Structure Level Flood Damage Analysis: NFIP & HAZUS

Midwest Flooding 2008
Albion Township, Dane County, WI

Prepared for the Association of State Floodplain Managers
September 1, 2010

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1.0 Introduction

The Association of State Floodplain Managers (ASFPM) conducted this report in an effort to understand better the capabilities of FEMA's HAZUS-MH[1] loss estimation software at the individual structure level of analysis. A structure level analysis is supported in HAZUS through User Defined Facilities (UDF) and allows the import of attributes (e.g. square footage, assessed value) and point locations for buildings in an area of interest.

This report compares (1) HAZUS estimated flood damages against (2) National Flood Insurance Program (NFIP) damage claims from the June 2008 flooding for Albion Township in Dane County, Wisconsin and against (3) local assessment values. These three comparisons are the basis of this analysis and are shown in the figure below:

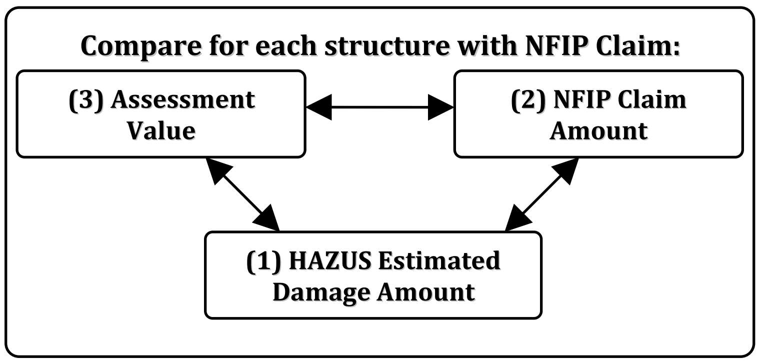

Figure 1: Comparisons for User Defined Facilities (UDF) Analysis

This analysis provides a starting point for developing HAZUS best practices and creating guidelines for analysis of damage estimates using UDF. It is a pilot project to determine the feasibility of performing meaningful UDF analysis on a large scale. The sample size of this analysis is constrained to the 18 structures with National Flood Insurance Program (NFIP) claims in the study area. ASFPM chose Dane County, Wisconsin as the study area because data was easily acquired through existing relationships and the flooding events in 2008 provided recent measurable data from NFIP claims that could be compared to HAZUS estimates.

The following list outlines the remaining content of this report:

- Chapter 2 introduces information about the study area and the flooding event in 2008 that resulted in NFIP claims. Chapter 2 also contains a brief description of FEMA's HAZUS software[2] and introduces the User Defined Facility analysis.
- Chapter 3 discusses the data used in this analysis and the procedures utilized to deal with issues of estimating required data, lack of data, and data inaccuracy.
- Chapter 4 deals with the general methods used to import the UDF into HAZUS.[3]
- Chapter 5 provides the results of the UDF analysis and shows the comparisons made between the HAZUS estimated damages, the NFIP claims, and the assessed values for the individual structures.

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[1] HAZUS-MH is software developed and distributed by the Federal Emergency Management Agency (FEMA) and stands for HAZards United States-Multi-Hazards; commonly referred to as HAZUS.
[2] Discussions related to the HAZUS software are not limited to Chapter 2 and can be found throughout the report where appropriate. For additional information on HAZUS, visit *http://www.fema.gov/hazus/* online.
[3] Further elaboration on the specific technical methods used for this analysis can be found in the appendix to this document entitled *"Technical Procedure – Importing User Defined Facilities into HAZUS."*

- Chapter 6 & 7 state the conclusions of this report and makes recommendations to resolve some data issues discussed in Chapter 3 and highlights a couple HAZUS bug fixes that may help users performing UDF analyses in the future.

This analysis used HAZUS-MH MR3 with Patch 3 on Environmental Systems Research Institute (ESRI) ArcGIS 9.3 with Service Pack 1 and was executed by Jason Hochschild, a Geographic Information System (GIS) Specialist contracted by ASFPM to implement the analysis. This analysis was conducted from August 2009 through March 2010.

2.0 Study Area and Background Information

The Township of Albion in Dane County, Wisconsin was chosen as the study area for the following reasons:

- The region was impacted by the flooding event in June 2008 and had 18 NFIP claims on properties near the shore of Lake Koshkonong. *(See Section 2.1)*
- Dane County produces and distributes GIS data and imagery at the county level that meet the data requirements for this analysis. *(See Section 3.1 & 3.2)*
- Assessor Data was made available by the company contracted to perform assessments for the township. *(See Section 3.2)*

Distribution of the 18 structures is spatially split into two areas, as can be seen in the map which includes parcels, flood boundary and flood depth.

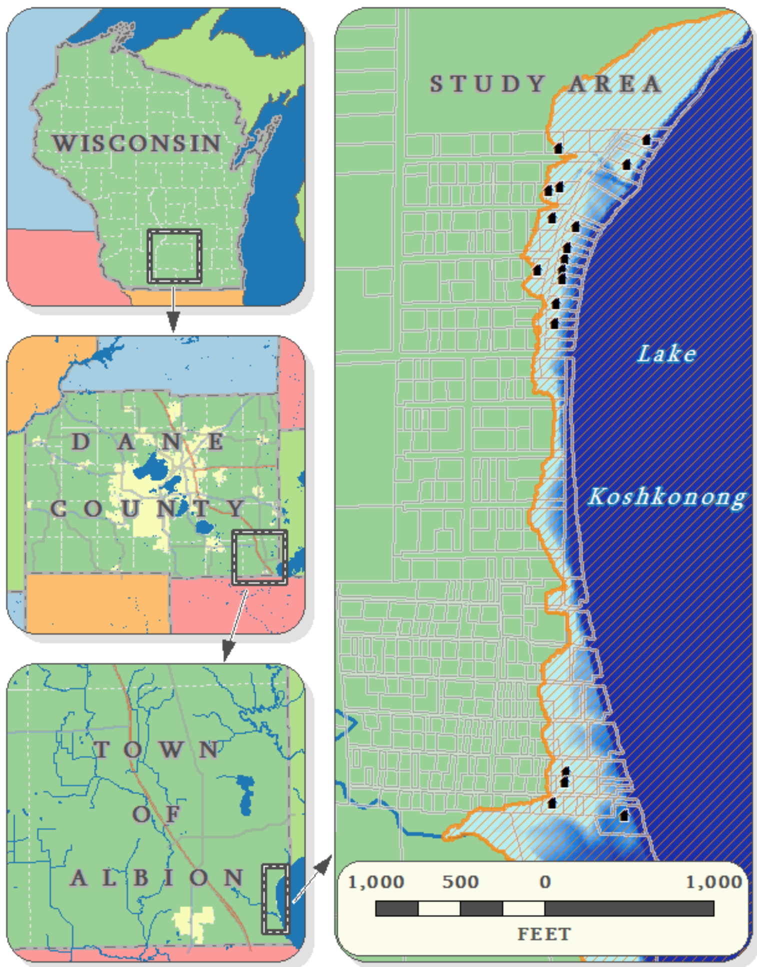

Figure 2: Study Area

2.1 Midwest Flooding of June 2008

This report looks at 18 structures and compares the calculated damage estimates from a HAZUS UDF analysis to the reported NFIP claims from June 2008. The flooding that occurred throughout Wisconsin in 2008 was not just a single isolated flood. This flood event was built on top of a number of other events that laid the groundwork for the catastrophic flooding seen that summer. These conditions are well described in the USGS report entitled "*Flood of June 2008 in Southern Wisconsin*":

> In June 2008, heavy rain caused severe flooding across southern Wisconsin. The floods were aggravated by saturated soils that persisted from unusually wet antecedent conditions from a combination of floods in August 2007, more than 100 inches of snow in winter 2007–08, and moist conditions in spring 2008. The flooding caused immediate evacuations and road closures and prolonged, extensive damages and losses associated with agriculture, businesses, housing, public health and human needs, and infrastructure and transportation.[4]

Dane County, WI, June 14, 2008. Photo by Barry Bahler / FEMA via FEMA website

The antecedent conditions of the flooding in 2007 and heavy snowfall that winter were aggravating factors in the severity of the flooding in 2008. The list below shows the number of affected counties for each Federal Declaration:

- August 2007: flooding warranted a Major Disaster Declaration for 14 counties[5]
- February 2008: record snowfall caused an Emergency Declaration in 11 counties[6]
- June 2008: flooding led to a Major Disaster Declaration in the 31 counties encompassing the entire southern half of Wisconsin[7]

Each event was a devastating natural disaster on their own, but their compounding effect on water and ground conditions helped lead to the severity of the situation in June 2008. HAZUS does not take these antecedent conditions into account when it runs its default hazard identification analysis to estimate flood damages for an area. However, while HAZUS is not a robust flood modeling tool, the overall flood hazards, including the antecedent conditions could be modeled outside of HAZUS and subsequently imported as depth grids – allowing HAZUS to be used as a tool to estimate damages for a given or calculated flood extent.

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[4] Fitzpatrick, F.A.; Peppler, M.C.; Walker, J.F.; Rose, W.J., Waschbusch, R.J., and Kennedy, J.L., 2008, Flood of June 2008 in Southern Wisconsin: U.S. Geological Survey Scientific Investigations Report 2008–5235, 24 p.

[5] August 2007 Severe Storms and Flooding: http://www.fema.gov/news/event.fema?id=8705

[6] February 2008 Snow: http://www.fema.gov/news/event.fema?id=9547

[7] June 2008 Severe Storms, Tornadoes and Flooding: http://www.fema.gov/news/event.fema?id=10028

2.2 HAZUS-MH

The HAZUS-MH software is a tool developed by FEMA that combines natural disaster planning and loss estimation methodologies with the power of the spatial analysis and graphic display capabilities of Geographic Information Systems (GIS). The software began as a planning and loss estimation tool for earthquakes and was subsequently expanded to include modules for floods and hurricane winds. HAZUS' loss methodology is built on data collected from past events throughout the United States.

Originally released in 2002, the HAZUS-MH Flood Model has been improved in terms of performance and methodological accuracy over time. While the tool is built on recognized methodology and available data, many assumptions are made regarding the vulnerability of the built environment, the hazard, and the loss estimates. Therefore appropriate caution must be used when applying HAZUS analysis results to specific policy implementations or mitigation planning:[8]

> The user should always be aware that numbers produced by software models such as HAZUS are to be used with a certain degree of caution. Uncertainty within the results can be introduced from a number of sources including the use of national datasets to represent local conditions, simplifications within the model introduced to allow the model to have flexibility with Level 1 users, and errors introduced as part of the mathematical processing within the software code. Finally, user input can also have a great affect on the uncertainty associated with the results.[9]

The Flood Model comes with a suite of damage functions including most of the available depth-damage curves from the Federal Insurance Administration (now known as the Federal Insurance and Mitigation Administration within the Department of Homeland Security) and the US Army Corps of Engineers. The General Building Stock (GBS) inventory is provided through the allocation of census block data via statistical analysis and broad assumptions for first floor square footage and elevation.[10] Damage estimation is calculated through area weighted damage estimates based on the depth of flooding within a given census block. Losses are developed for the GBS based on the potential for repair or replacement of the structure and/or content.

The HAZUS-MH User Manual describes three levels of analysis:[11]

1. A Level 1 analysis is a "Default Data Analysis" where user-supplied data is limited and "estimates will be crude and will be appropriate as initial loss estimates to determine where detailed analyses are warranted."
2. A Level 2 analysis requires some user-supplied data and combines "local and default hazard, building and damage data." The User Defined Facilities (UDF) analysis described in this report is a Level 2 analysis.
3. A Level 3 analysis is an "Advanced Data and Models Analysis" and "incorporates results from engineering and economic studies carried out using methods and software not included within the methodology."

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[8] For more information on the uncertainty of HAZUS results, see the "Message to Users" section in the HAZUS-MH MR4 Flood User Manual, pages *ix-x*.
[9] HAZUS-MH MR4 Flood User Manual, Section 1.8, page 1-11.
[10] Statistical analysis and assumptions used for General Building Stock are described throughout the HAZUS-MH MR4 Flood Model Technical Manual.
[11] HAZUS-MH MR4 Flood User Manual, Section 1.4, pages 1-4 and 1-5.

The analysis in this report uses data from individual buildings by uploading attributes into the UDF table in HAZUS. Differences between this Level 2 analysis and a standard Level 1 analysis are discussed in the following section that focuses on UDF analysis in HAZUS.

2.3 Using HAZUS with User Defined Facilities (UDF)

Data for individual structures are imported into HAZUS to allow the comparative analysis between (1) HAZUS damage estimates, (2) NFIP damage claims for the June 2008 flooding in Albion and (3) local assessment values. Analysis is run based on the geographic coordinates of each building's centroid – or single point location – and the attributes for the individual buildings. This Level 2 analysis using UDF is in contrast to the default Level 1 HAZUS analysis in which the Flood Model estimates losses using a comprehensive, default national inventory (the GBS described in section 2.2) when a user does not have locally derived data such as building locations. A Level 1 analysis assumes the GBS is evenly distributed across an entire census block, so if 50% of the block is flooded, HAZUS will assume 50% of the buildings are in the flood zone. In a UDF analysis, HAZUS determines which buildings are in the flood zone based on the location of each building's centroid imported into the UDF table, so only the buildings intersecting the flood zone are used in the damage calculations.

In UDF analysis, HAZUS first calculates an estimated damage percentage based on occupancy type, number of stories, foundation type, first floor height and the calculated or imported flood depth. HAZUS then calculates the damage amount based on the replacement cost and the previously calculated damage percentage:

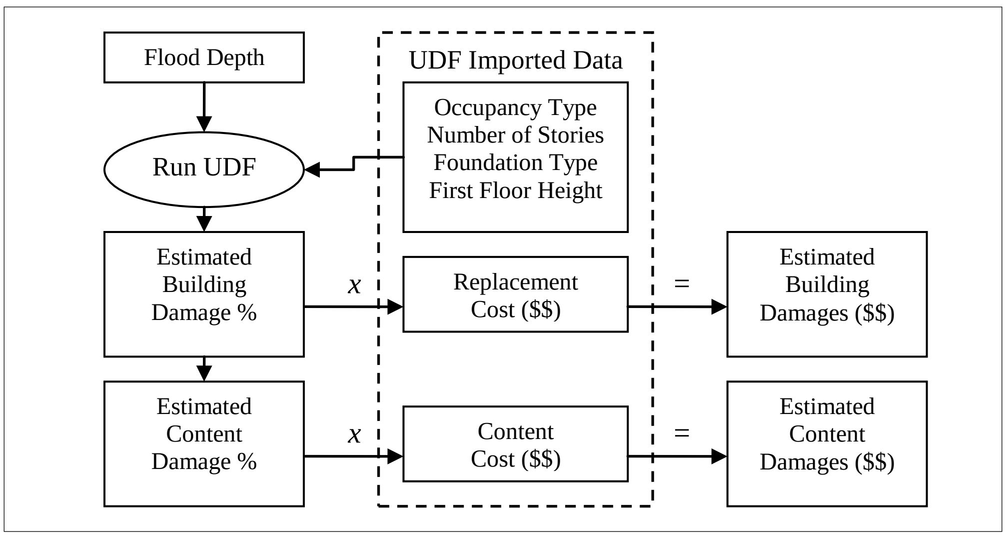

Figure 3: HAZUS Specific Inputs to Calculate UDF Damages

HAZUS calculates the damage percentage for each structure by cross referencing the appropriate depth-damage curve[12] included in the program using the data imported into the UDF table and the depth of flooding at that location. These depth-damage curves are customizable if a user has more accurate local information, but the default depth damage curves were used during this analysis. As shown in Figure 3, HAZUS uses the damage percentage to calculate a dollar amount of damage based on the cost of replacement for each UDF. For example, if a structure's replacement cost is $100,000 and HAZUS determines that a foundation type of "Basement" with

[12] Depth-damage curves available in HAZUS are developed by US Army Corp of Engineers (USACE) and the Flood Insurance Agency (FIA).

a 2 foot first floor height in an area inundated to 3 feet has a 25% damage estimate, then HAZUS calculates $25,000 in building damages. This procedure is calculated for each structure that is imported and the results are displayed as a table in HAZUS.

The result of the calculation described above for the estimated damage amount is the value that is used in this analysis to compare to the NFIP claim amount. The National Flood Insurance Program (NFIP) calculates damages after a flooding event with insurance adjusters using the information provided when a homeowner purchases the policy and the actual viewable damage. NFIP uses Replacement Cost Value to determine the cost to replace damaged property and uses Actual Cash Value, which is depreciated Replacement Cost Value, to reimburse for contents.[13] The value for *Cost of Contents* for structures in the study area is an unknown and therefore is not used in this analysis, while replacement cost has been estimated using the structure assessment value, see Section 3.3 in the following chapter on data for more details.

3.0 Datasets & Attributes

Data and attributes are the crucial component of an analysis. HAZUS damage estimations that are calculated using the most recent and complete data would be expected to provide the most accurate results. The next section lists the attributes imported into HAZUS for UDF analysis, followed by a list datasets by source with brief descriptions or issues associated with that data. The last section deals with the assumptions made to approximate replacement cost and discusses HAZUS defaults for first floor height based on foundation type.

3.1 Attributes

The list of attributes imported for a UDF analysis includes location, year built, occupancy type, replacement cost for the structure and the contents, number of stories, square footage, type of building material, foundation type, first floor height and whether or not there are flood protection structures in the vicinity (Table 1). Many of these attributes may or may not be available from the county or local community and care should be taken to assess the completeness and accuracy of all recorded attributes. For the Township of Albion, available data and attributes were collected, aggregated and imported into HAZUS for each of the individual structures. Where data was not available, HAZUS defaults or best approximations were used – each instance is described in the later sections of this chapter. The following table lists the attributes used in this UDF analysis and shows, where applicable, the originating dataset and from where it was acquired:

[13] http://www.floodsmart.gov/floodsmart/pages/about/coverage_from_nfip.jsp accessed March 2010.

Attributes for UDF Analysis	Dataset	Data From
Latitude	Building Footprint Centroids	Dane County LIO
Longitude	Building Footprint Centroids	Dane County LIO
Address	Address in Parcels	Dane County LIO
Occupancy Type	Land Use Code in Footprint Centroids	Dane County LIO
Replacement Cost	Approximated by Assessment Value in Parcels	Dane County LIO
Content Cost	*Not used; HAZUS default defined by Replacement Cost and Occupancy.*	
Year Built	Town of Albion Assessor Data	Accurate Appraisal, LLC
Number Stories	Town of Albion Assessor Data	Accurate Appraisal, LLC
Area	Town of Albion Assessor Data	Accurate Appraisal, LLC
Design Level	*Used HAZUS default, defined by Year Built*	
Building Type	*Unavailable*	
Foundation Type	Town of Albion Assessor Data	Accurate Appraisal, LLC
First Floor Height	*Unavailable; Used HAZUS default, defined by Foundation Type*	
Shelter Capacity	*Unavailable*	
Flood Protection	*Used HAZUS Default, page 6-9 HAZUS User Manual*	

Table 1: Data Attributes for User Defined Facilities (UDF) Analysis

3.2 Datasets

The small study area and limited needs as far as number of datasets to be collected helped minimize the time required for data collection. All the pertinent data available was collected in approximately one month from the following organizations:

3.2.1 Dane County Land Information Office (LIO)

Building Centroids

The building centroids are derived from Dane County's building footprint polygon layer, created as part of the county's Land Use Inventory in 2005 and thus contains a land use type. The LIO additionally delineated primary (houses, businesses) vs. secondary (garages, outbuildings) structure type. The attribute for land use in the building footprint centroids layer is the key for determining a structure's occupancy type, one of the imported fields that HAZUS uses in the estimation of damage.

Parcels

The countywide parcels layer dataset from the LIO defines the spatial extent of a property and is used in this analysis to populate an address field in the centroids layer. The parcels data also contains the assessment values that are used in this analysis as approximations of a structure's replacement cost[14] and later used as a metric of comparison to the calculated flood damage values.

Orthoimagery

High resolution (1-foot), gray scale orthoimagery was used to verify location and type of structures. As an example, several structures were identified as residential homes, while actually

[14] See Section 3.3.1 for further discussion on approximating replacement cost in this analysis.

being motor homes located within a campground. DCiMap, an interactive Web Mapping application developed by the LIO was also a major resource used for determining locational accuracies between structures, parcels and addresses.

3.2.2 Accurate Appraisal, LLC

Property Assessment Values

The township of Albion contracts property assessment valuation to Accurate Appraisal, LLC, who provided data for the township containing the needed year built, number of stories and the square footage of the first floor for each structure. The data also contained a field delineating a basement as full, partial, or no basement which was used to populate the foundation type field.[15] Accurate Appraisal's dataset contained recent assessment values from after the flooding so assessment values from the county's parcel layer were used.

3.2.3 USGS Wisconsin Water Science Center

Flood Depth Grids

The USGS Wisconsin Water Science Center provided the flood depth grids from this specific flooding event on its website as an accompaniment to its "Flood of June 2008 in Southern Wisconsin" (SIR 2008-5235) report.[16] Without this depth grid, the flood height from a FEMA Flood Information Study would have to be used to create a surface in ArcGIS and then raster processing would subtract that surface from a Digital Elevation Model (DEM) to create a depth grid.

3.2.4 Wisconsin Emergency Management

NFIP Claims

The NFIP claims data were requested and acquired from the WI State Hazard Mitigation Officer, Wisconsin Emergency Management. This dataset was not imported into HAZUS for determining damage estimates, but is the basis of the comparison between HAZUS estimated damage values and the actual damage amounts. This dataset contains the addresses and NFIP claim amounts for the properties affected by the June 2008 flooding.

3.2.5 WisconsinView

National Agriculture Imagery Program (NAIP) Orthophotos

Color, 1-meter resolution, orthophotography was needed to verify structure locations and identify inconsistencies in other datasets. Imagery dataset for Dane County was downloaded from WisconsinView.org, a data portal for Wisconsin imagery.

3.2.6 Additional Imagery

Other imagery was obtained from dynamic web applications, including Bing Maps 3D Bird's Eye View and Google Maps Street View, specifically for determining quality assurance.

3.3 Attribute Defaults and Approximations

The data fields for replacement cost, content cost, foundation type and first floor height are needed for HAZUS to calculate accurate damage estimations. This section focuses on values that are approximated for this analysis.

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[15] See Section 3.3.3 for further discussion on using foundation type in this analysis.
[16] Visit *http://wi.water.usgs.gov/surface-water/flood2008/* for more information.

3.3.1 Replacement Cost

For UDF analysis, HAZUS calculates damage amounts by first determining the percentage of damage based on the flood depth at the location of each structure and then multiplies this percentage by the value that is input into HAZUS for replacement cost.[17] Comprehensive data does not seem to be available for the replacement cost of individual structures in this area. Assessment data *is* available for parcels which represents a tangible value that is based off real ground conditions and is ubiquitous enough that comparisons can be made between individual parcels not only at the township level but up to the county or regional level. Insurance companies calculate replacement cost using detailed software that takes into account the type of building materials used, the quality of finish materials installed and data from other categories such as the value of the fixtures throughout the house.[18]

Initial research into determining the replacement cost of a structure suggested that the total assessment, which includes the assessed value for the land and all improvements made to the property, could possibly be used as a substitute for replacement cost. Assessment values in Wisconsin are based in part on replacement values, but other factors influence assessments such as the recent sales in that market, depreciation for older structures and income that rental property can leverage. An important point to note is that every property is not individually assessed each year but rather statistical methods are used that take into account the above market factors and assessment values are adjusted accordingly. Another complication is that appraisal values, as opposed to assessment values, generally offer a more in depth valuation of a property than tax assessments and therefore could be a good candidate for an estimation of replacement cost, but appraisals tend to be tied to real estate transactions so may not be timely or exist for every structure in an area and do not seem to exist in a publicly available dataset.

Assessment values in the parcel dataset are broken into assessed value for land and assessed value for improvements, referred to as *structure assessment* from this point forward. When these values, specifically the land assessment, were examined for the structures in the study area, a pattern emerged that can be seen in the map:

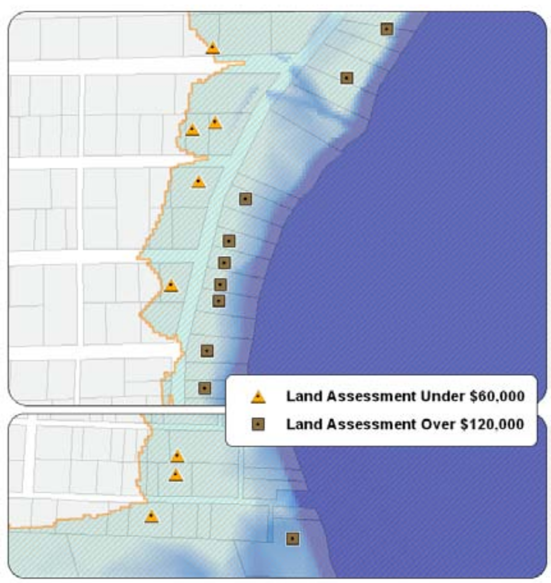

Figure 4: Land Assessment Values

[17] Section 2.3 and Figure 3 covered how HAZUS makes this damage calculation.

[18] There are various industry software applications used by insurance companies to assess replacement cost (e.g. Marshall & Swift's SwiftEstimator®) and there are a number of online websites that charge fees to calculate the replacement cost of a building based on user inputted details about a building. This type of data is available for purchase from private data wholesalers, such as ChoicePoint, but these options involve cost and it may be difficult to determine the accuracy and completeness of a dataset prior to purchase.

The noticeable variation between the land assessments is a product of waterfront land parcels being assessed higher in this area. This presents a problem with using total assessment as an approximation for replacement value because it can be assumed that it would cost a similar amount to replace an 800 square foot house whether or not it exists on waterfront property. To include the land value in the replacement cost would artificially inflate the replacement cost of a structure that is waterfront and artificially decrease the replacement cost of a structure inland.

Additionally, since waterfront structures tend to have deeper flooding, even larger discrepancies in damage estimates would occur between waterfront and inland properties when using an artificially inflated replacement cost to calculate damage amount on a deeply flooded structure compared to using an artificially deflated replacement value on a less flooded structure (Figure 5)

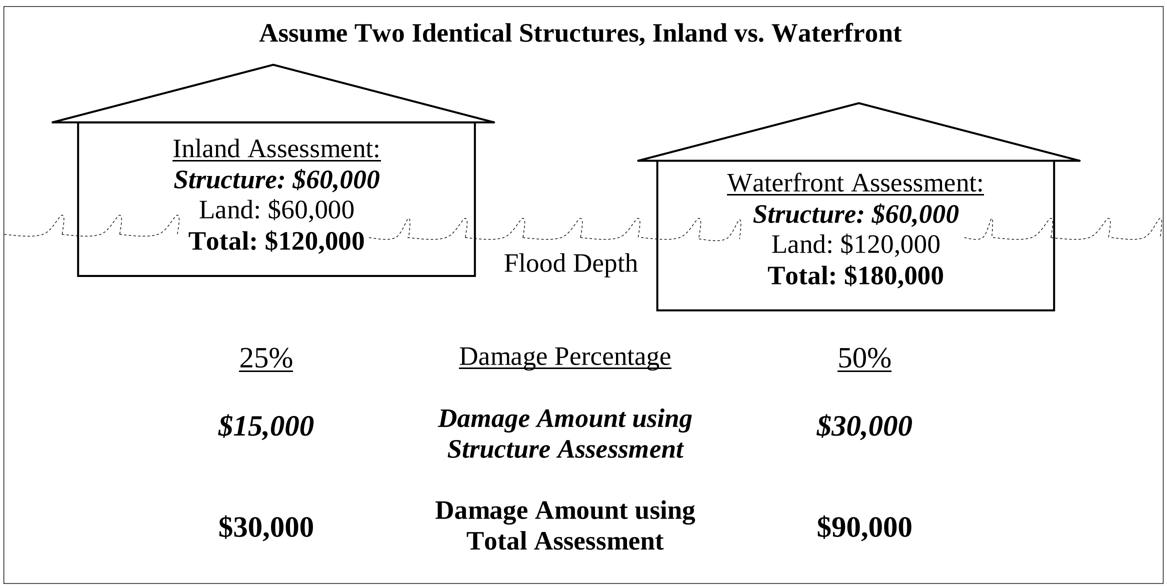

Figure 5: Estimating Replacement Cost: Structure Assessment vs. Total Assessment

The solution of replacement cost for this analysis, while admittedly not perfect, is to use the structure assessment as an approximation of replacement cost. This is the best available data and is a value that is more or less based on similar criteria across the region. Another justification for using the structure assessment is that others who wish to perform analyses of this type will more likely have access to assessment values than to actual replacement costs for the reasons described above.

3.3.2 Content Cost

HAZUS can calculate the amount of damage to contents of a flooded structure provided a value is input when importing the UDF. Like structure replacement cost, the content replacement cost is highly variable and an unknown in the datasets used for this analysis. There are online calculators for homeowners and industry software for insurance agents that can be used to determine the cost of the contents of a structure, but the data necessary for that determination is beyond the scope of this analysis.

For cases where content cost is unknown, HAZUS defines the default value for content cost as the replacement cost of the structure multiplied to a value assigned based on the occupancy type.[19] For example, the content cost of a RES1 structure is (0.5 * Replacement Cost) while the content cost for a COM6 is (1.5 * Replacement Cost). Only four of the 18 imported structures had NFIP claims for contents damage so a useful comparison cannot be made between HAZUS content damage estimates for the 14 structures without content claims, therefore the determination was made to ignore content cost and content damage for this analysis.

3.3.3 Foundation Type and First Floor Height

Foundation type and first floor height above grade are two pieces of data that this report recommends be collected for all structures in order to better estimate flood damages using UDF analysis. HAZUS includes these two pieces of data in the calculation for damage percentage along with the flood depth at each structure. A crawlspace foundation with a high first floor height is going to receive less damage than a slab on grade foundation with a minimal first floor height above grade. HAZUS assigns a numerical value for foundation types[20] and each foundation type has a corresponding default first floor height.[21]

Neither the county building assessment datasets nor the Township's assessor datasets used in this analysis contain data on first floor height above grade and neither specifically have the foundation type as HAZUS defines it for a UDF analysis: such as pile, pier, basement, crawlspace, slab on grade. The assessor dataset contained a field labeled '*Basement'* which was populated with the values *No*, *Partial* or *Full*. The assumptions made for foundation type are shown in the table below:

***Basement* Field from Assessors Dataset**	**Assigned to HAZUS Foundation Type**	**HAZUS Foundation Type Value**	**First Floor Height**
No	Slab on grade	7	1
Partial	Basement	4	2
Full	Basement	4	2

Table 2: Foundation Type and First Floor Height Assumptions

The default first floor height in HAZUS for a slab on grade foundation type is 1 foot while the default first floor height for a basement foundation type is 4 feet. The default was used for the slab on grade, but the default first floor height of 4 feet for a basement foundation height is excessive for Wisconsin based on regional building techniques for houses with basements. A closer approximation to reality is a 2 foot first floor height so that value was used for the basement foundation type for this analysis.

4.0 Methods

With the data in hand and the assumptions for replacement cost and first floor height decided, this analysis moves into the stage of actual data preparation and running the UDF analysis. The methods used to perform this analysis are outlined in the HAZUS-MH MR4 Flood User Manual and HAZUS-MH MR4 Flood Technical Manual. This chapter discusses a summary of the steps taken to perform the UDF analysis.[22]

[19] HAZUS MR4 Flood User Manual, Table 6.5, page 6-9.
[20] HAZUS MR4 Flood User Manual, Table 6.3, page 6-8.
[21] HAZUS MR4 Flood User Manual, Table 6.4, page 6-9.
[22] Further elaboration on the specific technical methods used for this analysis can be found in the appendix to this document entitled *"Technical Procedure – Importing User Defined Facilities into HAZUS."*

4.1 Data Manipulation and Preprocessing

Since the import tool for UDF is selective about the data types that can be imported, steps must be taken to clean the data into a format that HAZUS will accept. The dataset that defines the location of structures is the building footprint centroids feature class. All the additional attributes necessary for the analysis are either spatially joined or table joined to this dataset (see Section 4.2).

Figure 6.7 on page 6-7 of the HAZUS User Manual lists the Field Names, Data Types and Field Lengths for the fields that can be imported for a UDF analysis and is reproduced in Table 3. As shown previously in Table 1, not all of this data is available so it was necessary to use HAZUS defaults or appropriate approximations.

Field	Type	Size
CONTACT	Text	40
NAME	Text	40
ADDRESS	Text	40
CITY	Text	40
STATE	Text	2
ZIPCODE	Text	40
PHONENUMBER	Text	47
OCCUPANCY	Text	5
YEARBUILT	Integer	2
COST	Currency	8
BACKUPPOWER	Yes/No	1
NUMSTORIES	Byte	1
AREA	Single	4

Field	Type	Size
BLDGTYPE	Text	15
LATITUDE	Double	16
LONGITUDE	Double	16
COMMENT	Text	40
CONTENTCOST	Currency	8
DESIGNLEVEL	Text	1
FOUNDATIONTYPE	Text	1
FIRSTFLOORHT	Double	8
SHELTERCAPACITY	Integer	2
BLDGDAMAGEFNID	Text	10
CONTDAMAGEFNID	Text	10
INVDAMAGEFNID	Text	10
FLOODPROTECTION	Long Int	4

Table 3: User Defined Facilities Data Fields

4.2 Join Data

Each piece of necessary data in Table 3 was appended to the centroids layer through either a spatial join or a table join. One difficulty was parcels that contained more than one building footprint centroid, but this was easily fixed manually because the size of the dataset was only 18 properties. The specific methods used to join the data can be found in the appendix to this document, entitled *"Technical Procedure – Importing User Defined Facilities into HAZUS."*

4.3 Importing User Defined Facilities (UDF) into HAZUS

UDFs are imported through the *User Defined Facilities* option under the *Inventory* menu in HAZUS. The structure data will import provided the data table is formatted properly and the data types agree with what HAZUS is programmed to expect. The actual import does not take very long; a test run of about 2,500 points took approximately 15 minutes. After import, the structure data points are listed in a table (Table 4) and then a HAZUS analysis can be run.

Struc-ture	Occu-pancy Type	Replacement Cost (Thousands of USD)	Content Cost (Thousands of USD)	Year Built	Area (Sq. Ft. in Thousands)	Number of Stories	Design Level
1	RES1	$ 250.70	$ 125.35	1990	1.08	1	3
2	RES1	$ 196.00	$ 98.00	1960	0.70	1	1
3	RES1	$ 133.40	$ 66.70	1960	1.35	1	2
4	RES1	$ 171.80	$ 85.90	1970	0.98	2	3
5	RES1	$ 119.30	$ 59.65	1950	0.80	1	2
6	RES1	$ 284.00	$ 142.00	1975	0.90	1	3
7	RES1	$ 297.10	$ 148.55	1990	1.56	1	3
8	RES1	$ 86.00	$ 43.00	1940	0.94	1	1
9	RES1	$ 80.20	$ 40.10	1950	0.64	1	2
10	RES1	$ 324.50	$ 162.25	1990	0.65	2	3
11	RES1	$ 216.00	$ 108.00	1940	0.68	1	1
12	RES1	$ 150.40	$ 75.20	1980	1.06	1	3
13	RES1	$ 226.00	$ 113.00	1970	0.78	1	3
14	RES1	$ 212.60	$ 106.30	1960	0.70	1	2
15	RES1	$ 118.30	$ 59.15	1940	1.25	1	1
16	RES1	$ 106.90	$ 53.45	1965	0.74	1	2
17	RES1	$ 259.00	$ 129.50	1970	0.69	2	3
18	RES1	$ 210.90	$ 105.45	1980	0.72	1	1

Table 4: Data Imported into UDF Tables in HAZUS

The analysis was run with the above data twice. The first analysis appended a Foundation Type of Basement (HAZUS Foundation Type Value = 4) and a First Floor Height of 2 feet. The second analysis used a Foundation Type of Slab on Grade (HAZUS Foundation Type Value = 7) and a First Floor Height of 1 foot. These foundation types and first floor heights were used in order to compare the difference in the HAZUS results.

4.4 Flood Depth Grid

The USGS flood depth grid described in the datasets section was used because the flood damage claims from the June 2008 floods should be analyzed against the actual flood depths for that flooding event. Under the *Hazard* menu option of *User Data* is where a flood depth grid can be imported. The parameters should be set to feet or meters based on the units of the data that the depth grid was created from, in this case it is feet because the depth grid was derived from Dane County's DEM.

4.5 Run HAZUS Analysis and View Results

Running the HAZUS analysis is straight forward: under the menu *Analysis* > *Run…* > check *User Defined Structures* in the *Analysis Options* dialog box. The only other deviation compared to a standard HAZUS analysis is that the results of a UDF analysis do not show up in the normal reporting mechanism that uses Crystal Reports in HAZUS. The *User Defined Facilities Loss* table is found by choosing *Results* > *User Defined Facilities…* This table shows each of the individual structures with their associated *Building Damage Percent* and *Building Loss in U.S. Dollars* as well as *Content Damage Percent* and *Content Loss in U.S. Dollars*. These results can be displayed on a map and symbolized. The table of the results containing the estimated damage percentage and estimated damage amount for each structure can be exported for comparison.

5.0 Results and Comparisons

The purpose of this analysis is to compare (1) HAZUS damage estimates to (2) NFIP claim amounts and to (3) assessment values. The UDF data was imported into HAZUS using the methods described above, the HAZUS analysis was run, and the results follow in Table 5.1.

				Foundation = Slab & 1st Floor Height = 1'		Foundation = Basement & 1st Floor Height = 2'	
Structure	**(3)** Structure Assessment (2008 USD)	**(2)** NFIP Building Claim (2008 USD)	Flood Depth (ft)	Building Damage %	**(1)** HAZUS Damage Estimate	Building Damage %	**(1)** HAZUS Damage Estimate
1	$ 120,100	$ 106,688	3.60	26.33%	$ 31,617.15	24.54%	$ 29,466.73
2	$ 66,000	$ 34,177	3.73	26.88%	$ 17,739.07	26.01%	$ 17,164.19
3	$ 122,500	$ 34,225	0.81	13.76%	$ 16,852.42	10.06%	$ 12,319.98
4	$ 139,100	$ 13,240	0.27	2.94%	$ 4,089.54	9.60%	$ 13,358.66
5	$ 66,400	$ 10,004	2.28	23.28%	$ 15,455.18	18.70%	$ 12,417.58
6	$ 142,700	$ 82,471	2.98	25.28%	$ 36,078.96	21.75%	$ 31,044.21
7	$ 166,500	$ 72,673	3.75	28.40%	$ 47,284.41	30.00%	$ 49,946.04
8	$ 53,700	$ 41,258	2.48	23.44%	$ 12,589.90	18.93%	$ 10,163.54
9	$ 53,100	$ 48,763	1.52	18.62%	$ 9,888.58	11.93%	$ 6,336.87
10	$ 193,900	$ 75,059	3.88	18.47%	$ 35,817.53	26.71%	$ 51,787.30
11	$ 91,000	$ 3,672	3.21	25.36%	$ 23,077.59	21.96%	$ 19,983.56
12	$ 94,200	$ 24,470	1.70	21.95%	$ 20,674.09	16.92%	$ 15,939.14
13	$ 95,400	$ 51,106	3.44	26.90%	$ 25,658.84	26.06%	$ 24,857.57
14	$ 77,600	$ 44,038	3.41	29.45%	$ 22,854.30	32.63%	$ 25,319.75
15	$ 90,400	$ 12,419	1.40	21.80%	$ 19,707.24	16.70%	$ 15,096.87
16	$ 65,400	$ 5,044	2.09	22.07%	$ 14,435.66	17.10%	$ 11,181.55
17	$ 69,000	$ 43,900	5.61	21.03%	$ 14,513.84	31.59%	$ 21,794.59
18	$ 80,300	$ 53,322	3.95	26.89%	$ 21,592.39	26.04%	$ 20,909.37
Sum:	**$ 1,787,300**	**$ 756,529**			**$ 389,926.70**		**$ 389,087.48**
Mean:	***$ 99,294***	***$ 42,029***	***2.78***	***22.38%***	***$ 21,662.59***	***21.51%***	***$ 21,615.97***

Table 5: UDF Analysis Results with NFIP Claims and Structure Assessments

5.1 Results

Table 5 shows the assessment values, claim amounts, depth of flooding, estimated damage percentage and estimated damage amount for the 18 UDFs, as well as totals and averages for both of the foundation type and first floor height combinations. A brief summary of the results follows:

- Most of the HAZUS Damage Estimates are less than the NFIP Claim Amounts (only 4 of the 18 structures for Slab on Grade and 5 of the 18 structures for Basement had higher damage estimates than claims).[23]
- The average Damage Estimates for both foundation types are a little over $21,000 and the average NFIP Claim Amount is about $42,000.
- The average Damage Percentage was about 22% for the Slab on Grade analysis and about 21.5% for the Basement analysis.
- The highest Damage Estimates are around $50,000 (Structure 7 for both foundation types and Structure 10 for Basement).
- The highest NFIP Claim was over $100,000 (Structure 1) and the lowest Claim Amount was under $4,000 (Structure 11).

[23] The structures with damage estimates that exceeded the NFIP claims can be more clearly seen in the comparison table discussed in the next section (Table 6).

- The average flood depth for the 18 structures was 2.78 feet, with a range of values from 0.27 feet to 5.61.

5.2 Comparisons

Figure 6 graphically represents the three comparisons for this report:

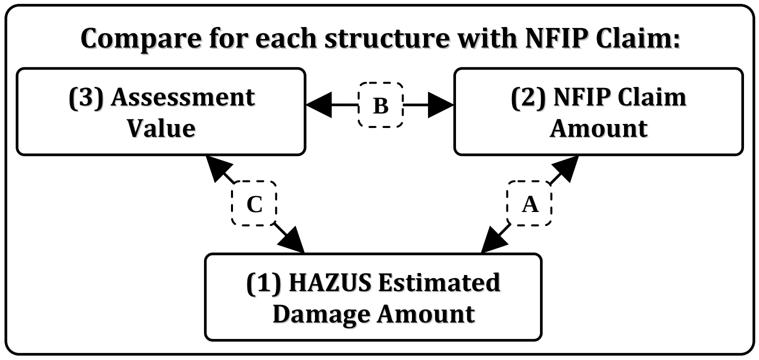

Figure 6: Comparison for User Defined Facilities (UDF) Analysis

The comparisons provided in Table 6 below can be verbally stated as:

A. "HAZUS estimated damage as a percentage of the claim amount"
B. "Claim amount as a percentage of the assessment"
C. "HAZUS estimated damage as a percentage of the assessment"

		Foundation = Slab & 1st Floor Height = 1'		Foundation = Basement & 1st Floor Height = 2'	
Structure	[B] (2) NFIP Claim / (3) Structure Assessment	[A] (1) HAZUS Damage / (2) NFIP Claim	[C] (1) HAZUS Damage / (3) Structure Assessment	[A] (1) HAZUS Damage / (2) NFIP Claim	[C] (1) HAZUS Damage / (3) Structure Assessment
1	88.83%	29.64%	26.33%	27.62%	24.54%
2	51.78%	51.90%	26.88%	50.22%	26.01%
3	27.94%	49.24%	13.76%	36.00%	10.06%
4	9.52%	30.89%	2.94%	100.90%	9.60%
5	15.07%	154.49%	23.28%	124.13%	18.70%
6	57.79%	43.75%	25.28%	37.64%	21.75%
7	43.65%	65.06%	28.40%	68.73%	30.00%
8	76.83%	30.52%	23.44%	24.63%	18.93%
9	91.83%	20.28%	18.62%	13.00%	11.93%
10	38.71%	47.72%	18.47%	69.00%	26.71%
11	4.04%	628.47%	25.36%	544.21%	21.96%
12	25.98%	84.49%	21.95%	65.14%	16.92%
13	53.57%	50.21%	26.90%	48.64%	26.06%
14	56.75%	51.90%	29.45%	57.50%	32.63%
15	13.74%	158.69%	21.80%	121.56%	16.70%
16	7.71%	286.19%	22.07%	221.68%	17.10%
17	63.62%	33.06%	21.03%	49.65%	31.59%
18	66.40%	40.49%	26.89%	39.21%	26.04%
Compare Totals from Table 5.1:	**42.33%**	**51.54%**	**21.82%**	**51.43%**	**21.77%**

Table 6: Comparison between Damage Estimates, Claims and Assessments

The key comparison for this report is represented between HAZUS estimated damages and NFIP claims amount (Comparison A). The percentages can be used to find easily the individual structures that HAZUS over estimated when compared to the NFIP claim amount by looking for values greater than 100%. Ratios around 100% show structures where the HAZUS damage estimate was close to the actual NFIP claim.

As stated above, the values vary greatly at the individual structure level throughout these results, but comparisons can be made between the totals of each HAZUS run. The last row of Table 6 compares the totals from Table 5 for making overall comparisons between the totals instead of each individual structure. For both foundation types, the HAZUS damage estimates were about 51% of the NFIP Claims.

Interestingly, when comparing the NFIP claims amount to the structure assessment (Comparison B), 9 of the 18 structures would be considered *significantly damaged* – damages greater than 50% of the value of the structure would trigger enforcement of certain NFIP regulations. When comparing HAZUS damage estimates to structure value (Comparison C), for any structure, no damage percentage gets above 33% or would be considered significantly damaged.

Qualitatively, the deviation in percentages between NFIP claims to the structure value (Comparison B) with a range between 4.04% - 91.83%, which is larger than the deviation when comparing HAZUS estimates to structure value (Comparison C) that ranges between 9.6% - 32.63% for basements and 2.94% - 29.45 for slab-on-grade.

6.0 Conclusions and Time Considerations

The goals set out for this report were:

1. *Look at a specific region with the best available data to compare actual damages to HAZUS damage estimates.*

Based on the estimated damage amounts from the UDF analysis, HAZUS damage estimates were, on average, approximately 51% of the actual NFIP claim amounts. The discrepancy can be attributed to a couple of unknowns, including using the structure assessment value as replacement cost and the manner in which HAZUS uses the imported attributes to determine damage percentages.

2. *Provide a starting point for developing HAZUS best practices and creating guidelines for analysis of damage estimates using UDF.*

This report serves as the starting point for understanding UDF analysis. This is far from a comprehensive look at the entirety that is UDF analysis in HAZUS, but this report and the appendix to this document entitled *"Technical Procedure – Importing User Defined Facilities into HAZUS"* serve as documentation to any HAZUS user interested in pursuing UDF analysis. The appendix contains a more complete step by step procedure of how to get the data assembled and delineates how to import the UDF data into HAZUS.

3. *Determine the feasibility of performing meaningful UDF analysis on a large scale.*

The functionality to import UDF into HAZUS works and produces results at the small scale. The only obstacle to doing UDF analysis on a large scale is the time consideration. The time necessary to gather data, check its accuracy and use approximations to fill in any gaps is a concern for an analysis on UDF. Time budgeted for those tasks can increase as the size of the study area increases. Approximately 80 hours were spent manipulating data, formatting it and joining it together for this analysis on 18 structures in Albion. Much of that time was working through some of the problems a first time user may encounter such as software crashes trying to import a Geodatabase feature class into the UDF table or getting the field types correct.

Future attempts at UDF analysis should not take as much time now that potential pitfalls have been highlighted and custodians of data such as the Dane County Land Information Office are taking the time to attribute building footprint data for the purposes of individual structure analysis. Probable setbacks beyond building footprint attribution may be estimating replacement value or de-aggregating parcel data where multiple valid individual structures exist on large parcels. The accuracy of a county wide analysis would be dependent on the availability of currently uncollected data such as foundation type and first floor height, as well as the necessity to determine an accurate measure of replacement cost.

If 80 hours were allocated to each township, and since Dane county would contain almost 35 townships if villages and cities were removed, it could be estimated that a county wide analysis would take 2,800 hours just to get the data manipulated and aggregated. The Dane County LIO estimated approximately 40 hours were spent determining a primary versus accessory building attribute for each structure in the township, but noted that both rural areas and urban areas can cause additional challenges either in time spent covering large areas or time spent interpreting clusters, and projecting one township to the whole county is not very straightforward. Ignoring that fact, 40 hours per township with a 15% cushion yields about 1,600 additional hours that would be necessary for determining primary vs. secondary structures. This number could be greatly reduced if only structures in and near a flood plain were manually attributed as primary or secondary. Additional time requirements to be considered are the computational processes of importing UDF and the HAZUS damage estimation, but in terms of only a few hours, not days.

These numbers are very high estimates and equate to a one year project for two people, but this researcher believes the actual time frame is closer to 6 months if focused only on structures in and near the flood plain. Total time could be further reduced with additional input from interested parties that could refine the processes described in this report.

7.0 Issues, Recommendations and Further Research

Issues and recommendations related to datasets, data processing and software use are as follow:

1. Parcel datasets and building footprints/centroids were not always correctly aligned. For example, there were instances when a building footprint intersected parcel lines, or parcel lines were not based on As Built construction. Correct alignment between buildings and parcels would optimize the spatial join between them. For a more complete discussion of this issue see the companion report "*Technical Procedures and Issues for Importing User Defined Facilities*".

2. Building footprints/centroids lacked comprehensive attributes for describing the structures represented. Time was saved processing building centroids because Dane County's LIO made efforts to add land use and primary/secondary structure type. It

would be recommended that building footprints/centroids include essential attributes such as the postal address or assessor ID, allowing direct linking to supporting databases, avoiding issues described in #1 above.

3. Elevation Certificates created and maintained by Floodplain Managers for certain structures contain even more essential information not available in the assessor or parcel datasets. Additional attributes include reference floor elevation, adjacent grade description and base flood elevations – all tied to vertical datum. It would be recommended that all building related attributes be considered in the development of a comprehensive building database based in part on attributes contained on Elevation Certificates.

4. Extending the previous two recommendations toward the development of a national floodplain management data model, a crucial component would be a building/structure data model containing attribute data crucial for all hazard risk analysis to include flood risk analysis.

5. Make the User Defined Facilities analysis more transparent by publishing the method HAZUS uses to assign damage percentage from the attributes imported into the UDF table.

6. There is a HAZUS limitation that prevents imported User Defined Facilities form being reconnected with the original data that was imported due to HAZUS removing user defined attributes. This limitation could be resolved by supporting or maintaining user defined attribute columns such as a unique identifier (e.g. object ID) that would allow linking back to original or other supporting datasets.

7. There is a bug in HAZUS that truncates Latitude and Longitude values to four decimal places during the UDF import process. This bug essentially decreases the spatial accuracy of any building point locations. This bug has been communicated to the HAZUS development team.

8. HAZUS does not support importing UDFs from a Geodatabase, which is not consistent with HAZUS MR3 User Manual documentation that describes this procedure as possible – see HAZUS User Manual, Section 6.1, p. 6.1.

Opportunities for further research include:

1. Run a similar UDF analysis on an area with a larger population of structures with NFIP Claims.

2. Determining actual replacement costs instead of using approximations such as assessment values – very difficult due to large number of variables over time

3. Determining actual content costs instead of using linear defaults based on occupancy type and replacement cost

4. Determining whether private insurance companies have specifics for individual structures and can share data, specifically for replacement cost, foundation, etc.