Comparing HAZUS Flood Loss Estimates Across Hazard Identification Methods and Building Stock Inventory Data

Albion Township
Dane County, Wisconsin

Prepared for the Association of State Floodplain Managers
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Comparing HAZUS Flood Loss Estimates Across Various Hazard Identification Methods and Building Stock Inventory Data

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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 loss estimation software at the individual structure level of analysis. This analysis compares HAZUS damage estimates using three methods to identify the 1% annual chance (100-yr) flood hazard along with three levels of building inventory data for a total of nine (9) comparative analysis scenarios.

<u>The three 100-yr hazard identification methods:</u>

1. Flood depth grids created in HAZUS by importing a DEM and using the default **Hydrology and Hydraulic** modeling to delineate streams and determine flood extent
2. Flood depth grids created by the HAZUS **Enhanced Quick Look** tool based on DFIRM polygons and a DEM
3. A combination of flood depth grids derived from the **Enhanced Quick Look and Flood Information Tool** (FIT), which uses DFIRM base flood elevations and boundaries

<u>The three levels of building inventory data:</u>

A. Using the default **General Building Stock (GBS)** that is included with HAZUS
B. Updating the GBS by using the **Comprehensive Data Management System** (CDMS) to aggregate User Defined Facilities data
C. Importing **User Defined Facilities** data containing the point location of structures and their attributes

The figure below shows the relationship among the results for the three HAZUS methods used on the three levels of data – each analysis scenario is uniquely identified (e.g. 1A):

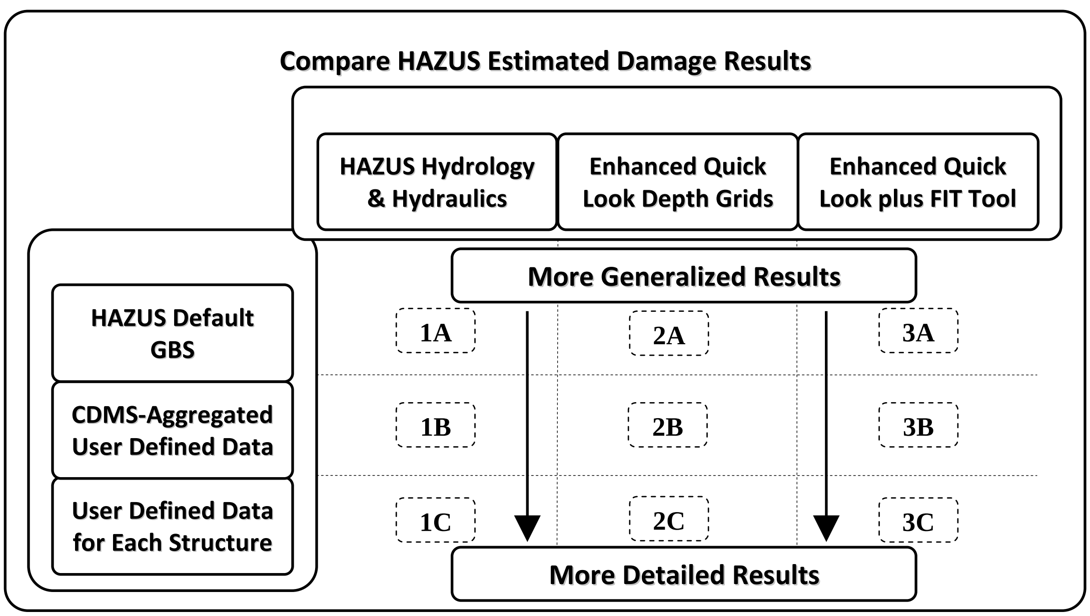

Figure 1: Comparative Analyses Matrix

The rationale for choosing the 3 hazard identification methods is based on the desire to explore any differences in flood damage estimates due to differences in flood hazard boundaries. The special flood hazard area boundary (1% annual chance or 100-yr flood) delineated in the Digital Flood Insurance Rate Map (DFIRM) serves as the benchmark due to its regulatory and legal standing. Recognizing it is not desirable to use the Enhanced Quick Look tool to generate flood depth grids based on the DFIRM boundary, as of the date of this report, it is the only option available within HAZUS.

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 March 2010 through July 2010.

2.0 Study Area

ASFPM explored the use of HAZUS' User Defined Facilities (UDF) functionality in the report *"Structure Level Flood Damage Analysis: NFIP & HAZUS"* using the Township of Albion in Dane County, Wisconsin. That analysis was limited to 18 structures that had reported National Flood Insurance Program (NFIP) claims from the 2008 flooding; this analysis serves as a follow-up to that report by incorporating the township level UDF analysis into its comparison of the methods and data described in Figure 1.

The study region for this analysis is constrained to the census blocks that make up the boundaries of the township of Albion in southeastern Dane County, Wisconsin. The map below shows Albion and includes the point location of the 932 User Defined Facilities imported for the UDF portion of the analysis (Category C in Figure 1).

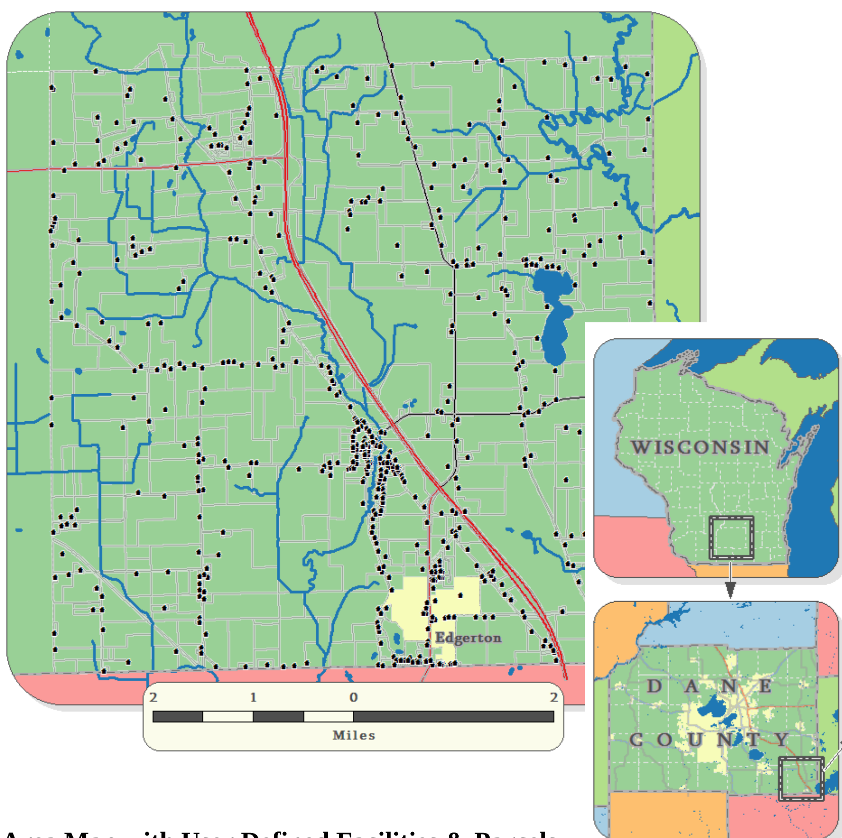

Figure 2: Study Area Map with User Defined Facilities & Parcels

3.0 Datasets & Attributes

Data and attributes are the crucial component of an analysis. Much of the data for this analysis had been collected for ASFPM's *"Structure Level Flood Damage Analysis: NFIP & HAZUS"* report. 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.

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:

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 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 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 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 Federal Emergency Management Agency (FEMA)

Digital Flood Insurance Rate Maps (DFIRMs)

FEMA produces Flood Insurance Rate Maps (FIRM) and Flood Insurance Study (FIS) for communities in the United States. Digital Flood Insurance Rate Maps (DFIRM) were available containing GIS files of flood extent boundaries, base flood elevations and cross sections of some of the waterways for this study area. DFIRM flood boundaries were used with the county DEM to create Enhanced Quick Look flood depth grids and the cross sections were used in the process of creating flood depth grids using FIT in HAZUS.

3.2.3 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. Accurate Appraisal's dataset contained recent assessment values from after the flooding so assessment values from the county's parcel layer were used.

3.2.4 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.

3.2.5 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.

4.0 Methods

HAZUS was run nine times as shown in Figure 1. The methods to run HAZUS are outlined in the HAZUS-MH MR3 Flood User Manual and HAZUS-MH MR3 Flood Technical Manual. For this report, HAZUS was run in the standard method in order to get the damage estimates for each of the 9 hazard/data combinations.

4.1 Hazard Identification Methods

The following sections describe the procedure for each of the three hazard identification methods followed by Figure 3, which shows the resulting flood hazard boundaries for each method.

4.1.1 HAZUS Default Hydrology and Hydraulics (H&H) Method

HAZUS can be run "out-of-the-box" with little additional data inputs except for a DEM. HAZUS can determine flood extents by processing the DEM to delineate stream channels and estimate areas of inundation. HAZUS will determine the necessary extents of the DEM based on the size of the study region and will link a user to the USGS to download the DEM. For this method, a high resolution DEM from Dane County was merged to the USGS DEM in order to process the hydrology and hydraulics.[1]

Calculating the hydrology and hydraulics is computationally intensive with a high resolution the DEM. The procedure in the HAZUS menu under *Hazard > Develop Stream Network* took over 24 hours to process. Then the procedure under *Hazard > Riverine > Hydrology* failed a number of times after a HAZUS hung on a couple of stream reaches. After determining the problem reaches and not including them in the scenario, the processing took over 48 hours to complete. Finally, the procedure under *Hazard > Riverine > Delineate Floodplain* took an additional 24 hours.

4.1.2 Enhanced Quick Look Method

HAZUS includes functionality called Enhanced Quick Look (EQL) that allows users to upload a DEM and a DFIRM flood boundary to create a flood depth grid. HAZUS then allows a user to use this flood depth grid to run a "Quick Analysis" to get faster results than a standard analysis.

This comparative analysis used the depths grids created with Enhanced Quick Look but then imported them into each analysis as the Flood Depth Grid under *Hazard > User Data* and used the standard *Analysis > Run* instead of the Quick Analysis.

4.1.3 Enhanced Quick Look plus Flood Information Tool Method

HAZUS also has the ability to create flood depth grids from DFIRM cross sections using the Flood Information Tool (FIT). For this study area, only one stream channel had cross sections so the FIT was used to create the depth grid for that stream and it was merged to the Enhanced Quick Look flood depth grid.

[1] The Dane County DEM was first clipped to the extent of the county prior to merging with the USGS DEM in order to remove edge artifacts from the raster dataset.

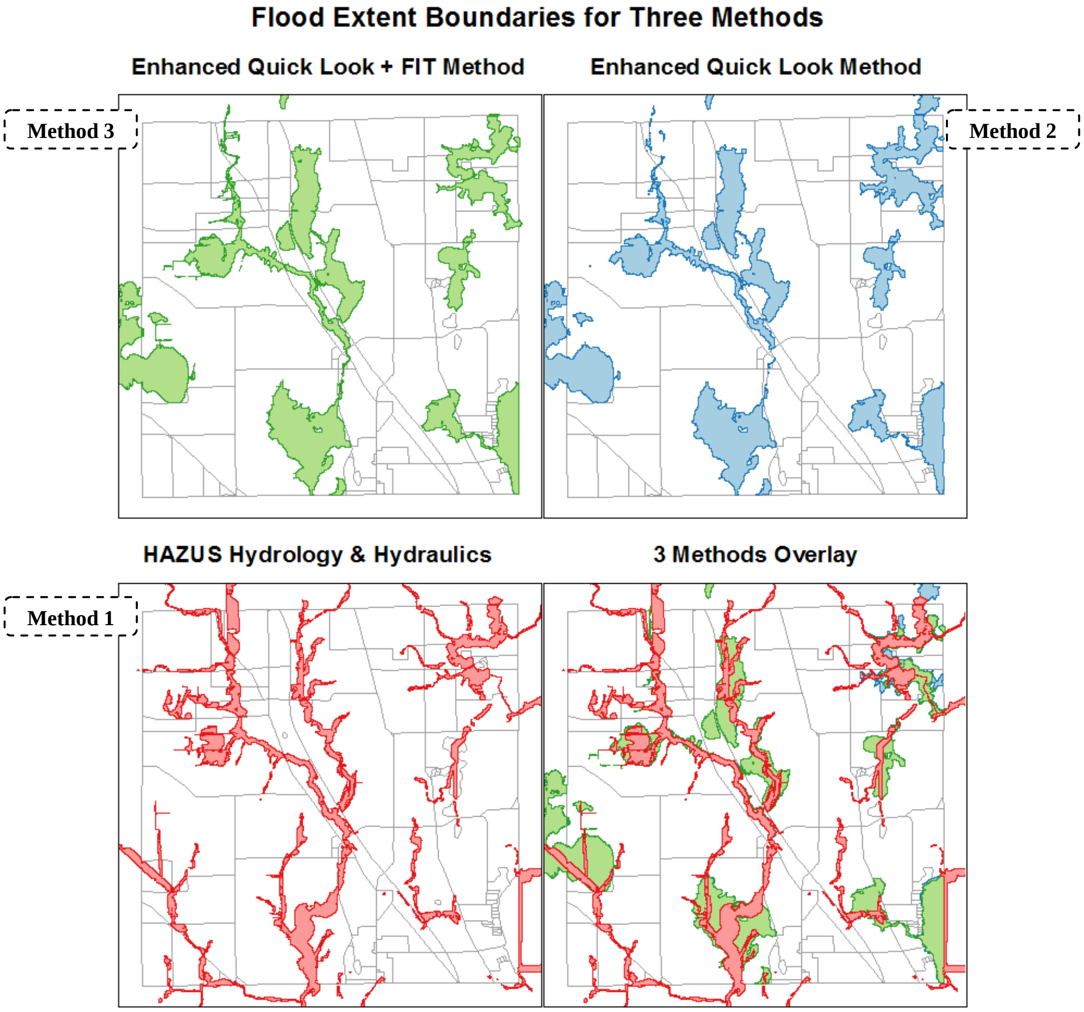

Figure 3: Flood Depth Grid Boundary Comparison Analysis[2]

4.2 Structure Data Levels

The following sections describe the three levels of structure data that were used against each of the three previous hazard identification methods.

4.2.1 HAZUS Default Census Block Data

Even though HAZUS includes default data that can be used to run an analysis, it is important to note the manual states: "The results of a HAZUS run using default data will have large margins of error."[3] HAZUS estimates losses using a comprehensive, national inventory called the General Building Stock (GBS) that serves as the default when a user does not have locally derived data such as UDF building locations. The HAZUS Technical Manual discusses GBS succinctly:

> The General Building Stock (GBS) includes residential, commercial, industrial, agricultural, religious, government and education buildings. Damage is estimated in

[2] Notice how the default method with the imported DEM fails to properly create a depth grid for Lake Koshkonong in southeast Albion. Most of the flood damages occur in that highly populated area due to lake flooding, so the results are affected by HAZUS not properly determining hydrology and hydraulics for an inland lake.

[3] HAZUS-MH MR4 Flood User Manual, Chapter 3, page 3-1.

> percent and is weighted by the area of inundation at a given depth for a given census block. The entire composition of the general building stock within a given census block is assumed to be evenly distributed throughout the block.[4]

The default analysis method assumes the GBS is evenly distributed across the entire census block, so if 50% of the block is flooded, HAZUS will assume 50% of the buildings are in the flood zone. This may not represent the actual ground conditions and damage estimates that are calculated with these assumptions may not produce accurate results.

4.2.2 GBS Updated with Comprehensive Data Management System

Due to the issues described in the last section, HAZUS allows for users to update the census data using the Comprehensive Data Management System (CDMS). For this report, the data gathered for the User Defined Facility (UDF) analysis was the basis for updating the default census data. The UDF data was prepared as a table of attributes for each individual structure, but instead of importing them into HAZUS as point locations, the table was imported into the CDMS and it aggregated the data up to the census block level. This procedure leaves the user with similar assumptions related to even distribution, but should improve the accuracy of the building stock.

4.2.3 User Defined Facility Data

User Defined Facility data is the location and attributes of individual structures. The UDF analysis in HAZUS preserves the point location of features instead of assuming building stock is evenly distributed across a census block. In a UDF analysis, HAZUS determines which buildings are in the flood zone based on the location of each building imported into the UDF table, so only the buildings intersecting the flood zone are used in the damage calculations. An in-depth look at UDF analysis can be found in the ASFPM report *"Structure Level Flood Damage Analysis: NFIP & HAZUS"*

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 4).

[4] HAZUS-MH MR4 Flood Technical Manual, Section 3.2.1, page 3-1.

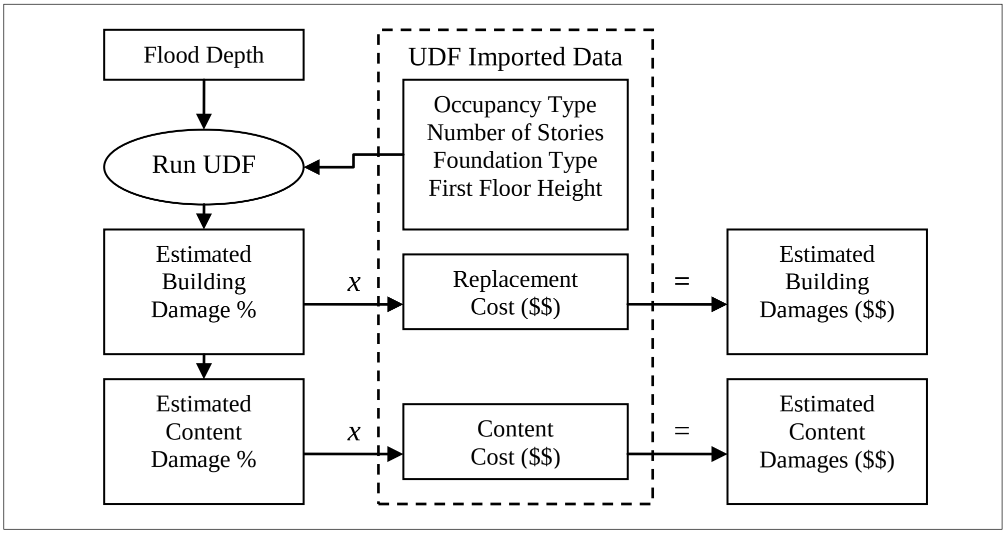

Figure 4: HAZUS Inputs for UDF Damage Calculations

The attributes that can be imported into the UDF analysis are shown in the table below:

Field	Type	Size	Field	Type	Size
CONTACT	Text	40	BLDGTYPE	Text	15
NAME	Text	40	LATITUDE	Double	16
ADDRESS	Text	40	LONGITUDE	Double	16
CITY	Text	40	COMMENT	Text	40
STATE	Text	2	CONTENTCOST	Currency	8
ZIPCODE	Text	40	DESIGNLEVEL	Text	1
PHONENUMBER	Text	47	FOUNDATIONTYPE	Text	1
OCCUPANCY	Text	5	FIRSTFLOORHT	Double	8
YEARBUILT	Integer	2	SHELTERCAPACITY	Integer	2
COST	Currency	8	BLDGDAMAGEFNID	Text	10
BACKUPPOWER	Yes/No	1	CONTDAMAGEFNID	Text	10
NUMSTORIES	Byte	1	INVDAMAGEFNID	Text	10
AREA	Single	4	FLOODPROTECTION	Long Int	4

Table 2: User Defined Facilities Data Fields

5.0 Results and Discussion

The purpose of this analysis is to compare the HAZUS damage estimates from three different methods for deriving flood hazard boundaries and three levels of building datasets. The three hazard methods and three data levels yields nine analysis scenarios. The results in Figure 5 and Table 3 provide a basic summary of the estimated number of damaged residential buildings and related economic losses. The values of each HAZUS analysis come from the Global Summary Report (see Appendix A) for Scenarios: 1A, 2A & 3A and Scenarios 1B, 2B & 3B. The UDF values are derived from database tables for Scenarios 1C, 2C & 3C.

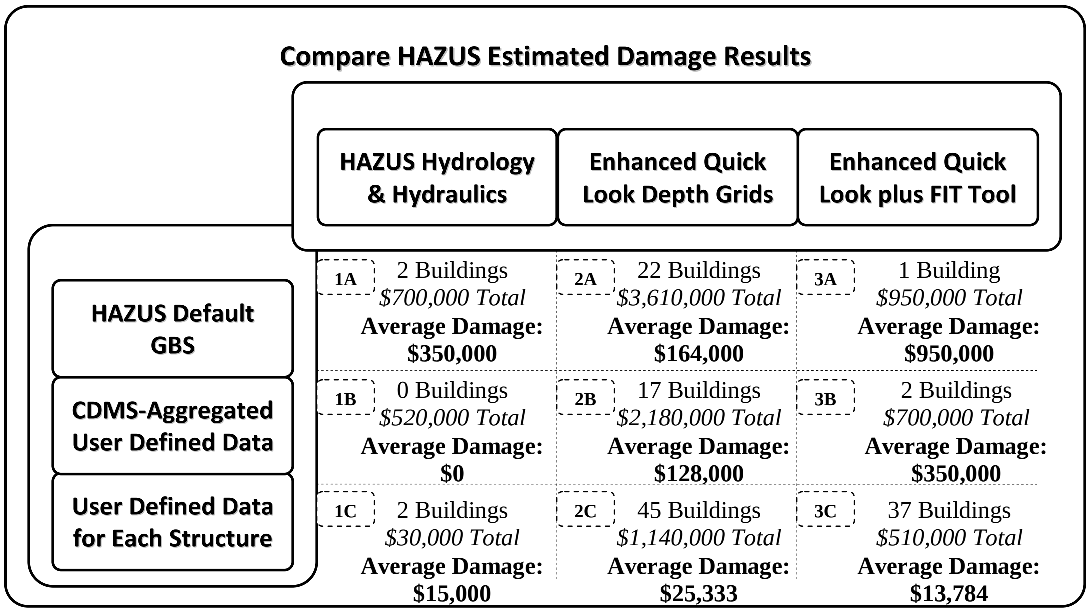

Figure 5: Comparing Average Damage Values

Scenarios	Residential Buildings Damaged	Residential Building Related Losses	Total Building Related Losses	Residential Occupancies as % of Total Loss
1A: Default GBS & H&H	2	$ 700,000	$ 850,000	63.87%
1B: GBS w/ CDMS & Default H&H	0	$ 520,000	$ 590,000	86.41%
1C: UDF & Default H&H	2 (2)*	$ 30,000	$ 60,000	50.00%
2A: Default GBS & EQL	22	$ 3,610,000	$ 3,910,000	83.95%
2B: GBS w/ CDMS & EQL	17	$ 2,180,000	$ 2,210,000	98.56%
2C: UDF & EQL	45	$ 1,140,000	$ 1,140,000	100.00%
3A: Default GBS & EQL / FIT	1	$ 950,000	$ 1,130,000	69.97%
3B: GBS w/ CDMS & EQL / FIT	2	$ 700,000	$ 700,000	96.60%
3C: UDF & EQL / FIT	37	$ 510,000	$ 510,000	100.00%

Table 3: Results for Estimated Damages to Residential Buildings

Results are focused on residential buildings since only one analysis (1C) included non-residential buildings (2 industrial buildings*). The number of buildings damaged includes both moderate (< 50%) and substantial damage (> 50%). Due to HAZUS modeling assumptions and the coarseness of census blocks within HAZUS, the building counts are only reported for summary and discussion purposes. The “Total Building Related Losses” do include damages to non-residential buildings such as Commercial or Industrial. Rounding methods applied to building count totals within HAZUS are likely the reason for having total building related losses higher than residential losses while not reporting any building counts for non-residential buildings. For example in Scenario 3A there was 1 building damaged with $950,000 in residential structure damage and $1,130,000 in total damages, which includes non-residential, but there are no non-residential buildings included in the overall building count. Essentially, it would be anticipated that if there were economic damages to non-residential buildings that there would be non-residential buildings counted.

A brief summary of the results follows:

- *Most damaged buildings:* Scenario 2C, using the Enhanced Quick Look (EQL) flood depth grids with the User Defined Facilities point data
- *Highest total monetary loss:* Scenario 2A, using the EQL flood depth grids with the HAZUS default data
- *Highest average monetary loss:* Scenario 3A, using the EQL plus FIT flood depth grids with the HAZUS default data
- The averages are higher for the HAZUS default data than the CDMS updated data for each of the three methods
- The averages are lowest for all three methods when using User Defined Facilities
- Scenarios 1A, 1B, 3A and 3B seem to produce unrealistic numbers in the number of buildings damaged compared to the total damages. Scenario 3A exemplifies this with 1 building damaged for approximately $1 million

Figures 6, 7 & 8 below contain map pairs for each hazard identification method that show the results between HAZUS default data and the CDMS updated data at the census block level. Each map also contains locations of the damaged User Defined Facilities. A brief summary of the maps:

- There are areas with HAZUS estimated damages that may not have any actual structures as seen from the point locations of the User Defined Facilities. This can be seen more clearly in Figure 3 (p. 6) as default hydrology and hydraulic (H&H) methods generate 100-yr flooding in areas not populated due to lowlands/wetlands (not shown)
- There is a lack of damage along the shore of Lake Koshkonong in southeast Albion for the 1A and 1B analyses that uses a Level 1 or default H&H processing. The lack of damage in this area is due to the limitations of HAZUS to create a flood depth grid for the inland lakes as part of its default H&H modeling

What can be seen from the results is that General Building Stock (GBS) data included with HAZUS (Scenario 1A: $700,000) produced higher damage estimates than either User Defined Facility data that had been aggregated using CDMS (Scenario 1B: $520,000) or UDF data by itself (Scenarios 1C: $30,000). This trend held across each of the different hazard identification methods. It seems logical that using User Defined Facilities data should be the most accurate way to determine damage estimates since it is using the actual structure locations and a reasonable estimate for replacement cost. However, a comparison of replacement cost vs. assessment cost was not performed. This issue also highlights the limitation of assuming even distribution of structures across the census block, which is the case when using the default GBS or the CDMS updated GBS based on census blocks.

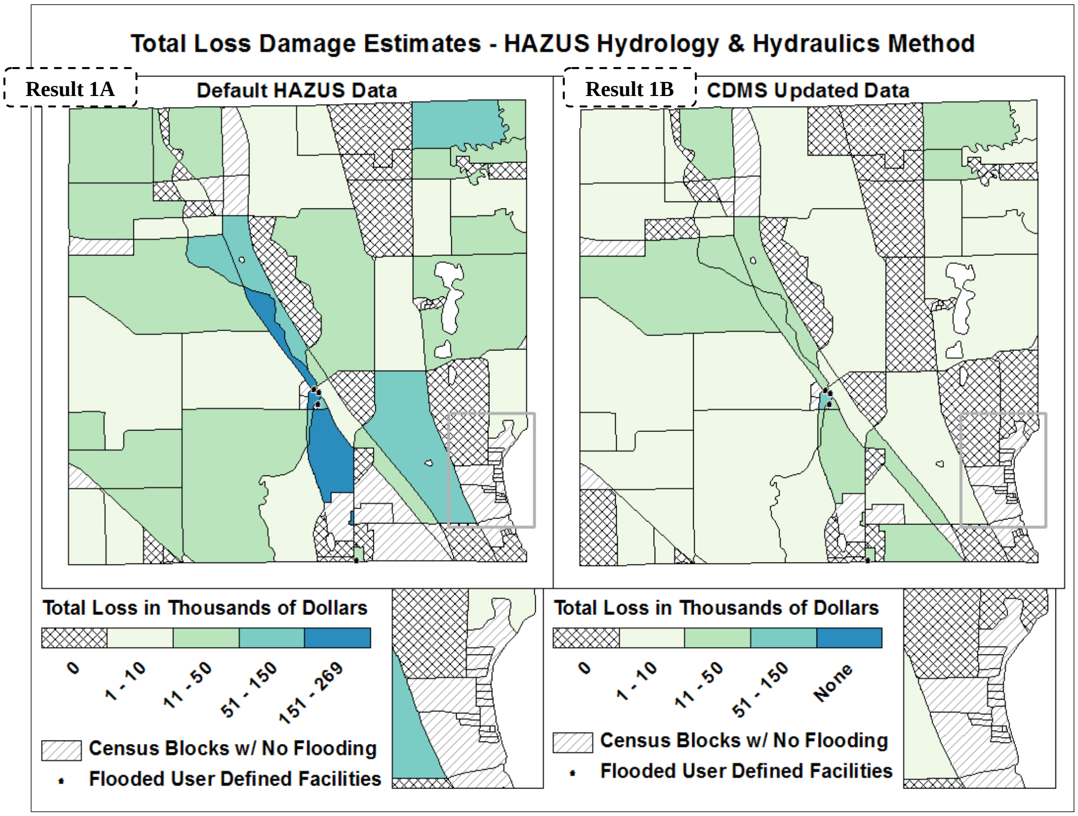

Figure 6: Total Loss by HAZUS Hydrology & Hydraulics Method

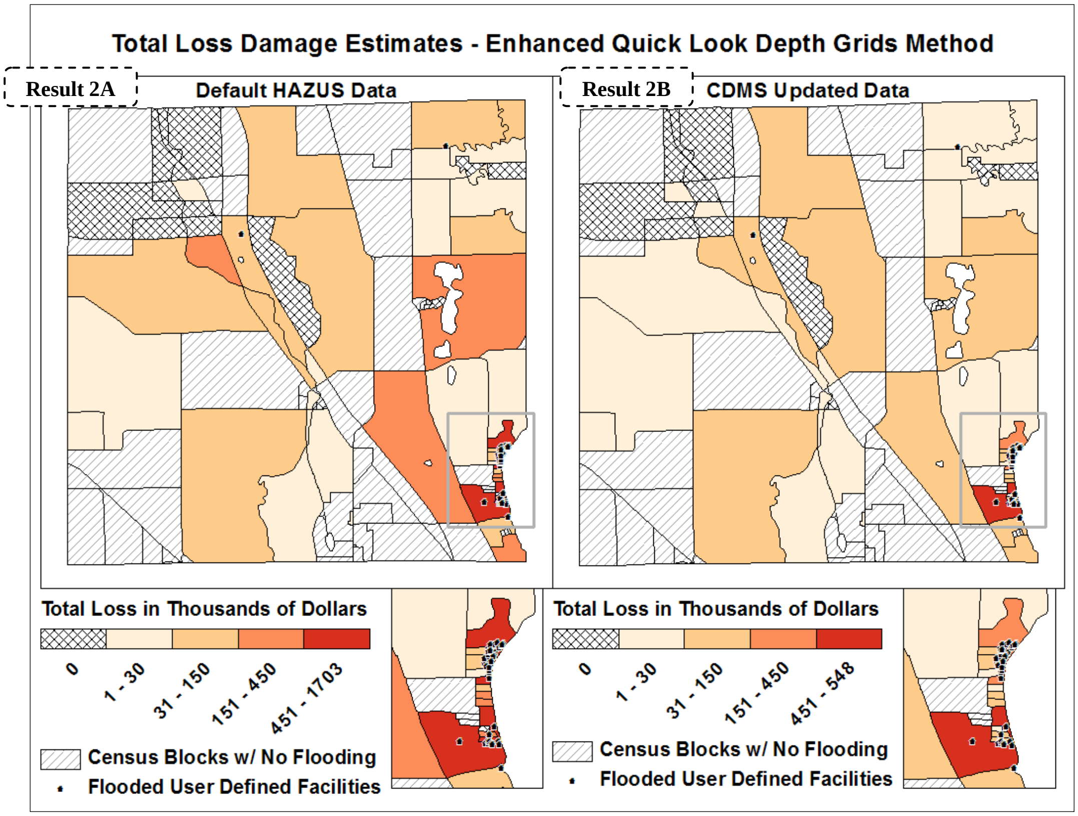

Figure 7: Total Loss by Census Block for Enhanced Quick Look Method

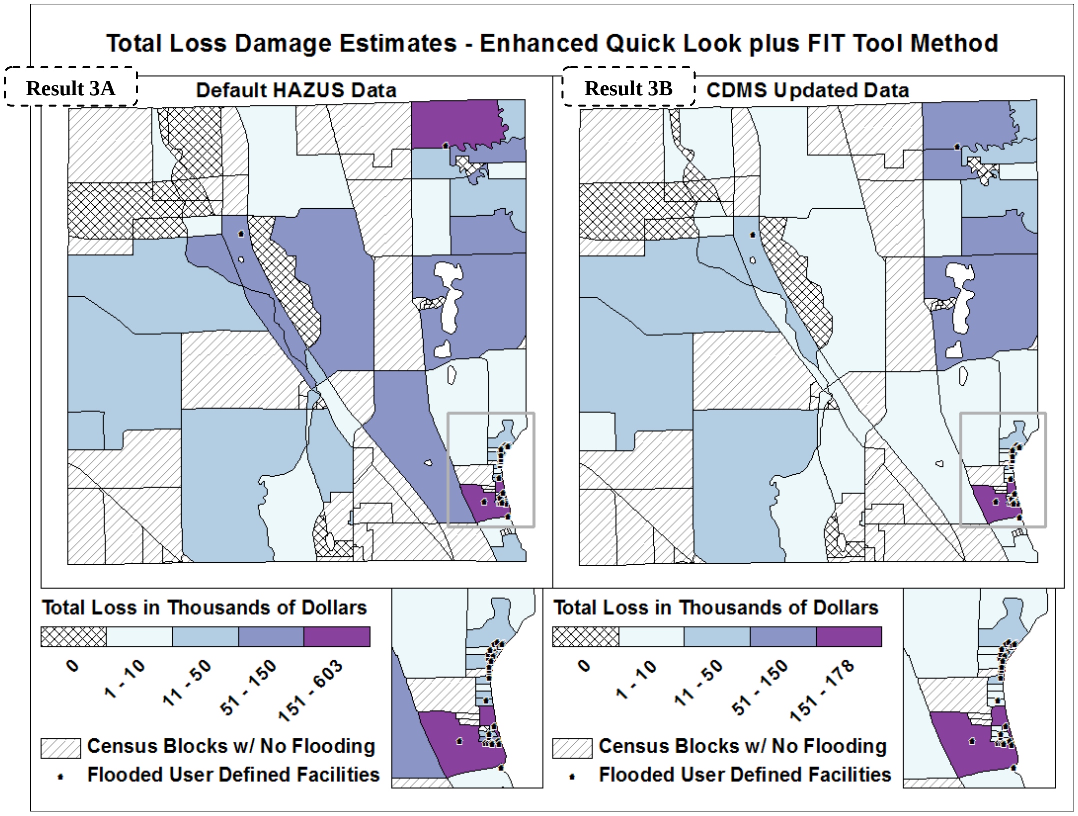

Figure 8: Total Loss by Census Block for Quick Look plus FIT Method

6.0 Issues, Considerations and Further Research

Issues and considerations 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 – Importing User Defined Facilities into HAZUS*".

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. Determine what relationships might exist between replacement costs and property assessment or market values. Likely this would be based on regional and local influences in looking at how each of these values is determined. Regional approximations would help facilitate translating between each value and may help validate the replacement cost model utilized by HAZUS

2. Investigate potential collaborations with private insurance companies with regards to specifics for individual structures and data sharing, specifically for replacement cost, foundation, flood damage claims – both non-NFIP and NFIP

3. Utilize other methods and/or software for modeling hydrology and hydraulic in determination of flood hazard boundaries and depth grids. Explore HEC-RAS, HEC-HMS, HEC-GeoRAS and others

Appendix A – HAZUS Global Summary Reports

The following pages show the Building Damage and the Economic Loss sections of each *Global Summary Report* for the six analyses for level A and B with reports. Reports for building damage and economic loss are not available within HAUS for User Defined Facilities and thus are not shown. The total numbers of damaged buildings and total estimated building losses from the images have been reproduced in Table 3 of Section 6.0 – Conclusion and Discussion, along with the totals from the User Defined Facilities results for each of the three methods.

Figures 9 and 10 below show the General Building Stock Exposure for the HAZUS default data and CDMS updated data, respectively, from the *Global Summary Reports*.

Building Inventory

General Building Stock

HAZUS estimates that there are 858 buildings in the region which have an aggregate total replacement value of 160 million (2006 dollars). Table 1 and Table 2 present the relative distribution of the value with respect to the general occupancies by Study Region and Scenario respectively. Appendix B provides a general distribution of the building value by State and County.

Table 1
Building Exposure by Occupancy Type for the Study Region

Occupancy	Exposure ($1000)	Percent of Total
Residential	132,343	82.5%
Commercial	20,039	12.5%
Industrial	2,461	1.5%
Agricultural	4,010	2.5%
Religion	445	0.3%
Government	0	0.0%
Education	1,145	0.7%
Total	**160,443**	**100.00%**

Figure 9: General Building Stock Exposure with HAZUS Default Data

Building Inventory

General Building Stock

HAZUS estimates that there are 932 buildings in the region which have an aggregate total replacement value of 137 million (2006 dollars). Table 1 and Table 2 present the relative distribution of the value with respect to the general occupancies by Study Region and Scenario respectively. Appendix B provides a general distribution of the building value by State and County.

Table 1
Building Exposure by Occupancy Type for the Study Region

Occupancy	Exposure ($1000)	Percent of Total
Residential	113,470	82.6%
Commercial	6,299	4.6%
Industrial	13,883	10.1%
Agricultural	3,646	2.7%
Religion	0	0.0%
Government	47	0.0%
Education	0	0.0%
Total	**137,345**	**100.00%**

Figure 10: General Building Stock Exposure with HAZUS CDMS Updated Data

Analysis 1A – Default GBS and Default H&H

Building Damage

General Building Stock Damage

HAZUS estimates that about 2 buildings will be at least moderately damaged. This is over 0% of the total number of buildings in the scenario. There are an estimated 0 buildings that will be completely destroyed. The definition of the 'damage states' is provided in Volume 1: Chapter 5 of the HAZUS Flood technical manual. Table 3 below summarizes the expected damage by general occupancy for the buildings in the region. Table 4 summarizes the expected damage by general building type.

Table 3: Expected Building Damage by Occupancy

	1-10		11-20		21-30		31-40		41-50		Substantially	
Occupancy	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**
Agriculture	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Commercial	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Education	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Government	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Industrial	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Religion	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Residential	0	0.00	0	0.00	0	0.00	2	100.00	0	0.00	0	0.00
Total	**0**		**0**		**0**		**2**		**0**		**0**	

Table 4: Expected Building Damage by Building Type

	1-10		11-20		21-30		31-40		41-50		Substantially	
Building Type	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**
Concrete	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ManufHousing	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Masonry	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Steel	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Wood	0	0.00	0	0.00	0	0.00	2	100.00	0	0.00	0	0.00

Economic Loss

The total economic loss estimated for the flood is 1.69 million dollars, which represents 1.75 % of the total replacement value of the scenario buildings.

Building-Related Losses

The building losses are broken into two categories: direct building losses and business interruption losses. The direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the flood. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the flood.

The total building-related losses were 1.67 million dollars. 0% of the estimated losses were related to the business interruption of the region. The residential occupancies made up 63.87% of the total loss. Table 6 below provides a summary of the losses associated with the building damage.

Table 6: Building-Related Economic Loss Estimates

(Millions of dollars)

Category	Area	Residential	Commercial	Industrial	Others	Total
Building Loss						
	Building	0.70	0.08	0.05	0.02	0.85
	Content	0.38	0.28	0.08	0.06	0.80
	Inventory	0.00	0.00	0.02	0.01	0.03
	Subtotal	**1.08**	**0.37**	**0.15**	**0.08**	**1.67**
Business Interruption						
	Income	0.00	0.00	0.00	0.00	0.00
	Relocation	0.00	0.00	0.00	0.00	0.00
	Rental Income	0.00	0.00	0.00	0.00	0.00
	Wage	0.00	0.00	0.00	0.00	0.00
	Subtotal	**0.00**	**0.00**	**0.00**	**0.00**	**0.01**
ALL	**Total**	**1.08**	**0.37**	**0.15**	**0.08**	**1.68**

Analysis 1B – GBS w/ CDMS Update & Default H&H

Building Damage

General Building Stock Damage

HAZUS estimates that about 0 buildings will be at least moderately damaged. This is over 0% of the total number of buildings in the scenario. There are an estimated 0 buildings that will be completely destroyed. The definition of the 'damage states' is provided in Volume 1: Chapter 5 of the HAZUS Flood technical manual. Table 3 below summarizes the expected damage by general occupancy for the buildings in the region. Table 4 summarizes the expected damage by general building type.

Table 3: Expected Building Damage by Occupancy

Occupancy	1-10		11-20		21-30		31-40		41-50		Substantially	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Agriculture	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Commercial	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Education	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Government	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Industrial	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Religion	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Residential	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total	**0**		**0**		**0**		**0**		**0**		**0**	

Table 4: Expected Building Damage by Building Type

Building Type	1-10		11-20		21-30		31-40		41-50		Substantially	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ManufHousing	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Masonry	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Steel	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Wood	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00

Economic Loss

The total economic loss estimated for the flood is 0.60 million dollars, which represents 0.68 % of the total replacement value of the scenario buildings.

Building-Related Losses

The building losses are broken into two categories: direct building losses and business interruption losses. The direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the flood. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the flood.

The total building-related losses were 0.59 million dollars. 0% of the estimated losses were related to the business interruption of the region. The residential occupancies made up 86.41% of the total loss. Table 6 below provides a summary of the losses associated with the building damage.

Table 6: Building-Related Economic Loss Estimates

(Millions of dollars)

Category	Area	Residential	Commercial	Industrial	Others	Total
Building Loss						
	Building	0.52	0.03	0.02	0.02	0.59
	Content	0.00	0.00	0.00	0.00	0.00
	Inventory	0.00	0.00	0.00	0.00	0.01
	Subtotal	**0.52**	**0.04**	**0.02**	**0.02**	**0.59**
Business Interruption						
	Income	0.00	0.00	0.00	0.00	0.00
	Relocation	0.00	0.00	0.00	0.00	0.00
	Rental Income	0.00	0.00	0.00	0.00	0.00
	Wage	0.00	0.00	0.00	0.00	0.00
	Subtotal	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
ALL	**Total**	**0.52**	**0.04**	**0.02**	**0.02**	**0.59**

Analysis 2A – Default GBS & Enhanced Quick Look

Building Damage

General Building Stock Damage

HAZUS estimates that about 22 buildings will be at least moderately damaged. This is over 9% of the total number of buildings in the scenario. There are an estimated 4 buildings that will be completely destroyed. The definition of the 'damage states' is provided in Volume 1: Chapter 5 of the HAZUS Flood technical manual. Table 3 below summarizes the expected damage by general occupancy for the buildings in the region. Table 4 summarizes the expected damage by general building type.

Table 3: Expected Building Damage by Occupancy

	1-10		11-20		21-30		31-40		41-50		Substantially	
Occupancy	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Agriculture	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Commercial	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Education	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Government	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Industrial	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Religion	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Residential	0	0.00	0	0.00	4	18.18	7	31.82	7	31.82	4	18.18
Total	**0**		**0**		**4**		**7**		**7**		**4**	

Table 4: Expected Building Damage by Building Type

Building Type	1-10		11-20		21-30		31-40		41-50		Substantially	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ManufHousing	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Masonry	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Steel	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Wood	0	0.00	0	0.00	4	18.18	7	31.82	7	31.82	4	18.18

Economic Loss

The total economic loss estimated for the flood is 6.61 million dollars, which represents 6.41 % of the total replacement value of the scenario buildings.

Building-Related Losses

The building losses are broken into two categories: direct building losses and business interruption losses. The direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the flood. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the flood.

The total building-related losses were 6.59 million dollars. 0% of the estimated losses were related to the business interruption of the region. The residential occupancies made up 83.95% of the total loss. Table 6 below provides a summary of the losses associated with the building damage.

Table 6: Building-Related Economic Loss Estimates

(Millions of dollars)

Category	Area	Residential	Commercial	Industrial	Others	Total
Building Loss						
	Building	3.61	0.19	0.10	0.01	3.91
	Content	1.93	0.55	0.12	0.04	2.64
	Inventory	0.00	0.01	0.02	0.00	0.04
	Subtotal	**5.54**	**0.74**	**0.25**	**0.05**	**6.59**
Business Interruption						
	Income	0.00	0.00	0.00	0.00	0.00
	Relocation	0.01	0.00	0.00	0.00	0.01
	Rental Income	0.00	0.00	0.00	0.00	0.00
	Wage	0.00	0.00	0.00	0.00	0.00
	Subtotal	**0.01**	**0.01**	**0.00**	**0.00**	**0.01**
ALL	**Total**	**5.55**	**0.75**	**0.25**	**0.05**	**6.60**

Analysis 2B – GBS w/ CDMS Update & Enhanced Quick Look

Building Damage

General Building Stock Damage

HAZUS estimates that about 17 buildings will be at least moderately damaged. This is over 8% of the total number of buildings in the scenario. There are an estimated 2 buildings that will be completely destroyed. The definition of the 'damage states' is provided in Volume 1: Chapter 5 of the HAZUS Flood technical manual. Table 3 below summarizes the expected damage by general occupancy for the buildings in the region. Table 4 summarizes the expected damage by general building type.

Table 3: Expected Building Damage by Occupancy

	1-10		11-20		21-30		31-40		41-50		Substantially	
Occupancy	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Agriculture	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Commercial	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Education	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Government	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Industrial	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Religion	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Residential	0	0.00	0	0.00	3	17.65	6	35.29	6	35.29	2	11.76
Total	**0**		**0**		**3**		**6**		**6**		**2**	

Table 4: Expected Building Damage by Building Type

Building Type	1-10		11-20		21-30		31-40		41-50		Substantially	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ManufHousing	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Masonry	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Steel	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Wood	0	0.00	0	0.00	3	17.65	6	35.29	6	35.29	2	11.76

Economic Loss

The total economic loss estimated for the flood is 2.22 million dollars, which represents 2.80 % of the total replacement value of the scenario buildings.

Building-Related Losses

The building losses are broken into two categories: direct building losses and business interruption losses. The direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the flood. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the flood.

The total building-related losses were 2.21 million dollars. 0% of the estimated losses were related to the business interruption of the region. The residential occupancies made up 98.56% of the total loss. Table 6 below provides a summary of the losses associated with the building damage.

Table 6: Building-Related Economic Loss Estimates

(Millions of dollars)

Category	Area	Residential	Commercial	Industrial	Others	Total
Building Loss						
	Building	2.18	0.01	0.00	0.02	2.21
	Content	0.00	0.00	0.00	0.00	0.00
	Inventory	0.00	0.00	0.00	0.00	0.00
	Subtotal	**2.18**	**0.01**	**0.00**	**0.02**	**2.21**
Business Interruption						
	Income	0.00	0.00	0.00	0.00	0.00
	Relocation	0.00	0.00	0.00	0.00	0.00
	Rental Income	0.00	0.00	0.00	0.00	0.00
	Wage	0.00	0.00	0.00	0.00	0.00
	Subtotal	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
ALL	**Total**	**2.18**	**0.01**	**0.00**	**0.02**	**2.21**

Analysis 3A – Default GBS & Enhanced Quick Look / Flood Info Tool

Building Damage

General Building Stock Damage

HAZUS estimates that about 1 building will be at least moderately damaged. This is over 2% of the total number of buildings in the scenario. There are an estimated 0 buildings that will be completely destroyed. The definition of the 'damage states' is provided in Volume 1: Chapter 5 of the HAZUS Flood technical manual. Table 3 below summarizes the expected damage by general occupancy for the buildings in the region. Table 4 summarizes the expected damage by general building type.

Table 3: Expected Building Damage by Occupancy

	1-10		11-20		21-30		31-40		41-50		Substantially	
Occupancy	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**
Agriculture	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Commercial	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Education	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Government	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Industrial	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Religion	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Residential	0	0.00	0	0.00	1	100.00	0	0.00	0	0.00	0	0.00
Total	**0**		**0**		**1**		**0**		**0**		**0**	

Table 4: Expected Building Damage by Building Type

Building Type	**1-10**		**11-20**		**21-30**		**31-40**		**41-50**		**Substantially**	
	Count	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**	**Count**	**(%)**
Concrete	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ManufHousing	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Masonry	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Steel	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Wood	0	0.00	0	0.00	1	100.00	0	0.00	0	0.00	0	0.00

Economic Loss

The total economic loss estimated for the flood is 2.12 million dollars, which represents 1.93 % of the total replacement value of the scenario buildings.

Building-Related Losses

The building losses are broken into two categories: direct building losses and business interruption losses. The direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the flood. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the flood.

The total building-related losses were 2.10 million dollars. 0% of the estimated losses were related to the business interruption of the region. The residential occupancies made up 69.97% of the total loss. Table 6 below provides a summary of the losses associated with the building damage.

Table 6: Building-Related Economic Loss Estimates

(Millions of dollars)

Category	**Area**	**Residential**	**Commercial**	**Industrial**	**Others**	**Total**
Building Loss						
	Building	0.95	0.11	0.06	0.01	1.13
	Content	0.53	0.31	0.07	0.03	0.95
	Inventory	0.00	0.01	0.02	0.00	0.03
	Subtotal	**1.48**	**0.43**	**0.15**	**0.04**	**2.10**
Business Interruption						
	Income	0.00	0.00	0.00	0.00	0.00
	Relocation	0.00	0.00	0.00	0.00	0.00
	Rental Income	0.00	0.00	0.00	0.00	0.00
	Wage	0.00	0.00	0.00	0.00	0.00
	Subtotal	**0.01**	**0.00**	**0.00**	**0.00**	**0.01**
ALL	**Total**	**1.48**	**0.43**	**0.15**	**0.04**	**2.11**

Analysis 2C – GBS w/ CDMS Update & Enhanced Quick Look / Flood Info Tool

Building Damage

General Building Stock Damage

HAZUS estimates that about 2 buildings will be at least moderately damaged. This is over 2% of the total number of buildings in the scenario. There are an estimated 0 buildings that will be completely destroyed. The definition of the 'damage states' is provided in Volume 1: Chapter 5 of the HAZUS Flood technical manual. Table 3 below summarizes the expected damage by general occupancy for the buildings in the region. Table 4 summarizes the expected damage by general building type.

Table 3: Expected Building Damage by Occupancy

	1-10		11-20		21-30		31-40		41-50		Substantially	
Occupancy	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Agriculture	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Commercial	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Education	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Government	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Industrial	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Religion	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Residential	0	0.00	0	0.00	1	50.00	0	0.00	1	50.00	0	0.00
Total	**0**		**0**		**1**		**0**		**1**		**0**	

Table 4: Expected Building Damage by Building Type

Building Type	1-10		11-20		21-30		31-40		41-50		Substantially	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Concrete	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
ManufHousing	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Masonry	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Steel	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Wood	0	0.00	0	0.00	1	50.00	0	0.00	1	50.00	0	0.00

Economic Loss

The total economic loss estimated for the flood is 0.71 million dollars, which represents 0.88 % of the total replacement value of the scenario buildings.

Building-Related Losses

The building losses are broken into two categories: direct building losses and business interruption losses. The direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the flood. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the flood.

The total building-related losses were 0.70 million dollars. 0% of the estimated losses were related to the business interruption of the region. The residential occupancies made up 96.60% of the total loss. Table 6 below provides a summary of the losses associated with the building damage.

Table 6: Building-Related Economic Loss Estimates

(Millions of dollars)

Category	Area	Residential	Commercial	Industrial	Others	Total
Building Loss						
	Building	0.68	0.00	0.00	0.01	0.70
	Content	0.00	0.00	0.00	0.00	0.00
	Inventory	0.00	0.00	0.00	0.00	0.00
	Subtotal	**0.68**	**0.00**	**0.00**	**0.01**	**0.70**
Business Interruption						
	Income	0.00	0.00	0.00	0.00	0.00
	Relocation	0.00	0.00	0.00	0.00	0.00
	Rental Income	0.00	0.00	0.00	0.00	0.00
	Wage	0.00	0.00	0.00	0.00	0.00
	Subtotal	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
ALL	**Total**	**0.68**	**0.00**	**0.00**	**0.01**	**0.70**