Hazus Inventory Technical Manual

Hazus 4.2 Service Pack 3

February 2021

FEMA

Table of Contents

List of Figures

List of Tables

Acronyms and Abbreviations

Acronym/ Abbreviation	Definition
ABFE	Advisory Base Flood Elevation
AC	Alternating Current
ACS	American Community Survey
AEBM	Advanced Engineering Building Module
AGDAM	Agriculture Flood Damage Analysis
AGR	Agriculture
APA	American Planning Association
ASCE	American Society of Civil Engineers
BFE	Base Flood Elevation
BUR	Built-Up Roof
C	Concrete
CACFDAS	Computerized Agricultural Crop Flood Damage Assessment System
CAS	Chemical Abstracts Service
CBECS	Commercial Buildings Energy Consumption Survey
CDMS	Comprehensive Data Management System
CECB	Concrete, Engineered Commercial Building
CERB	Concrete, Engineered Residential Building
COM	Commercial
CPI	Consumer Price Index
DC	Direct Current
DOE	Department of Energy
EDU	Education
EF	Essential Facilities
EIA	Energy Information Administration
EOC	Emergency Operations Center
EQ	Earthquake
ESRI	Environmental Systems Research Institute
ETM+	Enhanced Thematic Mapper+ (Landsat)
FDA	Flood Damage Assessment
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FFE	First Floor Elevation
FL	Flood
ft	Feet
GADM	Database of Global Administrative Areas
GBS	General Building Stock
GEOID	Geographic Identifiers
GHIN	Global Hazards Information Network
GIS	Geographic Information Systems

Acronym/ Abbreviation	Definition
GOV	Government
GS	Ground Shaking
GVW	Gross Vehicle Weight
HC	High-Code
HEC-FIA	USACE Hydrologic Engineering Center, Flood Impact Assessment
HIFLD	Homeland Infrastructure Foundation-Level Data
HPL	High Potential Loss
HS	Special High-Code
HU	Hurricane
HUC	Hydrologic Unit Code
IND	Industrial
IR	Income Ratio
ITE	Institute of Transportation Engineers
km	Kilometer
Lidar	Light detection and ranging
LEHD	Longitudinal Household Employer Dynamic Database
LC	Low-Code
LS	Special Low-Code
LULC	Land Use Land Cover
M	Masonry
MC	Moderate-Code
MECB	Masonry, Engineered Commercial Building
MERB	Masonry, Engineered Residential Building
MGD	Million Gallons per Day
MH	Mobile Homes or Manufactured Housing
MLR	Masonry, Low-Rise
MMUH	Masonry, Multi-Unit Housing
MR	Maintenance Release
MRLC	Multi-Resolution Land Characteristics Consortium
MS	Special Moderate-Code
MSF	Masonry, Single-family
MW	Megawatts
NADA	National Automobile Dealers Association
NASS	National Agriculture Statistical Service
NBI	National Bridge Inventory
NEHRP	National Earthquake Hazards Reduction Program
NFHL	National Flood Hazard Layer
NFIP	National Flood Insurance Program
NHGIS	National Historical Geographic Information System
NIBS	National Institute of Building Sciences
NLCD	National Land Cover Database

Acronym/ Abbreviation	Definition
NPTS	National Personal Travel Survey
NRI	National Resources Inventory
NSI	National Structure Inventory
PC	Precast Concrete
PC	Pre-code
PDC	Pacific Disaster Center
PGD	Permanent Ground Deformation
PGV	Peak Ground Velocity
RCMP	Residential Construction Mitigation Program
REL	Religion/Non-Profit
RES	Residential
RM	Reinforced Masonry
S	Steel
SBT	Specific Building Type
sec	Second
SECB	Steel, Engineered Commercial Building
SERB	Steel, Engineered Residential Building
SF1	Summary File 1
SF3	Summary File 3
SFHA	Special Flood Hazard Areas
SFR	Single-family Residential
SIC	Standard Industrial Classification
SLTT	State, Local, Tribal, and Territorial
SP	Service Pack
SPM	Single-Ply Membrane
SPMB	Steel, Pre-Engineered Metal Building
SR	Service Release
TS	Tsunami
TSWS	Truck Size and Weight Study
UDF	User-Defined Facilities
URM	Unreinforced Masonry
USACE	U.S. Army Corp of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
W	Wood
WBC	Wind Building Characteristic
WMUH	Wood, Multi-Unit Housing
WSF	Wood, Single-family
WTP	Water Treatment Plant

Section 1. Introduction to the FEMA Hazus Loss Estimation Methodology

1.1 Background

The Hazus Loss Estimation Methodology provides state, local, tribal, and territorial (SLTT) officials with a decision support software for estimating potential losses from four natural hazards: floods, hurricanes, earthquakes, and tsunamis. This loss estimation capability enables users to anticipate the consequences of natural hazard events and develop plans and strategies for reducing risk. The Geographic Information Systems (GIS)-based software can be applied to study geographic areas of varying scale with diverse population characteristics and can be implemented by users with a wide range of technical and subject matter expertise.

This Methodology has been developed, enhanced, and maintained by the Federal Emergency Management Agency (FEMA) to provide a tool for developing natural hazard loss estimates for use in:

- Anticipating the possible nature and scope of the emergency response needed to cope with disasters.
- Developing plans for recovery and reconstruction following a disaster.
- Mitigating the possible consequences of natural hazards.

The use of this standardized Methodology provides nationally-comparable estimates that allow the federal government to plan natural hazard responses and guide the allocation of resources to stimulate risk mitigation efforts.

This *Hazus Inventory Technical Manual* documents the background information used to establish the baseline datasets provided within the Hazus software. The focus of this Inventory Technical Manual are the common datasets used by all four individual natural hazard models, and to provide a single source document that avoids repeating information over all the hazard-specific Technical Manuals. Together, these technical documents provide a comprehensive overview of this nationally applicable loss estimation methodology.

In addition to this *Hazus Inventory Technical Manual* and the four hazard-specific Technical Manuals, there are separate Hazus User Guidance documents related to the four hazards and the Hazus Comprehensive Data Management System (CDMS) tool. These documents outline the background and instructions for developing a Study Region and defining a scenario to complete a hazard-specific loss estimation study using Hazus. They also provide information on how to modify inventory and improve hazard data and analysis parameters for advanced applications, and how to calculate and interpret loss results.

1.2 Hazus Uses and Applications

Hazus can be used by various users with a wide range of needs for information. A state, local, tribal, or territorial government official may be interested in the costs and benefits of specific mitigation strategies and may want to know the expected losses if mitigation strategies have (or have not) been applied. Emergency response teams may use the results of a loss analysis in planning and performing emergency response exercises. In particular, they might be interested in the operating capacity of emergency facilities such as fire stations, emergency operations centers, and police stations. Emergency planners may want estimates of temporary shelter requirements for different disaster events. Federal and state government officials may require an estimate of economic losses (both short term and long term) in order to direct resources to affected communities after an event. In addition, government agencies may use loss analyses to obtain quick estimates of impacts in the hours immediately following a disaster to best direct resources to the disaster area. Insurance companies may be interested in the estimated monetary losses, so they can assess asset vulnerability.

Natural hazard loss estimation analyses have a variety of uses for various departments, agencies, and community officials. As users become familiar with the loss estimation methodology, they can determine which Hazus Methodology is the most suitable for their needs, and how to appropriately interpret the results of the analysis.

1.3 Assumed User Expertise

Users can be divided into two groups: those who perform the analysis and those who use the analysis results. For some analyses, these two groups occasionally consist of the same people, but generally this will not be the case. However, the more interaction that occurs between these two groups, the better the analysis will be. End users of the loss estimation analysis need to be involved from the beginning to make results more usable.

Any risk modeling effort can be complex and would benefit from input of an interdisciplinary group of experts. A loss analysis could be performed by a representative team consisting of the following:

- Geologists
- Geotechnical engineers
- Structural engineers
- Architects
- Economists
- Meteorologists
- Wind engineers
- Civil engineers
- Hydrologists
- Social scientists
- Emergency planners
- GIS specialists
- Policy makers

The individuals needed to perform the analysis can provide valuable insight into the risk assessment process. For example, with the recent direct integration of probabilistic and deterministic earthquake ground motion data from the U.S. Geological Survey (USGS) into Hazus, defining earthquake hazard scenarios using authoritative data has become much easier. In addition to subject matter expert involvement, at least one GIS specialist should participate on the team.

If a state, local, tribal, or territorial agency is performing the analysis, some of the expertise may be found in-house. Experts are generally found in several departments: building permitting, public works, planning, public health, engineering, information technologies, finance, historical preservation, natural resources, and land records. Although internal expertise may be readily available, the importance of external participation of individuals from academic institutions, citizen organizations, and private industry cannot be underestimated.

1.4 When to Seek Help

The results of a loss estimation analysis should be interpreted with caution because baseline values have a great deal of uncertainty. Baseline inventory datasets are the datasets that are provided with Hazus. If the loss estimation team does not include individuals with expertise in the areas described above, it is advisable to retain objective reviewers with subject matter expertise to evaluate and comment on map and tabular data outputs.

If the user intends to modify the default inventory data or parameters, assistance from a subject matter expert would benefit the project. For example, if the user wishes to change default percentages of specific building types for the region, collaborating with a structural engineer with knowledge of regional design and construction practices will be helpful. Similarly, if damage-motion relationships (fragility curves) need editing, input from a structural engineer will be required.

1.5 Technical Support

Technical Support contact information is provided in the Hazus application at **Help|Obtaining Technical Support**; technical assistance is available via the Hazus Help Desk by email at FEMA-Hazus-support@fema.dhs.gov (preferred) or by phone at 1-877-FEMA-MAP (1-877-336-2627). The FEMA Hazus website also provides answers to Frequently Asked Questions, and information on software updates, training opportunities, and user group activities.

FEMA-provided resources also include the **Hazus Virtual Training Library**, a series of short videos arranged into playlists that cover various Hazus topics, from an introduction to Hazus methodologies, to targeted tutorials on running Hazus analyses, to best practices when sharing results with decision makers. This easily accessible learning material provides quick topic-refreshers, free troubleshooting resources, and engaging guides to further Hazus exploration.

The application's **Help** menu references the help files for ArcGIS. Since Hazus was built as an extension to ArcGIS functionality, knowing how to use ArcGIS and ArcGIS Help Desk will help Hazus users.

Technical support on any of the four hazards is available at the contacts shown via **Help|Obtaining Technical Support**.

1.6 Uncertainties in Loss Estimates

Although the Hazus software offers users the opportunity to prepare comprehensive loss estimates, it should be recognized that uncertainties are inherent in any estimation methodology, even with state-of-the-art techniques. Any region or city studied will have an enormous variety of buildings and facilities of different sizes, shapes, and structural systems built over a range of years under varying design codes. A variety of components contribute to transportation and utility system damage estimations in certain hazard models.

There are also insufficient comprehensive data from past events or laboratory experiments to determine precise estimates of damage based on different measures of hazard severity, such as known ground motions, flood depths, or wind speeds. To deal with this complexity and lack of data, buildings and components of systems are grouped into categories based on key characteristics. The relationships between measures of hazard severity and average degree of damage with associated losses for each building category are based on current data and available theories.

The results of a natural hazard loss analysis should not be looked upon as a prediction. Instead, they are only an estimate, as uncertainty inherent to the model will be influenced by quality of inventory data and the hazard parameters.

1.7 Hazus Versions and Inventory Status

Table 1-1 below lists each of the Hazus versions and any major changes to data with each release.

Table 1-1 Hazus Versions and Inventory Data

Hazus Version	Release Date	Hazards	Inventory Summary	GBS RSMeans Version
HAZUS97	1997	EQ	1990 Census data, Earthquake added using Census tracts	1994
HAZUS99	Dec. 1999	EQ	1990 Census data	1994
HAZUS99 SR1	2001	EQ	1990 Census data	1994
HAZUS99 SR2	Mar. 2002	EQ, FL	1990 Census data, Flood added using Census blocks	1994
HAZUS-MH 1.0	Jan. 2004	EQ, FL, HU	2000 Census data, Hurricane added using Census tracts	2002
HAZUS-MH MR1	Jan. 2005	EQ, FL, HU	2000 Census data	2002
HAZUS-MH MR2	May 2006	EQ, FL, HU	2000 Census data	2005
HAZUS-MH MR3	Jul. 2007	EQ, FL, HU	2000 Census data, CDMS added	2006
HAZUS-MH MR4	Aug. 2009	EQ, FL, HU	2000 Census data	2006
HAZUS-MH MR5	Dec. 2010	EQ, FL, HU	2000 Census data	2006
Hazus-MH 2.0	Jun. 2011	EQ, FL, HU	2000 Census data, storm surge added (with Hurricane using Census block for analysis)	2006
Hazus-MH 2.1	Feb. 2012	EQ, FL, HU	2000 Census data	2006
Hazus 2.2	Jan. 2015	EQ, FL, HU	2010 Census data	2014
Hazus 2.2 SP1	May 2015	EQ, FL, HU	2010 Census data, optional dasymetric for flood	2014
Hazus 3.0	Nov. 2015	EQ, FL, HU	2010 Census data, dasymetric as default for flood	2014
Hazus 3.1	Apr. 2016	EQ, FL, HU	2010 Census data	2014
Hazus 3.2	Oct. 2016	EQ, FL, HU	2010 Census data	2014
Hazus 4.0	Mar. 2017	EQ, FL, HU, TS	2010 Census data, Tsunami added using NSI data (with new data in territories)	2014*
Hazus 4.2	Jan. 2018	EQ, FL, HU, TS	2010 Census data	2014*
Hazus 4.2 SP1	May 2018	EQ, FL, HU, TS	2010 Census data	2018*
Hazus 4.2 SP2	Feb. 2019	EQ, FL, HU, TS	2010 Census data	2018*
Hazus 4.2 SP3	May 2019	EQ, FL, HU, TS	2010 Census data, update of Essential Facilities with Homeland Infrastructure Foundation-Level Data (HIFLD) data	2018*

Hazus Version	Release Date	Hazards	Inventory Summary	GBS RSMeans Version
Hazus 4.2 SP3 Tools and Data	Dec. 2019	EQ, FL, HU, TS	2010 Census data; updated PR and VI data to work with EQ, FL, TS; update of Essential Facilities and some Systems data with HIFLD data (FEMA, 2019c)	2018*

** NSI Data for Guam, American Samoa, and Northern Mariana Islands use 2016 RSMeans Values.*
*** EQ=Earthquake, FL=Flood, HU=Hurricane, TS=Tsunami, SR=Service Release, MR=Maintenance Release, SP=Service Pack*

Section 2. Introduction to Inventory Data

This brief overview of the Hazus Inventory Data is intended to provide a background on natural hazard modeling in general, and how inventory data has been developed in the Hazus program.

The Hazus Methodologies will generate an estimate of the consequences to a city or region from a natural hazard scenario or from a probabilistic hazard. The resulting "loss estimate" will generally describe the scale and extent of damage and disruption that may result from a potential event. The following information can be obtained:

- *Quantitative estimates of losses* in terms of direct costs for repair and replacement of damaged buildings and system components, direct costs associated with loss of function (e.g., loss of business revenue, relocation costs), casualties, household displacements, quantity of debris, and regional economic impacts.
- *Functionality losses* in terms of loss-of-function and restoration times for critical facilities such as hospitals, and components of transportation and utility systems, and simplified analyses of loss-of-system-function for electrical distribution and potable water systems.
- *Extent of induced hazards* in terms of exposed population and building value due to potential flooding or fire following an earthquake.

To generate this information, the Hazus Methodology contains baseline inventory data, including:

- Classification systems used in assembling inventory and compiling information on the building stock, the components of transportation and utility systems, and demographic and economic data.
- Standard calculations for estimating type and extent of damage, and for summarizing losses.
- National and regional databases containing information for use as baseline (built-in) data useable in the calculation of losses, if there is an absence of user-supplied data.

These systems, methods, and data have been combined in a user-friendly GIS software for this loss estimation application.

The Hazus software uses GIS technologies for performing analyses with inventory data and displaying losses and consequences on applicable tables and maps. The Methodology permits estimates to be made at several levels of complexity, based on the level of inventory entered for the analysis (i.e., baseline data versus locally enhanced data). The more concise and complete the inventory information, the more accurate the results.

The Methodology to conduct a Hazus analysis incorporates inventory collection and hazard identification into the natural hazards impact assessment. For example, the steps used in the Earthquake Model are as follows:

- *Select the area to be studied.* The Hazus Study Region (the region of interest) is created based on Census tract, county, or state level aggregation of data. The area generally includes a city, county, or group of municipalities. It is generally desirable to select an area that is under the jurisdiction of an existing regional planning group.
- *Specify the earthquake hazard scenario.* In developing the scenario earthquake, consideration should be given to credible earthquake sources and potential fault locations using the USGS and Hazus datasets, or subject matter experts.

- *Provide information on local soil and geological conditions, if available.* Soil characteristics include site classification according to the National Earthquake Hazards Reduction Program (NEHRP) and susceptibility to landslides and liquefaction.
- *Integrate local inventory data.* Include essential facilities, systems, General Building Stock, or user-defined facilities.
- *Use the formulas embedded in Hazus*. Compute probability distributions for damage to different classes of buildings, facilities, and system components. Then, estimate the loss-of-function.
- *Compute estimates of direct economic loss, casualties and shelter needs using the damage and functionality information.*
- *Estimate fire risks following earthquake impacts*, such as the number of ignitions and extent of fire spread.
- *Estimate the amount and type of debris.*

The user plays a major role in selecting the scope and nature of the output of a loss estimation analysis. A variety of maps can be generated for visualizing the extent of the losses. Generated reports provide numerical results that may be examined at the level of the Census tract or aggregated by county or region.

2.1 Inventory Data Overview

An important requirement for estimating losses is the identification and valuation of the building stock, infrastructure, and population exposed to a hazard i.e., an inventory. Consequently, Hazus includes a comprehensive inventory in estimating losses. This inventory serves as the baseline when the users of the model do not have better data available. The inventory data represent the General Building Stock (GBS) for the continental United States, Hawaii and the U.S. Territories. This Census-derived information also includes demographic information. Additionally, the model contains national data for essential facilities and infrastructure. This inventory is used to estimate damage and the direct economic losses for the General Building Stock or the associated impact to functionality for essential facilities.

There are differences in the terminology used to distinguish between types or categories of structures. The term “structure” refers to all constructions, such as a building, bridge, water tank, shed, carport, or other man-made thing that is at least semi-permanent. A building is a structure with a roof and walls that is intended for use by people and/or inventory and contents, such as a house, school, office, or commercial storefront. A facility corresponds to a particular place, generally a building, with an intended purpose, such as a school, hospital, electric power station, or water treatment facility. Some facilities are defined as ‘essential facilities’ meaning the facility is critical to maintaining services and functions vital to a community, especially during disaster events. The buildings, essential facilities, and transportation and utility systems considered by the Hazus Methodology are as follows:

- *General Building Stock:* The key GBS databases in Hazus include building area (calculated as square footage) by occupancy and building type, building count by occupancy and building type, building and content valuation by occupancy and building type, and general occupancy mapping. Most of the commercial, industrial, and residential buildings in a region are not considered individually when calculating losses. Buildings within Census subdivisions (either Census tract or block, depending on the hazard) are aggregated and categorized. Building information derived from Census data and Dun & Bradstreet data are used to form groups of 36 specific building types and 33 occupancy classes. Degree of damage is computed for each grouped combination of specific building type and occupancy class.

- *Essential and high potential loss facilities*: Essential facilities are those facilities vital to emergency response and recovery following a disaster. They can include medical care facilities, police and fire stations, emergency operations centers (EOC), and schools. For this class of structures, damage and loss-of-function are evaluated on a building-by-building basis. There may be significant uncertainties in each estimate. Essential facilities may also include high potential loss facilities. These facilities include dams and levees, nuclear power plants, and military installations, however these kinds of high potential loss facility data are not included in the baseline Hazus inventories.
- *Transportation systems*: Transportation systems, including highways, railways, light rail, bus systems, ports, ferry systems, and airports, are classified into components such as bridges, stretches of roadway or track, terminals, and port warehouses. Probabilities of damage and losses are computed for each component of the system, but total system performance is not evaluated, and cascading impacts from one system to another are not analyzed.
- *Utility systems*: Utility systems, including potable water, electric power, wastewater, communications, and liquid fuels (oil and gas), are treated in a manner like transportation systems. Probabilities of damage and losses are computed for each component of the system, but total system performance is not evaluated, and cascading impacts from one system to another are not analyzed.

This Inventory Technical Manual will focus on GBS, essential facilities, and transportation and utility systems. Some hazard-specific inventory items will be briefly discussed in Section 11 with references to the appropriate Technical Manual that contain full descriptions and information for these items.

2.2 Level of Analysis

Hazus is designed to support two general types of analysis (Basic and Advanced), split into three levels of data updates (Levels 1, 2, and 3). Figure 2-1 provides a graphic representation of the various levels of analysis.

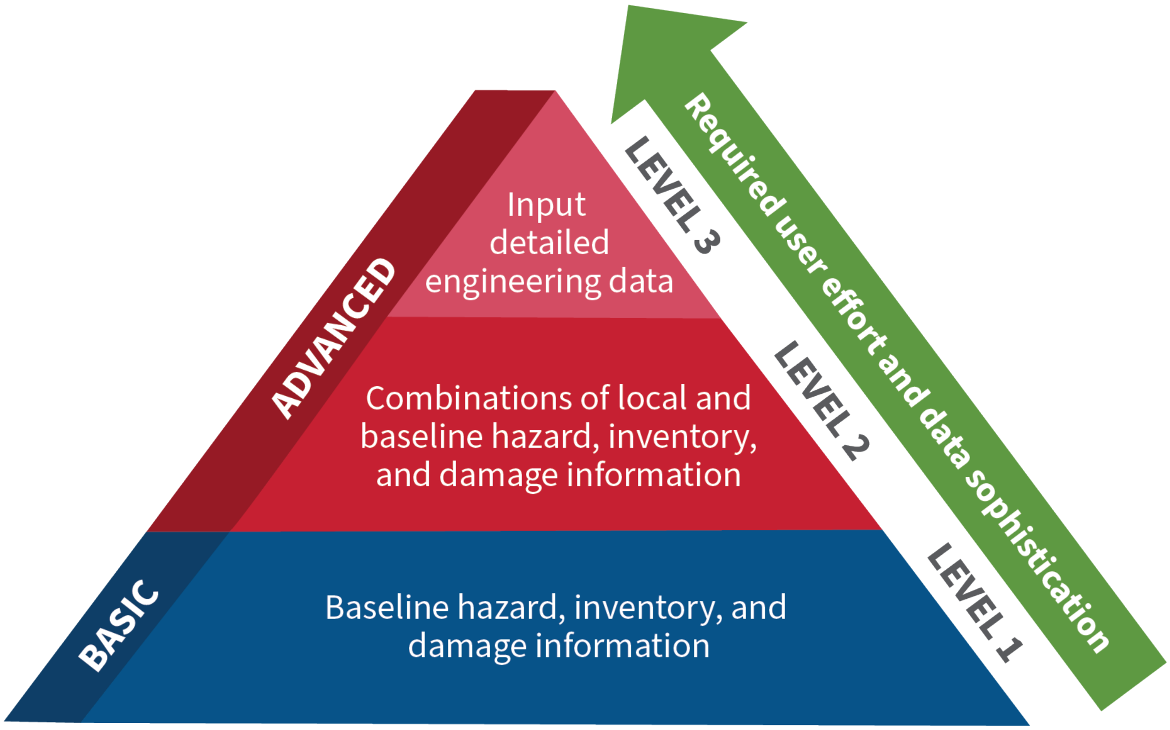

Figure 2-1 Level of Hazus Analysis

2.2.1 Analysis Based on Baseline Information

The basic level of analysis uses only the baseline databases built into the Hazus software and Methodology for building area and value, population characteristics, costs of building repair, and certain basic economic data. This level of analysis is commonly referred to as a Level 1 analysis. In a basic analysis (Level 1), hazard data is uniformly applied or generated from minimal input data and applied to the baseline inventory data with little to no user modification. Direct economic and social losses associated with the GBS and essential facilities are computed. Baseline data for transportation and utility systems are included; thus, these systems are considered in the basic level of analysis. However, there is a significant level of uncertainty pertaining to the estimates and this basic analysis is only available in certain hazard models.

Other than defining the Study Region, selecting hazard information, and making decisions concerning the extent and format of the output, an analysis based on baseline data requires minimal effort from the user. As indicated, the estimates involve large uncertainties when inventories are limited to the baseline data. This level of analysis is suitable primarily for preliminary evaluations and crude comparisons among different Study Regions with a Census tract as the smallest regional unit. A basic Level 1 analysis could be used for comparisons and preliminary evaluations to assist in identifying potential mitigation actions within a community, which could be useful if evaluating funding priority for projects.

2.2.2 Analysis with User-Supplied Inventory

Results from an analysis using only baseline inventory can be improved upon greatly with at least a minimum amount of locally-developed input. Improved results are highly dependent on the quality and quantity of improved inventory data. The significance of the improved results also relies on the user's analysis priorities. This level of advanced analysis is commonly referred to as a Level 2 or Level 3 analysis. The following inventory improvements impact the accuracy of Level 2 and Level 3 advanced analysis results:

- Use of locally available data or estimates of the square footage of buildings in different occupancy classes.
- Use of local expertise to modify (primarily by professional judgment) the databases that determine the percentages of specific building types associated with different occupancy classes.
- Preparation of a detailed inventory of all essential facilities.
- Collection of detailed inventory and cost data to improve evaluation of losses and lack of function in various transportation and utility systems.
- Use of locally available data concerning construction costs or other economic parameters.
- Compilation of information concerning high potential loss facilities.

Section 3. General Building Stock: Spatial Data

The first aspect of the GBS to be described in this manual pertains to spatial data. Each of the four hazard models in Hazus uses a different baseline spatial approach to apply GBS data. Earthquake and hurricane modeling are typically performed at the Census tract geometry. Flood modeling goes down to Census block to better reflect the geographic scale sensitivity of flood hazard. Tsunami modeling makes use of the National Structure Inventory point data representation. Table 3-1 below summarizes the current status of the major GBS spatial data elements by spatial data type, hazard, sources, and an overview of how frequently data is planned to be updated. The table summarizes information based on the three different types of GBS spatial data, all of which will be described in greater detail later in this Section:

- *Census Boundary Data:* These data relate to Hazus's use of slightly modified (clipped for water features) default U.S. Census boundaries at the tract and block subdivision levels.
- *Dasymetric Data:* These data, also primarily based on the U.S. Census boundaries, have been much more drastically modified based on land cover patterns to include those areas where structures are most likely to be found.
- *National Structure Inventory (NSI) Data:* NSI data, developed for FEMA by the U.S. Army Corps of Engineers (USACE), takes a different approach to approximating structure locations by evenly distributing possible structure coordinates (points) across Census geometries. Table 1-1, shown earlier in this document, describes Hazus versions and includes information on when each of these spatial data types was first introduced in Hazus.

This Section provides a summary of the geographic coverage of available GBS data in the U.S., and will elaborate on the above three GBS spatial data types.

Table 3-1 General Building Stock Inventory for Spatial Data

Spatial Data Type	Data Element	Hazards	Current Source	Date of Current Hazus Data	How Often is Source Data Updated?	Processing Required
Census Boundary Data	Census Tract Geometries	• Earthquake • Hurricane (baseline)	U.S. Census Bureau	2010	10 years	Clipped based on water bodies
Census Boundary Data	Census Block Geometries	• Flood • Hurricane (when combined with Flood)	U.S. Census Bureau	2010	10 years	Clipped based on water bodies
Dasymetric Data	Dasymetric Block Geometries	• Flood • Hurricane • Tsunami	U.S. Census Bureau	2010	10 years	Clipped Census boundaries based on USACE processing of National Land Cover Data (2001 and 2011)

Spatial Data Type	Data Element	Hazards	Current Source	Date of Current Hazus Data	How Often is Source Data Updated?	Processing Required
Dasymetric Data	Dasymetric Block Geometries	• Flood • Hurricane • Tsunami	U.S. Army Corps of Engineers	2011	None planned	Clipped Census boundaries based on USACE processing of National Land Cover Data (2001 and 2011)
NSI Data	NSI Geometries	• Tsunami	U.S. Census Bureau	2010	10 years	Processed and developed by the USACE for USACE Hydrologic Engineering Center, Flood Impact Assessment (HEC-FIA)
NSI Data	NSI Geometries	• Tsunami	U.S. Army Corps of Engineers	2010	Updating began in 2017	Processed and developed by the USACE for HEC-FIA
NSI Data	NSI Geometries	• Tsunami	HIFLD Open Schools & Educational Facilities	2018	Annually	Processed and developed by the USACE for HEC-FIA
NSI Data	NSI Geometries	• Tsunami	Longitudinal Household Employer Dynamic (LEHD) database	2010	Annually	Processed and developed by the USACE for HEC-FIA

3.1 Census Boundary Data

Census blocks, the smallest geographic area for which the Bureau of the Census collects and tabulates decennial Census data, were formed by streets, roads, railroads, streams and other bodies of water, other visible physical and cultural features, and the legal boundaries shown on Census Bureau maps. Conceptually, a Census block can be thought of as a unit with roughly the population of a city block. However, there is no official minimum population for a Census block (almost half have zero population), and the original 1990 minimum size (30,000 square feet) can be overwritten, when it makes sense, by bounding features. There is also no maximum size for a Census block, so in low population rural areas Census blocks can be several to hundreds of square miles. To implement Census blocks (and other Census boundaries such as tracts) within a database environment, the Census Bureau made use of Geographic Identifiers (GEOIDs) to establish a unique naming convention to apply to different geographic areas. In Hazus, the most common GEOIDs used are Census blocks (15-digit code), Census tracts (11-digit code), and counties (5-digit code). More information on Census boundaries and the use of GEOIDs can be found at Census Bureau (1994) and Census Bureau (2018).

As shown in Table 3-1, the baseline GBS spatial data for the Earthquake and Hurricane Models use Census tracts. Census blocks were the original baseline GBS spatial data for flood, and for when a combined storm surge analysis is conducted using both hurricane and flood. Tract and block data are clipped using the water features from the Census Bureau. As will be described in the next section, the baseline Census block boundary data has been further clipped based on land use, known as dasymetric data, for use in flood and storm surge analyses

There are some data maintenance considerations Hazus users should keep in mind related to Census boundary data:

- *Boundary changes.* Many boundaries, especially at the Census block-level, change over time. For areas with high growth, each decadal Census might alter existing tracts and blocks, both adding new features and changing spatial boundaries. There is not a simple 1-to-1 relationship between any two sets of Census data. Even county-level information may change over time with new counties being created or old counties being merged and renamed. Also, modern surveying methods can alter county and sometimes state boundary data over time.
- *Census updates.* While new Census boundary data are often available prior to each Census, the associated detailed tabular data for population counts that is used by Hazus typically is not released until 3 or 4 years after each Census. Therefore, the next update of Hazus Census-related data may have to wait until 2023 or 2024.

Some elements in the GBS baseline database are established from Census bureau sources that are less detailed than individual states. Table 3-2 provided the lists of states within Census defined regions and divisions.

Table 3-2 Census Regions and Divisions

Census Region	Census Division	States
Northeast	New England	CT, MA, ME, NH, RI, VT
	Middle Atlantic	NJ, NY, PA
Midwest	East North Central	IL, IN, MI, OH, WI
	West North Central	IA, KS, MN, MO, ND, NE, SD
South	South Atlantic	DC, DE, FL, GA, MD, NC, SC, VA, WV
	East South Central	AL, KY, MS, TN
	West South Central	AR, LA, OK, TX
West	Mountain	AZ, CO, ID, MT, NM, NV, UT, WY
	Pacific	AK, CA, HI, OR, WA

3.2 Dasymetric Data

Prior to Hazus 2.2 Service Pack 1 in May 2015, riverine and coastal flood and storm surge analysis in Hazus used the major water body clipped Census block data from the 2010 Census. One underlying assumption for GBS analysis in Hazus is that the building exposure is uniformly (homogeneously) distributed throughout a Census block. These Census blocks generally cover the entire land area, except in some areas where large water features have been removed. Because of this extensive coverage of the blocks, there are areas within them that are not developed and have few or no structures. Over the years, analyses have shown that using Homogenous Hazus Census block data may lead to an overestimation of losses, though overestimation is not solely caused by homogeneous data.

With the release of Hazus 2.2 Service Pack 1 in May 2015, Hazus users were able to access and download new dasymetric state datasets. Dasymetric mapping removes undeveloped areas (such as areas covered by bodies of water, wetlands, or forests) from the Census blocks, changing their shape and reducing their size in these areas. Dasymetric mapping was first developed as a cartographic technique by Benjamin Semenov-Tianshansky in 1911. Today, the Environmental Systems Research Institute (ESRI), developer of GIS software upon which Hazus is built, defines dasymetric mapping as "a technique in which attribute data that is organized by a large or arbitrary area unit is more accurately distributed within that unit by the overlay of geographic boundaries that exclude, restrict, or confine the attribute in question. For example, a population attribute organized by Census tract might be more accurately distributed by the overlay of water bodies, vacant land, and other land-use boundaries within which it is reasonable to infer that people do not live." (ESRI 2015; cf. USGS 2015).

Due to confidentiality, privacy, and other concerns, population data collected by the U.S. Census Bureau is aggregated to different levels of geographic boundaries (e.g., from a local address to a block, tract, county, or state). As such, data aggregated to those geographic units does not always reflect the actual location or distribution of human populations or the built environment.

According to the Multi-Resolution Land Characteristics Consortium (MRLC), the National Land Cover Database (NLCD) serves as the definitive Landsat-based, 30-meter resolution, land cover database for the Nation. The NLCD provides spatial reference and descriptive data for characteristics of the land surface such as thematic class (e.g., urban, agriculture, and forest), percent impervious surface, and percent tree canopy cover (Homer et al., 2012). Thus, Hazus loss estimates can be significantly improved by employing dasymetric mapping techniques to constrain Census population data to actual locations based on the NLCD.

With the release of Hazus 3.0 in November 2015, the Hazus program made the dasymetric datasets the default for analysis for flood, while using homogeneous datasets for aggregation. This decision was based around the assumption that the bulk of modern disaster mitigation and analysis is likely to be in urban areas or areas that are built out, where dasymetric data can be a more accurate representative dataset. However, this decision was also done with the understanding that dasymetric data may not be the ideal choice everywhere, especially in locations that have increasing development in previously un-developed areas.

With the assistance of the USACE Hydrologic Engineering Center – Flood Impact Assessment Team (HEC-FIA Team), the Hazus Census blocks were clipped to remove areas identified as water, wetlands and forest. The data for clipping is provided by the NLCD, prepared by the USGS (USGS, 2012). This dasymetric approach provides users with an improvement of the accuracy of Census block-based loss estimations, but does not serve as a complete replacement of the need for site-specific data enhancements from local datasets.

USACE performed the clipping of the Census blocks based on the MRLC's NLCD in 2011, which was posted for download in 2014 for the contiguous U.S. and Alaska. At the time of incorporation, the NLCD 2011 was the most recently rectified complete Land Use Land Cover (LULC) classification. NLCD 2011 is a LULC classification scheme that has been applied consistently across the conterminous United States at a spatial resolution of 30 meters. NLCD 2011 is based primarily on the unsupervised classification of Landsat Enhanced Thematic Mapper+ (ETM+) flown circa 2011. As shown in Table 3-3 below, the Developed classes 21, 22, 23, and 24, as well as the

Cultivated classes 81 and 82 were maintained in each block, while the undeveloped, riparian, wetlands, and other classes were removed from the Census block polygons.

Table 3-3 NLCD 2011 Classifications for Dasymetric Mapping Usage

Class	Value	Dasymetric Mapping	Classification Description
Water	11	No	*Open Water* – areas of open water, generally with less than 25% cover of vegetation or soil.
Water	12	No	*Perennial Ice/Snow* – areas characterized by a perennial cover of ice and/or snow, generally greater than 25% of total cover.
Developed	21	Yes	*Developed, Open Space* – areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.
Developed	22	Yes	*Developed, Low Intensity* – areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% of total cover. These areas most commonly include single-family housing units.
Developed	23	Yes	*Developed, Medium Intensity* – areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.
Developed	24	Yes	*Developed High Intensity* – highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.
Barren	31	No	*Barren Land (Rock/Sand/Clay)* – areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.
Forest	41	No	*Deciduous Forest* – areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.
Forest	42	No	*Evergreen Forest* – areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage.
Forest	43	No	*Mixed Forest* – areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover.
Shrubland	51	No	*Dwarf Scrub* – Alaska only areas dominated by shrubs less than 20 centimeters tall with shrub canopy typically greater than 20% of total vegetation. This type is often co-associated with grasses, sedges, herbs, and non-vascular vegetation.
Shrubland	52	No	*Shrub/Scrub* – areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation.

Class	Value	Dasymetric Mapping	Classification Description
			This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.
Herbaceous	71	No	*Grassland/Herbaceous* – areas dominated by graminoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management, such as tilling, but can be utilized for grazing.
Herbaceous	72	No	*Sedge/Herbaceous* – Alaska only areas dominated by sedges and forbs, generally greater than 80% of total vegetation. This type can occur with significant other grasses or other grass like plants, and includes sedge tundra, and sedge tussock tundra.
Herbaceous	73	No	*Lichens* – Alaska only areas dominated by fruticose or foliose lichens generally greater than 80% of total vegetation.
Herbaceous	74	No	*Moss* – Alaska only areas dominated by mosses, generally greater than 80% of total vegetation.
Planted/Cultivated	81	*Yes*	*Pasture/Hay – areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.*
Planted/Cultivated	82	Yes	*Cultivated Crops* – areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.
Wetlands	90	No	*Woody Wetlands* – areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.
Wetlands	95	No	*Emergent Herbaceous Wetlands* – Areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.

Figure 3-1 and Figure 3-2 show an example of how the NLCD data categories related to developed areas is used to classify the areas that would be included in a dasymetric boundary.

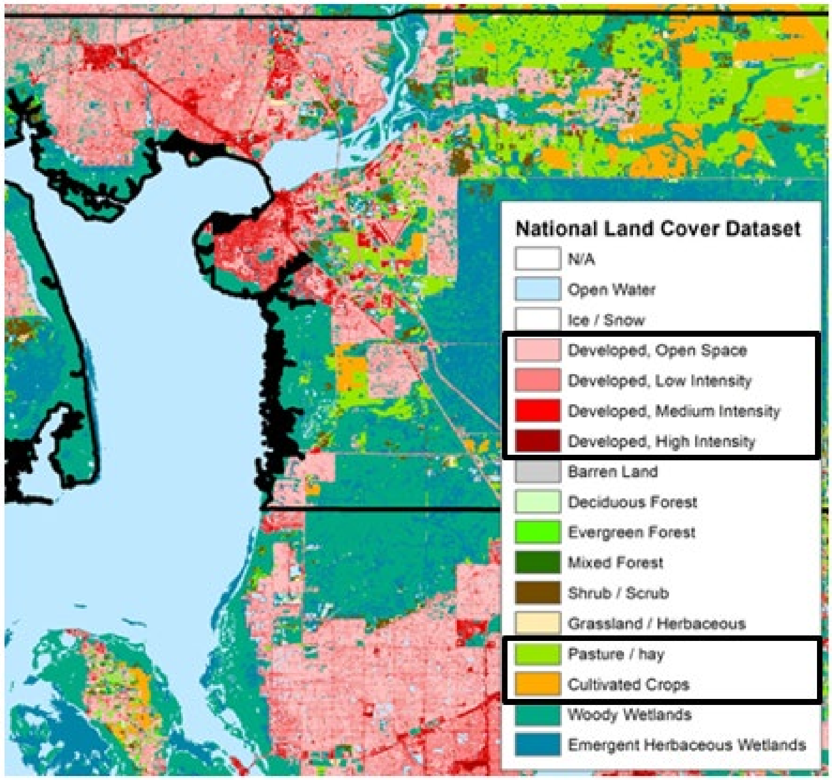

Figure 3-1 NLCD Data Categories

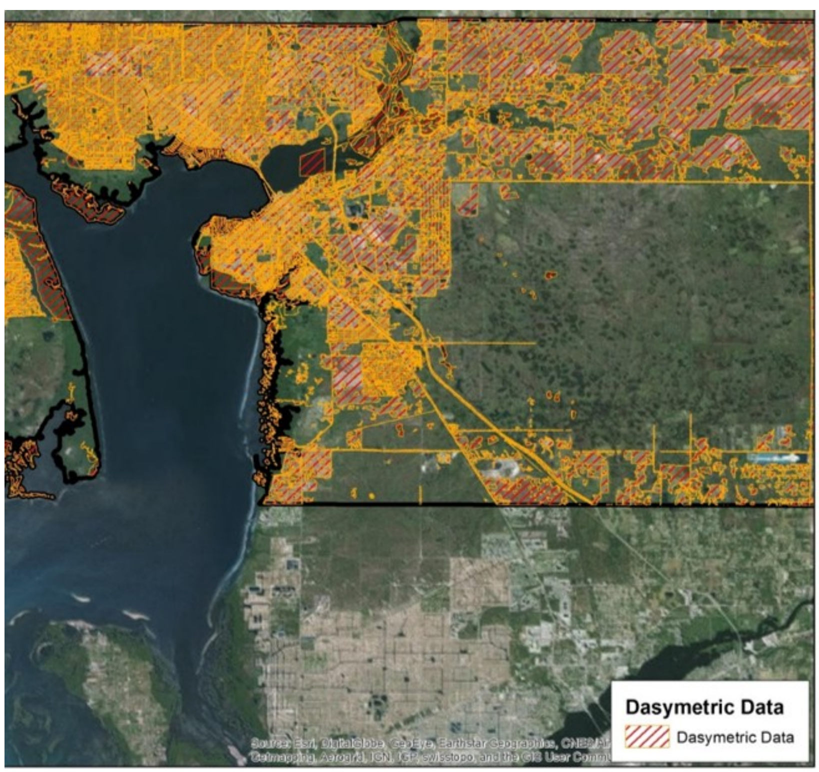

Figure 3-2 Use of NLCD Data for Dasymetric Boundary

Some known issues with the dasymetric data include the following:

- Entire Census blocks may occasionally be determined to be non-urbanized by the NLCD, while Census data for the block indicates structures. A typical example would be a house located under dense tree cover. Since the NLCD is derived from aerial imagery, it may not report a structure being there, while the Census survey would. In this situation, Hazus dasymetric data retains the entire block, unclipped. For the majority of states, these situations represent less than 1% of the buildings in each state.
- The HEC-FIA Team's processing of data incorporates error checking for bad Census blocks that cannot be processed. In addition, if a Census block contains no LULC developed code grid cells, the block is not clipped. This is not an issue, provided there is no Hazus inventory in that block. However, there are plenty of cases where the USGS LULC data indicate that an entire block is undeveloped, but Hazus indicates there is inventory in that block. Therefore, the HEC-FIA Team's processing algorithm provides statistics on the number of blocks and the number of structures that are contained in those blocks. Those statistics for each state are used to estimate the potential impacts where USGS and Hazus datasets do not agree. For the vast majority of states processed, the inventory in these blocks is less than 1% of the total inventory and is considered to have insignificant impacts. There are several (mostly Western) states where this ratio is somewhat higher.

3.3 National Structure Inventory Data

The GBS for the Tsunami Model utilizes the National Structure Inventory (NSI) developed by USACE HEC-FIA in coordination with FEMA. The NSI utilizes the Hazus GBS that was initially compiled at the Census block-level using U.S. Census Bureau data for the development of residential structures data, while Dun & Bradstreet provides the data for nonresidential structures. In addition, the NSI approach leverages the Flood Model dasymetric blocks distributing a point-based dataset within developed portions of Census blocks. This helps prevent the location of buildings in undeveloped areas such as open space, wetlands, and beaches. This improves the accuracy when intersecting the inventory data with the tsunami hazard data. Figure 3-3 provides an illustration around the Diamond Head-Waikiki area of Hawaii, where buildings are concentrated in a high density developed area and buildings are removed in areas of open space. Since the NSI point data are notional, rather than site-specific structure locations, the Tsunami Model aggregates the inventory and results reporting of these structures at the Census block for creating tables and thematic mapping. Furthermore, several post-processing steps to the NSI data allowed the incorporation of additional value-added attributes, enhancing the accuracy of the NSI data for tsunami loss estimation. These included the addition of earthquake building type and seismic design level attributes required for the estimation of tsunami losses.

Figure 3-3 Example of NSI building data

The National Structure Inventory Design and Development Plan, available from the Hazus Help Desk (see Section 1.5), describes the overall design and development of the NSI for USACE systems. In addition, the Hazus Release 3.0 FAQ for Homogeneous and Dasymetric Datasets provided an overview of the process and data. The NSI data may be downloaded at FEMA (2020). The Hazus state databases now contain the point data feature class tsGbsNsi that was created.

The NSI development assumed exposure only exists within areas where satellite and land-use data confirm as a built environment, as shown in the Hazus dasymetric data described earlier. The Developed and Cultivated classes were maintained in each Census block, while the undeveloped, riparian, wetlands, and other classes were removed from the distribution of NSI data. Each structure in the NSI has a unique ID (fieldname NsiID). The ID is a concatenation of Specific Occupancy Type, County FIPS, and 7-digit ID created in sequence (e.g., AGR1 72005 00014207). Further details on how NSI data was developed will be detailed in other sections of this Technical Manual, such as during the discussion on structure replacement values for NSI data in territories in Section 6.

3.4 Geographic Coverage

The development of Hazus GBS data has changed over time as more hazards were modeled, and geographic coverage expanded from the states to the territories. The section will initially summarize geographic coverage by hazard, and then will provide a more in-depth discussion on the development of data in the territories.

3.4.1 Hazards

For the Earthquake Model, Hazus supports Study Regions and analysis in all fifty states, DC, PR, and VI. Inventory data updates in 2019 expanded earthquake analysis to VI from previous versions.

For the Flood Model, Hazus currently supports Study Regions and analysis in all fifty states, DC, PR, and VI. Building counts, values, and areas were aggregated for every Census block and tract in PR and VI in 2019, to supplement default U.S. Census data to allow flood analysis. The types of flood analysis that can be performed in PR and VI are limited. New Hazus program data to enable coastal flood modeling for PR and VI is available by contacting the Hazus Help Desk (see Section 1.5). Hazus Level 1 Riverine Flood analysis cannot be completed for multiple return periods for VI and PR due to a lack of the regression equations necessary to represent hydrology.

For the Hurricane Model, Hazus currently supports Study Regions and analysis in HI and the Atlantic and Gulf of Mexico states that fall within the American Society of Civil Engineers (ASCE) High Wind Zone (ME, NH, VT, MA, RI, CT, NY, NJ. PA, DE, WV, DC, MD, VA, NC, SC, GA, FL, AL, MS, LA, TX). For Hazus 2.1, there was a FEMA project to include PR, but that effort was not fully implemented as a standard feature in Hazus releases after Hazus 2.1. Hurricane-related building data is planned to be developed for PR and VI in future Hazus versions.

For the Tsunami Model, Hazus currently supports Study Regions and analysis in five very high-risk states on the Pacific coast (HI, AK, WA, OR, CA) and five high risk territories (PR, VI, GU, AS, and MP).

3.4.2 Territories

PR and VI have the most developed Hazus datasets. In 2019, enhancements were made to PR data (including Essential Facilities inventory), starting from the previous work performed for the PR Hazus 2.1 data, the existing Hazus State Database for PR, and the NSI data, which were developed by USACE. The VI also had a 2019 data update for GBS and facilities data. Both PR and VI use 2018 RSMeans replacement values. FEMA (2019b) provides a table of the data sources used for the 2019 data update for PR and VI.

As part of the development work for the Tsunami Model in 2017, new state databases were developed for GU, AS, and MP, along with the original development of data for VI.

These datasets included the following layers:

- *State:* Administrative boundary for Territory, based on Database of Global Administrative Areas (GADM) Boundaries.
- *County:* Administrative boundaries for Counties (Districts), based on GADM.
- *Census tract:* Tract boundaries and demographic data based on 2010 U.S. Census
- *Census block:* Based on 1 km grids provided by Landscan 2014 and demographic data based on 2010 U.S. Census.
- *Essential Facilities:* Includes schools, hospitals, police stations, fire stations, and Emergency Operations Centers or EOCs and was developed by the Pacific Disaster Center (PDC) from public sources. Since multiple data sources were used for each Territory, searching by Territory name in the Global Hazards Information Network (GHIN) provides the metadata pages for each data layer.

The NSI methodology described earlier provided the capability to provide a baseline General Building Stock inventory for the 44 (of 78 total) counties in PR that are located along the coast. However, the remaining U.S. Territories generally lacked the detailed U.S. Census and other data available for U.S. States (FEMA, 2020).

In addition, no equivalent Census block-level demographic data are available for the territories. Data from the PDC was utilized to develop an NSI for the remaining territories.

The first step was to develop a building point data layer based on available points of interest from PDC (2010), essential facility data developed by PDC (2014-2016), parcel (GU only, PDC 2000), land use, and building footprint data (AS only, PDC 2001), as well as imagery from ESRI World Imagery in 2016. Within lower-lying coastal regions, special care was taken to ensure that data in those high-risk areas were comprehensive and well located.

The NSI data development extended beyond spatial features to other Hazus GBS databases, which will be described in more detail in Section 4, Section 5, and Section 6.

Section 4. General Building Stock: Occupancy and Building Types

GBS tabular data includes the characteristics of residential, commercial, industrial, agricultural, religious, governmental, and educational buildings. The entire composition of the general building stock within a given Census subdivision, such as Census block for the Flood Model, is assumed to be evenly distributed throughout the block. The building area (square foot by occupancy) is included in the table from which all the other tables are based.

All four hazard models use common data to ensure that users do not have inventory discrepancies when switching between hazards. For example, the Flood Model displays GBS data at the Census block, while the Earthquake Model displays GBS data at the Census tract level. To support hurricane surge modeling in Hazus, the Hurricane Model will display and perform analysis at the Census block-level if the user has included the Flood Model in the Study Region.

The key GBS databases include the following (denoting the *Hazus Inventory Technical Manual* Section where described):

- *General Occupancy Mapping and Building Types (Section 4):* These data provide a general mapping for the GBS inventory data from the general and specific occupancy to general building type (e.g., Wood) and specific building types. Generally, all four models agree. However, a user can modify the general occupancy mapping at the Census block-level in the Flood Model, thereby requiring them to select an "average" value at the tract level in other models, which will result in variances. This should not be an issue for users making this type of change.
- *Building Area by Occupancy (Section 5):* These data are the estimated floor area in square feet by specific occupancy (e.g., COM1). These data are also aggregated for general occupancies (e.g., Residential).
- *Building Count by Occupancy (Section 5):* These data provide the user with an estimated building count by specific occupancy . These data are also aggregated for general occupancies.
- *Other Building Characteristics (Section 5 and Section 11):* These data include the additional GBS supplemental databases used by one or multiple hazards for loss calculations, such as the number of stories, and hazard-specific characteristics like foundation types and first floor elevations.
- *Demographics (Section 5)*: These data provide housing and population statistics for the Study Region.
- *Building Replacement Value by Occupancy (Section 6):* These data provide the user with estimated replacement values by specific occupancy. These data are also aggregated for general occupancies.

4.1 Occupancy

In the original development of Hazus earthquake methods for HAZUS99, 28 specific occupancy classifications were used in the baseline inventory. The primary purpose of building classifications is to group buildings with similar valuation, damage, and loss characteristics into a set of pre-defined groups for analysis. For example, the damage and loss modules represent a typical response of the occupancy classification to inundation caused by flooding. During the development of Hazus and the Flood Model, the number of specific occupancy classifications increased from 28 to 33 to allow for an enhanced classification of the multi-family dwellings (RES3A – RES3F). This was accepted by the Hazus Program and the Hurricane, Flood, and Tsunami Models were developed to use the same specific occupancy classifications. The Tsunami Model retained these same specific occupancy classes.

Table 4-1 shows the 33 specific occupancy classifications and the Standard Industrial Classification used in the development of the non-residential facilities.

Table 4-1 Hazus General and Specific Occupancy Classes

Hazus General Occupancy Class	Hazus Specific Occupancy Class	Class Description	Standard Industrial Classification (SIC)
Residential	RES1	Single-family Dwelling	
Residential	RES2	Mobile Home	
Residential	RES3A	Multi-Family Dwelling - Duplex	
Residential	RES3B	Multi-Family Dwelling – 3-4 Units	
Residential	RES3C	Multi-Family Dwelling – 5-9 Units	
Residential	RES3D	Multi-Family Dwelling – 10-19 Units	
Residential	RES3E	Multi-Family Dwelling – 20-49 Units	
Residential	RES3F	Multi-Family Dwelling – 50+ Units	
Residential	RES4	Temporary Lodging	70
Residential	RES5	Institutional Dormitory	
Residential	RES6	Nursing Home	8051, 8052, 8059
Commercial	COM1	Retail Trade	52, 53, 54, 55, 56, 57, 59
Commercial	COM2	Wholesale Trade	42, 50, 51
Commercial	COM3	Personal and Repair Services	72, 75, 76, 83, 88
Commercial	COM4	Business/Professional/Technical Services	40, 41, 44, 45, 46, 47, 49, 61, 62, 63, 64, 65, 67, 73, 78 (except 7832), 81, 87, 89
Commercial	COM5	Depository Institutions (Banks)	60
Commercial	COM6	Hospital	8062, 8063, 8069
Commercial	COM7	Medical Office/Clinic	80 (except 8051, 8052, 8059, 8062, 8063, 8069)
Commercial	COM8	Entertainment & Recreation	48, 58, 79 (except 7911), 84
Commercial	COM9	Theaters	7832, 7911
Commercial	COM10	Parking	
Industrial	IND1	Heavy	22, 24, 26, 32, 34, 35 (except 3571, 3572), 37
Industrial	IND2	Light	23, 25, 27, 30, 31, 36 (except 3671, 3672, 3674), 38, 39
Industrial	IND3	Food/Drugs/Chemicals	20, 21, 28, 29
Industrial	IND4	Metals/Minerals Processing	10, 12, 13, 14, 33
Industrial	IND5	High Technology	3571, 3572, 3671, 3672, 3674

Hazus General Occupancy Class	Hazus Specific Occupancy Class	Class Description	Standard Industrial Classification (SIC)
Industrial	IND6	Construction	15, 16, 17
Agriculture	AGR1	Agriculture	01, 02, 07, 08, 09
Religion	REL1	Church/Non-Profit	86
Government	GOV1	General Services	43, 91, 92 (except 9221, 9224), 93, 94, 95, 96, 97
Government	GOV2	Emergency Response	9221, 9224
Education	EDU1	Schools/Libraries	82 (except 8221, 8222)
Education	EDU2	Colleges/Universities	8221, 8222

For the development of the NSI data where the typical Census and Dun & Bradstreet data were not available, the Hazus Specific Occupancy types were based on available points of interest data (e.g., restaurants, hotels, etc.), essential facilities (e.g., schools, hospitals, fire, and police stations), parcel data (e.g., multi-family, religious), land use (e.g., residential, commercial, and recreation zoning), as well as imagery. However, it was necessary to assign default-specific occupancies to many of the structure data points that could not be identified. The default specific occupancies for the NSI data were RES1 for Residential, COM1 for Commercial, and IND1 for Industrial. The default specific occupancy types were used for up to 50% of the total occupancy type assignments. These types produce reasonable valuations. However, reporting results by General Occupancy type, rather than Specific Occupancy type, should be considered more reliable when using NSI data.

4.2 Building Types

Each of the four Hazus Models use different schemes related to building types. While each hazard has the same five general building types of Wood Frame, Steel Frame, Concrete, Masonry, and Manufactured Housing, the specific building types (SBTs) differ by hazard.

4.2.1 Earthquake and Tsunami Specific Building Types

Table 4-2 lists the 36 model SBTs used by the Earthquake and Tsunami Models. These specific building types are based on the classification system of FEMA 178, *NEHRP Handbook for the Seismic Evaluation of Existing Buildings* (FEMA, 1992) and may now be found in more recent ASCE publications, including *FEMA 310, Handbook for the Seismic Evaluation of Buildings--A Prestandard* (FEMA, 1998). In addition, the methodology breaks down FEMA 178 classes into height ranges and includes mobile homes.

Table 4-2 Earthquake and Tsunami Model Specific Building Types

Specific Building Type Label	Description	Height			
		Range		Typical	
		Name	Stories	Stories	Feet
W1	Wood, Light Frame (≤ 5,000 sq.ft)		1 - 2	1	14
W2	Wood, Commercial & Industrial (> 5,000 sq.ft)		All	2	24
S1L S1M S1H	Steel Moment Frame	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 13	24 60 156
S2L S2M S2H	Steel Braced Frame	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 13	24 60 156
S3	Steel Light Frame		All	1	15
S4L S4M S4H	Steel Frame with Cast-in-Place Concrete Shear Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 - 7 8+	2 5 13	24 60 156
S5L S5M S5H	Steel Frame with Unreinforced Masonry Infill Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 – 7 8+	2 5 13	24 60 156
C1L C1M C1H	Concrete Moment Frame	Low-Rise Mid-Rise High-Rise	1 – 3 4 – 7 8+	2 5 12	20 50 120
C2L C2M C2H	Concrete Shear Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 – 7 8+	2 5 12	20 50 120
C3L C3M C3H	Concrete Frame with Unreinforced Masonry Infill Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 – 7 8+	2 5 12	20 50 120
PC1	Precast Concrete Tilt-Up Walls		All	1	15
PC2L PC2M PC2H	Precast Concrete Frames with Concrete Shear Walls	Low-Rise Mid-Rise High-Rise	1 - 3 4 – 7 8+	2 5 12	20 50 120
RM1L RM1M	Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms	Low-Rise Mid-Rise	1-3 4+	2 5	20 50
RM2L RM2M RM2H	Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms	Low-Rise Mid-Rise High-Rise	1 - 3 4 – 7 8+	2 5 12	20 50 120

Specific Building Type Label	Description	Height			
		Range		Typical	
		Name	Stories	Stories	Feet
URML URMM	Unreinforced Masonry Bearing Walls	Low-Rise Mid-Rise	1 - 2 3+	1 3	15 35
MH	Mobile Homes		All	1	10

A general description of each of the 16 structural systems of specific building types is given below.

4.2.1.1 Wood, Light Frame (W1)

These are typically single-family or small, multi-family dwellings of not more than 5,000 square feet of floor area. The essential structural feature of these buildings is repetitive framing by wood rafters or joists on wood stud walls. Loads are light and spans are small. These buildings may have relatively heavy masonry chimneys and may be partially or fully covered with masonry veneer. Most of these buildings, especially the single-family residences, are not engineered but constructed in accordance with “conventional construction” provisions of building codes. Hence, they usually have the components of a lateral-force-resisting system even though it may be incomplete. Lateral loads are transferred by diaphragms to shear walls. The diaphragms are roof panels and floors that may be sheathed with sawn lumber, plywood, or fiberboard sheathing. Shear walls are sheathed with boards, stucco, plaster, plywood, gypsum board, particle board, or fiberboard, or interior partition walls sheathed with plaster or gypsum board.

4.2.1.2 Wood, Greater than 5,000 ft^2 (W2)

These buildings are typically commercial or industrial buildings, or multi-family residential buildings with a floor area greater than 5,000 square feet. These buildings include structural systems framed by beams or major horizontally spanning members over columns. These horizontal members may be glue-laminated (glu-lam) wood, solid-sawn wood beams, or wood trusses, or steel beams or trusses. Lateral loads usually are resisted by wood diaphragms and exterior walls sheathed with plywood, stucco, plaster, or other paneling. The walls may have diagonal rod bracing. Large openings for stores and garages often require post-and-beam framing. Lateral load resistance on those lines may be achieved with steel rigid frames (moment frames) or diagonal bracing.

4.2.1.3 Steel Moment Frame (S1)

These buildings have a frame of steel columns and beams. In some cases, the beam-column connections have very small moment resisting capacity but, in other cases, some of the beams and columns are fully developed as moment frames to resist lateral forces. Usually, the structure is concealed on the outside by exterior nonstructural walls, which can be of almost any material (curtain walls, brick masonry, or precast concrete panels), and on the inside by ceilings and column furring. Diaphragms transfer lateral loads to moment-resisting frames. The diaphragms can be almost any material. The frames develop their stiffness by full or partial moment connections. The frames can be located almost anywhere in the building. Usually, the columns have their strong directions oriented, so some columns act primarily in one direction while the others act in the other direction. Steel moment frame buildings are typically more flexible than shear wall buildings. This low stiffness can result in large inter-story drifts that may lead to relatively greater nonstructural damage.

4.2.1.4 Steel Braced Frame (S2)

These buildings are like steel moment frame buildings except that the vertical components of the lateral-force-resisting system are braced frames rather than moment frames.

4.2.1.5 Steel Light Frame (S3)

These buildings are pre-engineered and pre-fabricated with transverse rigid frames. The roof and walls consist of lightweight panels, usually corrugated metal. The frames are designed for maximum efficiency, often with tapered beam and column sections built up of light steel plates. The frames are built in segments and assembled in the field with bolted joints. Lateral loads in the transverse direction are resisted by the rigid frames with loads distributed to them by diaphragm elements, typically rod-braced steel roof framing bays. Tension rod bracing typically resists loads in the longitudinal direction.

4.2.1.6 Steel Frame with Cast-In-Place Concrete Shear Walls (S4)

The shear walls in these buildings are cast-in-place concrete and may be bearing walls. The steel frame is designed for vertical loads only. Diaphragms of almost any material transfer lateral loads to the shear walls. The steel frame may provide a secondary lateral-force-resisting system depending on the stiffness of the frame and the moment capacity of the beam-column connections. In modern “dual” systems, the steel moment frames are designed to work together with the concrete shear walls.

4.2.1.7 Steel Frame with Unreinforced Masonry Infill Walls (S5)

This is one of the older types of buildings. The infill walls usually are offset from the exterior frame members, wrap around them, and present a smooth masonry exterior with no indication of the frame. Solidly infilled masonry panels, when they fully engage the surrounding frame members (i.e., lie in the same plane), may provide stiffness and lateral load resistance to the structure.

4.2.1.8 Reinforced Concrete Moment Resisting Frames (C1)

These buildings are like steel moment frame buildings except that the frames are reinforced concrete. There are a large variety of frame systems. Some older concrete frames may be proportioned and detailed such that brittle failure of the frame members can occur in earthquakes, leading to a partial or full collapse of the buildings. Modern frames in zones of high seismicity are proportioned and detailed for ductile behavior and are likely to undergo large deformations during an earthquake without brittle failure of frame members and collapse.

4.2.1.9 Concrete Shear Walls (C2)

The vertical components of the lateral force-resisting system in these buildings are concrete shear walls that are usually bearing walls. In older buildings, the walls often are quite extensive, and the wall stresses are low, but reinforcing is light. In newer buildings, the shear walls often are limited in extent, generating concerns about boundary members and overturning forces.

4.2.1.10 Concrete Frame Buildings with Unreinforced Masonry Infill Walls (C3)

These buildings are like steel frame buildings with unreinforced masonry infill walls except that the frame is of reinforced concrete. In these buildings, the shear strength of the columns, after cracking of the infill, may limit the semi-ductile behavior of the system.

4.2.1.11 Precast Concrete Tilt-Up Walls (PC1)

These buildings have a wood or metal deck roof diaphragm, which often is very large, distributing lateral forces to precast concrete shear walls. The walls are thin but relatively heavy, while the roofs are relatively light. Older or non-seismic-code buildings often have inadequate connections for the anchorage of the walls to the roof for out-of-plane forces, and the panel connections are often brittle. Tilt-up buildings are usually one or two stories in height. Walls can have numerous openings for doors and windows of such size that the wall looks more like a frame than a shear wall.

4.2.1.12 Precast Concrete Frames with Concrete Shear Walls (PC2)

These buildings contain floor and roof diaphragms, typically composed of precast concrete elements with or without cast-in-place concrete topping slabs. Precast concrete girders and columns support the diaphragms. The girders often bear on column corbels. Closure strips between precast floor elements and beam-column joints are usually cast-in-place concrete. Welded steel inserts are often used to interconnect precast elements. Precast or cast-in-place concrete shear walls resist lateral loads. For buildings with precast frames and concrete shear walls to perform well, the details used to connect the structural elements must have enough strength and displacement capacity; however, in some cases, the connection details between the precast elements have negligible ductility.

4.2.1.13 Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms (RM1)

These buildings have perimeter bearing walls of reinforced brick or concrete-block masonry. These walls are the vertical elements in the lateral-force-resisting system. The floors and roofs are framed with wood joists and beams either with plywood or braced sheathing, the latter either straight or diagonally sheathed, or with steel beams with metal deck with or without concrete fill. Interior wood posts or steel columns support wood floor framing; steel columns support steel beams.

4.2.1.14 Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms (RM2)

These buildings have bearing walls like those of reinforced masonry bearing wall structures with wood or metal deck diaphragms, but the roof and floors are composed of precast concrete elements such as planks or tee-beams and the precast roof and floor elements are supported on interior beams and columns of steel or concrete (cast-in-place or precast). The precast horizontal elements often have a cast-in-place topping.

4.2.1.15 Unreinforced Masonry Bearing Walls (URM)

These buildings include structural elements that vary depending on the building’s age and, to a lesser extent, its geographic location. In buildings built before 1900, the majority of floor and roof construction consists of wood sheathing supported by wood framing. In large multistory buildings, the floors are cast-in-place concrete supported by the unreinforced masonry walls and/or steel or concrete interior framing. In unreinforced masonry constructed built after 1950 outside California, wood floors usually have plywood rather than board sheathing. In regions of lower seismicity, buildings of this type constructed more recently can include floor and roof framing consisting of metal deck and concrete fill supported by steel framing elements. The perimeter walls, and possibly some interior walls, are unreinforced masonry. The walls may or may not be anchored to the diaphragms. Ties between the walls and diaphragms are more common for the bearing walls than for walls parallel to the floor framing. Roof ties are usually less common and more erratically spaced than those at the floor levels. Interior partitions that interconnect the floors and roof can reduce diaphragm displacements.

4.2.1.16 Mobile Homes (MH)

These are prefabricated housing units trucked to the site and placed on isolated piers, jack stands, or masonry block foundations (usually without any positive anchorage). Floors and roofs of mobile homes are usually constructed with plywood and outside surfaces are covered with sheet metal.

4.2.2 Flood Specific Building Types

Although most flood depth-damage functions are independent of structural system or construction material, the Hazus inventory database includes Specific Building Type as a basic parameter because of the importance of structure type on the estimation of earthquake, tsunami, and hurricane damage. Within the Flood Model, the Specific Building Types are a simplified version of the ones used by the Earthquake Model and are listed in Table 4-3.

Table 4-3 Flood Model Specific Building Types

Specific Building Type Label	Description	Height			
		Range		Typical	
		Name	Stories	Stories	Feet
Wood (W)	Wood (light frame and commercial and industrial)	N/A	All	1 to 2	14 to 24
Steel (S)	Steel frame structures including those with infill walls or concrete shear walls	Low-Rise	1 - 3	2	24
		Mid-Rise	4 - 7	5	60
		High-Rise	8+	13	156
Concrete (C)	Concrete frame or shear wall structures including tilt-up, precast, and infill walls	Low-Rise	1 - 3	2	20
		Mid-Rise	4 - 7	5	50
		High-Rise	8+	12	120
Masonry (M)	All structures with masonry bearing walls	Low-Rise	1 - 3	2	20
		Mid-Rise	4 - 7	5	50
		High-Rise	8+	12	120
Manufactured Housing (MH)	Manufactured Housing		All	1	10

A general discussion of the five (5) specific building types for flood modeling is provided below.

4.2.2.1 Wood (W)

Within the Hazus Model, there are two general types of wood structures: 1) small, multi-family or single-family dwellings of not more than 5,000 square feet of floor area; and 2) large multi-family, commercial, or industrial buildings of more than 5,000 square feet of floor area. The essential structural feature of the smaller (5,000 square feet or less) buildings is repetitive framing by wood rafters or joists on wood stud walls. These buildings may have masonry chimneys and may be partially or fully covered with masonry veneer. Most of these buildings, especially the single-family residences, are not engineered but are constructed in accordance with “conventional construction” provisions of building codes. The floors and roofs may be sheathed with sawn lumber, plywood, or fiberboard sheathing. Walls are covered with boards, stucco, plaster, plywood, gypsum board, particleboard, or fiberboard, or a combination of several materials. Interior partition walls are usually covered with plaster or gypsum board.

The larger buildings (floor areas greater than 5,000 square feet) have framing systems consisting of beams or major horizontal members spanning between columns supporting lighter floor joists or rafters. These horizontal members may be glue-laminated wood, solid-sawn wood beams, wood or steel trusses, or steel beams. The exterior walls are covered with plywood, stucco, plaster, other types of paneling, or a combination of materials. The interior surfaces of the walls and interior partitions usually are covered with gypsum board or plaster.

4.2.2.2 Steel (S)

Steel buildings are usually framed with a series of steel girders spanning between steel columns supporting beams and various forms of wood or concrete floors and roof. Exterior walls are constructed of steel siding, window walls, or cladding panels, but may include cast-in-place concrete shear walls or unreinforced masonry infill walls. If ceilings are used in these buildings, they are usually suspended acoustical tiles. These buildings most commonly accommodate offices, warehouses, commercial, or industrial occupancies.

4.2.2.3 Concrete (C)

Concrete buildings are those where the structural frames and/or exterior walls are made of reinforced concrete, either cast-in-place, pre-cast tilt-up, or pre-cast elements. Interior framing can be steel, wood, concrete, pre-cast, or any combination. These buildings are most commonly used for office, warehouse, commercial, or industrial occupancies. Interior finishes are usually concrete, gypsum board, or plaster.

4.2.2.4 Masonry (M)

Masonry buildings are those where the exterior walls are masonry, either reinforced or unreinforced. These buildings are most commonly used for office, warehouse, commercial, industrial, or multi-family occupancies. Interior finishes are usually concrete, gypsum board, or plaster.

4.2.2.5 Manufactured Housing (MH)

These are prefabricated housing units that are trucked to the site and then placed on isolated piers, jack stands, or masonry block foundations (usually without any positive anchorage). Floors and roofs of mobile homes usually are constructed with plywood and outside surfaces are covered with sheet metal.

4.2.3 Hurricane Specific Building Types

The 39 SBTs used in the Hurricane Model are listed and briefly described in Table 4-4. Each identifier begins with W, M, C, S, or MH, representing the general building type to which the SBT belongs.

Table 4-4 Hurricane Model Specific Building Types

Specific Building Type Label	Description
WSF1	Wood, Single-family, One-story
WSF2	Wood, Single-family, Two or More Stories
WMUH1	Wood, Multi-Unit Housing, One-story
WMUH2	Wood, Multi-Unit Housing, Two Stories
WMUH3	Wood, Multi-Unit Housing, Three or More Stories
MSF1	Masonry, Single-family, One-story
MSF2	Masonry, Single-family, Two or More Stories
MMUH1	Masonry, Multi-Unit Housing, One-story
MMUH2	Masonry, Multi-Unit Housing, Two Stories
MMUH3	Masonry, Multi-Unit Housing, Three or More Stories
MLRM1	Masonry, Low-Rise Strip Mall, Up to 15 Feet
MLRM2	Masonry, Low-Rise Strip Mall, More than 15 Feet
MLRI	Masonry, Low-Rise Industrial/Warehouse/Factory Buildings
MERBL	Masonry, Engineered Residential Building, Low-Rise (1-2 Stories)
MERBM	Masonry, Engineered Residential Building, Mid-Rise (3-5 Stories)
MERBH	Masonry, Engineered Residential Building, High-Rise (6+ Stories)
MECBL	Masonry, Engineered Commercial Building, Low-Rise (1-2 Stories)
MECBM	Masonry, Engineered Commercial Building, Mid-Rise (3-5 Stories)
MECBH	Masonry, Engineered Commercial Building, High-Rise (6+ Stories)
CERBL	Concrete, Engineered Residential Building, Low-Rise (1-2 Stories)
CERBM	Concrete, Engineered Residential Building, Mid-Rise (3-5 Stories)
CERBH	Concrete, Engineered Residential Building, High-Rise (6+ Stories)
CECBL	Concrete, Engineered Commercial Building, Low-Rise (1-2 Stories)

Specific Building Type Label	Description
CECBM	Concrete, Engineered Commercial Building, Mid-Rise (3-5 Stories)
CECBH	Concrete, Engineered Commercial Building, High-Rise (6+ Stories)
SPMBS	Steel, Pre-Engineered Metal Building, Small
SPMBM	Steel, Pre-Engineered Metal Building, Medium
SPMBL	Steel, Pre-Engineered Metal Building, Large
SERBL	Steel, Engineered Residential Building, Low-Rise (1-2 Stories)
SERBM	Steel, Engineered Residential Building, Mid-Rise (3-5 Stories)
SERBH	Steel, Engineered Residential Building, High-Rise (6+ Stories)
SECBL	Steel, Engineered Commercial Building, Low-Rise (1-2 Stories)
SECBM	Steel, Engineered Commercial Building, Mid-Rise (3-5 Stories)
SECBH	Steel, Engineered Commercial Building, High-Rise (6+ Stories)
MHPHUD	Manufactured Home, Pre-HUD
MH76HUD	Manufactured Home, 1976 HUD
MH94HUD-I	Manufactured Home, 1994 HUD - Wind Zone I
MH94HUD-II	Manufactured Home, 1994 HUD - Wind Zone II
MH94HUD-III	Manufactured Home, 1994 HUD - Wind Zone III

The descriptions of the 39 Hurricane specific building types are given below.

4.2.3.1 Wood, Single-family, One-story (WSF1)

The WSF1 model building is a wood-framed, single-story, single-family house. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.2 Wood, Single-family, Two or More Stories (WSF2)

The WSF2 model building is a wood-framed, two-story, single-family house. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.3 Wood, Multi-Unit Housing, One-story (WMUH1)

The WMUH1 model building is a wood-framed, single-story, marginally engineered or non-engineered, multi-family dwelling or hotel/motel. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.4 Wood, Multi-Unit Housing, Two Stories (WMUH2)

The WMUH2 model building is a wood-framed, two-story, marginally engineered or non-engineered, multi-family dwelling or hotel/motel. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.5 Wood, Multi-Unit Housing, Three or More Stories (WMUH3)

The WMUH3 model building is a wood-framed, three-story, marginally engineered or non-engineered, multi-family dwelling or hotel/motel. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.6 Masonry, Single-family, One-story (MSF1)

The MSF1 model building is a masonry wall, single-story, single-family house. The masonry walls can be either reinforced or unreinforced. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.7 Masonry, Single-family, Two or More Stories (MSF2)

The MSF2 model building is a masonry wall, two-story, single-family house. The masonry walls can be either reinforced or unreinforced. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.8 Masonry, Multi-Unit Housing, 1-story (MMUH1)

The MMUH1 model building is a masonry wall, single-story, marginally engineered or non-engineered, multi-family dwelling or hotel/motel. The masonry walls can be either reinforced or unreinforced. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.9 Masonry, Multi-Unit Housing, Two Stories (MMUH2)

The MMUH2 model building is a masonry wall, single-story, marginally engineered or non-engineered, multi-family dwelling or hotel/motel. The masonry walls can be either reinforced or unreinforced. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.10 Masonry, Multi-Unit Housing, Three or More Stories (MMUH3)

The MMUH3 model building is a masonry wall, single-story, marginally engineered or non-engineered, multi-family dwelling or hotel/motel. The masonry walls can be either reinforced or unreinforced. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.11 Masonry, Low-Rise Strip Mall, Up to 15 Feet (MLRM1)

The MLRM1 model building is a masonry wall, low-rise strip mall building, up to 15 feet in height. The masonry walls can be either reinforced or unreinforced. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.12 Masonry, Low-Rise Strip Mall, More than 15 Feet (MLRM2)

The MLRM2 model building is a masonry wall, low-rise strip mall building, more than 15 feet in height. The masonry walls can be either reinforced or unreinforced. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.13 Masonry, Low-Rise Industrial/Warehouse/Factory Buildings (MLRI)

The MLRI model building is a 240,000 square foot, masonry wall, industrial building or warehouse. The masonry walls can be either reinforced or unreinforced. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.14 Masonry, Engineered Residential Building, Low-Rise (MERBL)

The MERBL model building is a two-story, engineered, reinforced masonry wall, residential building with a compartmented floor plan. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.15 Masonry, Engineered Residential Building, Mid-Rise (MERBM)

The MERBM model building is a five-story, engineered, reinforced masonry wall, residential building with a compartmented floor plan. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.16 Masonry, Engineered Residential Building, High-Rise (MERBH)

The MERBH model building is an eight-story, engineered, reinforced masonry wall, residential building with a compartmented floor plan. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.17 Masonry, Engineered Commercial Building, Low-Rise (MECBL)

The MERBL model building is a two-story, engineered, reinforced masonry wall, commercial building with an open floor plan. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.18 Masonry, Engineered Commercial Building, Mid-Rise (MECBM)

The MERBL model building is a five-story, engineered, reinforced masonry wall, commercial building with an open floor plan. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.19 Masonry, Engineered Commercial Building, High-Rise (MECBH)

The MERBL model building is an eight-story, engineered, reinforced masonry wall, commercial building with an open floor plan. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.20 Concrete, Engineered Residential Building, Low-Rise (CERBL)

The CERBL model building is a two-story, engineered, reinforced concrete, residential building with a compartmented floor plan. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.21 Concrete, Engineered Residential Building, Mid-Rise (CERBM)

The CERBM model building is a five-story, engineered, reinforced concrete, residential building with a compartmented floor plan. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.22 Concrete, Engineered Residential Building, High-Rise (CERBH)

The CERBH model building is an eight-story, engineered, reinforced concrete, residential building with a compartmented floor plan. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.23 Concrete, Engineered Commercial Building, Low-Rise (CECBL)

The CERBL model building is a two-story, engineered, reinforced concrete, commercial building with an open floor plan. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.24 Concrete, Engineered Commercial Building, Mid-Rise (CECBM)

The CERBL model building is a five-story, engineered, reinforced concrete, commercial building with an open floor plan. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.25 Concrete, Engineered Commercial Building, High-Rise (CECBH)

The CERBL model building is an eight-story, engineered, reinforced concrete, commercial building with an open floor plan. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.26 Steel, Pre-Engineered Metal Building, Small (SPMBS)

The SPMBS model building is a 4,000 square foot, pre-engineered, steel frame, metal clad building. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.27 Steel, Pre-Engineered Metal Building, Medium (SPMBM)

The SPMBS model building is a 50,000 square foot, pre-engineered, steel frame, metal clad building. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.28 Steel, Pre-Engineered Metal Building, Large (SPMBL)

The SPMBS model building is a 500,000 square foot, pre-engineered, steel frame, metal clad building. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.29 Steel, Engineered Residential Building, Low-Rise (SERBL)

The SERBL model building is a two-story, engineered, steel frame, residential building with a compartmented floor plan. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.30 Steel, Engineered Residential Building, Mid-Rise (SERBM)

The SERBM model building is a five-story, engineered, steel frame, residential building with a compartmented floor plan. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.31 Steel, Engineered Residential Building, High-Rise (SERBH)

The SERBH model building is an eight-story, engineered, steel frame, residential building with a compartmented floor plan. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.32 Steel, Engineered Commercial Building, Low-Rise (SECBL)

The SERBL model building is a two-story, engineered, steel frame, commercial building with an open floor plan. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.33 Steel, Engineered Commercial Building, Mid-Rise (SECBM)

The SERBM model building is a five-story, engineered, steel frame, commercial building with an open floor plan. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.34 Steel, Engineered Commercial Building, High-Rise (SECBH)

The SERBH model building is an eight-story, engineered, steel frame, commercial building with an open floor plan. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.35 Manufactured Home, Pre-HUD (MHPHUD)

The MHPHUD model building is a manufactured home built prior to the 1976 HUD standard. The home can be either tied-down or unrestrained. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.36 Manufactured Home, 1976 HUD (MH76HUD)

The MHPHUD model building is a manufactured home built to the 1976 HUD standard. The home can be either tied-down or unrestrained. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.37 Manufactured Home, 1994 HUD Region I (MH94HUD-I)

The MHPHUD model building is a manufactured home built to the 1994 HUD standard for Wind Zone I. The home can be either tied-down or unrestrained. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.38 Manufactured Home, 1994 HUD Region II (MH94HUD-II)

The MHPHUD model building is a manufactured home built to the 1994 HUD standard for Wind Zone II. The home can be either tied-down or unrestrained. See the *Hazus Hurricane Model*

Technical Manual Appendices (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

4.2.3.39 Manufactured Home, 1994 HUD Region III (MH94HUD-III)

The MHPHUD model building is a manufactured home built to the 1994 HUD standard for Wind Zone III. The home can be either tied-down or unrestrained. See the *Hazus Hurricane Model Technical Manual Appendices* (available by contacting the Hazus Help Desk, see Section 1.5) for a detailed description of the options for the construction components for this type of structure.

Section 5. General Building Stock: Baseline Database for Building Characteristics

The Hazus Occupancy and Building Types provide the framework for establishing the detailed Hazus baseline database for building characteristics. The occupancy and building types are anticipated to remain unchanged for future Hazus versions. The GBS Hazus Baseline Database, however, is expected to be updated over time to use time-dependent data sources.

Table 5-1 summarizes the current status of the major GBS tabular database elements by data type, hazard, sources, and an overview of how often source data is currently planned to be updated. Section 3.4 provides additional information on the Geographic Coverage of Hazus data.

This Section will provide details on each of the main GBS tabular database elements, including background information on how the database was developed, and plans for future maintenance and updates.

Table 5-1 Baseline GBS Database Summary Table

Tabular Data Type	Data Element	Hazards	Current Source	Date of Current Hazus Data	How Often is Source Data Updated?	Processing Required
Building Area	Building Area by Specific Occupancy	All	Department of Energy	1998	None planned	SIC/NAIC Codes converted to Hazus specific occupancy
Building Area	Building Area by Specific Occupancy	All	Dun & Bradstreet	2006	Continuously	SIC/NAIC Codes converted to Hazus specific occupancy
Building Count	Building Count by Specific Occupancy	All	U.S. Census Bureau	2010	10 years	NAIC Codes converted to Hazus specific occupancy, Non-RES1 and RES2 derived from typical building sizes
Building Count	Building Count by Specific Occupancy	All	RSMeans	2018	Annually	NAIC Codes converted to Hazus specific occupancy, Non-RES1 and RES2 derived from typical building sizes
Specific Occupancy to General Building Type	Mapping Scheme: Specific Occupancy to Gen. Bldg Type	All	ATC-13	1985	None planned	Methodology created using ATC-13
EQ General Building Type to EQ Specific Bldg Type and Design Level	Mapping Scheme: Gen. Bldg. Type to EQ Spec. Bldg. Type and EQ Design Level	EQ, TS	ATC-13	1985	None planned	Methodology created using ATC-13

Tabular Data Type	Data Element	Hazards	Current Source	Date of Current Hazus Data	How Often is Source Data Updated?	Processing Required
EQ Specific Building Type to Foundation Type	Mapping Scheme: Spec. Bldg. Type to Foundation Type	EQ, TS	Department of Energy	1997	None planned	Shallow foundations assumed
FL Specific Occupancy to Foundation Type	Mapping Scheme: Foundation Types to Specific Occupancy	FL, TS	Department of Energy Reports	1997	None planned	Methodology created using reports
HU General Building Type to HU Specific Building Type	Mapping Scheme: Gen. Bldg. Type to HU Spec. Bldg. Type	HU	Florida Residential Constructio n Mitigation Program (RCMP) database	1999	Annually (No planned update in Hazus)	Methodology created using database and surveys
HU General Building Type to HU Specific Building Type	Mapping Scheme: Gen. Bldg. Type to HU Spec. Bldg. Type	HU	Contractor Survey	1999	None planned	Methodology created using database and surveys
HU Specific Building Type to HU Wind Characteristics	Mapping Scheme: HU Spec. Bldg. Type to Wind Characteristics	HU	Contractor Survey	1999	None planned	Methodology created using surveys

** Updates in 2019 for Puerto Rico and U.S. Virgin Islands were based on individual structure data and were not developed using the same methods as other Census GBS and NSI data. Detailed methods provided in FEMA (2019b).*

5.1 Background

Hazus GBS data has primarily been developed from the U.S. Census residential data, supplemented with non-residential data from other data sources. Housing unit counts from the Census data are the basis for estimating the number of structures. With each Census, the Hazus development team has had to adapt data creation methods, as the baseline datasets from the Census Bureau change over time.

Table 1-1 at the beginning of this document summarizes the changes over time by Hazus version. The current version of Hazus, Hazus 4.2 SP3, uses 2010 Census data and primarily RSMeans 2018 economic values. The 2010 Census data was developed for Hazus in 2014 and was first available with Hazus 2.2 in January 2015. Many of the GBS tables in this Section were updated in 2014 in conjunction with the development of the Hazus baseline data from the 2010 Census.

5.1.1 Housing Units

Census data is based around the concept of a housing unit. The Census defines a housing unit as a house, an apartment, a group of rooms, or a single room occupied or intended for occupancy as separate living quarters. Census surveys gather information at the housing unit level and then summarizes statistics on characteristics of these units at different levels of geographic aggregation like blocks and tracts. Because Hazus is a model based around the concept of damages to individual buildings, the Census unit counts have to be converted into building equivalents. For single-family houses and manufactured housing, one housing unit is equivalent to one building, so the raw count can be used directly in Hazus. For other types of buildings, like apartments or group housing like dormitories, Hazus has established standard approaches (described later in this Section) to convert housing units into equivalent buildings with standardized building areas by specific occupancy types.

5.1.2 Building Age

One example of a Census building characteristic other than unit counts that is used in Hazus modeling is building age. At the block group level, Census data provides unit counts by a range of years, typically decades, for construction. In assigning the age of buildings, the Hazus Methodology assumes that typical development practices result in the homogenous development of all blocks within a single block group. For all hazards, the median year of construction is derived and used in several calculations. Also, Hazus assumes the same distribution of building age for all specific occupancies. In other words, the commercial/industrial development and the residential development throughout the block group are assumed to occur concurrently. Based on this assumption, the Census block group age is distributed throughout the constituent Census blocks to both residential and non-residential development.

Building age is also important because building codes (and expected building performance) change over time. For example, with flood, development regulations change when a community enters the National Flood Insurance Program. The Census building age data are used to determine the percent of structures that were built before entering the National Flood Insurance Program, denoted as pre-FIRM, and those afterwards, denoted as post-FIRM. Building age data is used for all hazards as part of the way that the hazard-specific mapping schemes are established.

5.2 Building Area and Count

The 2014 Hazus data update for 2010 Census data focused primarily on GBS data and inventory analysis parameters, such as mapping schemes, that have linkages and dependencies to the new Census block and tracts. As mentioned in Section 3, Census boundaries change over time, and there are no simple one-to-one relationships of Census units from one Census to the next. The source data for all the boundaries used in the Hazus 2014 data update came from the National Historical Geographic Information System (NHGIS). The other key source of data is the previous Hazus data based on the 2000 Census. This legacy data included information from both the Census and the Dun & Bradstreet data for non-residential occupancy types to develop the general building stock inventory. In this section, this legacy data will be referred to as the Hazus 2006 data to reflect the final 2006 RSMeans update.

The 2010 Census used about 11 million Census blocks for the US, DC, and PR, which is a 35% increase over the number found in the 2000 Census. Some states saw a dramatic redistricting of blocks resulting in major changes (e.g., +107% for Alaska, +96% for Virginia). These changes required a complete regeneration of the Census block boundaries. The process did not only redraw the boundaries, it included a cleanup task as they relate to water bodies, coastal boundaries cleanup, and removal of all water body blocks (labeled as 99 in the Census).

Once the block boundaries were generated, the geographic boundaries were combined to generate the higher tiers of data: tracts, counties, and states. Several associated attributes were also generated since they are needed by Hazus, such as the centroid points (latitude & longitude), areas, number of child objects within (for example, the number of blocks in each tract), and other characteristics. The NHGIS source took the original Census data, TIGER files, and American Community Survey (ACS) original data sets and packaged them in a more user-friendly delivery system, including a large archive of past years data.

When Hazus data were previously generated, most of the attributes for detailed tables, such as the demographics table, were generated out of the Summary File 1 (SF1) and Summary File 3 (SF3) and were provided at Census block resolution. In 2010, the Census Bureau decided not to collect the SF3 data and replaced it with sampled surveys conducted yearly by the Bureau in the ACS. While some of the data contained in SF3 files remains a part of the ACS, the resolution of the ACS data is not consistent, depending on the ACS range. For example, the ACS collects data yearly for places with 65,000 people or more, but only every three years for communities of 20,000 or more. In addition, the ACS collects data for use in five-year estimates for all areas, regardless of population. This change in data acquisition sources complicated the process of populating certain Hazus data, such as demographics tables (i.e., Census block based), since the source data is delivered at different levels of resolution (SF1 data is by Census block while the ACS data is by block group), unlike the 2000 Census data in which both the SF1 and SF3 sets were available at the Census block-level. To solve this problem, the SF1 data was supplemented with the needed ACS data and custom data algorithms were created to process and calculate fields, disaggregate the ACS data to the block level, and create 100% Hazus compatible tables for data such as demographics.

5.2.1 Building Area for RES1

For building area (calculated as square footage), the 2010 Census data provides estimates of the single-family attached and detached housing units at the Census block-level. Because RES1 structures have such a wide variation in building areas across the country and is influenced by the relative income of one region to another, a multi-step approach is used to assign RES1 building areas and associated replacement values (described in Section 6). Table 5-2 shows how a factor called the Income Ratio (IR) is used to assign typical building area by Census Division for buildings with and without basements. The IR takes the Census block group median income and divides it by the average median income for the Census Division. This provides a basis to adjust RES1 building area both by relative income and regionally. The source data used to develop this table was regional DOE data with default values for typical building area per single-family home from Energy Information Administration (EIA) data on heated floor space. These baseline data were provided by region and income group. The breakdown reflects not only how typical housing size varies across the U.S., but also how, in general, higher income areas tend to contain larger single-family homes. One limitation is that some data are provided at the Census block group level, which is aggregated at a higher level than the data preferred by Hazus.

For structure counts, the baseline typical building area data were derived from a detailed, unpublished database provided by the EIA. Only information on families in single-family residences, aggregated across all foundation/basement types, was used. The raw database included information on the number of households by region, income category, and housing floor space. Regional data were available by 9 multi-state Census divisions. RES1 and RES2 building counts came from this Census data, while other counts were derived from average area values for different building occupancies. Assessor data from around the United States, including that from six proof-of-concept communities, was reviewed to develop preliminary estimates of average floor area for multi-family housing. This data was then peer reviewed by engineering experts to develop an average building area per number of units for the unit ranges provided by the Census data.

Table 5-2 RES1 Building Area Per Unit by Census Division

Census Division[1]	Income Ratio (IR)	Basement	
		No[2]	Yes[3]
New England	IR < 0.5	1,300	975
	0.5 < IR < 0.85	1,500	1,125
	0.85 < IR < 1.25	1,800	1,350
	1.25 < IR < 2.0	1,900	1,425
	IR < 2.0	2,200	1,650
Middle Atlantic	IR < 0.5	1,300	975
	0.5 < IR < 0.85	1,500	1,125
	0.85 < IR < 1.25	1,700	1,275
	1.25 < IR < 2.0	1,900	1,425
	IR < 2.0	2,200	1,650
East North Central	IR < 0.5	1,300	975
	0.5 < IR < 0.85	1,600	1,200
	0.85 < IR < 1.25	1,700	1,275
	1.25 < IR < 2.0	1,800	1,350
	IR < 2.0	2,500	1,875
West North Central	IR < 0.5	1,300	975
	0.5 < IR < 0.85	1,500	1,125
	0.85 < IR < 1.25	1,800	1,350
	1.25 < IR < 2.0	1,800	1,350
	IR < 2.0	2,300	1,725
South Atlantic	IR < 0.5	1,400	1,050
	0.5 < IR < 0.85	1,600	1,200
	0.85 <IR < 1.25	1,700	1,275
	1.25 < IR < 2.0	2,000	1,500
	IR < 2.0	2,300	1,725
East South Central	IR < 0.5	1,300	975
	0.5 < IR < 0.85	1,400	1,050
	0.85 < IR < 1.25	1,700	1,275
	1.25 < IR < 2.0	1,900	1,425
	IR < 2.0	2,500	1,875

Census Division[1]	Income Ratio (IR)	Basement	
		No[2]	Yes[3]
West South Central	IR < 0.5	1,300	975
	0.5 < IR < 0.85	1,700	1,275
	0.85 < IR < 1.25	1,800	1,350
	1.25 < IR < 2.0	1,900	1,425
	IR < 2.0	2,500	1,875
Mountain	IR < 0.5	1,200	900
	0.5 < IR < 0.85	1,500	1,125
	0.85 < IR < 1.25	1,700	1,275
	1.25 < IR < 2.0	1,800	1,350
	IR < 2.0	2,600	1,950
Pacific	IR < 0.5	1,300	975
	0.5 < IR < 0.85	1,500	1,125
	0.85 < IR < 1.25	1,700	1,275
	1.25 < IR < 2.0	1,900	1,425
	IR < 2.0	2,100	1,575

[1] Census Division list of states given in Table 3-2
[2] Based on building area data in square feet from the Energy Information Administration, Housing Characteristics 1993.
[3] (Area of main living area if basement present) = 0.75 x (Area of main living area if no basement). This adjustment allows consistent application of the Means cost models, in which basement areas are added-on, and are assumed to be 1/3 of main living area.
** Updates in 2019 for Puerto Rico and U.S. Virgin Islands were based on individual structure data and did not use this approach, see detailed methods provided in FEMA (2019b).*

While the RES1 building areas shown in the previous table were not updated as part of the 2014 Hazus data update, Table 5-3 for percent with basements was updated with EIA 2009 data.

Table 5-3 Basement Distribution by Census Division

Census Division[1]	Percent with Basement[2]	Percent without Basement
New England	72%	28%
Middle Atlantic	58%	42%
East North Central	57%	42%
West North Central	56%	44%
South Atlantic	19%	81%
East South Central	18%	82%
West South Central	2%	98%
Mountain	26%	74%
Pacific	8%	92%

[1] Census Division list of states given in Table 3-2
[2] Based on U.S. Energy Information Administration (EIA), 2009 Residential Energy Consumption Survey (RECS), Final Release April 2013, Structural and Geographic Characteristics of U.S. Homes, by Census Region, and Division.
** Updates in 2019 for Puerto Rico and U.S. Virgin Islands were based on individual structure data and did not use this approach, see detailed methods provided in FEMA (2019b).*

Once the parameters above were defined, an algorithm was developed to estimate the RES1 (single-family residential) building area.

Equation 5-1 Estimation of the Single-Family Residential Building Area (RES1)

$$\begin{aligned}\mathrm{RES1(sq.ft)} = {} & \mathrm{Total\ Single - Family\ Units\ (from\ Census)} \\ & * [(\mathrm{Percent\ of\ units\ with\ basement}) \\ & * (\mathrm{floor\ area\ wuth\ basement\ based\ on\ Income\ Ration\ and\ Region}) \\ & + (\mathrm{Percent\ of\ units\ without\ basement}) \\ & * (\mathrm{floor\ area\ without\ basement\ based\ in\ Ratio\ and\ Region})]\end{aligned}$$

An example of Equation 5-1 using a New England Census block that consists of 81% basement and 19% no basement, and an Income Ratio (IR) of 0.67 is below.

Equation 5-2 Example of Estimation of RES1 using New England Census Block

$$\mathrm{RES1\ (sq.ft.)} = [\mathrm{Census\ value}] * [(0.81) * (1{,}125) + (0.19) * (1{,}500)]$$

Building height or number of stories is an additional data type used for RES1 as shown in Table 5-4. The Northeast region has a larger percentage of two-story single-family homes than any other Census region. The South and West regions have a majority of one-story single-family homes.

Table 5-4 Percent Distribution of Number of Stories for Single-family Residences

Census Region[1]	One-Story[2]	Two-Story	Three-Story	Split Level
Northeast	25%	68%	5%	2%
Midwest	50%	46%	2%	2%
South	66%	32%	1%	1%
West	66%	30%	2%	2%

[1] Census Region list of states given in Table 3-2
[2] Based on EIA, 2009 Residential Energy Consumption Survey, Final Release April 2013, Structural and Geographic Characteristics of U.S. Homes, by Census region.
** Updates in 2019 for Puerto Rico and U.S. Virgin Islands were based on individual structure data and did not use this approach, see detailed methods provided in FEMA (2019b).*

5.2.2 Building Area for RES2

The building area used for manufactured housing has changed over time as better data sources have been developed for the U.S. These sources include various internet websites for manufactured housing sales (new and used), housing manufacturers, and finally additional U.S. Census data. There was a great deal of information regarding sales and shipment of manufactured housing since the 1970s, but there was very little information regarding the attrition rate experienced over the same 30-year span. Evaluating data from the Manufactured Housing Institute for the 1980s and 1990s found a general growth trend in the size of the units for both the single wide and double wide (also known as single-section and multi-section) manufactured housing.

For the original Hazus development, the American Housing Survey for the US, 1997 (September 1999) contained estimated building areas for manufactured housing (labeled Mobile Home in the Census tables) based on a surveyed population of over 8 million manufactured homes across the United States. The survey did not differentiate between single-section and multi-section units, but when the values are charted, the distribution presents natural points to estimate these dimensions. Using this distribution, it was possible to estimate representative values for single-section and multi-section units of 950 square feet and 1,400 square feet, respectively. These values were used in early Hazus versions.

As part of the 2014 Hazus data update, the average square feet for RES2 was established at the Census Region using the same 2009 EIA as other building area updates. Table 5-5 lists these latest building area values.

Table 5-5 Building Areas for Manufactured Housing

Census Region[1]	Building Area (sq.ft)[2]
Northeast	1,030
Midwest	1,090
South	1,128
West	995

[1] Census Region list of states given in Table 3-2
[2] Based on EIA, 2009 Residential Energy Consumption Survey, Final Release April 2013, Structural and Geographic Characteristics of U.S. Homes, by Census region.
** Updates in 2019 for Puerto Rico and U.S. Virgin Islands were based on individual structure data and did not use this approach, see detailed methods provided in FEMA (2019b).*

5.2.3 Building Area for RES3

For consistency with other updates performed as part of the 2014 Hazus data update, the unit area assumptions for the multi-family (RES3A through RES3F) inventory also looked at the available EIA data. As mentioned previously, the Census data provides the number of housing units, but not the number of structures. To convert the number of housing units for multi-family inventory into a building area, assumptions must be made concerning average building areas of typical units for each of the RES3 categories. Table 5-6 shows the current assumed Hazus distribution of the building area by unit by Census Region.

Table 5-6 Unit Areas for Multi-Family Dwellings (RES3A-RES3F) by Census Region

Census Region[1]	RES3A and RES3B Building Area (sq.ft) by Housing Unit[2]	RES3C, RES3D, RES3E, and RES3F Building Area (sq.ft) by Housing Unit
Northeast	1,191	849
Midwest	1,279	787
South	945	916
West	930	811

[1] Census Region list of states given in Table 3-2
[2] Based on U.S. Energy Information Administration (EIA), 2009 Residential Energy Consumption Survey (RECS), Final Release April 2013, Structural and Geographic Characteristics of U.S. Homes, by Census Region, and Division.
** Updates in 2019 for Puerto Rico and U.S. Virgin Islands were based on individual structure data and did not use this approach, see detailed methods provided in FEMA (2019b).*

For building height or number of stories for multi-family residences, the Housing Characteristics 1993 report did not provide any distribution by the number of floors. This information was enhanced in the Residential Energy Consumption 1997 report with a broad distribution of the number of floors that is best represented in Table 5-7. The data provides more detail than what is displayed in the table, but there is no value in providing additional definitions above five floors based on the current damage functions.

Table 5-7 Percent Distribution of Number of Stories for Multi-Family Residences

Census Region[1]	1-2 Stories	3-4 Stories	5+ Stories[2]
Northeast	29%	26%	45%
Midwest	49%	29%	22%
South	66%	21%	13%
West	58%	25%	17%

[1] Census Region list of states given in Table 3-2
[2] Based on A Look at Residential Energy Consumption in 1997 (DOE, 1999) Table HC1-13a converted to percent of total multi-family dwellings.
** Updates in 2019 for Puerto Rico and U.S. Virgin Islands were based on individual structure data and did not use this approach, see detailed methods provided in FEMA (2019b).*

5.2.4 Building Area for RES5

Establishing the building area for RES5 (Institutional Housing) is based on the actual population of those buildings rather than the number of housing units. Table 5-8 summarizes these assumptions by Census group quarters type.

Table 5-8 RES5 Building Area per Person by Group Quarters Type

Census Group Quarters Type	Building Area (sq.ft) per Person
Correctional Facilities	100
Other institutions	700
College Dormitories	400
Military Quarters	800
Other non-institutions	700

** From original development of Hazus by the National Institute of Building Sciences in 1999.*
*** Updates in 2019 for Puerto Rico and U.S. Virgin Islands were based on individual structure data and did not use this approach, see detailed methods provided in FEMA (2019b).*

Hazus assumes the total building area of a RES5 structure is 25,000 square feet. This value is used to calculate the building counts (detailed for all specific occupancies in upcoming sections).

5.2.5 Building Area for RES4, RES6, and Non-Residential Occupancies

The methods used to establish building area for RES4, RES6, and non-residential occupancies have changed over the history of the Hazus program. In the original Hazus development, the HAZUS99 Earthquake Model inventory used the Dun & Bradstreet business inventory at the Census tract level for all non-residential structures and those facilities commercial in nature, but provide housing for people, such as hotels (RES4) and nursing homes (RES6). The Dun & Bradstreet data represented approximately 76% (approximately 14 million) of the total estimated businesses in the United States (approximately 19 million). While initially, this might seem like a low representation, the Dun & Bradstreet database accounted for 98% of the gross national product. Dun & Bradstreet states the remaining businesses are likely to be smaller and home-based. If true, the proxy inventory established for residential dwelling accounts for these businesses in the total damage estimates.

Dun & Bradstreet provided the data aggregated on the SIC definitions used previously in the development of the HAZUS99 Earthquake Model. The Dun & Bradstreet data obtained for the Flood Model provided building area for businesses at the Census block-level. Dun & Bradstreet performs regular random sampling of businesses in their database to obtain the actual building area. Dun & Bradstreet then utilized proprietary algorithms to estimate the building area for the remaining businesses. According to Dun & Bradstreet, the building area is sampled for approximately 25% of their business database and the remainder is modeled. With their data, Dun & Bradstreet provided a count of businesses, the total building area (modeled and sampled), and the total number of employees. The Dun & Bradstreet data contained information on all non-residential uses, including some agricultural facilities, general government offices, schools, and churches. Comparison with Hazus original proof of concept (POC) data and other available data showed relatively good agreement.

The Dun & Bradstreet data were used in Hazus through the 2006 data update for the 2000 Census data. Dun & Bradstreet's total building area was divided by the average structure building area to establish building counts.

For the Hazus 2010 Census data update in 2014, a different approach had to be used for the non-residential occupancies (RES4, RES6, COM1, COM2, COM3, COM4, COM5, COM6, COM7, COM8, COM9, IND1, IND2, IND3, IND4, IND5, IND6, AGR1, REL1, GOV1, GOV2, EDU1, and EDU2). Due to funding limitations, updated Dun & Bradstreet data were not available for the 2014 update. The alternative approach used the Hazus 2006 update data as the starting data source and was adjusted as described below:

- All data were re-mapped from the 2000 Census blocks to the 2010 Census blocks. This required the development of a complex mapping table that maps the 2000 blocks to the 2010 blocks, while considering all spatial changes and changes in data resolution (as discussed earlier).
- Once the 2006 building area values were redistributed to the 2010 Census blocks, an adjustment factor of +7% (derived from studying the economic output growth between 2006 and 2010) was applied to the occupancies RES4, RES6, COM1, COM2, COM3, COM4, COM5, COM6, COM7, COM8, COM9, REL1, GOV1, GOV2, EDU1, EDU2.

This established total building area by Census block for these specific occupancies. Baseline building area values, based on the 2014 data update, for RES4, RES6, and all non-residential specific occupancies are shown in Table 5-9.

Table 5-9 Typical Building Area for RES4, RES6, and Non-Residential Occupancies

Occupancy	Building Area (sq.ft)
RES4	135,000
RES6	25,000
COM1	110,000
COM2	30,000
COM3	10,000
COM4	80,000
COM5	4,100
COM6	55,000

Occupancy	Building Area (sq.ft)
COM7	7,000
COM8	5,000
COM9	12,000
COM10	145,000
IND1	30,000
IND2	30,000
IND3	45,000
IND4	45,000
IND5	45,000
IND6	30,000
AGR1	30,000
REL1	17,000
GOV1	11,000
GOV2	11,000
EDU1	130,000
EDU2	50,000

Also, as part of the Hazus 2010 Census data update in 2014, the non-residential height table was updated, as shown in Table 5-10. This table was derived from the EIA, the 2003 Commercial Buildings Energy Consumption Survey (CBECS), and the Number of Buildings for Non-Mall Buildings, 2003. The height distribution is a function of the year built.

Table 5-10 Percent Distribution of Number of Floors by Year Built Non-Residential Buildings (including RES4, RES5, and RES6)

Median Year Built	Low-Rise (1-3 stories)	Mid-Rise (4-7 stories)	High-Rise (8+ stories)
1919 or Before	87%	12%	1%
1920-1945	94%	5%	1%
1946-1959	98%	1%	1%
1960-1969	97%	2%	1%
1970-1979	97%	2%	1%
1980-1989	97%	2%	1%
1990-1999	98%	1%	1%
2000+	97%	2%	1%

5.2.6 Building Count for RES1 and RES2

In Hazus-MH MR2 and earlier versions, building count data for each occupancy was estimated by dividing the total building area for each Census block (or tract) and occupancy by a single typical or standard value of building square foot by occupancy. For example, RES1 structures were assumed to be 1,600 square feet, while COM1 structures were assumed to be 110,000 square feet, etc. Since the building area for residential structures was originally derived from housing unit count data available in the U.S. Census, it made sense to utilize these housing unit counts directly for RES1 and RES2 occupancies, rather than to utilize data derived from a two-step proxy (estimating building area from housing unit count, then estimating building count from building area).

For Hazus-MH MR3 and on, revised building count data were generated for RES1 and RES2 occupancies from block group and block level Census data:

- Block group level Census data - total count of all housing units, including the count of housing units in each housing category (1 unit detached, 1 unit attached, 2 units, 3 or 4 units, 5 - 9 units, 10 - 19 units, 20 - 49 units, 50+ units, and mobile home).
- Block level data - total count of all housing units.

For each Census block group, the percent of all housing units assumed to be single-family (RES1) was estimated as the sum of "1 unit detached" and "1 unit attached" counts, divided by total Census block group housing unit count. Similarly, the percent of all housing units assumed to be manufactured housing (RES2) was taken as the ratio of "mobile home" counts divided by total Census block group housing unit count. This assumes construction across the Census block group is homogeneous - the same assumption that was made in developing the original Hazus building area databases. To estimate Census block RES1 and RES2 counts, the Census block group ratios identified above were multiplied by the total Census block housing unit count.

5.2.7 Building Count for RES3

For the 2014 Hazus data update, a new approach was implemented for building counts for RES3 buildings. Rather than dividing the building area by a default building area (which is used for most other specific occupancies) to derive an initial building count value, Table 5-11 was used to directly calculate building counts from Census housing unit counts. This better supports the approach detailed earlier that RES3 structures in different regions of the country will have different sizes.

Table 5-11 Housing Units Counts to Building Counts for Multi-family Dwellings (RES3A-RES3F)

Housing Unit Type	RES3A Duplex 2 units	RES3B Triplex/Quad 3 or 4 units	RES3C 5 to 9 units	RES3D 10 to 19 units	RES3E 20 to 49 units	RES3F 50 or more units
Number of Units per Structure	2	4	7	14	34	76

** Updates in 2019 for Puerto Rico and U.S. Virgin Islands were based on individual structure data and did not use this approach, see detailed methods provided in FEMA (2019b).*

5.2.8 Building Count for Other Occupancies

The building count data for all other occupancy classifications are estimated using the following rules:

When the total building area is greater than per structure building area from Table 5-7 and Table 5-9, building counts are rounded using typical rounding rules. When the total building area is less than the per structure building area, but greater than a minimum value of 750, then the building count is set to a count of one. The minimum value of 750 square feet was an arbitrary value. A sensitivity analysis using values of 500, 750, and 1,000 was conducted. Considering the 7% increase in building area between the 2000 and the 2010 data, the minimum value of 750 appeared to be the closest value generating the expected variability.

The final adjustment was to compare rounded and unrounded totals at the Census block-level by county and by specific occupancy. For those blocks with the greatest differences between their rounded and unrounded values, the final county total for each specific occupancy are adjusted to ensure the rounded total and unrounded total are in agreement.

5.3 Garages

The development of a distribution of garages within a Census block assists in the assignment of valuation functions, as shown in Table 5-12.

Table 5-12 Percent Distribution of Garage Types for Single-Family Residential Structures (% of total)

Census Region[1]	One-Car[2]	Two-Car	Three-Car	Carport	None
Northeast	29%	31%	5%	2%	33%
Midwest	21%	51%	9%	2%	17%
South	14%	39%	4%	8%	35%
West	16%	51%	11%	6%	16%

[1] Census Region list of states given in Table 3-2
[2] Based on EIA, 2009 Residential Energy Consumption Survey, Final Release April 2013, Structural and Geographic Characteristics of U.S. Homes, by Census region
** Updates in 2019 for Puerto Rico and U.S. Virgin Islands were based on individual structure data and did not use this approach, see detailed methods provided in FEMA (2019b).*

5.4 All Hazards Mapping Scheme

As noted in Table 5-1 at the beginning of the section, all hazards use the same mapping scheme to link specific occupancy to general building type. The term “mapping scheme” in Hazus relates to the use of one or multiple lookup tables to link related data elements, such as specific occupancy with general building type. Mapping schemes for the Western U.S. buildings (pre-1950, 1950-1970, and post-1970) are based on information provided in the Earthquake Damage Evaluation Data for California publication by the Applied Technology Council (ATC-13, 1985). The mapping schemes for the rest of the U.S. are based on proprietary insurance data, knowledge of a limited number of experts, and inferences drawn from tax assessor’s records.

For detailed tables with the mapping scheme for all hazards, from specific occupancy to general building types, and the earthquake specific building types, see Appendix A: Earthquake and Tsunami GBS Mapping Scheme Tables.

5.5 Other Earthquake Building Characteristics

The only other mapping scheme for the Earthquake Model mentioned in Table 5-1 is earthquake specific building type to foundation type. Hazus currently assumes a shallow foundation as the default value for structures. More details on this assumption can be found in the *Hazus Earthquake Model Technical Manual* (FEMA, 2021).

5.6 Other Flood Building Characteristics

In Table 5-1, the only flood specific mapping scheme mentioned is flood specific occupancy to foundation type, which ultimately leads to first floor elevation based on foundation type. Flood GBS data requires information on number of stories and year built to infer pre-FIRM and post-FIRM construction, which impacts both first floor elevation assumptions, but also the choice of depth damage functions used to estimate flood damages.

5.6.1 Flood Foundation Types

The distribution of foundations, the associated first floor heights, and the pre/post-FIRM relationships are the controlling parameters affecting flood damage within the model. The Flood Model allows the user to define or control these parameters in the Flood Specific Occupancy Mapping dialogs, which are discussed in further detail in the *Hazus Flood Model Technical* Manual (FEMA, 2021). This section will focus on the process by which the foundation distributions and the first-floor heights are defined.

To properly develop a distribution of foundation types, the following foundation definitions are used:

- *Pile:* An open foundation, composed of tall and slender members, embedded deeply into the ground. A pile is a single element, not built-up on site like a pier. Cast-in-place columns supported by a deep foundation (pile cap, mat, or raft below the anticipated scour depth) will be classified as a pile foundation. In some pile-supported buildings, shear walls may be used to transfer shear from the upper building to the embedded foundation elements.
- *Pier:* An open foundation (no load-bearing perimeter walls) usually built of masonry units and supported by shallow footings. Piers usually range from approximately 2 feet to 8 feet in height.
- *Solid Wall:* Load-bearing perimeter walls greater than 4 feet in height, usually supported by shallow footings. Floor beams or joists usually rest atop the walls and may or may not be supported by interior piers or columns.
- *Basement or Garden-Level Basement:* Any level or story with its floor subgrade on all sides. Usually load bearing, masonry or concrete walls around the perimeter of the building, supported on shallow footings. Floor beams or joists rest atop the walls. Shallow basements with windows slightly above grade are defined as a garden level basement.
- *Crawlspace:* Usually short (less than 4 feet high), load bearing, masonry or concrete walls around the perimeter of the building footprint, supported on shallow footings. Floor beams or joists rest atop the walls and may also rest on interior piers.
- *Fill:* Soil built up above the natural ground elevation and used to support a slab or shallow footings.
- *Slab-on-Grade:* Concrete slab resting on the ground. It may have its edges thickened or turned down but does not rely on other walls or footings for support.

Within the Flood Model, all Census blocks have been assigned a code identifying the primary local flood hazard type (riverine, coastal, or lake) as well as a foundation mapping scheme. Mapping schemes are provided for pre- and post-FIRM development and applied at the Census block based on the community's entry date into the NFIP as reported in the Community Status Book.

The rules for the Census block mapping schemes are as follows:

- The default value for all Census blocks is "R" (riverine).
- Those Census blocks that are immediately adjacent to the Great Lakes are coded as "L" for Great Lakes.
- Those Census blocks that are within coastal regions are coded as "C" (coastal).

For those Census blocks with both riverine and coastal hazards, it is assumed that the coastal foundation practices will dominate, since the building codes for coastal hazards are more stringent, so these blocks are coded as “C” (coastal).

5.6.1.1 Riverine Building Foundation Types

Foundation type can be determined from either the Housing Characteristics report (1993) or the Residential Energy Consumption report (1997), with the exception of areas that are subjected to coastal flood hazards. Foundation types like pilings are not considered or mentioned in either report, but this information can be derived from the H. John Heinz III Center data collected for their report “The Hidden Cost of Coastal Hazards” (Heinz Center, 2000). Coastal hazard areas will be discussed later in this section.

When the two reports were compared, there seemed to be only moderate differences in the total percentages. For this reason, the Residential Energy Consumption (1997) Census division reporting was used to enhance accuracy of the foundation distributions available to the user. While the Residential Energy Consumption report does not consider multi-family residences of five units or less, it is assumed this distribution can be applied to these structures, since the numbers are so similar to the distributions found in the Housing Characteristics report.

For non-coastal development, Table 5-13 provides the recommended distribution of foundation types (basement, crawlspace, or slab on grade) for single- and multi-family residences of less than five units. Riverine foundation distributions do not vary by pre-FIRM or post-FIRM.

Table 5-13 Percent Distribution of Foundation Types for Single-family and Multi-Family Residences (% of total)

Census Division[1]	Pile[2]	Pier / Post	Solid Wall	Basement/ Garden Level	Crawl Space	Fill	Slab-on-Grade
New England	0%	0%	0%	81%	10%	0%	9%
Mid Atlantic	0%	0%	0%	76%	10%	0%	14%
East North Central	0%	0%	0%	68%	21%	0%	11%
West North Central	0%	0%	0%	75%	13%	0%	12%
South Atlantic[3]	0%	0%	0%	23%	35%	0%	42%
East South Central	0%	0%	0%	25%	49%	0%	26%
West South Central	0%	0%	0%	5%	38%	0%	57%
Mountain	0%	0%	0%	32%	29%	0%	39%
Pacific	0%	0%	0%	13%	45%	0%	42%

[1] Census Division list of states given in Table 3-2
[2] Based on A Look at Residential Energy Consumption in 1997 (Nov 1999) Table HC1-9b through HC1-12b as a percent of single-family housing units.
[3] Puerto Rico and U.S. Virgin Islands use South Atlantic values.

5.6.1.2 Riverine Building Floor Height Above Grade

With the distribution of default foundation types determined, it is necessary to determine what this means in terms of first floor elevation. For the sake of consistency, it was determined that the measurement of floor height from grade to the top of the finished floor for both pre-FIRM and post-FIRM would be a good basis for default values. Table 5-14 provides the default pre-FIRM or post-FIRM elevations for each foundation type in riverine flood hazard areas.

Table 5-14 Default Floor Heights Above Grade to Top of Finished Floor (Riverine)

ID	Foundation Type	Pre-FIRM	Post-FIRM
1	Pile	7 feet	8 feet
2	Pier (or post and beam)	5 feet	6 feet
3	Solid Wall	7 feet	8 feet
4	Basement (or Garden Level)	4 feet	4 feet[1]
5	Crawlspace	3 feet	4 feet
6	Fill	2 feet	2 feet
7	Slab	1 foot	1 foot[1]

[1] Typically not allowed but may exist
** Source Data: Expert Opinion*

Note that the heights shown here are default values. In most cases, regulations are written to include freeboard above the Base Flood Elevation (BFE). Additionally, typical engineering design will shift from one foundation type to another, depending on the height necessary to elevate the structure above BFE. Therefore, it is recommended to use the following guidelines for post-FIRM foundation distributions:

- *Piles*: Used when the BFE plus freeboard is 8 feet or greater.
- *Piers:* Used when the BFE plus freeboard is less than 6 feet. If BFE plus freeboard is greater than 6 feet, typical construction practice is to use other foundation types such as solid walls or piles.
- *Solid Walls:* Used when the BFE plus freeboard is less than 8 feet. If the BFE plus freeboard is greater than 8 feet, typical construction practice is to use piles.
- *Basements:* Typically, not allowed in post-FIRM development in the SFHA. The user should establish the post-FIRM distribution to match what is actually occurring in the regulated areas.
- *Crawlspaces:* Used when the BFE plus freeboard is less than 4 feet. If BFE plus freeboard is greater than 4 feet, typical construction practice is to use other foundation types such as piers, solid walls, or piles.
- *Fill:* Used when the BFE plus freeboard is less than 2 feet. If the BFE plus freeboard is greater than 2 feet, typical construction practice is to use other foundation types such as crawlspace, piers, solid walls, or piles.
- *Slab-on-Grade:* Typically not allowed in post-FIRM development within the SFHA. The user should establish the post-FIRM distribution to match what is occurring in the regulated areas.

5.6.1.3 Coastal Building Foundation Types

The H. John Heinz III Center for Science, Economics and the Environment has developed a report discussing coastal erosion along the U.S. coastline. Part of this effort entailed collecting data from several coastal communities in areas along coastlines. Their study included site visits to survey the areas of interest. While the data they developed was collected for a different task, it contained detailed information on the structures along U.S. coastlines. For additional information regarding the methodology of data collection and the complete metadata discussion, please refer to the Heinz Center's report (Heinz Center, 2000).

The Heinz Center's data was supplied with the necessary metadata to allow for analysis to identify potential usefulness for the Flood Model. The data contained information regarding foundation types and the structures flood zone (i.e., Zone A, Zone V, etc.). The data was graphically plotted in order to find distinct construction features by geographic region and appropriate flood zone for the development of a modifier table. Table 5-15 shows the table for pre-FIRM structures that is applied to those Census blocks that are within or intersect with the coastal Flood Rate Insurance Mapping (FIRM) zones.

Table 5-15 Distribution of Pre-FIRM Foundation Types (% of total)

Coastline	Pile	Pier	Solid Wall	Basement	Crawl Space	Fill	Slab
Pacific	7%	7%	1%	2%	46%	0%	37%
Great Lakes	0%	1%	0%	0%	29%	0%	70%
North Atlantic	47%	7%	2%	0%	34%	0%	10%
South Atlantic[1]	34%	7%	2%	0%	20%	0%	37%
Gulf of Mexico	34%	7%	1%	1%	21%	0%	36%

[1] Puerto Rico and U.S. Virgin Islands use South Atlantic values.
** Source Data: The H. John Heinz III Center for Science, Economics and the Environment study data 2000, and expert opinion*

Table 5-15 shows that the Heinz Center did not find any structures located on elevated fill in any of their sample communities. The field for elevated fill was kept so users could modify the foundation types to include this classification if it exists within their community. The communities investigated by the Heinz Center had an unusually high number of pile foundations due to modern hurricane experiences. To accommodate this, the North Atlantic, South Atlantic and Gulf Coast Zones V were modified slightly to increase the use of pier foundations and reduce the pile foundations. The team also reduced the slab-on-grade foundations and increased the use of the crawlspace foundations for the Great Lake Zone A.

For post-FIRM structures, Table 5-16 provides the default distribution for the Flood Model. It should be noted that the Heinz Center data includes some foundation types that should not have been utilized within the flood zones indicated. For example, the North Atlantic Zone V (Coastal) data includes some slab-on-grade structures. This may be an indication that some of the structures were built just before or were under construction while the ordinances were being put in place.

It is important to note the Flood Model will apply the Zone A and Zones V throughout a given Census block based on the zone information available from mapping. The mapping used to assign coastal and riverine Census blocks was part of the 2000 Census data updates prior to Hazus 1.0 and utilized the latest available digital floodplain mapping at that time, along with supplemental data sources such as the coastline geometry from the Hurricane Model.

Table 5-16 Percent Distribution of Post-FIRM Foundation Types by Coastal Zones

Zone	Coastline	Pile	Pier	Solid Wall	Basement	Crawlspace	Fill	Slab-on-Grade
Zone V	Pacific	60%	255	0%	0%	10%	0%	5%
	Great Lakes	5%	0%	10%	0%	30%	0%	55%
	North Atlantic	75%	15%	5%	0%	0%	0%	5%
	South Atlantic[1]	80%	15%	2%	0%	1%	0%	2%
	Gulf of Mexico	85%	10%	2%	0%	1%	0%	2%
Zone A	Pacific	20%	5%	0%	0%	55%	0%	20%
	Great Lakes	5%	0%	10%	0%	30%	0%	55%
	North Atlantic	40%	10%	5%	0%	30%	0%	15%
	South Atlantic[1]	50%	15%	2%	0%	20%	0%	13%
	Gulf of Mexico	50%	15%	2%	0%	20%	0%	13%

[1] Puerto Rico and U.S. Virgin Islands use South Atlantic values.
** Source Data: The H. John Heinz III Center for Science, Economics and the Environment study data 2000 and expert opinion*

5.6.1.4 Coastal Building Floor Height Above Grade

For coastal flood areas, a consistent measure of floor height from grade to the top of the finished floor was selected for both Zone A and Zone V heights. While the FIA uses to the bottom of the lowest horizontal structural member, utilizing a constant reference point in the structures made the table clearer and easier for the user to understand. Within the Flood Model, the floor height will automatically be adjusted to reference the lowest horizontal structural member to make the height consistent with the damage curves, which follows the FEMA coastal approach.

Table 5-17 provides the default elevations for each foundation type in coastal flood hazard areas. This table also shows the changes in foundation type and height by flood hazard zone and pre-FIRM or post-FIRM. Typically, foundations like slab-on-grade, fill, and crawlspaces are not allowed in Zone V construction, but there will be occasional communities where these foundations exist in some numbers, due to map revisions or delays in compliance enforcement. For this reason, Zone V elevations are provided for these foundation types.

Table 5-17 Default Floor Heights Above Grade to Top of Finished Floor (Coastal)

ID	Foundation Type	Pre-FIRM	Post-FIRM	
			Zone A	Zone V
1	Pile (or column)	7 feet	8 feet	8 feet
2	Pier (or post and beam)	5 feet	6 feet	8 feet
3	Solid Wall	7 feet	8 feet	8 feet
4	Basement (or Garden Level)	4 feet	4 feet[1]	4 feet[1]
5	Crawlspace	3 feet	4 feet	4 feet[1]
6	Fill	2 feet	2 feet	2 feet[1]
7	Slab	1 foot	1 foot[1]	1 foot[1]

[1] Typically not allowed but may exist
** Source Data: Expert Opinion*

The heights shown here are default values for coastal areas. In most cases, regulations are written to include a freeboard above the BFE. Additionally, typical engineering design will shift from one foundation type to another depending on the height requirements to elevate the structure above BFE. It is recommended to use the following guidelines for post-FIRM foundation distributions:

- *Pile*: This foundation is typically utilized when the BFE plus freeboard is 8 feet or greater.
- *Pier:* This foundation is typically utilized when the BFE plus freeboard is less than 6 feet (Zone A) and 8 feet (Zone V). If BFE plus freeboard is greater than these heights, typical construction practice is to use other foundation types, such as solid walls or piles.
- *Solid Wall:* This foundation is typically utilized when the BFE plus freeboard is less than 8 feet. If the BFE plus freeboard is greater than 8 feet, general construction practice is to use piles.
- *Basement:* This is typically not allowed in post-FIRM development. The user should establish the post-FIRM distribution to match what is actually occurring in the regulated areas.
- *Crawlspace*: This foundation is typically utilized when the BFE plus freeboard is less than 4 feet. If BFE plus freeboard is greater than 4 feet, typical construction practice is to use other foundation types such as piers, solid walls, or piles. This foundation type is typically not allowed in areas identified as Zone V.
- *Fill:* This foundation is typically utilized when the BFE plus freeboard is less than 2 feet. If the BFE plus freeboard is greater than 2 feet, typical construction practice is to use other foundation types such as crawlspace, piers, solid walls, or piles. This foundation type is typically not allowed in areas identified as Zone V.
- *Slab-on-Grade:* This is typically not allowed in post-FIRM development. The user should establish the post-FIRM distribution to match what is actually occurring in the regulated areas.

As with the values in Table 5-16, the foundation results in Table 5-17 were slightly modified to account for the unusually high percentage of pile foundations.

5.6.2 First Floor Height Above Grade

Due to a lack of geographic variance of the First Floor Height Above Grade (FFHAG) by pre-/post-FIRM, Census block controlling hazard type, Flood Zone, and foundation type, FFHAG was factored out from the flood mapping schemes. FFHAG is now available from the Flood Model GUI by following Inventory > General Building Stock > First Floor Height Above Grade. The Default FFHAG set for the whole United States is shown in Table 5-18. The default FFHAG set is read-only. Users can customize the user-defined FFHAG set (located on the next tab). The 168 combinations yield 56 independent FFHAG IDs, please refer to the notes for FFHAG ID description.

Table 5-18 Default First Floor Height Above Grade Set

FFE ID	FIRM	Block Type	Zone	Foundation	Basement	First Floor Height (ft.)	Notes
1	Pre-	Riverine	Zone A Coastal	Pile	N	7	Pre-FIRM construction in Census blocks with Riverine construction (e.g., Hazard Type = R)
			Zone CA Coastal	Pile	N	7	
			Riverine	Pile	N	7	
			Zone V Coastal	Pile	N	7	
2	Pre-	Riverine	Zone A Coastal	Pier	N	5	
			Zone CA Coastal	Pier	N	5	
			Riverine	Pier	N	5	
			Zone V Coastal	Pier	N	5	
3	Pre-	Riverine	Zone A Coastal	Solid Wall	N	7	
			Zone CA Coastal	Solid Wall	N	7	
			Riverine	Solid Wall	N	7	
			Zone V Coastal	Solid Wall	N	7	
4	Pre-	Riverine	Zone A Coastal	Basement/ Garden	B	4	
			Zone CA Coastal	Basement/ Garden	B	4	
			Riverine	Basement/ Garden	B	4	
			Zone V Coastal	Basement/ Garden	B	4	
5	Pre-	Riverine	Zone A Coastal	Crawl Space	N	3	
			Zone CA Coastal	Crawl Space	N	3	
			Riverine	Crawl Space	N	3	
			Zone V Coastal	Crawl Space	N	3	
6	Pre-	Riverine	Zone A Coastal	Fill	N	2	
			Zone CA Coastal	Fill	N	2	
			Riverine	Fill	N	2	
			Zone V Coastal	Fill	N	2	
7	Pre-	Riverine	Zone A Coastal	Slab on Grade	N	1	
			Zone CA Coastal	Slab on Grade	N	1	
			Riverine	Slab on Grade	N	1	
			Zone V Coastal	Slab on Grade	N	1	
8	Post-	Riverine	Zone A Coastal	Pile	N	8	Post-FIRM construction in Census blocks with Riverine construction (e.g., HazardType = R)
			Zone CA Coastal	Pile	N	8	
			Riverine	Pile	N	8	
			Zone V Coastal	Pile	N	8	
9	Post-	Riverine	Zone A Coastal	Pier	N	6	
			Zone CA Coastal	Pier	N	6	
			Riverine	Pier	N	6	
			Zone V Coastal	Pier	N	6	

FFE ID	FIRM	Block Type	Zone	Foundation	Basement	First Floor Height (ft.)	Notes
10	Post-	Riverine	Zone A Coastal	Solid Wall	N	8	
			Zone CA Coastal	Solid Wall	N	8	
			Riverine	Solid Wall	N	8	
			Zone V Coastal	Solid Wall	N	8	
11	Post-	Riverine	Zone A Coastal	Basement/ Garden	B	4	
			Zone CA Coastal	Basement/ Garden	B	4	
			Riverine	Basement/ Garden	B	4	
			Zone V Coastal	Basement/ Garden	B	4	
12	Post-	Riverine	Zone A Coastal	Crawl Space	N	4	
			Zone CA Coastal	Crawl Space	N	4	
			Riverine	Crawl Space	N	4	
			Zone V Coastal	Crawl Space	N	4	
13	Post-	Riverine	Zone A Coastal	Fill	N	2	
			Zone CA Coastal	Fill	N	2	
			Riverine	Fill	N	2	
			Zone V Coastal	Fill	N	2	
14	Post-	Riverine	Zone A Coastal	Slab on Grade	N	1	
			Zone CA Coastal	Slab on Grade	N	1	
			Riverine	Slab on Grade	N	1	
			Zone V Coastal	Slab on Grade	N	1	
15	Pre-	Coastal	Zone A Coastal	Pile	N	7	Pre-FIRM construction in Census blocks with Coastal construction (e.g., HazardType = C)
			Zone CA Coastal	Pile	N	7	
			Riverine	Pile	N	7	
			Zone V Coastal	Pile	N	7	
16	Pre-	Coastal	Zone A Coastal	Pier	N	5	
			Zone CA Coastal	Pier	N	5	
			Riverine	Pier	N	5	
			Zone V Coastal	Pier	N	5	
17	Pre-	Coastal	Zone A Coastal	Solid Wall	N	7	
			Zone CA Coastal	Solid Wall	N	7	
			Riverine	Solid Wall	N	7	
			Zone V Coastal	Solid Wall	N	7	
18	Pre-	Coastal	Zone A Coastal	Basement/ Garden	B	4	Pre-FIRM construction in Census blocks with Coastal construction (e.g., HazardType = C)
			Zone CA Coastal	Basement/ Garden	B	4	
			Riverine	Basement/ Garden	B	4	
			Zone V Coastal	Basement/ Garden	B	4	

FFE ID	FIRM	Block Type	Zone	Foundation	Basement	First Floor Height (ft.)	Notes
19	Pre-	Coastal	Zone A Coastal	Crawl Space	N	3	
			Zone CA Coastal	Crawl Space	N	3	
			Riverine	Crawl Space	N	3	
			Zone V Coastal	Crawl Space	N	3	
20	Pre-	Coastal	Zone A Coastal	Fill	N	2	
			Zone CA Coastal	Fill	N	2	
			Riverine	Fill	N	2	
			Zone V Coastal	Fill	N	2	
21	Pre-	Coastal	Zone A Coastal	Slab on Grade	N	1	
			Zone CA Coastal	Slab on Grade	N	1	
			Riverine	Slab on Grade	N	1	
			Zone V Coastal	Slab on Grade	N	1	
22	Post-	Coastal	Zone A Coastal	Pile	N	8	Post-FIRM construction in Census blocks with Coastal construction (e.g., HazardType = C), subjected to A-Zone type flooding, including both Riverine and Coastal A-Zones (e.g., ZoneTypeID = 1)
			Zone CA Coastal	Pile	N	8	
			Riverine	Pile	N	8	
23	Post	Coastal	Zone A Coastal	Pier	N	6	
			Zone CA Coastal	Pier	N	6	
			Riverine	Pier	N	6	
24	Post-	Coastal	Zone A Coastal	Solid Wall	N	8	
			Zone CA Coastal	Solid Wall	N	8	
			Riverine	Solid Wall	N	8	
25	Post-	Coastal	Zone A Coastal	Basement/ Garden	B	4	
			Zone CA Coastal	Basement/ Garden	B	4	
			Riverine	Basement/ Garden	B	4	
26	Post-	Coastal	Zone A Coastal	Crawl Space	N	4	
			Zone CA Coastal	Crawl Space	N	4	
			Riverine	Crawl Space	N	4	
27	Post-	Coastal	Zone A Coastal	Fill	N	2	
			Zone CA Coastal	Fill	N	2	
			Riverine	Fill	N	2	
28	Post-	Coastal	Zone A Coastal	Slab on Grade	N	1	
			Zone CA Coastal	Slab on Grade	N	1	
			Riverine	Slab on Grade	N	1	
29	Post-	Coastal	Zone V Coastal	Pile	N	8	Post-FIRM construction in Census blocks with Coastal construction (e.g., HazardType = C), subjected to V-Zone type flooding (e.g., ZoneTypeID = 2)
30	Post-	Coastal	Zone V Coastal	Pier	N	8	
31	Post-	Coastal	Zone V Coastal	Solid Wall	N	8	
32	Post-	Coastal	Zone V Coastal	Basement/ Garden	B	4	
33	Post-	Coastal	Zone V Coastal	Crawl Space	N	4	
34	Post-	Coastal	Zone V Coastal	Fill	N	2	

FFE ID	FIRM	Block Type	Zone	Foundation	Basement	First Floor Height (ft.)	Notes
35	Post-	Coastal	Zone V Coastal	Slab on Grade	N	1	
36	Pre-	Lake	Zone A Coastal	Pile	N	7	Pre-FIRM construction in Census blocks with Lakes construction (e.g., HazardType = L)
			Zone CA Coastal	Pile	N	7	
			Riverine	Pile	N	7	
			Zone V Coastal	Pile	N	7	
37	Pre-	Lake	Zone A Coastal	Pier	N	5	
			Zone CA Coastal	Pier	N	5	
			Riverine	Pier	N	5	
			Zone V Coastal	Pier	N	5	
38	Pre-	Lake	Zone A Coastal	Solid Wall	N	7	
			Zone CA Coastal	Solid Wall	N	7	
			Riverine	Solid Wall	N	7	
			Zone V Coastal	Solid Wall	N	7	
39	Pre-	Lake	Zone A Coastal	Basement/ Garden	B	4	
			Zone CA Coastal	Basement/ Garden	B	4	
			Riverine	Basement/ Garden	B	4	
			Zone V Coastal	Basement/ Garden	B	4	
40	Pre-	Lake	Zone A Coastal	Crawl Space	N	3	
			Zone CA Coastal	Crawl Space	N	3	
			Riverine	Crawl Space	N	3	
			Zone V Coastal	Crawl Space	N	3	
41	Pre-	Lake	Zone A Coastal	Fill	N	2	
			Zone CA Coastal	Fill	N	2	
			Riverine	Fill	N	2	
			Zone V Coastal	Fill	N	2	
42	Pre-	Lake	Zone A Coastal	Slab on Grade	N	1	
			Zone CA Coastal	Slab on Grade	N	1	
			Riverine	Slab on Grade	N	1	
			Zone V Coastal	Slab on Grade	N	1	
43	Post-	Lake	Zone A Coastal	Pile	N	8	Post-FIRM construction in Census blocks with Lakes construction (e.g., HazardType = L), subjected to A-Zone type flooding, including both Riverine and Coastal A-Zones (e.g., ZoneTypeID = 1)
			Zone CA Coastal	Pile	N	8	
			Riverine	Pile	N	8	
44	Post-	Lake	Zone A Coastal	Pier	N	6	
			Zone CA Coastal	Pier	N	6	
			Riverine	Pier	N	6	
45	Post-	Lake	Zone A Coastal	Solid Wall	N	8	
			Zone CA Coastal	Solid Wall	N	8	
			Riverine	Solid Wall	N	8	

FFE ID	FIRM	Block Type	Zone	Foundation	Basement	First Floor Height (ft.)	Notes
46	Post-	Lake	Zone A Coastal	Basement/ Garden	B	4	
			Zone CA Coastal	Basement/ Garden	B	4	
			Riverine	Basement/ Garden	B	4	
47	Post-	Lake	Zone A Coastal	Crawl Space	N	4	Post-FIRM construction in Census blocks with Lakes construction (e.g., HazardType = L), subjected to A-Zone type flooding, including both Riverine and Coastal A-Zones (e.g., ZoneTypeID = 1
			Zone CA Coastal	Crawl Space	N	4	
			Riverine	Crawl Space	N	4	
48	Post-	Lake	Zone A Coastal	Fill	N	2	
			Zone CA Coastal	Fill	N	2	
			Riverine	Fill	N	2	
49	Post-	Lake	Zone A Coastal	Slab on Grade	N	1	
			Zone CA Coastal	Slab on Grade	N	1	
			Riverine	Slab on Grade	N	1	
50	Post-	Lake	Zone V Coastal	Pile	N	8	Post-FIRM construction in Census blocks with Lakes construction (e.g., HazardType = L), subjected to V-Zone type flooding (e.g., ZoneTypeID = 2)
51	Post-	Lake	Zone V Coastal	Pier	N	8	
52	Post-	Lake	Zone V Coastal	Solid Wall	N	8	
53	Post-	Lake	Zone V Coastal	Basement/ Garden	B	4	
54	Post-	Lake	Zone V Coastal	Crawl Space	N	4	
55	Post-	Lake	Zone V Coastal	Fill	N	2	
56	Post-	Lake	Zone V Coastal	Slab on Grade	N	1	

5.6.3 Building Year Built and Pre-FIRM/Post-FIRM Designation

The U.S. Congress established the National Flood Insurance Program (NFIP) with the passage of the National Flood Insurance Act of 1968. Therefore, all buildings built before the community entered the NFIP should be designated as pre-FIRM. Post-FIRM designation should be based on the year the community (viewed by Census block in the Flood Specific Occupancy Mapping) started participating in the NFIP. Users can edit the entry date and modify pre-FIRM/post-FIRM designations.

The NFIP entry dates were updated for all communities in the United States during the 2014 Hazus data update. Using the FEMA Community boundaries and IDs of all communities in the United States and Census block centroids, a community ID was assigned to each Census block. The community IDs were related to the Flood Map Status Information Service (FMSIS, 2014) database, which contains the NFIP entry dates. The Hazus database tables for this information (flSchemeMapping tables) were updated in the state data.

5.7 Other Hurricane Building Characteristics

Table 5-1 mentions two hurricane-related mapping schemes. The first hurricane mapping scheme is hurricane general building type to hurricane specific building type, as shown in Table 4-3. Aerial photographs were used to estimate the fraction of one and two-story houses. Data from the Residential Construction Mitigation Program (RCMP) was used to identify the number of stories, shape, and specific occupancy. Historic building codes were used to determine building types in different parts of the country (National Building Code vs. International Building Code, etc.) There are currently no plans to update these hurricane specific building types.

The second hurricane mapping scheme mentioned in Table 5-1 was hurricane specific building type to hurricane wind building characteristics (WBCs). The following sections will provide an overview of each of these characteristics.

5.7.1 Roof Shape

Roof shape can have three values in Hazus: Hip, Gable, and Flat. The shape of a roof, siting, fastening, and composition will determine the structure's resilience during a hurricane. Coastal areas especially require corrosion-resistant structural connectors. A hip roof is a type of roof where all sides slope downwards to the walls, usually with a gentle slope. Hipped roofs have no gables or other vertical sides to the roof. A gable roof is a classic, most commonly occurring roof shape in temperate climate areas. It consists of two roof sections sloping opposite directions and placed so the highest, horizontal edges meet to form the roof ridge. A flat roof is almost level in contrast with sloped roofs. They are mostly used in arid climates and allow the roof space to be used for living space or a living roof. Flat roofs are often used for commercial buildings throughout the world.

5.7.2 Roof Cover Type

Roof cover refers to the layers of materials that make up the roof above roof deck. Built-up roof (BUR) covers are composed of multiple plies of roofing felts adhered to each other and to the insulation substrate with a full mop of hot asphalt, coal tar, or cold adhesive. The number of plies of roofing felt ranges from three to five. Roofing felts are commonly made of polyester, organic or glass-based materials. The surfacing on BUR covers is most often gravel or slag.

Single-ply Membrane (SPM) covers are normally attached to the insulation substrate by adhesives (hot asphalt or cold applied materials) or by mechanical fasteners. Adhered SPM covers can be fully adhered or partially adhered. The adhesive in partially adhered SPM covers will typically have 50% coverage in the central portions of the roof and greater coverage at or near the edges and corners of the roof. Common membranes are thermoplastic membranes, thermoset membranes, modified bitumen membranes, and liquid applied membranes.

Hazus WBCs include roof covering conditions with values of New, Good, and Poor, and secondary water resistance with values of Yes and No.

5.7.3 Roof Deck Attachment

Roof deck is defined as boards or plywood nailed to the roof rafters or trusses. It is also called roof sheathing and can fail during a high-wind event if not properly installed or insufficiently fastened. Sheathing loss is one of the most common structural failures in hurricanes. Fastener spacing and size requirements for coastal constructions are typically different than for non-coastal areas.

For all roof shapes, Hazus uses two roof fastener conditions of 6-penny and 8-penny nails, different spacing options of 6x12 inches or 6x6 inches, and deck age categories of New/Average or Old.

5.7.4 Roof Frame and Wall Connections

Framing the roof properly is important for the stability of the entire building envelope. The frame of the roof needs to be tied down appropriately, especially in high-wind situations. Hazus WBCs include Strapped and Toe-Nailed roof-wall connection conditions and joist spacing of 4 or 6 feet.

5.7.5 Fenestrations

Fenestration is the design, construction, or presence of openings in a building. Openings need to be designed to be water and wind resistant. A successful moisture barrier system will limit water infiltration into unwanted areas and allow drainage and drying of wetted building materials. Hazus WBCs include Window Area of Low, Medium or High and Shutters as Yes or No. For unshuttered houses with garages, WBCs for garage doors include None, Weak, or Standard Door. For shuttered houses with garages, the WBCs for garage doors are None or meet the South Florida Building Code 1994 standards.

5.7.6 Other Characteristics

Other WBCs take into account other structure characteristics that influence building performed during wind events. For example, Hazus uses a WBC for Wind Debris to include Residential, Residential and Commercial Mix, Varies by Direction, and None. Units per flood of single unit versus multi-unit is another WBC. For masonry structures, there is a WBC for with and without reinforcing. Finally, there is a Tie Down WBC with Yes and No values.

5.7.7 WBC Mapping Schemes

Like the development of the specific building types, surveys were used to develop the additional WBCs, focusing primarily on roof types. Aerial photographs were used to estimate roof cover type. In cases where the homes had a roof, which was a combination of a hip section and a flat section, it was classified as a hip roof building. The same classification scheme was used for homes with combined flat and gable roofs. In cases where the roof was a hip/gable combination, the building was classified by the dominant roof style. Roof cover data was also collected from the Florida RCMP. Other characteristic data were collected using a survey sent to contractors familiar with construction practices for hurricane-prone regions.

More details on these mapping schemes can be found in the *Hazus Hurricane Model Technical Manual* (FEMA, 2021).

5.8 Other Tsunami Building Characteristics

When FEMA developed the Tsunami Methodology, they leveraged the existing Earthquake and Flood Model-specific inventory attributes, rather than requiring the development of new tsunami-specific vulnerability attributes. The tsunami building damage functions described are based entirely on specific earthquake building types and seismic design levels used by the Earthquake Model. The estimate of finished floor height required to estimate the depth of tsunami within structures is based on the Flood Model foundation types and finished floor height relationships.

Because the Tsunami Methodology uses these other existing Hazus tables for certain building characteristics, only one new unique tsunami inventory table was required for modeling. The point data feature class tsGbsNsi was created and loaded into each Tsunami State Database. The required attributes for tsGbsNsi are summarized in Table 5-19 and it is the only inventory dataset required to produce tsunami general building stock losses and casualties.

Table 5-19 Tsunami Model National Structure Inventory (SQL Table Name *tsNsiGbs*)

Column Name	Description	Data Type
NsiID	Unique ID	String Data: Max 24 characters
EqBldgTypeId	Index Value Based on Specific Earthquake Building Type	Integer Data: Small integer type used for ID fields
EqDesignLevelId	Index Value Based on Seismic Design Level	Integer Data: Small integer type used for ID fields
SOccTypeId	Index Value Based on Hazus Specific Occupancy Type	Integer Data: Small integer type used for ID fields
FoundTypeId	Index Value Based on Hazus Flood Foundation Type	Integer Data: Small integer type used for ID fields
CBFips	Census Block ID	String Data: Max 15 characters
NStories	Number of Stories	Integer Data: Regular integer type used for data fields
AreaSqft	Building Area (ft^2)	Decimal Data: Numeric type with 38 digits and 8 decimal places
PerSqftAvgVal	Square footage Replacement Value ($\$/ft^2$)	Decimal Data: Numeric type with 38 digits and 20 decimal places
FirstFloorHt	Height of First Floor Relative to Ground Surface (feet)	Decimal Data: Numeric type with 38 digits and 8 decimal places
ValStruct	Replacement Value of Structure ($USD)	Decimal Data: Numeric type with 38 digits and 8 decimal places
ValCont	Replacement Value of Contents ($USD)	Decimal Data: Numeric type with 38 digits and 8 decimal places
ValOther	Replacement Value of Other ($USD)	Decimal Data: Numeric type with 38 digits and 8 decimal places
ValVehic	Replacement Value of Vehicles ($USD)	Decimal Data: Numeric type with 38 digits and 8 decimal places
MedYrBlt	Median Year Built	Integer Data: Regular integer type used for data fields
Pop2pmU65	Under Age 65 Daytime Population	Integer Data: Regular integer type used for data fields
Pop2pmO65	Age 65 and Older Daytime Population	Integer Data: Regular integer type used for data fields
Pop2amU65	Under Age 65 Nighttime Population	Integer Data: Regular integer type used for data fields
Pop2amO65	Age 65 and Older Nighttime Population	Integer Data: Regular integer type used for data fields
Latitude	Latitude (Decimal Degrees)	Decimal Data: Numeric type with 38 digits and 8 decimal places
Longitude	Longitude (Decimal Degrees)	Decimal Data: Numeric type with 38 digits and 8 decimal places

The following sections provide details on how particular fields in this table were derived for NSI data.

5.8.1 Earthquake-Derived Characteristics

In the case of the Earthquake SBTs, they were assigned to the NSI points based on the percentages available in the existing Earthquake Model State Occupancy to Building Type Mapping Schemes. The field EqBldgTypeId is an ID representing the Earthquake Model SBTs.

Since these did not exist for the new territories in the Tsunami Model, Hawaii was used for the Pacific Territories, while Puerto Rico's schema was applied to estimate SBTs for the Virgin Islands. Note that all existing Earthquake Model schemes assign only low-rise building types (<4-5 stories). These distribution tables were added to each state database. An example from Hawaii for COM1 building type distribution percentages are shown in Table 5-20.

Table 5-20 Hawaii Tsunami Occupancy to Building Type Distribution for COM1 Example

SchemeID	Specific Occupancy	EqBldgTypeId	Percent
HI2	COM1	C1L	5.92%
HI2	COM1	C2L	9.99%
HI2	COM1	C3L	1.11%
HI2	COM1	PC1	15.17%
HI2	COM1	PC2L	4.81%
HI2	COM1	RM1L	16.08%
HI2	COM1	RM2L	1.92%
HI2	COM1	S1L	8.97%
HI2	COM1	S2L	1.04%
HI2	COM1	S3	1.95%
HI2	COM1	S4L	1.04%
HI2	COM1	URML	6%
HI2	COM1	W2	26%

The Tsunami Model also has a field called EqDesignLevelId that represents the Earthquake Model seismic design level of the structure, as shown in Table 5-21.

Table 5-21 Hazus Tsunami Seismic Design Levels

DesignLevelID	EqDesignLevelId	DesignLevelDesc
1	PC	Pre-Code
2	LC	Low Code
3	MC	Moderate Code
4	HC	High Code
5	LS	Low Code - Special
6	MS	Moderate Code - Special
7	HS	High Code - Special

The Earthquake Model uses a statewide default mapping scheme to assign seismic design level. For the NSI, an approach utilizing Census block-level data with the estimated Median Year Built of the structure, and typical benchmark code adoption years for each State and Territory was used to assign a seismic design level for structures within the Census block. The benchmark years are based on a review of online resources, including information from the International Code Council's

Building Code Assessment Project, as well as the Earthquake Engineering Research Institute and the Western States Seismic Policy Council. Since benchmark years represent a combination of considerations regarding adoption, implementation and enforcement were also used in selecting the default design levels summarized in Table 5-22. This approach better distributes structures in older areas to lower seismic designs rather than randomly assigning seismic design levels across the state regardless of when the structures were built. Also, the vertical Occupancy to EQ Specific Building Type mapping scheme was adopted from Puerto Rico and provided as a new State Database table (*tsSOccupSBTPct*) for each Territory.

Table 5-22 Estimated Benchmark Year Tsunami Seismic Design Levels for States and Territories

State	Pre-Code* (PC)	Low Code (LC)	Moderate Code (MC)	High Code (HC)	Special High-Code (HS)
Alaska	≤ 1964	1965-1994	1995-2000	≥ 2001	NA
California	≤ 1940	1941-1975	1976-1994	1995-2000	≥ 2001
Hawaii	≤ 1974	1975-1994	1995-2000	≥ 2001	NA
Oregon	≤ 1974	1975-1994	1995-2000	≥ 2001	NA
Washington	≤ 1955	1956-1974	1975-2003	≥ 2004	NA
Puerto Rico	≤ 1974	1975-1994	1995-2005	≥ 2006	NA
U.S. Virgin Islands	≤ 1974	1975-2005	≥ 2006	NA	NA
Northern Mariana Islands	≤ 1974	1975-2005	≥ 2006	NA	NA
Guam	≤ 1974	1975-2005	≥ 2006	NA	NA
American Samoa	≤ 1974	1975-2005	≥ 2006	NA	NA

** W1 in CA coastal counties will be at least MC (no PC or LC W1, per EQ Technical Manual) and LC (no PC W1) in other States*

Since the current default earthquake mapping schemes lack both mid- and high-rise structures, thresholds based on building size for the NSI structures were utilized to reclassify low-rise into mid-rise (four to seven stories), and high-rises (eight or more stories) for the Honolulu region. This is a critical requirement for the implementation of the Tsunami Methodology in coastal urban areas. The continued classification of these buildings into low-rise categories will substantially inflate losses in urban areas when erroneously applying low-rise tsunami damage state parameters to high-rise buildings.

Based on the numbers of high and mid-rise buildings in the Honolulu region, the largest NSI buildings based on building area were assigned high- and low-rise building types. For example, if 100 high-rise and 200 mid-rise buildings were identified in the region, the largest 100 NSI points were assigned high-rise types and the next 200 largest were assigned to mid-rise earthquake specific building types, based on their low-rise earthquake specific building type. The assumption is that large area buildings in coastal urban environments indicate taller, rather than wider buildings. Available data sources were used for calibrations, including The Skyscraper Page, to ensure that counts of high-rise types in the urban area are in rough alignment. The remaining four-story buildings in the NSI structure database were assigned to mid-rise building types. This may be feasible for other urban areas and can benefit Earthquake Model building mapping schemes that currently include only low-rise building types.

5.8.2 Flood-Derived Characteristics

Tsunami Model data include fields related to First Floor Height (FirstFloorHt) and Foundation Type (FoundTypeId). These attributes are interrelated since the First Floor Height is directly related to the Flood Foundation Type. It includes a Foundation Type ID and the corresponding First Floor Height based on the Flood Model for evaluation of tsunami inundation depth in the structure. As summarized in Table 5-23, these data provide estimates of first floor heights as a function of foundation type and building age. Median Year Built relative to the Flood Insurance Rate Map (FIRM) adoption for the community representing entry into the NFIP were used to establish pre-FIRM or post-FIRM construction. Table 5-24 provides the assumed default distribution of foundation types for coastal areas.

Table 5-23 Default Tsunami First-Floor Heights above Grade to Top of Finish

Foundation Type	Pre-FIRM (feet)	Post-FIRM	
		Zone A (feet)	Zone V (feet)
Pile (or column)	7	8	8
Pier (or post and beam)	5	6	8
Solid Wall	7	8	8
Basement	4	4	4
Crawl	3	4	4
Fill	2	2	2
Slab	1	1	1

Table 5-24 Percent Distribution of Tsunami Foundation Types for Coastal Areas

Foundation Types	Pile	Pier	Solid Wall	Basement	Crawl-space	Fill	Slab
Pre-Firm Construction – All	7%	7%	1%	2%	46%	0%	37%
Post-Firm Construction – Zone A (Special Flood Hazard Area)	20%	5%	0%	0%	55%	0%	20%
Post-Firm Construction – Zone V (Special Flood Hazard Area – High Hazard)	60%	25%	0%	0%	10%	0%	5%

5.8.3 Other Tsunami Characteristics

Tsunami Model data has a field called SOccType that assigns the Hazus Specific Occupancy Type. This is the occupancy type of the structure as defined in the Hazus GBS data aggregated by Census block. NSI points are based on the number of a given occupancy type in a Census block provided by the Hazus GBS. For example, if the Hazus GBS indicates there are seven RES1 occupancy types in a particular Census block, then seven RES1 points are distributed within the developed portion of that block. This helps to define attributes of the structure like building and content value, day and night population distribution, number of stories, number of households, and other generic characteristics.

The default distribution and data associated with each educational (EDU) NSI point has been replaced by a site-specific dataset of school locations, including Colleges and Universities, Private Schools, and Public Schools. The data include numbers of students, teachers, and staff. The data provide national coverage, ensure more accurate locations of school facilities in relation to the tsunami hazard, and provide important daytime population exposure estimates for evacuation and casualty modeling. This dataset is available from the U.S. EPA's Environmental Dataset Gateway and is available for download as ORNL_Education.zip.

The field CBFips represents the Census block that the structure exists in. This attribute is a string field with 15 numeric characters. In the case of data for the U.S. territories, this is a 15-character ID of the 1 km grid cell with population. Views of Hazus GBS based on NSI points inventory and results tables, as well as thematic mapping, are based on the Census Block IDs and geometries.

The field N_Stories represents the structure's number of stories provided for single and multi-family residences based on U.S. Census region. This is an integer and is also used to classify Earthquake Specific Building Types into low-, mid-, and high-rise earthquake building types. Since no high-rises exist in the default Hazus mapping schemes, the maximum number of stories in the base NSI data is 5 stories. For new territories in the Tsunami Model, the Puerto Rico multi-story residential distribution was used. However, the number of stories was occasionally provided in the essential facility data for the territories.

The fields called AreaSqft and PerSqftAvgVal are interrelated attributes since the base NSI data do not include building area (AreaSqft). Processing consisted of determining the average replacement value per square foot for each NSI structure (PerSqftAvgVal) by dividing the total dollar value of a given specific occupancy by the total building area of the occupancy for each Census tract. As will be described in Section 6, building area valuations are based on RSMeans replacement costs by occupancy types that are then modified by county modification factors to reduce or increase replacement costs based on local costs of materials and services. In addition, the household income for each Census tract relative to the national median is used to adjust the single-family (RES1) replacement costs based on construction quality. Once PerSqftAvgValue is calculated, AreaSqft is estimated by dividing structural value (ValStruct) by PerSqftAvgValue.

Building areas for territories, as shown in Table 5-25, were developed from building footprint data for American Samoa. Average building area by specific occupancy type were used when the area was not available using footprints.

Table 5-25 Default Building Area for NSI Data for Territories Except Puerto Rico

Specific Occupancy	Hazus Definition	Territory Default Building Area (sq.ft)[1]
AGR1	Agriculture	3,000
COM1	Retail Trade	3,000
COM10	Parking	5,500
COM2	Wholesale Trade	3,700
COM3	Personal and Repair Services	3,800
COM4	Professional/Technical Service	4,600
COM5	Banks	5,000
COM6	Hospital	5,000
COM7	Medical Office/Clinic	3,000
COM8	Entertainment & Recreation	2,900
COM9	Theaters	7,000
EDU1	Schools/Libraries	2,700

Specific Occupancy	Hazus Definition	Territory Default Building Area (sq.ft)[1]
EDU2	Colleges/Universities	9,200
GOV1	General Services	3,300
GOV2	Emergency Response	5,000
IND1	Heavy	2,200
IND2	Light	3,700
IND3	Food/Drugs/Chemicals	4,900
IND4	Metals/Minerals Processing	4,900
IND5	High Technology	4,900
IND6	Construction	4,900
REL1	Church	6,300
RES1	Single-Family Dwelling	1,500
RES2	Mobile Home	1,000
RES3A	Multi-Family Dwelling - Duplex	2,700
RES3B	Multi-Family Dwelling – 3-4 Units	5,400
RES3C	Multi-Family Dwelling – 5-9 Units	7,300
RES3D	Multi-Family Dwelling – 10-19 Units	10,000
RES3E	Multi-Family Dwelling – 20-49 Units	31,000
RES3F	Multi-Family Dwelling – 50+ Units	50,000
RES4	Temporary Lodging (e.g., hotels)	9,300
RES5	Institutional Dormitory (e.g., prisons)	30,000
RES6	Nursing Home	20,000

[1] Assigned based on occupancy averages determined from available building footprints and parcel data for U.S. territories, rather than U.S. averages (MeansModelDesc); institutions such as schools, hospitals, etc. are represented by multiple points on structure and therefore each building footprint is typically far less than institutional averages. Puerto Rico uses standard GBS RSMeans 2018 replacement values.

The fields called ValStruct, ValCont, ValOther, and ValVehic are provided by the NSI data based on the Hazus GBS building and content replacement values by occupancy type, as well as the vehicle replacement value disaggregated from the block to the NSI point. These are the valuation attributes in dollars for Structure, Content, Other, and Vehicles, respectively. These are directly obtained from Hazus GBS valuations for each occupancy type. The aggregated specific occupancy value within each Census block is equally distributed to each NSI point in that block based on specific occupancy.

Median year built (fieldname MedYrBlt) is provided by the U.S. Census and applied within the Hazus demographic data attributes at the Census block-level. These values are contained in the hzDemographicsB table in each state database and were joined with NSI structure data points based on Census Block ID.

Tsunami Model data also made use of 2010 Census demographic data to provide the population distribution by age and general occupancy types that were used to populate the Hazus demographic table at the tract level (hzDemographicsT) as shown in Table 5-26.

Table 5-26 Example of Tsunami Tract Level Demographics Data for Guam Used for Population Distribution

Tract	Total Pop.	Res. Day		Res. Night		Working Com.		Working Ind.		Commute 5pm	School Enrollment	
		65+	Under 65	65+	Under 65	Day	Night*	Day	Night		K to 12	College
6601004650	3,808	313	732	313	3,332	1,598	160	29	3	200	936	200
6601007250	4,917	436	1,294	436	4,313	1,631	163	48	5	215	1,293	215
6601013100	2,137	181	440	181	1,867	864	86	24	2	121	507	121
6601017650	8,875	717	1,722	717	7,787	3,639	364	68	7	524	2,205	524
6601026100	6,822	445	1,419	445	6,094	2,762	276	66	7	389	1,741	389
6601028050	44,943	3,252	9,737	3,252	39,880	17,648	1,765	459	46	2,229	11,618	2,229
6601034800	1,051	56	383	56	955	387	39	17	2	34	174	34
6601036500	2,273	145	531	145	2,041	844	84	25	3	103	625	103
6601046250	15,191	789	3,549	789	13,808	5,797	580	139	14	1,130	3,787	1,130
6601050150	1,850	138	510	138	1,654	572	57	5	1	63	562	63
6601051450	6,825	427	1,701	427	6,128	2,584	258	116	12	286	1,711	286
6601059250	1,454	115	283	115	1,279	591	59	12	1	99	354	99
6601062500	6,084	370	2,157	370	5,626	1,710	86	43	2	396	1,408	396
6601065750	2,592	245	558	245	2,240	1,052	105	20	2	128	589	128
6601069650	3,050	198	685	198	2,733	1,185	119	9	1	160	813	160
6601071600	19,685	1,374	3,956	1,374	17,351	9,408	941	192	19	930	3,825	930
6601078750	782	33	249	33	722	264	26	7	1	27	202	27
6601083300	20,539	1,123	5,338	1,123	18,674	7,213	721	205	21	1,232	5,428	1,232
6601084600	6,480	390	1,552	390	5,846	2,404	240	21	4	335	1,758	335
Total	**159,358**	**10,747**	**36,796**	**10,747**	**142,331**	**62,153**	**6,130**	**1,525**	**150**	**8,601**	**39,536**	**8,601**

** Working night is estimated based on 5% of daytime working population. Res – Residential. Com – Commercial. Ind – Industrial.*

This data is stored in the following fields:

- *POP_2AM_U65:* This is the population at night for the structure for people under the age of 65 based on Census Bureau's LEHD data. This is an integer.
- *POP_2AM_O65***:** This is the population at night for the structure for people over the age of 65 based on Census Bureau's LEHD data. This is an integer.
- *POP_2PM_U65:* This is the population at day for the structure for people under the age of 65 based on Census Bureau's LEHD data. This is an integer.
- *POP_2PM_O65:* This is the population at day for the structure for people over the age of 65 based on Census Bureau's LEHD data. This is an integer.

The Census block-level demographic data are not directly provided by the U.S. Census; however, the 2010 U.S. Census tract level demographics were distributed to the 1 km blocks using a population ratio determined from the Landscan 2014 total ambient (24 hour average) population.

Distribution of the population by age and general occupancy type was performed by first calculating a population distribution ratio for each NSI point. The ratio is the NSI point building area divided by the total building area for the general occupancy type for the Census tract, and provided the basis for the 2010 Census population distribution to the NSI points (Table 5-27), with few exceptions described below.

Table 5-27 Distribution of 2010 Census Population to Tsunami NSI for Territories Except Puerto Rico

Census 2010	National Structure Inventory
O65ResidDay	Distribute to Residential (all res except RES4 & RES6) Pop2pmO65
U65ResDay	Distribute to Residential (all res except RES4 & RES6) Pop2pmU65
O65ResNight	Distribute to Residential (all res except RES4 & RES6) Pop2amO65
U65ResNight	Distribute to Residential (all res except RES4 & RES6) Pop2amU65
WorkingCom	Distribute to Commercial (and GOV1, exclude COM6 & COM10) Pop2pmU65
WorkComNight	Distribute to Commercial (and GOV1, exclude COM6 & COM10) Pop2amU65
WorkingInd	Distribute to Industrial Pop2pmU65
WorkIndNight	Distribute to Industrial Pop2amU65
SchoolEnrollmentKto12	Distribute to EDU1 Pop2pmU65
SchoolEnrollmentCollege	Distribute to EDU2* Pop2pmU65

** Based on a ratio determined by the total EDU2 building area for the State, based on the assumption that college students come from all surrounding tracts. Puerto Rico used standard GBS approaches for these values.*

The use of population by building area (given as square footage) estimates from FEMA (2016) and the *Hazus Earthquake Model Technical Manual* (FEMA, 2021) were utilized to increase accuracy when assigning population to essential and high occupancy facilities. These estimates provide the peak day and peak night defaults utilized by the Hazus CDMS tool for preparing inventories for the Advanced Earthquake Building Model (AEBM) (Table 5-28). The defaults were used to provide a quality check of the results of distributing populations from U.S. Census aggregated data to the NSI points. Rounding the NSI point populations to integers resulted in some loss of fractions. Some manual editing was required, and checks were made to ensure that the night and day populations were balanced and did not exceed state level populations. For example, a check was made to ensure daytime populations did not exceed nighttime for the entire territory.

Table 5-28 Tsunami Estimated Peak Day and Night Occupancy Loads for Territories except Puerto Rico

Occupancy	Description	Peak Day (~2:00 pm) (sq ft/person)	Peak Night (~2:00 am) (sq ft/person)	Sources for Estimate
AGR1	Agriculture	250	12,500	Hazus Flood for employees; Hazus Earthquake for day and night ratios
COM1	Retail Trade	167	8,333	FEMA (2016); Hazus Earthquake for day and night ratios
COM10	Parking	-	-	Not applicable
COM2	Wholesale Trade	900	45,000	Hazus Flood for employees; Hazus Earthquake for day and night ratios
COM3	Personal and Repair Services	590	5,900	Similar to IND2, Hazus Earthquake for day and night ratios

Occupancy	Description	Peak Day (~2:00 pm) (sq ft/person)	Peak Night (~2:00 am) (sq ft/person)	Sources for Estimate
COM4	Professional/Technical Services	250	12,500	FEMA (2016); Hazus Earthquake for day and night ratios
COM5	Banks	250	12,500	FEMA (2016); Hazus Earthquake for day and night ratios
COM6	Hospital	200	667	FEMA (2016); Hazus Earthquake for day and night ratios
COM7	Medical Office/Clinic	200	-	FEMA (2016); Hazus Earthquake for day and night ratios
COM8	Entertainment & Recreation	75	-	Hazus Tsunami
COM9	Theaters	75	-	Hazus Tsunami
EDU1	Grade Schools	71	3,571	FEMA (2016); Hazus Earthquake for day and night ratios
EDU2	Colleges/Universities	83	4,167	FEMA (2016); Hazus Earthquake for day and night ratios
GOV1	General Services	250	12,500	FEMA (2016); Hazus Earthquake for day and night ratios
GOV2	Emergency Response	300	300	Hazus Tsunami
IND1	Heavy	550	5,500	Hazus Flood for employees; Hazus Earthquake for day and night ratios
IND2	Light	590	5,900	Hazus Flood for employees; Hazus Earthquake for day and night ratios
IND3	Food/Drugs/Chemicals	540	5,400	Hazus Flood for employees; Hazus Earthquake for day and night ratios
IND4	Metals/Minerals Processing	730	7,300	Hazus Flood for employees; Hazus Earthquake for day and night ratios
IND5	High Technology	300	3,000	Hazus Flood for employees; Hazus Earthquake for day and night ratios
IND6	Construction	250	2,500	Hazus Flood for employees; Hazus Earthquake for day and night ratios
REL1	Churches and Other Nonprofit	20	-	Hazus Tsunami
RES1	Single-Family Dwelling	1,201	841	Based on National median area (2,169 sqft) and average household (2.58) size from U.S. Census. Hazus Earthquake for day and night ratios
RES2	Manuf. Housing	461	323	FEMA (2016); Hazus Earthquake for day and night ratios
RES3A	Duplex	461	323	FEMA (2016); Hazus Earthquake for day and night ratios
RES3B	Triplex / Quads	461	323	FEMA (2016); Hazus Earthquake for day and night ratios
RES3C	Multi-dwellings (5 to 9 units)	461	323	FEMA (2016); Hazus Earthquake for day and night ratios

Occupancy	Description	Peak Day (~2:00 pm) (sq ft/person)	Peak Night (~2:00 am) (sq ft/person)	Sources for Estimate
RES3D	Multi-dwellings (10 to 19 units)	461	323	FEMA (2016); Hazus Earthquake for day and night ratios
RES3E	Multi-dwellings (20 to 49 units)	461	323	FEMA (2016); Hazus Earthquake for day and night ratios
RES3F	Multi-dwellings (50+ units)	461	323	FEMA (2016); Hazus Earthquake for day and night ratios
RES4	Temporary Lodging - Hotel	2,105	400	FEMA (2016); Hazus Earthquake for day and night ratios
RES5	Institutional Dormitory	2,105	400	FEMA (2016); Hazus Earthquake for day and night ratios
RES6	Nursing Home	115	115	Hazus Tsunami

** General guidance only, peak loads provide worst case estimates of casualties, actual occupants may vary substantially by geography, season, time of day, day of week, holidays, etc. Puerto Rico used standard GBS approach for these values.*

Population distribution to essential and high occupancy facilities for the territories was done separately to ensure peak day and night values were reasonable.

Table 5-29 summarizes the day and night, as well as the under and over 65 population distribution for these occupancy types based on building area.

Table 5-29 Tsunami Population Distributions for Special Occupancy Cases for Territories except Puerto Rico (Area=sq.ft.)

Specific Occupancy	Pop2pmU65	Pop2pmO65	Pop2amU65	Pop2amO65
Hospitals (COM6)	0.95 * Area/200	0.05 * Area/200	0.95 * Area/667	0.05 * Area/667
Emergency Services (GOV2)	Area/300	NA	Area/300	NA
Hotels (RES4)	0.95 * Area/2,105	0.05 * Area/2,105	0.95 * Area/400	0.05 * Area/400
Nursing Homes (RES6)	0.05 * Area/115	0.95 * Area/115	0.05 * Area/115	0.95 * Area/115

It is also important to note that the Tsunami Model casualty interface includes a processing step where the user is presented with the day and night, under and over 65 exposed populations that can be edited to include any transient or visitor populations common in tsunami risk areas such as beach populations and cruise ships.

5.9 Demographics

The current demographic data in Hazus comes from the 2010 Census. The population Census data describes the characteristics of the population, including age, income, housing, and ethnic origin. The population information is aggregated to a Census block-level. The Census data are used to estimate direct social loss due to displaced households, casualties due to floods, and estimating building area for certain occupancy classes.

The Census data were processed for all Census blocks in the United States, and 37 fields of direct importance to the methodology were extracted and stored. These fields are shown in Table 5-30 and are used as part of the modeling for the modules listed in the columns. For example, many of the household unit subcounts are used as part of the calculations for GBS data by specific occupancy types.

Table 5-30 Demographics Data and Module Utilization within Hazus

Description of Field	Shelter	Casualty	Occupancy Types	Transportation and Utility Systems
Total Population in Census Block	*	*		*
Total Household in Census Block	*			*
Total # of People in Group Quarters	*			
Total # of Males and Females < 16 years old	*	*		
Total # of Males and Females 16-65 years old	*	*		
Total # of Males and Females > 65 years old	*	*		
Total # of People – White	*			
Total # of People – Black	*			
Total # of People - Native American	*			
Total # of People – Asian	*			
Total # of People – Hispanic	*			
Total # of People – Pacific Islander	*			
Total # of People – Other Race	*			
Total # of Households with Income < $10,000	*			
Total # of Households with Income $10 - $20K	*			
Total # of Households with Income $20 - $30K	*			
Total # of Households with Income $30 - $40K	*			
Total # of Households with Income $40 - $50K	*			
Total # of Households with Income $50 - $60K	*			
Total # of Households with Income $60 - $75K	*			
Total # of Households with Income $75 - $100K	*			
Total # of Households with Income > $100,000	*			
Total in Residential Population during Day		*		
Total in Residential Population at Night		*		
Total Working Population in Commercial Industry		*		
Total Working Population in Industrial Industry		*		
Total Commuting at 5 PM		*		

Description of Field	Shelter	Casualty	Occupancy Types	Transportation and Utility Systems
Total Owner Occupied - Single Household Units	*		*	
Total Owner Occupied - Multi-Household Units	*		*	
Total Owner Occupied - Multi-Household Structure	*		*	
Total Owner Occupied - Mobile Homes	*		*	
Total Renter Occupied - Single Household Units	*		*	
Total Renter Occupied - Multi-Household Units	*		*	
Total Renter Occupied - Multi-Household Structure	*		*	
Total Renter Occupied - Mobile Homes	*		*	
Total Vacant - Single Household Units			*	
Total Vacant - Multi-Household Units			*	
Total Vacant - Multi-Household Structure			*	
Total Vacant - Mobile Homes			*	
Structure Built before 1940			*	
Structure Built 1940 - 1949			*	
Structure Built 1950 - 1959			*	
Structure Built 1960 - 1969			*	
Structure Built 1970 - 1979			*	
Structure Built 1980 - 1989			*	
Structure Built 1990 – 1998			*	
Structure Built After 1998			*	
Median Year Built			*	

Fields with an Asterisk (*) represent the Census data were processed for all Census blocks in the United States, and 37 fields of direct importance to the methodology were extracted and stored.

For the Tsunami NSI data, the population estimates for each NSI structure are developed by USACE from the Census Bureau's Longitudinal Employer–Household Dynamics (LEHD) data (Will Lehman, USACE Economist, personal communication). The LEHD program produces several datasets, including Quarterly Workforce Indicators and the LEHD Origin-Destination Employment Statistics. These statistics, which can be useful for consequence modeling, provides employment statistics, including worker counts, linking residence and work locations at the Census block-level. The LEHD method of population assignment uses four population pools: working population and residential population, day, and night. Census 2010 population data are used to approximate the total residential population of a Census block. The LEHD dataset is then used to identify the nonresidential population of the block, as well as model the movement of population from residential structures into nonresidential.

Section 6. General Building Stock: Baseline Database for Economic Values

The final all hazard GBS data type covered in this manual are economic values, which are used for loss calculations in Hazus. The specific economic data types to be covered include Structure Replacement Value, Contents Replacement Value, and Other Economic Values, such as other primary economic values used by more than one hazard, including business inventory value, and disruption impacts to individuals and businesses from relocation, and losses of different types of income.

Table 6-1 summarizes the current status of these major GBS economic values by data type, hazard, sources, and an overview of how often source data is currently planned to be updated.

Table 6-1 GBS Economic Data Summary

Tabular Data Type	Data Element	Hazards	Current Source	Date of Current Hazus Data	How Often is Source Data Updated?	Processing Required
Structure Replacement Value	Structure Replacement Value by Specific Occupancy and regional/county multiplier	All	RSMeans	2018*	Annually	Area is multiplied by $/ft^2 provided by RSMeans, county multiplier derived from zip codes
Contents Replacement Value	Content Replacement Value by Specific Occupancy	All	National Institute of Building Sciences (NIBS) approximation based on percent of structure	1999	None planned	Structure value multiplied by constant percent by specific occupancy
Other Economic Values	Various Hazus Tables related to establishing economic value for different factors	All	Variety of sources	2017	Annually	Most economic factors can be annually adjusted based on annual CPI values

** All structure replacement values based on 2018 RSMeans except RES2 (2016 Manufactured Housing Survey Annual Data) and data for American Samoa, Guam, and Northern Mariana Islands (2014 RSMeans data adjusted by CPI to 2016).*

6.1 Structure Replacement Value

Building replacement cost models within Hazus are based on industry-standard cost-estimation models published in RSMeans Square Foot Costs (RSMeans, 2018). Replacement cost data are stored within Hazus at the Census tract and Census block-level for each occupancy class. For each Hazus occupancy class, a default structure full replacement cost model (cost per square foot) has been determined and is provided in Table 6-2. Commercial and industrial occupancies have a typical building replacement cost model associated with each occupancy class (e.g., COM4, Professional/Technical/Business Services, is represented by a typical, 80,000 square foot, 5 to 10 story office building). In most cases, the typical building chosen to represent the occupancy class is the same as was used in the original Earthquake Model (based on RSMeans, 1994), except for single-family residential, multi-family residential, and industrial uses. Building area (given as square footage) costs presented in the table represent an average from the various alternatives for exterior wall construction (wood siding over wood frame, brick veneer over wood frame, concrete block over wood joists, etc.). For non-residential structures, the default configuration assumes structures without basements.

Table 6-2 Default Full Structure Replacement Cost

Specific Occupancy	Means Model Description (Means Model Number)	Structure Replacement Cost/sq.ft (2018)
RES1	See Table 6-3	
RES2	U.S. Census Bureau 2016 Manufactured Housing Survey Annual Data, see Table 6-6	
RES3A	SFR Avg two-story, MF adj, 2,200 sq.ft	$124.25
RES3B	SFR Avg 2 ½ story, MF adj, 4,400 sq.ft	$109.66
RES3C	Apt, 1-3 stories, 8,000 sq.ft (M.010)	$201.33
RES3D	Apt., 1-3 stories, 15,000 sq.ft (M.010)	$187.75
RES3E	Apt., 4-7 stories, 40,000 sq.ft (M.020)	$188.48
RES3F	Apt., 4-7 stories, 80,000 sq.ft (M.020)	$174.53
RES4	Hotel, 4-7 stories, 135,000 sq.ft (M.350)	$182.28
RES5	College Dorm, 2-3 stories, 25,000 sq.ft (M.130)	$199.63
RES6	Nursing Home, two-story, 25,000 sq.ft (M.450)	$215.91
COM1	Store, Dept., one-story, 110,000 sq.ft (M.610)	$114.47
COM2	Warehouse, 30,000 sq.ft (M.690)	$120.00
COM3	Garage, Repair, 10,000 sq.ft (M.290)	$139.88
COM4	Office, 5-10 stories, 80,000 sq.ft (M.470)	$176.29
COM5	Bank, one-story, 4,100 sq.ft (M.050)	$261.33
COM6	Hospital, 2-3 stories, 55,000 sq.ft (M.330)	$302.35
COM7	Medical office, two-story, 7,000 sq.ft (M.410)	$226.54
COM8	Restaurant, one-story, 5,000 sq.ft (M.530)	$227.53
COM9	Movie Theatre, 12,000 sq.ft (M.440)	$190.95
COM10	Garage, Pkg, five-story, 145,000 sq.ft (M.270)	$80.59
IND1	Factory, one-story, 30,000 sq.ft (M.200)	$133.03
IND2	Warehouse, 30,000 sq.ft (M.690)	$120.00
IND3	College Lab, one-story, 45,000 sq.ft (M.150)	$180.47
IND4	College Lab, one-story, 45,000 sq.ft (M.150)	$180.47
IND5	College Lab, one-story, 45,000 sq.ft (M.150)	$180.47
IND6	Warehouse, 30,000 sq.ft (M.690)	$120.00
AGR1	Warehouse, 30,000 sq.ft (M.690)	$120.00
REL1	Church, one-story, 17,000 sq.ft (M.090)	$190.53
GOV1	Town Hall, one-story, 11,000 sq.ft (M.670)	$149.83

Specific Occupancy	Means Model Description (Means Model Number)	Structure Replacement Cost/sq.ft (2018)
GOV2	Police Station, two-story, 11,000 sq.ft (M.490)	$254.23
EDU1	School, High, 130,000 sq.ft (M.570)	$201.63
EDU2	College Class. 2-3 stories, 50,000 sq.ft (M.120)	$171.05

** All replacement cost values based on RSMeans 2018.*

The RES1 (single-family residential) replacement cost model requires additional information to assign values to GBS data. This information includes adjustments for basements, RSMeans construction classes (Economy, Average, Custom, and Luxury), number of stories, and garages. Within RSMeans, basements are not considered in the base cost of the structure and are handled as an additive adjustment (additional cost per square foot of main structure). Table 6-3 provides replacement costs for the various single-family dwelling configurations available in the default building inventory (One-, Two-, and Three-story and split-level), assuming a typical size of 1,800 square feet. Costs have been averaged for the various alternatives for exterior wall construction.

Table 6-3 Replacement Costs (and Basement Adjustment) for RES1 Structures

Means Construct. Class	Height Class	Average Base cost per sq.ft	Adjustment for Finished Basement (cost/ sq.ft of main str.)	Adjustment for Unfinished Basement (cost/ sq.ft of main str.)
Economy	One-story	$97.61	$26.45	$9.55
	Two-story	$104.04	$15.20	$6.30
	Three-story	$104.04	$15.20	$6.30
	Split level	$96.69	$15.20	$6.30
Average	One-story	$116.66	$32.80	$11.25
	Two-story	$122.75	$21.05	$7.40
	Three-story	$127.94	$16.65	$5.80
	Split level	$113.66	$21.05	$7.40
Custom	One-story	$159.51	$53.65	$21.65
	Two-story	$163.95	$30.90	$12.90
	Three-story	$168.69	$22.55	$9.60
	Split level	$153.15	$30.90	$12.90
Luxury	One-story	$188.84	$59.00	$22.65
	Two-story	$194.94	$34.55	$13.85
	Three-story	$201.09	$25.50	$10.40
	Split level	$181.61	$34.55	$13.85

** All replacement cost values based on RSMeans 2018.*

Because the Flood Model default single-family residential (SFR) damage model is based on the FIA credibility-weighted depth damage functions, whose coverage extends to garages, the replacement cost of garages is included in the basic replacement cost. Relevant RSMeans models for SFR garages include costs by construction class (Economy, Average, Custom, and Luxury), for detached and attached one-car, two-car and three-car garages, constructed of wood or masonry. For incorporation into Hazus, costs by size and construction class have been averaged for attached/detached and various materials. Average costs associated with garage types included in the default inventory for single-family residential structures (one-car, two-car, and three-car) were provided in Table 6-4.

Table 6-4 Single-family Residential Garage Adjustment

Means Construction Class	Garage Type	Average Additional Garage Cost per Residence
Economy	One-car	$18,676
	Two-car	$29,263
	Three-car	$39,580
Average	One-car	$19,410
	Two-car	$30,224
	Three-car	$40,768
Custom	One-car	$21,577
	Two-car	$34,319
	Three-car	$46,713
Luxury	One-car	$25,105
	Two-car	$40,136
	Three-car	$54,821

** All replacement cost values based on RSMeans 2018.*

Weighting factors for the RSMeans construction class for the given Census block (also used in the replacement value calculations) are shown in Table 6-5.

Table 6-5 Percent Distribution of RSMeans Construction/Condition Model Weights

Income Ratio	Luxury	Custom	Average	Economy
IR < 0.5	-	-	-	100
0.5 <= IR < 0.85	-	-	25	75
0.85 <= IR < 1.25	-	25	75	-
1.25 <= IR < 2.0	-	100	-	-
IR <= 2.0	100	-	-	-

** Income Ratio (IR) is calculated as the Census block group median household income divided by the Census Region median household income.*

Structure replacement values for RES2 structures, based on U.S. Census Bureau 2016 Manufactured Housing Survey Annual Data, are given in Table 6-6.

Table 6-6 Manufactured Housing Replacement Cost Model

Census Region[1]	Cost per Square Foot (2016)[2]
Northeast	$60.74
Midwest	$47.32
South	$45.51
West	$63.61

[1] Census Region list of states given in Table 3-2
[2] All replacement cost values based on Census Bureau 2016 Manufactured Housing Survey Annual Data.

For NSI data for Guam, American Samoa, and Northern Mariana Islands, a different approach is used for replacement values. Structural replacement cost valuations, as shown in Table 6-7, were developed based on RSMeans 2014 adjusted to 2016 using the Consumer Price Index (CPI) approach and application of Hawaii cost-modification factors.

Table 6-7 Default Replacement Costs for Guam, American Samoa, and Northern Mariana Islands

Specific Occupancy	Hazus Definition	Territory Cost/Square Foot (2016)[1]
AGR1	Agriculture	$124.52
COM1	Retail Trade	$128.23
COM10	Parking	$89.17
COM2	Wholesale Trade	$124.52
COM3	Personal and Repair Services	$151.22
COM4	Professional/Technical Service	$205.03
COM5	Banks	$297.11
COM6	Hospital	$392.73
COM7	Medical Office/Clinic	$282.33
COM8	Entertainment & Recreation	$262.06
COM9	Theaters	$196.54
EDU1	Schools/Libraries	$203.44
EDU2	Colleges/Universities	$226.54
GOV1	General Services	$160.88
GOV2	Emergency Response	$273.55
IND1	Heavy	$152.53
IND2	Light	$124.52
IND3	Food/Drugs/Chemicals	$241.89
IND4	Metals/Minerals Processing	$241.89
IND5	High Technology	$241.89
IND6	Construction	$124.52
REL1	Church	$209.84
RES1	Single-Family Dwelling	Table 6-8
RES2	Mobile Home	$49.10

Specific Occupancy	Hazus Definition	Territory Cost/Square Foot (2016)[1]
RES3A	Multi-Family Dwelling - Duplex	$133.02
RES3B	Multi-Family Dwelling – 3-4 Units	$116.94
RES3C	Multi-Family Dwelling – 5-9 Units	$209.99
RES3D	Multi-Family Dwelling – 10-19 Units	$197.50
RES3E	Multi-Family Dwelling – 20-49 Units	$215.96
RES3F	Multi-Family Dwelling – 50+ Units	$203.38
RES4	Temporary Lodging (e.g., hotels)	$221.62
RES5	Institutional Dormitory (e.g., prisons)	$238.52
RES6	Nursing Home	$242.21

[1] Territory replacement costs for NSI data are estimated using RSMeans 2014 adjusted to 2016 based on CPI and using HI location factor adjustment (1.17)

Single-Family (RES1) replacement costs are further adjusted by the average household income in each Census tract based on 2010 U.S. Census demographics relative to the U.S. median household income. This approach utilizes the income ratios and average RES1 replacement costs summarized in Table 6-8.

Table 6-8 Single-Family (RES1) Replacement Base Cost for Guam, American Samoa, and Northern Mariana Islands

Income Ratio (IR)	RES1 Replacement[1]
IR < 0.5	$107.39
0.5 ≤ IR < 0.85	$114.03
0.85 ≤ IR < 1.25	$142.63
1.25 ≤ IR < 2.0	$168.63
IR ≥ 2.0	$201.18

[1] Territory replacement costs for NSI data are estimated using RSMeans 2014 adjusted to 2016 based on CPI and using HI location factor adjustment (1.17)

Most American Samoa and Marianas tracts were assigned relatively low-income ratios, while Guam was largely comparable to U.S. median income averages.

2010 U.S. Census data contain general foundation type information (D401_S079 through D402_S082) that provided the percentage distribution of foundation types at the tract level for RES1 only. Since no other data were available, all other territory occupancy types were mapped to FoundationID 7 (slab), and FirstFloorHt = 1 foot, with the exception of RES2 (FoundationID 5 (crawl), FirstFloorHt = 3 feet).

For the Hurricane Model, specifically related to surge modeling, Hazus does further subdivide the overall building replacement value into individual subassemblies such as foundation or roof. This supports the ability of the model to properly account for damages from both flood and wind damages from coastal surges from hurricane events. See the *Hazus Hurricane Model Technical Manual* (FEMA, 2021) for more details on subassembly replacement values.

6.1.1 RES1 Equation

The equation defined below is used to develop the valuation for single-family residential buildings at the Census block-level. This equation utilizes socio-economic data from the Census to derive an appropriate RSMeans-based cost for each Census block. The earthquake and wind models use the equation defined below to develop the valuation for single-family residential buildings at the Census block-level.

The RES1 valuation can be summarized mathematically in the equation below:

Equation 6-1 RES1 Equation

$$V_{RES1,k} = (A_{RES1,k}) * \left[\sum_{i=1}^{4}\sum_{j=1}^{4} w_{i,k} * w_{j,k} * C_{i,j}\right] + (A_{RES1,k}) * w_{1,k}\left[\sum_{i=1}^{4}\sum_{j=1}^{4} w_{i,k} * w_{j,k} * C_{i,j,1}\right] + (RES1Cnt_k) * \left[\sum_{i=1}^{4}\sum_{j=1}^{4} w_{i,k} * w_{m,k} * C_{i,m}\right]$$

Where:

$V_{RES1,k}$	is the total estimated valuation for single-family residences (RES1) for a given Census block (k), prior to the application of location factors. $V_{RES1,k}$ (as tabulated in Hazus, after application of location factors) is editable when viewing the dollar exposure by specific occupancy table
$A_{RES1,k}$	is the total single-family residential (RES1) floor area (square feet) for a given Census block (k) found in the square foot by specific occupancy table. $A_{RES1,k}$ is editable when viewing the square foot by specific occupancy table
i	the RSMeans construction class (1 = Economy, 2 = Average, 3 = Custom, 4 = Luxury).
$w_{i,k}$	is the weighting factor for the RSMeans construction class (i) for the given Census block (k) and is determined from the income ratio range as shown in Table 6-5 above.
j	the number of stories class for single-family (RES1) structures (1 = One-story, 2 = Two-story, 3 = Three-story, and 4 = split level)
$w_{j,k}$	is the weighting factor for the number of stories class (j) for the given Census block (k) depending on the Census region of that block (by state FIPS). Weighting factors were developed from regional construction type distributions as discussed in Section 4.
$C_{i,j}$	is the single-family (RES1) cost per square foot for the given RSMeans construction class (i) and number of stories class (j). RES1 replacement costs are seen in the Table 6-3.
1	the basement status available for single-family residences (1 = yes, 2 = no)
$w_{1,k}$	is the weighting factor for basements for the given Census block (k) depending on the Census region of that block (by state FIPS). Weighting factors were developed from regional foundation type distributions as discussed in Section 5

$C_{i,j,1}$	the additional cost, per square foot of the main structure, for a finished basement for the given Means construction class (i) and number of stories class (j), as shown in Table 6-3. Note: $C_{i,j,1}$ = 0 when I = 2
m	the garage combinations available for single-family residences (1 = 1-car, 2 = 2-car, 3 = 3-car, 4 = carport, and 5 = none)
$w_{m,k}$	is the weighting factor for the garage type (m) for the given Census block (k) depending on the Census region of that block (by state FIPS). Weighting factors were developed from regional construction type distributions as discussed in Section 4.
$C_{i,m}$	the additional replacement cost for a given garage type (m), for the given RSMeans construction class (i) as shown in Table 6-4. Note: $C_{i,m}$ = 0 when m = 4 (covered carport) or m = 5 (none)
RES1Cnt	the count of RES1 structures within the given Census block (k) taken directly from the Building Count by Occupancy table

As the algorithm shows, the basic replacement cost per square foot is a function of the RSMeans construction class, the number of stories, and an additional cost per square foot of the main structure for the existence of a finished or unfinished basement. Finally, there is an additional cost per housing unit based on the garage associated with the structure.

6.1.2 RES2 Equation

RES2 specific occupancy is designated for manufactured housing, which represents mobile homes, but not single-family pre-manufactured housing. The U.S. Census provides a detailed count of the mobile homes within each Census block and this quantity is used to develop the total floor area (square foot) of the RES2 occupancy classification. The total floor area uses the average area by Census region as the basis for calculations. Unlike other occupancy classifications, there are no allowances for variation of floor heights (number of stories) or other valuation parameters. The valuation of manufactured housing is the straight multiplication of the total floor area by the default replacement cost per square foot, which as of the 2018 replacement cost model update, varies by Census region. The cost per square foot for each Census region is developed from the U.S. Census 2016 Manufactured Housing Survey Annual Data (latest available) on average square feet of floor area and average sales price of new manufactured homes given in Table 6-6.

The algorithm for manufactured housing is defined in Equation 6-2:

Equation 6-2 RES2 Equation

$$V_{RES2,k} = A_{RES2,k} * C_{RES2}$$

Where:

$V_{RES2,k}$	is the total estimated valuation for Manufactured Housing (RES2) for a given Census block (k)
$A_{RES2,k}$	is the total Manufactured Housing (RES2) floor area (square feet) for a given Census block (k) found in the square foot by specific occupancy table
C_{RES2}	is the Manufactured Housing (RES2) cost per square foot. RES2 replacement costs by Census region area given in Table 6-6

6.1.3 Other Occupancies Equation

The equation for the remaining residential occupancies (RES3-RES6) and all non-residential (COM, IND, EDU, REL, GOV, and AGR) occupancies is not as complex as the single-family model. It should be noted that the replacement costs seen in Table 6-2 are an average replacement cost by occupancy. In other words, the replacement cost is averaged across structure types, stories, and construction classes to produce the values shown.

The algorithm for the remaining residential occupancies and non-residential occupancies can be seen in the equation below:

Equation 6-3 Other Occupancies Equation

$$V_{x.k} = A_{x,k} * C_x$$

Where:

x	defines the remaining occupancy classifications for the remaining occupancies (i.e., RES5, COM1, REL1, etc.) for which the cost is being calculated
$V_{x,k}$	is the total estimated valuation for the specific occupancy (x) (such as RES4, COM3, or IND6) for a given Census block (k), prior to application of location factors. $V_{x,k}$ (as tabulated in Hazus, after application of location factors) is editable when viewing the dollar exposure by specific occupancy table
$A_{x,k}$	is the total floor area (square feet) for a specific occupancy (x) (such as RES3, COM8, IND4, GOV1, etc.) for a given Census block (k) found in the square foot by specific occupancy table
C_x	is the cost per square foot for the specific occupancy (x). The replacement costs are seen in Table 6-2 by specific occupancy

6.2 Contents Replacement Value

Contents replacement value was estimated as a percent of structure replacement value as part of the original development of Hazus by National Institute of Building Sciences (NIBS) in 1999. Table 6-9 summarizes these values for all Hazus specific occupancies.

Table 6-9 Baseline Hazus Contents Value Percent of Structure Value

Label	Contents Value (%)
RES1	50%
RES2	50%
RES3A-F	50%
RES4	50%
RES5	50%
RES6	50%
COM1	100%
COM2	100%
COM3	100%
COM4	100%

Label	Contents Value (%)
COM5	100%
COM6	150%
COM7	150%
COM8	100%
COM9	100%
COM10	50%
IND1	150%
IND2	150%
IND3	150%
IND4	150%
IND5	150%
IND6	100%
AGR1	100%
REL1	100%
GOV1	100%
GOV2	150%
EDU1	100%
EDU2	150%

6.3 County Modification Factors

All costs from RSMeans are average national costs. The national costs are localized by application of residential and non-residential RSMeans location factors that is provided with Hazus by states and counties throughout the U.S. These are applied in the development of GBS data for structure and contents replacement values.

6.4 Depreciated Building Replacement Values

The depreciation models utilized in the Flood Model were based on industry-standard depreciation methods presented in RSMeans 2006. Within RSMeans, two depreciation cost models are available: one for single-family residential structures and one for commercial/industrial/institutional structures.

6.4.1 Single-Family Residential Occupancy Depreciation Model

RSMeans (2006) includes three tabular depreciation models for residential structures based on actual structure age and general condition (Good, Average, and Poor). These models are shown graphically in Figure 6-1.

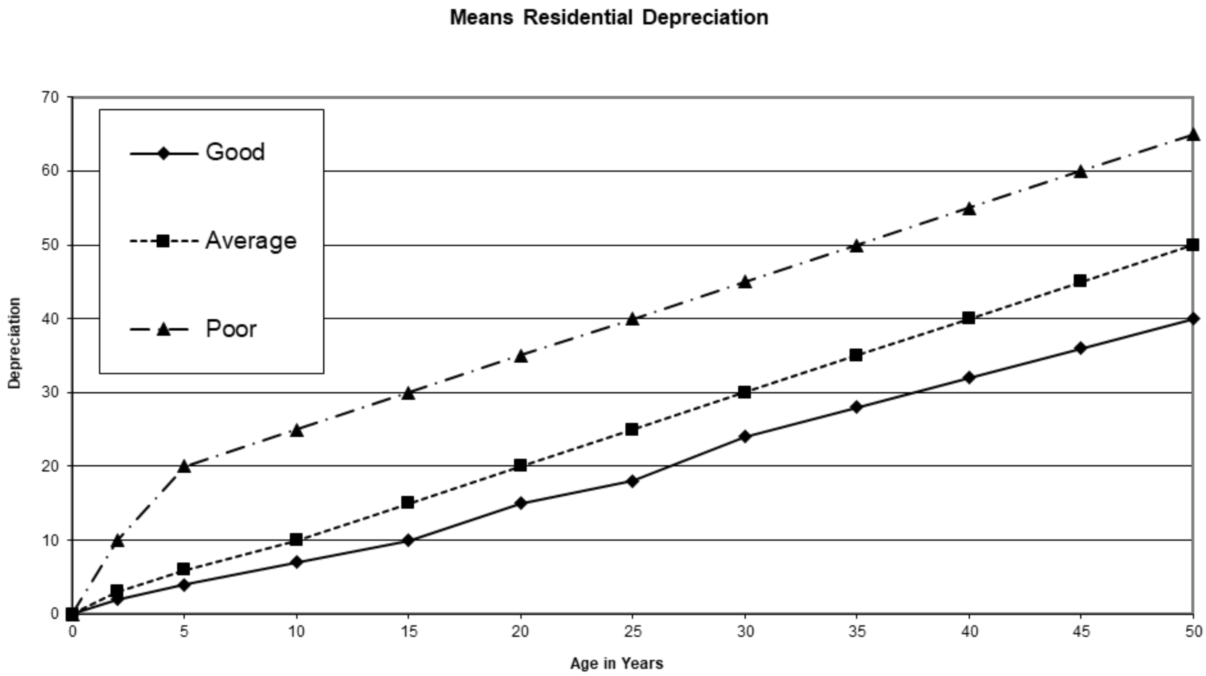

Figure 6-1 Single-Family Residential Depreciation Models

The underlying assumption in the Methodology used in the Flood Model is that for any community, some combination of the full replacement cost models (Economy, Average, Custom, or Luxury), and depreciation models (good, average, or poor) will best represent the true depreciated value. This basic premise was tested on more than 8,000 homes in Grand Forks, ND; more than 160,000 homes in Mecklenburg County, NC; and more than 60,000 homes in Fort Collins, CO. Results indicated that good agreement with assessed (depreciated) value could be attained from the models. A socioeconomic analysis was performed to determine the optimal means for selecting combinations of models based on available Census data.

6.4.2 Other Residential and Non-Residential Occupancies Deprecation Model

Unlike the residential depreciation model, the RSMeans commercial/industrial/institutional depreciation is determined from "observed age" and building framing material (frame, masonry on wood, and masonry on masonry or steel) as shown in Figure 6-2. The non-residential structure's "observed age" was assumed to reflect the structure's condition (e.g., the observed age should reflect any remodeling or renovation that would reduce deterioration, and therefore decrease the observed age).

It was assumed that chronological age is approximately equivalent to observed age for the non-residential structures, primarily because these structures are less likely to be used far beyond their typical life expectancy. For example, in Grand Forks, ND, many homes are significantly older than the typical life expectancy of about 50 to 60 years, whereas commercial and industrial structures did not demonstrate the same widespread longevity.

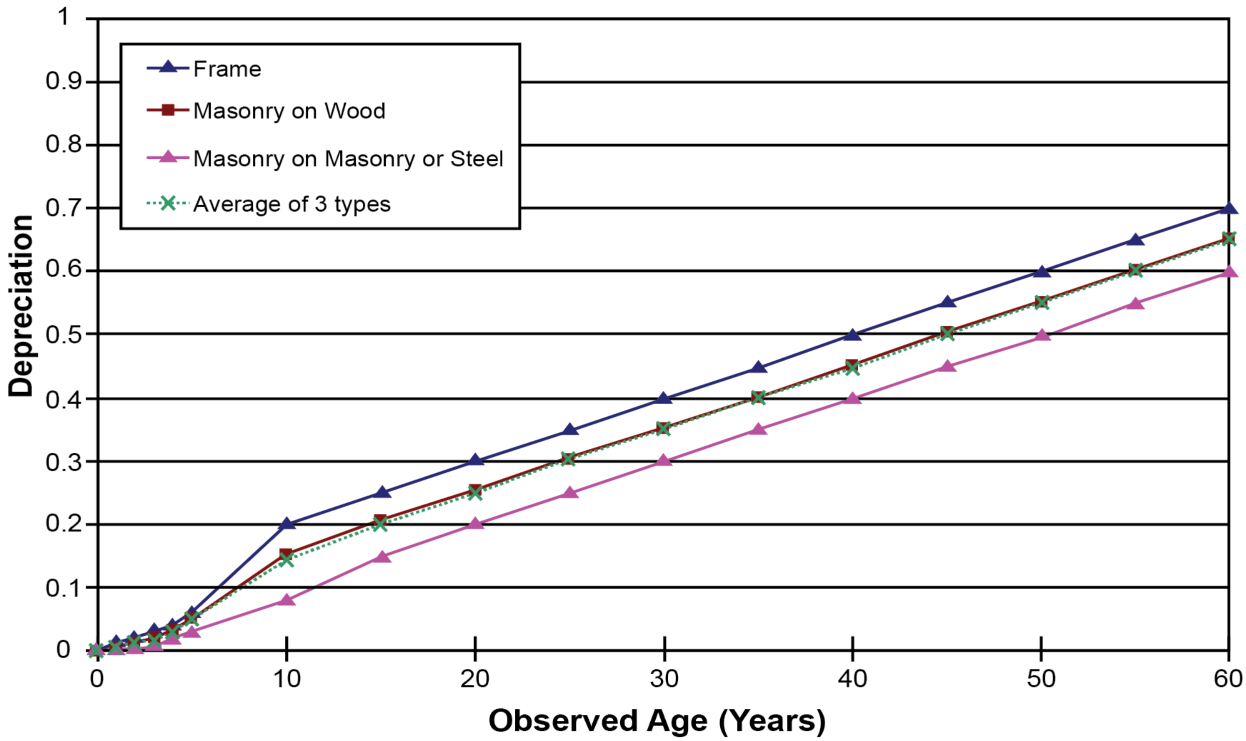

Figure 6-2 RSMeans Commercial/Industrial Depreciation Model

6.5 Other Economic Values

6.5.1 Business Inventory

For occupancies with inventory considerations (COM1, COM2, IND1 - IND6, and AGR1), inventory losses are estimated using Hazus default inventory values. Inventory values are estimated by first estimating annual sales (shown in Table 6-10) and then applying a value from Table 6-11 that represents inventory values as a percentage of annual sales.

Table 6-10 and Table 6-11 reflect 2017 values, which represent updated values from their original 1990 calculation. Tabulated monetary direct economic parameter values from the original *Hazus Earthquake Model Technical Manual* (FEMA, 2021) have been updated to 2017 costs for use in Hazus, using a ratio of the annual Consumer Price Index (CPI). The original dollar value was multiplied by the ratio of the CPI value for the current year to the CPI value for the year the data was developed. Annual CPIs for the years 1990 through 2018 are given in Table 6-12.

Table 6-10 Annual Gross Sales or Production

Label	Occupancy Class	Output/ Employment (2017) [4]	Sq.ft floor Space/Employee	Annual Sales (2017 $/sq.ft)
COM1	Retail Trade[1]	$53,355	825	$56
COM2	Wholesale Trade[1]	$76,794	900	$81
IND1	Heavy[2]	$487,252	550	$750
IND2	Light[2]	$143,667	590	$238
IND3	Food/Drugs/Chemicals[2]	$374,027	540	$733

Label	Occupancy Class	Output/ Employment (2017) [4]	Sq.ft floor Space/Employee	Annual Sales (2017 $/sq.ft)
IND4	Metals/Minerals Processing[2]	$678,975	730	$690
IND5	High Technology[2]	$185,987	300	$459
IND6	Construction[3]	$207,333	250	$808
AGR1	Agriculture[3]	$120,243	250	$156

[1] Values estimated using ratios from BLS "Industry Productivity & Cost Survey" data on Output per Person by Industry, 2016
[2] Values estimated from BLS "Major Sector Productivity & Costs" data on Output per Job by Industry, 2017
[3] Values estimated from BEA "Output by Industry" and BLS (Construction) and BEA (Agriculture) employment data, 2016
[4] Values adjusted from 1990 by CPI

Table 6-11 Business Inventory (% of Gross Annual Sales)

Label	Occupancy Class	Business Inventory (%)
COM1	Retail Trade	13%
COM2	Wholesale Trade	10%
IND1	Heavy	5%
IND2	Light	4%
IND3	Food/Drugs/Chemicals	5%
IND4	Metals/Minerals Processing	3%
IND5	High Technology	4%
IND6	Construction	2%
AGR1	Agriculture	8%

** Values from original development of Hazus by NIBS in 1999.*

Table 6-12 Consumer Price Index 1990–2018

Year	Annual CPI
1990	130.7
1991	136.2
1992	140.3
1993	144.5
1994	148.2
1995	152.4
1996	156.9
1997	160.5
1998	163.0
1999	166.6
2000	172.2
2001	177.1
2002	179.9
2003	184.0

Year	Annual CPI
2004	188.9
2005	195.3
2006	201.6
2007	207.3
2008	215.3
2009	214.5
2010	218.1
2011	224.9
2012	229.6
2013	233.0
2014	236.7
2015	237.0
2016	240.0
2017	245.1
2018	251.1

** Note: As of December 2019. Source U.S. Bureau of Labor Statistics*

6.5.2 Relocation Expenses (Rental and Disruption Costs)

Relocation expenses represent disruption costs to building owners for selected occupancies. These include all occupancies except entertainment (COM8), theaters (COM9), parking facilities (COM10), and heavy industry (IND1). Expenses contain disruption costs that include the cost of shifting and transferring, and the rental of temporary space. These costs are incurred once the building reaches a damage threshold of 10% (beyond damage state "Slight" in the Earthquake Model). Below that threshold, it is assumed unlikely the occupants will need to relocate.

Table 6-13 shows the 2017 values for rental and disruption costs. It should be noted the default values for rental costs and disruption costs provided in Table 6-13 have been updated from the original development year of 1994 to the year 2017 baseline using CPI scaling, as noted earlier. The rental costs in Table 6-13 can also be used in Hazus loss calculations where rent is considered a source of business income, which also requires information on the percent of owner occupation as shown in Table 6-14.

Table 6-13 Rental Costs and Disruption Costs

Label	Occupancy Class	Rental Cost (2017) ($/sq.ft /month)	Rental Cost (2017) ($/sq.ft /day)	Disruption Costs (2017) ($/sq.ft)
RES1	Single-family Dwelling	0.83	0.03	0.99
RES2	Mobile Home	0.58	0.02	0.99
RES3A	Multi-family Dwelling; Duplex	0.74	0.02	0.99
RES3B	Multi-family Dwelling; Triplex/Quad	0.74	0.02	0.99
RES3C	Multi-family Dwelling; 5–9 units	0.74	0.02	0.99
RES3D	Multi-family Dwelling; 10–19 units	0.74	0.02	0.99
RES3E	Multi-family Dwelling; 20–49 units	0.74	0.02	0.99
RES3F	Multi-family Dwelling; 50+ units	0.74	0.02	0.99

Label	Occupancy Class	Rental Cost (2017) ($/sq.ft /month)	Rental Cost (2017) ($/sq.ft /day)	Disruption Costs (2017) ($/sq.ft)
RES4	Temporary Lodging	2.48	0.08	0.99
RES5	Institutional Dormitory	0.50	0.02	0.99
RES6	Nursing Home	0.91	0.03	0.99
COM1	Retail Trade	1.41	0.05	1.32
COM2	Wholesale Trade	0.58	0.02	1.16
COM3	Personal and Repair Services	1.65	0.06	1.16
COM4	Professional/Technical/ Business Services	1.65	0.06	1.16
COM5	Banks	2.07	0.07	1.16
COM6	Hospital	1.65	0.06	1.65
COM7	Medial Office/Clinic	1.65	0.06	1.65
COM8	Entertainment & Recreation	2.07	0.07	0.00
COM9	Theaters	2.07	0.07	0.00
COM10	Parking	0.41	0.01	0.00
IND1	Heavy	0.25	0.01	0.00
IND2	Light	0.33	0.01	1.16
IND3	Food/Drugs/Chemicals	0.33	0.01	1.16
IND4	Metals/Minerals Processing	0.25	0.01	1.16
IND5	High Technology	0.41	0.01	1.16
IND6	Construction	0.17	0.01	1.16
AGR1	Agriculture	0.83	0.03	0.83
REL1	Church/Membership Organization	1.24	0.04	1.16
GOV1	General Services	1.65	0.06	1.16
GOV2	Emergency Response	1.65	0.06	1.16
EDU1	Schools/Libraries	1.24	0.04	1.16
EDU2	Colleges/Universities	1.65	0.06	1.16

** Values adjusted using CPI to 2017 from original values from development of Hazus by NIBS in 1999.*

Table 6-14 Percent Owner Occupied by Occupancy Class

Label	Occupancy Class	Percent Owner Occupied
RES1	Single-family Dwelling	75%
RES2	Mobile Home	85%
RES3A	Multi-family Dwelling; Duplex	35%
RES3B	Multi-family Dwelling; Triplex/Quad	35%
RES3C	Multi-family Dwelling; 5–9 units	35%
RES3D	Multi-family Dwelling; 10–19 units	35%
RES3E	Multi-family Dwelling; 20–49 units	35%

Label	Occupancy Class	Percent Owner Occupied
RES3F	Multi-family Dwelling; 50+ units	35%
RES4	Temporary Lodging	0%
RES5	Institutional Dormitory	0%
RES6	Nursing Home	0%
COM1	Retail Trade	55%
COM2	Wholesale Trade	55%
COM3	Personal and Repair Services	55%
COM4	Professional/Technical/ Business Services	55%
COM5	Banks	75%
COM6	Hospital	95%
COM7	Medial Office/Clinic	65%
COM8	Entertainment & Recreation	55%
COM9	Theaters	45%
COM10	Parking	25%
IND1	Heavy	75%
IND2	Light	75%
IND3	Food/Drugs/Chemicals	75%
IND4	Metals/Minerals Processing	75%
IND5	High Technology	55%
IND6	Construction	85%
AGR1	Agriculture	95%
REL1	Church/Membership Organization	90%
GOV1	General Services	70%
GOV2	Emergency Response	95%
EDU1	Schools/Libraries	95%
EDU2	Colleges/Universities	90%

** Values from original development of Hazus by NIBS in 1999.*

6.5.3 Loss of Income

Business activity generates several types of income. First, there is income associated with capital, or property ownership. Business generates profits, and a portion of this is paid out to individuals (as well as to pension funds and other businesses) as dividends, while another portion (retained earnings) is returned to the enterprise. Businesses also make interest payments to banks and bondholders for loans. They pay rent on property and make royalty payments for the use of tangible assets. Those in business for themselves, or in partnerships, generate a category called proprietary income, one portion of which reflects their profits and the other reflects a salary (e.g., the case of lawyers or dentists). Finally, the biggest category of income generated/paid is associated with labor. In most urban regions of the U.S., wage and salary income comprises more than 75% of total personal income payments.

It is possible to link income payments to various physical damage measures, including sales, property values, or building area. Income losses occur when building damage disrupts economic activity. Hazard specific equations for income losses in Hazus include variables for loss of income over time (Table 6-15), and the potential to recapture income (Table 6-16).

Business-related losses from disaster events can be recouped, to some extent, by working overtime after the event. For example, a factory closed for six weeks due to directly caused structural damage or indirectly-caused shortage of supplies may work extra shifts in the weeks or months following its reopening.

This ability to recapture production will differ across industries. It will be higher for those who produce durable output and lower for those who produce perishables or spot products (i.e., utility sales to residential customers, hotel services, and entertainment). Even some durable manufacturing enterprises would seem to have severe recapture limits because they already work three shifts per day. However, work on weekends, excess capacity, and temporary production facilities all can be used to make up lost sales.

Table 6-16 provides the full set of recapture factors (wage, income, and output recapture factors) that can be used with the hazard-specific equations to estimate the various types of income losses for the economic sectors used in the direct economic loss module for hazards like flood and earthquake.

Table 6-15 Proprietor's Income (2017)

Label	Occupancy Class	Income (2017) / sq.ft / year	Income (2017) / sq.ft / day	Wages (2017) / sq.ft / day	Employees / sq.ft	Output (2017) / sq.ft / day
RES1	Single-family Dwelling	0.000	0.000	0.000	0.000	0.000
RES2	Mobile Home	0.000	0.000	0.000	0.000	0.000
RES3A	Multi-family Dwelling; Duplex	0.000	0.000	0.000	0.000	0.000
RES3B	Multi-family Dwelling; Triplex/Quad	0.000	0.000	0.000	0.000	0.000
RES3C	Multi-family Dwelling; 5–9 units	0.000	0.000	0.000	0.000	0.000
RES3D	Multi-family Dwelling; 10–19 units	0.000	0.000	0.000	0.000	0.000
RES3E	Multi-family Dwelling; 20–49 units	0.000	0.000	0.000	0.000	0.000
RES3F	Multi-family Dwelling; 50+ units	0.000	0.000	0.000	0.000	0.000
RES4	Temporary Lodging	43.686	0.120	0.281	0.003	0.627
RES5	Institutional Dormitory	0.000	0.000	0.000	0.000	0.000
RES6	Nursing Home	72.811	0.199	0.470	0.005	1.045
COM1	Retail Trade	26.956	0.074	0.258	0.004	0.546
COM2	Wholesale Trade	44.209	0.121	0.318	0.002	0.710
COM3	Personal and Repair Services	58.248	0.160	0.375	0.004	0.837
COM4	Professional/Technical/ Business Services	458.975	1.257	0.447	0.004	1.222
COM5	Banks	523.745	1.435	0.728	0.006	3.968
COM6	Hospital	72.811	0.199	0.470	0.005	1.045
COM7	Medial Office/Clinic	145.621	0.399	0.939	0.010	2.090
COM8	Entertainment & Recreation	267.053	0.732	0.582	0.007	1.318

Label	Occupancy Class	Income (2017) / sq.ft / year	Income (2017) / sq.ft / day	Wages (2017) / sq.ft / day	Employees / sq.ft	Output (2017) / sq.ft / day
COM9	Theaters	87.373	0.239	0.564	0.006	1.255
COM10	Parking	0.000	0.000	0.000	0.000	0.000
IND1	Heavy	110.490	0.303	0.501	0.003	2.119
IND2	Light	110.490	0.303	0.501	0.003	2.119
IND3	Food/Drugs/Chemicals	147.320	0.404	0.670	0.004	2.825
IND4	Metals/Minerals Processing	334.730	0.917	0.518	0.003	2.241
IND5	High Technology	220.980	0.605	1.004	0.006	4.236
IND6	Construction	107.720	0.295	0.542	0.005	2.099
AGR1	Agriculture	102.224	0.280	0.111	0.004	1.045
REL1	Church/Membership Organization	58.248	0.160	0.375	0.004	2.090
GOV1	General Services	47.838	0.131	3.605	0.025	0.837
GOV2	Emergency Response	0.000	0.000	5.481	0.038	0.961
EDU1	Schools/Libraries	72.811	0.199	0.470	0.005	4.050
EDU2	Colleges/Universities	145.621	0.399	0.939	0.010	6.156

** Values adjusted using CPI to 2017 from original values from the development of Hazus by NIBS in 1999.*

Table 6-16 Hazus Recapture Factors

Specific Occupancy	Wage Recapture (%)	Employment Recapture (%)	Income Recapture (%)	Output Recapture (%)
RES1	0	0	0	0
RES2	0	0	0	0
RES3	0	0	0	0
RES4	0.60	0.60	0.60	0.60
RES5	0.60	0.60	0.60	0.60
RES6	0.60	0.60	0.60	0.60
COM1	0.87	0.87	0.87	0.87
COM2	0.87	0.87	0.87	0.87
COM3	0.51	0.51	0.51	0.51
COM4	0.90	0.90	0.90	0.90
COM5	0.90	0.90	0.90	0.90
COM6	0.60	0.60	0.60	0.60
COM7	0.60	0.60	0.60	0.60
COM8	0.60	0.60	0.60	0.60
COM9	0.60	0.60	0.60	0.60
COM10	0.60	0.60	0.60	0.60
IND1	0.98	0.98	0.98	0.98
IND2	0.98	0.98	0.98	0.98
IND3	0.98	0.98	0.98	0.98

Specific Occupancy	Wage Recapture (%)	Employment Recapture (%)	Income Recapture (%)	Output Recapture (%)
IND4	0.98	0.98	0.98	0.98
IND5	0.98	0.98	0.98	0.98
IND6	0.95	0.95	0.95	0.95
AGR1	0.75	0.75	0.75	0.75
REL1	0.60	0.60	0.60	0.60
GOV1	0.80	0.80	0.80	0.80
GOV2	0	0	0	0
EDU1	0.60	0.60	0.60	0.60
EDU2	0.60	0.60	0.60	0.60

** Values from the original development of Hazus by NIBS in 1999.*

Section 7. Essential Facilities: Medical Care, Emergency Response, and Schools

Essential facilities are those facilities that provide services to the community and should be functional after an event. Essential facilities include medical care facilities, fire stations, police stations, EOCs, and schools. The damage to essential facilities is determined on a site-specific basis. The purpose of the essential facility modules for each hazard (currently only earthquake, flood, and hurricane) is to determine the expected loss of functionality for these critical facilities. The data required for the analysis includes mapping of the essential facility occupancy class to a specific building type, or a combination of essential facility building type and design level

Table 7-1 summarizes the current status of the essential facilities' spatial and tabular database elements for medical, emergency response, and schools by data type, hazard, and sources. Table 7-2 provided details on how replacement values were calculated for these data.

Table 7-1 Baseline Essential Facilities (EF) Database Summary Table for Medical Care, Emergency Response, and Schools

EF Data Type	Data Element	Hazards	Current Source and Date of Current Hazus Data
Medical Care Spatial Data	Hospital Geometries (Lat/Long)	All	HIFLD Open Database – Hospitals and Veteran's Health Administration Medical Facilities (2019)
Medical Care Spatial Data	Hospital Geometries (Lat/Long)	All	State of Florida (2018), State of Hawaii (2016) & Global Hazards Information Network for U.S. Territories except PR and VI (2017)
Emergency Response: Fire Spatial Data	Fire Geometries (Lat/Long)	All	HIFLD Open Database – Fire Stations (2019)
Emergency Response: Fire Spatial Data	Fire Geometries (Lat/Long)	All	State of Florida (2018), State of Hawaii (2016) & Global Hazards Information Network for U.S. Territories except PR and VI (2017)
Emergency Response: Police Spatial Data	Police Geometries (Lat/Long)	All	HIFLD Open Database – Local Law Enforcement Locations (2019)
Emergency Response: Police Spatial Data	Police Geometries (Lat/Long)	All	State of Florida (2018), State of Hawaii (2016) & Global Hazards Information Network for U.S. Territories except PR and VI (2017)
Emergency Response: EOC Spatial Data	EOC Geometries (Lat/Long)	All	HIFLD Open Database – Local EOCs, State EOCs and FEMA Regional Headquarters (2019)
Emergency Response: EOC Spatial Data	EOC Geometries (Lat/Long)	All	State of Florida (2018), State of Hawaii (2016) & Global Hazards Information Network for U.S. Territories except PR and VI (2017)
Schools Spatial Data	School Geometries (Lat/Long)	All	HIFLD Open Database – Public Schools, Private Schools, Colleges and Universities, and Supplemental Colleges (2019)
Schools Spatial Data	School Geometries (Lat/Long)	All	State of Florida (2018), State of Hawaii (2016) & Global Hazards Information Network for U.S. Territories except PR and VI (2017)
EF Class Tabular Data	EF Usage Classification	All	Attributes established for each EF Class.

EF Data Type	Data Element	Hazards	Current Source and Date of Current Hazus Data
EQ and TS Bldg. Type for EF Class Tabular Data	Mapping Scheme: EQ Bldg. Type	EQ, TS	Regional or State Assumption
FL Bldg. Type for EF Class Tabular Data	Mapping Scheme: FL Bldg. Type	FL	Assumed from EF Usage Class
HU Bldg. Type for EF Class Tabular Data	Mapping Scheme: HU Bldg. Type	HU	Region or Sub-State Assumption
EF Structure Replacement Value	Structure Value	All	RSMeans (2018)
Foundation Type Tabular Data	Foundation Type	EQ, FL	Community Level (FL) or National (EQ) Assumption
Design Level Tabular Data	Design Level	EQ	Regional Assumption
Landslide Susceptibility Tabular Data	Landslide Susceptibility	EQ	National Default (0)
Liquefaction Susceptibility Tabular Data	Liquefaction Susceptibility	EQ	National Default (0)
Soil Type Tabular Data	Soil Type	EQ	National Default (D); USGS for Probabilistic
Wind Building Characteristics Tabular Data	Wind Building Characteristics	HU	Regional Assumption

** U.S. Territory Essential Facilities (except Puerto Rico and U.S. Virgin Islands) were completed in 2017 and developed by the Pacific Disaster Center using public sources. The sources for these data varied depending on the territory and the metadata for the layers can be found at the Global Hazards Information Network (GHIN) website.*
*** Puerto Rico and U.S. Virgin Islands data were added to Hazus databases in 2019.*
**** Source: Hazus Program Infrastructure Data Updates, Detailed Methodology (FEMA, 2019a)*

Table 7-2 HIFLD Data for Selected Essential Facility Type Elements

Element	Target States	Valuation Approach
Medical Care Facilities	All States, including Alaska, District of Columbia, Hawaii, and Puerto Rico	HIFLD beds times 450 square feet per bed times COM6 RSMeans Replacement Value times RSMeans Non-Residential County Location Factor [Use default COM6 building area when beds unpopulated]
Emergency Response: Fire Facilities	All States, including Alaska, District of Columbia, Hawaii, and Puerto Rico	Default GOV2 building area times GOV2 RSMeans Replacement Value times RSMeans Non-Residential County Location Factor
Emergency Response: Fire Facilities	All States, including Alaska, District of Columbia, Hawaii, and Puerto Rico	Default GOV2 building area times GOV2 RSMeans Replacement Value times RSMeans Non-Residential County Location Factor

Element	Target States	Valuation Approach
Emergency Response: Fire Facilities	All States, including Alaska, District of Columbia, Hawaii, and Puerto Rico	Default GOV2 building area times GOV2 RSMeans Replacement Value times RSMeans Non-Residential County Location Factor
School Facilities EFS1*	All States, including Alaska, District of Columbia, Hawaii, and Puerto Rico	School occupant count times EDU1 Peak Day building area per school occupant (71.4) times EDU1 RSMeans Replacement Value times RSMeans Non-Residential County Location Factor [Use default EDU1 building area when occupant count unpopulated]
School Facilities EFS2*	All States, including Alaska, District of Columbia, Hawaii, and Puerto Rico	School occupant count times EDU2 Peak Day building area per school occupant (83.3) times EDU2 RSMeans Replacement Value times RSMeans Non-Residential County Location Factor [Use default EDU2 building area when occupant count unpopulated]

** Peak Day building area per school occupant (student, faculty, staff) from FEMA P58.*
*** Source: Hazus Program Infrastructure Data Updates, Detailed Methodology (FEMA, 2019a)*

7.1 Classification

Essential facilities are classified based on facility function and, in the case of hospitals, size. Table 7-3 lists the classes of essential facilities used in the Hazus Methodology. Hospitals are classified according to number of beds, since the structural and nonstructural systems of a hospital are related to the size of the hospital (i.e., to the number of beds it contains).

Table 7-3 Classification of Essential Facilities

Label	Occupancy Class	Description
Medical Care Facilities		
MDFLT	Default Hospital	Assigned features similar to EFHM
EFHS	Small Hospital	Hospital with fewer than 50 Beds
EFHM	Medium Hospital	Hospital with beds between 50 & 150
EFHL	Large Hospital	Hospital with more than 150 Beds
EFMC	Medical Clinics	Clinics, Labs, Blood Banks
Emergency Response		
FDFLT	Default Fire Station	
EFFS	Fire Station	
PDFLT	Default Police Station	
EFPS	Police Station	
EDFLT	Default EOC	
EFEO	Emergency Operation Centers	
Schools		
SDFLT	Default School	Assigned features similar to ESF1
EFS1	Schools	Primary/ Secondary Schools (K-12)
EFS2	Colleges/Universities	Community and State Colleges, State and Private Universities

7.2 Spatial and Tabular Data

Beginning with Hazus 4.2 SP3 released in May 2019, essential facility spatial data and certain tabular data are directly updated from the Homeland Infrastructure Foundation-Level Data (HIFLD) Open datasets. FEMA (2019a) summarizes the current specific HIFLD Open databases used to populate the Hazus essential facilities (EF) data. The following sections provide some additional information on using HIFLD data.

7.2.1 Medical Care

Building areas for hospitals were estimated from the number of beds, where available, otherwise defaults were used. The following attributes are required:

- Usage classification (All Models)
- Number of licensed hospital beds (All Models)
- Earthquake building type (Earthquake Model)
- Design level (Earthquake Model)
- Landslide susceptibility (Earthquake Model)
- Liquefaction susceptibility (Earthquake Model)
- Soil type (Earthquake Model)
- Water depth (Earthquake Model)
- Hurricane building type (Hurricane Model)
- Wind building characteristics (Hurricane Model)
- Structure value (Flood Model)
- First floor elevation (Flood Model)
- Foundation type (Flood Model)

7.2.2 Fire Stations

The following attributes are required:

- Usage classification (All Models)
- Number of fire engines (Earthquake Model)
- Earthquake building type (Earthquake Model)
- Design level (Earthquake Model)
- Landslide susceptibility (Earthquake Model)
- Liquefaction susceptibility (Earthquake Model)
- Soil type (Earthquake Model)
- Water depth (Earthquake Model)
- Hurricane building type (Hurricane Model)
- Wind building characteristics (Hurricane Model)
- Structure value (Flood Model)
- First floor elevation (Flood Model)

- Foundation type (Flood Model)

7.2.3 Police Stations

The following attributes are required:

- Usage classification (All Models)
- Earthquake building type (Earthquake Model)
- Design level (Earthquake Model)
- Landslide susceptibility (Earthquake Model)
- Liquefaction susceptibility (Earthquake Model)
- Soil type (Earthquake Model)
- Water depth (Earthquake Model)
- Hurricane building type (Hurricane Model)
- Wind building characteristics (Hurricane Model)
- Structure value (Flood Model)
- First floor elevation (Flood Model)
- Foundation type (Flood Model)

7.2.4 Emergency Operations Center (EOC)

The following attributes are required:

- Usage classification (All Models)
- Earthquake building type (Earthquake Model)
- Design level (Earthquake Model)
- Landslide susceptibility (Earthquake Model)
- Liquefaction susceptibility (Earthquake Model)
- Soil type (Earthquake Model)
- Water depth (Earthquake Model)
- Hurricane building type (Hurricane Model)
- Wind building characteristics (Hurricane Model)
- Structure value (All Models)
- First floor elevation (Flood Model)
- Foundation type (Flood Model)

7.2.5 Schools

Building areas for schools were estimated from the numbers of students, teachers, and staff where available, and if the number of students was 0, no area was assigned. Occupancy estimates are from FEMA P58, otherwise defaults were used. The following attributes are required:

- Usage classification (All Models)
- Earthquake building type (Earthquake Model)

- Design level (Earthquake Model)
- Landslide susceptibility (Earthquake Model)
- Liquefaction susceptibility (Earthquake Model)
- Soil type (Earthquake Model)
- Water depth (Earthquake Model)
- Hurricane building type (Hurricane Model)
- Wind building characteristics (Hurricane Model)
- Structure value (Flood Model)
- First floor elevation (Flood Model)
- Foundation type (Flood Model)

For data items in Table 7-1 that show regional assumptions for designating values for a state, please see Appendix A: Earthquake and Tsunami GBS Mapping Scheme Tables.

For the Earthquake Model, the default mapping of essential facility occupancy classes to specific building type are also provided in Appendix B: Earthquake and Tsunami Essential Facilities Mapping Schemes. The default mapping of specific occupancy to specific building type mapping is based on General Building Stock occupancy classes COM6, GOV2, EDU1, and EDU2.

For the Flood Model, Table 7-4 includes additional default values used for certain structure data.

Table 7-4 Essential Facilities Inventory Occupancy Classification and Flood Model Default Parameters

Hazus Label	Occupancy Class	Default Building Type	Basement	First Floor Height (ft)	No. of Stories	Damage Functions	Functionality Depth (ft)
MDFLT	Default Hospital	Concrete	Yes	3	Mid	COM6	0.5
EFHS	Small Hospital	Concrete	Yes	3	Low	COM6	0.5
EFHM	Medium Hospital	Concrete	Yes	3	Mid	COM6	0.5
EFHL	Large Hospital	Concrete	Yes	3	Mid	COM6	0.5
EFMC	Medical Center	Concrete	Yes	3	Low	COM7	0.5
FDFLT	Default Fire Station	Concrete	No	0	Low	GOV2	2
EFFS	Fire Station	Concrete	No	0	Low	GOV2	2
PDFLT	Default Police Station	Concrete	Yes	0	Low	GOV2	1
EFPS	Police Station	Concrete	Yes	0	Low	GOV2	1
EDFLT	Default Emergency Center	Concrete	Yes	0	Low	GOV2	0.5
EFEO	Emergency Center	Concrete	Yes	0	Low	GOV2	1
SDFLT	Default School	Masonry	No	0	Low	EDU1	0.5
EFS1	School	Masonry	No	0	Low	EDU1	0.5
EFS2	University	Concrete	No	0	Low	EDU2	0.5

Some additional notes on the assumptions in Table 7-4:

- *Basement (Y/N):* The assumption developed from expert opinion is that EFFS, EFS1, and EFS2 do not have basements. All other essential facilities are assumed to have basements. The user can modify this field if their facility is incorrect using the Hazus essential facility dialog.
- *First Floor Height:* Assume EFEO, EFFS, EFS1, and EFS2 are at grade. Assume all other facilities are 3 feet above grade. The user can adjust this field using the Hazus essential facility dialog.
- *Number of Stories:* Assume all ESF1, EFHS, EFMC, EFFS, EFPS, and EFEO are all low-rise structures, and the EFHM, and EFHL are mid-rise. The user can adjust this field using the Hazus essential facility dialog.
- *Damage Functions:* Comparable damage functions from the General Building Stock should be used to determine the estimated damage (percent) from which a loss of function for essential facilities can be developed. The user can change the damage functions in the analysis parameters dialog.
- *Functional Depth:* The general assumption is that when the depth of flooding reaches the functional depth, usually at half a foot, typically the facility is closed and people evacuated. In the case of some hospitals, this does not always mean the patients are evacuated, but the trauma center will typically refuse new patients.

7.2.6 Limitations

The locations can vary from the actual site, one location may represent an entire campus of structures, and points are representing footprint polygons. Several defaults are provided in the data without verification – values, first floor heights, foundation types, building types, design levels, landslide, liquefaction, soil type, and water level are all national values of one type. Building types may not agree between models.

Section 8. High Potential Loss and Hazardous Materials

Besides the essential facilities associated with medical, emergency response, and schools, there are other types of facilities with the potential of being impacted by a disaster event. In Hazus, these other types of facilities are grouped into High Potential Loss (HPL) Facilities, including dams, nuclear power plants, military installations, and hazardous materials Facilities. Only military facilities are currently modeled in Hazus for potential losses in the Earthquake Model, while other HPL facilities are assessed for exposure only to hazards. The inventory data required for HPL facilities and hazardous materials facilities include the geographical location of the facility.

Table 8-1 summarizes the current status of the HPL facilities and hazardous materials by data type, hazard, and sources.

Table 8-1 Baseline High Potential Loss and Hazardous Materials Database Summary Table

Data Type	Data Element	Hazards	Current Source and Date of Current Hazus Data
Dams and Levees	Dams and Levees	Exposure Mapping Only	Not provided in Hazus
Nuclear Power Facility	Nuclear Power Facility	Exposure Mapping Only	Not provided in Hazus
Military Installations	Military Installations	EQ	Not provided in Hazus
Hazardous Materials	Hazardous Materials	Exposure Mapping Only	The baseline database was built from the 1999 EPA Toxic Release Inventory (TRI) database of hazardous materials sites. The TRI database is updated every year although it takes a year to process the data (2017)

8.1 High Potential Loss Facilities

The HPL classifications for dams, levees, nuclear power plants, and military installations are given in Table 8-2. The dam classifications are based on the National Inventory of Dams database (FEMA, 1993). While dams, levees, and nuclear power facilities have no current modeling capabilities in Hazus, military installations can be modeled in the Earthquake Model when additional data is provided, including location, classification, and replacement value. Each HPL facility should be treated on an individual basis by users who have sufficient expertise to evaluate the damage to such facilities. Required input to the damage evaluation module includes the following items:

- Earthquake capacity curves that represent median (typical) properties of the HPL facility structure, or a related set of engineering parameters, such as period, yield strength, and ultimate capacity, that may be used by seismic/structural engineering experts to select representative damage functions.
- Earthquake fragility curves for the HPL facility under consideration, or a related set of engineering parameters that can be used by seismic/structural engineering experts to select appropriate damage functions.

See *the Hazus Earthquake Model Technical Manual* (FEMA, 2021) for more details.

Table 8-2 High Potential Loss Facilities Classifications

Hazus Label	General Occupancy	Specific Occupancy
HPDA	Dams	Arch
HPDB	Dams	Buttress
HPDC	Dams	Concrete
HPDE	Dams	Earth
HPDG	Dams	Gravity
HPDM	Dams	Masonry
HPDR	Dams	Rock fill
HPDS	Dams	Stone
HPDT	Dams	Timber Crib
HPDU	Dams	Multi-Arch
HPDZ	Dams	Miscellaneous
HPLV	Levee	Levee
HPNP	Nuclear Power Facilities	Nuclear Power Facilities
HPMI1	Military Installations	Barracks/Group Quarters
HPMI2	Military Installations	Officer/Enlisted Quarters - Multi-Unit
HPMI3	Military Installations	Officer/Enlisted Quarters - Detached
HPMI4	Military Installations	Maintenance/Operations Shops
HPMI5	Military Installations	Administrative Offices
HPMI6	Military Installations	Mess Halls
HPMI7	Military Installations	Officer/Enlisted Clubs
HPMI8	Military Installations	Gymnasiums/Armory
HPMI9	Military Installations	Gas/Services Stations
HPMI10	Military Installations	PX/Retail Stores
HPMI11	Military Installations	Arsenals
HPMI12	Military Installations	Other
HPMI1	Military Installations	Barracks/Group Quarters

8.2 Hazardous Materials

Hazardous materials are chemicals, reagents, or substances that exhibit physical or health hazards, whether the materials are in a usable or waste state. The scale and consequences of hazardous material releases can vary from small, such as a gallon of paint falling off a shelf, to regional, such as a release of toxic chemicals from a processing plant. Some hazardous material incidents have led to human casualties in cases where explosions have occurred. Non-explosive hazardous materials incidents, which comprise the vast majority, typically lead to contamination of the environment and temporary health consequences to humans. Hazardous material releases can also lead to fires. Data on flood-caused hazardous material incidents indicate that there have been no human identified casualties. The consequences of these incidents have included fires and contamination of the environment, and have led to economic impacts because of the response and clean-up requirements.

Hazus does not directly estimate damage caused by the release of hazardous materials, nor does the model estimate the probabilities of such a release occurring. The user can, however, place the locations of the hazardous materials inventory onto the hazard data (such as a depth grid for the Flood Model, or wind speed map for the Hurricane Model) and identify those areas where the hazardous materials sites could be exposed to potential risk.

Hazus is restricted to only identifying the location of facilities containing hazardous materials that could lead to a significant immediate demand on health care and emergency response facilities. These types of incidents would include large toxic releases and fires or explosions. Thus, the baseline database of hazardous material facilities is limited to facilities where large quantities of chemicals considered highly toxic, flammable, or highly explosive are stored. Estimates of releases that could cause pollution of the environment and the need for long-term clean-up efforts are beyond the scope of this methodology.

Due to the limitations of state-of-the-art hazardous materials release models, the development of the Hazus hazardous materials module was restricted to establishing a standardized approach for classifying materials and developing a database that can be used by local planners to identify those facilities most likely to have significant releases due to natural hazards. A baseline database of potential sites was built from the 1999 EPA Toxic Release Inventory (TRI) database of hazardous materials sites. This Hazus database can be supplemented by the user with local information. A more-detailed vulnerability assessment would involve going to individual facilities to determine how chemicals are stored, the vulnerability of buildings and storage tanks, and other relevant information.

8.2.1 Classification

The most widely used detailed classification scheme has been developed by the National Fire Protection Association, and is presented in the 1991 Uniform Fire Code, among other documents. This classification scheme is shown in Table 8-3. The hazards posed by the various materials are divided into two major categories: Physical Hazards and Health Hazards. A more detailed description of these categories, with more extensive examples, can be found in Appendix VI-A of the 1991 Uniform Fire Code. Table 8-3 also contains minimum quantities of the materials that must be on site to require permitting according to the Uniform Fire Code. The minimum permit quantities might vary depending on whether the chemical is stored inside or outside of a building.

Table 8-3 Classification of Hazardous Materials and Permit Amounts

Label	Material Type	Permit Amount		Hazard Type & Remarks
		Inside Building	Outside Building	
HDFLT	Default			
HM01	Carcinogens	10 pounds	10 pounds	Health
HM02	Cellulose nitrate	25 pounds	25 pounds	Physical
HM03	Combustible fibers	100 cubic feet	100 cubic feet	Physical
Combustible Liquids				
HM04	Class I	5 gallons	10 gallons	Physical
HM05	Class II	25 gallons	60 gallons	Physical
HM06	Class III-A	25 gallons	60 gallons	Physical
HM07	Corrosive gases	Any amount	Any amount	Health [1]
HM08	Corrosive liquids	55 gallons	55 gallons	Physical; Health

Label	Material Type	Permit Amount		Hazard Type & Remarks
		Inside Building	Outside Building	
Cryogens				
HM 09	Corrosive	1 gallon	1 gallon	Health
HM 10	Flammable	1 gallon	60 gallons	Physical
HM 11	Highly toxic	1 gallon	1 gallon	Health
HM12	Nonflammable	60 gallons	500 gallons	Physical
HM13	Oxidizer (including oxygen)	50 gallons	50 gallons	Physical
HM14	Highly toxic gases	Any amount	Any amount	Health [1]
HM15	Highly toxic liquids & solids	Any amount	Any amount	Health
HM16	Inert	6,000 cubic feet	6,000 cubic feet	Physical [1]
HM17	Irritant liquids	55 gallons	55 gallons	Health
HM18	Irritant solids	500 pounds	500 pounds	Health
HM19	Liquefied petroleum gases	> 125 gallons	> 125 gallons	Physical
HM20	Magnesium	10 pounds	10 pounds	Physical
HM21	Nitrate film	(Unclear)	(Unclear)	Health
HM22	Oxidizing gases (including oxygen)	500 cubic feet	500 cubic feet	Physical [1]
Oxidizing Liquids				
HM23	Class 4	Any amount	Any amount	Physical
HM 24	Class 3	1 gallon	1 gallon	Physical
HM 25	Class 2	10 gallons	10 gallons	Physical
HM 26	Class 1	55 gallons	55 gallons	Physical
Oxidizing solids				
HM27	Class 4	Any amount	Any amount	Physical
HM28	Class 3	10 pounds	10 pounds	Physical
HM29	Class 2	100 pounds	100 pounds	Physical
HM30	Class 1	500 pounds	500 pounds	Physical
Organic Peroxide Liquids and Solids				
HM31	Class I	Any amount	Any amount	Physical
HM 32	Class II	Any amount	Any amount	Physical
HM 33	Class III	10 pounds	10 pounds	Physical
HM 34	Class IV	20 pounds	20 pounds	Physical
Other Health Hazards				
HM35	Liquids	55 gallons	55 gallons	Health
HM36	Solids	500 pounds	500 pounds	Health
HM37	Pyrophoric gases	Any amount	Any amount	Physical [1]
HM38	Pyrophoric liquids	Any amount	Any amount	Physical
HM39	Pyrophoric solids	Any amount	Any amount	Physical

Label	Material Type	Permit Amount		Hazard Type & Remarks
		Inside Building	Outside Building	
HM40	Radioactive materials	1 m Curie in unsealed source	1 m Curie in sealed source	Health [1]
HM41	Sensitizer, liquids	55 gallons	55 gallons	Health
HM42	Sensitizer, solids	500 pounds	500 pounds.	Health
HM43	Toxic gases	Any amount	Any amount	Health [1]
HM44	Toxic liquids	50 gallons	50 gallons	Health
HM45	Toxic solids	500 pounds.	500 pounds	Health
HM46	Unstable gases (reactive)	Any amount	Any amount	Physical [1]
Unstable Liquids (Reactive)				
HM47	Class 4	Any amount	Any amount	Physical
HM48	Class 3	Any amount	Any amount	Physical
HM49	Class 2	5 gallons	5 gallons	Physical
HM50	Class 1	10 gallons	10 gallons	Physical
Unstable Solids (Reactive)				
HM51	Class 4	Any amount	Any amount	Physical
HM52	Class 3	Any amount	Any amount	Physical
HM53	Class 2	50 pounds	50 pounds	Physical
HM54	Class 1	100 pounds	100 pounds	Physical
Water-Reactive Liquids				
HM55	Class 3	Any amount	Any amount	Physical
HM56	Class 2	5 gallons	5 gallons	Physical
HM57	Class 1	10 gallons	10 gallons	Physical
Water-Reactive Solids				
HM58	Class 3	Any amount	Any amount	Physical
HM59	Class 2	5 gallons	50 pounds	Physical
HM60	Class 1	10 gallons	100 pounds	Physical

[1] Includes compressed gases

8.2.2 Spatial and Tabular Data

The input to this module is a listing of the locations of facilities storing hazardous materials and the types/amounts of the materials stored at the facility. Facilities need only be identified if they use, store, or handle quantities of hazardous materials in excess of the quantities listed in Table 8-3. Other facilities that may have hazardous materials, but in quantities less than those listed in Table 8-3, should not be included in the database because it is anticipated that releases of these small quantities will not put significant immediate demands on health and emergency services. However, the user may choose to modify threshold amounts in building the database.

To build the hazardous materials database for a selected region, the user should attempt to gather the following information:

- Name of Facility or Name of Company

- Street Address
- City
- County
- State
- Zip Code
- Name of Contact in Company
- Phone Number of Contact in Company
- Standard Industrial Classification (SIC) Code
- Chemical Abstracts Service (CAS) Registry Number
- Chemical Name
- Chemical Quantity
- Hazus Hazardous Material Class (From Table 10-1)
- Latitude and Longitude of Facility

The CAS registry number is a numeric designation assigned by the American Chemical Society's Chemical Abstracts Service, and uniquely identifies a specific chemical compound. This entry allows one to conclusively identify a material regardless of the name or naming system used. To obtain this data, the user must identify the local agency with which users of hazardous materials must file for permits. Based upon current understanding of the process, this local agency would be the Fire Department for incorporated areas, and the County Health Department for unincorporated areas. The user may opt to view the information contained in a modified version of the Environmental Protection Agency-Toxics Release Inventory (EPA-TRI) Database provided in the methodology. This database, however, is limited and the user is urged to collect additional inventory.

The output of this module is a database that can be sorted according to any of the fields listed above. It can be displayed on a map and overlaid with other maps. More information on SARA Title III and the TRI Database can be found at EPA (2020a) and EPA (2020b).

Section 9. Transportation Systems

Hazus also includes modeling capabilities related to transportation infrastructure. The Transportation Module and associated inventory data in Hazus includes the following: highways, railways, light rail, bus, ports, ferries, and airports. The transportation classification system used in the Hazus Methodology was developed to provide an ability to differentiate between different system components with substantially different damage and loss characteristics. All transportation system elements can be modeled by the Earthquake Model. The Flood Model can only model impacts to bridges for highways, railways, and light rail.

Table 9-1 summarizes the current status of the transportation system spatial and tabular database elements by data type, hazard, and sources. The November 2019 Hazus Data and Tools Release includes updates to most of the transportation data with datasets from HIFLD. Table 9-1 represents the status of Hazus transportation systems at the end of 2019. Table 9-2 provides the updated valuations used for the HIFLD-based datasets. The remaining discussion in this section will provide more background into the different elements of each transportation system, Hazus classifications, and the Internal Hazus valuation used for these classes when not superseded by the recent HIFLD updates.

Table 9-1 Baseline Transportation System Databases Summary Table

Transportation Data Type	Data Element	Hazards	Current Source and Date of Current Hazus Data
Highway Segment Data	Highway Segment	EQ	National Highway Planning Network (2005)
Highway Bridge Data	Highway Bridge	EQ, FL	HIFLD Open Source: National Bridge Inventory (2018)
Highway Tunnel Data	Highway Tunnel	EQ	HIFLD Open Source: Road Tunnels (2019)
Railway Segment Data	Railway Segment	EQ	HIFLD Open Source: Railroads (2019)
Railway Bridge Data	Railway Bridge	EQ, FL	HIFLD Open Source: Railroad Bridges (2018)
Railway Tunnel Data	Railway Tunnel	EQ	National Bridge Inventory (2001)
Railway Facility Data	Railway Facility	EQ	Bureau of Transportation Statistics (2007)
Light Rail Segment Data	Light Rail Segment	EQ	HIFLD Open Source: Fixed Guideway Transit Links (2019)
Light Rail Bridge Data	Light Rail Bridge	EQ, FL	National Bridge Inventory (2001)
Light Rail Tunnel Data	Light Rail Tunnel	EQ	None
Light Rail Facility Data	Light Rail Facility	EQ	HIFLD Open Source: Fixed Guideway Transit Stations (2019)
Bus Data	Bus	EQ	HIFLD Open Source: Intermodal Passenger Connectivity Database (IPCD) (2019) where facility type = 2.
Port Data	Port	EQ	HIFLD Open Source: Port Facilities (2019)
Ferry Data	Ferry	EQ	USACE CEIWR Navigation Data Center (2007)

Transportation Data Type	Data Element	Hazards	Current Source and Date of Current Hazus Data
Airport Facility Data	Airport Facility	EQ	HIFLD Open Source: Aircraft Landing Facility (2019)
Airport Runway Data	Airport Runway	EQ	HIFLD Open Source: Airport Runway (2019)

** Source: Hazus Program Infrastructure Data Updates, Detailed Methodology (FEMA, 2019a)*

Table 9-2 Valuation Data for Transportation Elements

Element	Target States	Valuation Approach
Highway Segments	All States, including Alaska, District of Columbia, Hawaii, and Puerto Rico	Uses updated values for 2019 of $6,668K/km for four lane major road and $3,334K/km for two lane urban streets.
Highway Bridge	All States, including Alaska, District of Columbia, Hawaii, and Puerto Rico	New square-footage cost table provided by Caltrans and are added to CDMS and adjusted for other States relative to California based on RSMeans State non-residential factors (derived from average of county factors in each state).
Highway Tunnel	All States, including Alaska, District of Columbia, Hawaii, and Puerto Rico	Escalated legacy 2003 costs to 2019 using CPI to $18.6K per foot ($60.9 per meter) and adjusted by State RSMeans factors.
Railway Segment	All States, including Alaska, District of Columbia, Hawaii, and Puerto Rico	Use legacy value of $1,500K. Did not escalate to 2019 since there is uncertainty in base year and conversion issues in the legacy data. Adjusted by State RSMeans factors.
Railway Bridge	All States, including Alaska, District of Columbia, and Puerto Rico, not including Hawaii	Use legacy value of $5M. Chose not to escalate to 2019 since the value is already well above the source (G&E, 1994) report recommendation and with the new dataset, a large range of bridges, including more minor structures are included.
Railway Tunnel	All States, including Alaska, District of Columbia, Hawaii, and Puerto Rico	Use legacy value of $10,000K. Did not escalate to 2019 since there is uncertainty in base year and conversion issues in the legacy data.
Railway Facility	All States, including Alaska, District of Columbia, Hawaii, and Puerto Rico	Escalated legacy values to 2019 with $3,200K for stations and default facilities and $3,000K for Fuel and Dispatch.
Light Rail Segment	All states and District of Columbia, not including Alaska, Hawaii, or Puerto Rico	Use legacy value of $1,500K. Did not escalate to 2019 since there is uncertainty in base year and conversion issues in the legacy data. Adjusted by State RSMeans factors.
Light Rail Bridge	All States, including Alaska, District of Columbia, Hawaii, and Puerto Rico	Uses legacy data and value of $5,000K. Did not escalate to 2019 since there is uncertainty in base year and conversion issues in the legacy data.
Light Rail Tunnel	All States, including Alaska, District of Columbia, Hawaii, and Puerto Rico	Uses legacy data and value of $10,000K. Did not escalate to 2019 since there is uncertainty in base year and conversion issues in the legacy data.

Element	Target States	Valuation Approach
Light Rail Facility	All states and District of Columbia, not including Alaska, Hawaii, or Puerto Rico	Escalate legacy value of $2,600K to 2019 CPI of $3,200K, and adjust by RSMeans State factors.
Bus	All states, including Alaska, District of Columbia, and Hawaii, not including Puerto Rico	Escalate legacy value of $1M to 2019 $1.6M per facility and apply the State RSMeans factors.
Port	All states, including Alaska, Hawaii and Puerto Rico	Escalated to 2019 to $3,160K and adjusted by State RSMeans nonresidential ratios
Ferry	All States, including Alaska, District of Columbia, Hawaii, and Puerto Rico	Escalated to 2019 to $1,580K.
Airport Facility	All states and territories. Will use new FEMA deliverable for U.S. Virgin Islands	Large passenger airports area proxy is based on annual passenger volume and COM4 replacement value. Other urban facilities use larger default from manual ($12,600K 2019), while rural facilities will use default for hangar and lighter facilities ($5,000K 2019).
Airport Runway	All states and territories, including U.S. Virgin Islands	Length and width values provided by HIFLD Open for area and $95 sq.ft with nonresidential state ratios.

** The Internal Hazus replacement cost data in the existing transportation database was on 2001 NBI derived by the original Hazus development team in 2003 from expert opinion.*
*** Source: Hazus Program Infrastructure Data Updates, Detailed Methodology (FEMA, 2019a)*

9.1 Highway Transportation System

A highway system is composed of three components: roadways, bridges, and tunnels. In this section, a brief description for each is given.

- *Roadways*: Roadways are classified as major roads or urban roads. Major roads include interstate and state highways and other roads with four lanes or more. Parkways are also classified as major roads. Urban roads include intercity roads and other roads with two lanes.
- *Bridges:* Bridges are classified based on the following structural characteristics:
    - Seismic Design
    - *Number of spans:* single vs. multiple span bridges
    - *Structure type*: concrete, steel, and others
    - *Pier type:* multiple column bents, single column bents, and pier walls
    - *Abutment type and bearing type:* monolithic vs. non-monolithic, high rocker bearings, low steel bearings, and neoprene rubber bearings
    - *Span continuity:* continuous, discontinuous (in-span hinges), and simply supported
- *Tunnels:* Tunnels are classified as bored/drilled or cut and cover.

Additional background information for bridges is required, since the seismic design of a bridge is taken into account in terms of the (1) spectrum modification factor, (2) strength reduction factor due to cyclic motion, (3) drift limits, and (4) the longitudinal reinforcement ratio.

This classification scheme incorporates various parameters that affect damage into fragility analysis and provides a means to obtain better fragility curves when data become available. A total of 28 classes (HWB1 through HWB28) have been defined this way. These classes differentiate the bridge characteristics found in the National Bridge Inventory (NBI) from 1988. Table 9-3 and Table 9-4 summarize the key NBI characteristics used, while Table 9-5 presents the 28 bridge classes derived for Hazus with detailed value related to flood analysis. Year built from the NBI is used to classify as seismic if built in 1990 or later in California, and 1975 or later outside of California.

Table 9-3 Bridge Material Classes in NBI

Code	Description
1	Concrete
2	Concrete continuous
3	Steel
4	Steel continuous
5	Prestressed concrete
6	Prestressed concrete continuous
7	Timber
8	Masonry
9	Aluminum, Wrought Iron, or Cast
0	Other

Table 9-4 Bridge Types in NBI

Code	Description
01	Slab
02	Stringer/Multi-beam or Girder
03	Girder and Floor beam System
04	Tee Beam
05	Box Beam or Girders – Multiple
06	Box Beam or Girders – single or Spread
07	Frame
08	Orthotropic
09	Truss – Deck
10	Truss – Thru
11	Arch – Deck
12	Arch – Thru
13	Suspension
14	Stayed Girder
15	Movable – Lift
16	Movable – Bascule
17	Movable – Swing
18	Tunnel
19	Culvert
20	Mixed Types (applicable only to approach spans)
21	Segmental Box Girder
22	Channel Beam
00	Other

Table 9-5 Detailed Hazus Bridge Classification Scheme

Class	NBI Class	State	Year Built	# Spans	Length of Max. Span (meter)	Length less than 20 meters	K3D	Ishape	Design	Description
HWB1	All	Non-CA	< 1990		> 150	N/A	EQ1	0	Conventional	Major Bridge – Length > 150 meters
HWB1	All	CA	< 1975		> 150	N/A	EQ1	0	Conventional	Major Bridge – Length > 150 meters
HWB2	All	Non-CA	>= 1990		> 150	N/A	EQ1	0	Seismic	Major Bridge – Length > 150 meters
HWB2	All	CA	>= 1975		> 150	N/A	EQ1	0	Seismic	Major Bridge – Length > 150 meters
HWB3	All	Non-CA	< 1990	1		N/A	EQ1	1	Conventional	Single Span
HWB3	All	CA	< 1975	1		N/A	EQ1	1	Conventional	Single Span
HWB4	All	Non-CA	>= 1990	1		N/A	EQ1	1	Seismic	Single Span
HWB4	All	CA	>= 1975	1		N/A	EQ1	1	Seismic	Single Span
HWB5	101-106	Non-CA	< 1990			N/A	EQ1	0	Conventional	Multi-Col. Bent, Simple Support – Concrete
HWB6	101-106	CA	< 1975			N/A	EQ1	0	Conventional	Multi-Col. Bent, Simple Support – Concrete
HWB7	101-106	Non-CA	>= 1990			N/A	EQ1	0	Seismic	Multi-Col. Bent, Simple Support – Concrete
HWB7	101-106	CA	>= 1975			N/A	EQ1	0	Seismic	Multi-Col. Bent, Simple Support – Concrete
HWB8	205-206	CA	< 1975			N/A	EQ2	0	Conventional	Single Col., Box Girder – Continuous Concrete
HWB9	205-206	CA	>= 1975			N/A	EQ3	0	Seismic	Single Col., Box Girder – Continuous Concrete
HWB10	201-206	Non-CA	< 1990			N/A	EQ2	1	Conventional	Continuous Concrete
HWB10	201-206	CA	< 1975			N/A	EQ2	1	Conventional	Continuous Concrete
HWB11	201-206	Non-CA	>= 1990			N/A	EQ3	1	Seismic	Continuous Concrete
HWB11	201-206	CA	>= 1975			N/A	EQ3	1	Seismic	Continuous Concrete
HWB12	301-306	Non-CA	< 1990			No	EQ4	0	Conventional	Multi-Col. Bent, Simple Support – Steel
HWB13	301-306	CA	< 1975			No	EQ4	0	Conventional	Multi-Col. Bent, Simple Support – Steel
HWB14	301-306	Non-CA	>= 1990			N/A	EQ1	0	Seismic	Multi-Col. Bent, Simple Support – Steel
HWB14	301-306	CA	>= 1975			N/A	EQ1	0	Seismic	Multi-Col. Bent, Simple Support – Steel

Class	NBI Class	State	Year Built	# Spans	Length of Max. Span (meter)	Length less than 20 meters	K3D	Ishape	Design	Description
HWB15	402-410	Non-CA	< 1990			No	EQ5	1	Conventional	Continuous Steel
HWB15	402-410	CA	< 1975			No	EQ5	1	Conventional	Continuous Steel
HWB16	402-410	Non-CA	>= 1990			N/A	EQ3	1	Seismic	Continuous Steel
HWB16	402-410	CA	>= 1975			N/A	EQ3	1	Seismic	Continuous Steel
HWB17	501-506	Non-CA	< 1990			N/A	EQ1	0	Conventional	Multi-Col. Bent, Simple Support – Prestressed Concrete
HWB18	501-506	CA	< 1975			N/A	EQ1	0	Conventional	Multi-Col. Bent, Simple Support – Prestressed Concrete
HWB19	501-506	Non-CA	>= 1990			N/A	EQ1	0	Seismic	Multi-Col. Bent, Simple Support – Prestressed Concrete
HWB19	501-506	CA	>= 1975			N/A	EQ1	0	Seismic	Multi-Col. Bent, Simple Support – Prestressed Concrete
HWB20	605-606	CA	< 1975			N/A	EQ2	0	Conventional	Single Col., Box Girder – Prestressed Continuous Concrete
HWB21	605-606	CA	>= 1975			N/A	EQ3	0	Seismic	Single Col., Box Girder – Prestressed Continuous Concrete
HWB22	601-607	Non-CA	< 1990			N/A	EQ2	1	Conventional	Continuous Concrete
HWB22	601-607	CA	< 1975			N/A	EQ2	1	Conventional	Continuous Concrete
HWB23	601-607	Non-CA	>= 1990			N/A	EQ3	1	Seismic	Continuous Concrete
HWB23	601-607	CA	>= 1975			N/A	EQ3	1	Seismic	Continuous Concrete
HWB24	301-306	Non-CA	< 1990			Yes	EQ6	0	Conventional	Multi-Col. Bent, Simple Support – Steel
HWB25	301-306	CA	< 1975			Yes	EQ6	0	Conventional	Multi-Col. Bent, Simple Support – Steel
HWB26	402-410	Non-CA	< 1990			Yes	EQ7	1	Conventional	Continuous Steel
HWB27	402-410	CA	< 1975			Yes	EQ7	1	Conventional	Continuous Steel
HWB28										All other bridges that are not classified

The 28 bridge classes in Table 9-5 (HWB1 through HWB28) reflect the maximum number of combinations for 'standard' bridge classes.

Some of the items in Table 9-5 need further descriptions. K3D value shown in table represents different equations that calculate a factor that modifies the piers' 2-dimensional capacity to allow for the 3-dimensional arch action in the deck. The *Hazus Earthquake Model Technical Manual* (FEMA, 2021) includes in Section 7 the specific equations for the actual K3D values.

The Ishape item is a Boolean indicator for the Kshape factor. The Kshape factor is the modifier that converts cases for short periods to an equivalent spectral amplitude at T=1.0 second. When Ishape = 0, the Kshape factor does not apply. When Ishape = 1, the Kshape factor applies. The *Hazus Earthquake Model Technical Manual* (FEMA, 2021) includes in Section 7 more information on applying the Kshape factor.

As part of the updates to this bridge date, a new approach was implemented for retrofit bridges. When a retrofit bridge was identified from the available data, these were reclassified from Conventional to Seismic bridge classes using the date of reconstruction when available. This assumed the retrofits upgraded the bridges from conventional to seismic design and the approach was verified with Caltrans. Otherwise Hazus used the original year-built date to classify bridges.

Table 9-6 includes the full Hazus Highway Classification, including the legacy valuations still being used for elements not updated with HIFLD data.

Table 9-6 Hazus Highway System Classification

Label	Description
HDFLT	Default Highway Segment
HRD1	Major Roads (1 kilometer length, 4 lanes)
HRD2	Urban Roads (1 kilometer length, 2 lanes)
HDFLT	Default Bridge
HWB1	Major Bridge - Length > 150 meters (Conventional Design)
HWB2	Major Bridge - Length > 150 meters (Seismic Design)
HWB3	Single Span – (Not HWB1 or HWB2) (Conventional Design)
HWB4	Single Span – (Not HWB1 or HWB2) (Seismic Design)
HWB5	Concrete, Multi-Column Bent, Simple Support (Conventional Design), Non-California (Non-CA)
HWB6	Concrete, Multi-Column Bent, Simple Support (Conventional Design), California (CA)
HWB7	Concrete, Multi-Column Bent, Simple Support (Seismic Design)
HWB8	Continuous Concrete, Single Column, Box Girder (Conventional Design)
HWB9	Continuous Concrete, Single Column, Box Girder (Seismic Design)
HWB10	Continuous Concrete, (Not HWB8 or HWB9) (Conventional Design)
HWB11	Continuous Concrete, (Not HWB8 or HWB9) (Seismic Design)
HWB12	Steel, Multi-Column Bent, Simple Support (Conventional Design), Non-California (Non-CA)

Label	Description
HWB13	Steel, Multi-Column Bent, Simple Support (Conventional Design), California (CA)
HWB14	Steel, Multi-Column Bent, Simple Support (Seismic Design)
HWB15	Continuous Steel (Conventional Design)
HWB16	Continuous Steel (Seismic Design)
HWB17	PS Concrete Multi-Column Bent, Simple Support - (Conventional Design), Non-California
HWB18	PS Concrete, Multi-Column Bent, Simple Support (Conventional Design), California (CA)
HWB19	PS Concrete, Multi-Column Bent, Simple Support (Seismic Design)
HWB20	PS Concrete, Single Column, Box Girder (Conventional Design)
HWB21	PS Concrete, Single Column, Box Girder (Seismic Design)
HWB22	Continuous Concrete, (Not HWB20/HWB21) (Conventional Design)
HWB23	Continuous Concrete, (Not HWB20/HWB21) (Seismic Design)
HWB24	Same definition as HWB12 except that the bridge length is less than 20 meters
HWB25	Same definition as HWB13 except that the bridge length is less than 20 meters
HWB26	Same definition as HWB15 except that the bridge length is less than 20 meters and Non-CA
HWB27	Same definition as HWB15 except that the bridge length is less than 20 meters and in CA
HWB28	All other bridges that are not classified (including wooden bridges)
HDFLT	Default Highway Tunnel
HTU1	Highway Bored/Drilled Tunnel
HTU2	Highway Cut and Cover Tunnel

For the Internal Hazus highway segment data, the data provided in Hazus is the National Highway Planning Network created by the Federal Highway Administration (FHWA) in 2005. The dataset is updated every three to six years, with the latest data being from 2019. The inventory data required for earthquake analysis includes the geographical location, classification, length, and replacement cost of the system components. For flood analysis, the inventory data also includes a scour potential value from the source FHWA data. The *Hazus Flood Model Technical Manual* (FEMA, 2021) includes more information on the scour potential and how the Flood Model uses the scour to predict damages.

9.2 Railway Transportation System

A railway system consists of four components: tracks/roadbeds, bridges, tunnels, and facilities. This section provides a brief description of each.

- *Tracks/Roadbeds:* Tracks/roadbeds refers to the assembly of rails, ties, and fastenings, and the ground on which they rest. Only one classification is adopted for these components. This classification is analogous to that of urban roads in highway systems.
- *Bridges:* Railway bridges are classified in a manner similar to steel and concrete highway bridges.
- *Tunnels:* Railway tunnels follow the same classification as highway tunnels. That is, they are classified either as bored/drilled tunnels, or cut and cover tunnels.
- *Railway system facilities:* Railway system facilities include urban and suburban stations, maintenance facilities, fuel facilities, and dispatch facilities.
    - Urban and suburban stations are generally key connecting hubs that are important for system functionality. In the western U.S., these buildings are mostly made of reinforced concrete shear walls or moment resisting steel frames, while in the eastern U.S., the small stations are mostly wood and the large ones are mostly masonry or braced steel frames.
    - Maintenance facilities are housed in large structures that are not usually critical for system functionality as maintenance activities can be delayed or performed elsewhere. These building structures are often made of steel braced frames.
    - Fuel facilities include buildings, tanks (anchored, unanchored, or buried), backup power systems (if available, anchored or unanchored diesel generators), pumps, and other equipment (anchored or unanchored). It should be mentioned that anchored equipment in general refers to equipment designed with special seismic tiedowns or tiebacks, while unanchored equipment refers to equipment designed with no special considerations other than the manufacturer's normal requirements. Some vibrating components, such as pumps, are bolted down regardless of concern for earthquakes. As used here, "anchored" means all components have been engineered to meet seismic criteria, which may include bracing (e.g., pipe or stack bracing) or flexibility requirements (e.g., flexible connections across separation joints) as well as anchorage. These definitions of anchored and unanchored apply to all transportation system components. Above ground tanks are typically made of steel with roofs also made of steel. Buried tanks are typically concrete wall construction with concrete roofs. The fuel facility functionality module was determined with a fault tree analysis considering redundancies and subcomponent behavior. Note that generic building damage functions were used in this fault tree analysis to develop the overall fragility curve of fuel facilities. In total, five types of fuel facilities are considered. These are: fuel facilities with or without anchored equipment, with or without backup power (all combinations), and fuel facilities with buried tanks.
    - Dispatch facilities consist of buildings, backup power supplies (if available, anchored or unanchored diesel generators), and electrical equipment (anchored or unanchored). Damage functions for a generic reinforced concrete building with shear walls were used in this fault tree to develop the overall fragility curves for dispatch facilities. In total, four types of dispatch facilities are considered. These are dispatch facilities with or without anchored equipment and with or without backup power (all combinations).

Table 9-7 includes the full Hazus railway classification, including the legacy valuations still being used for elements not updated with HIFLD data.

Table 9-7 Hazus Railway System Classification

Label	Description
Railway Tracks	
RDFLT	Default Track
RTR	Railway Tracks (per km)
Railway Bridges	
RDFLT	Default Railway Bridge
RLB1	Steel, Multi-Column Bent, Simple Support (Conventional Design), Non-California (Non-CA)
RLB2	Steel, Multi-Column Bent, Simple Support (Conventional Design), California (CA)
RLB3	Steel, Multi-Column Bent, Simple Support (Seismic Design)
RLB4	Continuous Steel (Conventional Design)
RLB5	Continuous Steel (Seismic Design)
RLB6	Same definition as HWB1 except that the bridge length is less than 20 meters
RLB7	Same definition as HWB2 except that the bridge length is less than 20 meters
RLB8	Same definition as HWB4 except that the bridge length is less than 20 meters and Non-CA
RLB9	Same definition as HWB5 except that the bridge length is less than 20 meters and in CA
RLB10	All other bridges that are not classified
Railway Facilities	
RDFLT	Default Railway Facility
RST	Rail Urban Station (with all building type options enabled)
RFF	Rail Fuel Facility (different combinations for with or without anchored components and/or with or without backup power)
RDF	Rail Dispatch Facility (different combinations for with or without anchored components and/or with or without backup power)
RMF	Rail Maintenance Facility (with all building type options enabled)
Railway Tunnels	
RDFLT	Default Railway Tunnel
RTU1	Rail Bored/Drilled Tunnel
RTU2	Rail Cut and Cover Tunnel

For the Internal Hazus railway tunnel data, the data provided in Hazus is the NBI created by the FHWA in 2001. Currently, railway tunnels are no longer part of the NBI and are not updated in Hazus on a regular schedule. The inventory data required for earthquake analysis include the geographical location, classification, and replacement cost of the system components. Limitations for its current use are that the locations of the tunnels from the 2001 dataset are not very accurate and are incomplete.

For the Internal Hazus railway facility data, the data provided in Hazus is the Intermodal Terminal Facility Database created by the Bureau of Transportation Statistics in 2007. The dataset is updated annually with the latest data from 2018. The inventory data required for earthquake analysis include the geographical location, classification, and replacement cost of the system components.

9.3 Light Rail Transportation System

Like railway systems, light rail systems consist of railway tracks/roadbeds, bridges, tunnels, maintenance facilities, and dispatch facilities. The only difference between rail and light rail systems is in the fuel facilities, which for light rail are direct current (DC) power substations.

DC Power Substations: Light rail systems use electric power and have low voltage DC power substations. The DC power substations consist of electrical equipment, which converts the local electric utility AC power to DC power. Two types of DC power stations are considered. These are: (1) DC power stations with anchored (seismically designed) components and (2) DC power stations with unanchored (which are not seismically designed) components.

Table 9-8 includes the full Hazus light rail system classification, including the legacy valuations still being used for elements not updated with HIFLD data.

Table 9-8 Hazus Light Rail System Classification

Label	Description
Light Rail Tracks	
LDFLT	Default Light Rail Track
LTR	Light Rail Track
Light Rail Bridges	
LDFLT	Default Light Rail Bridges
LRB1	Steel, Multi-Column Bent, Simple Support (Conventional Design), Non-California (Non-CA)
LRB2	Steel, Multi-Column Bent, Simple Support (Conventional Design), California (CA)
LRB3	Steel, Multi-Column Bent, Simple Support (Seismic Design)
LRB4	Continuous Steel (Conventional Design)
LRB5	Continuous Steel (Seismic Design)
LRB6	Same definition as HWB1 except that the bridge length is less than 20 meters
LRB7	Same definition as HWB2 except that the bridge length is less than 20 meters
LRB8	Same definition as HWB4 except that the bridge length is less than 20 meters and Non-CA
LRB9	Same definition as HWB5 except that the bridge length is less than 20 meters and in CA
LRB10	All other bridges that are not classified

Label	Description
Light Rail Tunnels	
LDFLT	Default Light Rail Tunnel
LTU1	Light Rail Bored/Drilled Tunnel
LTU2	Light Rail Cut and Cover Tunnel
Light Rail Facilities	
LDFLT	Default Light Rail Facilities
LDC	Light Rail DC Substation
LDF	Light Rail Dispatch Facility (different combinations for with or without anchored components and/or with or without backup power)
LMF	Maintenance Facility (with all building type options enabled)

For the Internal Hazus light rail bridge data, the data provided in Hazus is the NBI created by the FHWA in 2001. While the NBI does update their data annually, the latest Hazus dataset is still from 2001. The inventory data required for earthquake analysis include the geographical location, classification, and replacement cost of the system components. The data required for the Flood Model includes geographical location, classification, scour potential, and replacement cost. The limitation with the current Hazus data is that the locations of the bridges from the 2001 dataset are not very accurate, and only highway bridges over light rail are included.

For the Internal Hazus light rail tunnels, no data is provided, but it can be modeled in the Earthquake Model. The inventory data required for earthquake analysis include the geographical location, classification, and replacement cost of the system components.

9.4 Bus Transportation System

A bus system consists mainly of four components: urban stations, fuel facilities, maintenance facilities, and dispatch facilities. This section provides a brief description of each.

- *Urban Stations:* These are mainly building structures.
- *Bus System Fuel Facilities:* Fuel facilities consist of fuel storage tanks, buildings, pump equipment and buried pipe, and sometimes backup power. The fuel facility functionality is determined with a fault tree analysis considering redundancies and sub-component behavior. The same sub-classes assumed for railway fuel facilities are assumed here.
- *Bus System Maintenance Facilities:* Maintenance facilities for bus systems are mostly of braced steel frames construction. The same classes assumed for railway maintenance facilities are assumed here.
- *Bus System Dispatch Facilities:* The same classes assumed for railway dispatch facilities above are assumed here.

Table 9-9 includes the Hazus bus system classification, including the legacy valuations still being used for elements not updated with HIFLD data.

Table 9-9 Hazus Bus System Classification

Label	Description
BDFLT	Default Bus facility
BPT	Bus Urban Station (with all building type options enabled)
BFF	Bus Fuel Facility (different combinations for with or without anchored components and/or with or without backup power)
BDF	Bus Dispatch Facility (different combinations for with or without anchored components and/or with or without backup power)
BMF	Bus Maintenance Facilities (with all building type options enabled)

9.5 Port Transportation System

A port system consists of four components: waterfront structures, cranes/cargo handling equipment, fuel facilities, and warehouses. This section provides a brief description of each.

- *Waterfront Structures:* Waterfront structures include wharves (port embankments), seawalls (protective walls from erosion), and piers (break-water structures that form harbors). Waterfront structures typically are supported by wood, steel, or concrete piles. Many also have batter piles to resist lateral loads from wave action and impact of vessels. Seawalls are caisson walls retaining earth fill material.
- *Cranes and Cargo Handling Equipment:* These are large equipment items used to load and unload freight from vessels. These can be stationary or mounted on rails.
- *Port Fuel Facilities***:** The fuel facility consists mainly of fuel storage tanks, buildings, pump equipment, piping, and sometimes backup power. These facilities are assumed to be equivalent to those for railway systems. The functionality of fuel systems is determined with a fault tree analysis, which considers redundancies and sub-component behavior.
- *Warehouses:* Warehouses are large buildings usually constructed of structural steel. In some cases, warehouses may be several hundred feet from the shoreline, while in other instances; they may be located on the wharf itself.

Table 9-10 includes the Hazus port and harbor system classification, including the legacy valuations still being used for elements not updated with HIFLD data.

Table 9-10 Hazus Port and Harbor System Classification

Label	Description	Hazus Valuation
PDFLT	Default Port facility	
PWS	Waterfront Structures	$1,500,000
PEQ1	Stationary Port Handling Equipment	$2,000,000
PEQ2	Rail Mounted Port Handling Equipment	$2,000,000
PWH	Port Warehouses (with all building type options enabled)	$1,200,000
PFF	Port Fuel Facility (different combinations for with or without anchored components and/or with or without backup power)	$2,000,000

** Replacement cost data in existing transportation database based on 2001 NBI derived by original Hazus development team in 2003 from expert opinion.*

9.6 Ferry Transportation System

A ferry system consists of the five components mentioned above: waterfront structures, fuel facilities, maintenance facilities, dispatch facilities, and passenger terminals. This section provides a brief description of each.

- *Waterfront Structures:* These are the same as those described for port systems above.
- *Fuel Facilities:* These facilities are similar to those for port systems above, but may be built for a smaller range of boat sizes associated with ferries as compared to ports.
- *Maintenance Facilities*: These are often steel braced frame structures, but other building types are possible.
- *Dispatch Facilities:* These are the same as those defined for railway systems.
- *Passenger Terminals:* These are often moment resisting steel frames, but other building types are possible.

Table 9-11 includes the Hazus ferry system classification, including the legacy valuations still being used for elements not updated with HIFLD data.

Table 9-11 Hazus Ferry System Classification

Label	Description
FDFLT	Ferry Default facility
FWS	Ferry Waterfront Structures
FPT	Passenger Terminals (with all building type options enabled)
FFF	Ferry Fuel Facility (different combinations for with or without anchored components and/or with or without backup power)
FDF	Ferry Dispatch Facility (different combinations for with or without anchored components and/or with or without backup power)
FMF	Piers and Dock Facilities (with all building type options enabled)

The Internal Hazus Ferry data is from USACE Institute for Water Resources (CEIWR) Navigation Data Center, Ports and Waterways Division in 2007. The inventory data required for ferry system's earthquake analysis include the geographical location, classification, and replacement cost of ferry system facilities.

9.7 Airport Transportation System

An airport system consists of the seven components mentioned above: runways, control towers, fuel facilities, terminal buildings, maintenance facilities, hangar facilities, and parking structures. This section provides a brief description of each.

- *Runways:* This component consists of well-paved “flat and wide surfaces”.

- *Control Towers:* Control towers consist of a building and the necessary equipment for air control and monitoring.
- *Fuel Facilities:* Previously defined in Section 9.2 of railway systems.
- *Terminal Buildings:* These are similar to urban stations of railway systems, but usually much larger in building area.
- *Maintenance and Hangar Facilities and Parking Structures:* Maintenance and hangar facilities and parking structures are mainly composed of buildings.

Table 9-12 includes the Hazus Airports Classification, including the legacy valuations still being used for elements that have not been updated with HIFLD data.

Table 9-12 Hazus Airport Facility Systems Classifications

Label	Description
ADFLT	Airport Default facility
ACT	Airport Control Tower (with all building type options enabled)
ATB	Airport Terminal Building (with all building type options enabled)
APS	Airport Parking Structure (with all building type options enabled)
AFF	Airport Fuel Facility (different combinations for with or without anchored components and/or with or without backup power)
AMF	Airport Maintenance & Hangar Facility (with all building type options enabled)
ARW	Airport Runway
AFO	Gliderport, Seaport, Stolport, Ultralight or Balloonport Facilities
AFH	Heliport Facilities

In summary, this section provided the latest status for Hazus data related to transportation systems. While many data sources have recently been updated from HIFLD sources, there are still some transportation systems with Internal Hazus transportation data.

Section 10. Utility Systems

Hazus also includes limited modeling capabilities related to utility systems. The Utility Module is composed of the following six systems:

- Potable Water
- Wastewater
- Oil (crude and refined)
- Natural Gas
- Electric Power
- Communication

The classification system used in the Hazus Methodology was developed to be able to differentiate utility system components with substantially different damage and loss characteristics. All utility system elements can be modeled by the Earthquake Model. The Flood Model can model roughly half of the utility system elements as shown in Table 10-1.

Table 10-1 summarizes the current status of the utility systems' spatial and tabular database elements by data type, hazard, sources, and an overview of how often the source data is currently planned to be updated. The Hazus development team is updating most of the utility data with datasets from HIFLD. Table 10-1 represents the status of Hazus utility systems at the end of 2019. Table 10-2 provides some supplemental information on the new HIFLD-based datasets. The remaining discussion in this Section will provide more background into the different elements of each utility system, Hazus classifications, and the Internal Hazus valuation used for these classes when not superseded by the recent HIFLD updates.

Table 10-1 Baseline Utility Systems Databases Summary Table

Transportation Data Type	Data Element	Hazards	Current Source and Date of Current Hazus Data
Potable Water Distribution Lines Data	Potable Water Distribution Lines	EQ	TIGER data (2017)
Potable Water Facilities Data	Potable Water Facilities	EQ, FL	Envirofacts Data Warehouse (2001)
Potable Water Pipelines Data	Potable Water Pipelines	EQ, FL	None
Wastewater Distribution Lines Data	Wastewater Distribution Lines	EQ	TIGER data (2017)
Wastewater Facilities Data	Wastewater Facilities	EQ, FL	HIFLD Open Data: EPA FRS (2019)
Wastewater Pipelines Data	Wastewater Pipelines	EQ	None
Oil Facilities Data	Oil Facilities	EQ, FL	Envirofacts Data Warehouse (2001)
Oil Pipelines Data	Oil Pipelines	EQ	None
Natural Gas Distribution Lines Data	Natural Gas Distribution Lines	EQ	TIGER data (2017)

Transportation Data Type	Data Element	Hazards	Current Source and Date of Current Hazus Data
Natural Gas Facilities Data	Natural Gas Facilities	EQ, FL	HIFLD Open Data: Natural Gas Processing Plants (2019) and Natural Gas Compressor Stations (2019)
Natural Gas Pipelines Data	Natural Gas Pipelines	EQ	HIFLD Open Data: Natural Gas Pipelines (2019)
Electrical Power Facility Data	Electrical Power Facility	EQ	HIFLD Open Data: Power Plants (2019)
Communication Facility Data	Communication Facility	EQ	FCC Broadcast Auxiliary Microwave database (2001)

** Source: Hazus Program Infrastructure Data Updates, Detailed Methodology (FEMA, 2019a)*

Table 10-2 HIFLD Data for Selected Utility Elements

Element	Target States	Valuation Approach
Wastewater Facilities	All states and territories. Will use new FEMA deliverable for U.S. Virgin Islands	Escalate legacy valuation to 2019, $110,965K or $111M for every facility
Natural Gas Facilities	Contiguous 48 states and Hawaii, not including Alaska, Puerto Rico, or Territories. Will use new FEMA deliverable for U.S. Virgin Islands	2019 adjusted legacy default of $1,750K, and RSMeans nonresidential adjustment factors
Natural Gas Pipelines	Lower 48 states, not including Alaska, District of Columbia, Hawaii, Puerto Rico, or Territories	Use 2019 value of $683K per km, escalated based on South Carolina values.
Electrical Power Facility	All 50 states, including District of Columbia and Puerto Rico, using 10MW threshold eliminates plants in American Samoa and Guam.	Escalate to 2019 $174,000K for small (<100MW) and $875,000K for medium and large (100-500MW and >500MW)

** Source: Hazus Program Infrastructure Data Updates, Detailed Methodology (FEMA, 2019a)*

10.1 Potable Water Systems

A potable water system typically consists of terminal reservoirs, water treatment plants, wells, pumping plants, storage tanks, and transmission and distribution pipelines. In this subsection, a brief description of each of these components is presented.

- *Terminal Reservoirs:* Terminal reservoirs are typically lakes (man-made or natural) and are usually located nearby and upstream of the water treatment plant. Vulnerability of terminal reservoirs and associated dams is not assessed in the Hazus loss estimation methodology. Therefore, even though reservoirs are an essential part of a potable water system, it is assumed in the analysis of water systems that the amount of water flowing into water treatment plants from reservoirs right after an earthquake is essentially the same as before the earthquake.

- *Transmission Aqueducts:* These transmission conduits are typically large size pipes (more than 20 inches in diameter) or channels (canals) that convey water from its source (reservoirs, lakes, and/or rivers) to the treatment plant.
    - Transmission pipelines are commonly made of concrete, ductile iron, cast iron, or steel. These could be elevated/at grade or buried. Elevated or at grade pipes are typically made of steel (welded or riveted), and they can run in single or multiple lines.
    - Canals are typically lined with concrete, mainly to avoid excessive loss of water by seepage and to control erosion. In addition to concrete lining, expansion joints are usually used to account for swelling and shrinkage under varying temperature and moisture conditions. Some damage to canals has occurred in historic earthquakes, but the modeling of damage to transmission aqueducts is outside the current scope of the methodology.
- *Water Treatment Plants (WTP):* Water treatment plants are generally composed of a number of physical and chemical unit processes connected in series, for the purpose of improving the water quality. A conventional WTP consists of a coagulation process, followed by a sedimentation process, and finally a filtration process. Alternately, a WTP can be regarded as a system of interconnected pipes, basins, and channels through which the water moves, and where the flow is governed by hydraulic principles. WTP are categorized as follows:
    - Small water treatment plants, with capacity ranging from 10 million gallons per day (mgd) to 50 mgd, are assumed to consist of a filter gallery with flocculation tanks (composed of paddles and baffles) and settling (or sedimentation) basins as the main components, as well as chemical tanks (needed in the coagulation and other destabilization processes), chlorination tanks, electrical and mechanical equipment, and elevated pipes.
    - Medium water treatment plants, with capacity ranging from 50 mgd to 200 mgd, are simulated by adding more redundancy to small treatment plants (i.e., twice as many flocculation, sedimentation, chemical, and chlorination tanks).
    - Large water treatment plants, with a capacity above 200 mgd, are simulated by adding even more redundancy to small treatment plants (i.e., three times as many flocculation, sedimentation, chemical, and chlorination tanks/basins).
- Water treatment plants are also classified based on whether the subcomponents (equipment and backup power) are anchored or not.
- *Pumping Plants:* Pumping plants are usually composed of a building, one or more pumps, electrical equipment, and in some cases, backup power systems. Pumping plants are classified as either small (less than 10 mgd capacity), medium (10 to 50 mgd) or large (more than 50 mgd capacity). Pumping plants are also classified with respect to whether the subcomponents (equipment and backup power) are anchored or not. Anchored means equipment designed with special seismic tie downs and tiebacks, while unanchored means equipment installed with manufacturers' normal requirements.
- *Wells:* Wells typically have a capacity between 1 and 5 mgd. Wells are used in many cities as a primary or supplementary source of water supply. Wells include a shaft from the

surface down to the aquifer, a pump to bring the water up to the surface, equipment used to treat the water, and sometimes a building, which encloses the well and equipment.

- *Water Storage Tanks:* Water storage tanks can be elevated steel, on ground steel (anchored/unanchored), on ground concrete (anchored/unanchored), buried concrete, or on ground wood tanks. Typical capacity of storage tanks is in the range of 0.5 mgd to 2 mgd.
- *Distribution Facilities and Distribution Pipes:* Distribution of water can be accomplished by gravity, or by pumps in conjunction with on-line storage. Except for storage reservoirs located at a much higher altitude than the area being served, distribution of water would necessitate, at least, some pumping along the way. Typically, water is pumped at a relatively constant rate, with flow in excess of consumption being stored in elevated storage tanks. The stored water provides a reserve for fire flow and may be used for general-purpose flow should the electric power fail, or in case of pumping capacity loss.

Distribution pipelines are commonly made of concrete (prestressed or reinforced), asbestos cement, ductile iron, cast iron, steel, or plastic. The selection of material type and pipe size are based on the desired carrying capacity, availability of material at the time of construction, durability, and cost. Distribution pipes represent the network that delivers water to consumption areas. Distribution pipes may be further subdivided into primary lines, secondary lines, and small distribution mains. The primary or arterial mains carry flow from the pumping station to and from elevated storage tanks, and to the consumption areas, whether residential, industrial, commercial, or public. These lines are typically laid out in interlocking loops, and all smaller lines connecting to them are typically valved so that failure in smaller lines does not require shutting off the larger pipeline. Primary lines can be up to 36 inches in diameter. Secondary lines are smaller loops within the primary mains and run from one primary line to another. They provide a large amount of water for firefighting without excessive pressure loss. Small distribution lines represent the mains that supply water to the user and to the fire hydrants.

Table 10-3 includes the Hazus potable water system classification, including the legacy valuations still being used for elements not updated with HIFLD data.

Table 10-3 Hazus Potable Water System Classification

Label	Description	Hazus Valuation
Potable Water Pipelines		
PDFLT	Default potable water pipes	$1,000
PWP1	Brittle Pipe (per break)	$1,000
PWP2	Ductile Pipe (per break)	$1,000
Potable Water Facilities		
PDFLT	Default potable water facilities	PWTS value
PPPL	Large Pumping Plant (> 50 MGD) [different combinations for with or without anchored components]	$525,000
PPPM	Medium Pumping Plant (10 to 50 MGD) [different combinations for with or without anchored components]	$525,000
PPPS	Small Pumping Plant (< 10 MGD) [different combinations for with or without anchored components]	$150,000

Label	Description	Hazus Valuation
PWE	Wells	$400,000
PSTAS	Above Ground Steel Tank	$800,000
PSTBC	Buried Concrete Tank	$1,500,000
PSTGC	On Ground Concrete Tank	$1,500,000
PSTGS	On Ground Steel Tank	$800,000
PSTGW	On Ground Wood Tank	$30,000
PWTL	Large WTP (> 200 MGD) [different combinations for with or without anchored components]	$360,000,000
PWTM	Medium WTP (50-200 MGD) [different combinations for with or without anchored components]	$100,000,000
PWTS	Small WTP (< 50 MGD) [different combinations for with or without anchored components]	$30,000,000
PCVS	Control Vaults and Control Stations	$50,000

** Replacement cost data in existing transportation database based on 2001 NBI derived by original Hazus development team in 2003 from expert opinion.*

For the Internal Hazus potable water distribution lines data, this data is based on total street length aggregated at the Census tract level and comes from the 2017 TIGER data created by the U.S. Census Bureau. It is assumed the water distribution pipe length equals the street length (80% being brittle pipe and 20% being ductile). The data required for the Earthquake Model includes: brittle length (km), ductile length (km), and tract number. The data is updated annually, with the latest update being from 2017.

For the Internal Hazus potable water facilities data, this data is provided by the Envirofacts Data Warehouse from EPA. The data in Hazus was last updated in 2001. The inventory data required for an earthquake analysis of potable water facilities include the location, replacement cost, anchoring, backup power, and classification. The requirements for the Flood Model include location, replacement cost, backup power, equipment elevation, flood protection, and utility classification.

For the Internal Hazus potable water pipelines data, no baseline data was provided with Hazus, but user-input data can be modeled in the Earthquake Model. Utility classification and replacement cost are required for modeling.

For the Flood Model, Table 10-4 includes additional default values used for certain potable water data. Equipment Height represents the assumed flood elevation where electrical equipment is damaged. The Functional Depth represents the assumed flood elevation where the facility is closed and people evacuated.

Table 10-4 Potable Water System Classifications, Functionality Thresholds, and Flood Model Default Parameters

Hazus Label	Specific Occupancy	Foundation Type	Equipment Height (ft)	Functionality Depth (ft)	Comments
PDFLT	Default potable water pipes	N/A	N/A	N/A	No damage expected from submergence
PWP1	Brittle Pipe	N/A	N/A	N/A	No damage expected from submergence
PWP2	Ductile Pipe	N/A	N/A	N/A	No damage expected from submergence
PDFLT	Default potable water facilities	Slab on grade	3	4	For above grade, assumes all equipment raised three feet above ground level. For below grade, assumes entrance is three feet above grade.
PPPL	Large Pumping Plant	Slab on grade	3	4	For above grade, assumes all equipment raised three feet above ground level. For below grade, assumes entrance is three feet above grade.
PPPM	Medium Pumping Plant	Slab on grade	3	4	For above grade, assumes all equipment raised three feet above ground level. For below grade, assumes entrance is three feet above grade.
PPPS	Small Pumping Plant	Slab on grade	3	4	For above grade, assumes all equipment raised three feet above ground level. For below grade, assumes entrance is three feet above grade.
PWE	Wells	Slab on grade	3	4	Assumes electrical equipment and openings are three feet above grade.
PSTAS	Above Ground Steel Tank	Slab on grade	80	80	
PSTBC	Buried Concrete Tank	Slab on grade	3	4	Vent three feet above grade
PSTGC	On Ground Concrete Tank	Slab on grade	0	24	Tank floor at grade and tank does not float.
PSTGS	On Ground Steel Tank	Slab on grade	0	24	Tank floor at grade and tank does not float.
PSTGW	On Ground Wood Tank	Slab on grade	0	24	Tank floor at grade and tank does not float.
PWTL	Large WTP	Slab on grade	3	4	Assumes all equipment raised 3 feet above the ground.
PWTM	Medium WTP	Slab on grade	3	4	Assumes all equipment raised 3 feet above the ground.
PWTS	Small WTP	Slab on grade	3	4	Assumes all equipment raised 3 feet above the ground.
PCVS	Control Vaults and Control Stations	Slab on grade	0	1	Assumes entrance is at grade and not sealed.

10.2 Wastewater Systems

A wastewater system typically consists of collection sewers, interceptors, lift stations, and wastewater treatment plants. In this section, a brief description of each of these components is given.

- *Collection Sewers*: Collection sewers are generally closed conduits that normally carry sewage with a partial flow. Collection sewers could be sanitary sewers, storm sewers, or combined sewers. Pipe materials that are used for potable water transportation may also be used for wastewater collection. The most commonly used sewer material is clay pipe manufactured with integral bell and spigot ends. These pipes range in size from 4 to 42 inches in diameter. Concrete pipes are mostly used for storm drains and for sanitary sewers carrying noncorrosive sewage (i.e., with organic materials). For the smaller diameter range, plastic pipes are also used.
- *Interceptors*: Interceptors are large diameter sewer mains. They are usually located at the lowest elevation areas. Pipe materials that are used for interceptor sewers are similar to those used for collection sewers.
- *Lift Stations:* Lift stations are important parts of the wastewater system. Lift stations serve to raise sewage over topographical rises. If the lift station is out of service for more than a short time, untreated sewage will either spill out near the lift station, or back up into the collection sewer system. Lift stations are classified as either small (capacity less than 10 mgd), medium (capacity 10 – 50 mgd), or large (capacity greater than 50 mgd). Lift stations are also classified as having either anchored or unanchored subcomponents.
- *Wastewater Treatment Plants:* Three sizes of wastewater treatment plants are considered: small (capacity less than 50 mgd), medium (capacity between 50 and 200 mgd), and large (capacity greater than 200 mgd). Wastewater treatment plants have the same processes as water treatment plants, with the addition of secondary treatment subcomponents.

Table 10-5 includes the Hazus wastewater system classification, including the legacy valuations still being used for elements not updated with HIFLD data.

Table 10-5 Hazus Wastewater System Classification

Label	Description	Hazus Valuation
Wastewater Pipelines		
WDFLT	Default wastewater pipe	$1,000
WWP1	Brittle Pipe	$1,000
WWP2	Ductile Pipe	$1,000
Wastewater Facilities		
WDFLT	Default wastewater facility	See Table 10-2
WWTL	Large WWTP (> 200 MGD) [different combinations for with or without anchored components]	See Table 10-2
WWTM	Medium WWTP (50-200 MGD) [different combinations for with or without anchored components]	See Table 10-2
WWTS	Small WWTP (< 50 MGD) [different combinations for with or without anchored components]	See Table 10-2
WLSL	Large Lift Stations (> 50 MGD) [different combinations for with or without anchored components]	See Table 10-2

Label	Description	Hazus Valuation
WLSM	Medium Lift Stations (10 MGD - 50 MGD) [different combinations for with or without anchored components]	See Table 10-2
WLSS	Small Lift Stations (< 10 MGD) [different combinations for with or without anchored components]	See Table 10-2
WWCV	Wastewater Control Vaults and Control Station	See Table 10-2

** Replacement cost data in existing transportation database based on 2001 NBI derived by original Hazus development team in 2003 from expert opinion.*

For the Internal Hazus wastewater distribution lines data, this data is based on total street length aggregated at the Census tract level and comes from the 2017 TIGER data created by the U.S. Census Bureau. It is assumed the wastewater distribution pipe length equals 60% of the street length (60% being brittle pipe and 40% being ductile). The data required for the Earthquake Model includes: brittle length (km), ductile length (km), and tract number. The data is updated annually with the latest one from 2017.

For the Internal Hazus wastewater pipelines data, no baseline data is provided in Hazus, but user-input data can be modeled in the Earthquake Model. Utility classification and replacement cost are required for modeling.

For the Flood Model, Table 10-6 includes additional default values used for certain potable water data. Equipment Height represents the assumed flood elevation where electrical equipment is damaged. The Functional Depth represents the assumed flood elevation where the facility is closed, and people evacuated.

Table 10-6 Potable Water Classifications, Functionality Thresholds, and Flood Model Default Parameters

Hazus Label	Specific Occupancy	Foundation Type	Equipment Height (ft)	Functionality Depth (ft)	Comments
WDFLT	Default wastewater pipe	N/A	N/A	N/A	No damage expected from submergence
WWP1	Brittle Pipe	N/A	N/A	N/A	No damage expected from submergence
WWP2	Ductile Pipe	N/A	N/A	N/A	No damage expected from submergence
WDFLT	Default wastewater facility	Slab on grade	3	4	Assumes entrance is 3 feet above ground level and is not sealed.
WWTL	Large WWTP	Slab on grade	3	4	Assumes entrance is 3 feet above ground level and is not sealed.
WWTM	Medium WWTP	Slab on grade	3	4	Assumes entrance is 3 feet above ground level and is not sealed.
WWTS	Small WWTP	Slab on grade	3	4	Assumes entrance is 3 feet above ground level and is not sealed.
WLSL	Large Lift Stations	Slab on grade	3	4	Assumes entrance is 3 feet above ground level and is not sealed.
WLSM	Medium Lift Stations	Slab on grade	3	4	Assumes entrance is 3 feet above ground level and is not sealed.
WLSS	Small Lift Stations	Slab on grade	3	4	Assumes entrance is 3 feet above ground level and is not sealed.
WWCV	Wastewater Control Vaults and Control Station	Slab on grade	0	1	Assumes entrance is at grade, and is not sealed.

10.3 Oil Systems

An oil system typically consists of refineries, pumping plants, tank farms, and pipelines. In this section, a brief description of each of these components is given.

- *Refineries:* Refineries are an important part of an oil system. They process crude oil before it can be used. Although the supply of water is critical to the functioning of a refinery, it is assumed in the methodology that an uninterrupted supply of water is available to the refinery. Two sizes of refineries are considered: small and medium/large:
    - Small refineries (capacity less than 100,000 barrels per day) are assumed to consist of steel tanks on grade, stacks, other electrical and mechanical equipment, and elevated pipes. Stacks are essentially tall cylindrical chimneys.
    - Medium and large refineries (capacity of 100,000 to 500,000 barrels per day and more than 500,000 barrels per day, respectively) are simulated by adding more redundancy to small refineries (i.e., twice as many tanks, stacks, elevated pipes).
- *Oil Pipelines:* Oil pipelines are used for the transportation of crude oil over long distances. About 75% of the crude oil is transported throughout the United States by pipelines. A large segment of industry and millions of people could be severely affected by the disruption of

crude oil supplies. Rupture of crude oil pipelines could lead to pollution of land and rivers. Pipelines are typically made of mild steel with submerged arc welded joints, although older gas welded steel pipe may be present in some systems. Buried pipelines are considered to be vulnerable to Peak Ground Velocity (PGV) and Permanent Ground Deformation (PGD).

- *Pumping Plants:* Pumping plants serve to maintain the flow of oil in cross-country pipelines. Pumping plants usually use two or more pumps. Pumps can be of either centrifugal or reciprocating type. However, no differentiation is made between these two types of pumps in the analysis of oil systems. Pumping plants are classified as having either anchored or unanchored subcomponents.
- *Tank Farms:* Tank farms are facilities that store fuel products. They include tanks, pipes, and electrical components. Tank farms are classified as having either anchored or unanchored subcomponents.

Table 10-7 includes the Hazus oil system classification, including the legacy valuations still being used for elements not updated with HIFLD data.

Table 10-7 Hazus Oil System Classification

Label	Description	Hazus Valuation
Oil Pipelines		
ODFLT	Default oil pipeline	$1,000
OIP1	Welded Steel Pipe with Gas Welded Joints	$1,000
OIP2	Welded Steel Pipe with Arc Welded Joints	$1,000
Oil Facilities		
ODFLT	Default oil facility	ORFS value
ORFL	Large Refinery (> 500,000 lb./day) [different combinations for with or without anchored components]	$750,000,000
ORFM	Medium Refinery (100,000 - 500,000 lb./ day) [different combinations for with or without anchored components]	$750,000,000
ORFS	Small Refinery (< 100,000 lb./day) [different combinations for with or without anchored components]	$175,000,000
OPP	Pumping Plant [different combinations for with or without anchored components]	$1,000,000
OTF	Tank Farms with Anchored Tanks [different combinations for with or without anchored components]	$2,000,000
OCV	Oil Control Vaults and Control Station	$50,000

** Replacement cost data in existing transportation database based on 2001 NBI derived by original Hazus development team in 2003 from expert opinion.*

For the Internal Hazus oil facilities data, the data are provided by the Envirofacts Data Warehouse from EPA. This data is updated annually with the latest one from 2001. The inventory data required for an earthquake analysis of oil facilities include the location, replacement cost, backup power, equipment elevation, flood protection, and utility classification. The requirements for the Flood Model include location, replacement cost, equipment elevation, flood protection, and utility classification.

For the Internal Hazus oil pipelines data, no baseline data are provided in Hazus, but user-input data can be modeled in the Earthquake Model. Utility classification and replacement cost are required for modeling.

For the Flood Model, Table 10-8 includes additional default values used for certain oil system data. Equipment Height represents the assumed flood elevation where electrical equipment is damaged. The Functional Depth represents the assumed flood elevation where the facility is closed and people evacuated.

Table 10-8 Oil System Classifications, Functionality Thresholds, and Flood Model Default Parameters

Hazus Label	Specific Occupancy	Foundation Type	Equipment Height (ft)	Functionality Depth (ft)	Comments
ODFLT	Default oil pipeline	N/A	N/A	N/A	No damage expected from submergence
OIP1	Welded Steel Pipe with Gas Welded Joints	N/A	N/A	N/A	No damage expected from submergence
OIP2	Welded Steel Pipe with Arc Welded Joints	N/A	N/A	N/A	No damage expected from submergence
ODFLT	Default oil facility	Slab on grade	3	4	Assumes all equipment raised 3 feet above the ground
ORFL	Large Refinery	Slab on grade	3	4	Assumes all equipment raised 3 feet above the ground
ORFM	Medium Refinery	Slab on grade	3	4	Assumes all equipment raised 3 feet above the ground
ORFS	Small Refinery	Slab on grade	3	4	Assumes all equipment raised 3 feet above the ground
OPP	Pumping Plant	Slab on grade	3	0	Assumes all equipment raised 3 feet above the ground
OTF	Tank Farms	Slab on grade	0	0	Assume tank bottom is at grade and tanks will not float.
OCV	Oil Control Vaults and Control Station	Slab on grade	0	1	Assumes entrance is at grade and is not sealed.

10.4 Natural Gas Systems

A natural gas system typically consists of compressor stations and pipelines, as defined below:

- *Compressor Stations*: Compressor stations serve to maintain the flow of gas in pipelines. Compressor stations consist of either centrifugal or reciprocating compressors. However, no differentiation is made between these two types of compressors in the analysis of natural gas systems. Compressor stations are categorized as having either anchored or unanchored subcomponents. The compressor stations are similar to pumping plants in oil systems.
- *Natural Gas Pipelines*: Natural gas pipelines are typically made of mild steel with submerged arc-welded joints, although older lines may have gas-welded joints. These are used for the transportation of natural gas over long distances. Many industries and residents could be severely affected should disruption of natural gas supplies occur.

Table 10-9 includes the Hazus natural gas system classification, including the legacy valuations still being used for elements not updated with HIFLD data.

Table 10-9 Hazus Natural Gas System Classification

Label	Description	Hazus Valuation
Buried Pipelines		
GDFLT	Default natural gas pipeline	See Table 10-2
NGP1	Welded Steel Pipe with Gas Welded Joints	See Table 10-2
NGP2	Welded Steel Pipe with Arc Welded Joints	See Table 10-2
Natural Gas Facilities		
GDFLT	Default natural gas facility	See Table 10-2
NGC	Compressor Stations [different combinations for with or without anchored components]	See Table 10-2
NGCV	Control Valves and Control Stations	See Table 10-2

For the Internal Hazus natural gas distribution lines data, this data is based on total street length aggregated at the Census tract level and comes from the 2010 TIGER data created by the U.S. Census Bureau. It is assumed the gas distribution pipe length equals 40% of the street length (10% being brittle pipe and 90% being ductile). The data required for the Earthquake Model includes: brittle length (km), ductile length (km), and tract number. The data is updated annually with the latest one from 2017.

For the Flood Model, Table 10-10 includes additional default values used for certain natural gas system data. Equipment Height represents the assumed flood elevation where electrical equipment is damaged. The Functional Depth represents the assumed flood elevation where the facility is closed and people evacuated.

Table 10-10 Natural Gas System Classifications, Functionality Thresholds, and Flood Model Default Parameters

Hazus Label	Specific Occupancy	Foundation Type	Equipment Height (ft)	Functionality Depth (ft)	Comments
GDFLT	Default natural gas pipeline	N/A	N/A	N/A	No damage expected from submergence
NGP1	Welded Steel Pipe with Gas Welded Joints	N/A	N/A	N/A	No damage expected from submergence
NGP2	Welded Steel Pipe with Arc Welded Joints	N/A	N/A	N/A	No damage expected from submergence
GDFLT	Default natural gas facility	Slab on grade	3	4	Assumes all equipment raised 3 feet above the ground
NGC	Compressor Stations	Slab on grade	3	4	Assumes all equipment raised 3 feet above the ground
NGCV	Control Valves and Control Stations	Slab on grade	0	1	Assumes entrance is at grade and is not sealed.

10.5 Electric Power Systems

The components of an electric power system considered in the loss estimation methodology are substations, distribution circuits, and generation plants. In this section, a brief description of each of these components is presented.

- *Substations*: An electric substation is a facility that serves as a source of energy supply for the local distribution area in which it is located. Substations can be entirely enclosed in buildings, where all the equipment is assembled into one metal clad unit. Other substations have step-down transformers, high voltage switches, oil circuit breakers, and lightning arrestors located outside the substation building. In the current loss estimation methodology, only transmission (138 kV to 765 kV or higher) and subtransmission (34.5 kV to 161 kV) substations are considered. These will be classified as high voltage (350 kV and above), medium voltage (150 kV to 350 kV) and low voltage (34.5 kV to 150 kV), and will be referred to as Large (500 kV) substations, Medium (230kV) substations, and Small (115 kV) substations, respectively. The classification is also a function of whether the subcomponents are anchored or typical (unanchored), as defined in Section 9.2. A substation has the following main functions:
    - Change or switch voltage from one level to another.
    - Provide points where safety devices such as disconnect switches, circuit breakers, and other equipment can be installed.
    - Regulate voltage to compensate for system voltage changes.
    - Eliminate lightning and switching surges from the system.
    - Convert AC to DC and DC to AC, as needed.
    - Change frequency, as needed.
- *Distribution Circuits*: The distribution system is divided into a number of circuits. A distribution circuit includes poles, wires, in-line equipment and utility-owned equipment at customer sites. A distribution circuit also includes above ground and underground conductors. Distribution circuits either consist of anchored or unanchored components.
- *Generation Plants*: Generation plant subcomponents include diesel generators, turbines, racks and panels, boilers and pressure vessels, and the building in which these are housed. The size of the generation plant is determined from the number of Megawatts (MW) of electric power that the plant can produce under normal operations. Small generation plants have a generation capacity of less than 100 MW. Medium generation plants have a capacity between 200 and 500 MW, while Large plants have a capacity greater than 500 MW. Fragility curves for generation plants with anchored versus unanchored subcomponents are presented. These plants produce alternating current (AC) and may be any of the types listed below. Fossil fuels are either coal, oil, or natural gas.
    - Hydroelectric
    - Steam turbine (fossil fuel fired or nuclear)
    - Combustion turbine (fossil fuel fired)
    - Geothermal
    - Solar
    - Wind

- Compressed air

Table 10-11 includes the Hazus electric power system classification, including the legacy valuations that are still being used for elements that have not been updated with HIFLD data.

Table 10-11 Hazus Electric Power Facilities System Classification

Label	Description	Hazus Valuation
EDFLT	Default electric power facilities	See Table 10-2
ESSL	Low Voltage (115 KV) Substation [different combinations for with or without anchored components]	See Table 10-2
ESSM	Medium Voltage (230 KV) Substation [different combinations for with or without anchored components]	See Table 10-2
ESSH	High Voltage (500 KV) Substation [different combinations for with or without anchored components]	See Table 10-2
EDC	Distribution Circuits (either Seismically Designed Components or Standard Components)	See Table 10-2
EPPL	Large Power Plants (> 500 MW) [different combinations for with or without anchored components]	See Table 10-2
EPPM	Medium Power Plants (100 - 500 MW) [different combinations for with or without anchored components]	See Table 10-2
EPPS	Small Power Plants (< 100 MW) [different combinations for with or without anchored components]	See Table 10-2

For the Internal Hazus electric power facilities data, the data are provided from the HIFLD Open Data: Power Plants (2019). This included data from all 50 states, including the District of Columbia and Puerto Rico. Because a 10 MW threshold was used, it does eliminate plants in American Samoa and Guam. The inventory data required for earthquake analysis includes location, replacement cost, and classification type.

For the Flood Model, Table 10-12 includes additional default values used for certain electric power system data. Equipment Height represents the assumed flood elevation where electrical equipment is damaged. The Functional Depth represents the assumed flood elevation where the facility is closed and people evacuated.

Table 10-12 Electric Power System Classifications, Functionality Thresholds, and Flood Model Default Parameters

Hazus Label	Specific Occupancy	Foundation Type	Equipment Height (ft)	Functionality Depth (ft)	Comments
EDFLT	Default electric power facilities	Slab on grade	3	4	Assumes all equipment raised 3 feet above the ground
ESSL	Low Voltage Substation	Slab on grade	0	4	Control room damaged starting at 0 feet, and maximized at 7' depth. Additional damage to cabling and incidental damage to transformers and switchgear.
ESSM	Medium Voltage Substation	Slab on grade	0	4	Control room damaged starting at 0 feet, and maximized at 7' depth. Additional damage to cabling and incidental damage to transformers and switchgear.
ESSH	High Voltage Substation	Slab on grade	0	4	Control room damaged starting at 0 feet, and maximized at 7' depth. Additional damage to cabling and incidental damage to transformers and switchgear.
EDC	Distribution Circuits	N/A	N/A	N/A	No damage expected from submergence
EPPL	Large Power Plant	Slab on grade	10	4	Support facilities damaged on ground level. Control and generation facilities damaged when water elevation reaches 2nd level.
EPPM	Medium Power Plant	Slab on grade	10	4	Support facilities damaged on ground level. Control and generation facilities damaged when water elevation reaches 2nd level.
EPPS	Small Power Plant	Slab on grade	10	4	Support facilities damaged on ground level. Control and generation facilities damaged when water elevation reaches 2nd level.

10.6 Communication Systems

The major components of a communication system are:

- Central offices and broadcasting stations (this includes all subcomponents such as central switching equipment).
- Transmission lines (these include all subcomponents such as equipment used to connect central office to end users).
- Cabling (low capacity links)

Central offices and broadcasting stations are the only components of the communication system considered in this section.

A communication facility consists of a building (a generic type is assumed in the methodology), central switching equipment (i.e., digital switches, anchored or unanchored), and back-up power supply (i.e., diesel generators or battery generators, anchored or unanchored) that may be needed to supply the requisite power to the center in case of loss of off-site power.

Table 10-13 includes the Hazus communication system classification, including the legacy valuations still being used for elements not updated with HIFLD data.

Table 10-13 Hazus Communication Facilities System Classification

Label	Description	Hazus Valuation
CDFLT	Default communication facility	CBO value
CCO	Central Offices (different combinations for with or without anchored components and/or with or without backup power)	$5,000,000
CBR	AM or FM radio stations or transmitters	$2,000,000
CBT	TV stations or transmitters	$2,000,000
CBW	Weather stations or transmitters	$2,000,000
CBO	Other stations or transmitters	$2,000,000
CCSV	Control Vault (FL only)	$50,000

** Replacement cost data in existing transportation database based on 2001 NBI derived by original Hazus development team in 2003 from expert opinion.*

The Internal Hazus communication facility data came from the FCC Broadcast Auxiliary Microwave database from 2001. This database is updated as needed. The latest data is from 2018. The inventory data required for communication systems earthquake analysis include the geographical location, replacement cost, anchoring, backup power, and classification. The flood analysis inventory requirements include location, replacement cost, equipment elevation, flood protection, and utility classification.

In summary, this section provided the latest status for Hazus data related to utility systems. While some data sources have recently been updated from HIFLD sources, still over half of the utility system elements make use of some Internal Hazus utility data.

Section 11. Additional Flood-Specific Inventory Data

There are two additional Hazus inventory datasets that are hazard-specific to the Flood Model that are not previously covered: agricultural products and vehicles.

11.1 Agricultural Products (Crops)

The Flood Model estimates damages to crops using a combination of data sources and modeling approaches researched during the original development of Hazus in the 1990s. The crop loss model selected was from the U.S. Army Corps of Engineers (USACE) and was called the Agriculture Flood Damage Analysis (AGDAM) approach (USACE-HEC, 1985). Other USACE models considered include the Hydraulic Engineering Center's Flood Impact Analysis (HEC-FIA) and Flood Damage Assessment (FDA) models and also a program called Computerized Agricultural Crop Flood Damage Assessment System (CACFDAS). To implement the AGDAM approach, Hazus would require the development of a crop inventory database that included geographic extent of major crops (focused within the continental U.S.) and crop value. The two data sources found that could populate the crop inventory database was the U.S. Department of Agriculture (USDA) National Resources Inventory (NRI) dataset and the National Agriculture Statistical Service (NASS) dataset. The current baseline data in Hazus used 1992 NRI data and 2000 NASS data.

11.1.1 National Resources Inventory (NRI) Dataset

The NRI dataset was created to allow the U.S. Department of Agriculture (USDA) to, "…assess the status, conditions and trends of resources at 5-year intervals." The NRI edition used for the original Hazus development, which has not been updated within Hazus, was the 1992 NRI dataset. The NRI data was compiled and presented at the sub-county-level. The NRI data consisted of point sample data taken throughout the county. This is associated with soils data and expansion factors that identify what each sample point represents in terms of acres.

The 1992 NRI dataset was used to develop sub-county polygons (intersection of the county boundary with the USGS 8-digit Hydrologic Unit codes or HUCS). For example, Story County, Iowa, is subdivided into six polygons (one of which had no data). The NRI data also provided sample points taken throughout the county. Each sample point was associated with specific HUC and county polygon, soils data and expansion factors, and statistical weighting factors that establish the total crop acreage and yields represented by the sample point. The NRI data were averaged over the collection interval (five years) to smooth variations in agriculture yields. These variations included changes in crop types, crop rotation, and seasonal or weather-related changes in yield. The total yields for each polygon were then summed over the five collection intervals and averaged to produce the yield. The NRI data provides a definition of the units of measure for each crop type (such as bushels). Due to data limitations, the agriculture inventory was not available for Alaska, Hawaii, and the U.S. territories. Table 11-1 lists the top 40 crops nationally included in the Hazus crop inventory dataset (limited to 20 per state).

Table 11-1 Crop Types used in Hazus

Crop Type
Alfalfa Hay
Apples
Bahiagrass
Barley
Bromegrass-Alfalfa Hay
Common Bermudagrass
Corn
Corn Silage
Corn, Sweet
Cotton Lint
Crested Wheatgrass-Alfalfa Hay
Flax
Grain Sorghum
Grapes, Wine
Grass Hay
Grass-Clover
Grass-Legume Hay
Improved Bermudagrass
Kentucky Bluegrass
Oats
Oranges
Orchard Grass
Orchardgrass-Alfalfa Hay
Peanuts
Pears
Potatoes, Irish
Reed Canarygrass
Rice
Smooth Bromegrass
Soybeans
Sugar Beets
Tall Fescue
Tall Fescue-Ladino
Timothy-Red Clover Hay
Tobacco
Tomatoes
Trefoil-Grass Hay
Watermelons
Wheat
Wheat, Winter

11.1.2 National Agriculture Statistical Service (NASS) Dataset

The NASS data is compiled annually by the NASS, a branch of the USDA, and covers nearly every aspect of the agriculture industry. The latest NASS data included in Hazus is from 2000 and all dollar values should be considered as 2000 values. This rigorous collection of data is used primarily to assess and estimate crop yields and future industry planting. The data is collected through a variety of sources. The key limitation of this data is that the crop yields are developed for the entire counties and do not assess regional variations in crop types or yields within a county, especially for larger counties in western states. The NASS data is expected to have variations over time due to changing crop yields from year to year. The NASS data, however, provides the most up-to-date estimate on the unit price for each crop type since the data is collected annually. By associating the crop types from the NASS data to the NRI, the crop price per unit (e.g., $ per bushel) was able to be obtained.

Based on a review of the previously mentioned crop loss models (FIA, AGDAM, and CACFDAS) used by the USACE, crop losses are substantially affected by the duration of a flood. Since the Flood Model does not include a flood hazard duration factor, the solution is to provide a table of results for a range of durations. The USACE has a set of duration functions with factors for 0, 3, 7, and 14 days of flood duration. The Flood Model provides a single table of losses by crop type for each duration period.

The USACE provides damage functions for several crop types and the Flood Model uses many of these functions as the default. A damage function library was developed based on damage and duration curves collected from the various USACE Districts. The growing season for each crop is included in the modeling data going from planting to harvest. All curves are based on a Julian calendar to account for the changing potential of loss between planting to harvest dates. Once a date is provided for the flood scenario, the Flood Model will determine the Julian date and identify the loss potential from the damage function. The loss will be increased by the duration factors as discussed above. The *Hazus Flood Model Technical Manual* (FEMA, 2021) contains additional information on how these data were derived and applied to the Hazus flood analysis.

11.2 Vehicles

Another dataset unique to the Flood Model, the vehicle inventory, was developed to allow the user to assess the additional losses possible due to vehicles remaining within flooded areas. Vehicles are represented as new or used in the three categories of passenger cars, light trucks (including SUVs), and heavy trucks (commercial/industrial vehicles including 18-wheelers). The current Hazus vehicle count data was last updated in 2009 based on the 2000 Census building areas and 2008 Dun & Bradstreet data. The vehicle cost values were last updated in 2014 based on 2010 new and used vehicle costs from a National Automobile Dealers Association (NADA) publication in 2011. Table 11-2 summarizes the current costs and distribution of vehicles used in Hazus.

Table 11-2 Vehicle Age Distribution by Vehicle Classification (Percentage Distribution)

Vehicle Type	Cost (2010)[1]		Distribution[2]	
	New	Used	New	Used
Cars	$27,029	$13,650	7%	93%
Light Trucks	$25,058	$12,655	9%	91%
Heavy Trucks	$91,306	$45,653	9%	91%

[1] The vehicle cost values were last updated in 2014 based on 2010 new and used vehicle costs from NADA, 2011

[2] Vehicle count data was last updated in 2009 based on the 2000 Census building areas and 2008 Dun & Bradstreet data.

Because vehicles are used by their owners throughout the day, the Flood Model stores vehicle data in two "snapshots" of time for the nighttime and the daytime. During the nighttime, passenger vehicles are more likely to be concentrated near residential structures and commercial industrial vehicles are more likely to remain in commercial areas. During the daytime, commercial and industrial areas are expected to see an influx of all varieties of vehicles. The following sections provide additional background information on how vehicle counts and costs were derived.

11.2.1 Vehicle Counts

Vehicle counts in Hazus were derived using a methodology similar to those used by Metropolitan Planning Organizations to identify parking and traffic patterns for planned development. For each Hazus specific occupancy, the known building area is used to derive an associated parking demand and an approximation of the number of vehicles. To calculate the nighttime and daytime vehicle counts, procedures are required to:

- Calculate vehicle inventory within census blocks of a study area.
- Allocate vehicles by time of day to different locations.

This vehicle location estimator approach is summarized in Figure 11-1 below.

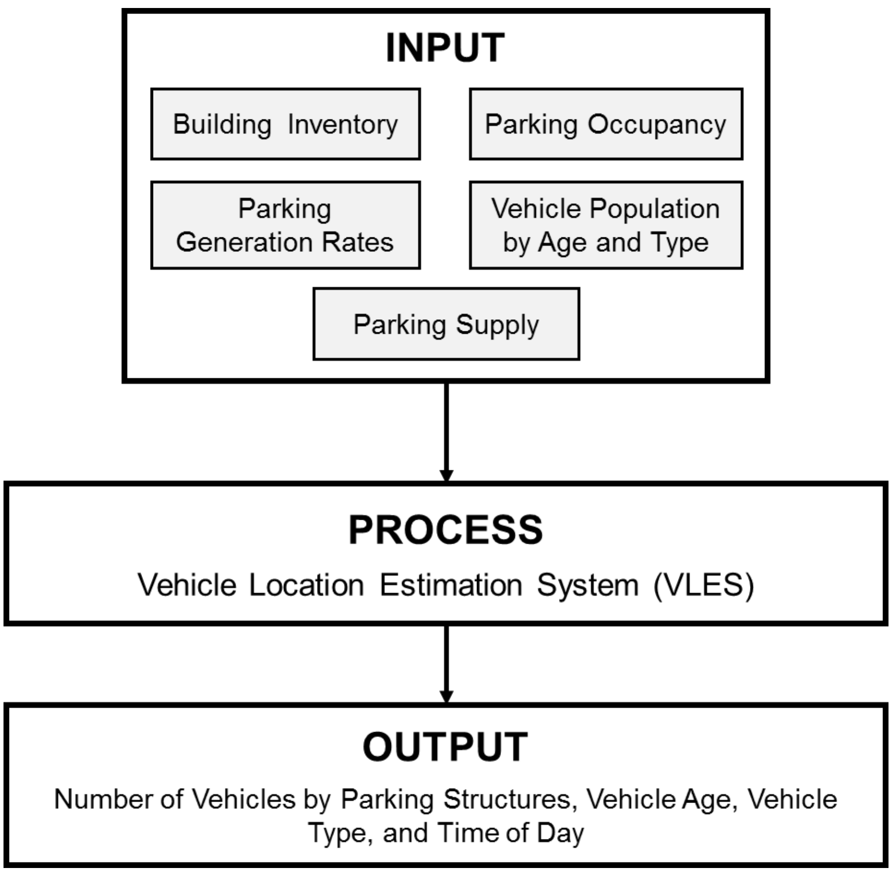

Figure 11-1 Vehicle Location Estimate System

11.2.1.1 Parking Generation Rates

Parking generation rates were used to associate the number of parked vehicles to building areas of different types of occupancy groups in Hazus during a flood event. Vehicle distributions are estimated for daytime and nighttime, with daytime assumed to be normal business hours. One source used in the original Hazus development was the 1987 Parking Generation manual from the Institute of Transportation Engineers (ITE). Another comprehensive source of parking in relation to land use is the Off-Street Parking Requirements manual compiled by the American Planning Association (APA). The original Hazus development also considered regional parking studies for areas around Austin, TX, Denver, CO, Indianapolis, IN, and Seattle, WA.

Each Hazus specific occupancy balanced different data sources to derive vehicle count and time of day information. For example, for retail trade (Hazus specific occupancy COM1), the ITE parking generation report devoted land use code 810-850 and 870-890 to retail trade, which includes shopping centers, restaurants, supermarkets, and so on. The ITE updated parking generation rate (data through April 2001) for shopping centers was available in a report from DKS Associates that utilizes results of 940 parking studies to characterize generalized retail trade activities. During regular business hours, average vehicles per 1,000 square feet of shopping center space generally fall between 3-4; during nighttime, observations are limited, and the rate falls sharply to between 0-1 vehicles per 1,000 square feet. Corresponding numbers for the 85th percentile were between 4.5-6 for the daytime and also between 0-1 during nighttime. Results from various parking studies included 2.5 (mid-day) at Austin, 1.74 at Indianapolis (for all land uses regardless of time), 1.2-3.8 (1.76-6.23 supplied, with 40%-67% utilization rate) at Puget Sound, and 1.7 at downtown Seattle.

The 1995 Dollars and Cents Guide to Shopping Centers found median amount of parking supplied by developers to be 5.1 spaces per 1,000 square feet gross land area in American neighborhoods and community-sized shopping centers; the Urban Land Institute recommends 4, 4.5, and 5 spaces per 1,000 square foot of retail for shopping centers under 400, 400-600, and over 600 thousand square feet. The off-street parking requirements manual from APA also indicated 5 spaces per thousand square feet floor area, while the minimum requirements for metro areas of Seattle, Portland, Tacoma, and San Francisco are 1-2.86, 2.5, 3, and 1-2, respectively.

Considering this information, 2.4 vehicles per 1,000 square feet was selected to be used as the mid-day rate, while 0.68 was selected as the night rate. For instance, if four is the peak parking demand, then parking utilization rates would be 60% and 17% of the peak rate, respectively. The expected utilization rates corresponding to the time of day were developed by considering the different parking data sources and is shown in Table 11-3.

Table 11-3 Expected Daily Utilization Commercial Parking Used in Hazus

Hour of Day	% of Peak
6:00	0%
7:00	8%
8:00	18%
9:00	42%
10:00	68%
11:00	87%
12:00	97%
13:00	100%
14:00	97%

Hour of Day	% of Peak
15:00	95%
16:00	87%
17:00	79%
18:00	82%
19:00	89%
20:00	87%
21:00	61%
22:00	32%
23:00	13%
24:00	0%

** Developed by National Institute of Building Sciences (NIBS) in 1999 as part of original Hazus development*

The approaches used for commercial parking were different than those used for multi-family dwellings, Hazus specific occupancy RES3. Since parking generation studies generally relate parked vehicles to residential units, average square footage of floor area shared by a unit needed to be estimated for the conversion. For this purpose, multi-family properties owned by Associated Estate Realty Corporation were referred. The company owned garden, townhome, ranch, mid-rise, and high-rise style properties across 12 Midwest states, including Indiana, Michigan, and Ohio. The average unit size of these properties was slightly over 900 square feet, excluding those with government assistance, which is generally smaller. This estimated parking requirement was compared with various residential construction projects and zoning requirements. After taking into account the shared public space of multi-family dwellings, 1,000 square feet per unit was assumed.

Peak parking generation per unit shown in ITE's study was around 1. The range of minimum parking requirements for Seattle, Portland, Tacoma, and San Francisco was 0.25-2. The number of average vehicles per household stabilizes around 1.8. These lower values may have been due to the bias found in urban areas, where crowded lands, convenient public transportation, and high-rise structures are prevalent. For Hazus modeling estimation purposes, 1.5 (for 5-49 units) was chosen, as this rate was closer to what was used in planning parking demand for new development. Similar data sources found a time of day utilization of 90% during daytime and 100% during nighttime for these RES3 structures, while assuming 50% daytime occupancy for hotels. The seemingly high occupancy during the daytime may be due to the bias of urban areas, where people utilize other means of travel than personal vehicles and parking of vehicles attracted by businesses. Summing up the factors for multi-family parking generation, 0.3 was used for the daytime, while 1.35 was used for the nighttime.

Similar processes were applied for each of the remaining occupancy groups in Hazus. More information was available for some of the occupancies than for others. Generally, parking studies of metropolitan areas, the National Personal Travel Survey (NPTS), and related projects of private organizations, were combined to develop a best estimate for this purpose.

11.2.1.2 Parking Supply and Occupancy

To complete the estimation of vehicle counts, once the numbers of vehicles potentially at risk are determined, these vehicles are further distributed to various parking facilities. These facilities include on-street, surface lot, garage, or underground. The provides a basis to determine the impacts of flood water levels on vehicles. This distribution is irrelevant to non-urban areas, where all vehicles can be assumed to be on the surface. In urban areas, population density and land values result in underground and multi-story parking facilities. The elevation of the parked vehicle will determine the level of damage, with below ground vehicles having no salvage value and above ground vehicles being afforded a level of added protection.

Parking supplied by each source and its respective occupancy in an area were taken together to distribute vehicles among four parking facility types. After consulting various parking studies, Table 11-4 shows the estimated distribution:

Table 11-4 Estimated Parking Distribution by Parking Area Type

Urban	On-Street	Surface Lot	Garage	Underground
Parking Spaces	12.5%	31.5%	33.6%	22.4%
Occupancy	78%	65%	45%	45%
Distribution	18%	37%	27%	18%

While the actual number of levels varies, a parking garage was represented by a five-floor structure, with the roof also available for parking. To estimate the impact of flood damage to vehicles in urban areas, it was assumed that 18% of vehicles are below ground level and under water during all flood events and, therefore, total losses. Another 60% of the vehicles (18% [on street] + 37% [surface lot] + 5% [first floor from garage]) were subject to damage based on the appropriate flood damage equation. The remainder was located at least one level above ground and are assumed to receive no damage.

All these factors related to parking generation rates and parking supply and occupancy were then applied at the Census block-level to the building areas by specific occupancy to derive total vehicle counts in the three vehicle categories for the two time periods. As mentioned above, the tables in Hazus with vehicle counts were last updated in 2009 based on the 2000 Census building areas and 2008 Dun & Bradstreet data.

11.2.2 Vehicle Cost

As shown above in Table 11-2, Hazus models vehicles by three types (cars, light trucks, and heavy trucks) divided between new and old. Vehicle class estimates were developed by compiling data from the National Automobile Dealers Association (NADA), the U.S. Department of Transportation's comprehensive Truck Size and Weight Study (TSWS), and the 1995 NPTS. The distribution of vehicle age and percentage of trucks versus cars were taken from NADA, with further distribution among trucks by size from TSWS.

The values shown in Table 11-2 for 2010 were prorated versions of the previous 2000 Census vehicle data. For the 2000 data, the 2001 NADA data that had the average selling price of a new light vehicle is $24,923, while that of a used light vehicle is $13,648. Thus, the value of an average used vehicle was approximately 55% of the value of a new vehicle. Vehicles sold at the dealership tended to be younger than the whole vehicle population. As such, average used vehicle values were assumed to be 50% of the value of the average new vehicle. The vehicle values given by NADA data did not differentiate between cars and trucks. The NADA estimates were actual dealer selling prices for NADA members and include all accessories and options sold with the vehicle. New vehicles were estimated to be 7% for cars and 9% for light- and heavy duty trucks of all vehicles sold. These estimates were obtained by dividing new vehicles by total vehicles in use between 1990-2000 in Car/Truck Scrappage and Growth in the U.S. table of 2001 Ward's Automotive Yearbook. From the same yearbook, the tables of U.S. Light Vehicle Sales by

Segment (2000) and Ward's 2001 Light Vehicle U.S. Market Segmentation and Prices were put together to determine average prices of new cars and light trucks, which are $22,618.47 and $20,969.21, respectively. These new car prices were applied in the vehicle value estimate. Using the table of U.S. Truck Shipments by Gross Vehicle Weight (GVW) by Make from the Ward's Automotive Yearbook, and researching websites such as Truck Paper, Truck Trader Online, Working Wheels, Trucks.com, and numerous individual dealers' inventory lists, each Make and Class (4-8) category was assigned a value to calculate the average price of a new heavy-duty truck. The estimate was $76,087.67.

For the latest 2010 cost data shown in Table 11-2, the NADA (2011) publication was compared with the previous 2000 data. New cars and light trucks were adjusted 19.5%, while used cars and light trucks were adjusted 20.7%. There was no available NADA data for heavy trucks, so a midpoint value of 20% was used to adjust these values. The final total vehicle value stored in baseline Hazus tables was computed by taking the number of total vehicles multiplied by the percentage of car/light truck/heavy truck, percentage of new/used vehicles, and the average value of vehicles that match those categories.

Section 12. References

Applied Technology Council (ATC). 1985. *Earthquake Damage Evaluation Data for California, ATC-13*. Redwood City, CA: Applied Technology Council.

Census Bureau. 1994. Geographic Areas Reference Manual, U.S. Department of Commerce, Economic and Statistics Administration, Census Bureau. https://www.Census.gov/programs-surveys/geography/guidance/geographic-areas-reference-manual.html.

Census Bureau. 2018. Understanding Geographic Identifiers, U.S. Department of Commerce, Economic and Statistics Administration, Census Bureau. https://www.Census.gov/programs-surveys/geography/guidance/geo-identifiers.html.

Department of Energy (DOE). 1993. Housing Characteristics for 1993. Office of Energy Markets and End Use, DOE/EIA-0314 (93), Published June 1995.

Department of Energy (DOE). 1995. A Look At Commercial Buildings in 1995 DOE/EIA-0625(97), Washington, D.C., Energy Information Administration Office of Energy Markets and End Use, US Department of Energy. Published October 1998.

Department of Energy (DOE). 1997. A Look at Residential Energy Consumption in 1997, DOE/EIA-0632(97). Published November 1999.

Dun & Bradstreet (D&B). 2006. Business Population Report aggregated by Standard Industrial Classification (SIC) and Census Block, May 2006.

ESRI. 2015. GIS Dictionary: "Dasymetric Mapping." http://support.esri.com/en/knowledgebase/GISDictionary/term/dasymetric%20mapping.

Environmental Protection Agency (EPA). 2020a. Summary of the Emergency Planning & Community Right-to-Know Act. https://www.epa.gov/laws-regulations/summary-emergency-planning-community-right-know-act.

Environmental Protection Agency (EPA). 2020b. Toxics Release Inventory (TRI) Program. https://www.epa.gov/toxics-release-inventory-tri-program.

Federal Emergency Management Agency (FEMA). 1992. *FEMA 178 - NEHRP Handbook for the Seismic Evaluation of Existing Buildings,* Washington, D. C.: Developed by the Building Seismic Safety Council (BSSC) for the Federal Emergency Management Agency (FEMA).

Federal Emergency Management Agency (FEMA). 1993. *Water Control Infrastructure, National Inventory of Dams 1992*, FEMA 246, Federal Emergency Management Agency and U.S. Army Corps of Engineers, Washington, D.C., October 1993.

Federal Emergency Management Agency (FEMA). 2016. *Seismic Performance Assessment of Buildings, Volume 1 Methodology*, First Edition, FEMA P-58-1, prepared by the Applied Technology Council for the Federal Emergency Management Agency, Washington, D.C.

Federal Emergency Management Agency (FEMA). 2019a. *Hazus Program Infrastructure Data Updates, Detailed Methodology*, Federal Emergency Management Agency. https://www.fema.gov/media-library/assets/documents/105743.

Federal Emergency Management Agency (FEMA). 2019b. *Hazus Program U.S. Territory Data Updates, Detailed Methodology*, Federal Emergency Management Agency. https://www.fema.gov/media-library/assets/documents/105743.

Federal Emergency Management Agency (FEMA). 2019c. *Hazus Tools and Data, User Release Notes, Version 1.0*, Federal Emergency Management Agency. https://www.fema.gov/media-library/assets/documents/105743.

Federal Emergency Management Agency (FEMA). 2021. *Hazus Earthquake Model Technical Manual*, Federal Emergency Management Agency, Washington, D.C.

Federal Emergency Management Agency (FEMA). 2021. *Hazus Hurricane Model Technical Manual*, Federal Emergency Management Agency, Washington, D.C.

Federal Emergency Management Agency (FEMA). 2021. *Hazus Tsunami Model Technical Manual*, Federal Emergency Management Agency, Washington, D.C.

Federal Emergency Management Agency (FEMA). 2021. NSI 1.0 data, Federal Emergency Management Agency. https://disasters.geoplatform.gov/publicdata/National/Data/NSI/.

Federal Emergency Management Agency (FEMA). 2021. *Hazus Flood Model Technical Manual*, Federal Emergency Management Agency, Washington, D.C.

G&E Engineering Systems, Inc. (G&E), 1994a, *NIBS Earthquake Loss Estimation Methods, Technical Manual*, Transportation Systems (Highway Systems), May 1994.

G&E Engineering Systems, Inc. (G&E), 1994b, *NIBS Earthquake Loss Estimation Methods, Technical Manual, Transportation Systems (Railway Systems*), May 1994.

G & E Engineering Systems, Inc. (G & E), 1994c, *NIBS Earthquake Loss Estimation Methods, Technical Manual, Transportation Systems (Airport Systems),* May 1994.

G&E Engineering Systems, Inc. (G&E), 1994d, *NIBS Earthquake Loss Estimation Methods*, Technical Manual, Water Systems, May 1994.

G&E Engineering Systems, Inc. (G&E), 1994e, *NIBS Earthquake Loss Estimation Methods*, Technical Manual, Waste Water Systems, May 1994.

G&E Engineering Systems, Inc. (G&E), 1994f, *NIBS Earthquake Loss Estimation Methods, Technical Manual, Fuel Systems,* June 1994.

G&E Engineering Systems, Inc. (G&E), 1994g, *NIBS Earthquake Loss Estimation Methods, Technical Manual, Electric Power Systems,* June 1994.

G&E Engineering Systems, Inc. (G&E), 1994h, *NIBS Earthquake Loss Estimation Methods, Technical Manual, Communication Systems*, June 1994.

Heinz Center. 2000. Evaluation of Erosion Hazards. Washington, D.C.: The H. John Heinz III Center for Science, Economics and the Environment.

Homer, C.H., Fry, J.A., and Barnes C.A. 2012. The National Land Cover Database, U.S. Geological Survey Fact Sheet 2012-3020. http://pubs.usgs.gov/fs/2012/3020/.

International Conference of Building Officials. 1991. *Uniform Fire Code*, 1991.

National Automobile Dealers Association. 2011. NADA Data: State of the Industry Report 2011, http://www.nada.org/NR/rdonlyres/0798BE2A-9291-44BF-A126-0D372FC89B8A/0/NADA_DATA_08222011.pdf

R.S. Means. 1994. Means Square Foot Costs, R.S. Means, Gordian.

R.S. Means. 2002. Means Square Foot Costs, R.S. Means, Gordian.

R.S. Means. 2005. Means Square Foot Costs, R.S. Means, Gordian.

R.S. Means. 2006. Means Square Foot Costs, R.S. Means, Gordian.

R.S. Means. 2014. Means Square Foot Costs, R.S. Means, Gordian.

R.S. Means. 2016. Means Square Foot Costs, R.S. Means, Gordian.

R.S. Means. 2018. Means Square Foot Costs, R.S. Means, Gordian.

USACE Hydraulic Engineering Center. 1985. AGDAM (Agriculture Flood Damage Analysis) User Manual (provisional), April 1985.

U.S. Department of Housing and Urban Development and U.S. Census Bureau 1999. American Housing Survey for the United States H150/97, Office of Policy Development and Research and the U.S. Census Bureau, September 1999.

U.S. Geological Survey (USGS). 2012. The National Land Cover Database, Fact Sheet 2012-3020, U.S. Department of the Interior, USGS. https://pubs.usgs.gov/fs/2012/3020/fs2012-3020.pdf.

USGS Western Geographic Science Center. 2015. Dasymetric Mapping: An Alternative Approach to Visually and Statistically Enhancing Population Density. http://geography.wr.usgs.gov/science/dasymetric/index.htm.

Appendix A. Earthquake and Tsunami GBS Mapping Scheme Tables

Table A-1. Distribution Percentage of Floor Area for Specific Occupancy Classes within each General Occupancy Class

Specific Occupancy Class		General Occupancy Class						
Label	**Occupancy Class**	**RES**	**COM**	**IND**	**AGR**	**REL**	**GOV**	**EDU**
RES1	Single-Family Dwelling	*						
RES2	Mobile Home	*						
RES3	Multi-Family Dwelling	*						
RES4	Temporary Lodging	*						
RES5	Institutional Dormitory	*						
RES6	Nursing Home	*						
COM1	Retail Trade		*					
COM2	Wholesale Trade		*					
COM3	Personal and Repair Services		*					
COM4	Professional/Technical		*					
COM5	Banks		*					
COM6	Hospital		*					
COM7	Medical Office/Clinic		*					
COM8	Entertainment & Recreation		*					
COM9	Theaters		*					
COM10	Parking		*					
IND1	Heavy			*				
IND2	Light			*				
IND3	Food/Drugs/Chemicals			*				
IND4	Metals/Minerals Processing			*				
IND5	High Technology			*				
IND6	Construction			*				
AGR1	Agriculture				100			
REL1	Church					100		
GOV1	General Services						*	
GOV2	Emergency Response						*	
EDU1	Schools							*
EDU2	Colleges/Universities							*

** The relative distribution varies by Census Tract and is computed directly from the specific occupancy class square footage inventory. For Agriculture (AGR) and Religion (REL) there is only one specific occupancy class, therefore the distribution is always 100%.*

Table A-2. Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, Low-Rise, Pre-1950, West Coast (after ATC-13, 1985)

Specific Occup. Class	Specific Building Type															
	W1	W2	S1L	S2L	S3	S4L	S5L	C1L	C2L	C3L	PC1	PC2L	RM1L	RM2L	URML	MH
RES2																100
RES3	73		1	1	1		6		3	3			1		9	2
RES4	34		2	1	2	1	19		16	3			4		18	
RES5	20		5	1		1			28	18			6		21	
RES6	45				10		5		10				20		10	
COM1		22	2		6	3	20		17	1			6		23	
COM2		8	3		4	2	41		18	1	3		5	2	13	
COM3		28	1	1	3		18		7		1		8		33	
COM4		27	2	1	3		19		15				7		26	
COM5		27	2	1	3		19		15				7		26	
COM6		8	5	2	11		11		27	2	1		27		6	
COM7		25	5	2	10		10		15	2	1		20		10	
COM8		8	12	1	2	3	16		27	4			5	1	21	
COM9		5	20	7			15		20	3			10		20	
COM10				8		8	18		43	7		1	6	3	6	
IND1		3	29	13	2	2	15		14	7	1		4	2	8	
IND2		4	14	8	22	1	18		16	1	1		2		13	
IND3		1	18	8	3	3	20		22		2		3		20	
IND4		2	24	12	7	2	13		16		2		2	6	14	
IND5			21	5	5		3		35	2	10	2	15		2	
IND6		32	3	2	10		18		8	7					13	7
AGR1	56		3	2	14		2		9					1	13	
REL1	22		8		2		21		15	5			8		19	
GOV1		9	8	1	3	4	12		42	4			6		11	
GOV2	45					2			37				3		13	
EDU1	11		6		3	3	21		21	4			9		22	
EDU2	2		5	10		5	15		20				20	5	18	

** Refer to Table A-22 for states' classifications.*
For "Res1" Distribution, Refer to Table A-17

Table A-3. Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, Low-Rise, 1950-1970, West Coast (after ATC-13, 1985)

Specific Occup. Class	Specific Building Type															
	W1	W2	S1L	S2L	S3	S4L	S5L	C1L	C2L	C3L	PC1	PC2L	RM1L	RM2L	URML	MH
RES2																100
RES3	72		1	2	2		1		6	2			8		3	3
RES4	55		1	2	2	2	3		11	2			18	1	3	
RES5	39		3	3		1	8		16	6			18	1	5	
RES6	70				3	1	1		5				20			
COM1		34	3	1	3	2	4		13	5	10	1	18	2	4	
COM2		12	4	5	5	3	3		18		22	1	19	4	4	
COM3		12	3	5	5	2	3		23	4	12	1	22	4	4	
COM4		34	3	3	1	2	3		17	5	3		23	4	2	
COM5		34	3	3	1	2	3		17	5	3		23	4	2	
COM6		32	5	2	4	3			16	6			28	4		
COM7		46	13	1	3	3			9				20		5	
COM8		13	17	12	3	3			13	6			30	3		
COM9		10	10	30			5		10		5		30			
COM10			5	8		20			34			5	20	6	2	
IND1		10	25	30	3			7	14				9	2		
IND2		8	5	14	17	4			10	5	22	3	12			
IND3			14	16	6	1		5	17		28	1	10	2		
IND4			18	25	9			11	10		7		15	3		2
IND5			4	9	3	2		4	20		35	3	15	4		1
IND6		30		1	15				7		4		20	3		20
AGR1	51		4	8	12				2		10		11	2		
REL1	20		4	1	3	3			24		4		37	4		
GOV1		21	6	3	2	2			26	5	4	2	27	2		
GOV2	50								13		7		20	10		
EDU1	25		3	4	5	4			20		4	2	29	4		
EDU2	5		2	12		5			20				50	6		

** Refer to Table A-22 for states' classifications.*
For "Res1" Distribution, Refer to Table A-18

Table A-4. Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, Low-Rise, Post-1970, West Coast (after ATC-13, 1985)

Specific Occup. Class	Specific Building Type															
	W1	W2	S1L	S2L	S3	S4L	S5L	C1L	C2L	C3L	PC1	PC2L	RM1L	RM2L	URML	MH
RES2																100
RES3	73				2	3			6	1		1	9			5
RES4	53		3		2	3		4	13				20	2		
RES5	33		3	3		6		5	24				23	3		
RES6	70								5		5		20			
COM1		26	9	1	2	1		6	10	1	15	5	21	3		
COM2		8	4	1	3	4		2	12		41	3	19	3		
COM3		13	3	2	2	3		3	13		20	5	34	2		
COM4		35	3	2	1	3		4	15		8	3	24	2		
COM5		35	3	2	1	3		4	15		8	3	24	2		
COM6		31	6	1	1	7		4	13		7		28	2		
COM7		47	16			5		4	6		2		20			
COM8		4	23	8	1	3		2	15		4	1	32	7		
COM9		5	27	20					12		4		27	5		
COM10			8	8		6		3	49		3	13	7	3		
IND1		11	19	28	3	2		1	9		11	3	11	1		1
IND2		3	13	9	6	3			10		41	3	12			
IND3		2	15	10	5	3			12		28	7	18			
IND4		1	26	18	5	4		1	11	1	12	5	15	1		
IND5		1	12	8	2	3			10		38	7	17	1		1
IND6		30	4	6	11				8		16	6	14			5
AGR1	40		8	11	8				3		11	1	15	1		2
REL1	23		12	3	1	6			26		1	3	22	3		
GOV1		8	15	4	3	7		2	32			4	16	9		
GOV2	40		3	7		23			10			7	3	7		
EDU1	24		9	6	1	5		3	16	3	4	3	21	5		
EDU2	5		10	10		5			20		5		40	5		

** Refer to Table A-22 for states' classifications.*
For "Res1" Distribution, Refer to Table A-19

Table A-5. Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, Mid-Rise, Pre-1950, West Coast (after ATC-13, 1985)

Specific Occup. Class	Specific Building Type										
	S1M	S2M	S4M	S5M	C1M	C2M	C3M	PC2M	RM1M	RM2M	URMM
RES3	15	4	5		1	19	25		8		23
RES4	18	4	12		1	20	20		8		17
RES5	16	1	5			40	20				18
RES6	20		5			35	20		10		10
COM1	8	6	3			21	34		11	1	16
COM2	8					27	53		5		7
COM3	18					22	42		5		13
COM4	25	7	10		2	22	16		9		9
COM5	25	7	10		2	22	16		9		9
COM6	18	4	6		1	35	19		8		9
COM7	20	5	5			30	20		10		10
COM8	25		20			40	5				10
COM9	30		10			40	10				10
COM10		10	5		2	55	18		3	2	5
IND1											
IND2			10			5	75				10
IND3	32	3	1		1	14	41		3		5
IND4	25	3	1			9	52				10
IND5	35	10				30	5		20		
IND6						20	80				
AGR1						25	75				
REL1						10	90				
GOV1	30	15	5		3	23	10		4		10
GOV2											
EDU2	10		20			60	3		5		2

** Refer to Table A-22 for states' classifications.*

Table A-6. Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, Mid-Rise, 1950-1970, West Coast (after ATC-13, 1985)

Specific Occup. Class	Specific Building Type										
	S1M	S2M	S4M	S5M	C1M	C2M	C3M	PC2M	RM1M	RM2M	URMM
RES3	10	15	6		4	37		1	21	6	
RES4	9	24	9		5	34	1		14	4	
RES5	6	1	11		9	45			18	10	
RES6	15	10	15		5	25			25	5	
COM1	7	25	5		3	31			22	7	
COM2	21	3			2	34		1	34	5	
COM3	10	3				28			54	5	
COM4	17	18	9		9	18		2	23	4	
COM5	17	18	9		9	18		2	23	4	
COM6	14	10	14		5	23		3	23	8	
COM7	15	10	15		5	25			25	5	
COM8	5		28			52			10	5	
COM9	5		30			50			10	5	
COM10	5	8	8		7	39		8	18	7	
IND1		10	20			40			20	10	
IND2		15	10			50			20	5	
IND3	11	4	10		30	20		1	15	9	
IND4					100						
IND5	10	5	13			32			30	10	
IND6											
AGR1											
REL1						80			10	10	
GOV1	15	6	15		11	28		2	18	5	
GOV2	5	10	10		5	60				10	
EDU2	20		15		5	35			15	10	

** Refer to Table A-22 for states' classifications.*

Table A-7. Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, Mid-Rise, Post-1970, West Coast (after ATC-13, 1985)

Specific Occup. Class	Specific Building Type									
	S1M	S2M	S4M	S5M	C1M	C2M	C3M	PC2M	RM1M	RM2M	URMM
RES3	9	23	8		10	28		7	12	3	
RES4	16	28	8		11	18		3	13	3	
RES5	9	10	11		16	34		4	11	5	
RES6	25	10	15		10	35			5		
COM1	34	9	3		12	17		5	15	5	
COM2	20	17			15	10		8	15	15	
COM3	11	17	3		10	17		12	17	13	
COM4	37	10	12		9	15		3	9	5	
COM5	37	10	12		9	15		3	9	5	
COM6	25	9	15		10	33		1	6	1	
COM7	25	10	15		10	35			5		
COM8		10			90						
COM9		10			90						
COM10	4	8	3		4	66		8	6	1	
IND1											
IND2											
IND3	62	5	1		23	4		1	3	1	
IND4	100										
IND5	18	14	3		34	13		5	10	3	
IND6											
AGR1											
REL1		5			90					5	
GOV1	25	11	15		22	12		4	9	2	
GOV2	25	20	35			20					
EDU2	20	5	10		25	25			10	5	

** Refer to Table A-22 for states' classifications.*

Table A-8. Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, High-Rise, Pre-1950, West Coast (after ATC-13, 1985)

Specific Occup. Class	Specific Building Type								
	S1H	S2H	S4H	S5H	C1H	C2H	C3H	PC2H	RM2H
RES3	39	1	2		8	24	23	3	
RES4	45	3	3		8	20	18	3	
RES5	15	5	10			30	40		
COM4	47	10	4		1	21	16	1	
COM5	47	10	4		1	21	16	1	
COM6	56	9	1		1	24	8	1	
COM7									
COM10									
AGR1									
GOV1	53	5	5		3	30	3	1	
EDU2	5	5	35			40	15		

** Refer to Table A-22 for states' classifications.*

Table A-9. Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, High-Rise, 1950-1970, West Coast (after ATC-13, 1985)

Specific Occup. Class	Specific Building Type								
	S1H	S2H	S4H	S5H	C1H	C2H	C3H	PC2H	RM2H
RES3	30	21	6		13	24		3	3
RES4	48	10	9		12	19		1	1
RES5	20	15	25		30	5			5
COM4	40	26	18		6	7		1	2
COM5	40	26	18		6	7		1	2
COM6	35	27	17		4	15		1	1
COM7									
COM10									
AGR1									
GOV1	46	13	22		10	8			1
EDU2	35	20	20		25				

** Refer to Table A-22 for states' classifications.*

Table A-10. Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, High-Rise, Post-1970, West Coast (after ATC-13, 1985)

Specific Occup. Class	Specific Building Type								
	S1H	S2H	S4H	S5H	C1H	C2H	C3H	PC2H	RM2H
RES3	44	6	5		18	20		5	2
RES4	56	10	6		16	9		2	1
RES5	25	18	20		37				
COM4	56	10	14		14	5		1	
COM5	54	10	15		15	5		1	
COM6	45	6	19		13	17			
COM7									
COM10									
AGR1									
GOV1	52	14	14		14	6			
EDU2	30	10	10		50				

** Refer to Table A-22 for states' classifications.*

Table A-11. Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, Low-Rise, Mid-West

Specific Occup. Class	Specific Building Type															
	W1	W2	S1L	S2L	S3	S4L	S5L	C1L	C2L	C3L	PC1	PC2L	RM1L	RM2L	URML	MH
RES2																100
RES3	75												2		23	
RES4	50												3	2	45	
RES5	20							4	13	2	22	4	2		33	
RES6	90														10	
COM1		30	2	4	11	6	7		5		5		2		28	
COM2		10	2	4	11	6	7	2	10	2	14	2	2		28	
COM3		30	2	4	11	6	7		5		5		2		28	
COM4		30	2	4	11	6	7		5		5		2		28	
COM5		30	2	4	11	6	7		5		5		2		28	
COM6				2	4	2	2	6	21	4	33	6	2		18	
COM7		30	2	4	11	6	7		5		5		2		28	
COM8		30	2	4	11	6	7		5		5		2		28	
COM9			2	6	14	8	10	4	13	2	22	4			15	
COM10			2	4	11	6	7	6	21	4	33	6				
IND1			5	10	25	13	17	2	7	2	12	2			5	
IND2		10	2	4	11	6	7	2	10	2	14	2	3		27	
IND3		10	2	4	11	6	7	2	10	2	14	2	3		27	
IND4			5	10	25	13	17	2	7	2	12	2			5	
IND5		10	2	4	11	6	7	2	10	2	14	2	2		28	
IND6		30	2	4	11	6	7		5		5		2		28	
AGR1		10	2	4	11	6	7	2	10	2	14	2	2		28	

Specific Occup. Class	Specific Building Type															
	W1	W2	S1L	S2L	S3	S4L	S5L	C1L	C2L	C3L	PC1	PC2L	RM1L	RM2L	URML	MH
REL1	30			3	5	3	4		5		5		2	2	41	
GOV1		15	14	21				7	6		4		3		30	
GOV2		14	7	17				4	12					3	43	
EDU1		10	5	12				5	7				11		50	
EDU2		14	6	12			2	8	11					10	37	

** Refer to Table A-22 for states' classifications.*
For "Res1" Distribution, Refer to Table A-20

Table A-12. Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, Mid-Rise, Mid-West

Specific Occup. Class	Specific Building Type										
	S1M	S2M	S4M	S5M	C1M	C2M	C3M	PC2M	RM1M	RM2M	URMM
RES3		10	7	3	14	39		7		2	18
RES4		10	7	3	14	37	2	7		2	18
RES5					25	62	2	11			
RES6											
COM1	3	20	16	6	11	27	2	5		2	8
COM2		7	3		14	37	2	7		3	27
COM3	3	20	16	6	11	27	2	5		2	8
COM4	3	20	16	6	11	27	2	5		2	8
COM5	3	20	16	6	11	27	2	5		2	8
COM6	3	20	16	6	12	30	2	6			5
COM7	3	20	16	6	11	27	2	5		2	8
COM8	3	20	16	6	11	27	2	5		2	8
COM9											
COM10	2	14	10	4	17	43	2	8			
IND1											
IND2		7	3		14	37	2	7		3	27
IND3		7	3		14	37	2	7		3	27
IND4											
IND5		7	3		14	37	2	7		3	27
IND6											
AGR1		7	3		14	37	2	7		3	27
REL1	3	20	16	6	11	27	2	5		2	8
GOV1	20	24			11	9				5	31
GOV2											
EDU2	7	14			9	13				13	44

** Refer to Table A-22 for states' classifications.*

Table A-13. Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, High-Rise, Mid-West*

Specific Occup. Class	Specific Building Type								
	S1H	S2H	S4H	S5H	C1H	C2H	C3H	PC2H	RM2H
RES3	3	13	4		16	44	7	7	6
RES4	3	13	4		16	44	7	7	6
RES5					26	74			
COM4	7	29	9		12	32	4	4	3
COM5	7	29	9		12	32	4	4	3
COM6	7	29	9		13	36	2	2	2
COM7	7	29	9		12	32	4	4	3
COM10	5	19	6		18	52			
AGR1	2	6	2		16	44	11	11	8
GOV1									
EDU2									

* *Refer to Table A-22 for states' classifications.*

Table A-14. Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, Low-Rise, East Coast

Specific Occup. Class	Specific Building Type														
	W1	W2	S1L	S2L	S3	S4L	S5L	C1L	C2L	C3L	PC1	PC2L	RM1L	RM2L	URML	MH
RES2																100
RES3	62			3				2	2				5	4	22	
RES4	48		5	4			4	8	4		3	3	3	3	15	
RES5	7		7	6			6	17	6	3	8	6	5	5	24	
RES6	22		11	8			8	8	3	2	4	3	5	4	22	
COM1		14	20	15	5		16	3	2		2		4	2	17	
COM2		10	21	15	7		16	3	2		2		3	4	17	
COM3		25	7	5	11		5	3	2		2		6	4	30	
COM4		26	11	8	4		9	4	2		3		5	4	24	
COM5		13	13	9	13		10	5	3		2	2	5	3	22	
COM6		2	22	15			18	10	4	2	5	4	3	2	13	
COM7		24	10	7	15		8	3	2		3		4	4	20	
COM8		19	19	13	6		15	3	2		2		3	3	15	
COM9		5	20	13	12	2	16	7	2		3	3	3	2	12	
COM10			10	7			8	30	11	6	14	12			2	
IND1		5	22	15	4	2	17	7	3		3	3	3	3	13	
IND2		10	15	9	15		11	5	3		2	2	4	5	19	
IND3		7	25	18	3		19	4	2		2	2	3	2	13	
IND4		7	26	19	3		20	3	2		2		2	3	13	
IND5		5	25	17	3	2	20	7	3		3	3		2	10	
IND6		10	21	14	7	2	16	5	2		2	2	2	3	14	
AGR1		48	8	6	12		7	2					3	2	12	

Specific Occup. Class	Specific Building Type															
	W1	W2	S1L	S2L	S3	S4L	S5L	C1L	C2L	C3L	PC1	PC2L	RM1L	RM2L	URML	MH
REL1	36		4	4			3	2	2		2		7	6	34	
GOV1		7	24	16	3		19	5	3		2	1	3	3	13	
GOV2		8	16	11	4		13	8	3	2	4	3	4	5	19	
EDU1		13	17	13			13	5	3		2	2	5	5	22	
EDU2		4	18	13			14	8	3	2	4	3	5	4	22	

** Refer to Table A-22 for states' classifications.*
For "RES1" Distribution, Refer to Table A-21

Table A-15. Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, Mid-Rise, East Coast

Specific Occup. Class	Specific Building Type										
	S1M	S2M	S4M	S5M	C1M	C2M	C3M	PC2M	RM1M	RM2M	URMM
RES3	3	4			6	3		14		13	57
RES4	9	12		3	18	9	2	11		7	29
RES5	7	10		3	23	11	3	12		5	26
RES6											
COM1	23	29	2	8	5	3		5		5	20
COM2	23	30	3	8	4	3		5		5	19
COM3	10	13		3	5	4		11		10	44
COM4	14	19	2	5	7	4		9		7	33
COM5	15	21	2	6	8	5		8		6	29
COM6	21	27	2	8	12	6	2	7		2	13
COM7	15	20	2	5	7	4		9		6	32
COM8	22	30	3	8	5	3		5		5	19
COM9											
COM10	10	13		3	38	17	6	11			2
IND1											
IND2	22	28	2	8	10	5	2	6		3	14
IND3	25	32	3	9	6	4		4		3	14
IND4											
IND5	24	32	3	9	9	6		5		2	10
IND6											
AGR1	19	25	2	7	4	2		7		6	28
REL1	5	9		2	4	3		12		12	53
GOV1	24	30	3	9	7	5		5		3	14
GOV2											
EDU2	17	23	2	6	10	5	2	8		4	23

** Refer to Table A-22 for states' classifications.*

Table A-16. Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, High-Rise, East Coast

Specific Occup. Class	Specific Building Type								
	S1H	S2H	S4H	S5H	C1H	C2H	C3H	PC2H	RM2H
RES3	8	21	8		34	17	2	5	5
RES4	8	21	8		34	17	2	5	5
RES5	6	16	6		40	20	3	5	4
COM4	15	36	15		15	8		2	9
COM5	15	36	15		15	8		2	9
COM6	14	35	14		17	8	2	2	8
COM7	15	38	15		14	8		2	8
COM10	5	12	5		43	21	4	6	4
AGR1	7	4	18		20	42			9
GOV1									
EDU2									

** Refer to Table A-22 for states' classifications.*

Table A-17. Distribution Percentage of Floor Area for Specific Building Types within "RES1" Building Occupancy Class, Pre-1950, West Coast

State FIPS*	State Abbreviation	State	Specific Building Type					
			W1	S3	S5L	C2L	RM1L	URML
02	AK	Alaska	99			1		
04	AZ	Arizona	60				25	16
06	CA	California	99				1	0
08	CO	Colorado	76				15	9
15	HI	Hawaii	92			1	4	3
16	ID	Idaho	95				3	2
30	MT	Montana	98				1	1
35	NM	New Mexico	74				16	10
32	NV	Nevada	97				2	1
41	OR	Oregon	99				1	
49	UT	Utah	82				11	7
53	WA	Washington	98				1	1
56	WY	Wyoming	92				5	3

** State FIPS are two digit unique number representative of each state and U.S. territory. Refer to Table A-22 for a complete list of State FIPS.*

Table A-18. Distribution Percentage of Floor Area for Specific Building Types within "RES1" Building Occupancy Class, 1950-1970, West Coast

State FIPS	State Abbreviation	State	Specific Building Type					
			W1	S3	S5L	C2L	RM1L	URML
02	AK	Alaska	99			1		
04	AZ	Arizona	60				36	4
06	CA	California	99				1	0
08	CO	Colorado	76				21	3
15	HI	Hawaii	92			1	6	1
16	ID	Idaho	95				4	1
30	MT	Montana	98				2	
35	NM	New Mexico	74				23	3
32	NV	Nevada	97				3	
41	OR	Oregon	99				1	
49	UT	Utah	82				16	2
53	WA	Washington	98				2	
56	WY	Wyoming	92				7	1

Table A-19. Distribution Percentage of Floor Area for Specific Building Types within "RES1" Building Occupancy Class, Post-1970, West Coast

State FIPS	State Abbreviation	State	Specific Building Type					
			W1	S3	S5L	C2L	RM1L	URML
02	AK	Alaska	99			1		
04	AZ	Arizona	60				40	
06	CA	California	99				1	0
08	CO	Colorado	76				24	
15	HI	Hawaii	92			1	7	
16	ID	Idaho	95				5	
30	MT	Montana	98				2	
35	NM	New Mexico	74				26	
32	NV	Nevada	97				3	
41	OR	Oregon	99				1	
49	UT	Utah	82				18	
53	WA	Washington	98				2	
56	WY	Wyoming	92				8	

Table A-20. Distribution Percentage of Floor Area for Specific Building Types within "RES1" Building Occupancy Class, Mid-West

State FIPS	State Abbreviation	State	Specific Building Type		
			W1	C2L	URML
05	AR	Arkansas	87		13
19	IA	Iowa	92		8
17	IL	Illinois	77	1	22
18	IN	Indiana	80		20
20	KS	Kansas	91		9
21	KY	Kentucky	88		12
22	LA	Louisiana	89		11
26	MI	Michigan	86		14
27	MN	Minnesota	95	1	4
29	MO	Missouri	76		24
28	MS	Mississippi	94		6
38	ND	North Dakota	98		2
31	NE	Nebraska	89	1	10
39	OH	Ohio	76		24
40	OK	Oklahoma	71		29
46	SD	South Dakota	97		3
47	TN	Tennessee	90		10
48	TX	Texas	100		
55	WI	Wisconsin	90		10

Table A-21. Distribution Percentage of Floor Area for Specific Building Types within "RES1" Building Occupancy Class, East Coast

State FIPS	State Abbreviation	State	Specific Building Type		
			W1	C2L	URML
01	AL	Alabama	95		5
09	CT	Connecticut	96		4
11	DC	District of Columbia	21	3	76
10	DE	Delaware	71	1	28
12	FL	Florida	25	5	70
13	GA	Georgia	93		7
25	MA	Massachusetts	96		4
24	MD	Maryland	71	1	28
23	ME	Maine	99		1
37	NC	North Carolina	90		10
33	NH	New Hampshire	97	1	2
34	NJ	New Jersey	91		9
36	NY	New York	85	1	14
42	PA	Pennsylvania	66		34
44	RI	Rhode Island	98		2
45	SC	South Carolina	92		8

State FIPS	State Abbreviation	State	Specific Building Type		
			W1	C2L	URML
51	VA	Virginia	75		25
50	VT	Vermont	96	2	2
54	WV	West Virginia	72		28

Table A-22. Regional Distribution of States

State FIPS	State Abbreviation	State Name	Group
02	AK	Alaska	West Coast
01	AL	Alabama	East Coast
05	AR	Arkansas	Mid-West
04	AZ	Arizona	West Coast
06	CA	California	West Coast
08	CO	Colorado	West Coast
09	CT	Connecticut	East Coast
11	DC	District of Columbia	East Coast
10	DE	Delaware	East Coast
12	FL	Florida	East Coast
13	GA	Georgia	East Coast
15	HI	Hawaii	West Coast
19	IA	Iowa	Mid-West
16	ID	Idaho	West Coast
17	IL	Illinois	Mid-West
18	IN	Indiana	Mid-West
20	KS	Kansas	Mid-West
21	KY	Kentucky	Mid-West
22	LA	Louisiana	Mid-West
25	MA	Massachusetts	East Coast
24	MD	Maryland	East Coast
23	ME	Maine	East Coast
26	MI	Michigan	Mid-West
27	MN	Minnesota	Mid-West
29	MO	Missouri	Mid-West
28	MS	Mississippi	Mid-West
30	MT	Montana	West Coast
37	NC	North Carolina	East Coast
38	ND	North Dakota	Mid-West
31	NE	Nebraska	Mid-West
33	NH	New Hampshire	East Coast
34	NJ	New Jersey	East Coast
35	NM	New Mexico	West Coast
32	NV	Nevada	West Coast
36	NY	New York	East Coast
39	OH	Ohio	Mid-West

State FIPS	State Abbreviation	State Name	Group
40	OK	Oklahoma	Mid-West
41	OR	Oregon	West Coast
42	PA	Pennsylvania	East Coast
44	RI	Rhode Island	East Coast
45	SC	South Carolina	East Coast
46	SD	South Dakota	Mid-West
47	TN	Tennessee	Mid-West
48	TX	Texas	Mid-West
49	UT	Utah	West Coast
51	VA	Virginia	East Coast
50	VT	Vermont	East Coast
53	WA	Washington	West Coast
55	WI	Wisconsin	Mid-West
54	WV	West Virginia	East Coast
56	WY	Wyoming	West Coast
60	AS	American Samoa	West Coast
66	GU	Guam	West Coast
69	MR	Northern Mariana Islands	West Coast
72	PR	Puerto Rico	East Coast
78	VI	Virgin Islands	East Coast

Appendix B. Earthquake and Tsunami Essential Facilities Mapping Schemes

Table B-1 Distribution Percentage of Floor Area for Specific Occupancy Classes within each General Occupancy Class

Specific Occupancy Class		General Occupancy Class		
		Medical	Emergency Response	Schools
Label	Occupancy Class	1	2	3
EFHS	Small Hospital	X		
EFHM	Medium Hospital	X		
EFHL	Large Hospital	X		
EFMC	Medical Clinics	X		
EFFS	Fire Station		X	
EFPS	Police Station		X	
EFEO	Emergency Operation Centers		X	
EFS1	Grade Schools			X
EFS2	Colleges/Universities			X

Table B-2 Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, Low-Rise, Pre-1950, West Coast

Specific Occup. Class	Specific Building Type														
	W1	W2	S1L	S2L	S3	S4L	S5L	C1L	C2L	C3L	PC1	PC2L	RM1L	RM2L	URML
EFHS		8	5	2	11		11		27	2	1		27		6
EFHM		8	5	2	11		11		27	2	1		27		6
EFHL		8	5	2	11		11		27	2	1		27		6
EFMC		8	5	2	11		11		27	2	1		27		6
EFFS	45					2			37				3		13
EFPS	45					2			37				3		13
EFEO	45					2			37				3		13
EFS1	11		6		3	3	21		21	4			9		22
EFS2	2		5	10		5	15		20				20	5	18

** Refer to Table A-22 for states' classifications.*

Table B-3 Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, Low-Rise, 1950-1970, West Coast

Specific Occup. Class	Specific Building Type														
	W1	W2	S1L	S2L	S3	S4L	S5L	C1L	C2L	C3L	PC1	PC2L	RM1L	RM2L	URML
EFHS		32	5	2	4	3			16	6			28	4	
EFHM		32	5	2	4	3			16	6			28	4	
EFHL		32	5	2	4	3			16	6			28	4	
EFMC		32	5	2	4	3			16	6			28	4	
EFFS	50								13		7		20	10	
EFPS	50								13		7		20	10	
EFEO	50								13		7		20	10	
EFS1	25		3	4	5	4			20		4	2	29	4	
EFS2	5		2	12		5			20				50	6	

** Refer to Table A-22 for states' classifications.*

Table B-4 Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, Low-Rise, Post-1970, West Coast

Specific Occup. Class	Specific Building Type														
	W1	W2	S1L	S2L	S3	S4L	S5L	C1L	C2L	C3L	PC1	PC2L	RM1L	RM2L	URML
EFHS		31	6	1	1	7		4	13		7		28	2	
EFHM		31	6	1	1	7		4	13		7		28	2	
EFHL		31	6	1	1	7		4	13		7		28	2	
EFMC		31	6	1	1	7		4	13		7		28	2	
EFFS	40		3	7		23			10			7	3	7	
EFPS	40		3	7		23			10			7	3	7	
EFEO	40		3	7		23			10			7	3	7	
EFS1	24		9	6	1	5		3	16	3	4	3	21	5	
EFS2	5		10	10		5			20		5		40	5	

** Refer to Table A-22 for states' classifications.*

Table B-5 Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, Mid-Rise, Pre-1950, West Coast

Specific Occup. Class	Specific Building Type										
	S1M	S2M	S4M	S5M	C1M	C2M	C3M	PC2M	RM1M	RM2M	URMM
EFHS	18	4	6		1	35	19		8		9
EFHM	18	4	6		1	35	19		8		9
EFHL	18	4	6		1	35	19		8		9
EFMC	18	4	6		1	35	19		8		9
EFFS											
EFPS											
EFEO											
EFS2	10		20			60	3		5		2

** Refer to Table A-22 for states' classifications.*

Table B-6 Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, Mid-Rise, 1950-1970, West Coast

Specific Occup. Class	Specific Building Type									
	S1M	S2M	S4M	S5M	C1M	C2M	C3M	PC2M	RM1M	RM2M	URMM
EFHS	14	10	14		5	23		3	23	8	
EFHM	14	10	14		5	23		3	23	8	
EFHL	14	10	14		5	23		3	23	8	
EFMC	14	10	14		5	23		3	23	8	
EFFS	5	10	10		5	60				10	
EFPS	5	10	10		5	60				10	
EFEO	5	10	10		5	60				10	
EFS2	20		15		5	35			15	10	

** Refer to Table A-22 for states' classifications.*

Table B-7 Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, Mid-Rise, Post-1970, West Coast

Specific Occup. Class	Specific Building Type										
	S1M	S2M	S4M	S5M	C1M	C2M	C3M	PC2M	RM1M	RM2M	URMM
EFHS	25	9	15		10	33		1	6	1	
EFHM	25	9	15		10	33		1	6	1	
EFHL	25	9	15		10	33		1	6	1	
EFMC	25	9	15		10	33		1	6	1	
EFFS	25	20	35			20					
EFPS	25	20	35			20					
EFEO	25	20	35			20					
EFS2	20	5	10		25	25			10	5	

** Refer to Table A-22 for states' classifications.*

Table B-8 Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, High-Rise, Pre-1950, West Coast

Specific Occup. Class	Specific Building Type								
	S1H	S2H	S4H	S5H	C1H	C2H	C3H	PC2H	RM2H
EFHS	56	9	1		1	24	8	1	
EFHM	56	9	1		1	24	8	1	
EFHL	56	9	1		1	24	8	1	
EFMC	56	9	1		1	24	8	1	
EFS2	5	5	35			40	15		

** Refer to Table A-22 for states' classifications.*

Table B- 9 Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, High-Rise, 1950-1970, West Coast

Specific Occup. Class	Specific Building Type								
	S1H	S2H	S4H	S5H	C1H	C2H	C3H	PC2H	RM2H
EFHS	35	27	17		4	15		1	1
EFHM	35	27	17		4	15		1	1
EFHL	35	27	17		4	15		1	1
EFMC	35	27	17		4	15		1	1
EFS2	35	20	20		25				

** Refer to Table A-22 for states' classifications.*

Table B-10 Distribution Percentage of Floor Area, for Specific Building Types within Each Building Occupancy Class, High-Rise, Post-1970, West Coast*

Specific Occup. Class	Specific Building Type								
	S1H	S2H	S4H	S5H	C1H	C2H	C3H	PC2H	RM2H
EFHS	45	6	19		13	17			
EFHM	45	6	19		13	17			
EFHL	45	6	19		13	17			
EFMC	45	6	19		13	17			
EFS2	30	10	10		50				

** Refer to Table A-22 for states' classifications.*

Table B-11 Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, Low-Rise, Mid-West

Specific Occup. Class	Specific Building Type														
	W1	W2	S1L	S2L	S3	S4L	S5L	C1L	C2L	C3L	PC1	PC2L	RM1L	RM2L	URML
EFHS		30	2	4	11	6	7		5		5		2		28
EFHM				2	4	2	2	6	21	4	33	6	2		18
EFHL				2	4	2	2	6	21	4	33	6	2		18
EFMC		30	2	4	11	6	7		5		5		2		28
EFFS		14	7	17				4	12					3	43
EFPS		14	7	17				4	12					3	43
EFEO		14	7	17				4	12					3	43
EFS1		10	5	12				5	7				11		50
EFS2		14	6	12			2	8	11					10	37

** Refer to Table A-22 for states' classifications.*

Table B- 12 Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, Mid-Rise, Mid-West

Specific Occup. Class	Specific Building Type										
	S1M	S2M	S4M	S5M	C1M	C2M	C3M	PC2M	RM1M	RM2M	URMM
EFHS	3	20	16	6	11	27	2	5		2	8
EFHM	3	20	16	6	12	30	2	6			5
EFHL	3	20	16	6	12	30	2	6			5
EFMC	3	20	16	6	11	27	2	5		2	8
EFFS											
EFPS											
EFEO											
EFS2	7	14			9	13				13	44

** Refer to Table A-22 for states' classifications.*

Table B-13 Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, High-Rise, Mid-West

Specific Occup. Class	Specific Building Type								
	S1H	S2H	S4H	S5H	C1H	C2H	C3H	PC2H	RM2H
EFHS	7	29	9		12	32	4	4	3
EFHM	7	29	9		13	36	2	2	2
EFHL	7	29	9		13	36	2	2	2
EFMC	7	29	9		12	32	4	4	3
EFEO									
EFS2									

** Refer to Table A-22 for states' classifications.*

Table B-14 Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, Low-Rise, East Coast

Specific Occup. Class	Specific Building Type														
	W1	W2	S1L	S2L	S3	S4L	S5L	C1L	C2L	C3L	PC1	PC2L	RM1L	RM2L	URML
EFHS		24	10	7	15		8	3	2		3		4	4	20
EFHM		2	22	15			18	10	4	2	5	4	3	2	13
EFHL		2	22	15			18	10	4	2	5	4	3	2	13
EFMC		24	10	7	15		8	3	2		3		4	4	20
EFFS		8	16	11	4		13	8	3	2	4	3	4	5	19
EFPS		8	16	11	4		13	8	3	2	4	3	4	5	19
EFEO		8	16	11	4		13	8	3	2	4	3	4	5	19
EFS1		13	17	13			13	5	3		2	2	5	5	22
EFS2		4	18	13			14	8	3	2	4	3	5	4	22

** Refer to Table A-22 for states' classifications.*

Table B-15 Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, Mid-Rise, East Coast

Specific Occup. Class	Specific Building Type										
	S1M	S2M	S4M	S5M	C1M	C2M	C3M	PC2M	RM1M	RM2M	URMM
EFHS	15	20	2	5	7	4		9		6	32
EFHM	21	27	2	8	12	6	2	7		2	13
EFHL	21	27	2	8	12	6	2	7		2	13
EFMC	15	20	2	5	7	4		9		6	32
EFFS											
EFPS											
EFEO											
EFS2	17	23	2	6	10	5	2	8		4	23

** Refer to Table A-22 for states' classifications.*

Table B-16 Distribution Percentage of Floor Area for Specific Building Types within Each Building Occupancy Class, High-Rise, East Coast

Specific Occup. Class	Specific Building Type								
	S1H	S2H	S4H	S5H	C1H	C2H	C3H	PC2H	RM2H
EFHS	15	38	15		14	8		2	8
EFHM	14	35	14		17	8	2	2	8
EFHL	14	35	14		17	8	2	2	8
EFMC	15	38	15		14	8		2	8
EFEO									
EFS2									

** Refer to Table A-22 for states' classifications.*