7. Interview Notes - Gerard N. von Dohlen

Date – October 24, 2014

Interview Technique – Conference Call

Conference call attendees

Interviewee:	Gerard N. von Dohlen
URS Participants:	Bill Slezak Stacy Mulrain

Gerard N. von Dohlen is the president of Port Newark Refrigerated Warehouse (PNRW) in Newark, NJ. The company specializes in juice concentrates, meat, and kosher products. Prior to Sandy, PNRW operated two facilities: one on Tyler Street in Port Newark, the other on Avenue C in the Ironbound section of the city. The company suffered flood damage during both Hurricane Irene and Hurricane Sandy. Mr. von Dohlen estimates that PNRW incurred $850,000 in total damage and clean-up costs from both storms. In addition, general maintenance costs have risen because the water continues to do damage to building components and equipment.

Prior to Sandy, PNRW employed approximately 90 people and generated $270,000 in revenue per week. The business currently employs 60 people and generates about $200,000 in revenue per week. This decrease in revenue is not necessarily a result of Sandy. At some point after the storm, the Port took PNRW's Tyler street building. According to Mr. von Dohlen, this was due to the Port's need for additional space. Cleaning the buildings and repairing the damage caused by Sandy cost PNRW approximately 2 weeks of revenue. Mr. von Dohlen estimates that the renovations needed to harden the Avenue C building against future flood events will cost approximately $1 million.

During Sandy, water flooded to 2.5 feet at the Avenue C location. It did not damage the inventory or the equipment, but a herculean cleaning effort was undertaken to thoroughly scrub and power wash the interior of the building, as it is used for food storage. The Tyler Street building was not inundated, and the inventory was not damaged. However, this location did suffer extensive damage to its electrical system and bore the brunt of the disorganization on the landside. At all hours, staff in both locations were subjected to a surge of customer inquiries regarding the disruption of their orders, and were compelled to manage these with the same level of exertion as their recovery efforts.

Mr. von Dohlen and PNRW faced Hurricane Sandy armed with some important lessons learned from Hurricane Irene, in 2011. During Irene, the engine room of the Avenue C location flooded with 4 feet of water, destroying the all of the control boxes, the electrical motors, and one transformer. PNRW purchased and installed a replacement transformer. The next day, underground electrical wires into the building decayed and fried. Since refrigerated storage is the primary service provided by PNRW, the company is extremely dependent upon electricity. The refrigerators and freezers are sealed well enough to keep food at the correct temperatures for three to four days, but power is needed to maintain temperature beyond that. After Irene, Mr. von Dohlen contracted with a company to secure 1MW generators for emergency situations, and he purchased and stored a quantity of electrical wire to replace any wire damaged during future flooding events.

Both of these contingency plans were thwarted during Hurricane Sandy. First, FEMA seized all of the generators in the area with an output capacity greater than 1MW, and all of the diesel fuel, to supply power to police, hospitals, and homes. For two days after the storm, PNRW's refrigerated warehouses had no power. PNRW was finally able to obtain two 200KW generators only to find that there was no diesel fuel to run them. Limited access to NY and a number of regulations restricting direct sales to NJ customers by non-New Jersey dealers made it extremely difficult for the company to obtain fuel. After dozens of phone calls, PNRW was able to purchase 500 gallons of diesel, and with the assistance of technicians from the generator company, ran the two generators in series at the Avenue C location. They conserved the fuel by running the generators for 12-14 hours and then turning them off. This location was able to begin making deliveries within three days.

Generators could not be obtained for the Tyler Street building. During Sandy, the water level at the Port rose four feet and stopped within three inches of the docks. Parking lots were flooded, and street lights and traffic signals lost power and remained out for over a week. Driving became almost impossible. The location of the Port's electrical system rendered it extremely vulnerable to damage. Transformers were located on concrete pads close to grade, and electrical wires ran underground through conduits to the circuit breakers inside of the buildings. During the surge, the transformers were inundated and saltwater penetrated the electrical conduits. After power was restored on Monday, the inundated wires shorted and tripped the circuit breakers on the utility poles. Mr. von Dohlen estimates that $11,000 worth of wire into his building needed to be replaced. This was anticipated, and PNRW was prepared. Five employees spent 24 hours fishing new wire through the conduit. However, despite the warehouse's effort and preparation, an additional 24 – 36 hours were spent waiting for the utility company to approve the new wiring and reset the breaker at the pole. With the exception of one emergency USDA food run (picked with propane-powered forklifts and flashlights), deliveries from the Port location were halted for more than a week.

Mr. von Dohlen was satisfied with the assistance that his company received from the Port Authority during Hurricane Sandy. However, he feels that FEMA's participation in the recovery effort was disastrous. The agency created more problems than it solved by interfering with and actually obstructing individual plans to prepare, regardless of existing contracts. To his great frustration, Mr. von Dohlen learned that FEMA could not operate many of the generators that it seized due to poor allocation and lack of technical expertise. In his opinion, people in crisis are better off dealing with people that they know. Organizations like FEMA do not understand the regions they are trying to assist, and they don't have the relationships with the community that local people have. Therefore, they cause more harm than good. Mr. von Dohlen was also extremely dissatisfied with the performance of the power company.

The fuel shortage has caused Mr. von Dohlen and others to consider storing diesel fuel. According to him, one 1MW generator consumes 60 gallons of diesel fuel per hour. Even if FEMA hadn't seized all of the generators, the 500 gallons of diesel fuel that PNRW was eventually able to procure would have only supplied a little over 8 hours of electricity.

Appendix B: Discussion on Measuring Secondary and Tertiary Effects of Natural Hazards

Task Statement for the Alward Institute for Collaborative Science

The NACCS team asked the Alward Institute to assist with identifying the steps necessary to go from the primary (or direct) effects of storm damage to its secondary and tertiary effects and then to assist in identifying ways to measure the secondary and tertiary effects. In particular, the Alward Institute was asked to provide input on Section 6.3.3 and Section 6.4.3 of the report, which address the manufacturing and retail community sectors.

Prepared by:
Dr. Stephen Cook, Senior Economist
Alward Institute for Collaborative Science

Discussion on Measuring Secondary and Tertiary Effects of Natural Hazards

The Alward Institute defined economic benefits as a change in economic surplus underlying the storm damages avoided. The following discussion shows the rational.

(1) We begin by re-writing the bullet points pertaining to Section 6.3.3 in symbolic mathematical notation. (2) We use this exercise as a lead into discussing impact analysis in general. (3) Then we will describe how we believe it relates to benefit analysis, economic surplus and damages avoided in particular.

Let subscripts:
i equals sectors (collection of industries producing similar output)
t equals time (day, weeks, months, as appropriate, i.e., consistent with the cost measures)
c equals clients
w equals workers
A equals administrative
T equals transportation
1 … 4 equal the different share parameters.

Let dependent variable:
QP equal total outlays (the product of quantity and price)

Let independent variables:
M equals total number of manufacturing facilities in the region
A equals total administrative hours
P equals price
T equals total transportation cost
D equals total distant traveled.

Let parameters
s_1 equals the share of manufacturing facilities damaged by the storm
s_2 and s_3 equal the share of administrative costs associated with clients and workers respectively affected by the storm
s4 equals the share of transportation costs affected by the storm.

The total administrative outlays from the storm equals the sum over time and by sector of the product of the firms damaged, the additional administrative time per firm caused by the storm and the administrative costs per unit of time.

Total administrative outlays are:

1. $$Q_A P_A = \sum_t \sum_i \left(s_{1it} M_{it} \frac{s_{2it} A_{cit} + s_{3it} A_{wit}}{M_{it}} \right) P_{Ait}$$

Similarly, the total transportation outlays from the storm equals the sum over time and by sector of the product of the firms damaged, the additional transportation miles time per firm caused by the storm and the transportation costs per mile per unit of time.

Total transportation outlays are:

$$2.\ Q_T P_T = \sum_t \sum_i \left(s_{1it} M_{it} \frac{s_{4it} T_{it}}{M_{it}} \right) \left(\frac{P_{Tit}}{D_{it}} \right) D_{it}$$

The total additional outlay for administration and transportations from the storm damage equals the sum of equations (1) and (2).

Total administrative and transportation outlays are:

$$3.\ \begin{aligned} QP &= Q_A P_A + Q_T P_T \\ &= \sum_t \sum_i s_{1it} M_{it} \left(\left(\frac{s_{2it} A_{cit} + s_{3it} A_{wit}}{M_{it}} \right) P_{Ait} + \left(\frac{s_{4it} T_{it}}{M_{it}} \right) \left(\frac{P_{Tit}}{D_{it}} \right) D_{it} \right) \\ &= \sum_t \sum_i s_{1it} \left((s_{2it} A_{cit} + s_{3it} A_{wit}) P_{Ait} + (s_{4it} T_{it}) P_{Tit} \right) \\ &= \sum_t \sum_i \left(s_{1it} s_{2it} A_{cit} P_{Ait} + s_{1it} s_{3it} A_{wit} P_{Ait} + s_{1it} s_{4it} T_{it} P_{Tit} \right) \end{aligned}.$$

Eq. (3) shows that the total additional outlays caused by the storm equal the sum over time and by sector of the product of the share of firms damaged and the share of outlays on administrative and transportations expenditures. This seems to us as a true statement as far as it goes.

Besides administration and transportations sectors, IMPLAN social accounts have data for about 500 sectors' production inputs—sectors that include administration, transportation and retail—some or all of which may be affected by the storm. Once the effects of storm damage on output to meet intermediate and final demand is measured, the effects can be translated into employment, income or value added. The latter measure is needed in the calculation of economic surplus.

Illustrative Example

To illustrate a more general approach to measuring the economic effects of storm damage, assume an input-output model based on social accounts of the economy with two sectors—agriculture and manufacturing. Assume that agriculture uses manufacturing's output as an input into its production and conversely. Assume these sectors produce output to meet the sum of final demand output for households, investing, government services and exports, collectively referred to as "exports" below.

Before the storm, the two sector economy has the output listed in Table B1.

Table B1. Two Sector Input-Output Model of Total, Direct and Indirect Output of an Economy: Before Storm Damage

	AG	MANUF	I-A	I-A	AG	MANUF	AG	MANUF	TOTAL	DIRECT	INDIRECT
	Shares	Shares	Inverse	Inverse	Exports	Exports	Output	Output	Output	Output	Output
AG	0.10	0.30	1.25	0.63	112,717	0	140,896	417,026	557,922	112,717	445,205
MANUF	0.20	0.40	0.42	1.88	0	667,241	46,965	1,251,077	1,298,042	667,241	630,801
TOTAL							187,862	1,668,103	1,855,964	779,958	1,076,006

Where

$$(I-A)^{-1} = I + A + A^2 + A^3 + \ldots + A^n$$

Table B2. Two Sector Input-Output Model of Share of Capacity after Storm Damage

	AG	MANUF.			AG	MANF.
	Shares	Shares			Exports	Exports
AG	100%	100%			50%	
MANUF.	100%	100%				50%

Regional Substitution

There is a possibility that other regions in the US expending output to meet the final demand previously met by the output in the storm damaged region. This inter-regional cross elasticity of supply can be incorporated into the share of capacity function in Table B2 by assumption. Let the degree of substitutability fall between zero and one by assumption. The product of the degree of substitutability and one minus the share of capacity equals the extent of output loss that can be made up by other regions. Add the result to the region's share of capacity after the storm gives a measure of output capacity adjusted for regional substitution. For this example we assume the short run degree of substitutability is zero.

Table B3. Two Sector Input-Output Model of Total, Direct and Indirect Output of an Economy: After Storm Damage

	AG	MANUF	I-A	I-A	AG	MANUF.	AG	MANUF.	TOTAL	DIRECT	INDIRECT
	Shares	Shares	Inverse	Inverse	Exports	Exports	Output	Output	Output	Output	Output
AG	0.10	0.30	1.25	0.63	56,359	0	70,448	208,513	278,961	56,359	222,602
MANUF.	0.20	0.40	0.42	1.88	0	333,621	23,483	625,538	649,021	333,621	315,401
TOTAL					56,359	333,621	93,931	834,051	927,982	389,979	538,003

Table B4. Two Sector Input-Output Model of Total, Direct and Indirect Output of an Economy: Loss from Storm Damage

	AG	MANUF.	AG	MANUF.	TOTAL	DIRECT	INDIRECT
	Exports	Exports	Output	Output	Output	Output	Output
AG	(56,359)	0	(70,448)	(208,513)	(278,961)	(56,359)	(222,602)
MANUF.	0	(333,621)	(23,483)	(625,538)	(649,021)	(333,621)	(315,401)
TOTAL			(93,931)	(834,051)	(927,982)	(389,979)	(538,003)
AG	-50%		-50%	-50%	-50%	-50%	-50%
MANUF.		-50%	-50%	-50%	-50%	-50%	-50%
TOTAL			-50%	-50%	-50%	-50%	-50%

Storm Damage Changes in Employment

To measure the impact on employment from storm damage, build on the information about the impact on output in Table B4. Before the storm, we know the ratio of employment to output. Applying these ratios to the numbers in Table B4 results in the impact on employment from the storm damage in Table B5.

Table B5. Two Sector Input-Output Model of Total, Direct and Indirect Employment of an Economy: Loss from Storm Damage

	AG	MANUF.	TOTAL	DIRECT	INDIRECT
	Emp. to Output (#/$1000)	**Emp. to Output (#/$1000)**	**Emp. to Output (#/$1000)**	**Emp. to Output (#/$1000)**	**Emp. to Output (#/$1000)**
AG	0.008	0.008	0.008	0.008	0.008
MANUF.	0.002	0.002	0.002	0.002	0.002
	Emp. (#)	Emp. (#)	Emp. (#)	Emp. (#)	Emp. (#)
AG	(564)	(1,668)	(2,232)	(451)	(1,781)
MANUF.	(47)	(1,251)	(1,298)	(667)	(631)
TOTAL	(611)	(2,919)	(3,530)	(1,118)	(2,412)

Some thoughts on how to measure economic surplus from storm damage avoidance.

Rose[5] has shown that a measure of the change in economic surplus equals the product of the average change in output, initial output price and the change in productivity.

Let subscripts:
i equals sectors 1 … n
t equals time, 0: initial, 1: subsequent.

Let the dependent variable:
ΔES equals the change in economic surplus

Let independent variables:
Q equals output quantity
P equals output price

Let parameter
k equals the change in production efficiency

[5] Rose, Roger N. "Supply Shifts and Research Benefits: Comment." *American Journal of Agricultural Economics* 62, no. 4 (1980): 834-837.

The change in economic surplus in a single sector using output is:

4. $$\begin{aligned}\Delta ES_i &= kP_{i0}Q_{i0} + 1/2\left(Q_{i1} - Q_{i0}\right)P_{i0}k \\ &= 1/2\left(Q_{i1} + Q_{i0}\right)P_{i0}k_i\end{aligned}.$$

We know or can derive the values of the P's and Q's from input-output models in Tables B1 and B3 above. The change in productive efficiency requires an addition calculation.

Let's begin with a visualization of the measure of economic surplus as described in eq. (4) in output price and quantity space.

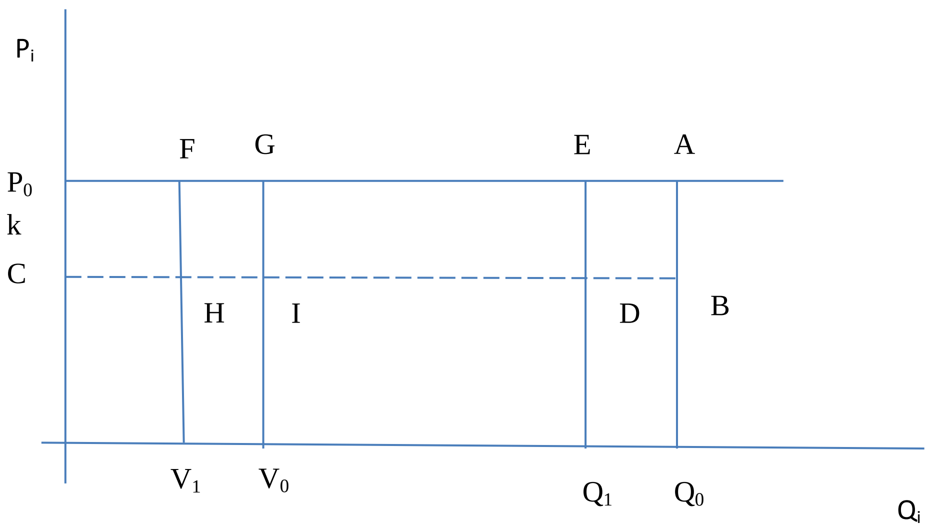

Figure B1. Measures of Economic Surplus using Output and Value Added

The measure of economic surplus in a single sector using output is:

5. $$\begin{aligned}&\Delta ES_i = kP_{i0}Q_{i0} + 1/2\left(Q_{i1} - Q_{i0}\right)P_{i0}k \\ &kP_{i0}Q_{i0} = P_0ABC \\ &1/2\left(kP_{i0}Q_{i1} - kP_{i0}Q_{i0}\right) = 1/2\left(P_0EDC - P_0ABC\right)\end{aligned}$$

It can be shown that in general equilibrium, the growth in value added equals the sum of the growth in technology and the share weighted growth in capital and labor intensity[6].

[6] Cooke, Stephen C. "The Role of Value Added in Benefit/Cost Analysis." Annals of Regional Science 25, no. 2 (1991): 145.

The measure of economic surplus in a single sector using value added (subscript *V*) is:

$$\Delta ES_{Vi} = ks_{Vi0}P_{i0}Q_{i0} + 1/2\left(s_{Vi1}Q_{i1} - s_{Vi0}Q_{i0}\right)P_{i0}k$$

6. $$ks_{Vi0}P_{i0}Q_{i0} = P_0 GIC$$
$$1/2\left(ks_{Vi1}P_{i0}Q_{i1} - ks_{Vi0}P_{i0}Q_{i0}\right) = 1/2\left(P_0 FHC - P_0 GIC\right)$$

Where:

$$s_{Vi1} = V_{i1}/P_{i1}Q_{i1}$$
$$s_{Vi0} = V_{i0}/P_{i0}Q_{i0} .$$

Storm Damage Changes Economic Efficiency

The growth in value added equals the sum of the growth in productivity and efficiency. Storm damage changes efficiency: the capital and labor intensity primarily by damaging capital and preventing labor from going to work. Storms tend to leave productivity unchanged—the unlocked mysteries of nature used to produce goods and services remain unlocked if not fully exploited.

7. $$G_{Vi} = G_{\eta i} + S_{Ki}G_{Ki} + S_{Li}G_{Li}$$
$$G_{Vi} - G_{\eta i} = S_{Ki}G_{Ki} + S_{Li}G_{Li} .$$

By translating the results for output in Tables B1 and B3 into measures of growth in value added while assuming no growth in technology, then the change in value added equals the sum of the share weighted growth in capital and labor intensity, i.e., a loss in efficiency. We define this loss in efficiency as the k-shift change in production efficiency.

The change in production efficiency is:

8. $$G_{Vi} - G_{\eta i} = S_{Ki}G_{Ki} + S_{Li}G_{Li} = k_i .$$

Let $G_{\eta i} = 0$, such that the change in productive efficiency is:

9. $$G_{Vi} = \ln\left(\frac{V_{i1}}{V_{i0}}\right) = \ln\left(\frac{s_{Vi1}}{s_{Vi0}}\frac{P_{i1}Q_{i1}}{P_{i0}Q_{i0}}\right).$$

Substituting and simplifying, the aggregate measure of economic surplus using value added is:

10. $$\Delta ES_V = \sum_i 1/2\left(s_{Vi1}P_{i0}Q_{i1} + s_{Vi0}P_{i0}Q_{i0}\right)\ln\left(\frac{s_{Vi1}}{s_{Vi0}}\frac{P_{i1}Q_{i1}}{P_{i0}Q_{i0}}\right).$$

If

$$P_{i0} \approx P_{i1} ,$$

then, the aggregate measure of benefits as economic surplus from damages avoided is measured as:

$$11.\ \ Benefits = \sum_i 1/2\left(s_{Vi1}P_{i1}Q_{i1} + s_{Vi0}P_{i0}Q_{i0}\right)\left(-\ln\left(\frac{s_{Vi1}}{s_{Vi0}}\frac{P_{i1}Q_{i1}}{P_{i0}Q_{i0}}\right)\right).$$

Assume
$s_{Vi0} < s_{Vi1}$
such that
$s_{V0} = .20$
$s_{V1} = .25.$

We assume that immediately after the storm, the destruction of capital and loss of intermediate inputs creates a demand for additional labor inputs per unit of output as labor is substituted for capital.

Table B6. Two Sector Input-Output Model of Total, Direct and Indirect Economic Surplus: Benefits as the Change in Value Added from Storm Damage Avoided

	AG	MANUF.	AG	MANUF.	TOTAL	DIRECT	INDIRECT
	Exports	**Exports**	**Output**	**Output**	**Output**	**Output**	**Output**
AG	8,609	0	10,761	31,851	42,612	8,609	34,003
MANUF.	0	50,961	3,587	95,552	99,139	50,961	48,178
TOTAL	8,609	50,961	14,348	127,402	141,750	59,570	82,181
% OF VA	-39%	-39%	-39%	-39%	-39%	-39%	-39%

Additional questions and answers based on the discussion

What is the relationship between benefits measured at the regional and national level?

The short answer is that there is no difference in the measure of benefit from damages avoided at the regional or national levels, the benefits are just more spatially and temporally disaggregated.

The primary economic impacts of storm damage are the effects of the storm on the region's ability to meet exogenous final demand defined above as "exports." Exogenous final demand for the region is different than that for the nation. This difference relates primarily to inter-regional trade that is outside the region at the regional level but inside at the national level. A derivation of a multi-regional input-output model in which, for example, the urban and rural sub-regional effects add to the consolidated national effect follows.

Round's Derivation of Multiplier Decomposition[7]

For a single region, the derivation of output (y) as a function of exogenous final demand (x) given fixed prices is as follows:

12) $y = Ay + x$,

13) $x = (I - A)y$,

14) $y = (I - A)^{-1} x = Mx$

Where M is the Leontief matrix of multipliers.

A consolidated region with two inter-related sub-regions can be model by separating the export-import-transfer flows between them from their respective totals. By so doing, each sub-region becomes an exogenous institution to the other sub-region with a column vector of exports & transfers and a row vector of imports and transfers to the other. At the same time this inter-sub-regional trade and transfers are endogenous to the consolidated region.

We would expect three effects from a consolidated bi-regional model: those contained within each sub-regions, those that feedback in a loop between regions and those that spillover (without feedback) from one to the other. The derivation of consolidated regional output as a function of exogenous final demand for the bi-region is as follows.

Assume a consolidated region with rural and urban sub-regions in which the rural region—a county or group of counties (economic development District 3 in Idaho w/o Ada County) is defined as:

[7] Round, J. I. (1985). Decomposing Multipliers for Economic Systems Involving Regional and World Trade.

15) $$y_1 = B_{11}y_1 + \hat{b}_{12}y_2 + x_1$$

Where *bji* is the proportion of inter-regional transfers from region *i* to *j* as a proportion of the total outlays in region *i*

The urban region, e.g., standard metro statistical area (SMSA) within or near the rural county (Ada County within district 3) is defined as:

16) $$y_2 = \hat{b}_{21}y_1 + B_{22}y_2 + x_2$$

Here, *bji* shows the proportion of imports to the total supply (domestic plus imports in region *i).*

Combined rural and urban region is:

17) $$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} B_{11} & \hat{b}_{12} \\ \hat{b}_{21} & B_{22} \end{bmatrix} \begin{bmatrix} y_1 \\ y_2 \end{bmatrix} + \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

After some internally consistent mathematical manipulation, then the multiregional input-output model in eq. (17) can be decomposed as:

18) $$y = M_{R3}M_{R2}M_{R1}x$$

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} (I - D_{21}D_{12})^{-1} & 0 \\ 0 & (I - D_{21}D_{12})^{-1} \end{bmatrix} \begin{bmatrix} I & D_{12} \\ D_{21} & I \end{bmatrix} \begin{bmatrix} (I - B_{11})^{-1} & 0 \\ 0 & (I - B_{22})^{-1} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$
$$= \begin{bmatrix} \left(I - M_{22}\hat{b}_{21}M_{11}\hat{b}_{12}\right)^{-1} & 0 \\ 0 & \left(I - M_{22}\hat{b}_{21}M_{11}\hat{b}_{12}\right)^{-1} \end{bmatrix} \begin{bmatrix} I & M_{11}\hat{b}_{12} \\ M_{22}\hat{b}_{21} & I \end{bmatrix} \begin{bmatrix} M_{11} & 0 \\ 0 & M_{22} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

Where:

$$D_{12} = (I - B_{11})^{-1}\hat{b}_{12} = M_{11}\hat{b}_{12}$$
$$D_{21} = (I - B_{22})^{-1}\hat{b}_{21} = M_{22}\hat{b}_{21}$$

Equation (18) represents a decomposition of the consolidated regional multiplier into the intra-regional effects (MR1) and the decomposed closed (MR3) and open (MR2) inter-regional effects.

Using a multi-regional input-output model allows the analyst either to measure the impact of the damage as the direct, indirect and induced effects from a reduction in foreign exports by closing the model with all categories of final demand except foreign exports—using a type 2 multiplier approach. Alternatively, the storm damage impacts on household consumption can be included in the reduction of final demand by using a type 1 multiplier approach. A bonus from using the multi-regional input-output approach is that the investment transfers that necessarily take place between regions during the rebuilding phase of recovery can be tracked as well.

As the measures of impacts on output by sector change, so will the associated change in valued added that are used to measure benefits.

An alternative to measuring the change in value added to measure economic surplus using an input-output model is to measure economic surplus with a computable equilibrium model that takes the substitute effects more explicitly into account.

Are the adjustments to economic damage within a region over time zero sum? And …

Are the adjustments to economic damage between regions zero sum?

I addressed both of these questions implicitly in my 1991 article cited above. In particular I spoke to the question of whether using economic surplus to measure benefits in full employment differs from that of a less than full employment economy. In short, the answer is no. This analysis applies regardless of whether the slack economy exists over time or between regions. Here is what I said:

When measuring benefits in a slack economy, we must address the issues of dealing consistently with the problems of (1) saved resources that become underemployed and (2) underemployed resources that are re-employed for a given public investment. Solow suggests that the federal government's responsibility to maintain full-employment by shifting aggregate demand is separate from its, or other governmental units', responsibility to make investments in infrastructure based on marginal productivity considerations and measured as benefit/cost ratios or internal rates of return [Solow R (1970) Growth theory, an exposition. Oxford University Press, New York, p 94]. This implies that the re-employment of underemployed resources from infrastructure investment should not be counted as an additional benefit of a government's supply-side investment policies beyond the effects of a more elastic input supply. Similarly, saved resources that become unemployed or underemployed as a result of an infrastructure investment should not be subtracted as a cost. To include the effects of underemployed or immobile resources in a slack economy in a benefit/cost analysis is tantamount to weighting a long-run investment measure by the effects of the federal government's short-run fiscal and monetary policies. Therefore, the procedure for measuring the direct and indirect benefits from investments in infrastructure as the change in economic surplus is the same in the context of either a taut or a slack economy.

What is the nature of direct damage to buildings and infrastructure vs. direct damage to the economy?

An economy implicitly contains two types of accounts: one for stocks and one for flows. The stock account measures wealth in part as the value of the physical (as well as human and social) capital while the flow account measures the value of the transactions between buyers and sellers.

Tables B1 and B3 above are explicit examples of flow accounts. Table B2 is an example of the change in the stock account.

Storm damage has a direct impact on the stock account in as much as it reduces the value of physical capital by destroying it. The reduction in physical capital and associated difficulty of labor getting to work can be expressed as a reduction in the return to labor and capital from using them in less than optimal combination. The loss of a stock can be represented as a reduction in a flow. The one is no more direct or any less real than the other because they map one to one onto each other. We contend that direct physical damage to buildings and infrastructure map directly to direct damages to economic stocks and flows.

Measures of stocks and flows

The discounted present value of the change in economic surplus until the economy returns to output at the pre-storm level equals the change in the stock value of the resources (physical and human) used to produce it. These are two ways to measure the damages of a storm: either as the change in the value of the stock or as the discounted present value in the economic surplus flow. These two measures should equal each other such that one can be used to determine the other.

Ananalogy

There is an analogy between a storm and a recession. A storm damages the value of physical capital by destroying it thereby reducing the ability of firms to use labor and capital in optimal combination. A recession damages the value of the physical capital by reducing its price through the reduced demand for output which also limits the need to use capital and labor in optimal combination. Conceptually, both the avoidance of loss from a storm or from a recession can be measured as the change in economic surplus.

Conclusion

In this analysis, we have identified the process needed to measure the economic impacts of storm damage as well as the measure of benefits from avoiding storm damage. For measuring economic impact, we suggest expanding the scope from administrative, transportation and retail to all the sectors that provide inputs into the production process. Further, we suggest using a multi-regional social accounting matrix framework to measure the national impacts of the damage. This approach is well adapted for applying Round’s multiplier decomposition such that the impact on the region rolls up to that for the nation without double counting. The process relies on an outside measure of damage to the physical capital including infrastructure by sector. A capacity vector is applied to the social accounts to provide an ex post measure of output. The difference between the ex-ante and ex-post measures of output from the input-output models provides a measure of the damage measure as the change in output. The capacity vector can be adjusted for inter-regional substitution effects. A zero as degree of substitutability implies all the losses for the region affect the nation. A one as the degree of substitutability means all lost capacity is made up elsewhere and there is no storm impact from a national economic perspective. The output change from storm damage can be expressed in terms of employment by using a vector of employment to output ratios.

The benefits of storm damage avoided are measured by adapting Rose's equation for the change in economic surplus. The unit of analysis for the change in economic surplus across all sectors of the economy is value added. The ex-ante and ex post measures of output can be transformed into measure of value added. The k-shift need in the Rose equation can also be measured as the change in productive efficiency using measures of the growth in value added. We argue that the change in the capital stock from the storm damage equals the discounted present value of the lost value added until the ex-ante level of output is restored. These benefits measure the opportunity cost to the nation of hardening the infrastructure.