Hazus Earthquake Model User Guidance

Hazus 6.1

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Acronyms and Abbreviations

Acronym/Abbreviation	Definition
AAL	Average Annualized Losses
AEBM	Advanced Engineering Building Model
ATC	Applied Technology Council
BCE	Before Common Era
CDMS	Comprehensive Data Management System
CEUS	Central and Eastern U.S.
EERI	Earthquake Engineering Research Institute
FEMA	Federal Emergency Management Agency
FFE	Fire Following Earthquake
FGDC	Federal Geographic Data Committee
ft2	Square Feet
GBS	General Building Stock
GIS	Geographic Information System
HLL	Hazus Loss Library
HPLF	High Potential Loss Facilities
HVAC	Heating, Ventilation and Air Conditioning
M	moment magnitude
NEHRP	National Earthquake Hazards Reduction Program
NEIC	National Earthquake Information Center
NFIP	National Flood Insurance Program
PEH	Potential Earthquake Hazards
PGA	Peak Ground Acceleration
PGD	Permanent Ground Deformation
PGV	Peak Ground Velocity
SA	Spectral acceleration
SLTT	State, Local, Tribal and Territorial government
SQL	Structured Query Language
TOC	Table of Contents
UDF	User-Defined Facilities
URM	Unreinforced masonry bearing wall building
URML	Low-rise unreinforced masonry bearing wall building
USGS	United States Geological Survey

Section 1. Introduction

1.1 Background

The Hazus Earthquake Loss Estimation Methodology provides state, local, tribal, and territorial (SLTT) officials with a decision support software for estimating potential losses from earthquake events. This loss estimation capability enables users to anticipate the consequences of earthquakes and develop plans and strategies for reducing risk. The Geographic Information System (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.

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

- Anticipating the possible nature and scope of the emergency response needed to cope with an earthquake-related disaster
- Developing plans for recovery and reconstruction following a disaster
- Mitigating the possible consequences of earthquakes

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

This *Hazus Earthquake Model User Guidance* outlines the background and instructions for developing a Study Region and defining a scenario to complete an earthquake loss estimation study using Hazus. It also provides information on how to modify inventory, improve hazard data and analysis parameters for advanced applications, and provide guidance on calculating and interpreting losses.

The *Hazus Earthquake Model Technical Manual (FEMA, 2024)* documents the methods used in calculating losses. A companion document, the *Hazus Inventory Technical Manual (FEMA, 2024)*, provides more detailed methodology and data descriptions for the inventory shared by each hazard model. Together, with other accompanying documents such as the *Advanced Engineering Building Module (AEBM) Technical and User's Manual (FEMA, 2002)* and the *Hazus Earthquake Model Standard Operating Procedures (FEMA, 2019)*, these documents provide a comprehensive overview of this nationally applicable loss estimation Methodology.

1.2 Hazus Uses and Applications

Hazus can be used by various types of users with varying information needs. An SLTT government official may be interested in the costs and benefits of specific mitigation strategies and thus may want to know the expected losses if mitigation strategies have (or have not) been applied (Section 8.2.12). Health officials may want information regarding the demands on medical care facilities and may be interested in the number and severity of casualties for different earthquakes scenarios (Section 8.2.4). Emergency response teams may use the results of a loss study 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 (Section 8.2.4). Emergency planners may want to know estimates of how much temporary shelter will be needed and for how long for different earthquake scenario events (Section 8.2.13). Federal and state government officials may require an estimate of economic losses (both short- and long-term) in order to direct resources to affected communities. In addition, government agencies may use loss studies to obtain quick estimates of impacts in the hours immediately following an earthquake to best direct resources to the disaster area (Section 8.2.3). Insurance companies may be interested in estimated monetary losses, so they can assess asset vulnerability (Section 8.2.2).

Earthquake 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 are able to determine how to use it to best suit their needs, and how to appropriately interpret the analysis results.

The products of Hazus analyses have several pre- and post-earthquake applications in addition to estimating the scale and extent of damage and disruption. Examples of pre-earthquake applications of the outputs are:

- Development of earthquake hazard mitigation strategies that outline policies and programs for reducing earthquake losses and disruptions indicated in the initial loss estimation study. Strategies can involve rehabilitation of hazardous existing buildings (e.g., unreinforced masonry structures), building code enforcement, development of appropriate zoning ordinances for land use planning in areas of liquefiable soils, and the adoption of advanced seismic building codes.
- Development of preparedness (contingency) planning measures that identify alternate transportation routes and planning earthquake preparedness and education seminars.
- Anticipation of the nature and scope of response and recovery efforts including the identification of alternative housing and the location, availability, and scope of required medical services and the establishment of a priority ranking for restoration of water and power resources.

Examples of post-earthquake applications of the outputs are:

- Projection of immediate economic impact assessments for state and federal resource allocation and support including supporting the declaration of a state and/or federal disaster by calculating direct economic impact on public and private resources, local governments, and the functionality of the area.

- Activation of immediate emergency recovery efforts including search and rescue operations, rapid identification and treatment of casualties, provision of emergency housing shelters, and rapid repair and availability of essential utility systems.
- Application of long-term reconstruction plans including the identification of long-term reconstruction goals, implementation of appropriate wide-range economic development plans for the impacted area, allocation of permanent housing needs, and the application of land use planning principles and practices.

Table 1-1 lists the earthquake model outputs. See Section 8.2 for details on each type of output.

Table 1-1 Earthquake Model Outputs

Output	Description
Ground Motion Descriptions/Maps	▪ Ground motions per Census tract ▪ Contour maps of ground shaking ▪ Permanent ground deformation per Census tract* ▪ Contour map of permanent ground deformation* ▪ Liquefaction probability* ▪ Landslide probability*
Direct Physical Damage – General Building Stock (GBS)	▪ Structural and nonstructural damage state probabilities by Census tract, building type, and design level, structural, nonstructural acceleration sensitive, and nonstructural drift sensitive ▪ Structural and nonstructural cost of repair or replacement ▪ Loss of contents ▪ Business inventory loss ▪ Relocation costs ▪ Business income loss ▪ Employee wage loss ▪ Loss of rental income ▪ Aggregate estimates of building damage by damage state, by general occupancy and by general building type. ▪ Aggregate estimates of economic loss by loss type, building type and occupancy type.
Direct Physical Damage – Essential facilities	▪ Structural damage state probabilities by facility ▪ Expected functionality at Day 1, 3, 7, 14, 30 and 90 by facility ▪ Aggregate estimates of hospital bed availability by County and hospital size

Output	Description
High Potential Loss Facilities	▪ Locations of dams* ▪ Locations of levees* ▪ Locations of nuclear plants* ▪ Structural damage state probabilities and expected functionality for military facilities (PR only)
Direct Physical Damage – User-Defined Facilities (UDF)*	▪ Damage state probabilities by facility ▪ Expected functionality by facility
Direct Physical Damage – Advanced Engineering Building Model (AEBM)*	▪ Damage state probabilities – structural, nonstructural acceleration sensitive, and nonstructural drift sensitive ▪ Casualties ▪ Loss – structural, nonstructural acceleration sensitive, and nonstructural drift sensitive, contents, business inventory, relocation, rental, business income, wage, and business interruption
Direct Physical Damage	▪ For components of the 13 transportation and utility systems, damage state probabilities, cost of repair or replacement, and expected functionality for various times following earthquake by facility ▪ For potable water, wastewater and natural gas pipeline distribution systems, the estimated number of leaks and breaks ▪ For potable water and electric power systems: estimate of service outages at Day 1, 3, 7, 30 and 90 ▪ Aggregate estimates of economic loss by facility type
Induced Physical Damage – Inundated Areas*	▪ Exposed population and exposed dollar value of GBS
Induced Physical Damage – Fire Following Earthquake (FFE)	▪ Population and building value exposed to FFE per Census tract ▪ Aggregate estimate of the expected number of fire ignitions, burnt area, and population and building value exposed
Induced Physical Damage – Debris	▪ Total building debris weight generated by type of material per Census tract ▪ Aggregate estimate of debris weight by material, and equivalent number of truckloads
Social Losses	▪ Number of displaced households per Census tract, and in aggregate ▪ Number of people requiring temporary shelter per Census tract, and in aggregate ▪ Casualties per Census tract in four categories of severity based on three different times of day (2 am, 2 pm and 5 pm). Aggregate estimates of casualties by time of day, injury severity, and general occupancy class.

* *Outputs cannot be obtained using only baseline data.*

The Hazus Earthquake Model comes with a large library of baseline nationwide inventory data, which can be updated with local data to increase the accuracy of the model. Once the user decides whether to use baseline data or update with local data (covered in detail in the *Hazus Comprehensive Data Management System (CDMS) User Guidance (FEMA, 2019)*), the ease with which reports and maps can be generated makes the software useful for a variety of applications.

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. 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 from an interdisciplinary group of experts. An earthquake loss analysis could be performed by a representative team consisting of the following:

- Geologists
- Geotechnical engineers
- Structural engineers
- Architects
- GIS specialists
- Economists
- Social scientists
- Emergency planners
- Policy makers

The individuals needed to perform the analysis can all provide valuable insight into the risk assessment process and will depend on the desired level of analysis, explained in greater detail in Section 2.3. In addition to subject matter involvement, at least one GIS specialist should participate on the team.

If a SLTT agency is performing the analysis, some of the expertise may be found internally. Experts are generally found in several departments: building permits, public works, planning, public health, engineering, information technologies, finance, historical preservation, natural resources, and land records. Although internal expertise may be most 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 datasets that are provided with Hazus. Further information on these can be found in the *Hazus Inventory Technical Manual* (FEMA, 2024). 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 a seismologist is not available to assist in the selection of earthquake epicenter, magnitude, and other parameters, the user should defer to readily available ground motion data provided by the US Geological Survey (USGS). This will allow users to take advantage of USGS subject matter expertise when defining their probabilistic or deterministic earthquake scenario.

If the user intends to modify the baseline inventory data or parameters, assistance from an individual with expertise in the subject is required. For example, if the user wishes to change baseline percentages of specific building types for the region, collaborating with a structural engineer with knowledge of regional design and construction practices is helpful. Similarly, if damage-motion relationships (fragility curves) need editing, input from a structural engineer is 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 and training opportunities.

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. Because Hazus was built as an extension to ArcGIS functionality, knowing how to use the ArcGIS and ArcGIS Help Desk will help Hazus users.

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

1.6 Uncertainties in Loss Estimates

Although the 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 that have been constructed over a range of years under diverse seismic design codes. In addition, there are a variety of components that contribute to transportation and utility system damage estimations and these components can have differing seismic resistance.

Due to this complexity, there is inherent uncertainty in modeling the structural resistance of most buildings and other facilities. Further, there are not sufficient data from past earthquakes or laboratory experiments to determine precise estimates of damage based on known ground motions, even for specific buildings and other structures. 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 key features of ground shaking and average degree of damage with associated losses for each building category are based on current data and available theories.

The results of an earthquake 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. This is particularly true in areas where seismic events are infrequent or where recorded data are scarce.

Section 2. Introduction to the Earthquake Loss Estimation Methodology

This brief overview of the Earthquake Methodology is intended for SLTT officials contemplating an earthquake analysis.

The Hazus Methodologies will generate an estimate of the consequences of either a deterministic or probabilistic scenario earthquake event to a city, county, or region. The resulting "loss estimate" will generally describe the scale and extent of damage and disruption that may result from the modeled earthquake 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, people displaced from residences, 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 and fire following earthquake.

To generate this information, the methodology includes:

- 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 in the absence of user-supplied data and useable in the calculation of losses.

These systems, methods, and data have been combined in the development of 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 data 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 following figure provides a gr”phic’representation of the modules that the Hazus Earthquake Model Methodology is comprised of, and their interrelation in deriving estimates.

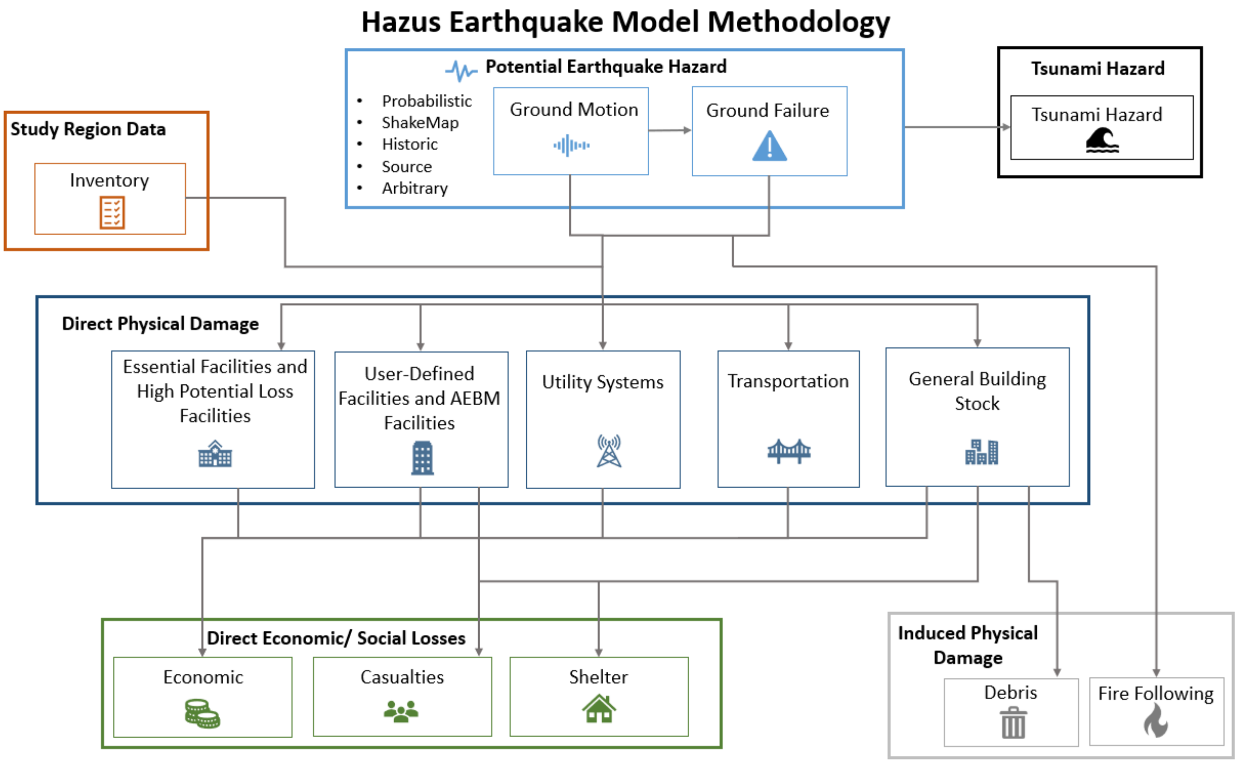


Figure 2-1 Hazus Earthquake Model Methodology Schematic

While Figure 2-1 shows the conceptual relationships, the steps used in the Hazus 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 Hazard Reduction Program (NEHRP) and susceptibility to landslides and liquefaction.
- *Integrate local inventory data*. Include essential facilities, transportation and utility systems, updates to GBS characteristics, user-defined facilities, or AEBM structures.

- *Use the formulas embedded in* Hazus. Compute probability distributions for damage to different classes of buildings, facilities, and system components using formulas embedded in Hazus. Then estimate the loss of function.

- *Compute estimates of direct economic loss, casualties, and shelter needs using the damage and functionality information*.

- *Estimate fire-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 Earthquake Hazards Considered in the Methodology

The earthquake-related hazards considered by the Hazus Methodology in evaluating damage, resultant losses, and casualties are collectively referred to as potential earthquake hazards (PEH). Most damage and loss caused by an earthquake is directly or indirectly the result of ground shaking. Thus, Hazus evaluates the geographic distribution of ground shaking as a result of a specific earthquake scenario and expresses ground shaking using several quantitative parameters (e.g., peak ground acceleration, spectral acceleration).

The following three features of earthquakes can cause permanent ground displacements and have an adverse effect on structures, roadways, pipelines, and other infrastructure system structures:

- *Fault rupture*: Ground shaking is caused by fault rupture, usually below the ground surface. However, fault rupture can reach the surface of the earth as a narrow zone of ground offsets and tear apart structures and pipelines in this zone.

- *Liquefaction*: This occurs when loose, water-saturated soils are shaken strongly and causes sudden loss of strength and stiffness in soils. This shaking can lead to settlement and horizontal movements of the ground.

- *Landslides*: Large downhill movement of soil or rock that is shaken free from hillsides or mountainsides during an earthquake event and can destroy anything in its path.

Soil type can have a significant effect on the intensity of ground motion at a particular site. Soil, as defined in this methodology, is classified in terms of geology. The quality of analysis is significantly reduced if soil amplification is not considered. Hazus now incorporates soil amplification provided by the USGS in the probabilistic ground motions. In addition, when using the USGS ShakeMap input for actual earthquakes or scenarios, site soil amplification is already included. The software contains several additional options for determining the effect of soil type on ground motions for a given magnitude and location. The user may opt to use the baseline soil classification or provide their own soil layer. Section 6 goes into greater detail regarding soil type impacts on loss estimation.

2.2 Definitions of Structures

There are differences between terminology used to designate distinctions 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 Methodology are as follows:

- *General Building Stock*: The key GBS databases in Hazus include 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 each Census tract are aggregated and categorized. Building information derived from Census and employment data are used to form groups of 36 specific building types and 33 occupancy classes (additional information on the Hazus baseline GBS inventory data is provided in the *Hazus Inventory Technical Manual (FEMA, 2024)*). Degree of damage is computed for each grouped combination of specific building type and occupancy class.

- *Essential facilities*: Essential facilities are the facilities that are vital to emergency response and recovery following a disaster. These facilities can include, but are not limited to, medical care facilities, emergency response facilities, 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.

- *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 each system, but total system performance is not evaluated.

- *Utility systems*: Utility systems, including potable water, electric power, wastewater, communications, and liquid fuels (oil and gas), are treated in a manner similar to transportation systems. Probabilities of damage and losses are computed for each component of each system, and simplified methods allow for the estimation of approximate system outage (i.e., total households without potable water or electricity), but detailed system performance is not evaluated, nor are cascading impacts from one system to another.

- *High potential loss facilities*: In any region or community, there will be certain types of structures or facilities for which damage and losses will not be (reliably) evaluated without facility-specific supplemental studies. These facilities include dams and levees, nuclear power plants, and military installations.

More specific data can be used to estimate potential damage and hazard effects using the UDF and AEBM, which are addressed in Section 9 and Section 10, respectively and also in the *Hazus AEBM Technical and User's Manual (FEMA, 2002)*. Hazardous Material Facilities are not currently analyzed separately but can be analyzed through incorporation into the UDF database.

2.3 Levels 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 2-2-2 provides a graphic representation of the various levels of analysis.

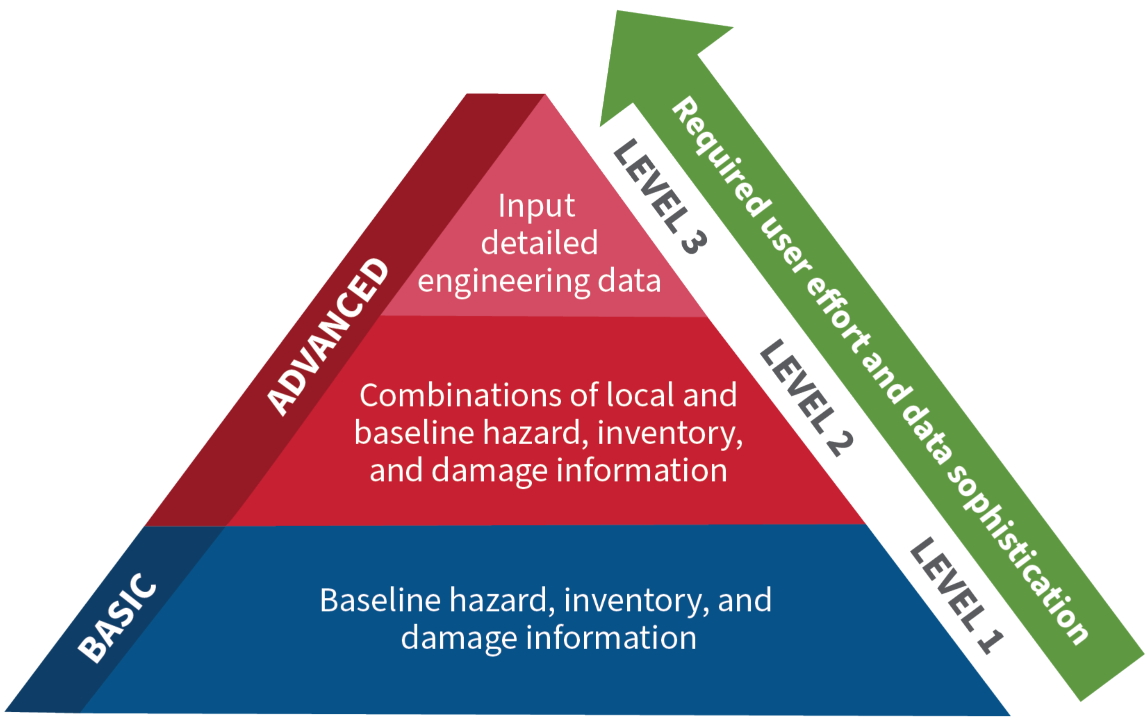


Figure 2-2-2 Levels of Hazus Analysis

2.3.1 Analysis Based on Baseline Information

The basic level of analysis uses only the baseline databases built into the Hazus software and Methodology on building square footage 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), one average soil condition is assumed for the entire Study Region. The effects of possible liquefaction and landslide hazards are ignored. 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.

Other than defining the Study Region, selecting the scenario earthquake(s), 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.

2.3.2 Analysis with User-Supplied Inventory Data

Results from an analysis using only baseline inventory data can be improved 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/Level 3 analysis. The following inventory improvements impact the accuracy of Level 2/Level 3 Advanced Analysis results:

- Development of maps of soil conditions affecting ground shaking, liquefaction and landslide potential. These maps, if available, are used for evaluating the effects of these local conditions on damage and losses.
- Use of locally available data or estimates of the square footage of buildings in different occupancy classes.
- Use of local expertise to modify the mapping scheme 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.
- Collection of data, such as number of fire trucks, for evaluating the probable extent of areas affected by post-earthquake fires.

Section 3. Getting Started Part 1: Hazus Startup Screen

The **Hazus Startup** screen is the first screen users will see after launching Hazus.

3.1 Hazus Startup

Before running a loss estimation analysis, users must define a Study Region. The Study Region in Hazus is the geographic unit for which data are aggregated, the earthquake hazard is defined, and the analysis is carried out. Before starting, make sure that the appropriate baseline Hazus data have been downloaded from the Map Service Center and extracted here: C:\HazusData\Inventory.

Hazus will prompt users to create a new region or import a previously created region. Users can also open, delete, duplicate, backup, or export an existing region.

3.2 Create New Region

The Study Region can be any combination of states, counties, cities, and Census tracts. The Hazus earthquake model includes baseline data and can be run for any of the 50 states, as well as the District of Columbia and Puerto Rico. The defined Study Region will depend on the purpose of the loss study. In many cases, the region will follow political boundaries such as city or county limits. If the user is performing an analysis for a particular city, the region must include at least the area within the city limits. On the other hand, if an analysis is looking at an entire metropolitan area, the region may consist of several counties. Defining the Study Region requires that users be able to identify the Census tracts that comprise the region. The user has the ability to import jurisdictional boundaries to assist in Census tract identification.

In the **Hazus Startup** screen, users will take the first step in defining the Study Region. In Figure 3-1, **Create a new region** has been selected. Click **OK** to activate the window shown in Figure 3-2.

Figure 3-1 Select Create a New Region in Hazus Startup

A wizard will present the dialog windows shown in Figure 3-3 and Figure 3-4 to guide users through the steps for creating a region. First, as shown in Figure 3-3, Hazus will prompt the user for a region name and description. Next, users will be asked to select one or more hazard types to analyze (Figure 3-4). Only hazard models that have been installed will be available for selection. The hazards selected here will be the ones that may be used for analysis of this Study Region. The user cannot add another hazard to this region after it has been created but can create a similar Study Region with different hazards.

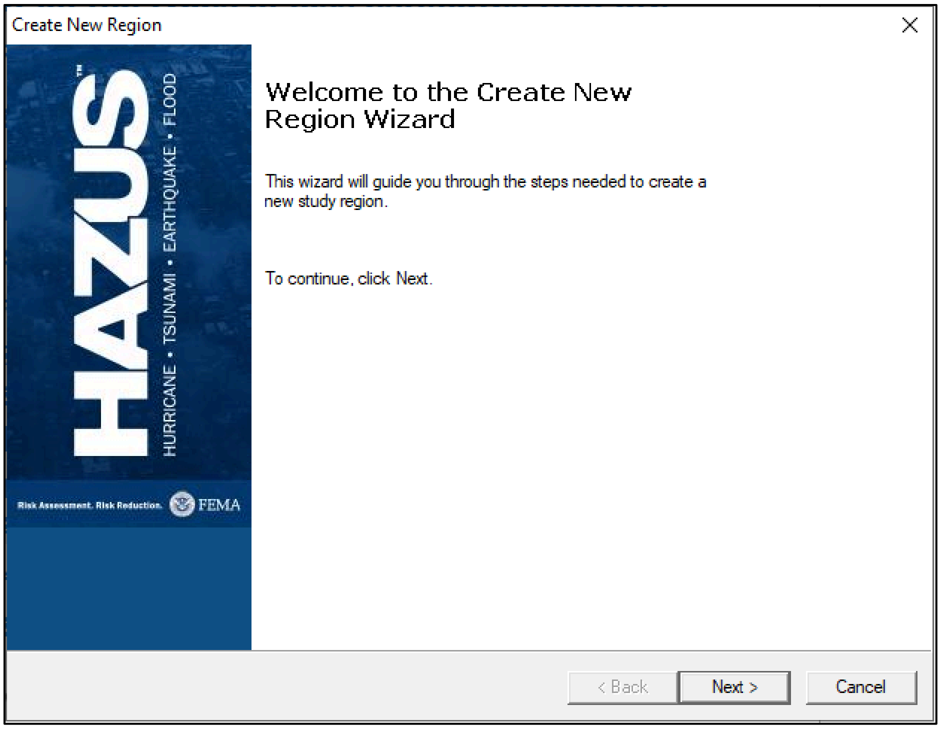


Figure 3-2 Select Create New Region in Wizard

Click **Next**, as shown in Figure 3-2, to open the window shown in Figure 3-3 and name the region in the first box (up to 18 characters, no spaces, and must not begin with a number). Enter a description of the region in the second box. This is especially helpful if multiple users will be accessing this region in the future. Click **Next**, which will open the window shown in Figure 3-4. Select **Earthquake** from the **Hazard Types** and click **Next**. This selection cannot be altered later.

The earthquake methodology is based on using Census tracts as the smallest geographic unit. Census tracts are divisions of land that are designed to contain 2,500 to 8,000 inhabitants with relatively homogeneous population characteristics, economic status, and living conditions. For this reason, the physical area within Census tracts will vary depending on the density of the population. In densely populated regions, Census tracts can be a few city blocks, whereas in rural areas a Census tract may be many square miles.

Census tract divisions and boundaries change only once every 10 years. Census tract boundaries never cross county boundaries; hence, Census tracts can completely and uniquely define all of the area within a county. This characteristic allows for a unique division of land from country to state to county to Census tract. Note, however, that a Census tract can cross city boundaries. A unique 11-digit number identifies Census tracts. The first two digits represent the Census tract's state, the next three digits represent the Census tract's county, and the last six digits represent a number that identifies the Census tract within the county. For example, a Census tract numbered 10050505800 is in Delaware (10) in Sussex County (050).

Users have the flexibility to define any arbitrary Study Region by selecting a set of Census tracts. The Study Region may overlap multiple states and counties or may contain only portions of counties or cities. Users can define any number of Study Regions (limited only by disk space) and can switch between them at any time. The steps to defining the Study Region are to (1) name the Study Region, (2) select the state or states (Note: HI cannot be selected with other states), (3) select counties (if the Study Region covers a portion of a state), and (4) select Census tracts (if the Study Region does not cover a full county/counties).

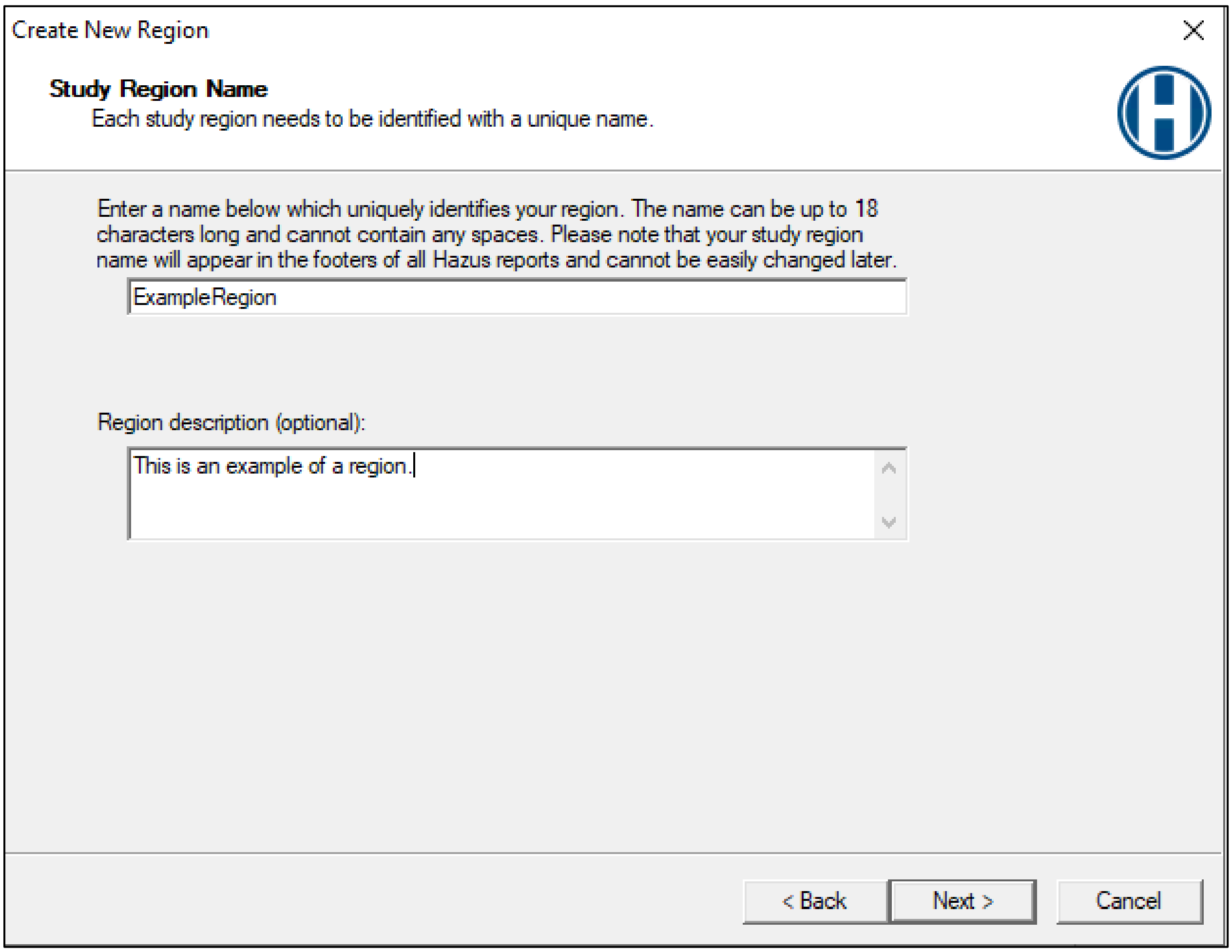


Figure 3-3 Create a Study Region Name

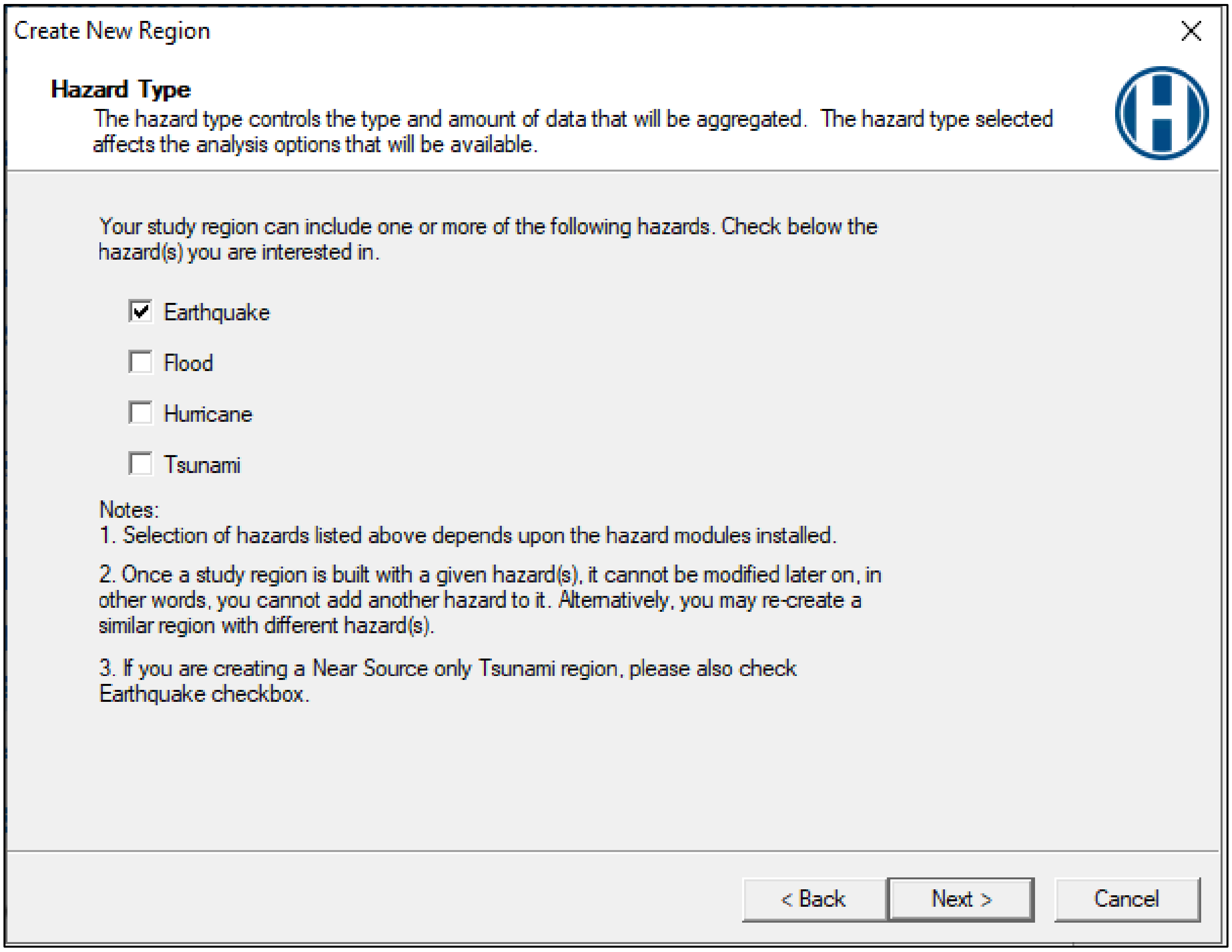


Figure 3-4 Select Hazard Type for New Region

From the window shown in Figure 3-5, select one of the three aggregation levels available for an earthquake analysis. It is important for users to make sure they have enough computer memory before starting the aggregation. Hardware and software requirements for each version of Hazus are available on the [FEMA website](). Census tract is the smallest allowable unit for analysis in the Hazus Earthquake Model and the level at which population and GBS values will be aggregated for estimating losses. The other aggregation levels (Census block, community [NFIP (National Flood Insurance Program)], and watershed) will be disabled because they are not applicable when the earthquake hazard is selected.

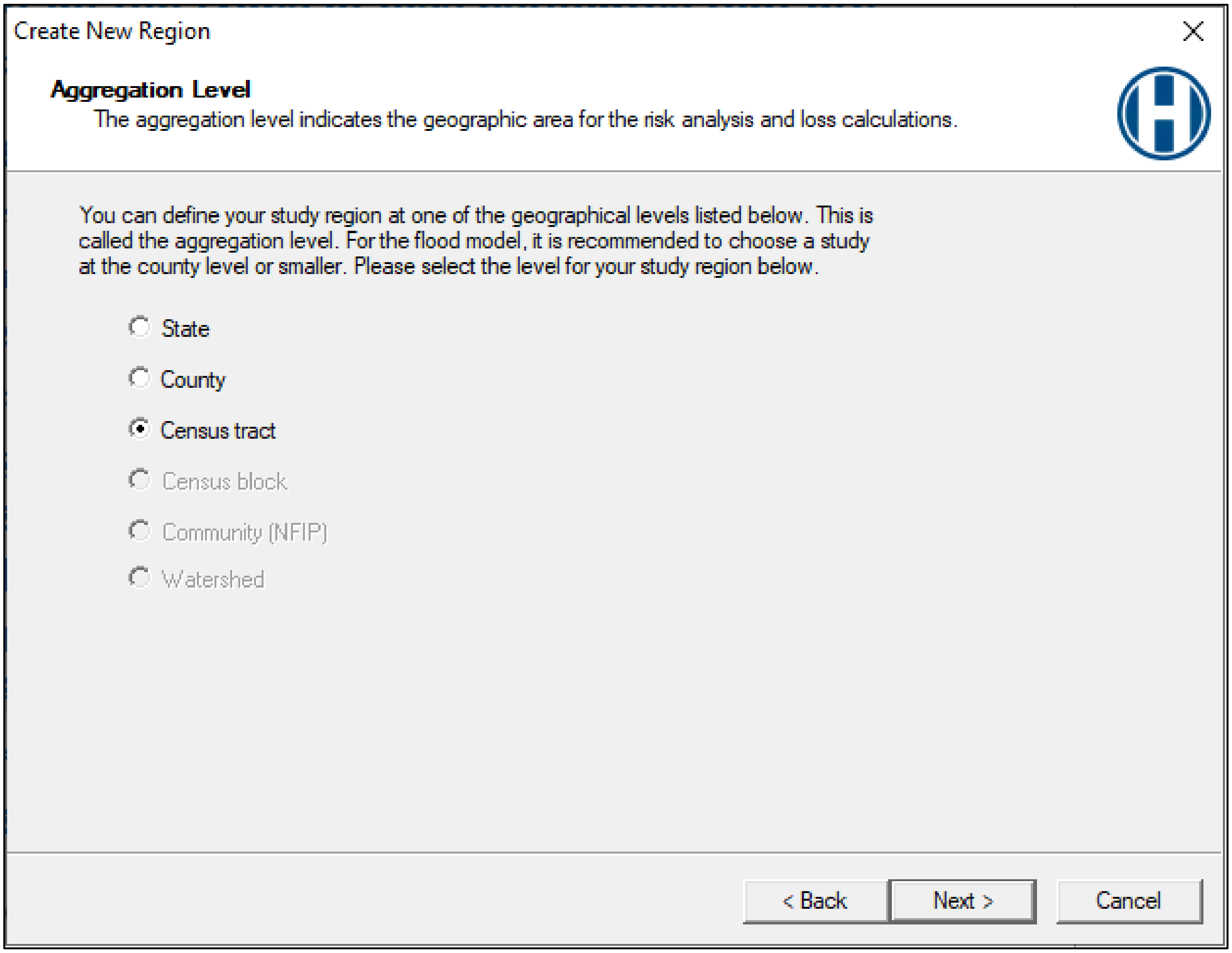


Figure 3-5 Select Desired Aggregation Level

The next step is to select which states or territories are to be included in the Study Region. When clicking “Next” from the “Aggregation Level,” Hazus will look for the relevant State Databases to start the aggregation process. These data need to be downloaded and installed separately per the instructions in the “Getting Started” document included in the Hazus 4.2 installation zip file. To select a state, click on the name of that state. To select multiple states, hold down the **<Ctrl>** key while clicking all the states to include. The user has selected California in the example shown in Figure 3-6.

Alternatively, users can click the **Show Map** button and choose the states from a map, as shown in Figure 3-6. **Show Map** includes the ability to select a region based on added GIS data, such as a jurisdiction boundary or ShakeMap area. When finished, press the **Next>** button (Figure 3-6) or **Selection Done** button (Figure 3-7).

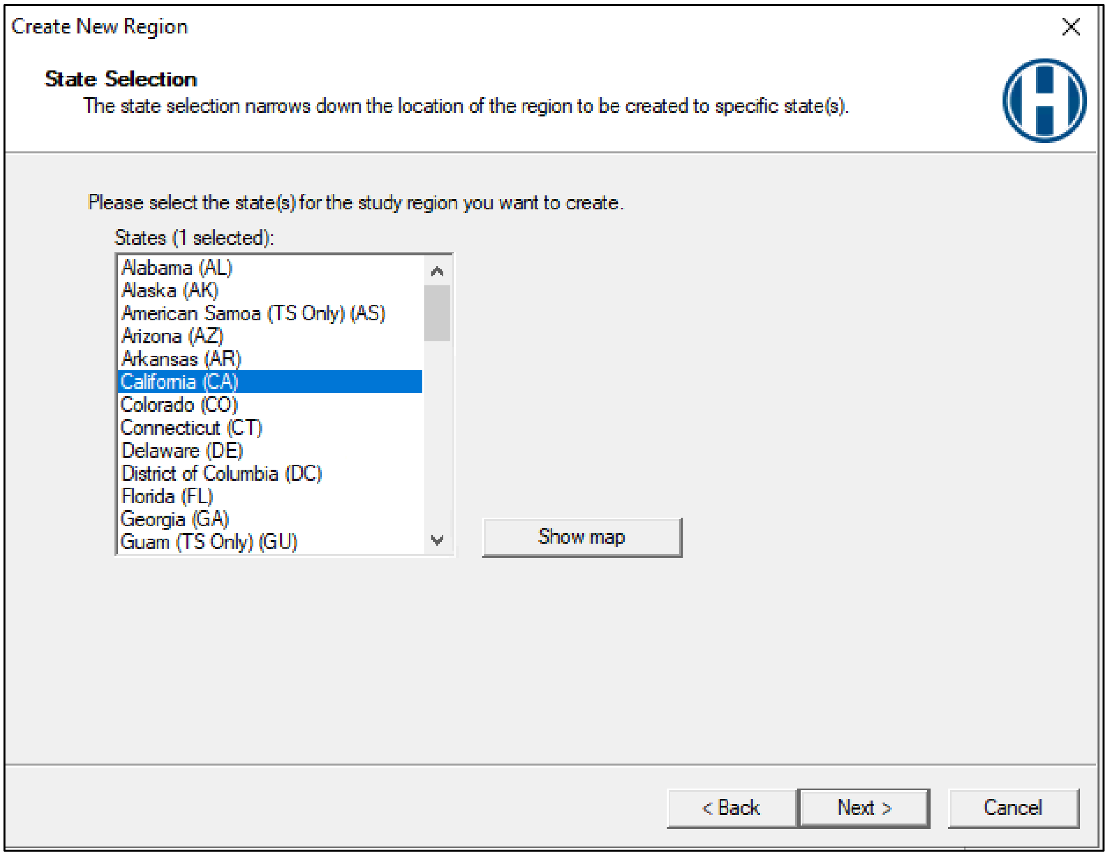


Figure 3-6 Select Appropriate State for the New Region

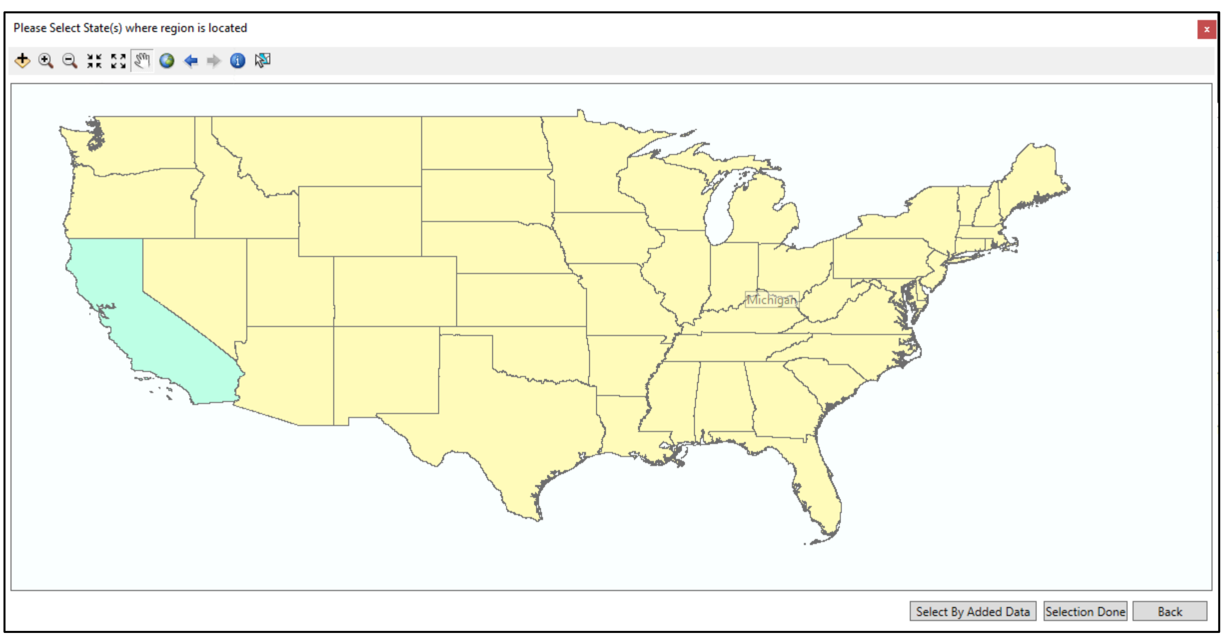


Figure 3-7 State Selection from Map

When users have finished selecting the state(s), they should click the **Next >** button.

Select the counties to include in the Study Region by clicking the names of the counties. Multiple counties can be selected by holding down the **<Ctrl>** key and clicking the desired counties, as shown in Figure 3-8.

Alternatively, users can click the **Show Map** button and choose the counties from a map of the state, as shown in Figure 3-9. **Show Map** includes the ability to select a region based on added GIS data, such as a jurisdiction boundary or ShakeMap area. To select multiple states, hold down the **Shift** key while clicking the desired states. When finished, press the **Selection Done** button.

Once the counties have been selected, click the **Next>** button (Figure 3-8) or **Selection Done** (Figure 3-9).

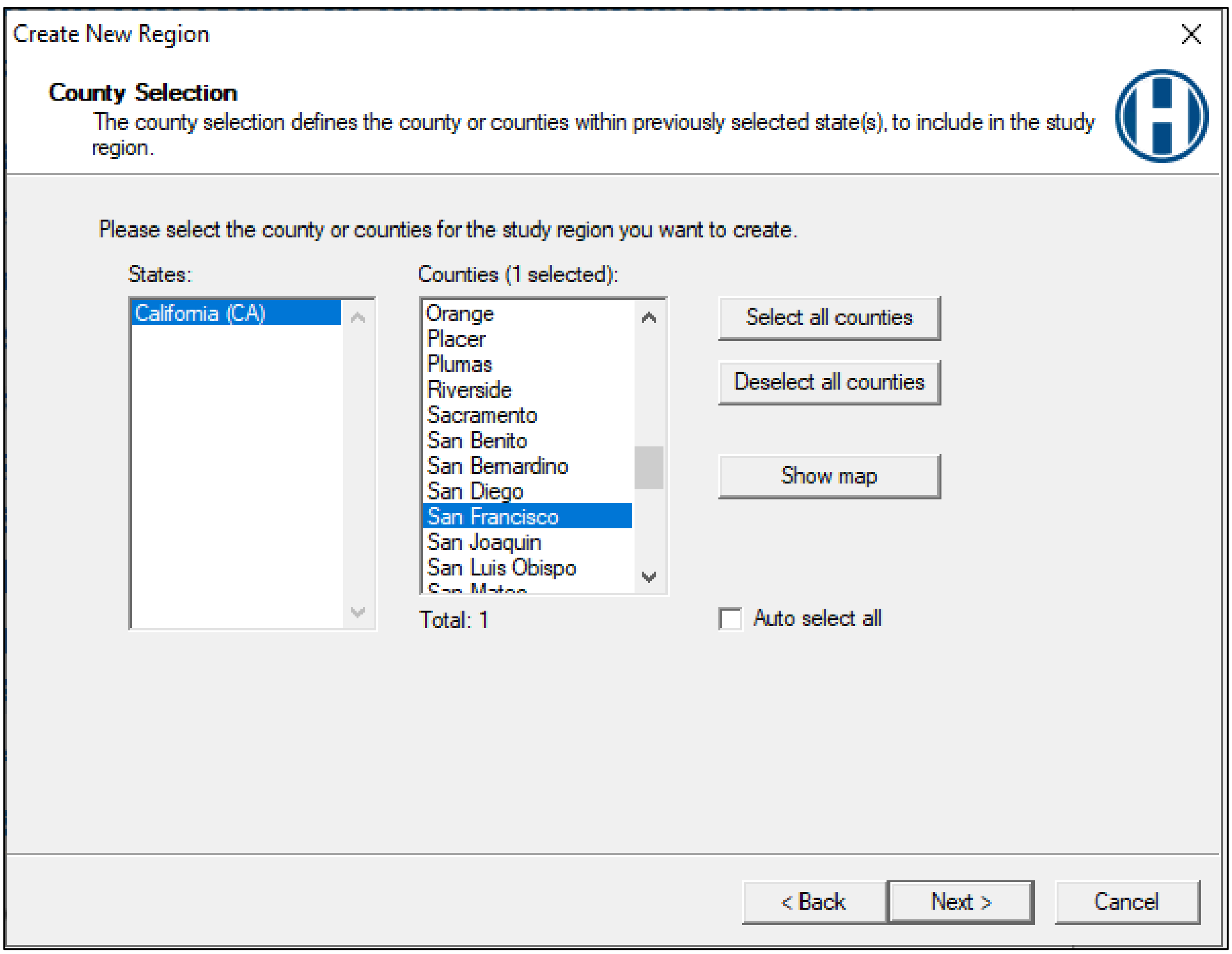


Figure 3-8 Select County for the New Region

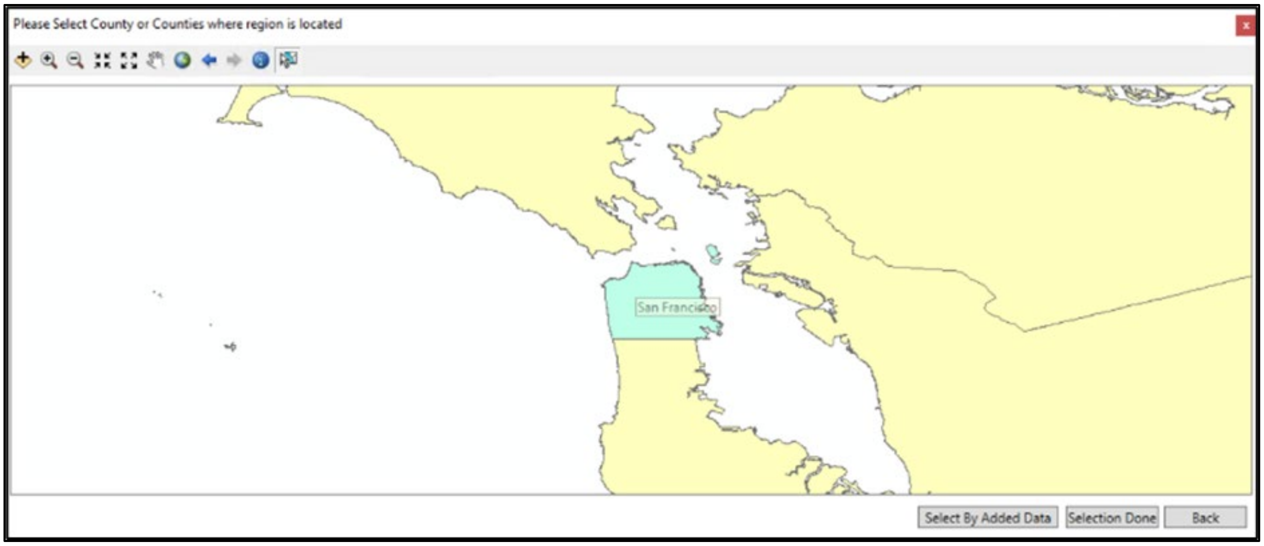


Figure 3-9 County Selection from Map

Once the County has been selected, Figure 3-10 presents a list of all Census tracts in the selected counties. Users can then select the Census tracts that define the Study Region from the list or from the map (Figure 3-11). The Census tracts do not have to have continuous numbering or be contiguous. Users may geographically select Census tracts by using the **Show Map** button, which brings up Figure 3-11. The selection of Census tracts from the map is helpful when choosing Census tracts that are near a city but are not in a numerical sequence or when the location of a city is known but the Census tract numbers around the city are not known. At any point in this process, the user can undo selections by using the **<Back** button.

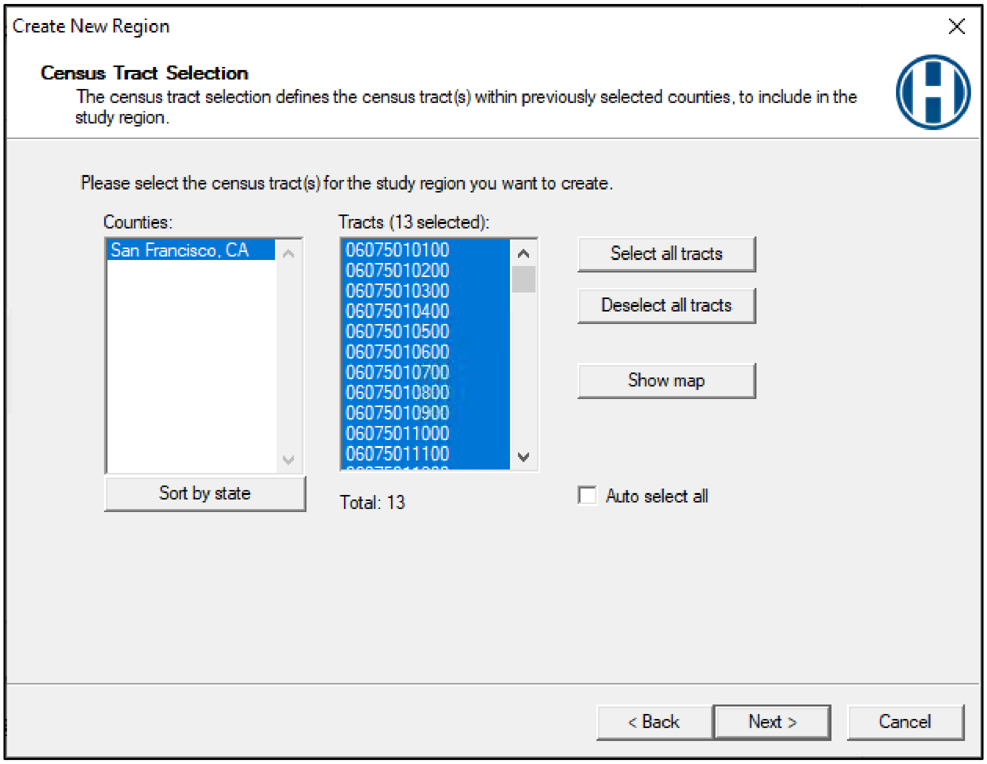


Figure 3-10 Census Tracts Selection from List

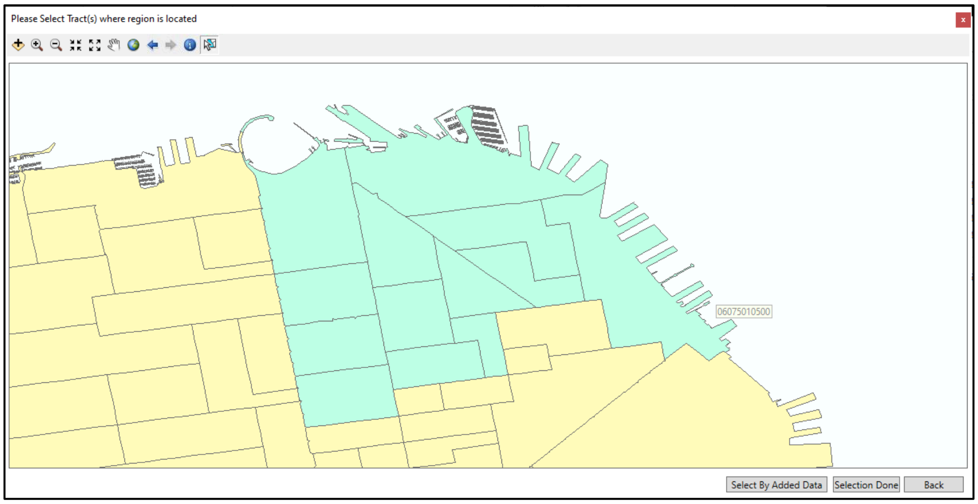


Figure 3-11 Census Tracts Selection from Map

When the Census tracts have been selected, click the **Finish** button (Figure 3-12). A processing status window will indicate the progress of aggregation (Figure 3-13) and then a window will show when aggregation has been successfully completed (Figure 3-14). If the user has not already done so, they will be prompted to copy the baseline inventory data for the state of interest per the Hazus installation instructions.

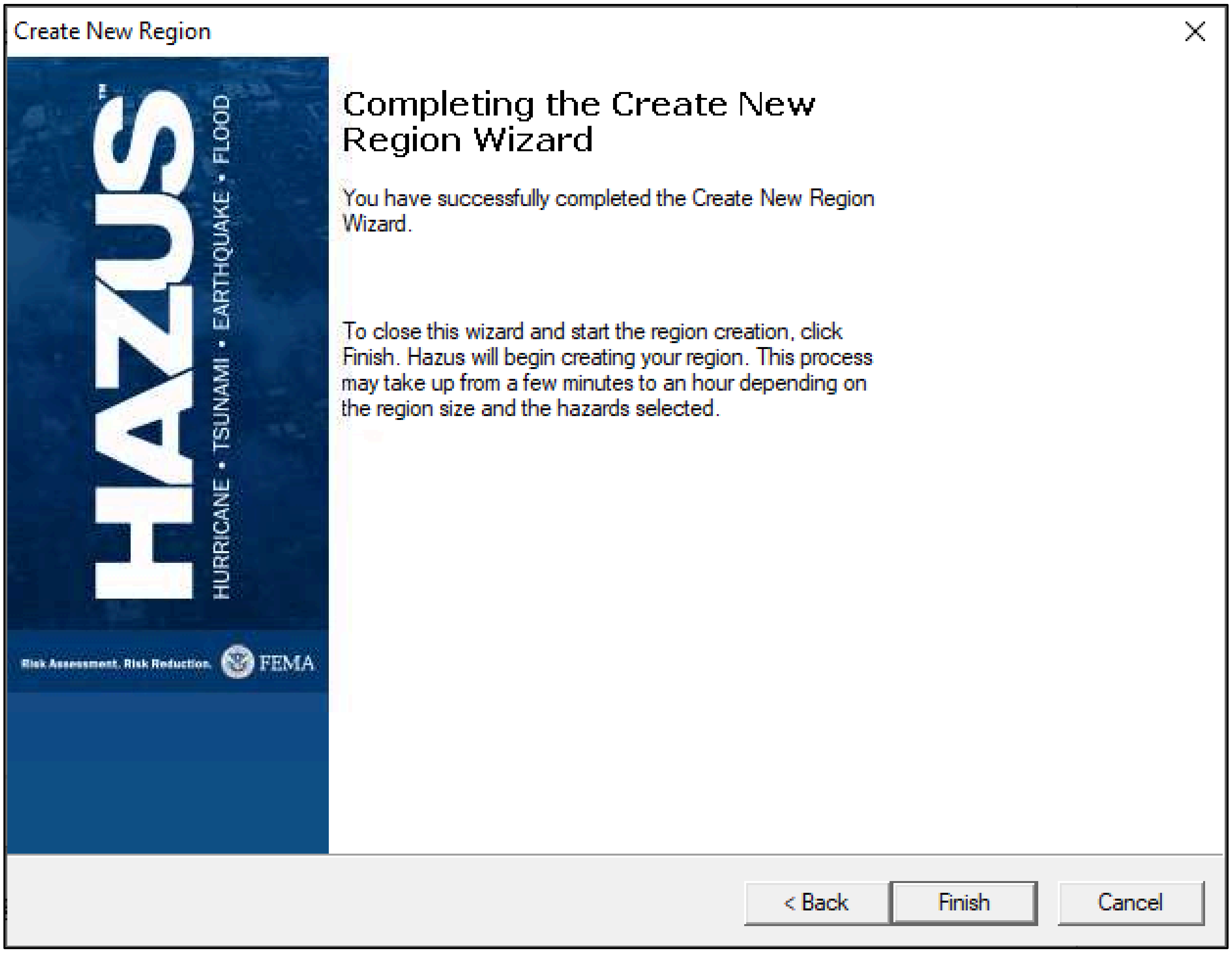


Figure 3-12 Create New Region Wizard Completion

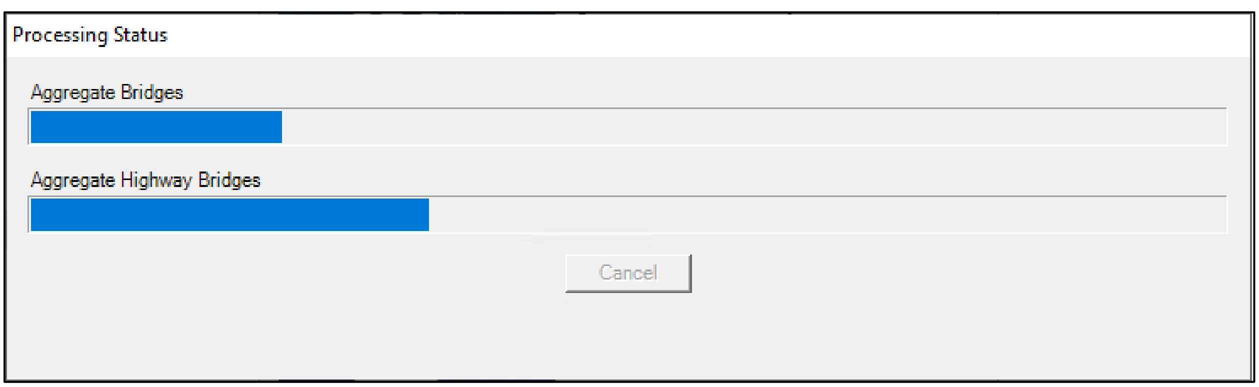


Figure 3-13 Create New Region Progress

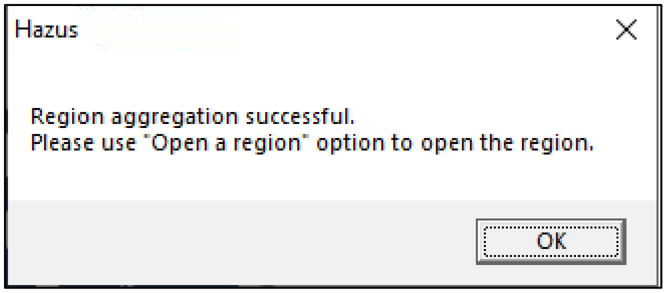


Figure 3-14 Create New Region Acknowledgement

3.3 Open Region

The **Open a region** option will not be available in the **Hazus Startup** screen in Figure 3-15 until a region has been created or imported. Select **Open a region** and click **OK.** The **Open Region Wizard** will appear (Figure 3-16). Click **Next.** An **Open Region** list will appear (Figure 3-17). Select which region should be opened. Click **Next.** Verify that the region name and hazard type are correct (Figure 3-18). Click **Finish.** Clicking **Finish** will launch ArcMap. If other hazard analyses besides earthquake are planning to be modeled, please refer to the appropriate Hazus User Guidance.

Figure 3-15 Select Open a Region

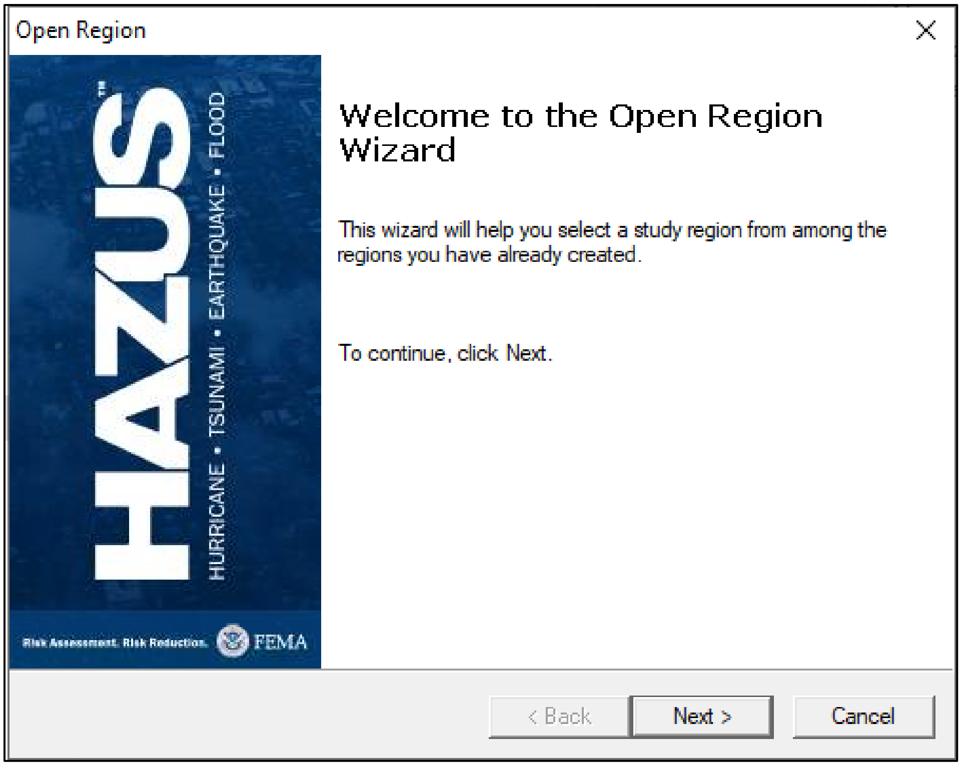


Figure 3-16 Open Region Wizard

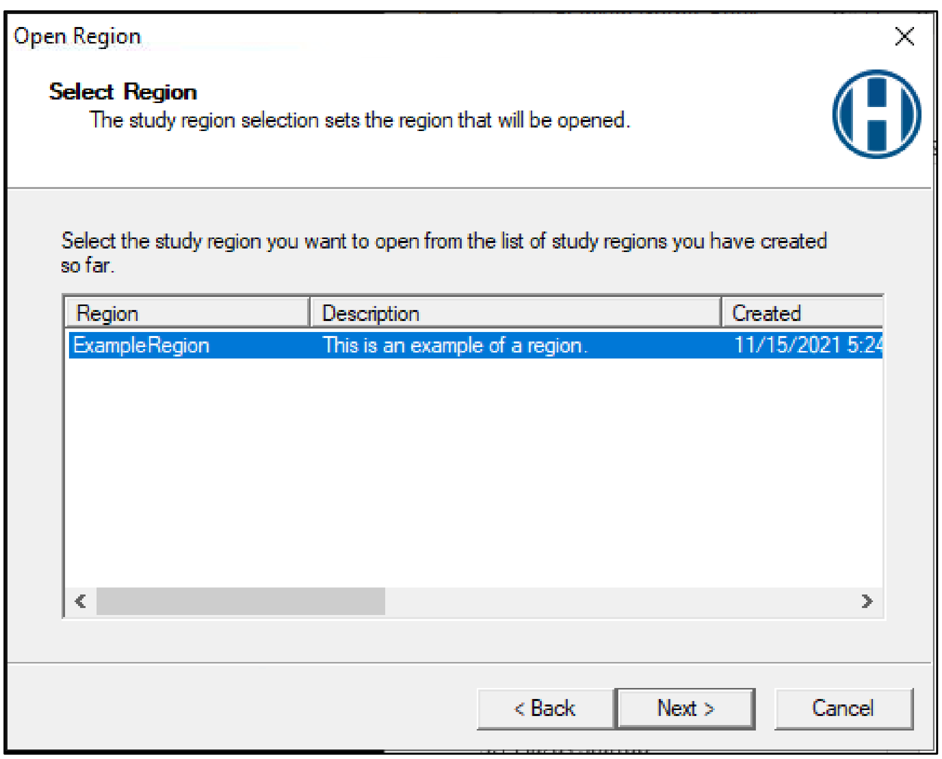


Figure 3-17 Select the Region to Open

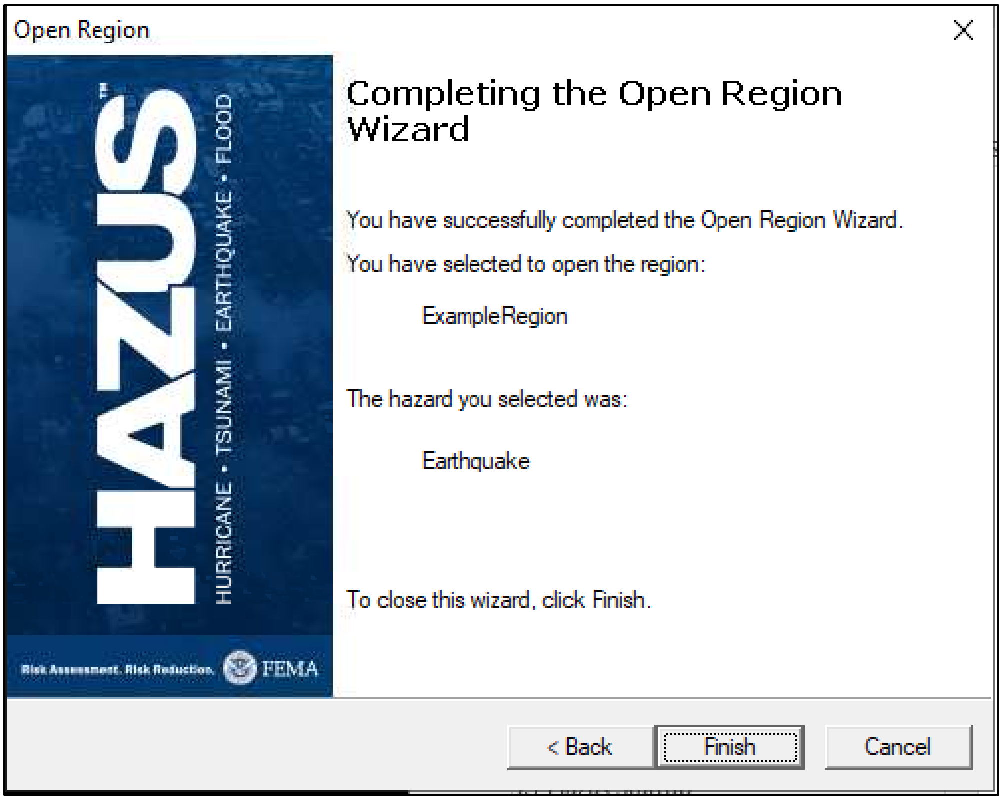


Figure 3-18 Open Region Wizard Completion

3.4 Delete Region

The **Delete a region** option will not be available in the **Hazus Startup** screen in Figure 3-19 until a region has been created or imported. Select **Delete a region** and click **OK.** A **Delete Region** list will appear (Figure 3-20). Select a region from the list and click **Delete** to permanently delete the region. The **Delete Region Confirmation** window will appear (Figure 3-21). Click **Yes** to delete or **No** to return to the **Delete Region** window. Click **Done** to close the window and return to the **Hazus Startup** screen.

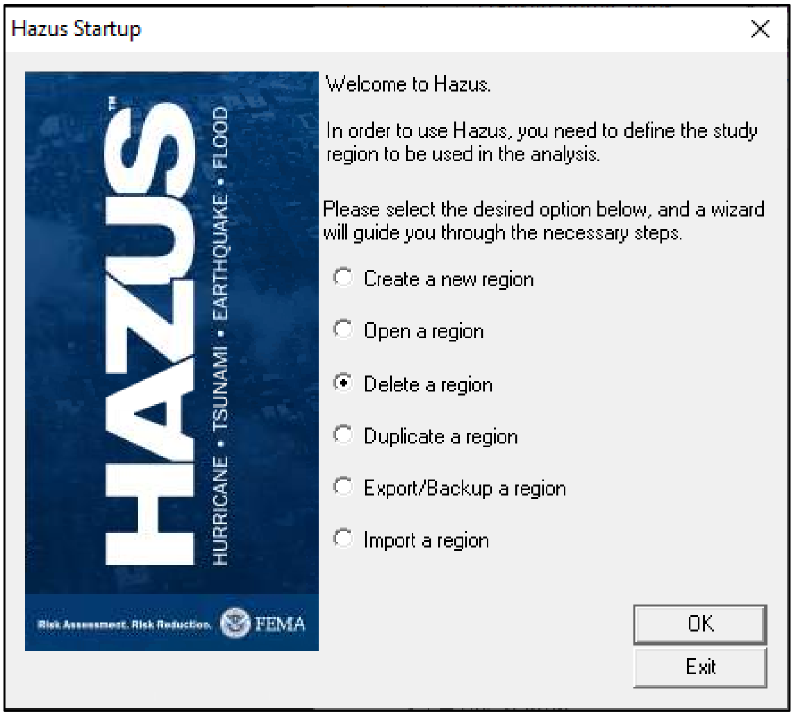


Figure 3-19 Select Delete a Region

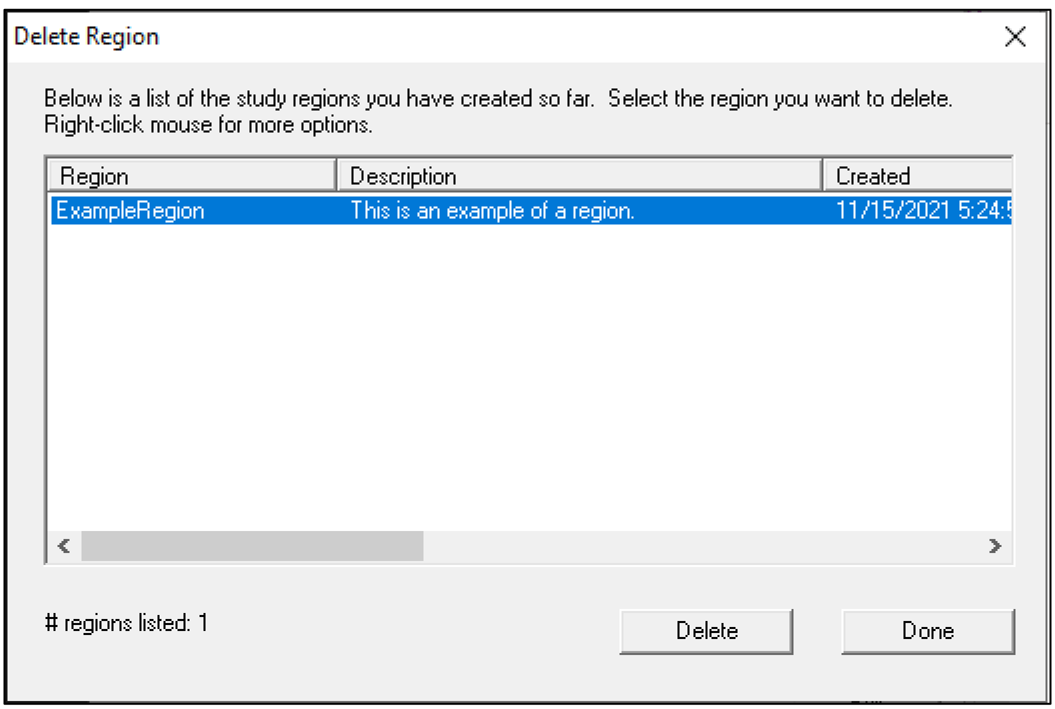


Figure 3-20 Select Region to Delete

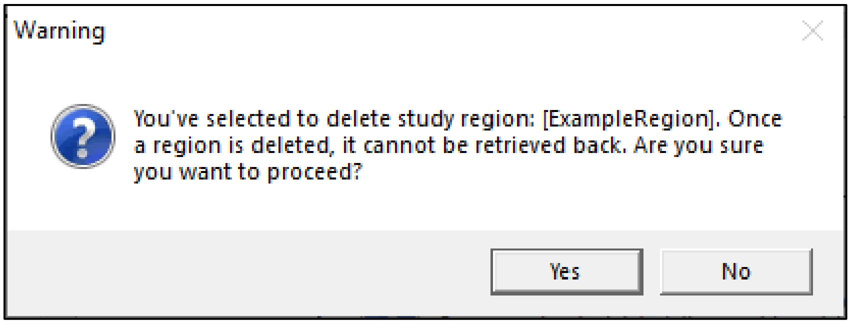


Figure 3-21 Delete Region Confirmation

3.5 Duplicate Region

The **Duplicate a region** option will not be available in the **Hazus Startup** screen in Figure 3-22 until a region has been created or imported. Select **Duplicate a region** and click **OK.** A **Duplicate Region** list will appear (Figure 3-23). Select the region from the list to be duplicated. Click **Duplicate.** A duplicate region confirmation window will appear, click **Yes** to duplicate or **No** to return to the **Hazus Startup** screen (Figure 3-24). The **Duplicate Region Name** dialog will appear (Figure 3-25). Enter the name of the new region (18 character limit, with no spaces and cannot begin with a number) and a brief description. Click **OK.** A progress bar will appear (Figure 3-26). It will close once the region has been successfully duplicated. This may take several minutes depending on the size of the region and the speed of the computer. A duplicate region completion notification (Figure 3-27) will appear to notify the user that the region has been duplicated. Click **OK** to return to the **Duplicate Region** list (Figure 3-23). Click **Done** to return to the **Hazus Startup** screen.

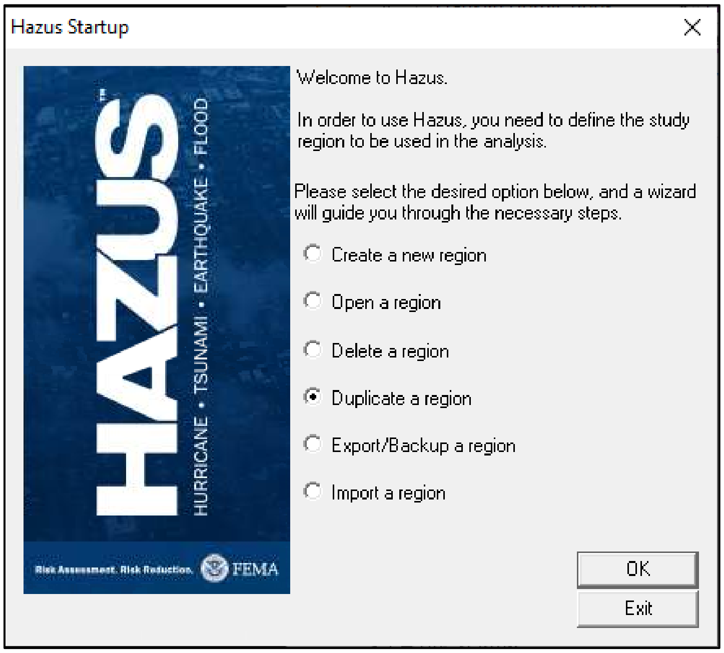


Figure 3-22 Select Duplicate a Region

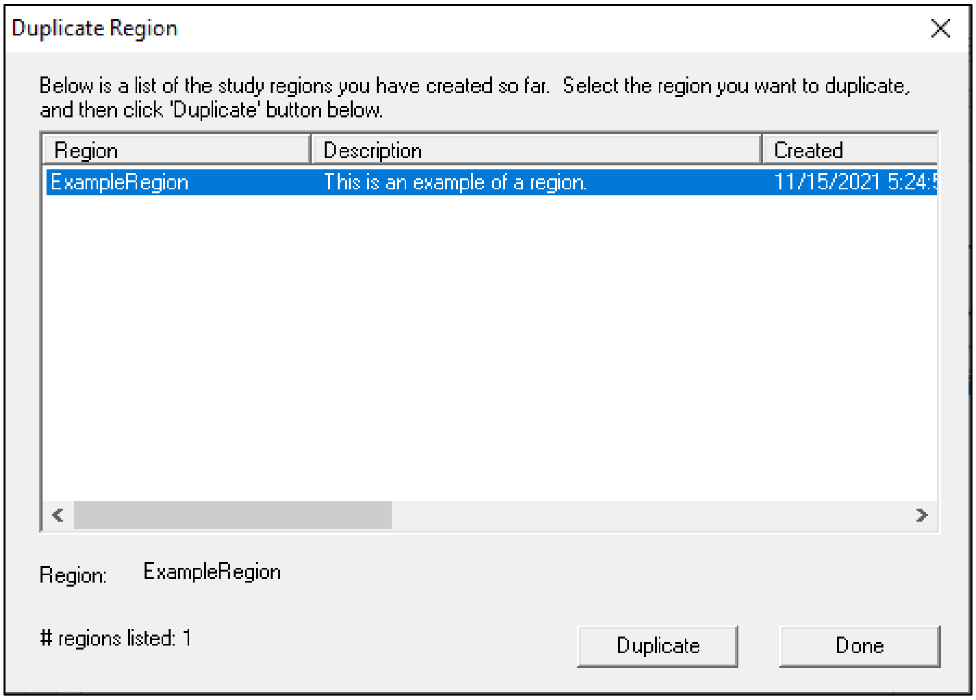


Figure 3-23 Select a Region to Duplicate

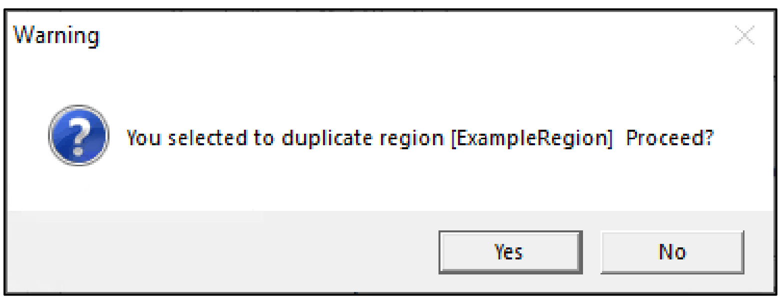


Figure 3-24 Duplicate Region Confirmation

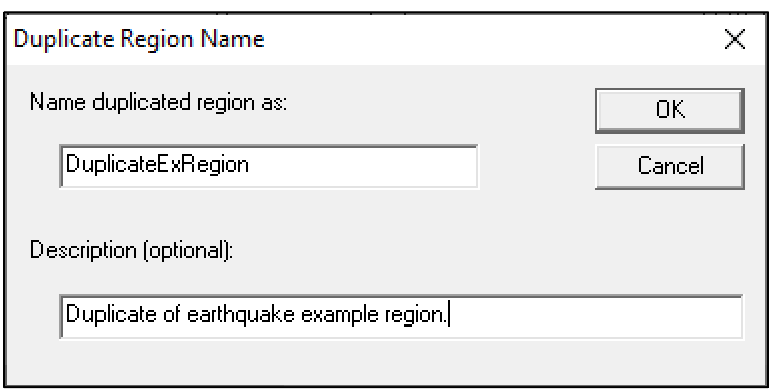


Figure 3-25 Provide Duplicate Region Name

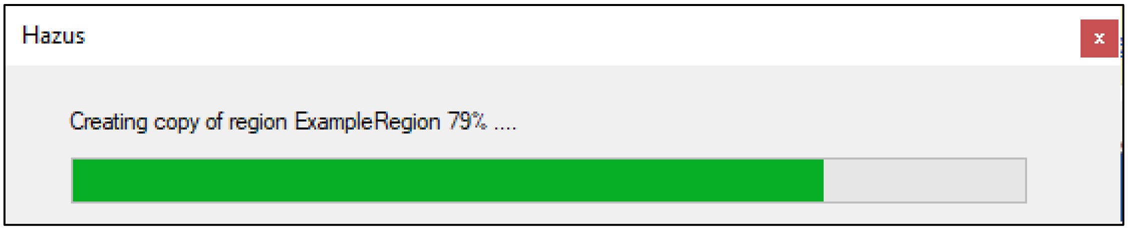


Figure 3-26 Duplicate Region Progress

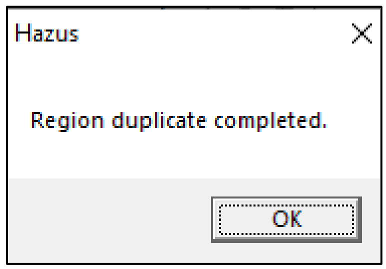


Figure 3-27 Duplicate Region Completed

3.6 Export/Backup a Region

The **Export/Backup a region** option will not be available in the **Hazus Startup** screen in Figure 3-28 until a region has been created or imported. Select **Export/Backup a region** and click **OK.** An **Export/Backup Region** list will appear (Figure 3-29). Select the region to export or backup from the list. Click **Browse** to select a file location to save the export/backup. Click **Export/Backup.** A progress bar (Figure 3-30) will appear. It will close once the region has been successfully exported. This may take several minutes depending on the size of the region and the speed of the computer. An **Export/Backup Region Completion** notification (Figure 3-31) will appear once the export has completed. Click **OK.**

Figure 3-28 Select Export/Backup a Region

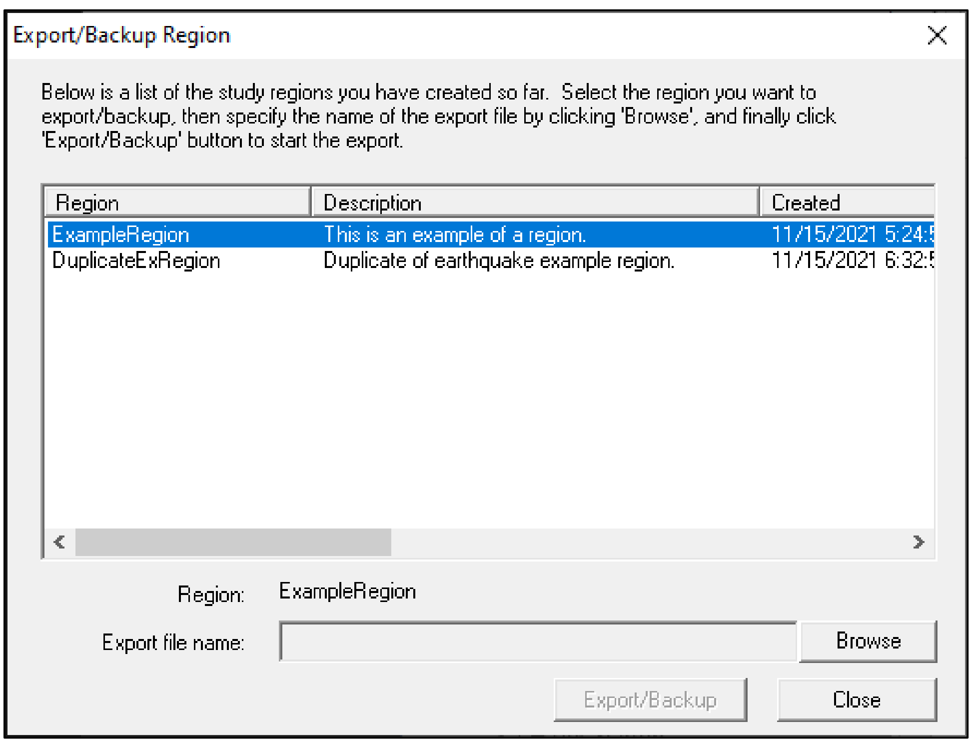


Figure 3-29 Select a Region to Export or Backup

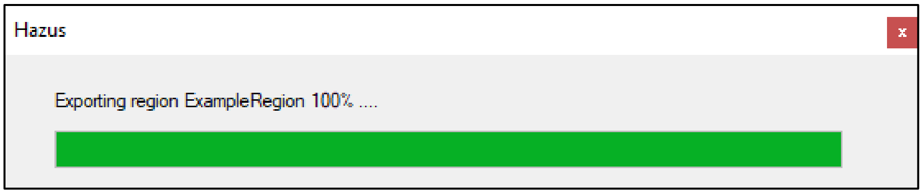


Figure 3-30 Export/Backup Region Progress

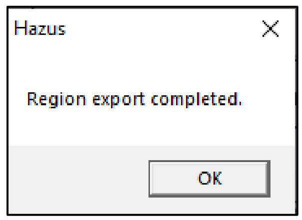


Figure 3-31 Export/Backup Region Completed

3.7 Import a Region

Select **Import a region** from the **Hazus Startup** screen in Figure 3-32 and click **OK**. A file explorer will open. Select an export Hazus Packaged Region (.hpr) file. In the **Imported Region Name** dialog (Figure 3-33), enter the name of the Study Region (18-character limit with no spaces and do not begin a Study Region name with a number) and a brief description. The name must be different than the imported .hpr file name. Click **OK**. A progress bar (Figure 3-34) will appear. It will close once the region has been successfully imported. This may take several minutes depending on the size of the region and the speed of the computer. A **Region Import Completion** notification will appear once the export has completed (Figure 3-35). Click **OK**. Please note that Hazus can import an HPR from the most recent previous version. HPR files from older versions may not import successfully.

Figure 3-32 Select Import a Region

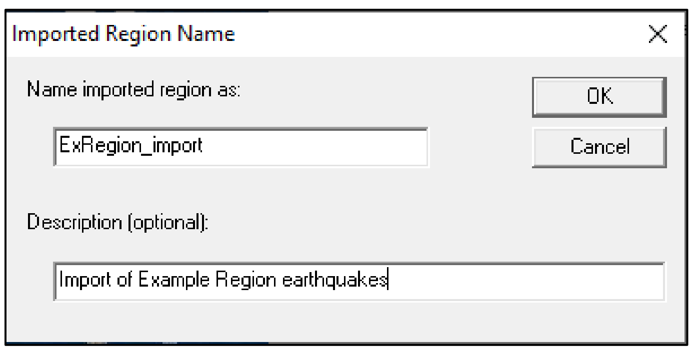


Figure 3-33 Provide the Name for the Imported Region

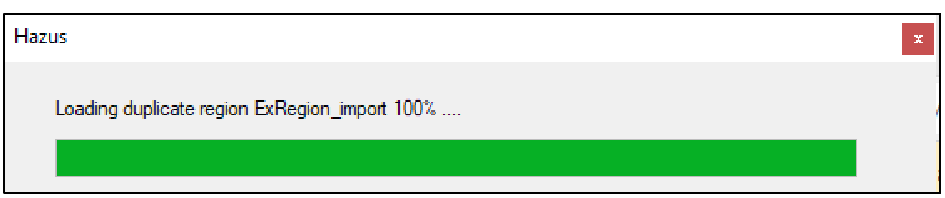


Figure 3-34 Import Region Progress

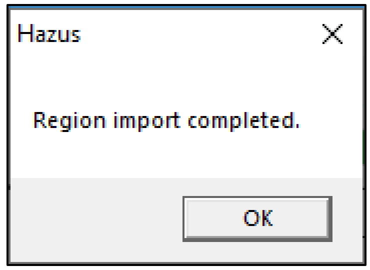


Figure 3-35 Region Import Completed

Section 4. Getting Started Part 2: Running a Basic Hazus Analysis

Hazus contains a variety of baseline parameters and databases. Users can run a loss estimation analysis using only baseline data, but the results will be subject to a great deal of uncertainty. If users wish to reduce the uncertainty associated with results, they can augment or replace the baseline information with improved data collected for the Study Region. This section guides users through a simple analysis using only baseline data. See Section 7.3, Section 9, and Section 10 for more detailed information about collecting and entering additional data or modifying baseline parameters and data.

However, it is important to note that Hazus will not include any inventory data that users have defined outside the limits of the Study Region. In fact, if users include facilities that are outside the defined Study Region, Hazus will exclude those facilities from the Study Region. The region will always be defined by a Census tract boundary or boundaries within which population, demographics, and GBS values are aggregated.

This section will walk users through an example basic Hazus analysis using the baseline Hazus-USGS ShakeMap hazard scenario for the 1989 Loma Prieta earthquake. **Note:** Users must create the "CA_SanFrancisco_eq" file referenced below by following the steps in Section 3 for creating a new region and selecting all census tracts in San Francisco County before proceeding.

Start Hazus, select **Open a region** radio button, then click **OK** (Figure 4-1). Refer to Section 3 for any questions regarding how to create a Study Region.

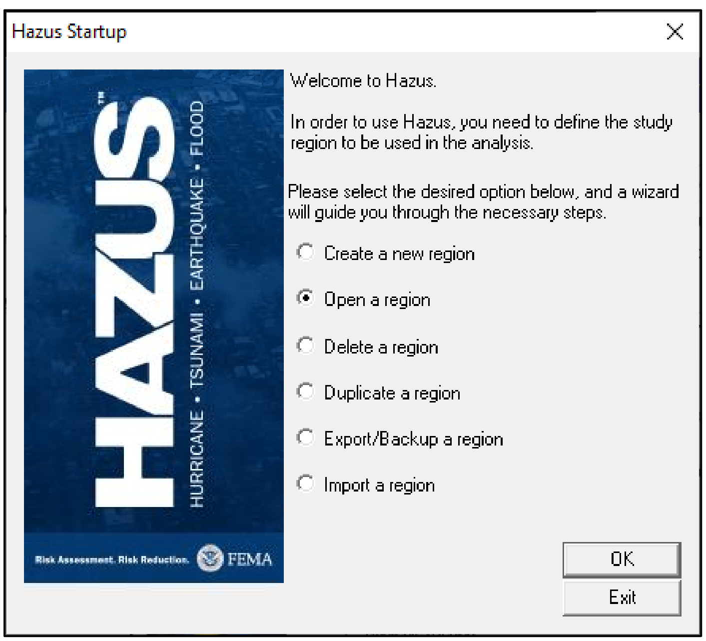


Figure 4-1 Open a New Region

The startup Hazus dialog window includes the option to open an existing region (Figure 4-2). If a valid Study Region is available, as shown in Figure 4-2, users can select it by the name and description it was given when the region was created and clicking **Next>**.

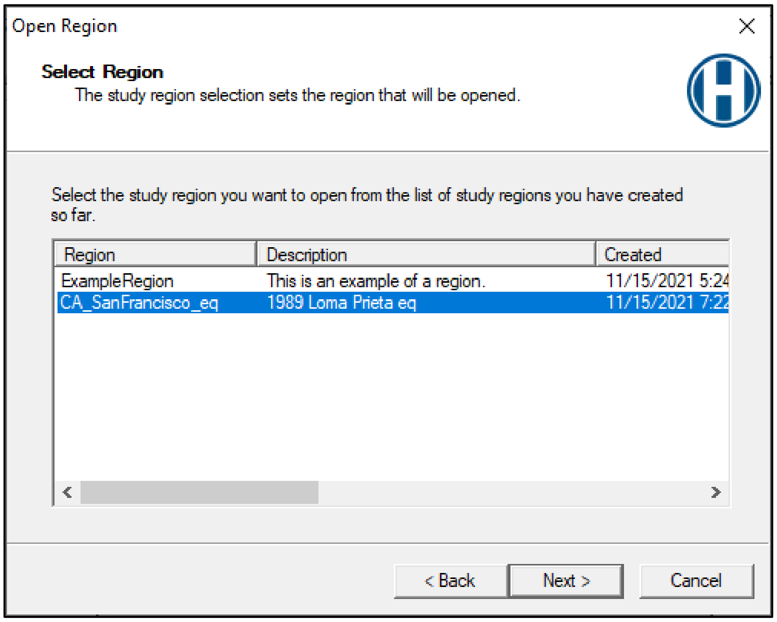


Figure 4-2 Open a Study Region

Click **Finish** in the **Completing the Open Region Wizard** to open the selected region, as shown in Figure 4-3.

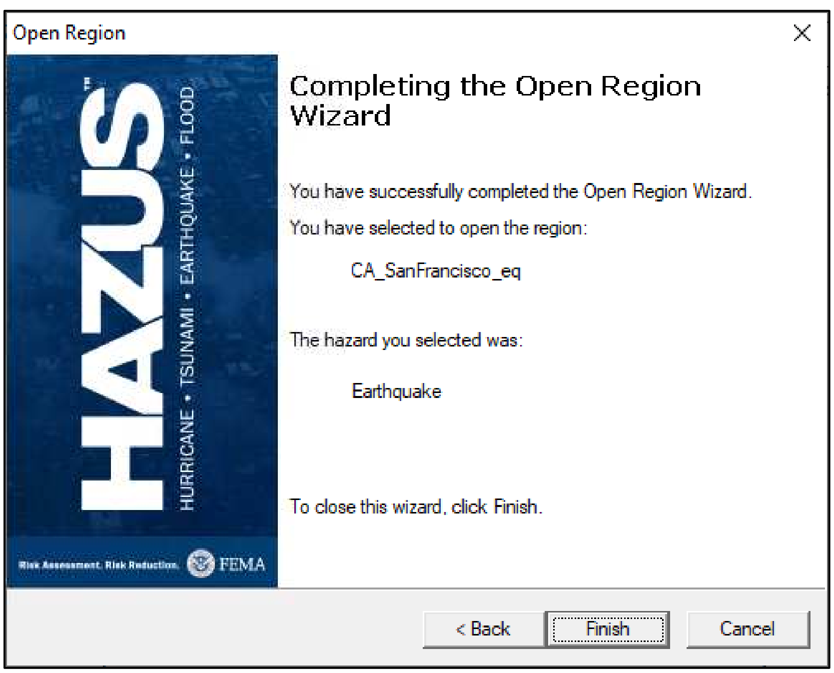


Figure 4-3 Completing the Open Region Wizard Dialog

When the Study Region is opened, the ArcMap interface will open and display the Study Region boundary (Figure 4-4).

The displayed map will have one or more layers, depending on which aggregation level was chosen. For example, if the Study Region has been defined to be a single state, and the aggregation level is equal to the Census tract, two boundary layers will be listed for display in the Table of Contents (TOC): one layer with a polygon representing the entire Study Region and one layer with all of the Census tracts in the Study Region. County boundaries (and other boundary layers) can be added by highlighting **Layers** in the TOC and right-clicking. Select the "**+**" sign to add more data layers.

Once the data layers are complete, the user will see that the four Hazus menus (Inventory, Hazard, Analysis and Results) and two buttons (Switch Hazard and Study Region Wizard) have been added to the ArcGIS graphical user interface. All ArcMap functions for which the installation is licensed will be available (e.g., view properties of each data layer).

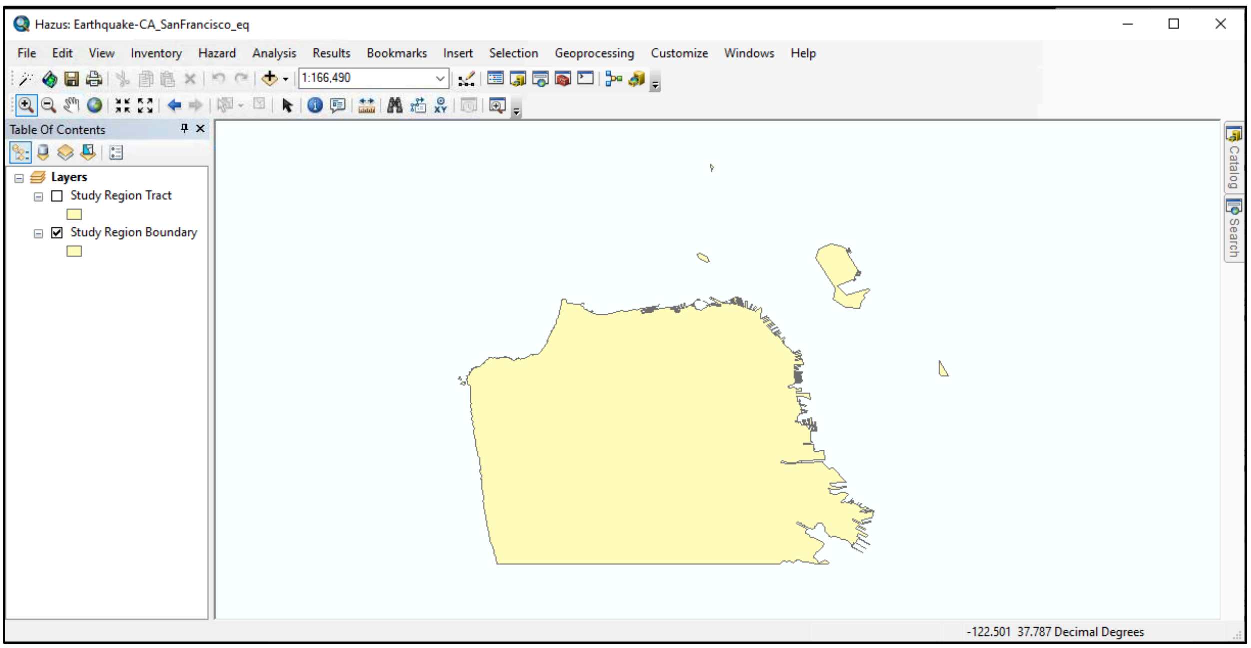


Figure 4-4 ArcMap Interface of the Study Region

The baseline inventory extracted from the state dataset for the Study Region can be displayed. Select the **Inventory Menu** to display the Study Region data including General Building Stock (GBS), essential facilities, high potential loss facilities, hazardous materials facilities, transportation systems, utility systems, and demographics (Figure 4-5). More information on inventory data are provided in Section 5.

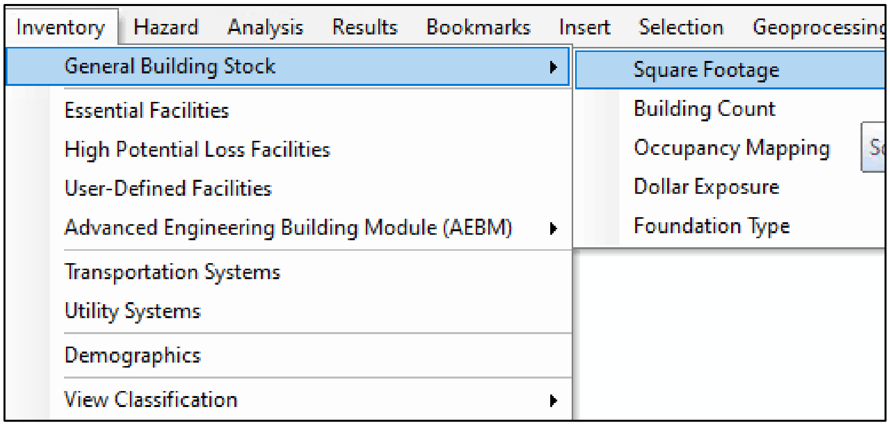
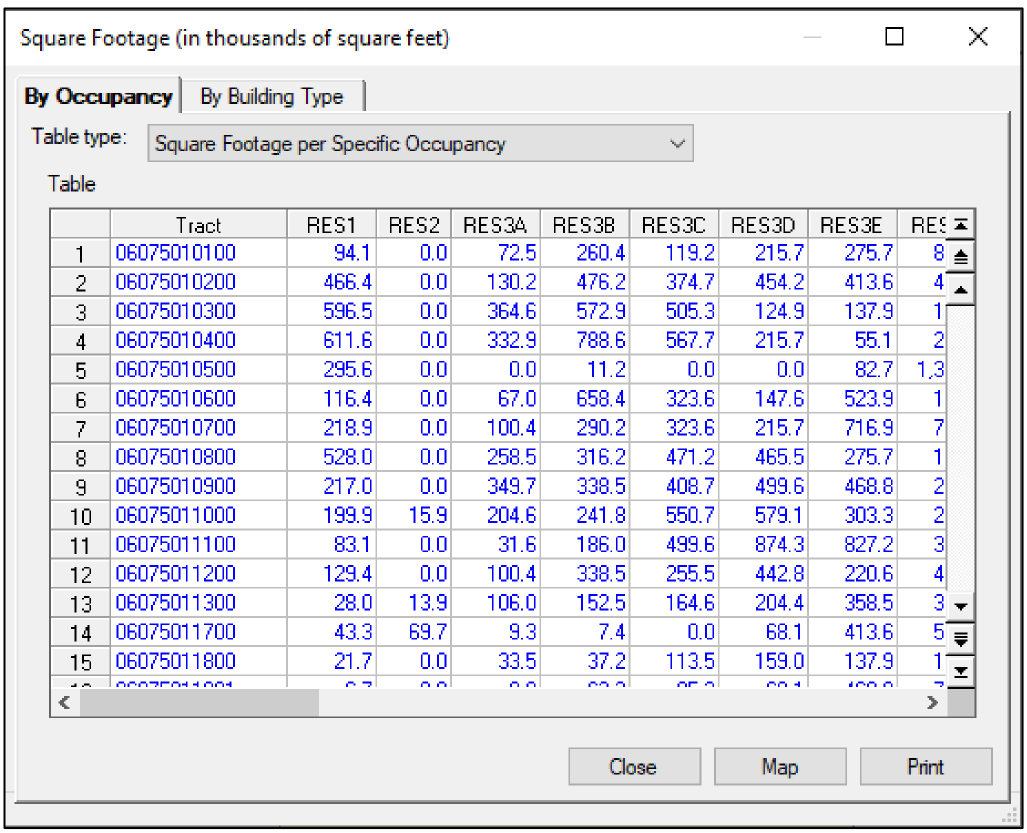


Figure 4-5 Hazus Inventory Menu

Inventories are viewable in tabular format and can also be mapped. Figure 4-6 and Figure 4-7 show examples of the baseline data that are available for a sample Study Region (downtown San Francisco). In Figure 4-7, the aggregate square footage of RES1 (single-family home) buildings is shown by Census tract, and highways and highway bridges are overlaid. **Note**: Highway bridges and highway segments can be added under the Inventory -> Transportation Systems options.



	Tract	RES1	RES2	RES3A	RES3B	RES3C	RES3D	RES3E	RES
1	06075010100	94.1	0.0	72.5	260.4	119.2	215.7	275.7	8
2	06075010200	466.4	0.0	130.2	476.2	374.7	454.2	413.6	4
3	06075010300	596.5	0.0	364.6	572.9	505.3	124.9	137.9	1
4	06075010400	611.6	0.0	332.9	788.6	567.7	215.7	55.1	2
5	06075010500	295.6	0.0	0.0	11.2	0.0	0.0	82.7	1,3
6	06075010600	116.4	0.0	67.0	658.4	323.6	147.6	523.9	1
7	06075010700	218.9	0.0	100.4	290.2	323.6	215.7	716.9	7
8	06075010800	528.0	0.0	258.5	316.2	471.2	465.5	275.7	1
9	06075010900	217.0	0.0	349.7	338.5	408.7	499.6	468.8	2
10	06075011000	199.9	15.9	204.6	241.8	550.7	579.1	303.3	2
11	06075011100	83.1	0.0	31.6	186.0	499.6	874.3	827.2	3
12	06075011200	129.4	0.0	100.4	338.5	255.5	442.8	220.6	4
13	06075011300	28.0	13.9	106.0	152.5	164.6	204.4	358.5	3
14	06075011700	43.3	69.7	9.3	7.4	0.0	68.1	413.6	5
15	06075011800	21.7	0.0	33.5	37.2	113.5	159.0	137.9	1

Figure 4-6 Baseline Building Stock Data Inventory – Tabular Format Example

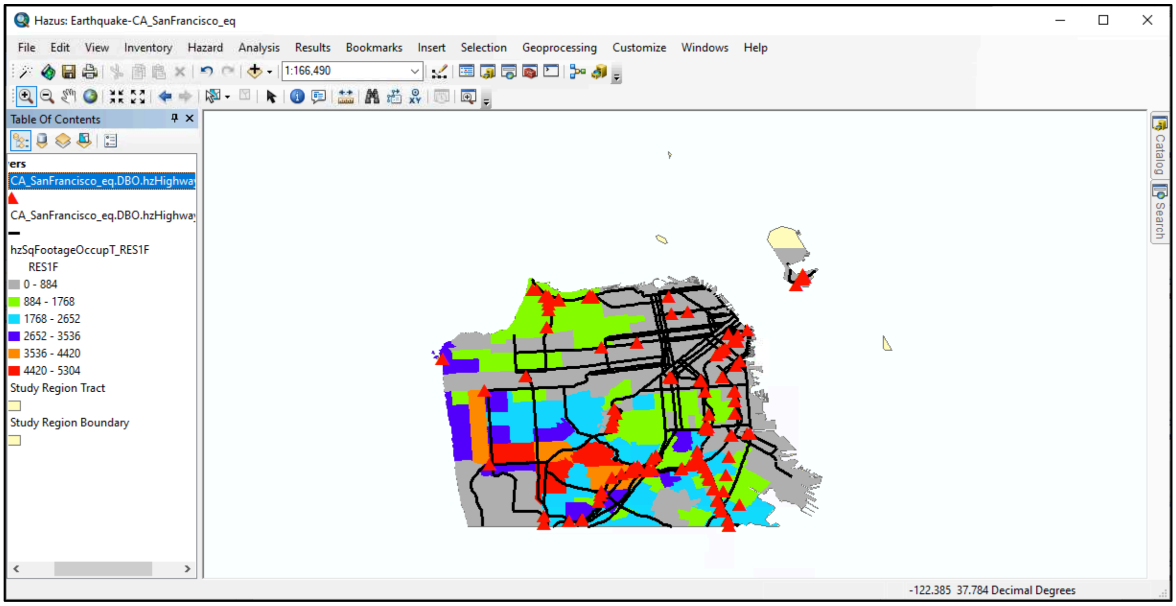


Figure 4-7 Baseline Inventory Data for Study Region – Map Output Example

After reviewing the inventory data, a basic analysis can be run. Under the **Hazard** menu, select **Scenario...** (Figure 4-8).

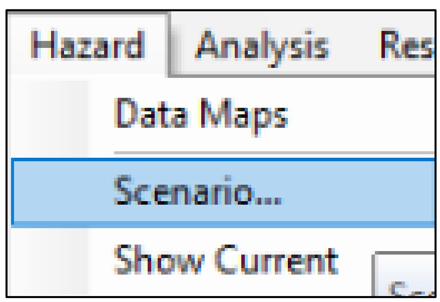


Figure 4-8 Scenario Under the Hazard Menu

This opens the Scenario Wizard window (Figure 4-9).

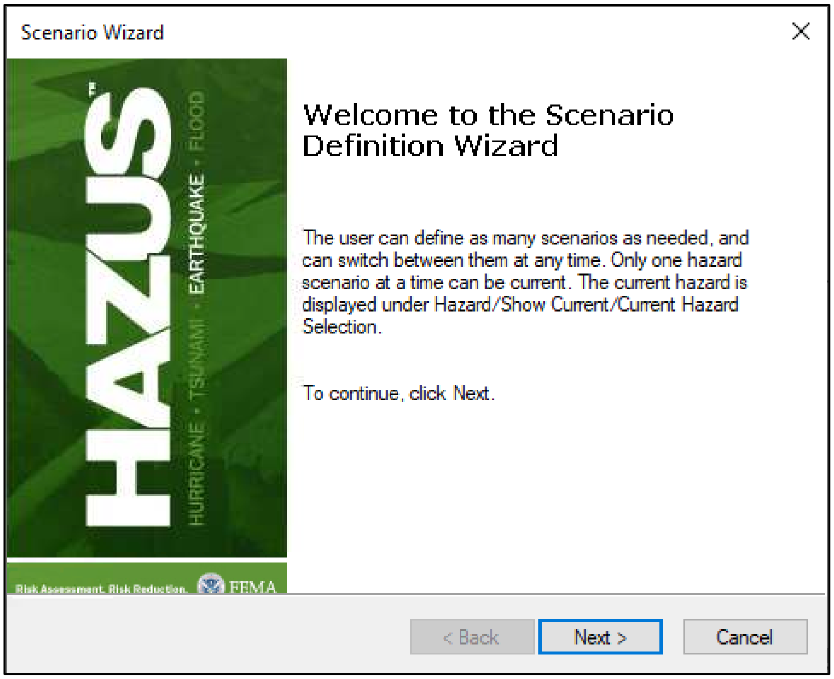


Figure 4-9 Scenario Wizard Window

Click the **Next** button. Select the **Define a new scenario** radio button and click **Next** (Figure 4-10).

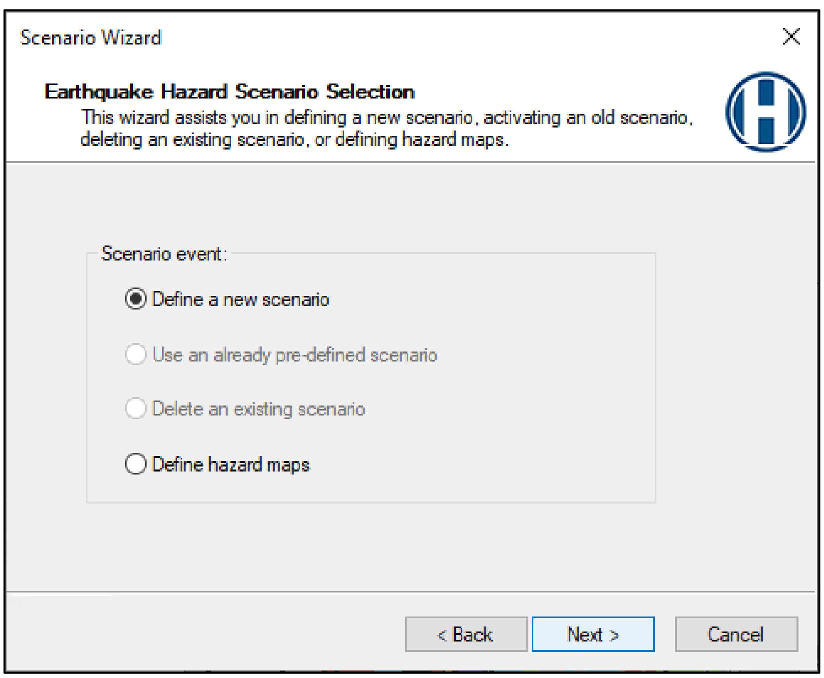


Figure 4-10 Scenario Wizard Scenario Event Window

Select the **USGS ShakeMap...** radio button and click **Next** (Figure 4-11).

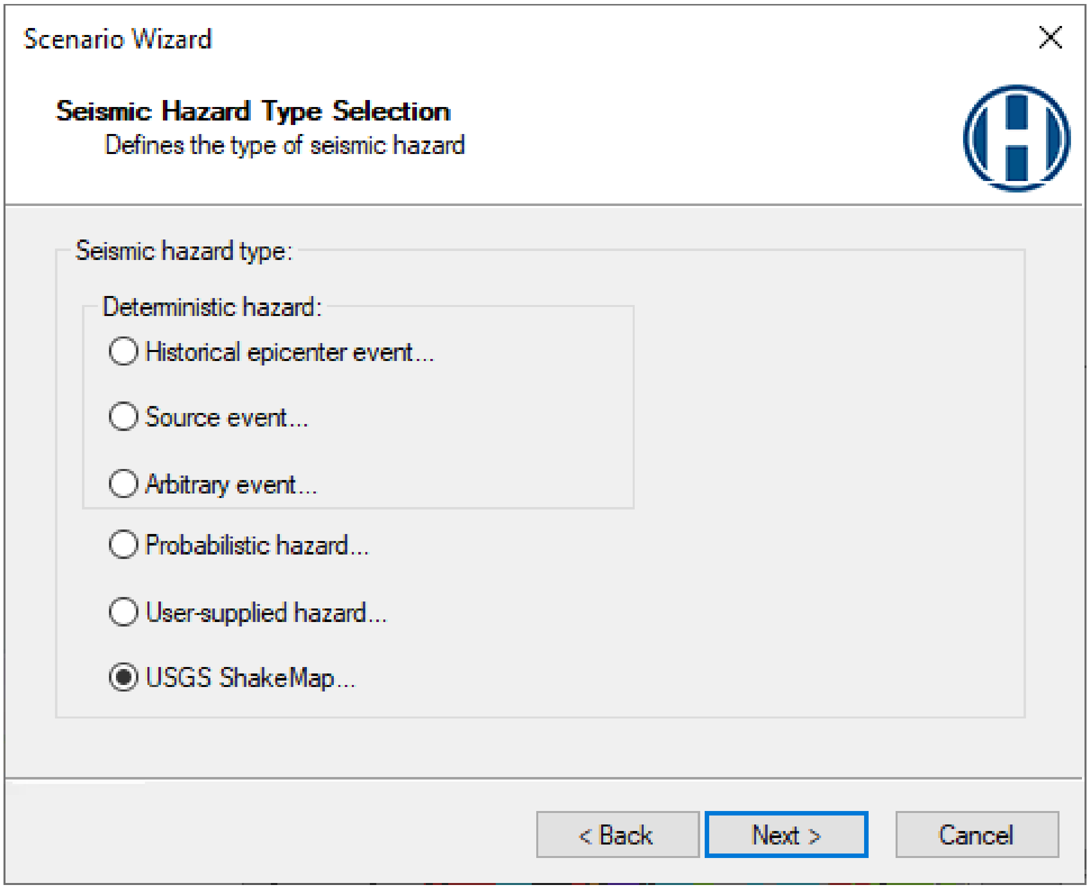


Figure 4-11 Scenario Wizard Seismic Hazard Type Window

In the **ShakeMap Download** window, find the magnitude 6.9 Loma Prieta earthquake that occurred on 10/17/1989, select its row and click **Download Selected ShakeMap Grid Data** (Figure 4-12). **Note**: You will want the settings in the ShakeMap Download window to match exactly those in Figure 4-12 to locate the correct event record.

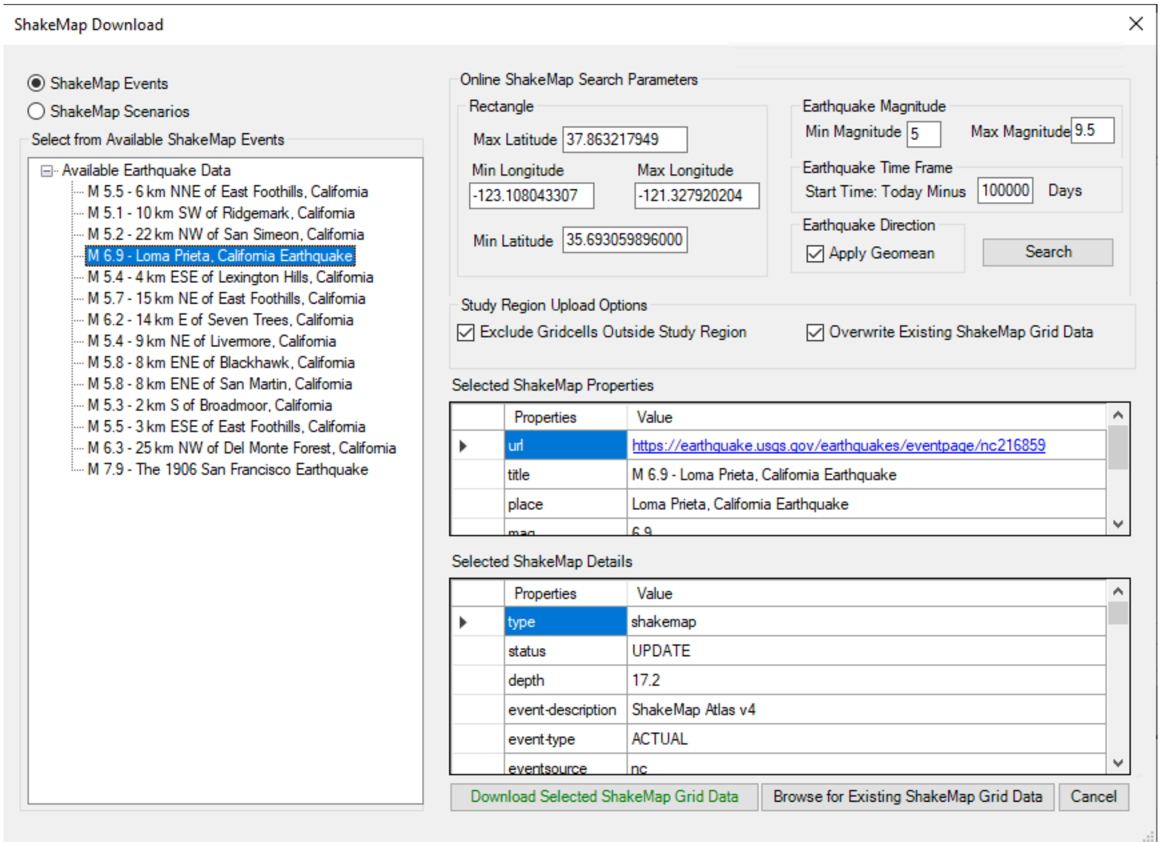


Figure 4-12 Selecting a USGS ShakeMap

If required, select the higher weighted grid based on the preference assigned by the USGS from the **Multiple grid.xml for One Event** dialog and click OK (Figure 4-13).

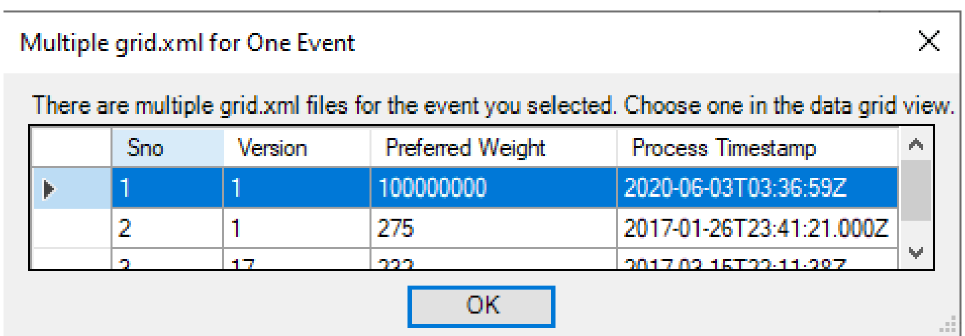


Figure 4-13 Multiple grid.xml for One Event dialog

The **User-defined Hazard Option** (Figure 4-14) dialog will appear, however nothing needs to be done since the dialog will use the ShakeMap data to make the necessary selections. Click **Next.**

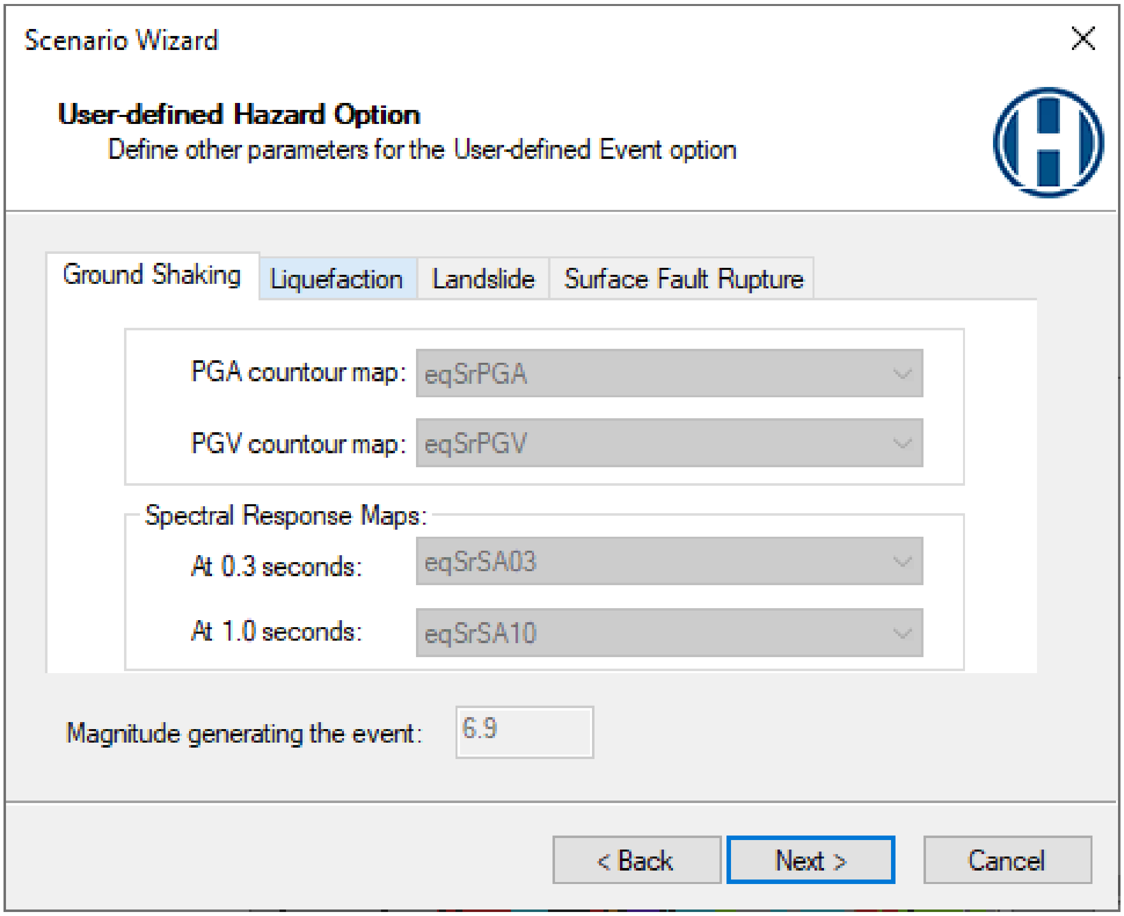


Figure 4-14 User-defined Hazard Option

The **Hazard Scenario Event Name Dialog** (Figure 4-15) will appear next and the name will be entered by the dialog (note when space is allowed the ShakeMap version number is concatenated to the end of the name and a new SQL table is available in the study region eqShakeMapScenario that captures additional ShakeMap metadata) using the data from the ShakeMap. Click **Next.**

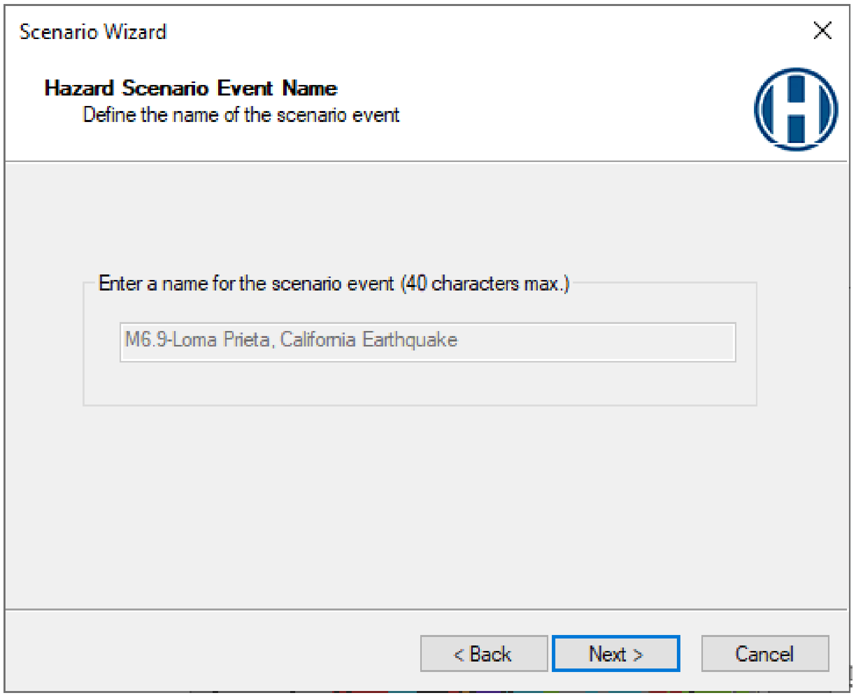


Figure 4-15 Hazard Scenario Event Name Dialog

Review the settings for the new scenario and click **Finish** (Figure 4-16).

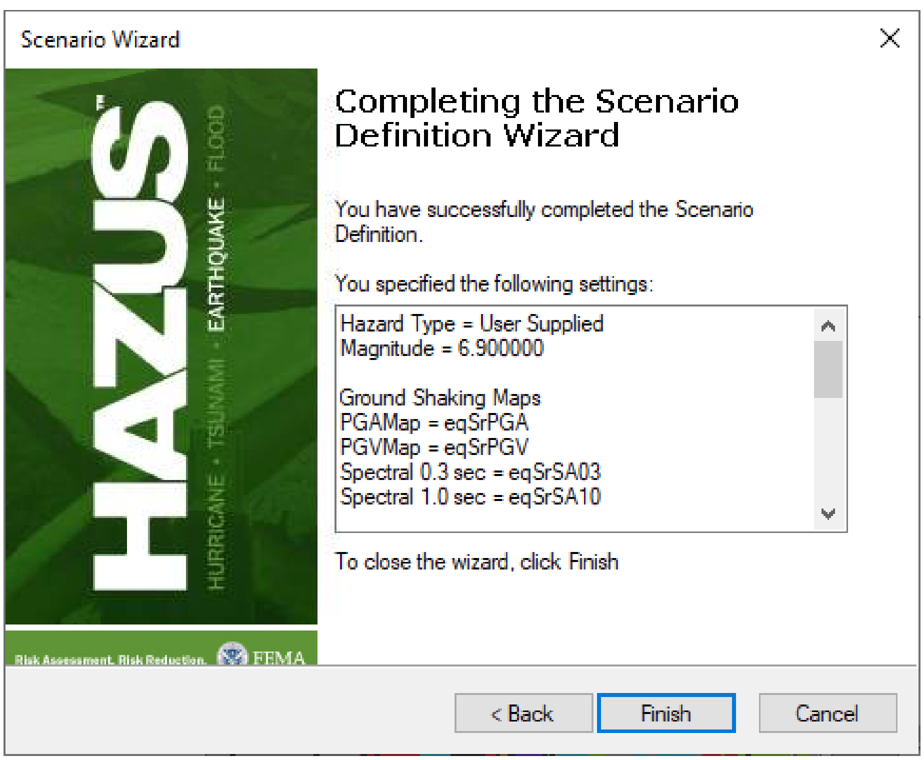


Figure 4-16 Completing the Scenario Definition Wizard Window

The software is now ready to run the earthquake loss estimation analysis using the newly created scenario. Under the **Analysis** menu select **Run** (Figure 4-17).

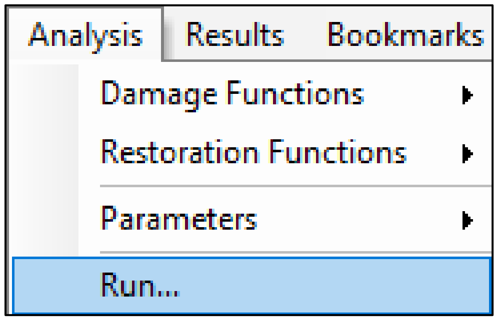


Figure 4-17 Running the Analysis

Select the individual analysis options that should be executed by selecting their check-boxes. Click OK (Figure 4-18).

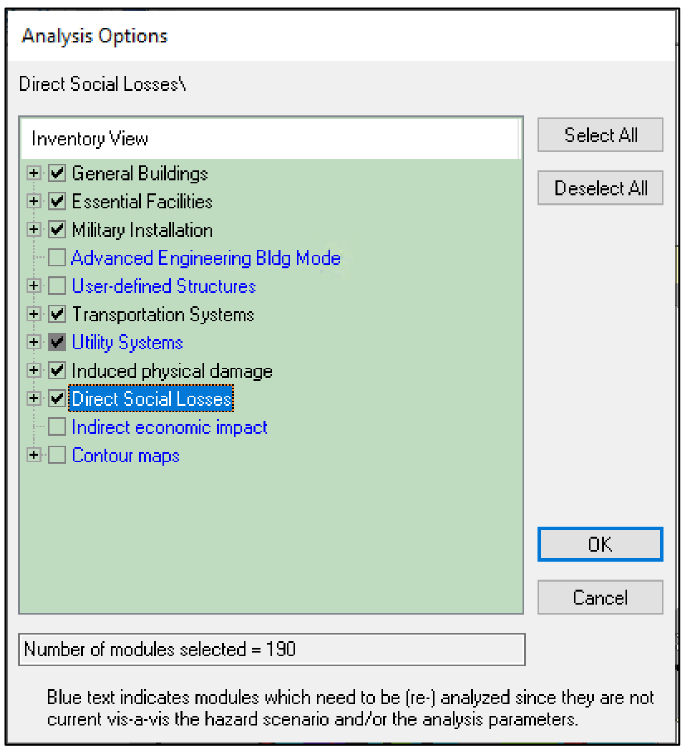


Figure 4-18 Analysis Options Window

The damage analysis is now running. Please be patient as this may take a few minutes. The more complex the Study Region is, the longer this step will take (Figure 4-19).

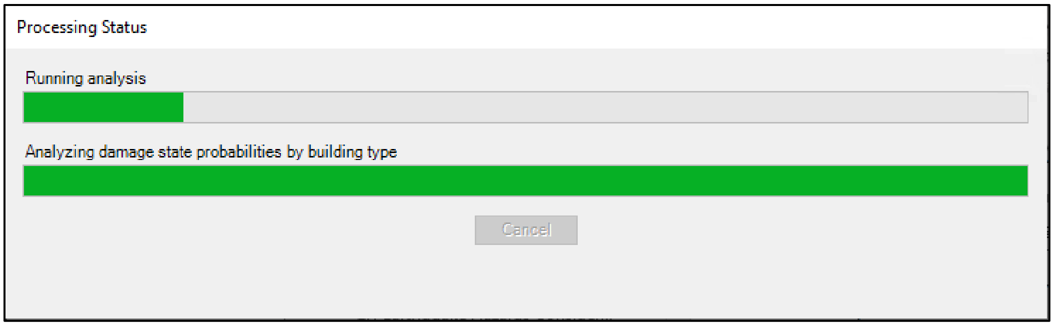


Figure 4-19 Analysis Processing Status Window

The analysis is now complete. Click **OK** to dismiss the Analysis Completed Successfully window (Figure 4-20).

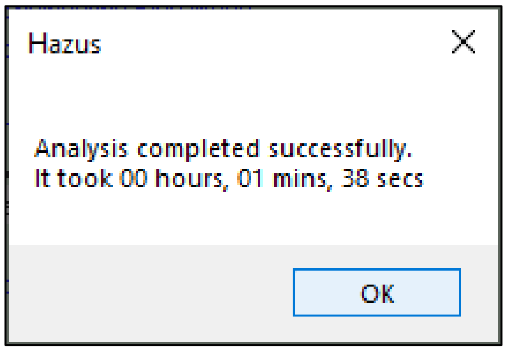


Figure 4-20 Analysis Completed Successfully Window

Congratulations! A USGS ShakeMap loss estimation analysis has been successfully run using the baseline inventory data in Hazus.

In reviewing output data, it is helpful to know that there are three types of output available: thematic map of results, table of results by Census tract, and results summarized by county and for the whole region. A variety of summary reports are also available using the **Results > Summary Reports** menu from the main menu bar. The Results menu is discussed in more detail in Section 8.

Section 5. Earthquake Model: Inventory Menu

5.1 Inventory Menu

The inventory menu, shown in Figure 5-1, provides the interface to all the data that are entered in Hazus. The installation of Hazus and download of state data provides a large and comprehensive baseline dataset that can be used as is or enhanced by the user with better data (replacing existing datasets) or additional data (filling in the baseline empty datasets).

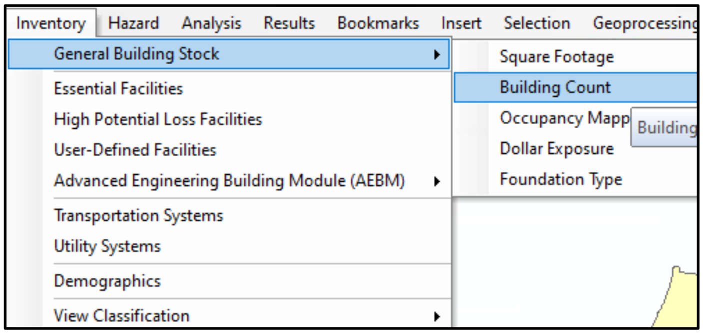


Figure 5-1 Hazus Inventory Menu

A quick glance at the inventory menu layout provides an overview of the inventory data types. All data in Hazus can be classified into the following categories:

- GBS data
- Site-specific data (essential facilities, high potential loss facilities, user-defined facilities, and AEBM)
- Transportation and utility systems
- Demographic data
- Other (metadata, reference data)

While many users will develop a local inventory that best reflects the characteristics of their region, such as building types and demographics, Hazus can produce estimates of losses based on minimum local input. Of course, the quality and uncertainty of the results will be affected by the detail and accuracy of the inventory and the economic and demographic data provided. Estimates calculated with Hazus baseline data would most likely be used only as initial estimates to determine where more detailed analyses would be warranted.

This section provides an overview of the inventory menu items.

5.2 Inventory Databases

Table 5-1 includes a list of baseline inventory information currently supplied with Hazus (detailed information about these datasets is available in the *Hazus Inventory Technical Manual (FEMA, 2024*).

Table 5-1 Baseline Inventory Datasets

Inventory Type	Datasets
GBS	▪ Square Footage, Building Count, Occupancy to Building Type Mapping, Dollar Exposure by Occupancy, and Foundation Type Ratios
Essential Facilities	▪ Medical Care Facilities ▪ Emergency Response Facilities (fire, police, emergency operations center) ▪ Schools
High Potential Loss Facilities **	▪ Dams and Levees* ▪ Nuclear Power Plants* ▪ Military Installations
User-Defined Facilities	▪ User-defined facility datasets
Transportation Systems	▪ Highway Segments, Bridges, and Tunnels ▪ Railroad Tracks, Bridges, Tunnels, and Facilities ▪ Light Rail Tracks, Bridges, Tunnels, and Facilities ▪ Bus Facilities ▪ Port Facilities ▪ Ferry Facilities ▪ Airports Facilities and Runways
Utility Systems	▪ Potable Water Facilities and Distribution Lines ▪ Wastewater Facilities and Distribution Lines ▪ Oil Facilities ▪ Natural Gas Facilities and Distribution Lines ▪ Electric Power Facilities ▪ Communication Facilities ▪ Potable water, wastewater, oil and natural gas pipelines*
Demographics	▪ Population Distribution ▪ Age, Gender, Ethnicity, and Income Distribution ▪ Homeownership Status, Age of Housing Stock and Property Value

* Baseline data are not provided, but placeholders are available to accept user-input data

** Hazus does not perform loss analysis on these datasets

The baseline databases are derived from publicly available data, eliminating data fields that are not needed for the methodology. The state-specific databases are available for download on the Hazus website and are then stored locally in specified file folders (HazusData/Inventory) related to state-specific data. When a Study Region is aggregated, Hazus extracts only those portions of the databases that are relevant to the area of the Study Region. Some Study Regions may not have all identified facility types within the baseline database. Incorporating local inventory data (using CDMS) is discussed in Section 9 (UDF) and Section 10 (AEBM).

5.3 Standardizing and Classifying Data

Two subjects that must be considered in the development of an inventory are classification of data and collection and handling of data. Classification systems are essential to ensuring a uniform interpretation of data and results. As discussed earlier, it can be difficult from a cost perspective to identify and individually inventory each building or component of each system. Thus, losses in a regional study are estimated based on general characteristics of buildings or system components, and classification systems are a tool to group structures or system components that would be expected to behave similarly in a seismic event. For each of the types of data that must be collected to perform a loss study, a classification system has been defined in this methodology. Building classifications for the GBS are described in the following two subsections.

5.3.1 General Building Stock

5.3.1.1 Building Classification – Specific Building Types

The building classification system used in this methodology was developed to provide an ability to differentiate between buildings with substantially different damage and loss characteristics. In general, buildings behave differently as a result of their structural systems (e.g., wood versus steel), the codes to which they were designed, their heights, their shapes or footprints, and local construction practices.

As a consequence of the variations in design, shape, height, and other characteristics, no two buildings will behave exactly the same when subjected to an earthquake. Therefore, **specific building types** are defined to represent the average characteristics of buildings in a class. Within any given building class, there will be a great deal of variation. The damage and loss estimation models in this methodology were developed for specific building types, and the estimated performance is based on the average characteristics of the total population of buildings within each class.

Table 5-2 provides a summary of the 36 specific building types that are defined in the methodology. Each specific building type is defined by a short description of the related structural system. For a detailed discussion of how the classification system was developed and the characteristics that were used to differentiate classes, see the *Hazus Inventory Technical Manual (FEMA, 2024)*.

Table 5-2 Structural Building Classifications (Specific Building Types)

Type	Description	Height			
		Range		Typical	
		Name	Stories	Stories	Feet
W1	Wood, Light Frame (< 5,000 sf)		1 to 2	1	14
W2	Wood, Commercial and Industrial (> 5,000 sf)		All	2	24
S1L	Steel Moment Frame	Low-Rise	1 to 3	2	24
S1M	Steel Moment Frame	Mid-Rise	4 to 7	5	60
S1H	Steel Moment Frame	High-Rise	8+	13	156
S2L	Steel Braced Frame	Low-Rise	1 to 3	2	24
S2M	Steel Braced Frame	Mid-Rise	4 to 7	5	60
S2H	Steel Braced Frame	High-Rise	8+	13	156
S3	Steel Light Frame		All	1	15
S4L	Steel Frame with Cast-in-Place Concrete Shear Walls	Low-Rise	1 to 3	2	24
S4M	Steel Frame with Cast-in-Place Concrete Shear Walls	Mid-Rise	4 to 7	5	60
S4H	Steel Frame with Cast-in-Place Concrete Shear Walls	High-Rise	8+	13	156
S5L	Steel Frame with Unreinforced Masonry Infill Walls	Low-Rise	1 to 3	2	24
S5M	Steel Frame with Unreinforced Masonry Infill Walls	Mid-Rise	4 to 7	5	60
S5H	Steel Frame with Unreinforced Masonry Infill Walls	High-Rise	8+	13	156
C1L	Concrete Moment Frame	Low-Rise	1 to 3	2	20
C1M	Concrete Moment Frame	Mid-Rise	4 to 7	5	50
C1H	Concrete Moment Frame	High-Rise	8+	12	120
C2L	Concrete Shear Walls	Low-Rise	1 to 3	2	20
C2M	Concrete Shear Walls	Mid-Rise	4 to 7	5	50
C2H	Concrete Shear Walls	High-Rise	8+	12	120
C3L	Concrete Frame with Unreinforced Masonry Infill Walls	Low-Rise	1 to 3	2	20

Type	Description	Height			
		Range		Typical	
		Name	Stories	Stories	Feet
C3M	Concrete Frame with Unreinforced Masonry Infill Walls	Mid-Rise	4 to 7	5	50
C3H	Concrete Frame with Unreinforced Masonry Infill Walls	High-Rise	8+	12	120
PC1	Precast Concrete Tilt-Up Walls		All	1	15
PC2L	Precast Concrete Frames with Concrete Shear Walls	Low-Rise	1 to 3	2	20
PC2M	Precast Concrete Frames with Concrete Shear Walls	Mid-Rise	4 to 7	5	50
PC2H	Precast Concrete Frames with Concrete Shear Walls	High-Rise	8+	12	120
RM1L	Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms	Low-Rise	1 to 3	2	20
RM1M	Reinforced Masonry Bearing Walls with Wood or Metal Deck Diaphragms	Mid-Rise	4+	5	50
RM2L	Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms	Low-Rise	1 to 3	2	20
RM2M	Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms	Mid-Rise	4 to 7	5	50
RM2H	Reinforced Masonry Bearing Walls with Precast Concrete Diaphragms	High-Rise	8+	12	120
URML	Unreinforced Masonry Bearing Walls	Low-Rise	1 to 2	1	15
URMM	Unreinforced Masonry Bearing Walls	Mid-Rise	3+	3	35
MH	Mobile Homes		All	1	10

5.3.1.2 Building Classification – Building Occupancy

The GBS is also classified based on occupancy. The occupancy classification is broken into **general occupancy** and **specific occupancy** classes. For the methodology, the general occupancy classification system consists of seven groups: residential, commercial, industrial, religion/non-profit, government, agricultural, and education. Specific occupancy consists of 33 classes (Table 5-3). Occupancy classes are used to account for the fact that contributions to losses are from damage to both the structural system and nonstructural elements. The types and costs of nonstructural elements are often governed by the occupancy of the building (e.g., a warehouse may have inexpensive wall coverings, but a bank may have expensive lighting and finishes).

If the structural systems of these two buildings experience the same amount of damage, the cost to repair the bank will be greater than the warehouse due to the more expensive finishes. Other issues related to occupancy may also be important in determining impacts, such as rental costs, number of employees, type of building contents, and importance of function. Finally, a great deal of inventory information, such as county business patterns or Census data, is available only by occupancy. Additional information and specifications on building occupancy classification can be found in the *Hazus CDMS User Guidance (FEMA, 2019)*.

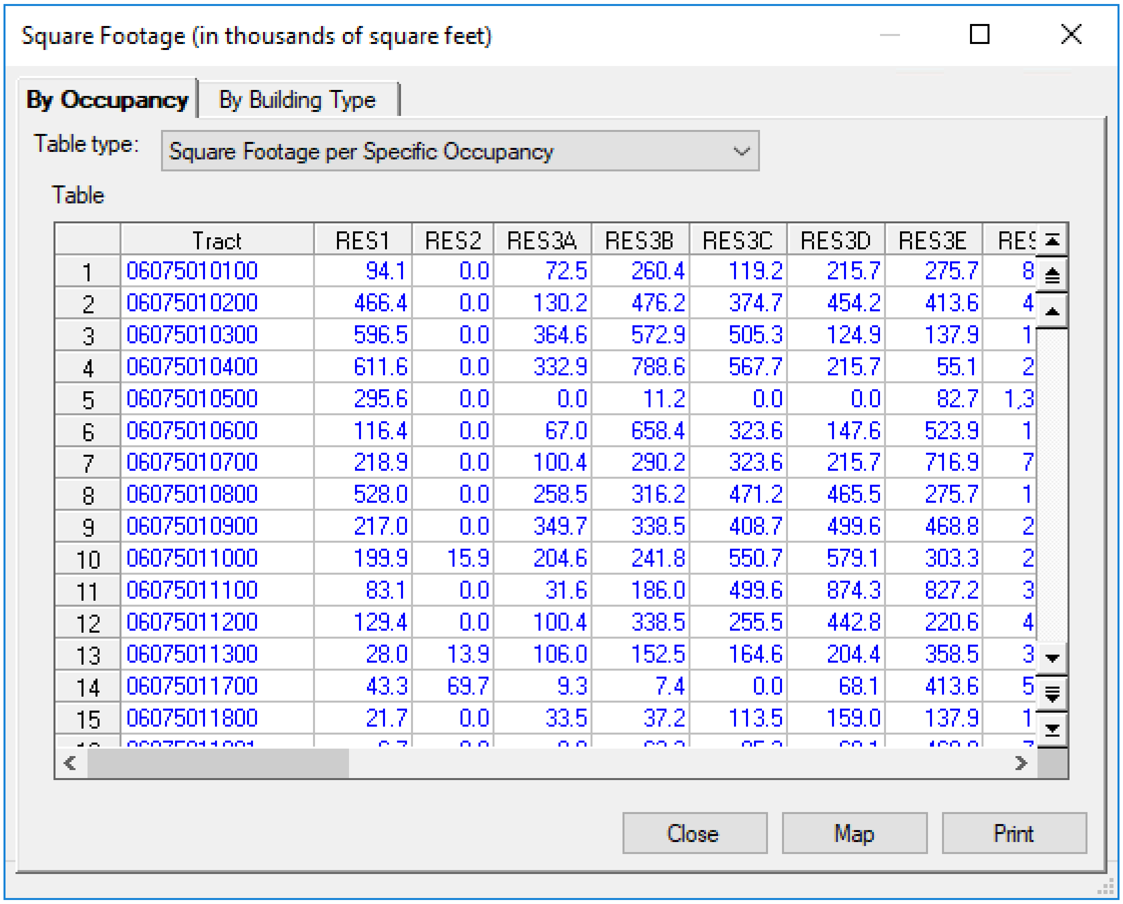
Table 5-3 Building Occupancy Classes

General Occupancy	Specific Occupancy	Occupancy Class	Example Descriptions
Residential	RES1	Single-Family Dwelling	House
	RES2	Mobile Home	Mobile Home
	RES3	Multi-Family Dwelling RES3A Duplex RES3B 3-4 Units RES3C 5-9 Units RES3D 10-19 Units RES3E 20-49 Units RES3F 50+ Units	Apartment/Condominium
	RES4	Temporary Lodging	Hotel/Motel
	RES5	Institutional Dormitory	Group Housing (military, college), Jails
	RES6	Nursing Home	
Commercial	COM1	Retail Trade	Store
	COM2	Wholesale Trade	Warehouse
	COM3	Personal and Repair Services	Service Station/Shop
	COM4	Professional/Technical Services	Offices
	COM5	Banks	
	COM6	Hospital	
	COM7	Medical Office/Clinic	
	COM8	Entertainment & Recreation	Restaurants/Bars

General Occupancy	Specific Occupancy	Occupancy Class	Example Descriptions
	COM9	Theaters	Theaters
	COM10	Parking	Garages
Industrial	IND1	Heavy	Factory
	IND2	Light	Factory
	IND3	Food/Drugs/Chemicals	Factory
	IND4	Metals/Minerals Processing	Factory
	IND5	High Technology	Factory
	IND6	Construction	Office
Agriculture	AGR1	Agriculture	Cattle Barn
Religion/ Non-Profit	REL1	Church/Non-Profit	
Government	GOV1	General Services	Office
	GOV2	Emergency Response	Police/Fire Station/Emergency Operations Center
Education	EDU1	Grade Schools	
	EDU2	Colleges/Universities	Does not include group housing

5.3.1.3 Building Classification – Square Footage

The Hazus baseline GBS inventory is also classified by building square footage. This classification is further broken down by occupancy (specific and general) and building type. All square footages are organized by Census tract (Figure 5-2).

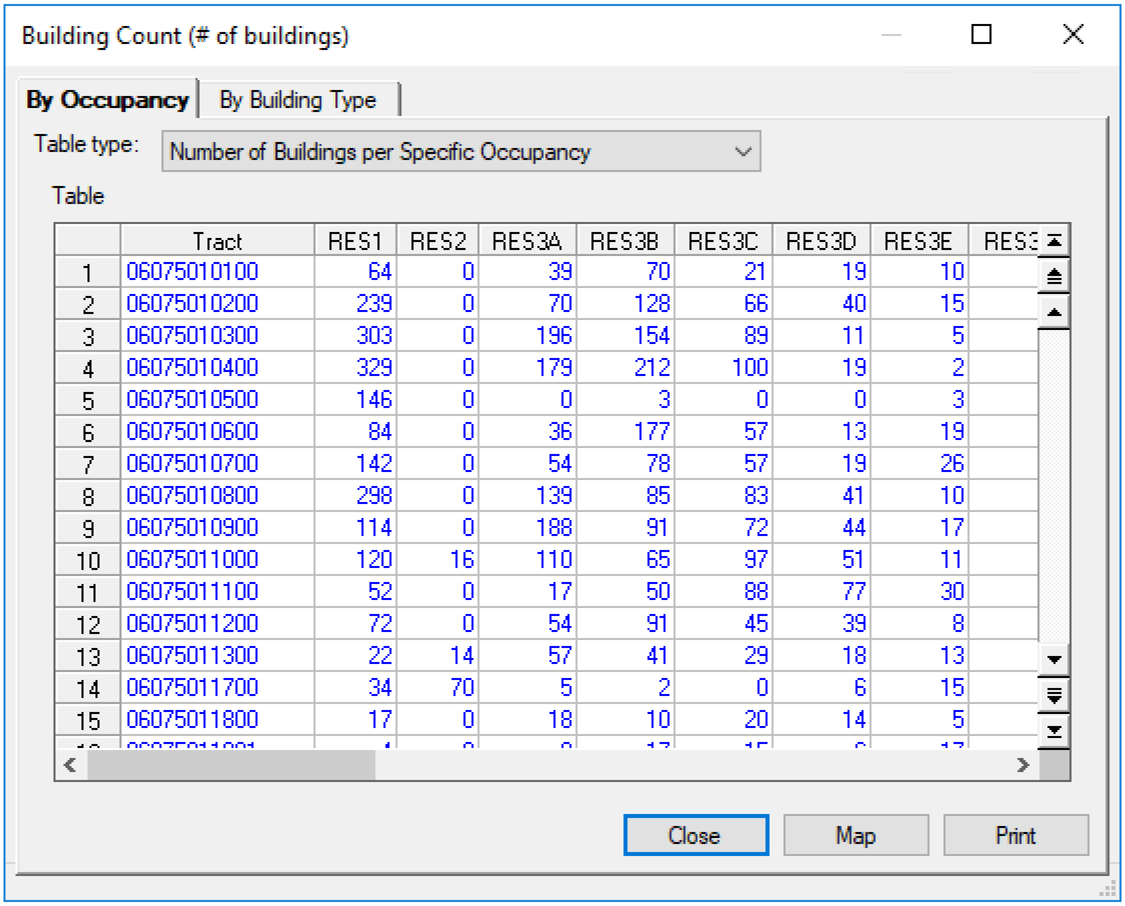


	Tract	RES1	RES2	RES3A	RES3B	RES3C	RES3D	RES3E	RES
1	06075010100	94.1	0.0	72.5	260.4	119.2	215.7	275.7	8
2	06075010200	466.4	0.0	130.2	476.2	374.7	454.2	413.6	4
3	06075010300	596.5	0.0	364.6	572.9	505.3	124.9	137.9	1
4	06075010400	611.6	0.0	332.9	788.6	567.7	215.7	55.1	2
5	06075010500	295.6	0.0	0.0	11.2	0.0	0.0	82.7	1,3
6	06075010600	116.4	0.0	67.0	658.4	323.6	147.6	523.9	1
7	06075010700	218.9	0.0	100.4	290.2	323.6	215.7	716.9	7
8	06075010800	528.0	0.0	258.5	316.2	471.2	465.5	275.7	1
9	06075010900	217.0	0.0	349.7	338.5	408.7	499.6	468.8	2
10	06075011000	199.9	15.9	204.6	241.8	550.7	579.1	303.3	2
11	06075011100	83.1	0.0	31.6	186.0	499.6	874.3	827.2	3
12	06075011200	129.4	0.0	100.4	338.5	255.5	442.8	220.6	4
13	06075011300	28.0	13.9	106.0	152.5	164.6	204.4	358.5	3
14	06075011700	43.3	69.7	9.3	7.4	0.0	68.1	413.6	5
15	06075011800	21.7	0.0	33.5	37.2	113.5	159.0	137.9	1

Figure 5-2 Building Classification – Square Footage

5.3.1.4 Building Classification – Building Count

The buildings in the Hazus building inventory are also classified by building counts per Census tract. Much like square footage, building counts are organized by occupancy (specific and general) and by building type (Figure 5-3).

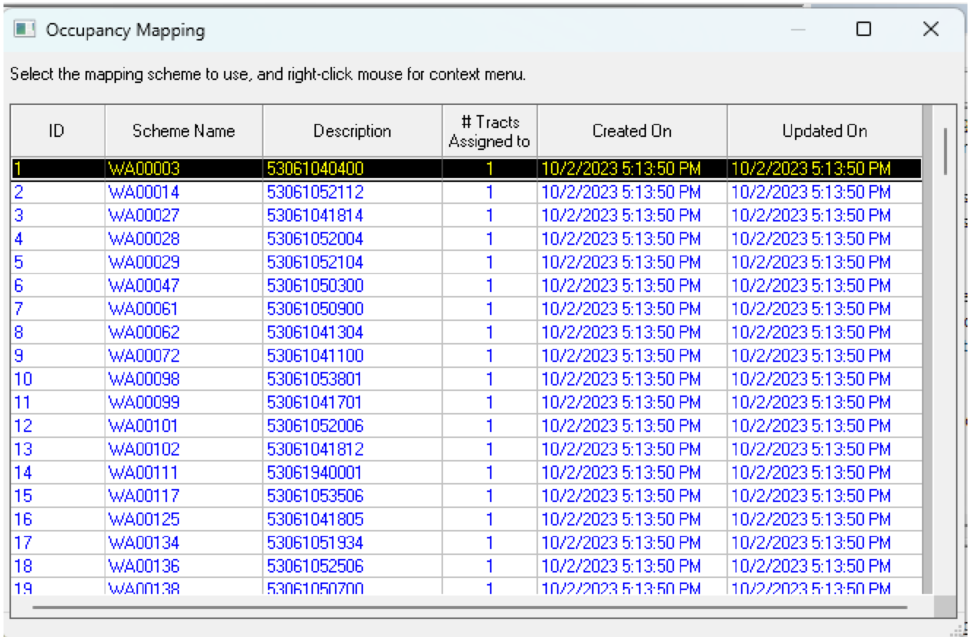


	Tract	RES1	RES2	RES3A	RES3B	RES3C	RES3D	RES3E
1	06075010100	64	0	39	70	21	19	10
2	06075010200	239	0	70	128	66	40	15
3	06075010300	303	0	196	154	89	11	5
4	06075010400	329	0	179	212	100	19	2
5	06075010500	146	0	0	3	0	0	3
6	06075010600	84	0	36	177	57	13	19
7	06075010700	142	0	54	78	57	19	26
8	06075010800	298	0	139	85	83	41	10
9	06075010900	114	0	188	91	72	44	17
10	06075011000	120	16	110	65	97	51	11
11	06075011100	52	0	17	50	88	77	30
12	06075011200	72	0	54	91	45	39	8
13	06075011300	22	14	57	41	29	18	13
14	06075011700	34	70	5	2	0	6	15
15	06075011800	17	0	18	10	20	14	5

Figure 5-3 Building Classification – Building Count

5.3.1.5 Building Classification – Occupancy Mapping

Hazus classifies buildings using mapping schemes. These mapping have been created for each census tract within in the United States and they are a way of organizing buildings by Census tract based on their building type (wood, concrete, steel, etc.). Each Census tract will contain a percentage for each building type used by Hazus (Figure 5-4). Users can create custom schemes and to assign various Census tracts to different schemes.

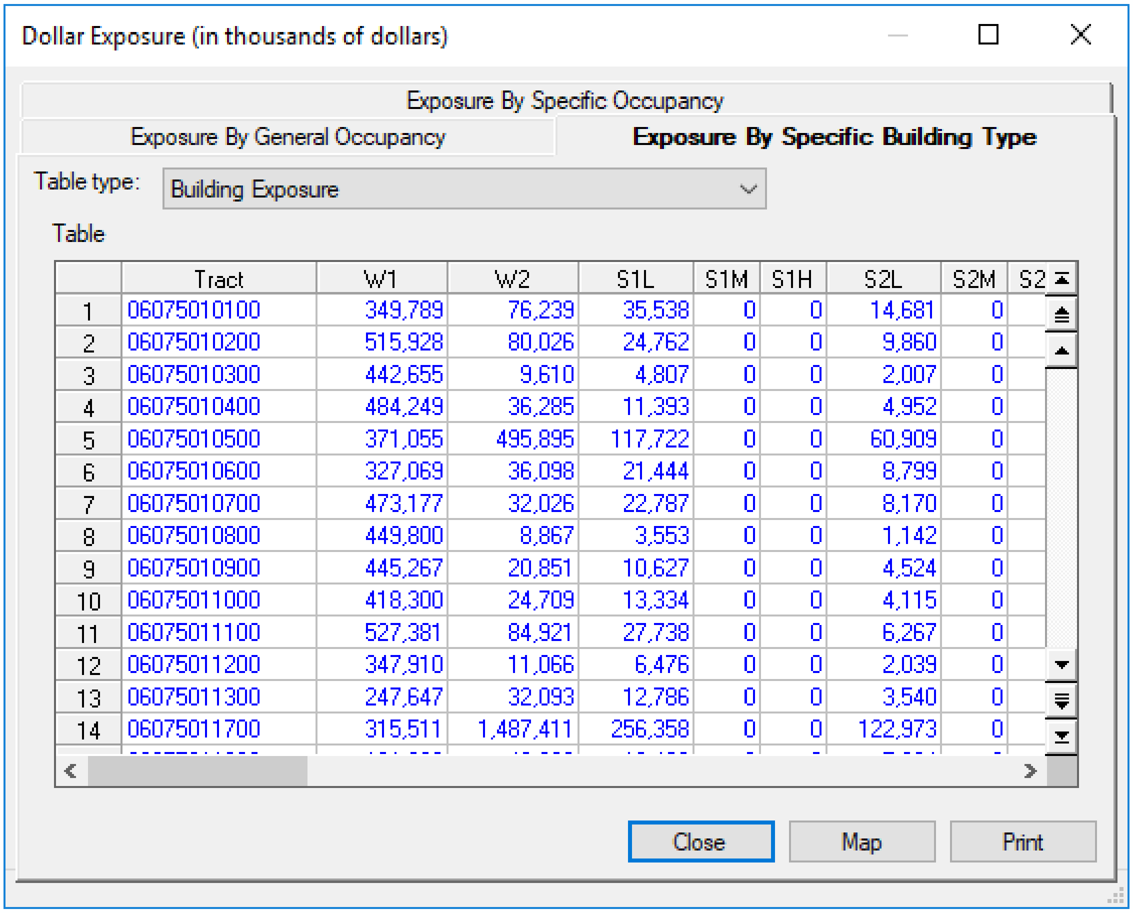


ID	Scheme Name	Description	# Tracts Assigned to	Created On	Updated On
1	WA00003	53061040400	1	10/2/2023 5:13:50 PM	10/2/2023 5:13:50 PM
2	WA00014	53061052112	1	10/2/2023 5:13:50 PM	10/2/2023 5:13:50 PM
3	WA00027	53061041814	1	10/2/2023 5:13:50 PM	10/2/2023 5:13:50 PM
4	WA00028	53061052004	1	10/2/2023 5:13:50 PM	10/2/2023 5:13:50 PM
5	WA00029	53061052104	1	10/2/2023 5:13:50 PM	10/2/2023 5:13:50 PM
6	WA00047	53061050300	1	10/2/2023 5:13:50 PM	10/2/2023 5:13:50 PM
7	WA00061	53061050900	1	10/2/2023 5:13:50 PM	10/2/2023 5:13:50 PM
8	WA00062	53061041304	1	10/2/2023 5:13:50 PM	10/2/2023 5:13:50 PM
9	WA00072	53061041100	1	10/2/2023 5:13:50 PM	10/2/2023 5:13:50 PM
10	WA00098	53061053801	1	10/2/2023 5:13:50 PM	10/2/2023 5:13:50 PM
11	WA00099	53061041701	1	10/2/2023 5:13:50 PM	10/2/2023 5:13:50 PM
12	WA00101	53061052006	1	10/2/2023 5:13:50 PM	10/2/2023 5:13:50 PM
13	WA00102	53061041812	1	10/2/2023 5:13:50 PM	10/2/2023 5:13:50 PM
14	WA00111	53061940001	1	10/2/2023 5:13:50 PM	10/2/2023 5:13:50 PM
15	WA00117	53061053506	1	10/2/2023 5:13:50 PM	10/2/2023 5:13:50 PM
16	WA00125	53061041805	1	10/2/2023 5:13:50 PM	10/2/2023 5:13:50 PM
17	WA00134	53061051934	1	10/2/2023 5:13:50 PM	10/2/2023 5:13:50 PM
18	WA00136	53061052506	1	10/2/2023 5:13:50 PM	10/2/2023 5:13:50 PM
19	WA00138	53061050700	1	10/2/2023 5:13:50 PM	10/2/2023 5:13:50 PM

Figure 5-4 Building Classification – Occupancy Mapping

5.3.1.6 Building Classification – Dollar Exposure

The buildings in Hazus are also classified by dollar exposure (in thousands of dollars) to an earthquake event. This classification is further divided by specific occupancy, general occupancy and specific building type (Figure 5-5). Table 5-4 details building occupancy descriptions by general occupancy class, specific occupancy class codes, occupancy class descriptions and examples of the occupancy types.



	Tract	W1	W2	S1L	S1M	S1H	S2L	S2M	S2
1	06075010100	349,789	76,239	35,538	0	0	14,681	0	
2	06075010200	515,928	80,026	24,762	0	0	9,860	0	
3	06075010300	442,655	9,610	4,807	0	0	2,007	0	
4	06075010400	484,249	36,285	11,393	0	0	4,952	0	
5	06075010500	371,055	495,895	117,722	0	0	60,909	0	
6	06075010600	327,069	36,098	21,444	0	0	8,799	0	
7	06075010700	473,177	32,026	22,787	0	0	8,170	0	
8	06075010800	449,800	8,867	3,553	0	0	1,142	0	
9	06075010900	445,267	20,851	10,627	0	0	4,524	0	
10	06075011000	418,300	24,709	13,334	0	0	4,115	0	
11	06075011100	527,381	84,921	27,738	0	0	6,267	0	
12	06075011200	347,910	11,066	6,476	0	0	2,039	0	
13	06075011300	247,647	32,093	12,786	0	0	3,540	0	
14	06075011700	315,511	1,487,411	256,358	0	0	122,973	0	

Figure 5-5 Building Classification – Dollar Exposure

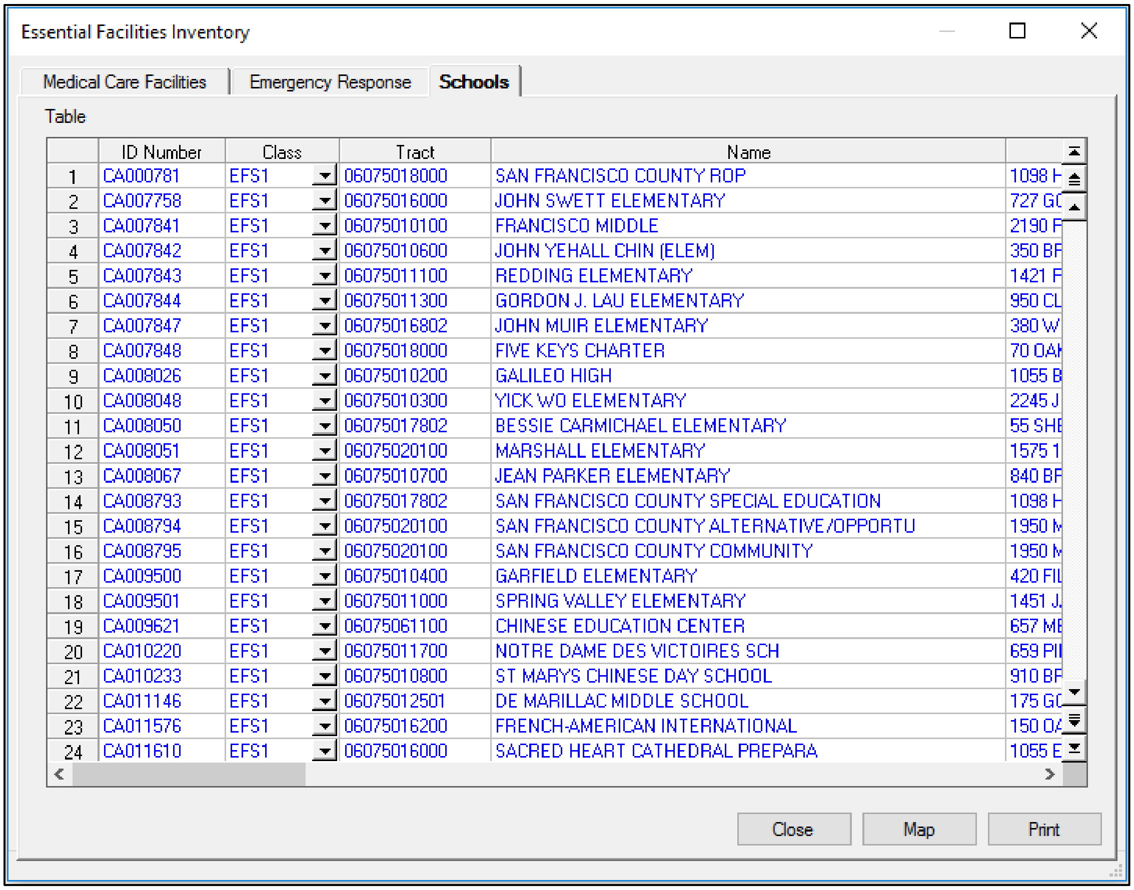
Table 5-4 Building Occupancy Classes

General Occupancy	Specific Occupancy	Occupancy Class	Example Descriptions
Residential	RES1	Single-Family Dwelling	House
	RES2	Mobile Home	Mobile Home
	RES3	Multi-Family Dwelling RES3A Duplex RES3B 3-4 Units RES3C 5-9 Units RES3D 10-19 Units RES3E 20-49 Units RES3F 50+ Units	Apartment/Condominium
	RES4	Temporary Lodging	Hotel/Motel
	RES5	Institutional Dormitory	Group Housing (military, college), Jails
	RES6	Nursing Home	

General Occupancy	Specific Occupancy	Occupancy Class	Example Descriptions
Commercial	COM1	Retail Trade	Store
	COM2	Wholesale Trade	Warehouse
	COM3	Personal and Repair Services	Service Station/Shop
	COM4	Professional/Technical Services	Offices
	COM5	Banks	
	COM6	Hospital	
	COM7	Medical Office/Clinic	
	COM8	Entertainment & Recreation	Restaurants/Bars
	COM9	Theaters	Theaters
	COM10	Parking	Garages
Industrial	IND1	Heavy	Factory
	IND2	Light	Factory
	IND3	Food/Drugs/Chemicals	Factory
	IND4	Metals/Minerals Processing	Factory
	IND5	High Technology	Factory
	IND6	Construction	Office
Agriculture	AGR1	Agriculture	Cattle Barn
Religion/ Non-Profit	REL1	Church/Non-Profit	
Government	GOV1	General Services	Office
	GOV2	Emergency Response	Police/Fire Station/Emergency Operations Center
Education	EDU1	Grade Schools	
	EDU2	Colleges/Universities	Does not include group housing

5.4 Inventory Database Format

Once data have been collected, they can be accessed more easily and updated in the future if they are maintained in an orderly manner. Database formats have been developed for all the data that are used by Hazus to perform an analysis. Figure 5-6 is an example of a database of school facilities in Hazus.



	ID Number	Class	Tract	Name	
1	CA000781	EFS1	06075018000	SAN FRANCISCO COUNTY ROP	1098 H
2	CA007758	EFS1	06075016000	JOHN SWETT ELEMENTARY	727 GO
3	CA007841	EFS1	06075010100	FRANCISCO MIDDLE	2190 F
4	CA007842	EFS1	06075010600	JOHN YEHALL CHIN (ELEM)	350 BR
5	CA007843	EFS1	06075011100	REDDING ELEMENTARY	1421 P
6	CA007844	EFS1	06075011300	GORDON J. LAU ELEMENTARY	950 CL
7	CA007847	EFS1	06075016802	JOHN MUIR ELEMENTARY	380 W
8	CA007848	EFS1	06075018000	FIVE KEYS CHARTER	70 OAK
9	CA008026	EFS1	06075010200	GALILEO HIGH	1055 B
10	CA008048	EFS1	06075010300	YICK WO ELEMENTARY	2245 J
11	CA008050	EFS1	06075017802	BESSIE CARMICHAEL ELEMENTARY	55 SHE
12	CA008051	EFS1	06075020100	MARSHALL ELEMENTARY	1575 1
13	CA008067	EFS1	06075010700	JEAN PARKER ELEMENTARY	840 BR
14	CA008793	EFS1	06075017802	SAN FRANCISCO COUNTY SPECIAL EDUCATION	1098 H
15	CA008794	EFS1	06075020100	SAN FRANCISCO COUNTY ALTERNATIVE/OPPORTU	1950 M
16	CA008795	EFS1	06075020100	SAN FRANCISCO COUNTY COMMUNITY	1950 M
17	CA009500	EFS1	06075010400	GARFIELD ELEMENTARY	420 FIL
18	CA009501	EFS1	06075011000	SPRING VALLEY ELEMENTARY	1451 J
19	CA009621	EFS1	06075061100	CHINESE EDUCATION CENTER	657 ME
20	CA010220	EFS1	06075011700	NOTRE DAME DES VICTOIRES SCH	659 PI
21	CA010233	EFS1	06075010800	ST MARYS CHINESE DAY SCHOOL	910 BR
22	CA011146	EFS1	06075012501	DE MARILLAC MIDDLE SCHOOL	175 GO
23	CA011576	EFS1	06075016200	FRENCH-AMERICAN INTERNATIONAL	150 OA
24	CA011610	EFS1	06075016000	SACRED HEART CATHEDRAL PREPARA	1055 E

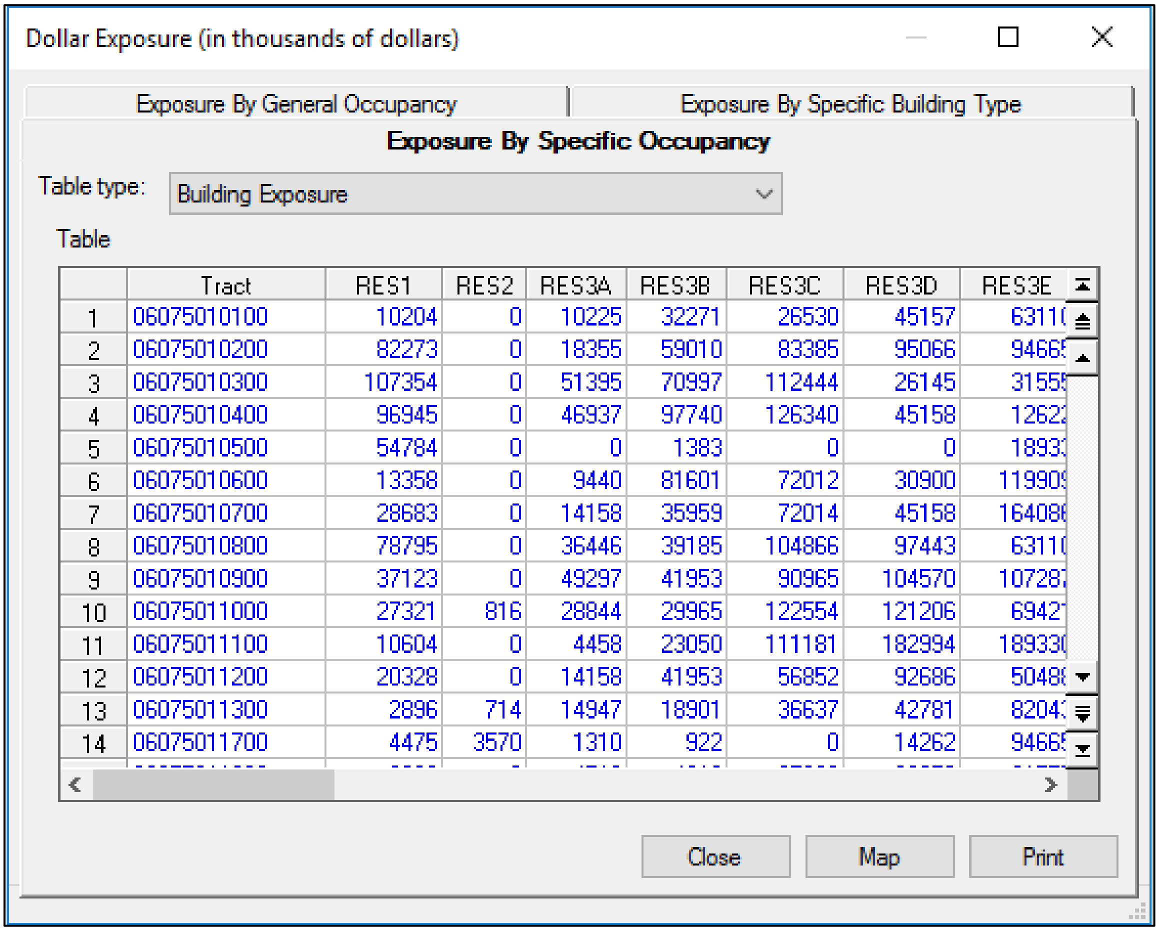
Figure 5-6 Example Database of School Facilities

The database contains fields that allow a variety of attributes about each facility to be added. For example, in addition to the name (as shown in Figure 5-6), there are data fields for address, city, zip code, contact name, phone number of the facility, class of facility (e.g., grade schools, college/universities), number of students, and structural type, among others. There is also a comment field that allows any information that does not fit in other fields to be included.

Some of these fields are not shown in Figure 5-6 but can be accessed by scrolling to the right. Some of the essential facilities may be missing information, such as the address. A missing address typically does not prevent a facility from being included in the database or in the analysis. In order to be included, only the latitude and longitude need be specified, while other attributes can be inferred (with corresponding uncertainty). Using CDMS is recommended for data import to minimize importing errors (please refer to *Hazus CDMS User Guidance* (FEMA, 2019) for more information).

Figure 5-7 shows a view of the inventory database for GBS. For GBS, data are stored by Census tract, and each Census tract contains the total square footage, total building count, and total replacement value for each of the seven general occupancy types: residential, commercial, industrial, agricultural, religious/non-profit, governmental, and educational. The inventory can also be viewed in terms of each specific occupancy type (e.g., RES1, RES2, RES3A) by clicking the **Exposure By Specific**

Occupancy tab to the left of the general classifications at the top of Figure 5-7. For example, in Census tract 06075010100, the value of single-family dwellings (RES1) is $10.2 million. At the lower right of the window, the **Map** button allows the user to graphically display the information by Census tract.



	Tract	RES1	RES2	RES3A	RES3B	RES3C	RES3D	RES3E
1	06075010100	10204	0	10225	32271	26530	45157	6311
2	06075010200	82273	0	18355	59010	83385	95066	9466
3	06075010300	107354	0	51395	70997	112444	26145	3155
4	06075010400	96945	0	46937	97740	126340	45158	1262
5	06075010500	54784	0	0	1383	0	0	1893
6	06075010600	13358	0	9440	81601	72012	30900	11990
7	06075010700	28683	0	14158	35959	72014	45158	16408
8	06075010800	78795	0	36446	39185	104866	97443	6311
9	06075010900	37123	0	49297	41953	90965	104570	10728
10	06075011000	27321	816	28844	29965	122554	121206	6942
11	06075011100	10604	0	4458	23050	111181	182994	18933
12	06075011200	20328	0	14158	41953	56852	92686	5048
13	06075011300	2896	714	14947	18901	36637	42781	8204
14	06075011700	4475	3570	1310	922	0	14262	9466

Figure 5-7 Value of GBS Inventory – Tabular Format Example

Data entry is in a familiar spreadsheet format to allow for easy entry and modification. Moving around in the database involves using the arrow keys at the bottom and to the right of the window. All data are stored in a structured query language (SQL) Server database (Microsoft SQL Server). The structures of all the parameter and inventory databases that are maintained by Hazus are provided in the *Hazus Inventory Technical Manual (FEMA, 2024*). For additional support regarding Hazus parameters or inventories, please contact the Hazus program.

5.4.1 Data Inventory Browser

Square footage data for the GBS dialog (Figure 5-8) is used as an example to describe the functionality of the various Hazus data browser.

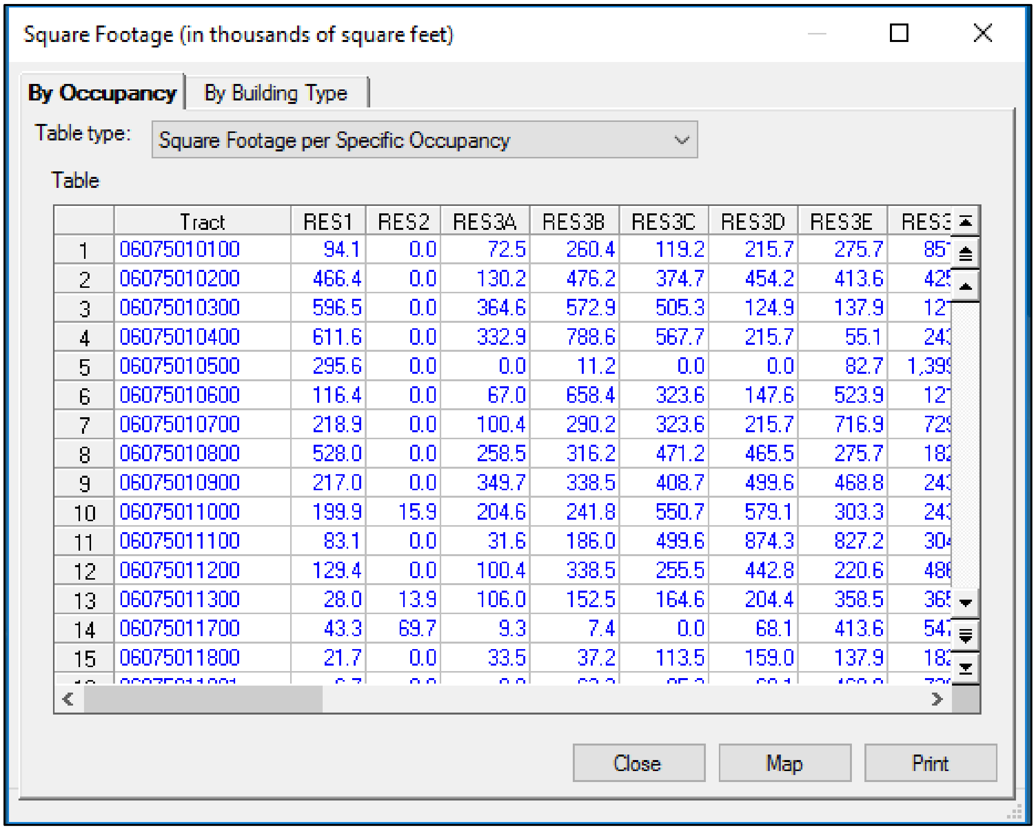


Figure 5-8 Hazus Inventory Square Footage Dialog Browser

The square footage data dialog (Figure 5-8) uses an interface and functionality that are common to all the Hazus dialogs. The key aspects are as follows:

- Data are organized (as needed) in separate tabs. For square footage data, the two major groups are **By Occupancy** and **By Building Type**.

- Within each tab, if a lower hierarchy is needed, combo-boxes are used. For square footage data, the combo-box provides two options: view the data by general occupancy and view it by specific occupancy.

- The data are always shown initially in read-only mode, which is reflected by blue text color.

- The browser's context menu (right-click mouse) always has eight options that are enabled or disabled automatically based on context.

    - The **Start Editing** option is used to start editing data. Text color will change from blue to black for the attributes that can be modified by the user; non-editable attributes will remain in blue. For square footage data, the Census tract numbers cannot be edited because the numbers are the original Census data which are affiliated with geography and provide interconnectivity to other tables and data; therefore, users cannot modify the value.

- The **Stop Editing** option is used when the user is finished editing data and wants to save. Hazus will prompt for a confirmation on saving the data. The prompt will also occur if the user closes the dialog without selecting the **Stop Editing** option.

- If the data support adding new records, the **Add New Record** option is selectable. This option will be disabled if the data do not support the addition of new records, such as in Census tract-based square footage data (Figure 5-8). Adding new Census tract data is disabled because the link between the tabular data and their geospatial attributes would be missing. The new Census tract must have its polygon boundary defined—a complex task that is challenging for the average user. The link to the other datasets that are aggregated by Census tract would also be missing (e.g., building count, occupancy mapping).

- To delete a record (if the functionality is not applicable to the current data, the option will be disabled), the entire record to be deleted is selected by clicking its record number on the left, right-clicking to get the context menu, and then selecting **Delete Selected Records.** After confirmation, the record is deleted. The same process applies if multiple adjacent records are to be deleted. To select multiple records, select the first record in the set, and while holding the **Shift** key, select the last record in the set. Note that the browser does not support the selection of non-adjacent records.

- The **Add New Record** option is not practical when many records are to be added to the table. If the data have been converted (outside Hazus) to a personal geodatabase (.mdb) file, it can be imported automatically by Hazus through the **Import** option. After selecting the input .mdb file, the user will be prompted for the exact table name within the geodatabase and then to map the attributes/fields from the input data to the target data. Once that is completed, data are imported into (i.e., appended onto) the current dataset. If the intent is to replace the existing data with the imported data, the existing data will need to be deleted as discussed above.

- The **Export** option allows the user to export the current data to a delimited text file. By baseline, the TAB is used as a delimiter, but users can select another delimited format (e.g., comma delimited) if preferred.

- The **Data Dictionary** option provides a detailed snapshot of the data schema. The schema consists of the list of fields, their exact name, type, and size. The number of records and the name of the index (if any) are also provided. The table is stored in an SQL server 2014 database. (All of the Hazus tables are accessible directly (outside Hazus) if SQL Server Management Studio is installed and available to the user. Direct access to the tables is not recommended unless the user has experience with the process and is familiar with the data structure in Hazus.)

- The Metadata option opens a document that has all the metadata information for the selected table. The metadata structure in Hazus follows the Federal Geographic Data Committee (FGDC) standard. The metadata document is editable by the user. The metadata document is needed in the scenario if the user has updated (or completely replaced) the baseline data with another source that, although in the same format, have origins that are different and that must be reflected in the corresponding metadata document (All metadata documents are stored in a Microsoft Word compatible format (.rtf). The user has the flexibility of editing the metadata document in Word if desired instead of the Hazus interface.)

5.5 Inventory Requirements

Each model in the earthquake loss estimation methodology requires a specific set of inventory input data (Table 5-5). The required data can take two forms: (1) inventory data, such as the square footage of buildings of a specified type, the length of roadways, or the population in the Study Region, which are used to estimate the amount of exposure or potential damage in the region and (2) characteristics of the local economy that are important in estimating losses (e.g., rental rates, construction costs, regional unemployment rates). This section summarizes the inventory information that is needed to perform a loss study.

Table 5-5 lists the inventory required for each type of output that is provided in the methodology, and a star is placed next to the input requirements that do not have baseline values. Baseline values are provided for most of the input information. Within Table 5-5, all the identified categories are required; however, a majority are provided with the Hazus baseline inventory data.

Table 5-5 Minimum Inventory for the Earthquake Loss Estimation Methodology

Model Category	Desired Output	Required Input
General Building Stock	Damage to GBS by occupancy or building type	Total ft^2 of each occupancy by Census tract, occupancy to building type relationships
Essential Facilities	Damage and functionality of essential facilities Loss of beds and estimated recovery time for hospitals	Location, design level, and building type of each facility Number of beds at each facility
High Potential Loss Facilities	Map of high potential loss facilities** Damage and loss for military installations	Locations and types of facilities* Location, building type, design level, and value of military installations
Transportation Systems	Damage to transportation components	Locations and classes of components
Utility Systems	Damage to utility components	Locations and classes of components
Induced Physical Damage	Inundation exposure	Inundation map*
	Type and weight of debris	GBS inventory and estimates of type and unit weight of debris

Model Category	Desired Output	Required Input
Fire Following Earthquake	Number of ignitions and percentage of burnt area by Census tract	GBS inventory, average speed of fire engines, and speed and direction of wind
Direct Social Losses	Number of displaced households	Number of households per Census tract
	Number of people requiring temporary shelter	Population including ethnicity, age, income, and ownership
	Casualties in four categories of severity based on 3 event times	Population distribution at 2 AM, 2 PM, and 5 PM
Economic Losses	Structural and nonstructural cost of repair or replacement	$/ft^2 to repair damage by occupancy and damage state
	Loss of contents	Contents value as percentage of replacement value by occupancy
	Business inventory damage/loss	Annual gross sales in $/ft^2
	Relocation costs	Relocation disruption cost in $ and rental costs in $/ft^2/month by occupancy
	Business income loss	Income in $/ft^{2}month by occupancy
	Employee wage loss	Wages in $/ft^2/month by occupancy
	Loss of rental income	Rental costs in $/ ft^2/month by occupancy
	Cost of damage to transportation components	Costs of repair/replacement of components
	Cost of damage to utility components	Costs of repair/replacement of components

** Input requirements that do not have baseline values*

*** Analyses are not run for some types of facilities: High Potential Loss Facilities, Hazard Waste Facilities when only using baseline Hazus state data*

5.6 Relationship between Building Types and Occupancy Classes

As discussed, contributions to the loss estimates come from damage to both the structural system and the nonstructural elements. In order to estimate losses, the structural system must be known or inferred for all the buildings in the inventory. Since much of the inventory information that is available is based on occupancy classes, inferences must be made to convert occupancy class inventory to specific building types. The inferences that affect inventory can introduce uncertainty in the loss estimates.

The relationship in the GBS, between structural type and occupancy class, will vary on a regional basis. For example, in California, the occupancy RES1 (single-family dwelling) can be 99% W1 (wood, light frame) and 1% RM1L (reinforced masonry bearing wall with wood or metal deck diaphragm, low-rise). In a city on the east coast, the relationship can be 85% W1, 14% URML (unreinforced masonry bearing wall, low-rise), and 1% C2L (concrete shear wall, low-rise).

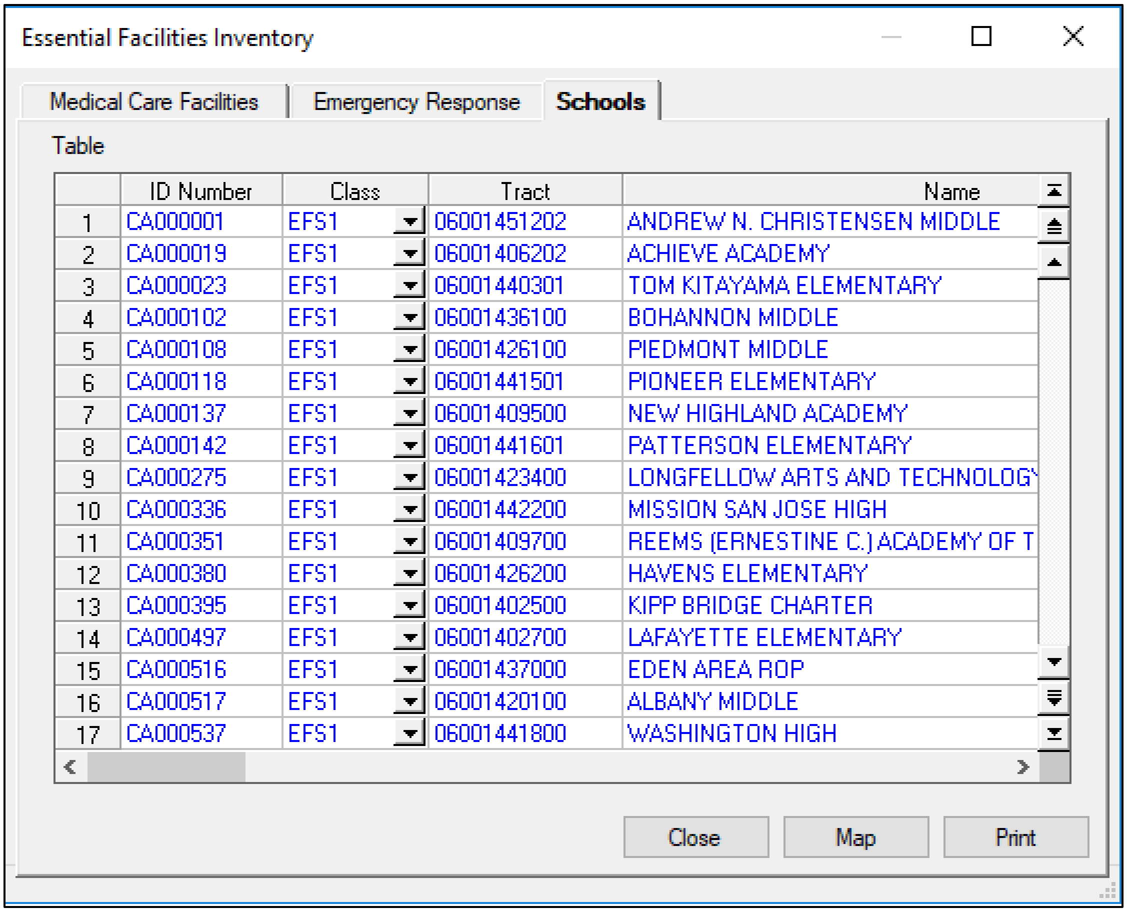
In most cases, structures in a Study Region or Census tract have been built at different times. As a result, some structures may have been built before 1950, some between 1950 and 1970, and others after 1970. An exception can be a large development that occurred over a short period in which most structures would have about the same age. Since construction practices change over time, so does the mix of structural types.

Hazus provides baseline mappings of specific occupancy classes to specific building types, examples of which may be found in the *Hazus Earthquake Model Technical Manual (FEMA, 2024)*. The baseline mapping schemes vary with assumed seismic zone (originally based on the Uniform Building Code [UBC] Seismic Zone). Baselines may need to be modified to reflect characteristics that are specific to a local region.

In addition to geographical location, the distributions can also depend on when the buildings were constructed and whether they are low-, medium-, or high-rise structures. Age is important because it affects the types of structures that exist in a region. For example, in California, unreinforced masonry (URM) structures were generally not built after 1940. Height is important when determining susceptibility to damage and loss. All Hazus baseline inventory is considered low-rise and should be updated as necessary.

5.7 Essential Facilities

Essential Facilities, including medical care facilities, emergency response facilities and schools, are those vital to emergency response and recovery following a disaster. School buildings are included in this category because of the role they often play in serving as public shelters and housing displaced people. Selecting Essential Facilities from the **Inventory > Essential Facilities** menu brings up the window shown in Figure 5-9. Mapping can be created by highlighting the column of interest in the database and clicking the **Map** button.



	ID Number	Class	Tract	Name
1	CA000001	EFS1	06001451202	ANDREW N. CHRISTENSEN MIDDLE
2	CA000019	EFS1	06001406202	ACHIEVE ACADEMY
3	CA000023	EFS1	06001440301	TOM KITAYAMA ELEMENTARY
4	CA000102	EFS1	06001436100	BOHANNON MIDDLE
5	CA000108	EFS1	06001426100	PIEDMONT MIDDLE
6	CA000118	EFS1	06001441501	PIONEER ELEMENTARY
7	CA000137	EFS1	06001409500	NEW HIGHLAND ACADEMY
8	CA000142	EFS1	06001441601	PATTERSON ELEMENTARY
9	CA000275	EFS1	06001423400	LONGFELLOW ARTS AND TECHNOLOGY
10	CA000336	EFS1	06001442200	MISSION SAN JOSE HIGH
11	CA000351	EFS1	06001409700	REEMS (ERNESTINE C.) ACADEMY OF T
12	CA000380	EFS1	06001426200	HAVENS ELEMENTARY
13	CA000395	EFS1	06001402500	KIPP BRIDGE CHARTER
14	CA000497	EFS1	06001402700	LAFAYETTE ELEMENTARY
15	CA000516	EFS1	06001437000	EDEN AREA ROP
16	CA000517	EFS1	06001420100	ALBANY MIDDLE
17	CA000537	EFS1	06001441800	WASHINGTON HIGH

Figure 5-9 Essential Facility Inventory

5.8 High Potential Loss Facilities

High Potential Loss Facilities (HPLF) include the following: dams, levees, nuclear power plants, and military installations. Selecting High Potential Loss Facilities from **Inventory > High Potential Loss Facilities** brings up the window as shown in Figure 5-10. While there is no baseline data for the High Potential Loss facilities with the exception of military facilities provided for PR, placeholder databases are available to accept user-input data.

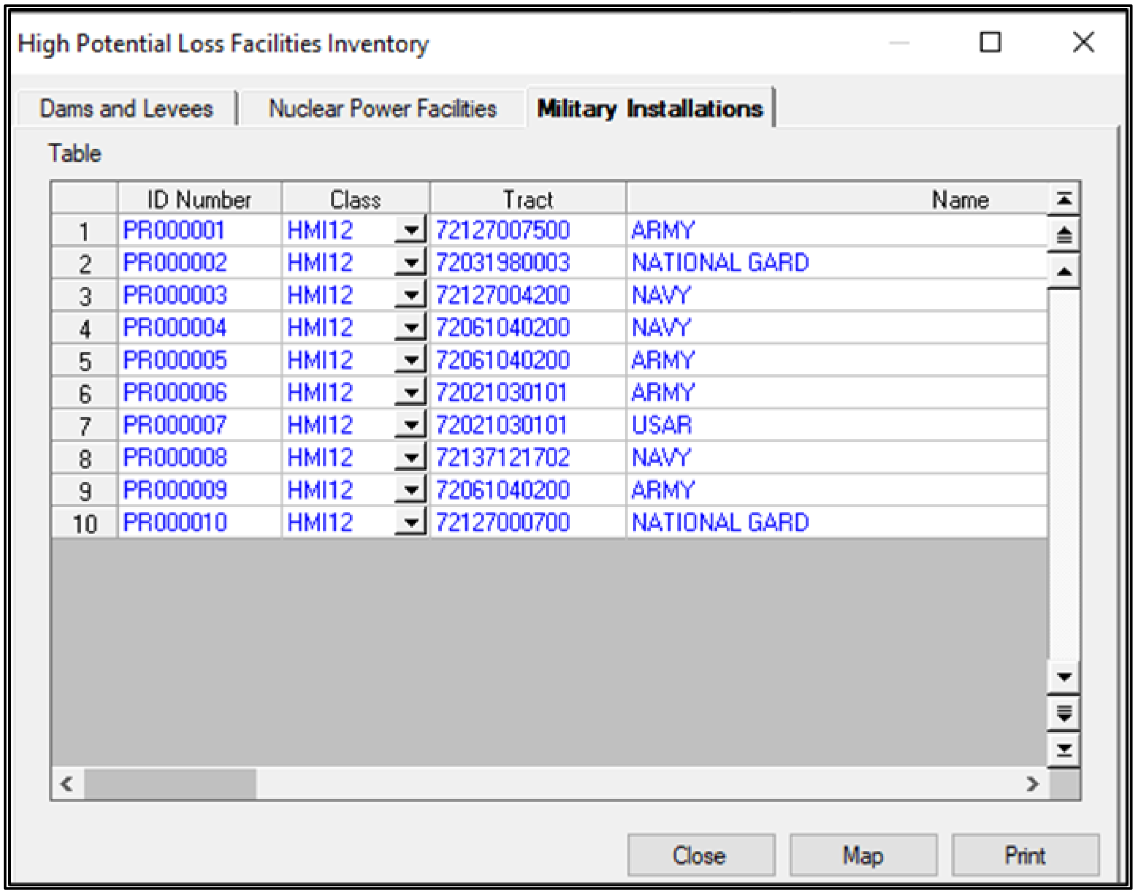


Figure 5-10 High Potential Loss Facilities Inventory for Puerto Rico

5.9 Transportation Systems

Transportation Systems include highways, railways, light rail systems, buses, ports, ferries, and airports. Selecting Transportation Systems from the **Inventory > Transportation Systems** brings up the window shown in Figure 5-11. Mapping can be created by selecting the transportation system of interest from the tabs at the top of the window, highlighting a column of interest in the database and clicking the **Map** button.

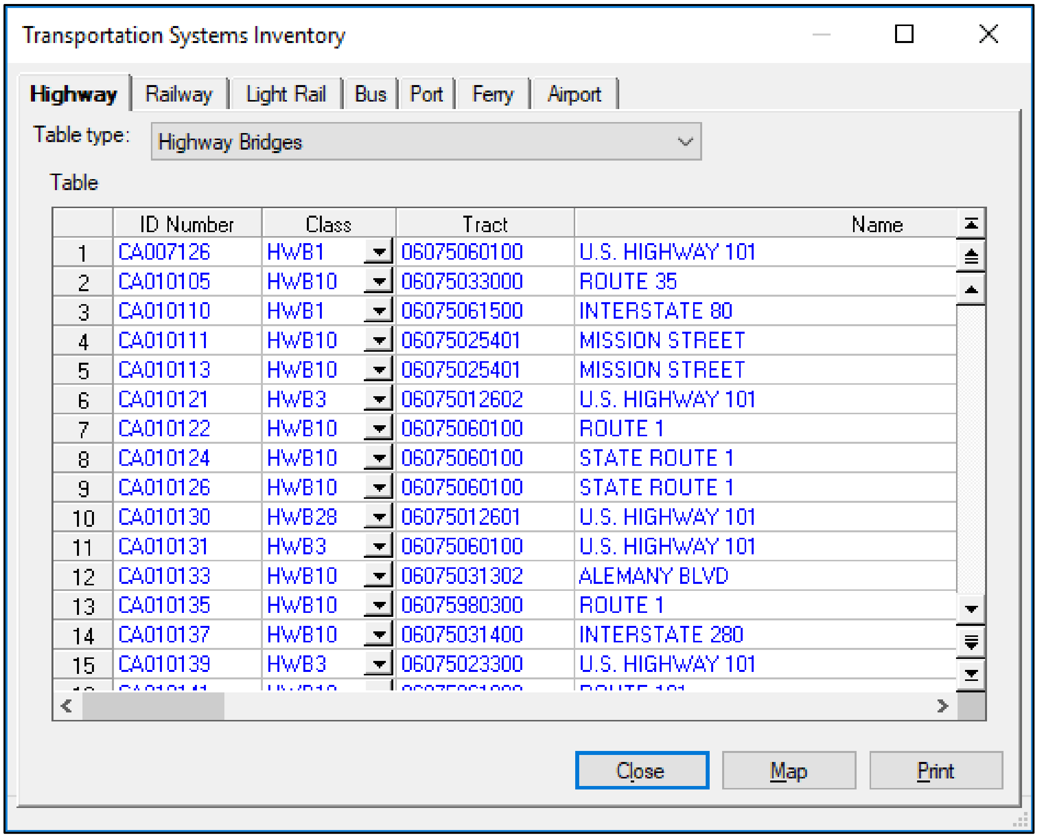


Figure 5-11 Transportation System Inventory

5.10 Utility Systems

Utility Systems include potable water, wastewater, oil, natural gas, electric power, and communications. Selecting Utility Systems from **Inventory > Utility Systems** brings up the window shown in Figure 5-12. Mapping can be created by selecting the utility system of interest from the tabs at the top of the window, highlighting a column of interest in the demographics database and clicking the **Map** button.

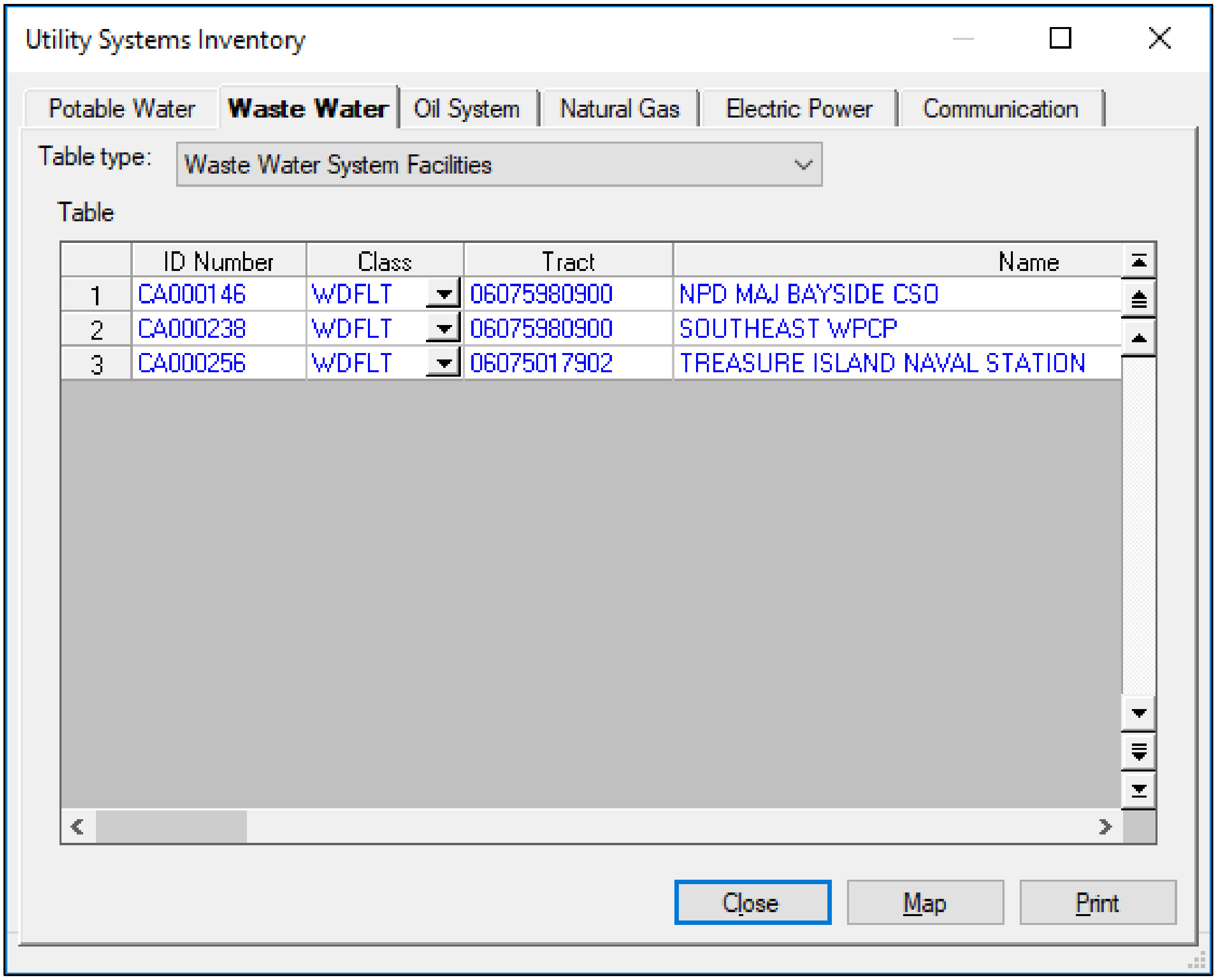
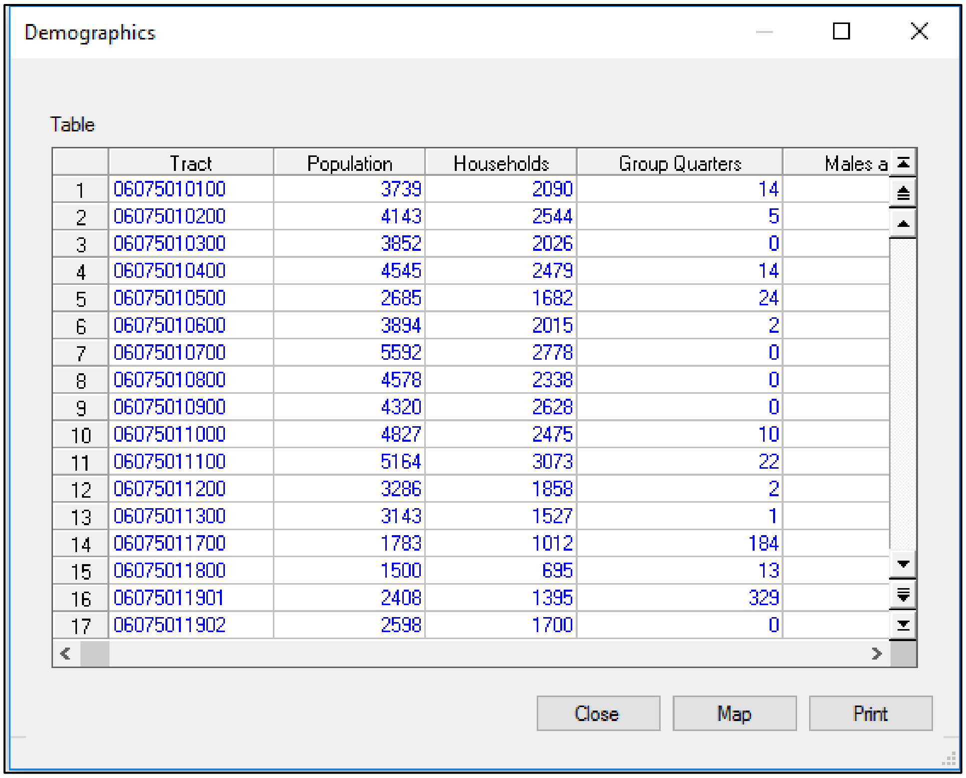


Figure 5-12 Utility Inventory

5.11 Demographics Data

Demographics data in Hazus are derived from the 2010 Census, have been aggregated to the Census tract, and can be viewed, modified, and mapped from the **Inventory > Demographics** menu as shown in Figure 5-13 and Figure 5-14. Mapping can be created by highlighting the column of interest in the database and clicking the **Map** button.



	Tract	Population	Households	Group Quarters	Males a
1	06075010100	3739	2090	14	
2	06075010200	4143	2544	5	
3	06075010300	3852	2026	0	
4	06075010400	4545	2479	14	
5	06075010500	2685	1682	24	
6	06075010600	3894	2015	2	
7	06075010700	5592	2778	0	
8	06075010800	4578	2338	0	
9	06075010900	4320	2628	0	
10	06075011000	4827	2475	10	
11	06075011100	5164	3073	22	
12	06075011200	3286	1858	2	
13	06075011300	3143	1527	1	
14	06075011700	1783	1012	184	
15	06075011800	1500	695	13	
16	06075011901	2408	1395	329	
17	06075011902	2598	1700	0	

Figure 5-13 Demographics Data View

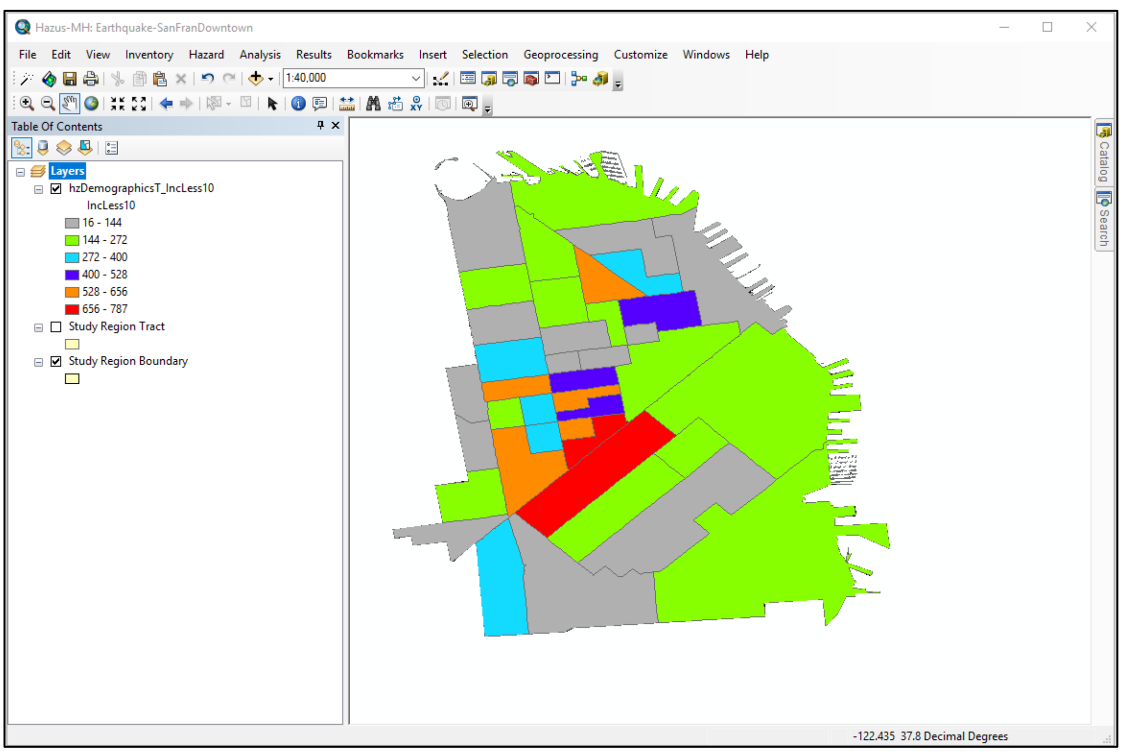


Figure 5-14 Demographics Data Mapping View

5.12 View Classification

View Classification will display classification codes for the various inventory menu items: General Building Stock, Essential Facilities, High Potential Loss Facilities, User-Defined Facilities, Transportation, and Utilities. Guidance related to inventory data associated with the Hazus Earthquake Methodology and software is detailed in the *Hazus Inventory Technical Manual* (FEMA, 2024).

Section 6. Earthquake Model: Hazard Menu

This section describes the Earthquake Model menus related to hazards. Hazus allows users to estimate losses based on one of three characterizations of the earthquake ground shaking hazard: deterministic hazard (scenario earthquake), probabilistic hazard, and user-supplied hazard (map of ground motion).

6.1 Selecting an Earthquake Scenario

A scenario earthquake is defined by its size and location and, when a fault is well defined, the fault rupture parameters. The definition of the scenario earthquake is not just a matter of earth science. Hazard management and political factors must be considered as well. Planning for mitigation and disaster response is generally based on large, damaging events, but the probability that such events will occur should also be considered. Significant research and experience have been gained over the years through the Earthquake Engineering Research Institute (EERI) scenario projects. The USGS also provides extensive guidance on the selection and development of earthquake scenarios. In addition, State Geological Surveys and regional seismic networks provide additional local expertise in the selection and development of realistic earthquake scenarios. Utilizing the USGS ShakeMap scenarios can help ensure that events are realistic and well-defined. Hazus results for many of these scenarios, as well as historic earthquakes are now published online in the Hazus Loss Library (HLL). Internal Hazus earthquake scenario definition options can allow the user to create unreasonable and unrealistic earthquake scenarios, however, the user is explicitly trusted to develop credible and useful approaches.

An earthquake scenario represents one realization of a potential future earthquake by assuming a particular magnitude, location, and fault-rupture geometry and estimating shaking using a variety of strategies. In planning and coordinating emergency response, utilities, local government, and other organizations are best served by conducting training exercises based on realistic earthquake situations. ShakeMap Scenario can also be used to examine exposure of structures, systems, utilities, and transportation corridors to specified potential earthquakes. A ShakeMap earthquake scenario is a predictive ShakeMap with an assumed magnitude and location, and, optionally, specified fault geometry.

Users are encouraged to utilize the USGS Scenario Catalogs:. These comprise credible events developed in consultation with the scientific community, with ground motion data produced by the latest scientific methods and source parameters. Specifically, the Building Seismic Safety Council (2014) Event Set was developed using a comprehensive set of sources incorporated in the development of the USGS national seismic hazard maps.

The Hazus earthquake scenario interface is designed to directly discover and link to online USGS ShakeMap scenarios that could impact a user's Study Region. The design includes searching for events that occur outside the area, but close enough to potentially result in Study Region losses;

however, some large regional scenarios can still be missed by the initial search parameters and users may need to expand their online search rectangle.

In regions where there may not be sufficient scenario ShakeMap coverage, such as the Atlantic seaboard or upper Midwest, internal Hazus options are available. In these cases, consideration should be given to calculating losses using several scenario earthquakes in which each scenario would be defined by different magnitudes, locations, and probabilities of occurrence since these factors are a major source of uncertainty.

Earthquake size is measured in Hazus by moment magnitude (M). Location is defined by latitude and longitude. It is important to note that the scenario event does not have to occur within the limits of the defined Study Region.

Rupture length is automatically computed by Hazus but can be overwritten by the user when the analysis is being done in the western states with western attenuation functions. A description of the technical approach to defining an earthquake scenario is provided in the *Hazus Earthquake Model Technical Manual (FEMA, 2024).* The rupture length is measured in kilometers. Hazus uses a relationship between rupture length and magnitude to estimate the default rupture length (Wells and Coppersmith, 1994).

One approach for scenario selection is to base the scenario earthquake on the largest earthquake known to have occurred in or near the region. This assumes that if such an earthquake has occurred before, it can occur again. Hazus includes a database of historical earthquakes based on the Global Hypocenter Database available from the National Earthquake Information Center (NEIC) (USGS, 1989), updated with additional data received from the NEIC in 2010. The NEIC database contains reported earthquakes from 300 BCE (before common era) to 2009 used in the development of the USGS national seismic hazard maps. Users can access the database by clicking **Historical epicenter event** and then selecting a historical earthquake for the scenario event. If several active faults exist in the region, it is appropriate to select maximum historical events from each fault and perform a loss study for each of the scenarios.

Once an event based on an historical epicenter has been chosen, the analysis can be run with that event or the earthquake can be modified. Users have the option to change the magnitude, earthquake depth, rupture length, and orientation of the rupture. The location of the event cannot be changed if a historical epicenter has been chosen. If a different location is to be used, select a different historical event or use the **Arbitrary Event** option.

In Hazus version 3.2, a new hazard interface was added to the Earthquake Scenario Wizard to allow users with an Internet connection to directly import USGS ShakeMap products for actual earthquakes, or to access previously downloaded ShakeMap grid data. This interface was updated with Hazus 4.2 Service Pack 2 to include online access to scenario ShakeMaps. The Earthquake Model has been integrated with USGS ShakeMap, allowing the importing of ground motion maps from significant earthquake events, as well as earthquake scenarios. If a user does not wish to use the new direct import functionality, the Earthquake Model preserves the ability for users to import their own Hazus-compliant ShakeMap data as User-Supplied Hazard Maps (see Section 6.8).

6.1.1.1 ShakeMap Overview

ShakeMap is a product of the USGS Earthquake Hazards Program in partnership with regional seismic networks and leverages additional localized data. ShakeMap provides near-real-time maps and digital data of ground motion and shaking intensity following significant earthquakes. The loss estimates identified after running analyses using ShakeMap data in Hazus can help emergency personnel respond appropriately in areas of immediate need. Federal, state, and local agencies and non-profits organizations use these maps for post-earthquake response and recovery, public and scientific information, preparedness exercises, and disaster planning.

A ShakeMap is a representation of ground shaking produced by an earthquake. The information it presents is different from the earthquake magnitude and epicenter that are released after an earthquake because ShakeMap focuses on the ground shaking produced by the earthquake, rather than the parameters describing the earthquake source. So, while an earthquake has one magnitude and one epicenter, it produces a range of ground shaking levels at sites throughout the region depending on distance from the earthquake, the rock and soil conditions at sites, and variations in the propagation of seismic waves from the earthquake due to complexities in the structure of the Earth's crust. More detailed scientific information for these maps can be found at the USGS ShakeMap website.

The ground motion map types required by Hazus for loss estimation analysis are:

- Peak Ground Acceleration Maps (PGA)
- Peak Ground Velocity Maps (PGV)
- Spectral Acceleration at 0.3 second period (SA 0.3)
- Spectral Acceleration at 1.0 second period (SA 1.0)

6.1.1.2 Using ShakeMap in Hazus

There are two methods of using ShakeMap data in the Hazus Earthquake Model: (1) directly downloading the grid data into the Study Region using the ShakeMap download interface and (2) importing the four ground motion contour maps as personal geodatabase feature classes in the Study Region.

6.1.1.3 Using ShakeMap Download Interface in Hazus

Once the Study Region for using the direct import tool is created, follow the steps below to acquire the appropriate ShakeMap. Real ShakeMap events are used within given radius.

1. In the Study Region, go to **Hazard > Scenario > Next** and choose Define a new scenario, as shown in Figure 6-1. Click Next>.

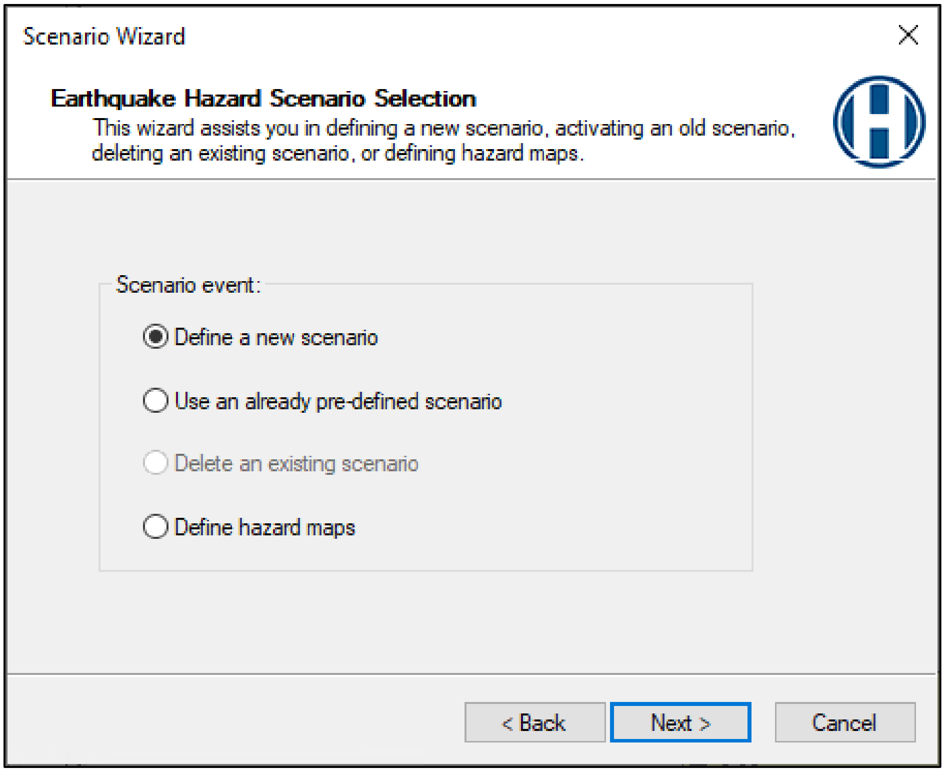


Figure 6-1 ShakeMap Earthquake Scenario Selection

2. Choose **USGS ShakeMap** (Figure 6-2) and click **Next>.**

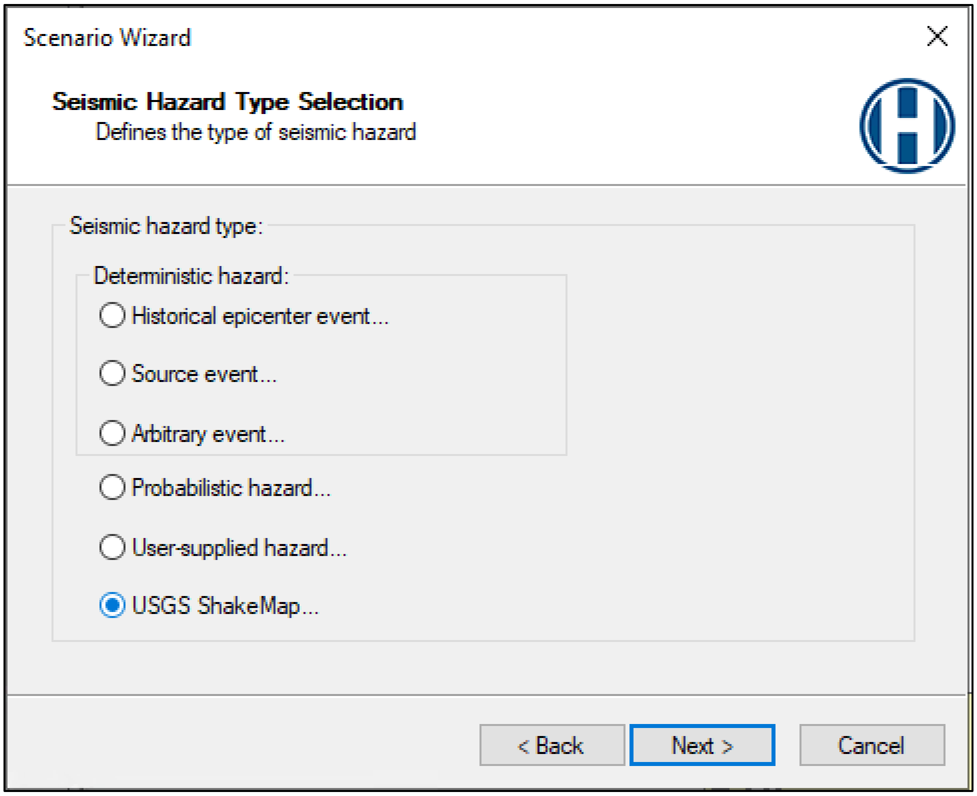


Figure 6-2 ShakeMap Earthquake Seismic Hazard Selection

3. The ShakeMap Download window will open (Figure 6-3). Users can select from a list of ShakeMap Events or ShakeMap Scenarios for download using the radio button at the upper left, and then select the event of interest from the left pane or adjust their USGS search parameters as needed. Hazus will search beyond the user's Study Region for actual events that may impact the region but occurred outside the region. The search distances from the Study Region increase with magnitude and if the user is in a central or eastern U.S. state (Table 6-1).

Table 6-1 ShakeMap Search Distances

U.S. Region	M 5 to 6	M 6 to 7	M 7 to 8	M > 8
Central or East	200 km	400 km	600 km	NA
West	0	50 km	100 km	600 km

"M" = Magnitude, "NA" = not applicable

Highlighting an event in the left pane will display the properties and details in the two large windows on the right. For some events, USGS may offer multiple grid files for download. In this case, a pop-up will appear with all available files and ask the user to select one. A "preferred weight" value is provided for each file, and it is recommended the user select the largest preferred weight. If a grid.xml file was downloaded previously and is stored on the local machine, users can re-import this file using the **Browse for existing ShakeMap grid data** button.

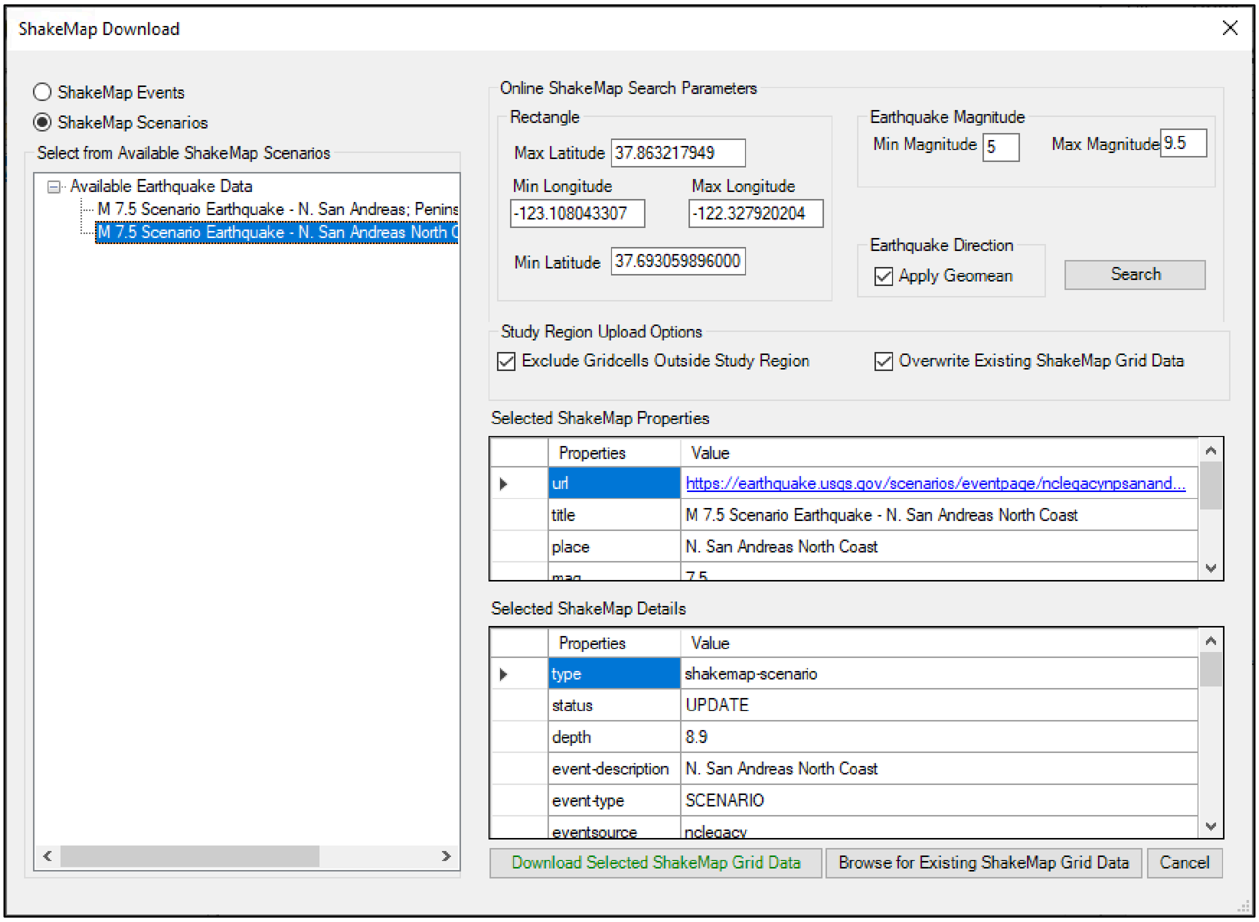


Figure 6-3 ShakeMap Download Window

4. Once an event is selected, click **Download Selected ShakeMap Grid Data** to import the ShakeMap data (Figure 6-4). A notice indicating the download is taking place will appear. A notice that the download is not responding is dependent on the user's machine and does not mean the download has stopped. Please be patient; download time will vary depending on the size of the event file and the speed of the user's Internet connection.

   Please note that both shapefiles and a personal geodatabase are downloaded. The complete .xml file is downloaded to: HazusData\HazardInput\EQ\Shakemap.The shape files are downloaded to: StudyRegionName\shape\ and the complete geodatabase is downloaded to: StudyRegionName\HazusShakemap.mdb.

5. Once the download is complete, the user will be guided through the rest of the Scenario Wizard (Figure 6-5). The user will need to confirm the event parameters imported from ShakeMap before completing the wizard. This interface will automatically label the four ground motion map layers, insert the magnitude and name the scenario. Additional

ShakeMap metadata parameters are extracted from the grid.xml header and stored in the eqShakeMapScenario table in the study region SQL database that may be accessed using SQL Server Management Studio (SSMS).

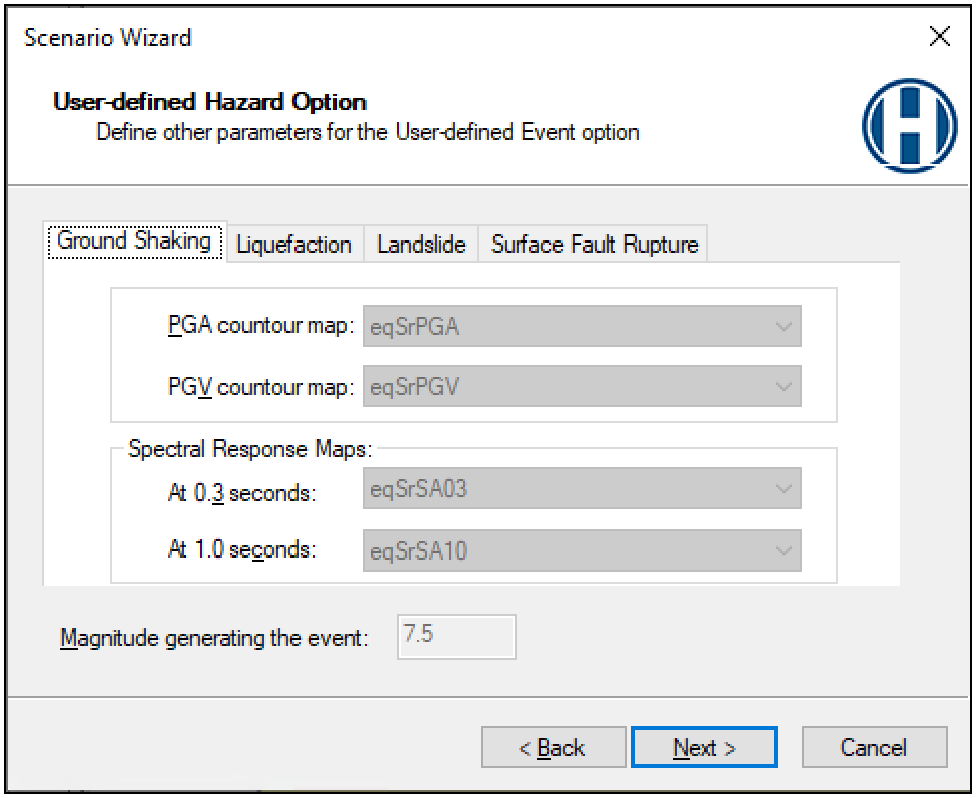


Figure 6-4 User-Defined Event Name

As outlined, the ShakeMap magnitude is used for the purpose of estimating earthquake duration and will not impact the ground motions. The scenario name incorporates the ShakeMap version number that is critical in tracking results, since the ShakeMap products are frequently updated with new observations, as well as improvements to methods and source parameters. New versions of the same earthquake event or scenario may result in significant changes in Hazus losses. In addition, certain events may show that multiple ShakeMaps are available from different networks that recorded and analyzed the earthquake (Figure 6-5). Hazus uses a weighting criterion based on the authoritative networks of the Advanced National Seismic System to list the recommended version first.

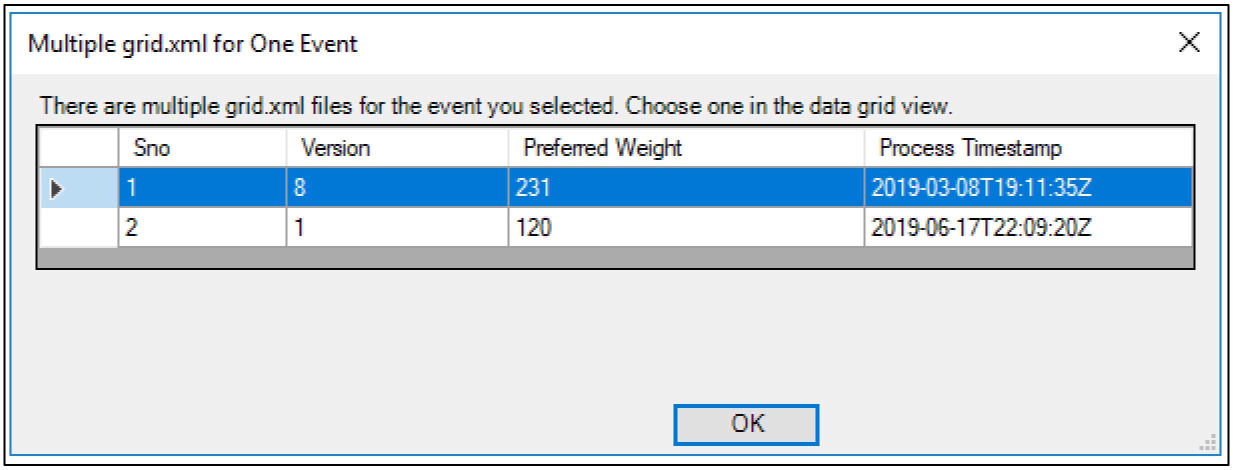


Figure 6-5 Generated Event List

It should be noted that USGS may limit the types of ShakeMap data available for download to Hazus. By default, Hazus will search for events occurring within the last 90 days and with a magnitude of 5.0 or greater. The 90-day window can be manually adjusted within Hazus (see Step 3 above), but it may benefit the user to check the USGS ShakeMap download archive for event availability prior to creating a Study Region.

6.1.2 Including Site Effects in the Analysis

The type of soil in the Study Region affects the amplitude of the ground motion. Soft soils tend to amplify certain frequencies within the ground shaking, resulting in greater damage. To include the effects of soils for Hazus scenarios that do not utilize amplified USGS ground motion data (ShakeMaps or amplified probabilistic ground motions), the user must supply a soil map. If a soil map is not supplied, Hazus bases ground motions on the default soil type (NEHRP Soil Class D/Stiff Soil). A digitized soil map can be imported into Hazus (see Section 6.6).

There are a variety of schemes for classifying soils, but Hazus uses the 1997 NEHRP Provisions classification scheme, based on the average shear wave velocity of the upper 30 meters of the local site geology (Table 6-2), with the default soil class being soil Class D (stiff soil). Refer to the *Hazus Earthquake Model Technical Manual (FEMA, 2024)* for more information on soil classification. A geotechnical engineer or geologist is required to convert the classification scheme of any user-supplied soil map for input into Hazus.

Table 6-2 Hazus Site Soil Classes (from the 1997 NEHRP Provisions)

Site Class	Site Class Description	Shear Wave Velocity (m/sec)	
		Minimum	Maximum
A	Hard Rock	1,500	
B	Rock	760	1,500

Site Class	Site Class Description	Shear Wave Velocity (m/sec)	
		Minimum	Maximum
C	Very Dense Soil and Soft Rock	360	760
D	Stiff Soils	180	360
E	Soft Soils		180
F	Soils Requiring Site-Specific Evaluations		

6.1.3 Including Ground Failure in the Analysis

Three types of ground failure are considered in Hazus: liquefaction, landslide, and surface fault rupture. Each ground failure type is quantified by permanent ground deformation (PGD), measured in inches. User provided values or susceptibility maps are required for Hazus to perform an assessment of PGD. PGD contributes to the losses of all inventory types and is entirely responsible for losses to many surface-built inventories, such as highways, railway track segments, and airport runways. Without user input, Hazus assumes no PGD occurs, and losses to these facility types are not assessed. When susceptibility data are provided, Hazus will evaluate and assign the area weighted average susceptibility for each Census tract for use with the GBS damage and loss calculations. When using large (>0.5gb) or very detailed (e.g., 1 arcsecond or higher) resolution liquefaction or landslide susceptibility maps, they may fail to add susceptibility values to all inventory items, especially polyline. Once these hazard maps are added to your scenario, map these inventory items and if no or default susceptibilities are assigned, please contact FEMA-Hazus-Support@fema.dhs.gov to obtain a process to manually update these.

6.1.3.1 Liquefaction

Liquefaction is a soil behavior phenomenon in which a saturated soil loses a substantial amount of strength, causing the soil to behave somewhat like a liquid. Soil may boil up through cracks in the ground and lose most of its strength and stiffness, which can cause uneven settlement of the soil or spreading of the soil. The result is that structures founded on soils that have liquefied tend to have more damage than those on other types of soils. Liquefaction can be particularly significant for systems where roads become bumpy, cracked, and unusable or underground pipelines break because of liquefaction. Silty and clayey soils tend to be less susceptible than sandy soils to liquefaction-type behaviors.

PGDs are commonly considered significant potential hazards associated with liquefaction because of lateral spreads or flow slides and differential settlement. Lateral spreads are ground failure phenomena that occur near abrupt topographic features (e.g., free-faces) and on gently sloping ground underlain by liquefied soil. Lateral spreading movements may be on the order of inches to several feet or more and are typically accompanied by surface fissures and slumping. Flow slides generally occur in liquefied materials on steeper slopes and may involve ground movements of hundreds of feet. As a result, flow slides can be the most catastrophic of the liquefaction-related ground-failure phenomena. Fortunately, flow slides are much less common than lateral spreads.

Settlement is a result of particles moving closer together into a denser state. Settlement can occur in both liquefied and non-liquefied zones with significantly larger contributions to settlement expected to result from liquefied soil. Since soil characteristics vary over even relatively small areas, settlements may occur differentially. Differential settlement can cause severe damage to structures and pipelines because it may tear them apart.

To include liquefaction in the analysis, users may specify a liquefaction susceptibility map. The three steps involved in the evaluation of liquefaction hazard are as follows:

1. Characterize liquefaction susceptibility (none to very high)
2. Assign probability of liquefaction
3. Assign expected permanent ground deformations.

Hazus performs steps 2 and 3 based on the user's characterization of liquefaction susceptibility considering the hazard parameters described below. A liquefaction susceptibility map, showing the susceptibility throughout the Study Region or for each Census tract, is a result of the first step. An experienced geotechnical engineer, familiar with both the region and with liquefaction, should be consulted in developing this map. These hazard maps are frequently developed by State Geological Surveys in high seismic zones. The relative liquefaction susceptibility of the soil (geologic conditions) in a region or subregion is characterized by using geologic map information and the classification system presented in Table 6-3.

Table 6-3 Liquefaction Susceptibility of Sedimentary Deposits

Type of Deposit	General Distribution of Cohesionless Sediments in Deposits	Likelihood that Cohesionless Sediments when Saturated Would Be Susceptible to Liquefaction (by Age of Deposit)			
		< 500 yr Modern	Holocene < 11 ka	Pleistocene 11 ka – 2 Ma	Pre-Pleistocene 11 ka – 2 Ma
Continental Deposits					
River channel	Locally variable	Very High	High	Low	Very Low
Floodplain	Locally variable	High	Moderate	Low	Very Low
Alluvial fan and plain	Widespread	Moderate	Low	Low	Very Low
Marine terraces and plains	Widespread	—	Low	Very Low	Very Low
Delta and fan-delta	Widespread	High	Moderate	Low	Very Low
Lacustrine and playa	Variable	High	Moderate	Low	Very Low
Colluvium	Variable	High	Moderate	Low	Very Low
Talus	Widespread	Low	Low	Very Low	Very Low
Dunes	Widespread	High	Moderate	Low	Very Low
Loess	Variable	High	High	High	Unknown
Glacial till	Variable	Low	Low	Very Low	Very Low
Tuff	Rare	Low	Low	Very Low	Very Low
Tephra	Widespread	High	High	?	?
Residual soils	Rare	Low	Low	Very Low	Very Low
Sebka	Locally variable	High	Moderate	Low	Very Low
Coastal Zone					
Delta	Widespread	Very High	High	Low	Very Low
Estuarine	Locally variable	High	Moderate	Low	Very Low
Beach - High Wave Energy	Widespread	Moderate	Low	Very Low	Very Low
Beach - Low Wave Energy	Widespread	High	Moderate	Low	Very Low
Lagoonal	Locally variable	High	Moderate	Low	Very Low
Fore shore	Locally variable	High	Moderate	Low	Very Low

Type of Deposit	General Distribution of Cohesionless Sediments in Deposits	Likelihood that Cohesionless Sediments when Saturated Would Be Susceptible to Liquefaction (by Age of Deposit)			
		< 500 yr Modern	Holocene < 11 ka	Pleistocene 11 ka – 2 Ma	Pre-Pleistocene 11 ka – 2 Ma
Artificial					
Uncompacted Fill	Variable	Very High	—	—	—
Compacted Fill	Variable	Low	—	—	—

High resolution (1:24,000 or greater) or lower resolution (1:250,000) geologic maps are generally available for many areas from geologists or regional USGS offices, state geological agencies, or local government agencies. The geologic maps typically identify the age, environment of the deposit, and material type for a particular mapped geologic unit. A depth-to-groundwater map is also a helpful reference and can be incorporated into Hazus as a separate map layer (see Section 6.6). In the absence of user-supplied groundwater depth maps, Hazus assumes a uniform, shallow depth to groundwater of 5 feet. Based on these characteristics, a relative liquefaction susceptibility rating (very low to very high) can be assigned from Table 6-3 to each soil type.

Based on the liquefaction susceptibility, depth to groundwater and the PGA, the probability of liquefaction is assigned during the analysis. Areas of geologic materials characterized as rock or rock-like are considered for the analysis in order to present no liquefaction hazard.

Finally, in order to evaluate the potential losses due to liquefaction, an expected PGD in the form of ground settlement or lateral spreading is assigned. The PGD is based on PGA, liquefaction susceptibility. Hazus assigns PGD using a procedure derived from experience as discussed in the *Hazus Earthquake Model Technical Manual (FEMA, 2024)*.

6.1.3.2 Landslide

As with liquefaction, to include landslide in the analysis, users must specify a landslide susceptibility map using the steps outlined in Section 6.6. The three steps involved in the evaluation of landslide hazard are as follows:

1. Characterize landslide susceptibility (I to X)

2. Assign probability of landslide

3. Assign expected permanent ground deformations.

Hazus performs steps 2 and 3 based on the user's characterization of landslide susceptibility and the hazard parameters described below. A landslide susceptibility map, showing the susceptibility throughout the Study Region or for each Census tract, is a result of the first step. An experienced geotechnical engineer, familiar with both the region and with earthquake-caused landslides should be consulted in developing this map. The methodology provides basic rules for defining the landslide susceptibility based on the geologic group, ground water level, slope angle, and the critical acceleration (a_c). Landslide susceptibility is measured on a scale of I to X, with X being the most susceptible. The geologic groups and associated susceptibilities are summarized in Table 6-4. Once landslide susceptibility has been determined, Hazus provides baseline values for probability of landslide for each landslide susceptibility category and estimates the expected PGD as a function of ground acceleration. The *Hazus Earthquake Model Technical Manual (FEMA, 2024)* describes the procedure in detail.

Table 6-6 Landslide Susceptibility* of Geologic Groups

DRY (groundwater below level of sliding)	0–10	10–15	15–20	20–30	30–40	>40
A: Strongly Cemented Rocks (crystalline rocks and well-cemented sandstone)	None	None	I	II	IV	VI
B: Weakly Cemented Rocks and Soils (sandy soils and poorly cemented sandstone)	None	III	IV	V	VI	VII
C: Argillaceous Rocks (shales, clayey soil, existing landslides, and poorly compacted fills)	V	VI	VII	IX	IX	IX

WET (groundwater level at ground surface)	0–10	10–15	15–20	20–30	30–40	>40
A: Strongly Cemented Rocks (crystalline rocks and well-cemented sandstone)	None	III	VI	VII	VIII	VIII
B: Weakly Cemented Rocks and Soils (sandy soils and poorly cemented sandstone)	V	VIII	IX	IX	IX	X
C: Argillaceous Rocks (shales, clayey soil, existing landslides, and poorly compacted fills)	VII	IX	X	X	X	X

** Landslide susceptibility (Slope Angle, Degrees) is measured on a scale of I to X, with X being the most susceptible*

6.1.3.3 Surface Fault Rupture

When an earthquake occurs, it is possible for the fault rupture to extend from its initiation at some depth all the way to the ground surface. Many earthquakes do not exhibit evidence of rupture at the ground surface, particularly in the eastern United States. Generally, surface fault rupture is observed only in the western United States and Alaska. When it occurs, displacements due to surface fault rupture can be on the order of several meters and can be a significant contributor to damage if a structure crosses or is built on top of the fault rupture. Pipelines, roadways, bridges, and railways that cross faults are vulnerable to surface fault rupture.

Surface fault rupture can be included by selecting the **General Buildings > Ground Failure** when the analysis is run. Hazus provides a default relationship between moment magnitude (**M**) and the displacement in meters that can result from surface fault rupture (see the *Hazus Earthquake Model Technical Manual (FEMA, 2024)* for more information). For any location along the fault rupture, fault displacement can occur, but the amount of fault displacement is described by a probability distribution.

6.2 Types of Earthquake Hazard Data Inputs

6.2.1 Deterministic Earthquake Hazards

For deterministic earthquakes (both actual and scenario), USGS ShakeMaps are the preferred data source recommended by FEMA and the USGS NEIC.

6.2.1.1 USGS ShakeMap

The utilization of USGS ShakeMaps is now the primary recommended source for deterministic hazard data for use in Hazus. USGS ShakeMaps are now widely available for both real events and scenarios through a direct data integration feed. USGS ShakeMaps for actual earthquake events incorporate ground motion recordings from instrumentation, earthquake source parameters developed by a seismologist, as well as felt earthquake report data. USGS ShakeMaps for scenario earthquakes are developed by the scientific community, incorporate the latest science in terms of ground motion modeling, as well as site soil amplification. Further, the entire set of available Hazus building fragility functions have been specifically calibrated for use with ShakeMap as the input ground motion data. Rather than assigning ground motions based on the Census tract centroid, as with the internal Hazus approach, with the Hazus integration of the ShakeMap grid, ground motion data are area weighted and averaged across the entire Census tract. Hazus incorporates an online interface to retrieve both actual earthquake and scenario ShakeMaps directly from the USGS. Section 6.3 of this document provides details on ShakeMap and how it can be incorporated into Hazus analyses. In areas where ShakeMap scenarios may be limited, internal Hazus options are available to model ground motions.

6.2.1.2 Alternative Deterministic Earthquake Hazard Sources

In the event that the desired scenario or event characterization is not available from the USGS, Hazus can define the **deterministic hazard** as a historical epicenter event, source event, or arbitrary event:

- **Historical Epicenter Event**: The historical epicenter event definition consists of selecting the desired event from the Hazus database of more than 6,000 historical events. For each historical event, the database includes a magnitude and depth, both of which can be overridden. The desired event can be selected from a list box or graphically from a map. The user will also need to select an attenuation relationship, although a default relationship will be suggested (Section 6.7.1).

- **Source Event:** For the western United States, the source event definition consists of selecting the desired fault source from the Hazus database of faults. The user can override the width, type, magnitude, and rupture length of the selected source event. The user graphically defines the epicenter of the event (on the fault map). The user will also need to select an attenuation relationship, although a default relationship will be suggested (Section 6.7.2).
- **Arbitrary Event:** An arbitrary earthquake event is defined by the location of its epicenter and its magnitude. The epicenter is defined by entry of latitude and longitude or graphically on a map. The user selects the attenuation relationship, inputs the epicenter lat/long, and specifies various event parameters, which depend on the selected attenuation relationship but generally include the magnitude and depth, and may also include rupture width, rupture orientation, and length (Section 6.7.3).

6.2.2 Probabilistic Earthquake Hazards

The **probabilistic hazard** option allows the user to generate estimates of damage and loss based on probabilistic seismic hazard for eight return periods assigned to each Census tract in the Study Region. Probabilistic hazard data are provided by the USGS and are derived from the latest national seismic hazard maps. In addition, the probabilistic ground motion data, like ShakeMap, include soil amplification (Section 6.8). However, if the user imports their own soils data, Hazus will use that data to provide the soil amplification for the USGS probabilistic ground motion maps.

6.2.2.1 Annualized Loss

An additional option in Hazus that utilizes probabilistic hazard data is **Annualized Loss**. Annualized loss is defined as the expected value of loss in any one year and is developed by aggregating losses calculated for the eight specified probabilistic return periods (100, 250, 500, 750, 1000, 1500, 2000 and 2500 year) and their exceedance probabilities (Section 6.8). Refer to the *Hazus Earthquake Model Technical Manual (FEMA, 2024)* and the USGS National Seismic Hazard Map for more details.

6.2.2.2 Return Period

A return period is a recurrence interval is an average time or an estimated average time between events. Typically, it is a statistical measurement based on historic data over an extended period and is used usually for risk analysis. The Hazus Earthquake Model has eight return periods (100, 250, 500, 750, 1000, 1500, 2000 and 2500 year).

6.2.3 User-supplied Earthquake Hazards

The **user-supplied hazard** (Section 6.8) option requires the user to supply digitized peak ground acceleration (PGA), peak ground velocity (PGV) and spectral acceleration (SA) contour maps (SA at 0.3 second and SA at 1.0 second). Damage and losses are computed based on the user-supplied maps.

6.3 Defining a New Scenario

Before an earthquake loss analysis can be run, the user must define the earthquake hazards that will serve as a basis for evaluating damage and losses. For an earthquake loss analysis, this involves selecting the USGS ShakeMap or identifying the size and location of the earthquake and estimating its associated ground motions and ground deformations due to ground failure. For this methodology, ground deformations due to liquefaction, landslides, and surface fault rupture can be included.

Click the **Hazard** menu, as shown in Figure 6-6 Hazard Definition Menu. Clicking the **Scenario** option allows users to define the earthquake hazard.

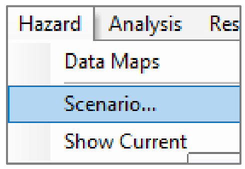


Figure 6-6 Hazard Definition Menu

The Scenario Wizard for entering a new event or hazard will appear. Select "Define a new scenario" to begin the scenario definition process and press **Next** (Figure 6-7). To import ShakeMap ground motions, click on **USGS ShakeMap**, then **Next>** (Figure 6-8). By default, the "ShakeMap Events" radio button in the upper left-hand corner will be selected. To search for scenario ShakeMaps, click the "ShakeMap Scenarios" radio button, and then click the Search button on the ShakeMap Download menu (Figure 6-9) to view scenario ShakeMaps located in the area. For more information regarding ShakeMaps please refer to Section 4, running additional analyses are covered later in Section 6.

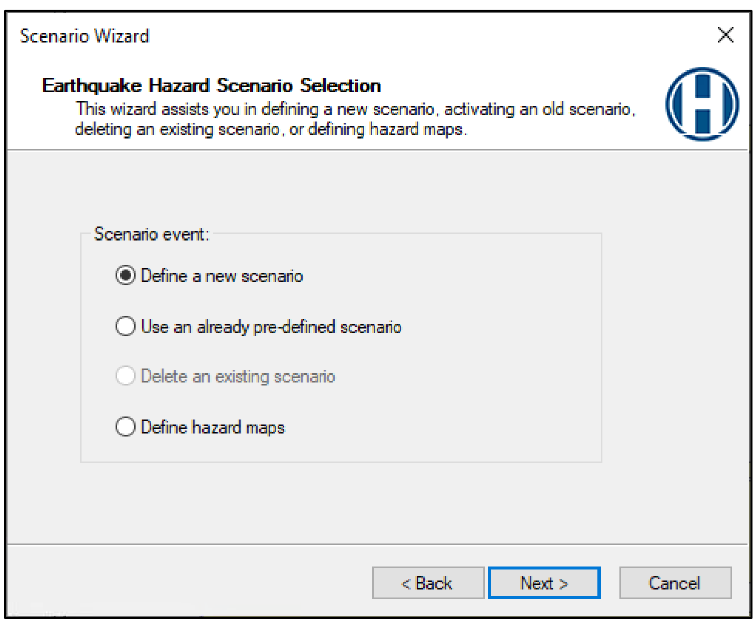


Figure 6-7 Earthquake Hazard Scenario Selection Window

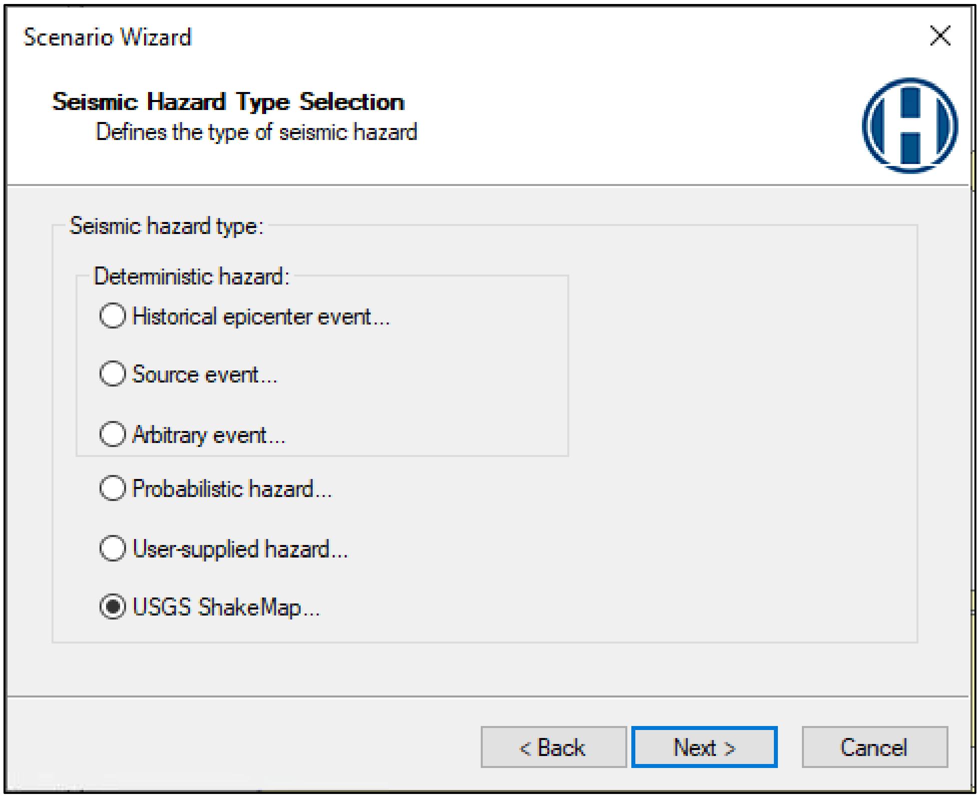


Figure 6-8 Earthquake Hazard Scenario Window

Select a ShakeMap event that appears in the display box and then click **Download Selected ShakeMap Grid Data** (Figure 6-9). Once the download is complete click **Next>** three more times to activate the ShakeMap scenario.

If no events appear, input parameters may need to be adjusted. Increasing the Earthquake Time Frame for Events or widening the Search Rectangle for Scenarios may help. If ShakeMap scenarios do not appear, other options can be used, such as source, historic and arbitrary.

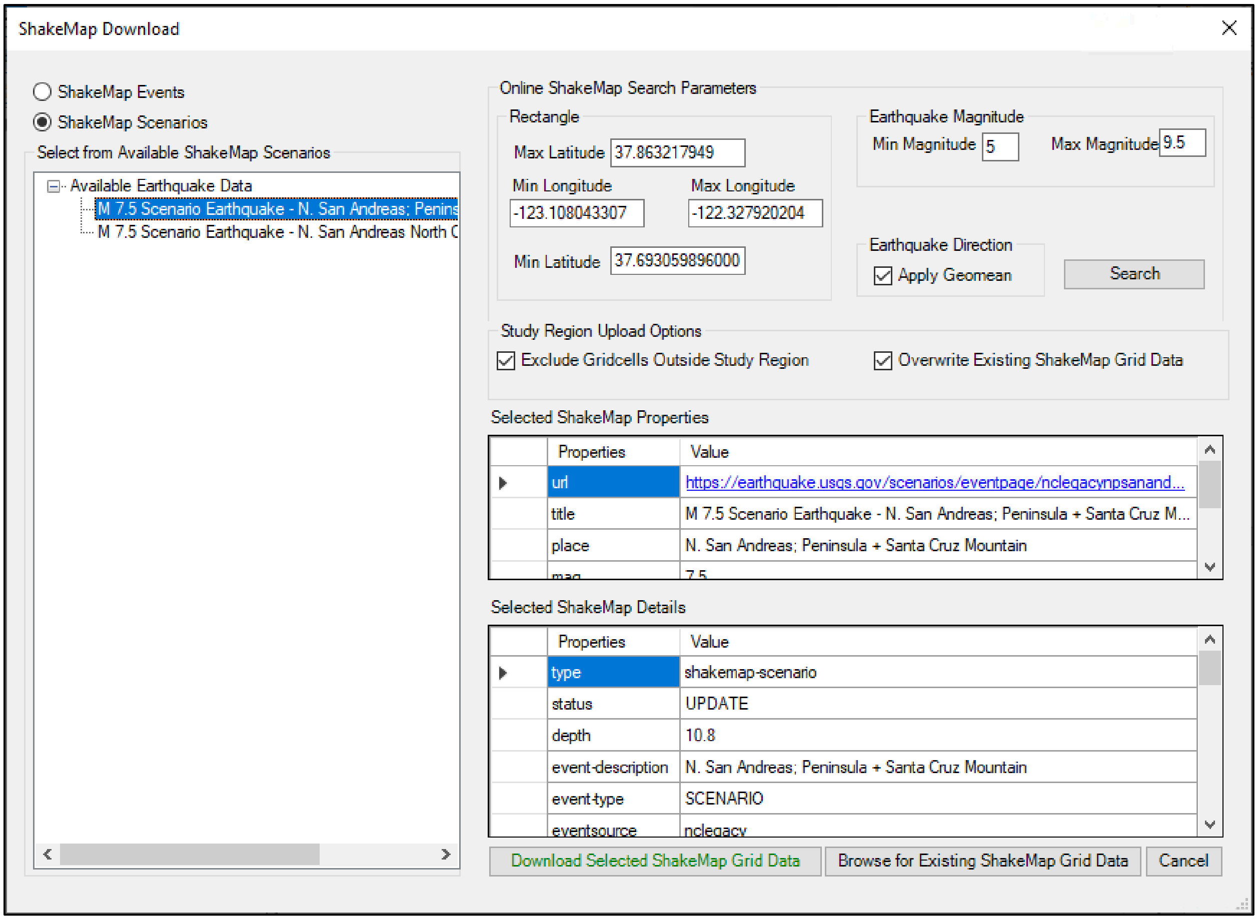


Figure 6-9 Defining a ShakeMap Earthquake Event

6.4 Using Pre-Defined Scenarios

If a scenario has already been defined in the current Study Region, users can use the pre-defined scenario to estimate losses. From the **Hazard** menu, select **Scenario** and click **Next>** to bring up the **Earthquake Hazard Scenario Selection** window (Figure 6-10). Select “**Use an already pre-defined scenario**” and click **Next>** to bring up a pick list of available scenarios (Figure 6-11).

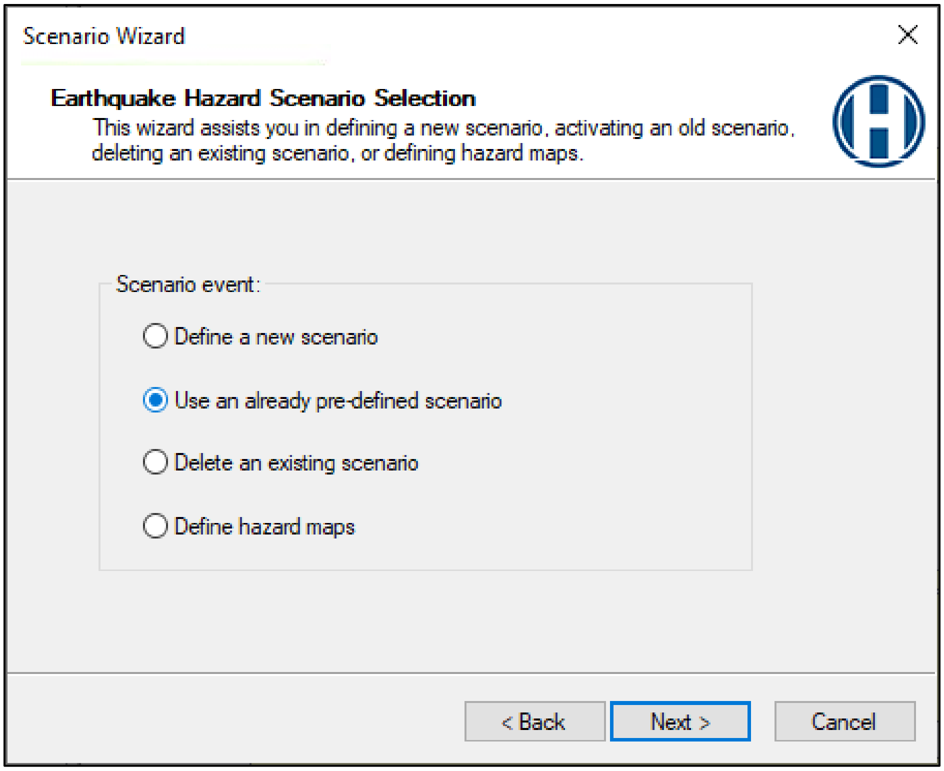


Figure 6-10 Open a Pre-defined Scenario

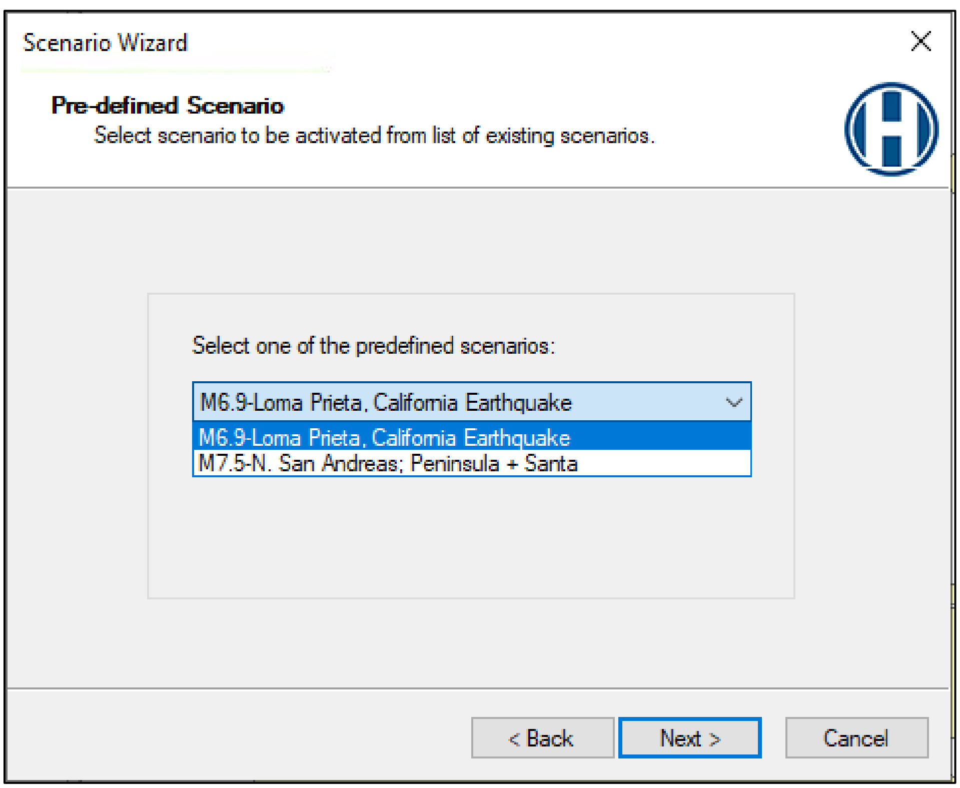


Figure 6-11 Select a Pre-Defined Scenario

6.5 Deleting an Existing Scenario

The **Delete an existing scenario** option under the **Scenario event** menu, shown in Figure 6-12, allows users to delete scenarios that are no longer needed. The **Delete an existing scenario** option allows users to delete multiple scenarios all at once by clicking on the scenarios. Select **Delete an existing scenario** from the **Scenario event** menu. The **Delete Existing Scenario** dialog will appear (Figure 6-13). Select the scenario(s) to be deleted and click **Next>**. To select multiple entries at one time, hold down the <Ctrl> key while selecting. Confirm and finalize the deletion of selected scenarios by clicking **Finish** (Figure 6-14).

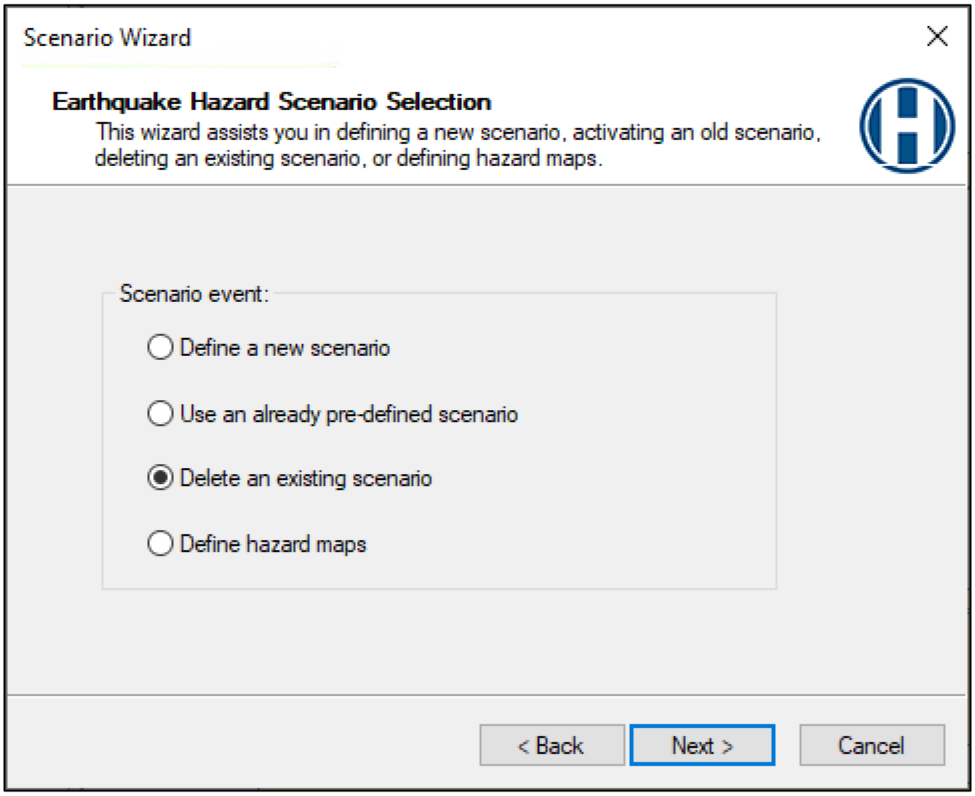


Figure 6-12 Deleting an Existing Scenario

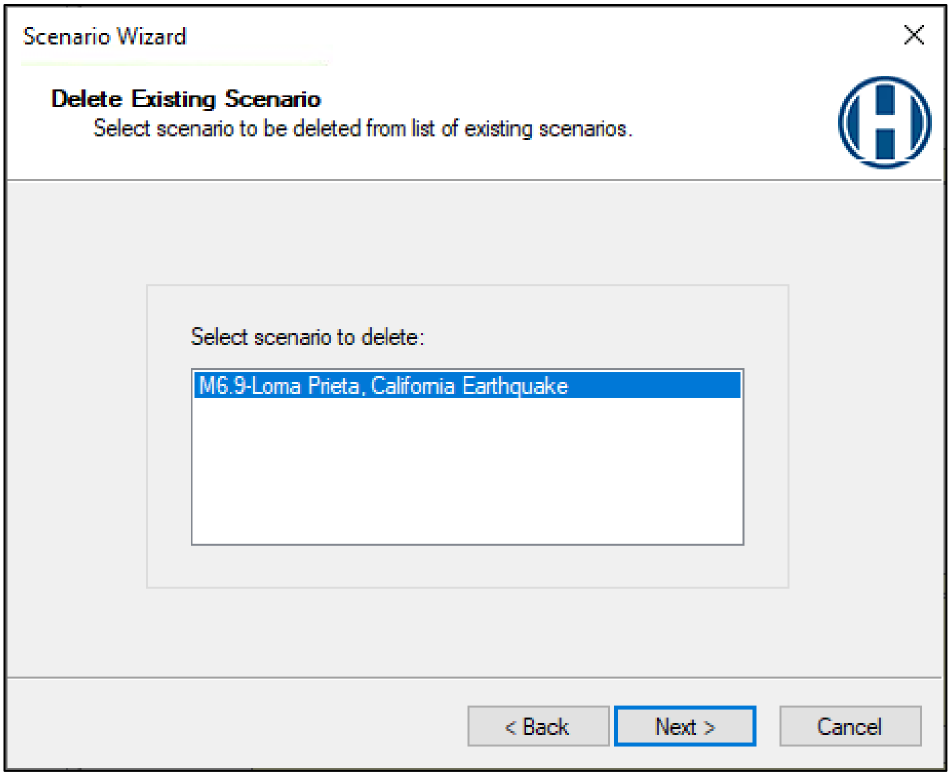


Figure 6-13 Select Scenario(s) to be Deleted

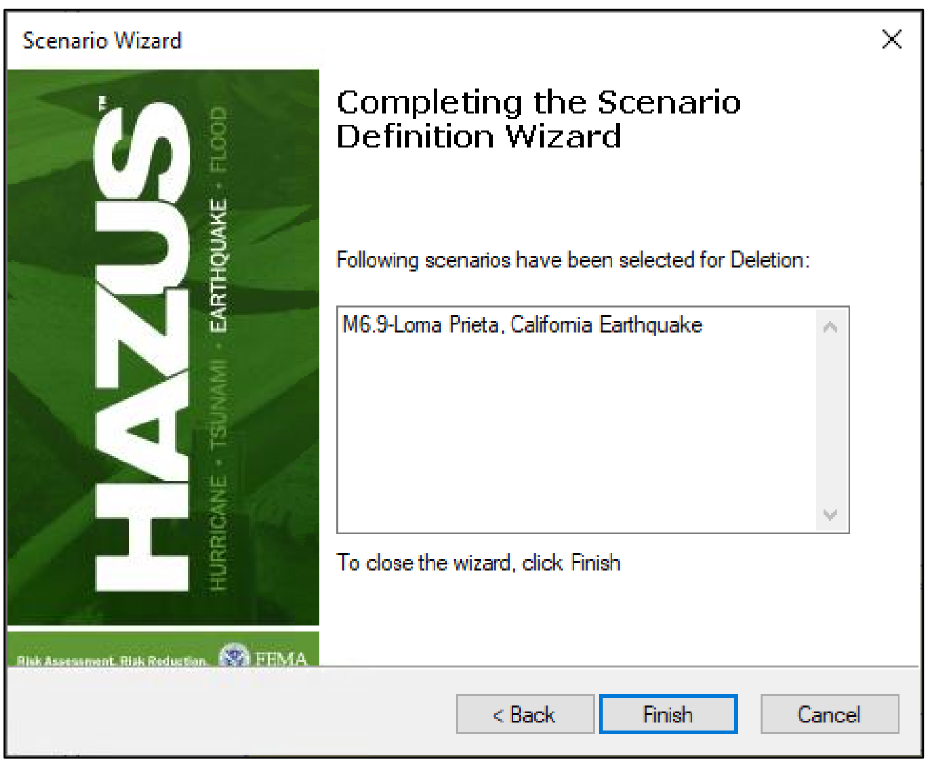


Figure 6-14 Confirmation of Scenario(s) to be Deleted

6.6 Loading and Defining Hazard Maps

Hazus assumes site class D for soils by default and assumes no data on liquefaction or landslide susceptibility are available, and that groundwater depth is at a uniform depth of 5 feet across the Study Region. The exception is with the use of a probabilistic earthquake scenario. These utilize ground motions amplified or reduced by site soil characteristics based on the USGS Vs30 methodology described in FEMA 366. If digital information is available from experts or other state agencies, the expert-generated maps will replace the baseline hazard assumptions.

When using a USGS ShakeMap as the ground motion hazard data input the soil hazard map is not used since ShakeMaps already include soil amplification.

6.6.1 Loading Hazard Maps

Once the hazard map data has been obtained from a government agency or subject matter expert the data will need to be loaded into Hazus. Prior to starting the import process make sure that the data map has been projected to WGS84 and is stored in a personal geodatabase. Click **Hazard > Data Maps** to bring up the Data Maps Dialog (Figure 6-15).

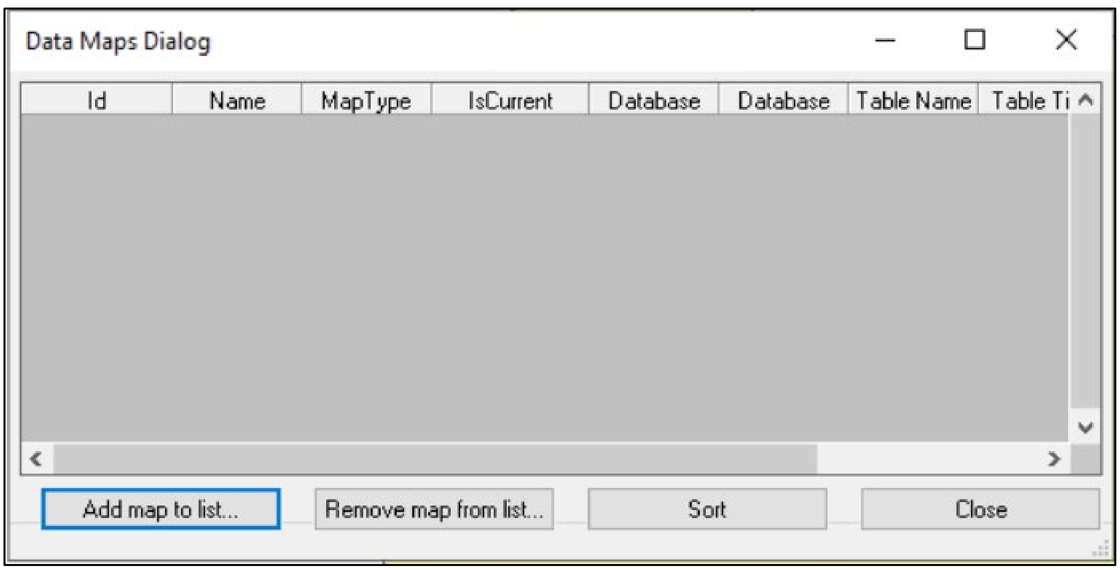


Figure 6-15 Data Maps Dialog Screen

Click **Add Map to list** and navigate to where the personal geodatabase is located. Select the database and click **Open**. The Data Map attributes dialog will appear (Figure 6-16).

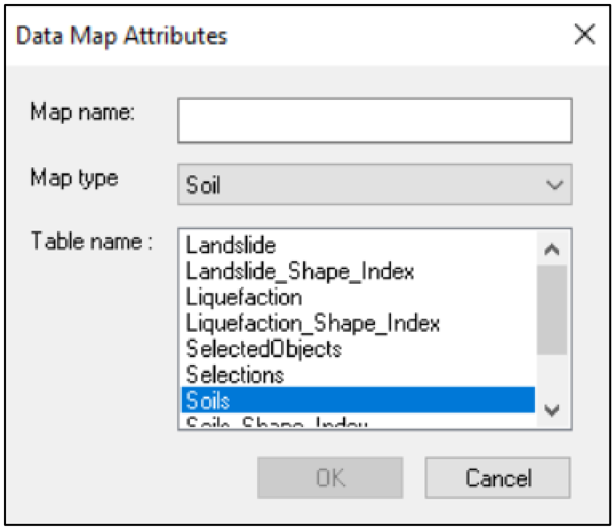


Figure 6-16 Data Map Attributes

This process is used to incorporate other hazard layers, such as liquefaction or soil. A unique **Map name** will need to be entered, then select the applicable **Map type,** and finally select the corresponding table in the personal geodatabase. Click **Ok** when complete. If the import is successful, the dialog will be populated like Figure 6-17.

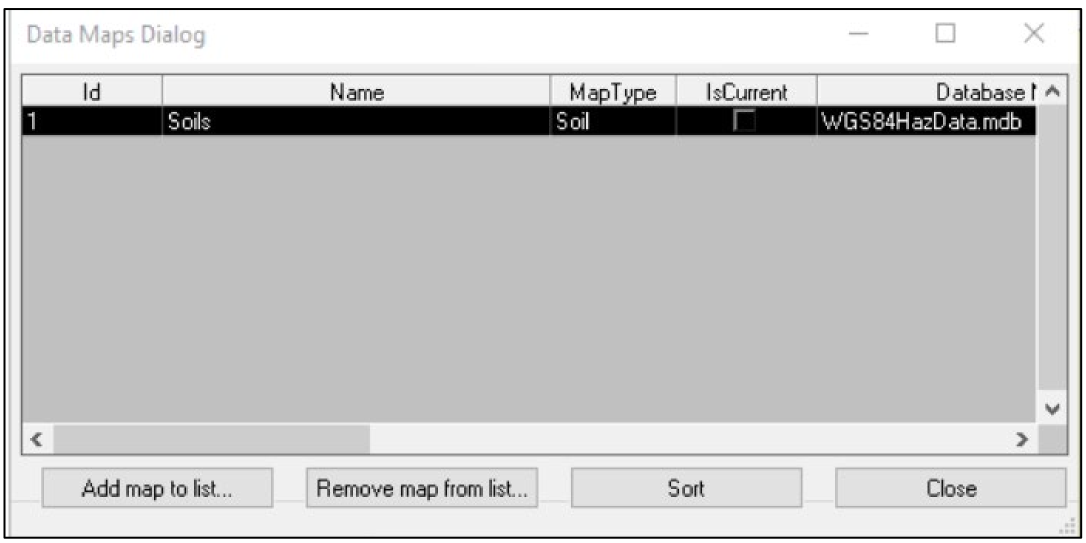


Figure 6-17 Populated Data Maps Dialog

6.6.2 Defining User-Supplied Hazard Data

The user can supply the ground shaking maps for estimating damage and loss. The ground shaking maps must be in geodatabase format and added to the list of available data maps defined in the Hazus menu **Hazard** > **Data Maps** (Figure 6-18). As in the probabilistic option, magnitude defined here does not change the ground motion severity, rather it provides the proxy for duration of shaking.

In addition to utilizing user-defined maps of ground shaking (peak ground acceleration, peak ground velocity, and spectral accelerations at 0.3 and 1.0 second periods), the following is a list of optional PGD maps that may be used to define the hazards:

- PGD due to settlement from liquefaction
- PGD due to lateral spreading from liquefaction
- Liquefaction probability
- PGD due to landslide
- Landslide probability
- PGD due to surface fault rupture
- Surface fault rupture probability.

To create a data map for one of the above hazards the following steps are needed:

- Create a personal geodatabase that includes at least one polygon feature class projected to WGS 84.
- Add a field of the correct field type to the attribute table.
- Digitize or import the data if a source is available.

Once the hazard map has been created it will need to be imported into Hazus. Select **Hazard > Data Maps** and a dialog box will appear (Figure 6-18).

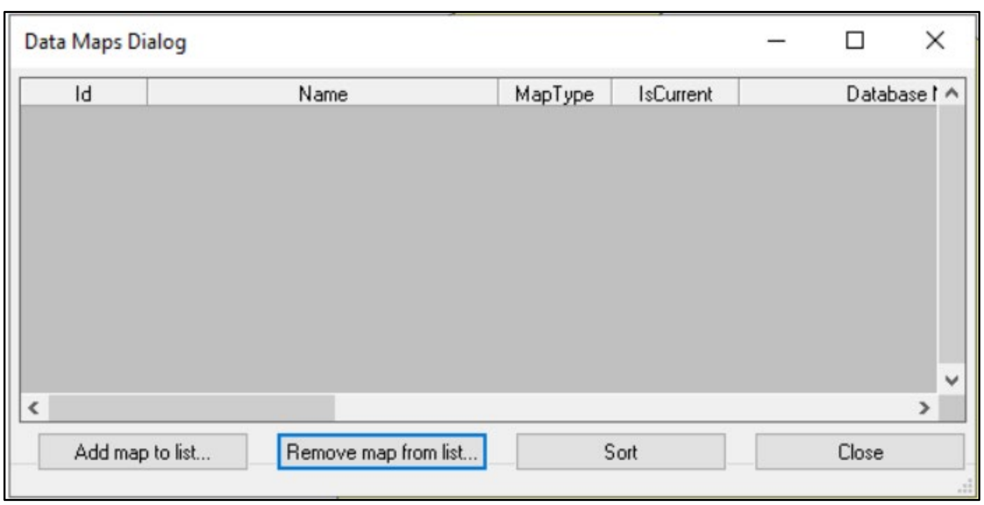


Figure 6-18 Data Maps Dialog Window

Click **Add map to list** and navigate to the personal geodatabase that contains the hazard maps. Once the database has been selected the following box will appear (Figure 6-19).

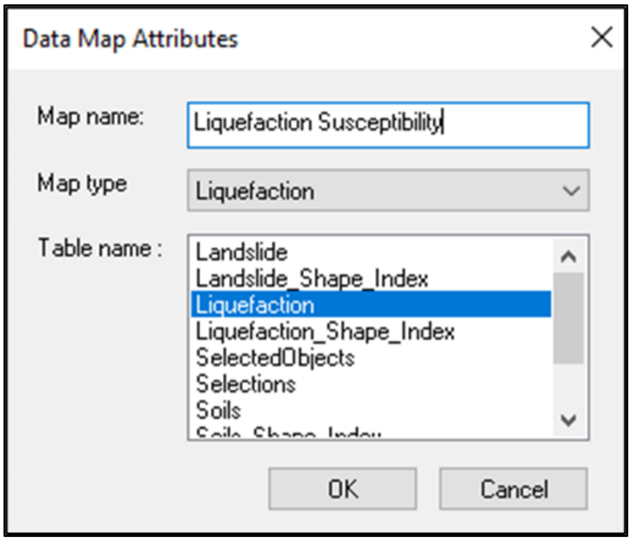


Figure 6-19 Data Map Attributes

The three input parameters will need to be attributed to continue:

- *Map name*: User enters a unique name based on the hazard type.
- *Map type:* Select the correct hazard type from the drop-down list.
- *Table name:* Select the correct feature class for the hazard.

Figure 6-20 shows all the types of user-defined hazard data maps that are possible to bring into Hazus.

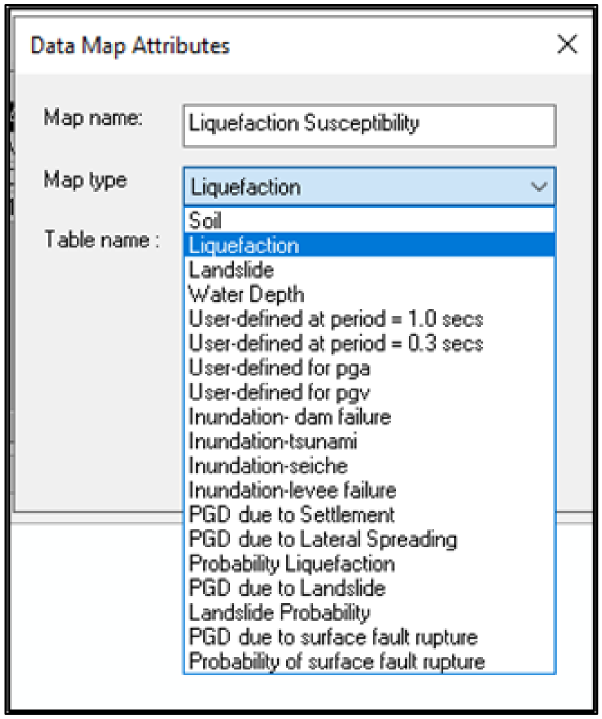


Figure 6-20 User-Defined Hazard Data Map Types

If Map type and Table name are incorrect an error will appear. Click OK to continue. When complete the dialog will look like Figure 6-21.

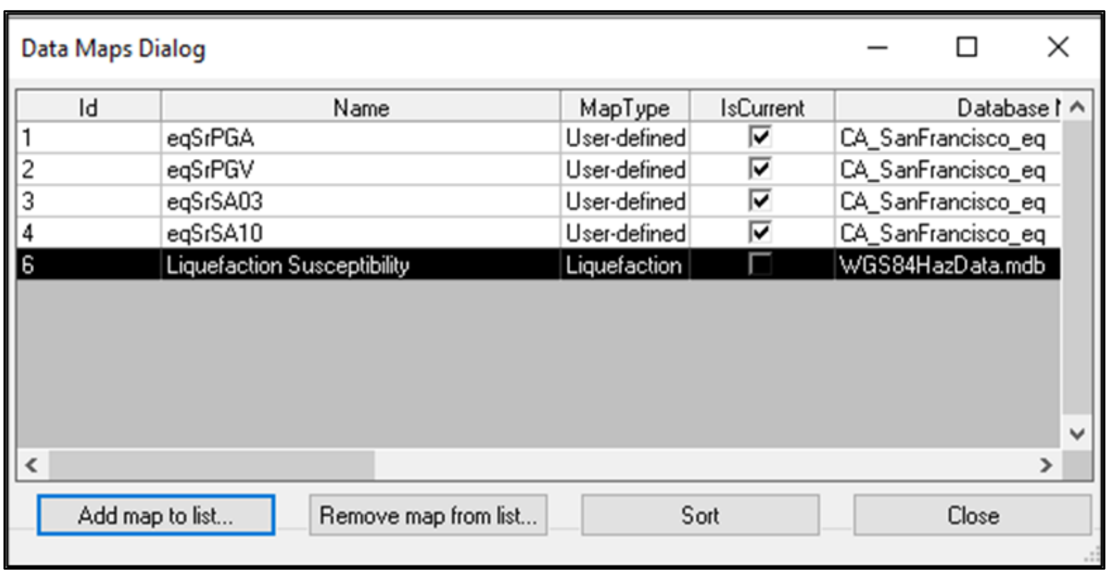


Figure 6-21 Data Maps Dialog Identification

To use the newly created data map, go to Hazard > Scenario > Define Hazard maps and click Next (Figure 6-22). Select the newly created data map from the drop-down and click Next and Finish to activate it.

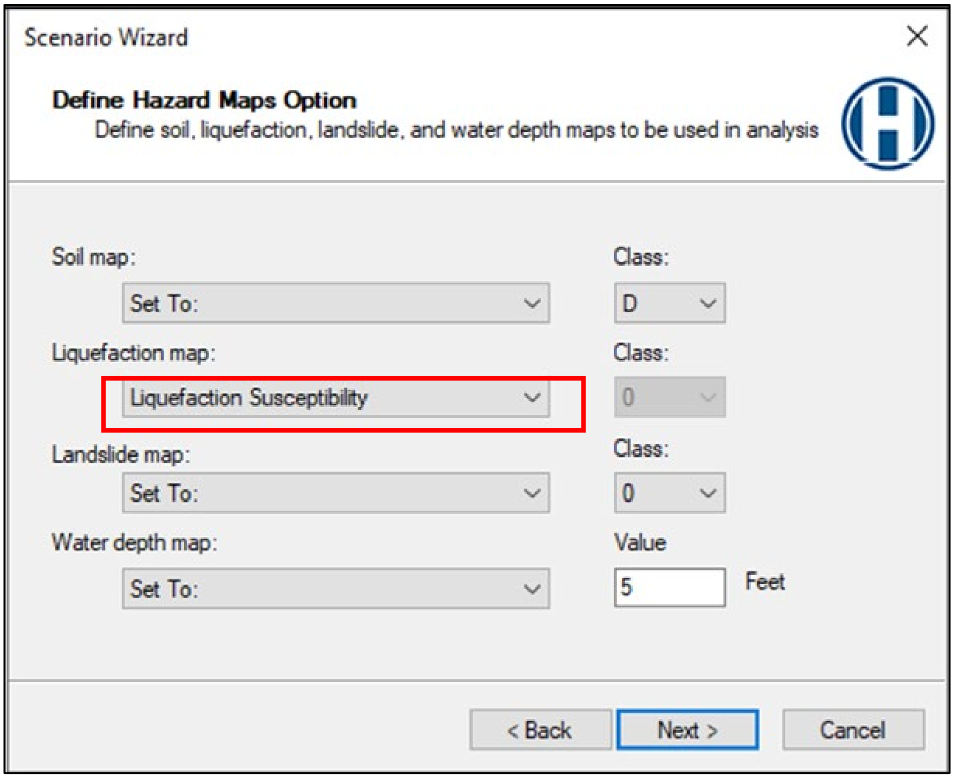


Figure 6-22 Selection of Liquefaction Map Window

To view the newly created hazard map, click **Hazard > Show Current** and click the Current Hazard Maps tab (Figure 6-23).

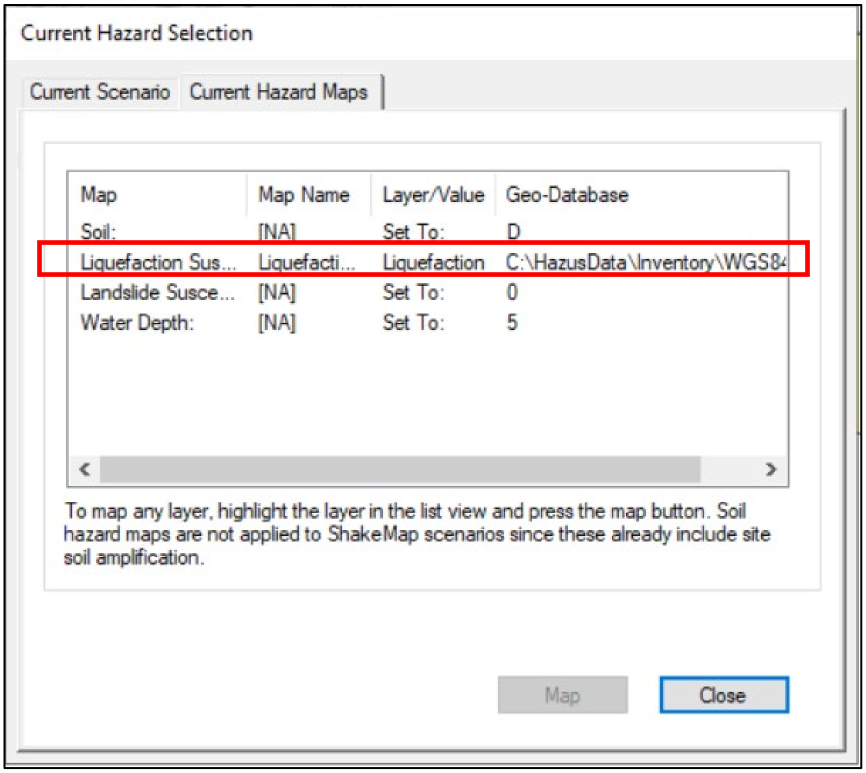


Figure 6-23 Selection of Liquefaction Map Current Hazard Maps

6.6.3 Defining the Hazard Map

The newly loaded hazard map must be defined before it can be used by Hazus. That can be accomplished by clicking **Hazard > Scenario** and then Next. In the Scenario Wizard select Define Hazard Maps (Figure 6-24). This will bring up the Define Hazard Maps Option wizard (Figure 6-25).

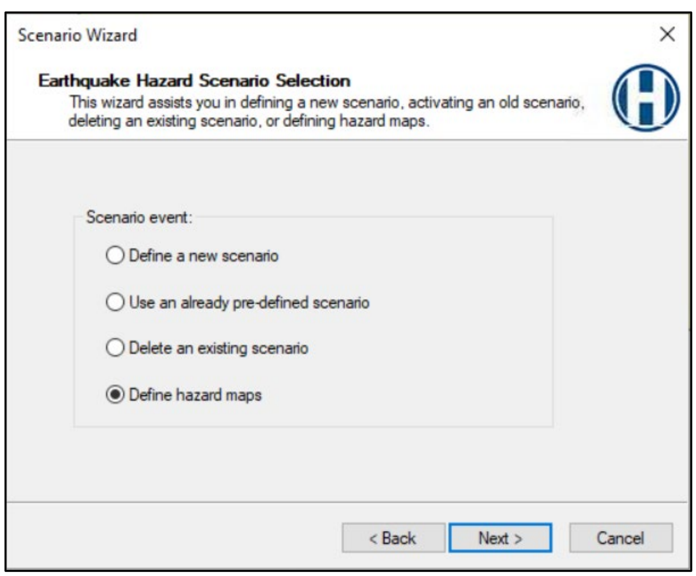


Figure 6-24 Earthquake Hazard Scenario Selection

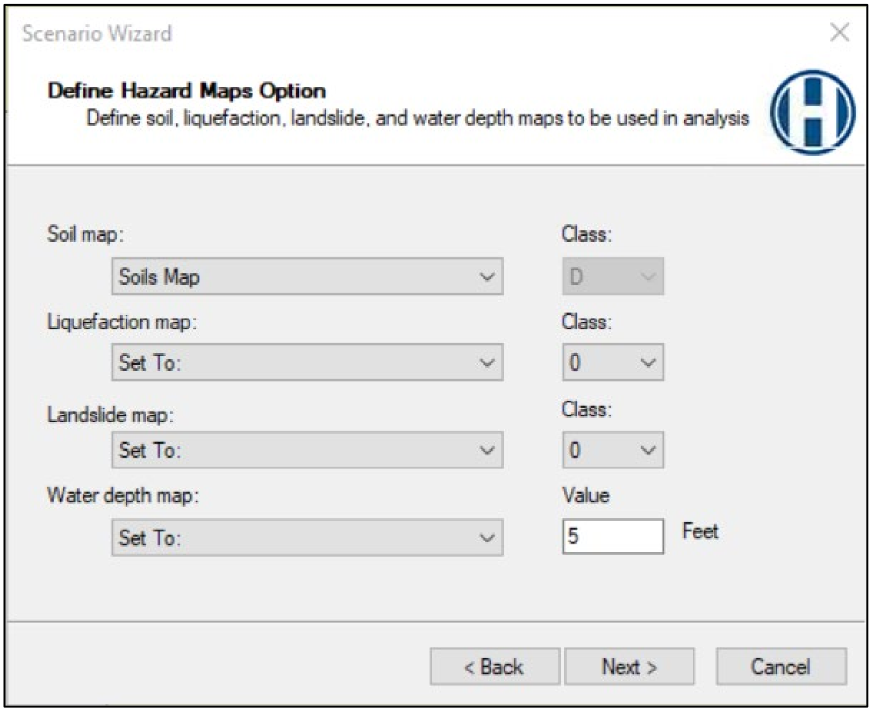


Figure 6-25 Define Hazard Map Option Wizard

Change the default Class value by clicking the Set To: drop down and selecting the data map that was imported earlier. This process can also be used to modify the default uniform assumptions. Click **Next, Finish** and **Finish** again to activate the data map. To confirm that the definition process worked correctly, click **Hazard > Show Current** and select the Current Hazard Maps tab (Figure 6-26).

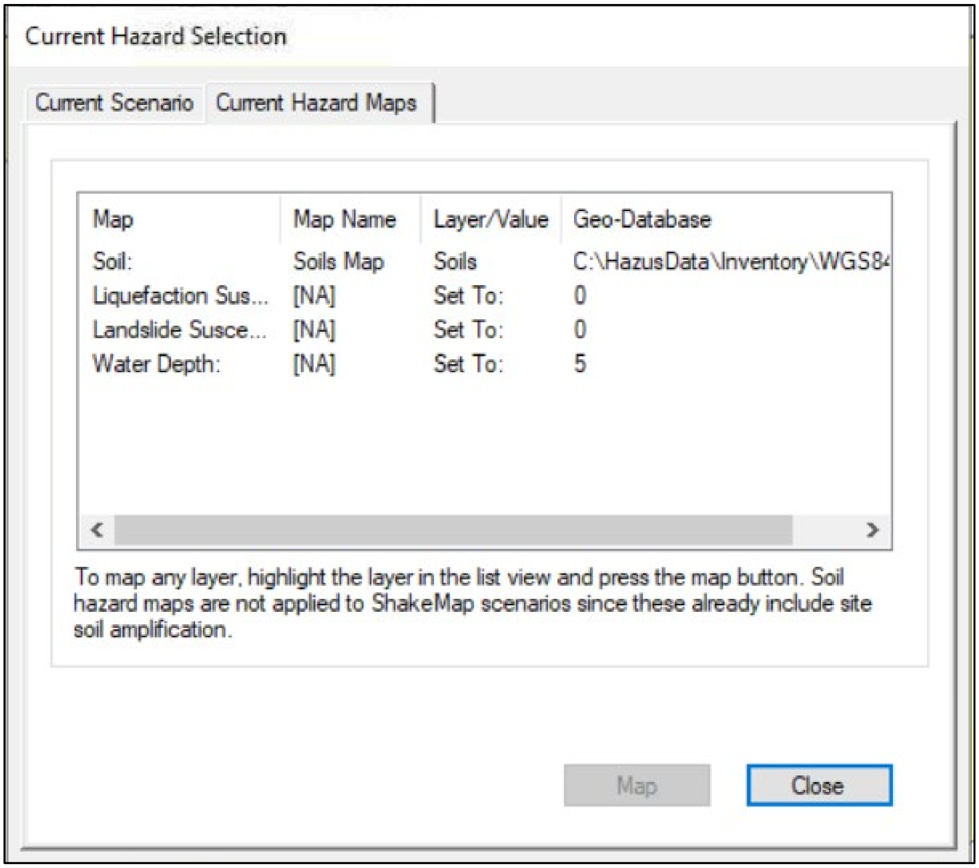


Figure 6-26 Current Hazard Map Selection

6.7 Defining a Deterministic Scenario

If an applicable USGS ShakeMap is not available, there are 3 internal approaches to defining a deterministic event that may be used; a historical epicenter event, a source event, and an arbitrary event.

Figure 6-27 shows the hazard definition menu. Clicking the **Scenario** option allows users to define the earthquake hazard using the Scenario Wizard. Scenario options are listed below.

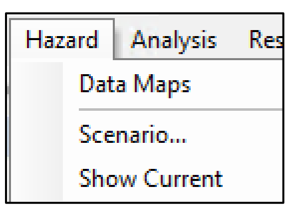


Figure 6-27 Hazard Definition Menu in Hazus

6.7.1 Historical Epicenter Event

Select **Historical epicenter event** from the **Seismic Hazard Type Selection** menu. Click **Next>** and a window displaying the earthquake epicenter database (Figure 6-28) will appear. Choose the historical event from the database and click **Next.**

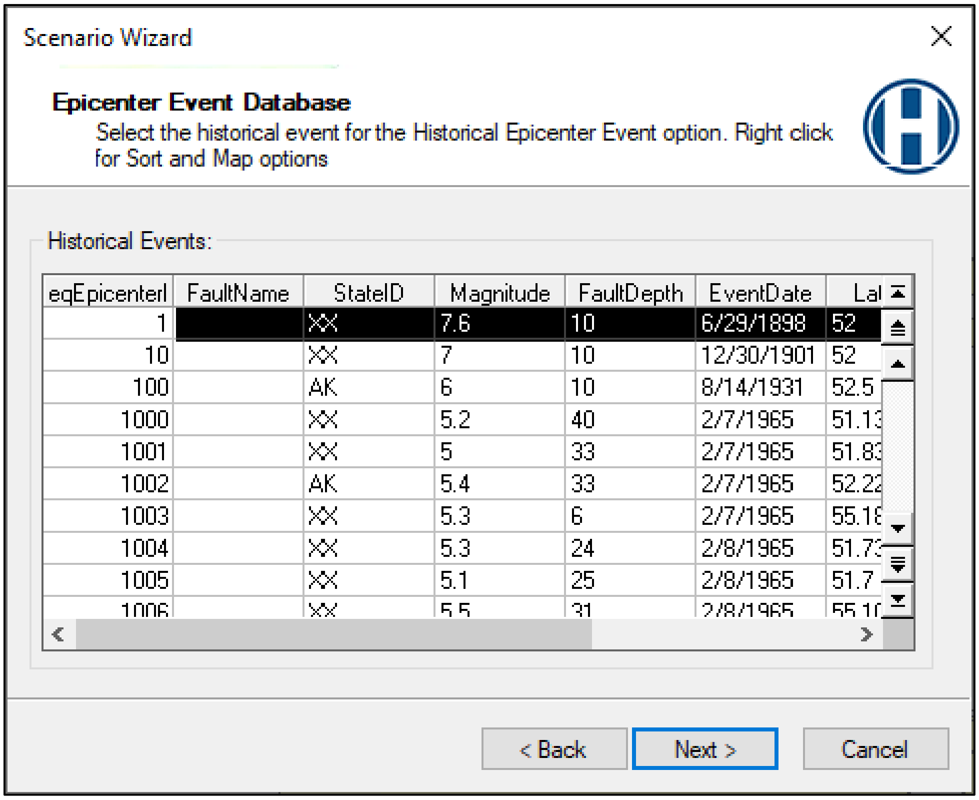


Figure 6-28 Seismic Hazard Type Selection Menu

Alternatively, select the historical epicenter from a map by right clicking the event record of general interest; note that users may have to zoom out to view historic epicenters. Select **Map** from the option list (Figure 6-29). and a window will open with historical epicenters plotted. Select an epicenter for analysis using the select button on the toolbar. Click the left mouse button once directly over the epicenter of interest. Choose **Selection Done** to return to the list (Figure 6-30), where the selected epicenter record will be highlighted. The list will contain epicenter details: fault name, state, magnitude, fault depth (km), event date, epicenter latitude/longitude, and source of event information.

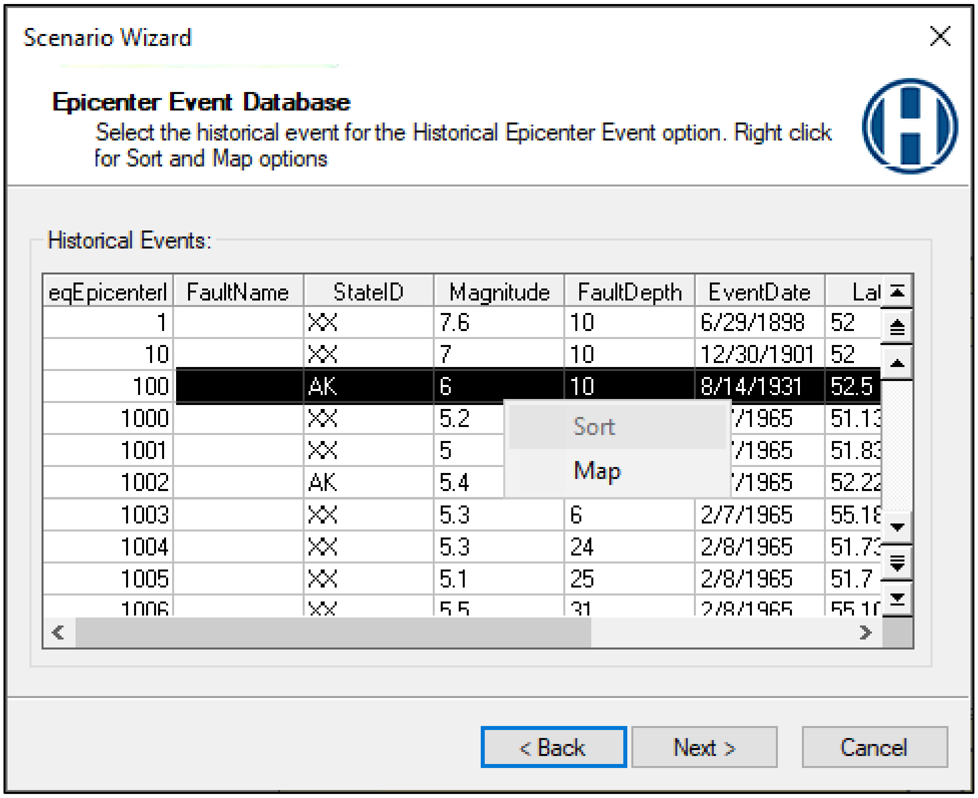


Figure 6-29 Select Historical Seismic Event

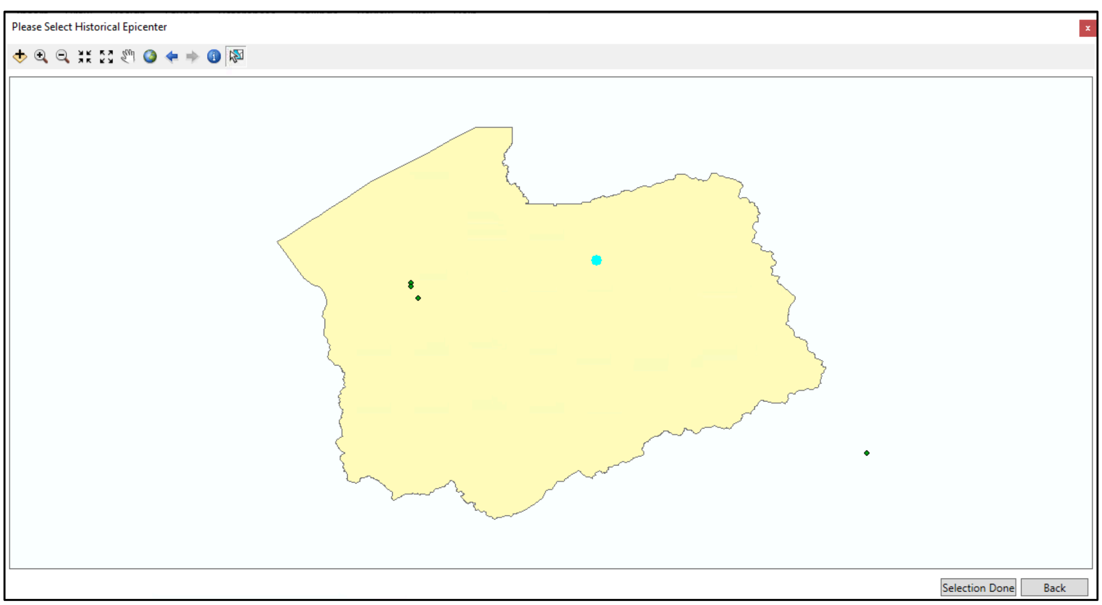


Figure 6-30 Select Epicenter from Map

Confirm the event selection by clicking **Next>**. Users will be provided a default attenuation function, however, other functions permissible for the region that may better fit the type of earthquake scenario may be chosen from the list (Figure 6-31), see also Section 6.6. The next dialog window (Figure 6-32) will allow edits to additional event parameters. Accept or edit the seismic event parameters given.

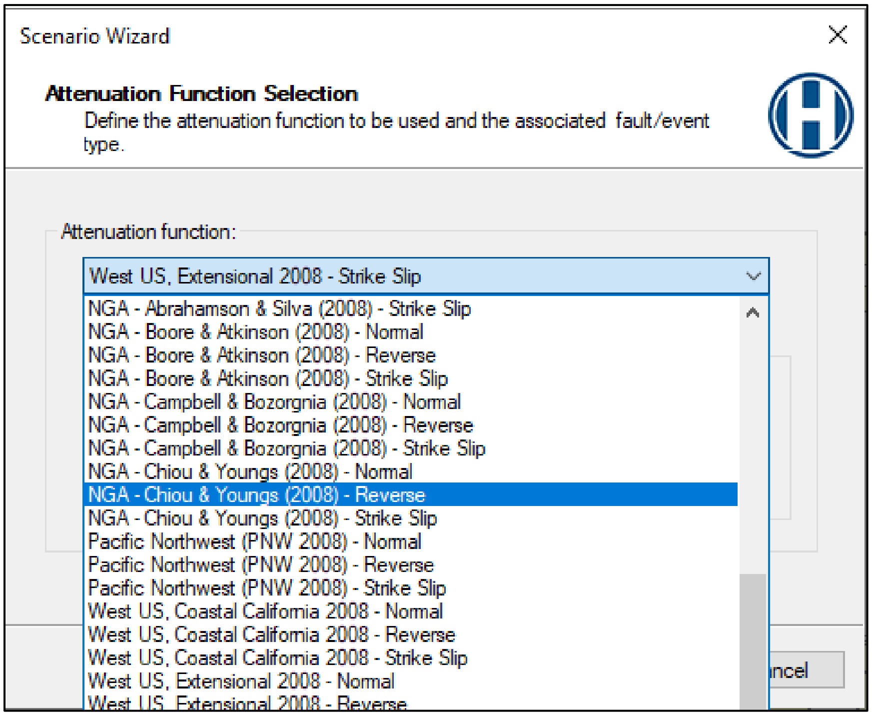


Figure 6-31 Attenuation Functions

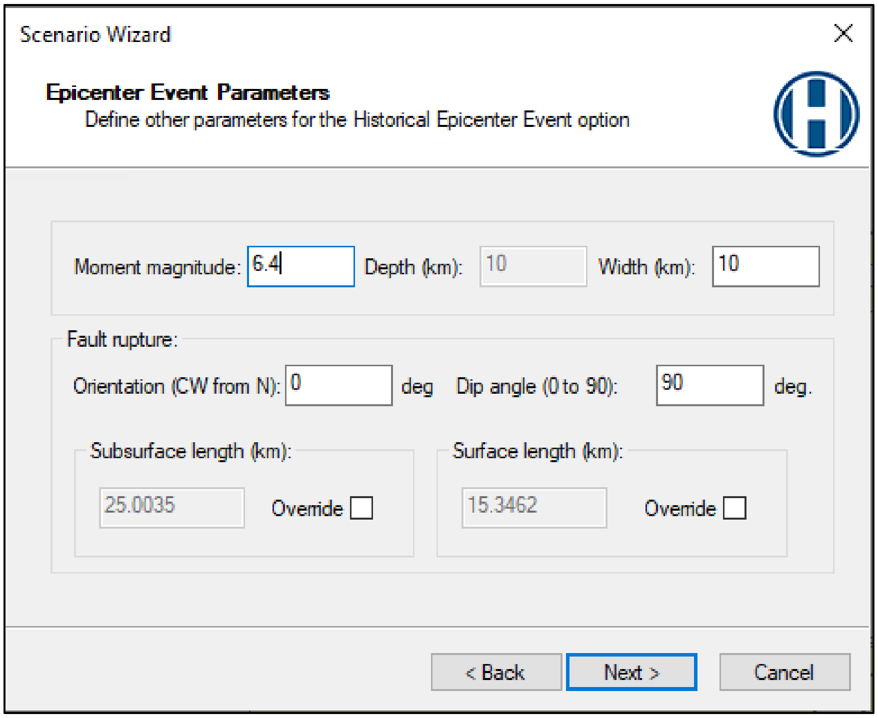


Figure 6-32 Epicenter Event Parameters

Rupture orientation is measured in degrees (0 to 360) clockwise from North. Rupture length is based on the default magnitude versus rupture length relationship unless overridden (Wells and Coppersmith, 1994). If users change the magnitude of the historical earthquake, Hazus computes a new rupture length to correspond to the new magnitude. Rupture length and orientation is not used in Central and Eastern U.S. (CEUS) states.

6.7.2 Fault Source Event

A database of faults used by the U.S. Geological Survey (USGS) for development of their national seismic hazard mapping program is supplied with Hazus for the Western U.S. (WUS) states. Using the **Hazard > Scenario** menu, select **Define a new scenario**, and then **Source event** (Figure 6-33).

Select a fault when presented with the fault database, as in Figure 6-33 or use the **Map** option (available through the context menu by right-clicking) to select the fault graphically from a map. The scenario earthquake can then be located anywhere along the selected fault. Each source is given a source number, and the database is presented so that sources are in numerical order. To sort the database using another parameter, highlight the desired column by clicking the title at the top of the column and then click **Sort** from the context menu. For example, to put the database in alphabetical order (as shown in the figure), highlight the fault name column and click **Sort**.

Once a source has been selected from the source database, users can define the location of the epicenter. Click the **Define** button in the next wizard page. Users will then be presented with a map of sources. The scenario event epicenter is defined by clicking a location within the map. A default attenuation function is provided based on fault type; however, a library of other appropriate functions is available for selection (see Section 6.6 for more information).

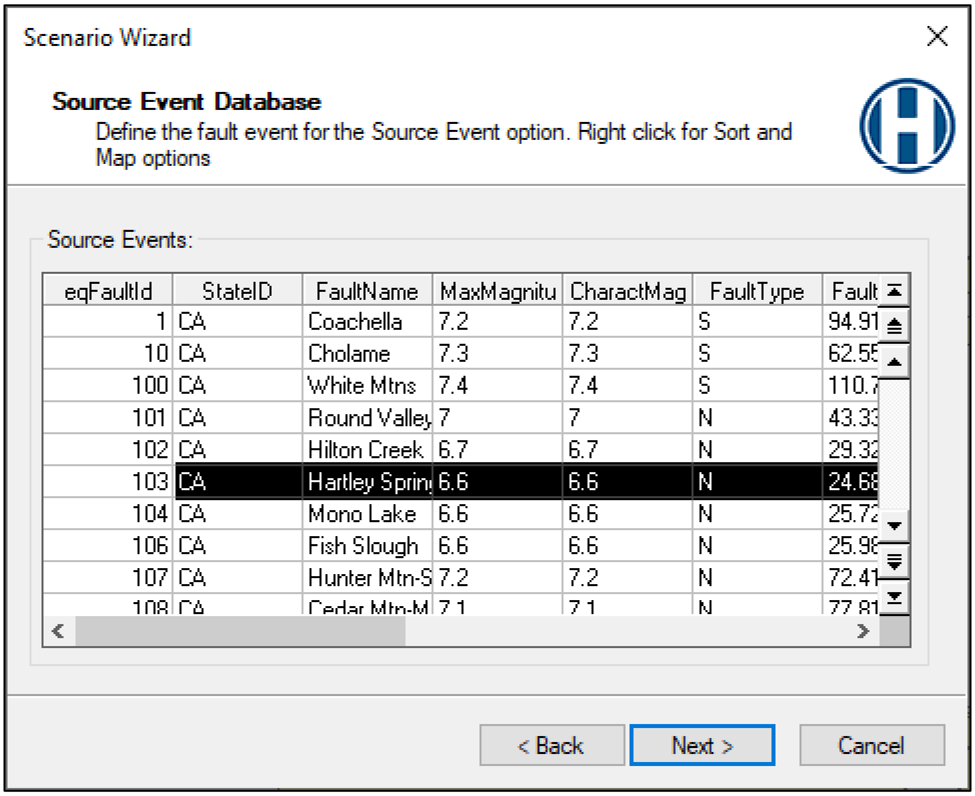


Figure 6-33 Selecting the Fault from the Hazus Source Event Database

6.7.3 Arbitrary Event

To define an arbitrary event, select **Define a new scenario** from the **Hazard > Scenario** menu, and then select **Arbitrary event,** and click **Next.** Then accept the default attenuation relationship and fault type or select another attenuation function and fault type and click next (see Section 6.6 for more information). Users will then use the dialog box shown (Figure 6-34) to define the location, magnitude, epicenter depth, rupture orientation, and rupture length. The latitude/longitude of the epicenter can be typed in the data entry fields or defined on the region map with the **Map** button. Rupture orientation is measured in degrees (0 to 360) clockwise from North.

Rupture length is based on the default magnitude versus rupture length relationship unless the user chooses to override it (Wells and Coppersmith, 1994). If the analysis is being done for an area in the western United States, the user will be given an option to edit the fault rupture length. When this is the case, the user can change the magnitude of the earthquake and then select **Override.** Hazus will compute a new rupture length to correspond to the new magnitude.

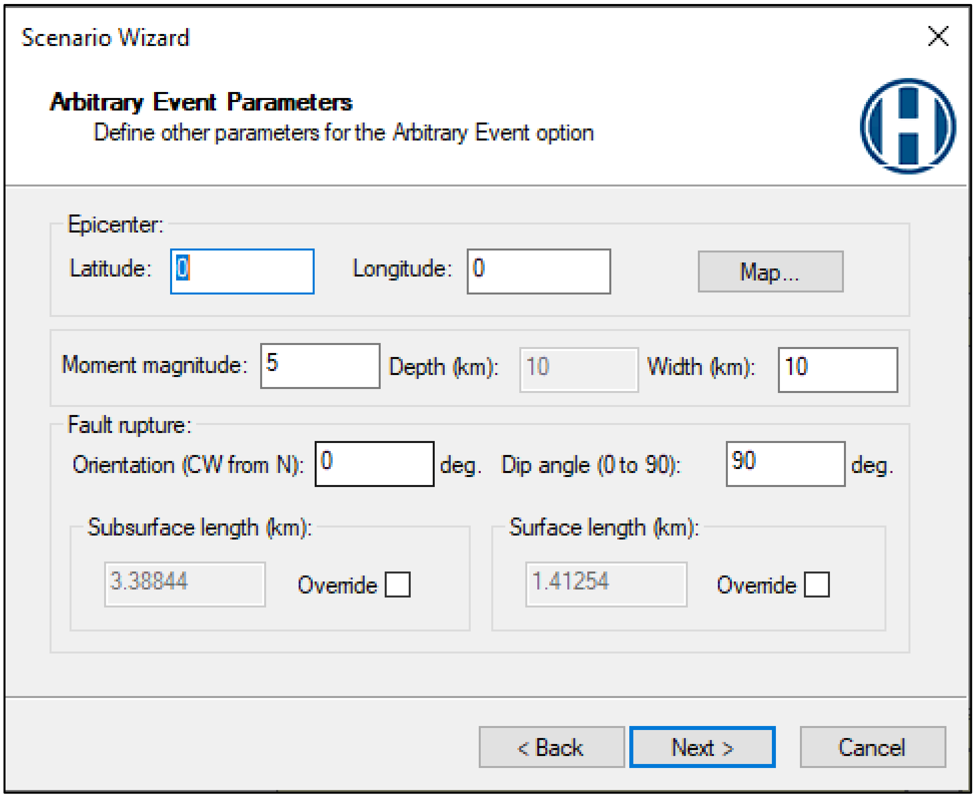


Figure 6-34 Define Parameters for an Arbitrary Event

6.7.4 Choosing an Attenuation Function

Hazus contains default attenuation relationships that define how ground motion varies as a function of distance from the source. There are 49 attenuation functions available for the western United States, and ten attenuation relationships are available for the eastern United States. The internal Hazus attenuation functions have not been updated since 2008. The user can select relevant attenuation relationships used in the analysis (Figure 6-31) and will be guided by Hazus to help ensure erroneous functions are not selected. For example, if a strike-slip fault is selected, only attenuation functions for strike-slip sources will be available. Detailed descriptions of the available attenuation relationships are provided in the *Hazus Earthquake Model Technical Manual (FEMA, 2024)*.

6.8 Defining a Probabilistic Hazard Event

The user can select a scenario based on ground shaking data derived from the USGS probabilistic seismic hazard curves. The probabilistic analysis option is available for eight return periods of ground shaking. The eight return periods are 100-year, 250-year, 500-year, 750-year, 1000-year, 1500-year, 2000-year, and 2500-year. The user specifies the desired return period through the drop-down menu shown in Figure 6-35, and enters the **Magnitude driving the probabilistic event** in the box below. The magnitude entry for probabilistic scenarios does not affect the ground motion severity, rather it is used as proxy for earthquake duration (short ($M \leq 5.5$), medium, or long ($M \geq 7.5$)). The magnitude value selected should be a reasonable representation of the predominant threat, however, it only needs to identify the appropriate duration category. The USGS provides an online tool to help determine the magnitude(s) that contribute the most to the probabilistic hazard for any area in the U.S., Alternatively, the user can select the **Annualized Loss** option to estimate average annualized losses (AAL) for the GBS and casualties, which utilizes the default assumptions per return period captured in Table 6-5.

Table 6-5 Default Magnitude values assumed by return period when estimating AAL

Return Period	Magnitude assumed for AAL	Duration Assigned
100	5.5	Short
250	5.5	Short
500	6.5	Moderate
750	6.5	Moderate
1000	6.5	Moderate

For any concerns about the appropriateness of the default magnitude assumption(s), consult a local earth science expert or email Hazus technical support.

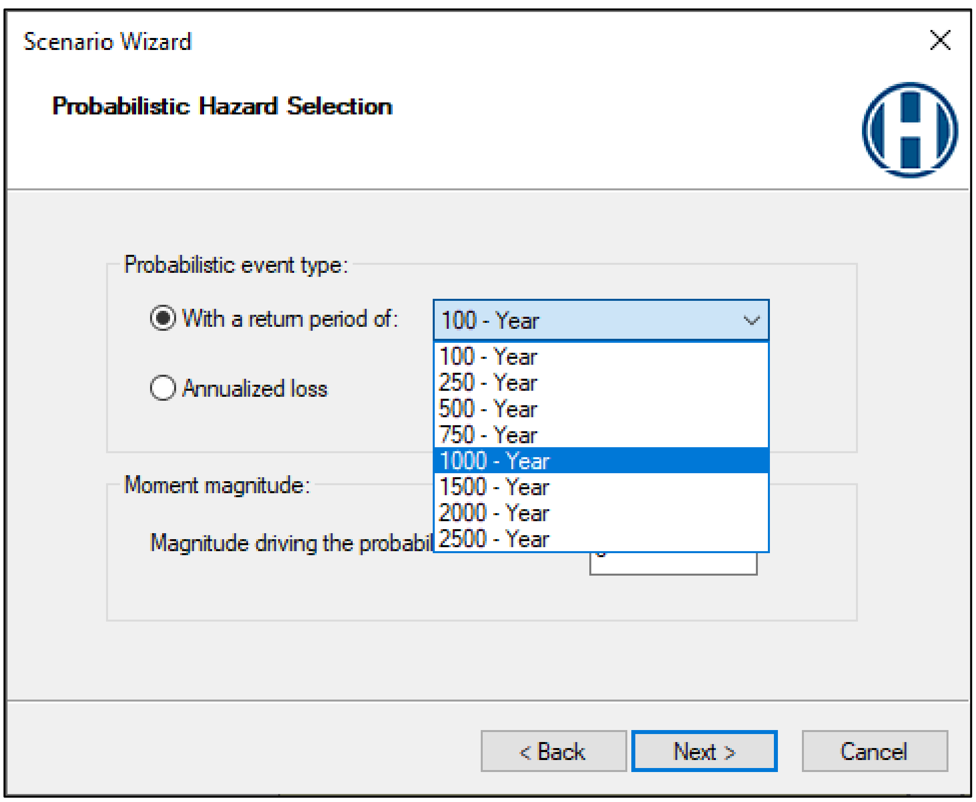


Figure 6-35 Probabilistic Hazard Options Window

6.9 Viewing the Currently Defined Hazard

At any time during data entry, analysis, or viewing of results, users can view the parameters that define the selected hazard by clicking the **Hazard > Show Current** option on the Hazus menu bar. An example of the displayed summary is shown in Figure 6-36. Current maps can be displayed by selecting the map and clicking the **Map** button. As of Hazus 4.2 Service Pack 2, the ground motion mapping symbology incorporates the official USGS ShakeMap color ramp (Figure 6-37).

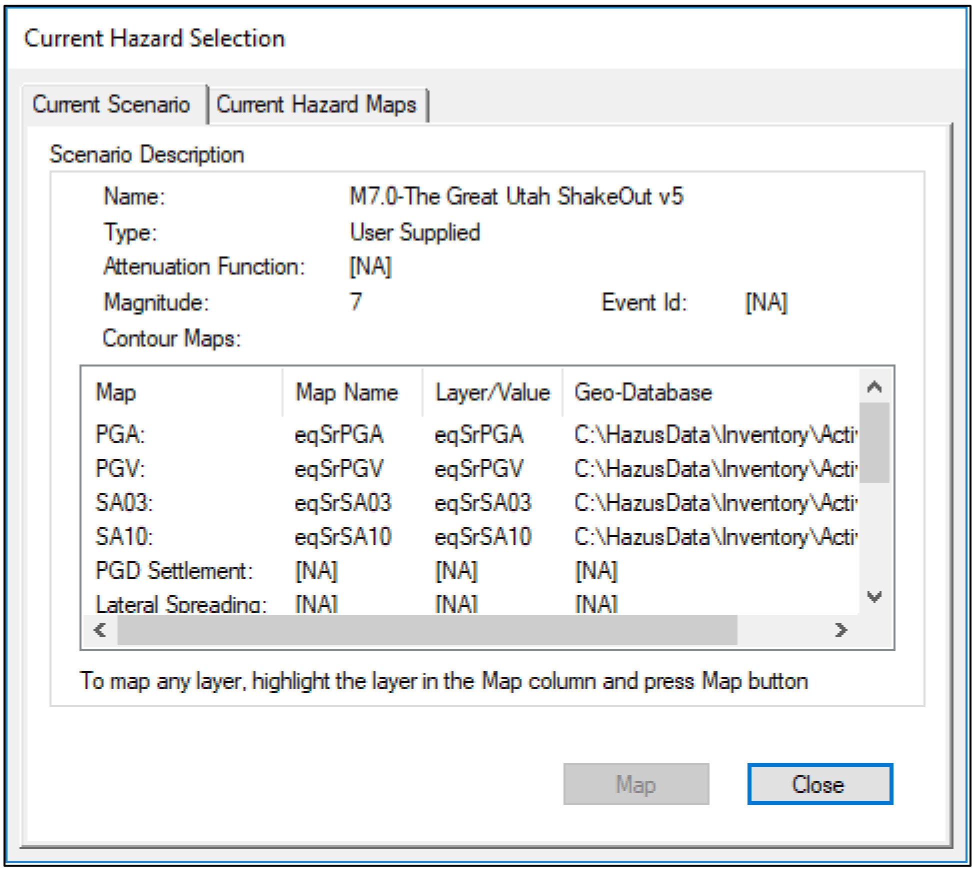


Figure 6-36 Viewing the Parameters of the Current Hazard Definition

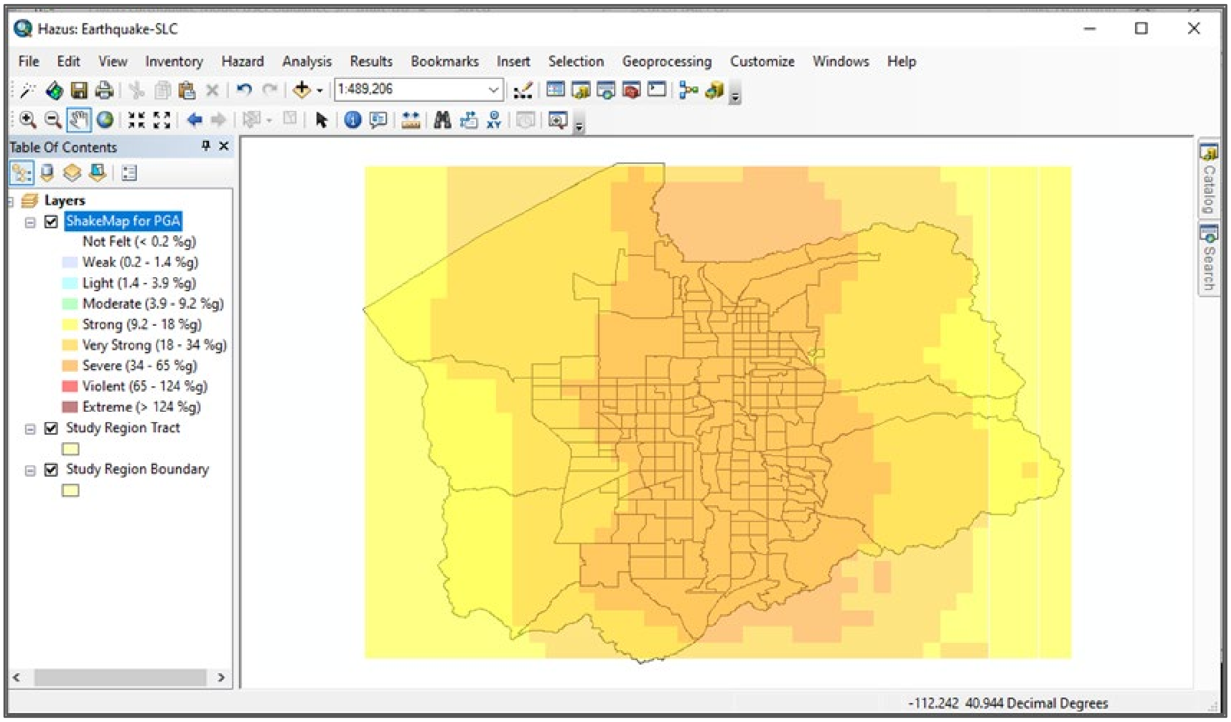


Figure 6-37 Sample Ground Motion Mapping: ShakeMap PGA

Section 7. Earthquake Model: Analysis Menu

Within Hazus, the Earthquake Model contains an analysis menu allowing the user to evaluate damage and losses. From this menu, the user can modify damage functions, restoration functions and various analysis parameters, as well as initiate analysis runs. Figure 7-1 shows the Hazus Analysis Menu.

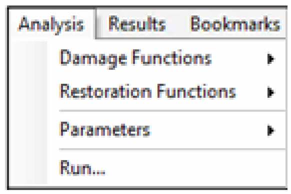


Figure 7-1 Hazus Analysis Menu

7.1 Damage Functions

Direct damage is estimated for structural and nonstructural components of buildings and for transportation and utility systems facilities. The analysis menu options allow the selection of the types of facilities and systems that are to be analyzed.

7.1.1 Definitions of Damage States – Building

Damage states are used in Hazus to estimate life-safety consequences of building damage, expected monetary losses due to building damage, expected monetary losses that may result as a consequence of business interruption, expected social impacts, and other economic impacts. Building damage predictions may also be used to study expected damage patterns in a given region for different scenario earthquakes (e.g., to identify the most vulnerable building types or the areas with the worst expected damage to buildings).

To serve these purposes, damage predictions must be descriptive. The user must be able to connect the nature and extent of the physical damage to a building type from the damage prediction output so that life-safety, societal, and monetary losses that result from the damage can be estimated. Building damage can best be described in terms of the nature and extent of damage exhibited by its components (e.g., beams, columns, walls, ceilings, piping, heating, ventilation and cooling (HVAC) equipment). For example, component damage descriptions such as “shear walls are cracked,” “ceiling tiles fell,” “diagonal bracing buckled,” or “wall panels fell out,” used together with such terms as “some” and “most,” would be sufficient to describe the nature and extent of overall building damage. Using these criteria, damage is described by five damage states: None, Slight, Moderate, Extensive, and Complete (Figure 7-2).

Figure 7-2 The Five Damage States

General descriptions for the structural damage states of 16 common building types are provided in the *Hazus Earthquake Model Technical Manual (FEMA, 2024)*. Table 7-1 provides an example of the definitions of damage states for light wood frame buildings. It should be understood that a single damage state could refer to a wide range of damage. For example, the **slight** damage state for light wood frame structures may vary from a few small cracks at one or two windows to small cracks at all the window and door openings. Hazus damage states are frequently translated directly to common damage descriptions for use by other programs, including FEMA's Individual Assistance and Red Cross categories of Affected, Minor, Major and Destroyed or the ATC-20 building safety tagging program's Red (unsafe), Yellow (limited entry), or Green (inspected). The typical cross walk to these categories is described in Table 7-2 below, however, local variations should be noted. For example, a building may be tagged as Red (unsafe) when it is undamaged but threatened by falling hazards from an adjacent building. However, translating Hazus damage states into these other categories can be very valuable in communicating impacts, as well as validating Hazus results in actual earthquakes.

Table 7-1 Examples of Structural Damage State Definitions: Wood, Light Frame

Damage State	Description
Slight	Small plaster or gypsum-board cracks at corners of door and window openings and wall-ceiling intersections; small cracks in masonry chimneys and masonry veneer.
Moderate	Large plaster or gypsum-board cracks at corners of door and window openings; small diagonal cracks across shear wall panels exhibited by small cracks in stucco and gypsum wall panels; large cracks in brick chimneys; toppling of tall masonry chimneys.
Extensive	Large diagonal cracks across shear wall panels or large cracks at plywood joints; permanent lateral movement of floors and roof; toppling of most brick chimneys; cracks in foundations; splitting of wood sill plates and/or slippage of structure over foundations; partial collapse of “room-over-garage” or other “soft-story” configurations; small foundation cracks.
Complete	Structure may have large permanent lateral displacement, may collapse, or be in imminent danger of collapse due to cripple wall failure or the failure of the lateral load resisting system; some structures may slip and fall off the foundations; large foundation cracks.

Table 7-2 Comparison of Hazus Damage States to Other Damage Categorization Schemes

Hazus Damage State	FEMA Individual Assistance	Red Cross	ATC-20 Building Inspections
Slight	Affected	Affected	Green (inspected)
Moderate	Minor	Minor	Green (inspected)
Extensive	Major	Major	Yellow (limited entry)
Complete	Destroyed	Destroyed	Red (unsafe)

Damage to nonstructural components is considered independent of building type. This is because partitions, ceilings, cladding, and other features are assumed to incur the same damage when subjected to the same inter-story drift or floor acceleration whether they are in a steel frame building or in a concrete shear wall building. Therefore, as shown in the example in Table 7-3, descriptions of nonstructural damage states are developed for common nonstructural systems rather than as a function of building type.

Table 7-3 Examples of Nonstructural Damage State Definitions: Suspended Ceilings

Damage State	Description
Slight	A few ceiling tiles have moved or fallen down.
Moderate	Falling of tiles is more extensive; in addition, the ceiling support framing (T-bars) has disconnected and/or buckled at a few locations; lenses have fallen off some light fixtures and a few fixtures have fallen; localized repairs are necessary.
Extensive	The ceiling system exhibits extensive buckling, disconnected T-bars, and falling ceiling tiles; ceiling partially collapses at a few locations and some light fixtures fall; repair typically involves removal of most or all ceiling tiles.
Complete	The ceiling system is buckled throughout and/or fallen and requires complete replacement; many light fixtures fall.

7.1.2 Building Damage Functions

Hazus estimates direct damage to structural and nonstructural building components separately. Structural components are the walls, columns, beams, and floor systems that are responsible for holding up the building. In other words, the structural components are the gravity and lateral load resisting systems. Nonstructural building components include building mechanical/electrical systems and architectural components such as partition walls, ceilings, windows, and exterior cladding, that are not designed as part of the building's load-carrying system. Equipment and furniture that are not an integral part of the building, such as computers and desks, are considered building contents.

Damage to structural components affects casualties, building disruption, cost of repair, and other losses differently than damage to nonstructural components. For example, if the ceiling tiles fall, business operations can probably resume once the debris is removed. On the other hand, if a column in a building is damaged, there could be a life-safety hazard until the column is repaired or temporarily shored, possibly resulting in a long-term disruption.

It should also be noted that the types of nonstructural components in a given building depend on the type of building occupancy. For example, single-family residences would not have exterior wall panels, suspended ceilings, or elevators while these items would be found in an office building. Hence, the relative values of nonstructural components in relation to overall building replacement value vary with type of occupancy. In the direct economic loss module, estimates of repair and replacement cost are broken down by occupancy to account for differences in types of nonstructural components.

Some nonstructural components (partition walls and windows) tend to crack and tear apart when the floors of the building move during an earthquake. As can be seen in Figure 7-3, the wall that extends from the first floor to the second floor is pulled out of shape due to the inter-story drift, causing it to crack and tear. In the methodology, this is called *drift-sensitive nonstructural damage*.

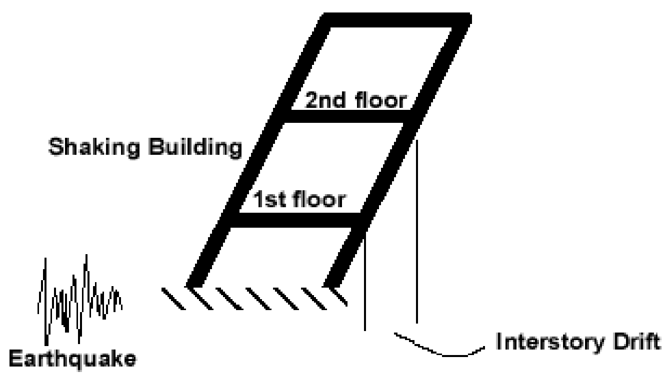


Figure 7-3 Inter-story Drift in a Shaking Building

Other nonstructural components such as mechanical equipment tend to get damaged by falling over or being torn from their supports due to the acceleration of the building. This is similar to being knocked off your feet if someone tries to pull a rug out from under you. In the methodology, this is called *acceleration-sensitive nonstructural damage*. Of course, many nonstructural components are affected by both acceleration and drift, but for simplification, components are identified with one or the other, as summarized in Table 7-4.

Table 7-4 Types of Nonstructural Building Components

Drift Sensitive	Acceleration Sensitive
▪ Wall partitions ▪ Exterior wall panels and cladding ▪ Glass ▪ Ornamentation	▪ Suspended ceilings ▪ Mechanical and electrical equipment ▪ Piping and ducts ▪ Elevators

7.1.2.1 Fragility Curves

Based on the damage state descriptions described in Section 7.1.1 and using a series of engineering calculations that are described in the *Hazus Earthquake Model Technical Manual (FEMA, 2024)*, **fragility curves** were developed for each building type. Fragility curves are characterized by a median value of the demand parameter (e.g., PGA or PGD) that corresponds to the threshold of the damage state and a beta value, which is a measure of the variability associated with that damage state. Hazus utilizes lognormal fragility curves, so the beta value is a lognormal standard deviation. A fragility curve describes the probability of being in a specific damage state as a function of the size of earthquake input. For structural damage, the fragility curves express damage as a function of building displacement (as illustrated in Figure 7-4). The fragility curves express nonstructural damage as a function of building displacement or acceleration, depending on whether they refer to drift-sensitive or acceleration-sensitive damage.

Baseline fragility curves are supplied with the methodology for all specific building types and can be viewed by clicking the **Analysis > Damage Functions > Buildings** menu and selecting from the various tabs: Structural Fragility Curves, Nonstructural Drift Fragility Curves and Nonstructural Acceleration Fragility Curves (Figure 7-5). Fragility curve parameters are presented by specific building type and design level; the various design levels may be selected using the “Table type” pull-down menu. Fragility curves betas vary by scenario type; original baseline values for use with typical scenario earthquakes and reduced values for use with User-defined hazard events (i.e., actual earthquake events, for which the uncertainty/beta values are reduced to reflect the reduced uncertainty in the input ground motions). Development of fragility curves is complex and is discussed in detail in the *Hazus Earthquake Model Technical Manual (FEMA, 2024)*. It is highly recommended that baseline curves be used in the loss studies. Modification of these fragility curves requires the input of a structural engineer experienced in seismic design.

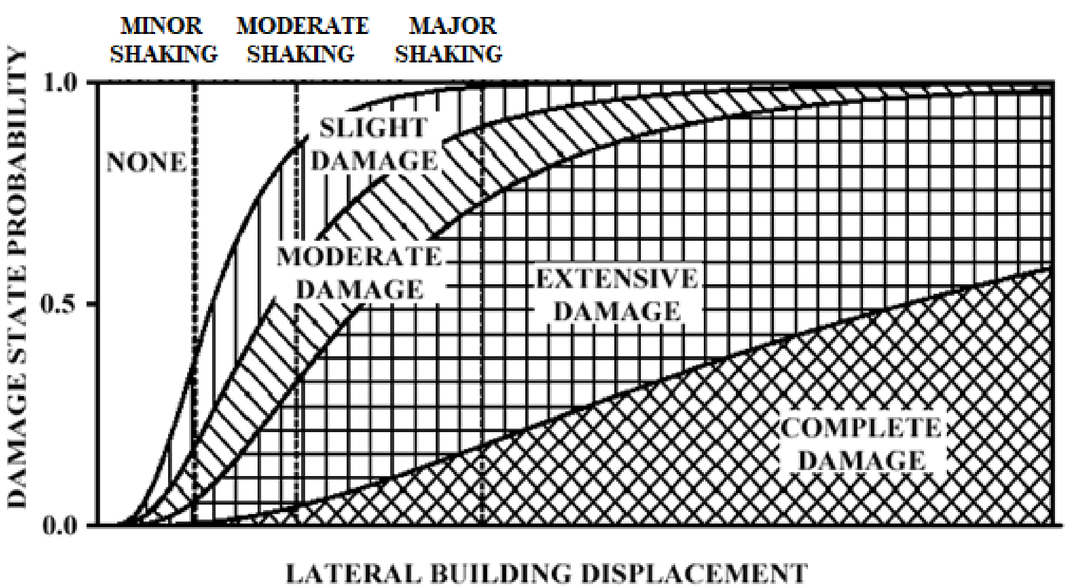
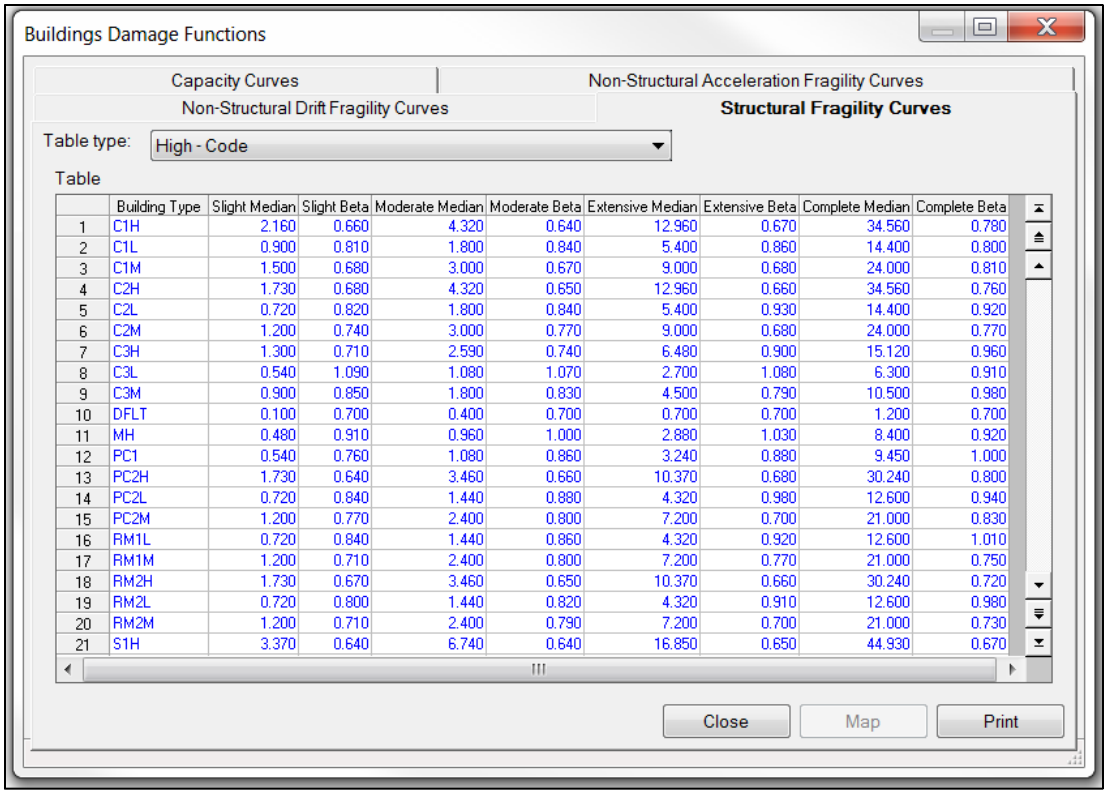


Figure 7-4 Sample Building Fragility Curve



	Building Type	Slight Median	Slight Beta	Moderate Median	Moderate Beta	Extensive Median	Extensive Beta	Complete Median	Complete Beta
1	C1H	2.160	0.660	4.320	0.640	12.960	0.670	34.560	0.780
2	C1L	0.900	0.810	1.800	0.840	5.400	0.860	14.400	0.800
3	C1M	1.500	0.680	3.000	0.670	9.000	0.680	24.000	0.810
4	C2H	1.730	0.680	4.320	0.650	12.960	0.660	34.560	0.760
5	C2L	0.720	0.820	1.800	0.840	5.400	0.930	14.400	0.920
6	C2M	1.200	0.740	3.000	0.770	9.000	0.680	24.000	0.770
7	C3H	1.300	0.710	2.590	0.740	6.480	0.900	15.120	0.960
8	C3L	0.540	1.090	1.080	1.070	2.700	1.080	6.300	0.910
9	C3M	0.900	0.850	1.800	0.830	4.500	0.790	10.500	0.980
10	DFLT	0.100	0.700	0.400	0.700	0.700	0.700	1.200	0.700
11	MH	0.480	0.910	0.960	1.000	2.880	1.030	8.400	0.920
12	PC1	0.540	0.760	1.080	0.860	3.240	0.880	9.450	1.000
13	PC2H	1.730	0.640	3.460	0.660	10.370	0.680	30.240	0.800
14	PC2L	0.720	0.840	1.440	0.880	4.320	0.980	12.600	0.940
15	PC2M	1.200	0.770	2.400	0.800	7.200	0.700	21.000	0.830
16	RM1L	0.720	0.840	1.440	0.860	4.320	0.920	12.600	1.010
17	RM1M	1.200	0.710	2.400	0.800	7.200	0.770	21.000	0.750
18	RM2H	1.730	0.670	3.460	0.650	10.370	0.660	30.240	0.720
19	RM2L	0.720	0.800	1.440	0.820	4.320	0.910	12.600	0.980
20	RM2M	1.200	0.710	2.400	0.790	7.200	0.700	21.000	0.730
21	S1H	3.370	0.640	6.740	0.640	16.850	0.650	44.930	0.670

Figure 7-5 Building Damage Functions: Fragility Curves

7.1.2.2 Capacity Curves

Building capacity curves (Figure 7-6) characterize a building's response to an earthquake event. A building capacity curve is a plot of a building's lateral load resistance as a function of a characteristic lateral displacement (i.e., a force-deflection plot). These curves describe the push-over displacement of each building type and seismic design level as a function of laterally-applied earthquake load. More specific information related to capacity curves can be found in the *Hazus Earthquake Model Technical Manual (FEMA, 2024).*

Two points are used to define the shape of the building capacity curves: yield capacity and ultimate capacity. For the GBS, capacity curve parameters can be viewed by clicking the **Analysis > Damage Functions > Buildings** menu (Figure 7-7). Capacity curve parameters are presented by specific building type and design level; the various design levels may be selected using the "Table type" pull-down menu.

In simple terms, within Hazus, estimated spectral accelerations and displacements are used to develop a response spectrum of demand at the building's location (Figure 7-6), which is intersected with the building's capacity curve to determine peak building response, which in turn, is used with the fragility curves (Section 7.2) to determine damage state.

It is highly recommended that the baseline capacity curves be used in the loss studies. Modification of these capacity curves requires the input of a structural engineer experienced in seismic design.

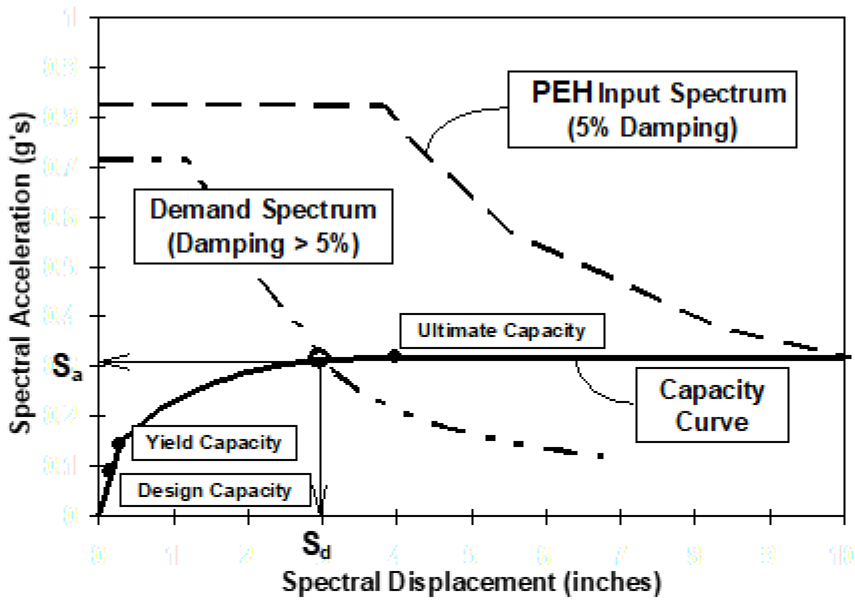
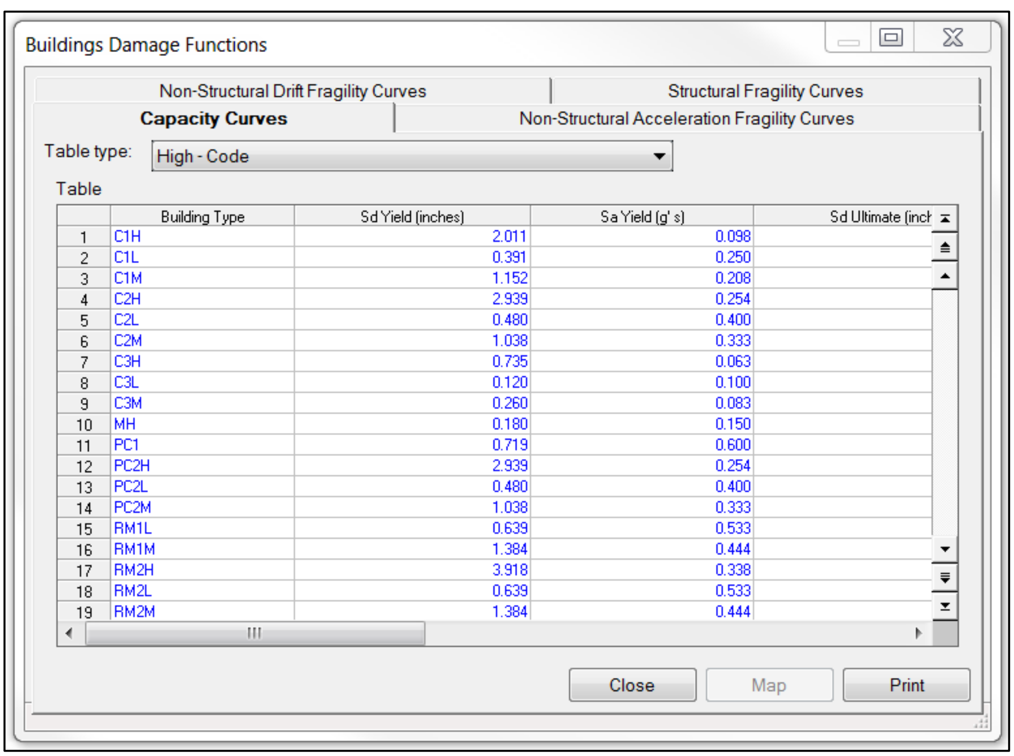


Figure 7-6 Example Capacity Curve and Spectral Demand



	Building Type	Sd Yield (inches)	Sa Yield (g' s)	Sd Ultimate (inch
1	C1H	2.011	0.098	
2	C1L	0.391	0.250	
3	C1M	1.152	0.208	
4	C2H	2.939	0.254	
5	C2L	0.480	0.400	
6	C2M	1.038	0.333	
7	C3H	0.735	0.063	
8	C3L	0.120	0.100	
9	C3M	0.260	0.083	
10	MH	0.180	0.150	
11	PC1	0.719	0.600	
12	PC2H	2.939	0.254	
13	PC2L	0.480	0.400	
14	PC2M	1.038	0.333	
15	RM1L	0.639	0.533	
16	RM1M	1.384	0.444	
17	RM2H	3.918	0.338	
18	RM2L	0.639	0.533	
19	RM2M	1.384	0.444	

Figure 7-7 Building Damage Functions: Capacity Curves

7.1.3 Transportation System Damage Functions

As with buildings, five damage states are defined for systems, including transportation systems: none, slight, moderate, extensive, and complete. For each component of each system, a description of the damage is provided for each damage state. Damage states can be defined in numerical terms or can be more descriptive, as shown in Table 7-5. Refer to the *Hazus Earthquake Model Technical Manual* for more information.

Table 7-5 Damage State Descriptions for Highway and Railway Bridges

Damage State	Description
Slight	Minor cracking and spalling to the abutment, cracks in shear keys at abutments, minor spalling and cracks at hinges, minor spalling at the column (damage requires no more than cosmetic repair) or minor cracking to the deck.
Moderate	Any column experience moderate (shear cracks) cracking and spalling (columns structurally still sound), moderate movement of the abutment (<2”), extensive cracking and spalling of shear keys, any connection having cracked shear keys or bent bolts, keeper bar failure without unseating, rocker bearing failure or moderate settlement of the approach.
Extensive	Any column degrading without collapse – shear failure (column structurally unsafe), significant residual movement at connections, or major settlement of the approach, vertical offset at the abutment, differential settlement at the connections, shear key failure at abutments.
Complete	Any column collapsing and connection losing all bearing support, which may lead to imminent deck collapse, tilting of the substructure due to foundation failure.

7.1.3.1 Transportation System Damage Functions

As with buildings, baseline damage functions (fragility curves) have been developed for all components of all systems (including both transportation and utility systems). Typical damage functions, using railway bridges as an example, are shown in Figure 7-8 and Figure 7-9. The damage functions are provided in terms of damage state exceedance probabilities for various levels of PGA and PGD. The top curve in Figure 7-8 gives the probability that the damage state is at least slight, given that the bridge has been subjected to a specified PGA. For example, if the bridge experiences a PGA of 0.4g, there is a 70% probability that the damage will be slight or worse. Figure 7-9 is similar except that it is in terms of PGD. Thus, if a bridge experiences a permanent ground deformation of 12 inches, there is a 100% chance that it will have at least slight damage and a 70% chance it will have moderate damage or worse.

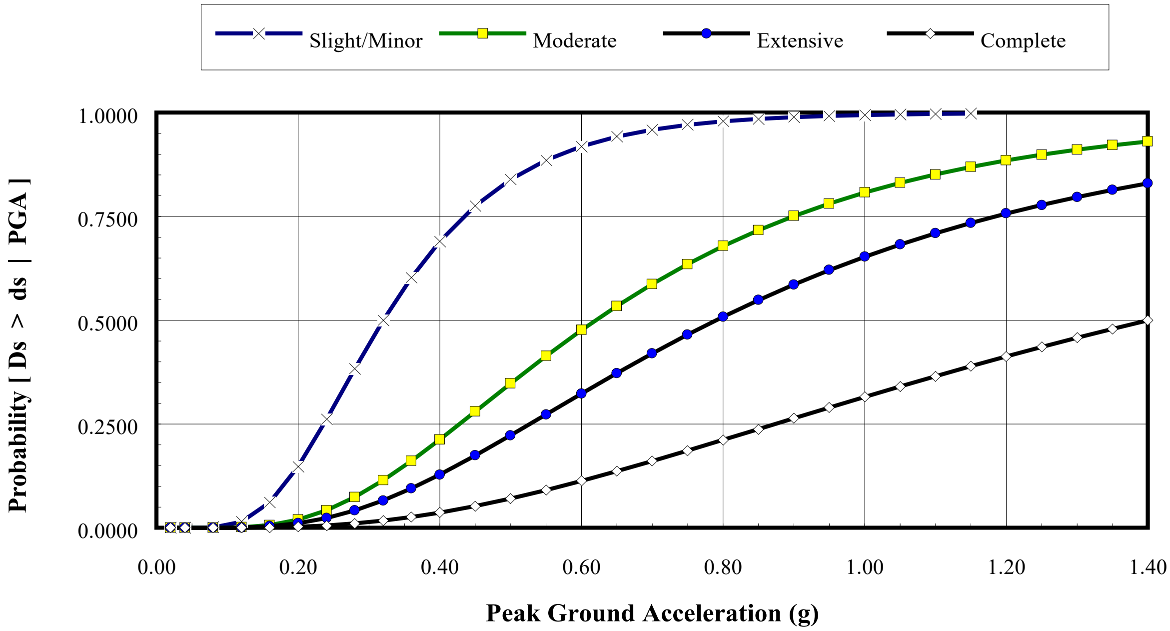


Figure 7-8 Fragility Curves at Various Damage States for Seismically Designed Railway Bridges Subject to Peak Ground Acceleration

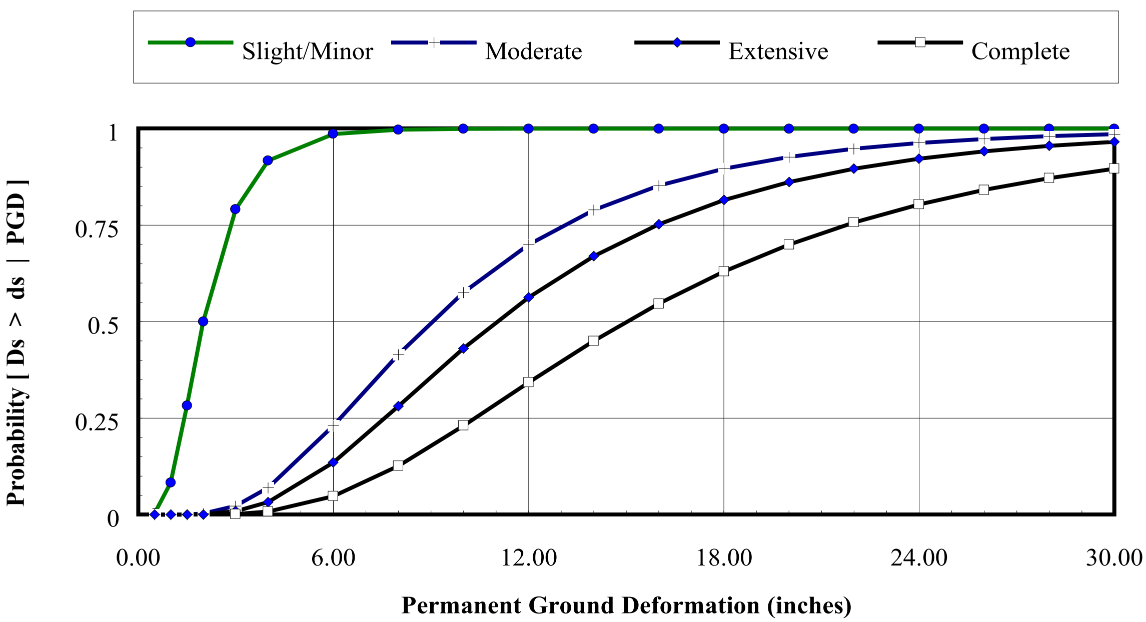


Figure 7-9 Fragility Curves at Various Damage States for Seismically Designed Railway Bridges Subject to Permanent Ground Deformation

The baseline damage functions are lognormally-distributed functions with parameters (medians and betas) as defined in the *Hazus Earthquake Model Technical Manual (FEMA, 2024)*. These parameters can also be viewed and modified within Hazus via the **Analysis > Damage Functions >**

Transportation Systems menu. The window for viewing parameters of fragility curves for railway bridge system components is shown in Figure 7-10. In this example, parameters of damage functions for PGA-induced damage are displayed. The user can also view parameters for PGD-induced damage by moving to the right within the table. The column “PGASlightMedian” contains the median PGA (g’s) for the slight damage state. Compare the slight damage fragility curve in Figure 7-8 with the parameters for the component RLB1 in Figure 7-10. The column “PGASlightBeta” contains the parameter beta, which is an indicator of the dispersion of the distribution. The larger the beta, the more spread out the fragility curve. The beta for slight damage to RLB1 is 0.6. While these parameters can be modified, baseline values should be used unless a structural engineer experienced in seismic design is consulted.

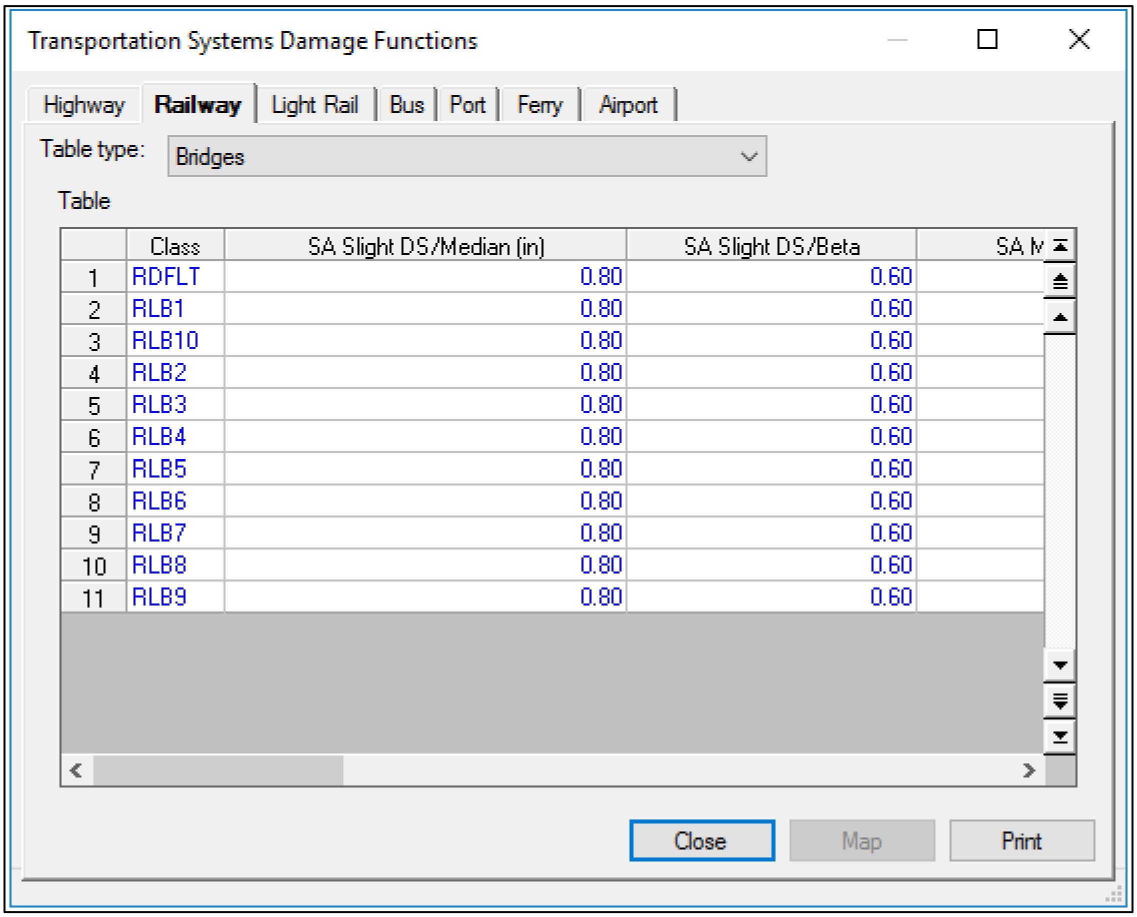


Figure 7-10 Transportation Systems Damage Functions: Railway Bridges

7.1.4 Utility System Damage Functions

As with buildings, five damage states are defined for systems, including utility systems: none, slight, moderate, extensive, and complete. For each component of each system, a description of the damage is provided for each damage state. Damage states can be defined in numerical terms or can be more descriptive, as shown in Table 7-6. Refer to the *Hazus Earthquake Model Technical Manual (FEMA, 2024)* for more information.

Table 7-6 Damage State Descriptions for Electrical Power Generation Plants

Damage State	Description
Slight	Turbine tripping, or light damage to diesel generator, or the building is in the slight damage state.
Moderate	Chattering of instrument panels and racks, considerable damage to boilers and pressure vessels, or the building is in the moderate damage state.
Extensive	Considerable damage to motor driven pumps, or considerable damage to large vertical pumps, or the building is in the extensive damage state.
Complete	Extensive damage to large horizontal vessels beyond repair, or extensive damage to large motor operated valves, or the building is in the complete damage state.

7.1.4.1 Utility System Damage Functions

Utility system damage functions have the same functional form as those for transportation systems discussed in Section 7.1.3.1 - lognormally distributed fragility curves defined by a median and beta.

Figure 7-11 shows an example of the Utility Systems Damage Functions table, accessible from the **Analysis > Damage Functions > Utility Systems** menu. The tabs allow the user to choose the utility type for review. While these parameters can be modified, baseline values should be used unless a structural engineer experienced in seismic design is consulted.

The linked image cannot be displayed. The file may have been moved, renamed, or deleted. Verify that the link points to the correct file and location.

Figure 7-11 Utility Systems Damage Functions Table

7.2 Restoration Functions

The damage state descriptions provide a basis for establishing loss of function and repair time of facilities. A distinction should be made between loss of function and repair time. In this methodology, loss of function is defined as the time that a facility is not capable of operating or providing service (i.e., the time needed to restore functionality). Loss-of-function or restoration time is, in general, shorter than repair time because essential service providers will relocate operations, bypass damaged components, or bring in temporary replacement facilities while repairs and construction are being completed. Loss of function (restoration time) is estimated in the methodology only for essential facilities, transportation systems, and utility systems. See Section 7.3.7.2 for more information on repair time.

Baseline restoration functions are provided with the methodology for essential facilities, transportation systems, and utility systems. An example of a set of restoration functions is shown in Figure 7-12. Restoration curves describe the fraction of facilities (or components in the case of systems) that are expected to be open or operational as a function of time following the earthquake. For example, looking at the curves in Figure 7-12, 10 days after the earthquake, approximately 20%

of the facilities that were in the extensive damage state immediately after the earthquake and approximately 60% of the facilities that were in the moderate damage state immediately after the earthquake are expected to be functional. Each curve is based on a normal distribution with a mean and standard deviation.

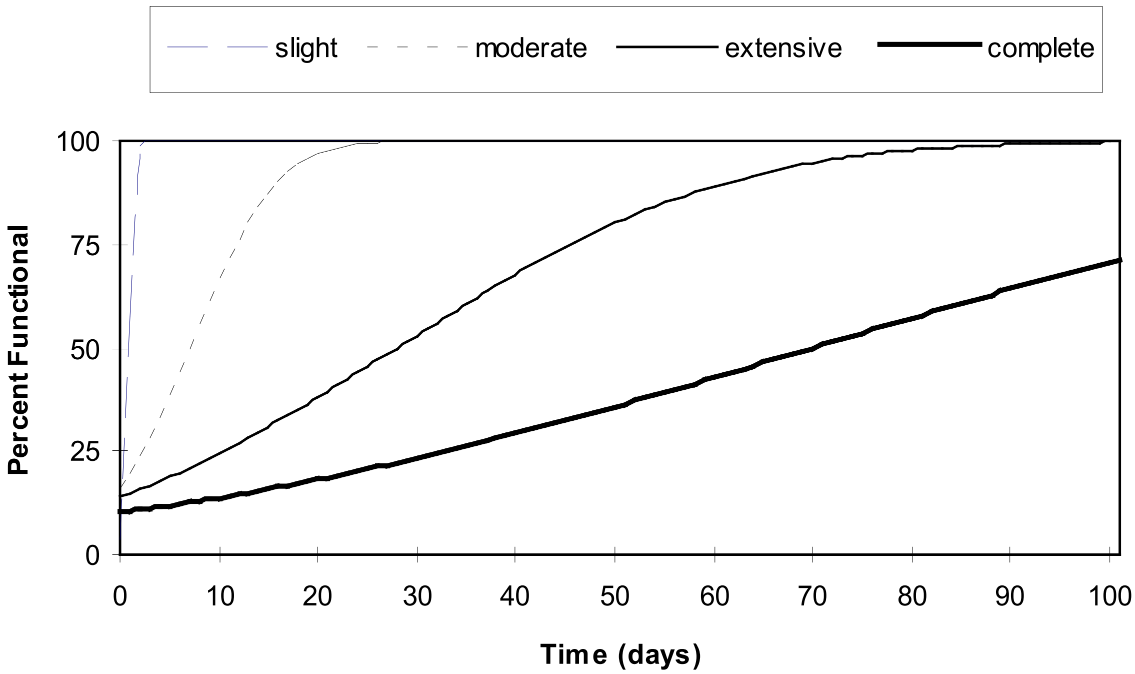


Figure 7-12 Restoration Functions for a Sample Facility Type

The parameters of the restoration functions are accessed through the **Analysis > Restoration Functions** menu and can be viewed and modified in a window such as the one shown in Figure 7-13 for essential facilities. Right click to start editing, type in a new value and then click **Close** to modify parameters for restoration curves. Users will be prompted to confirm modifications and save changes. Restoration curves are based on data published in ATC-13 (1985). It is strongly recommended that the baseline parameters be used unless individuals contributing to the project have expertise in the development of restoration functions.

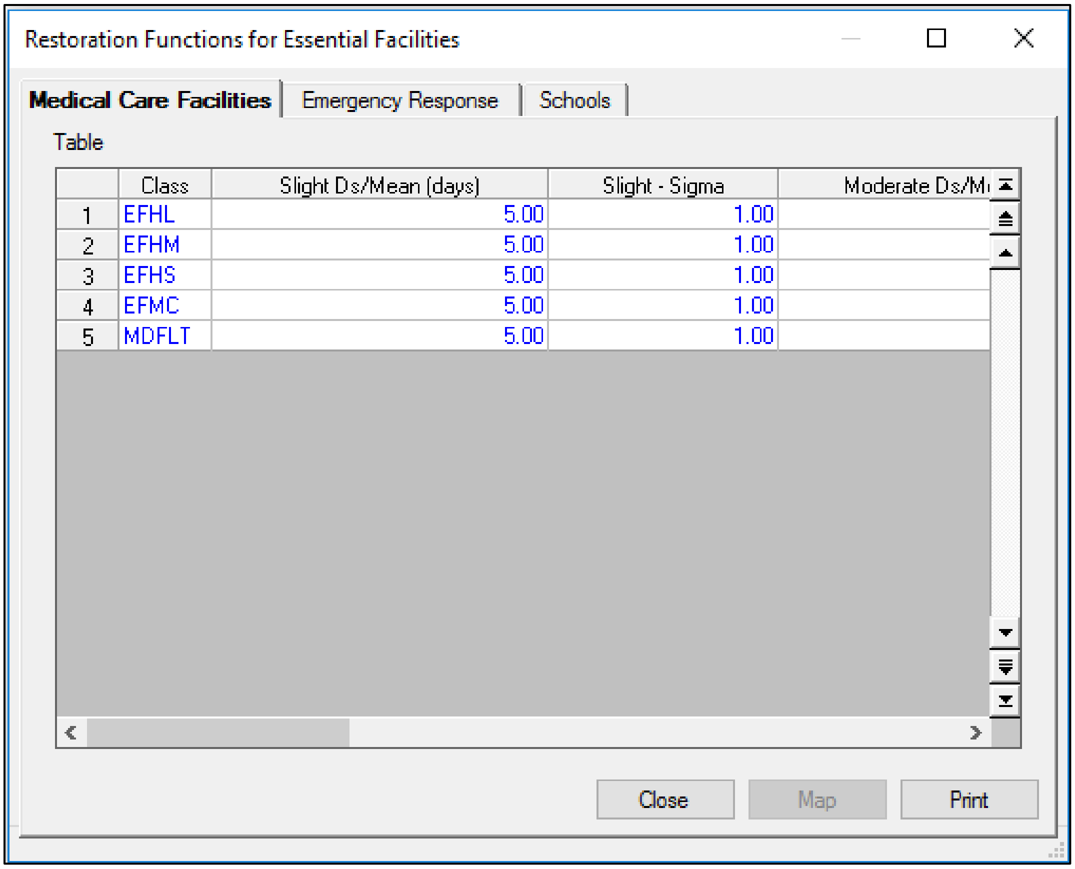


Figure 7-13 Reviewing and Modifying Restoration Functions

7.3 Parameters

In addition to baseline databases, the user is supplied with baseline analysis parameters documented within the *Hazus Earthquake Model Technical Manual (FEMA, 2024)*. Access the Hazus parameters from the **Analysis > Parameters** menu, shown in Figure 7-14. The menu provides access to the baseline parameters used in the analysis of **Hazard**, **Contours**, **Inundation Data Files**, **Fire Following**, **Debris**, **Casualties**, **Shelter**, **Building Economic**, **Transportation Systems Economic**, **Utility Systems Economic**, and **Indirect Economic.** In many cases these parameters are defined on a national basis without adjustments for regional variations. For some parameters, such as repair costs, regional variations are included. Examples of baseline parameters are soil amplification factors, percent of buildings that are owner occupied, and casualty rates for specific building types experiencing different damage states. The user can modify these parameters if better information is available. Each menu parameter is listed below (Figure 7-15).

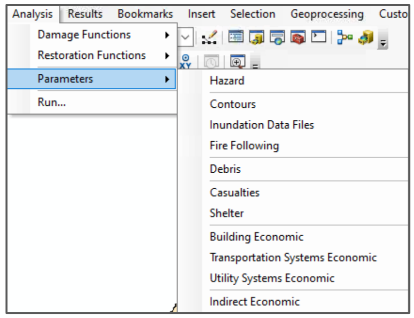


Figure 7-14 Analysis Parameters

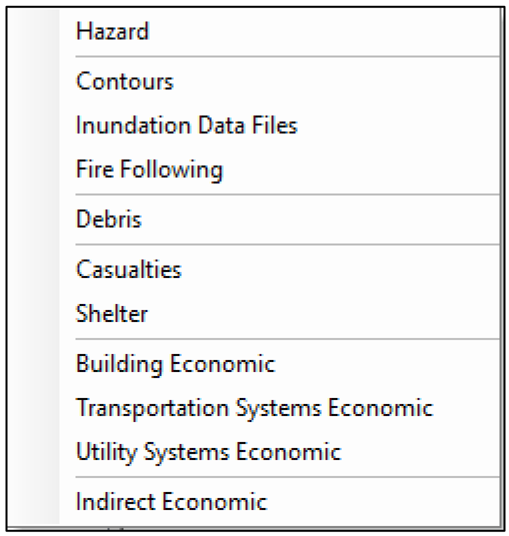


Figure 7-15 Analysis Parameter Types

7.3.1 Hazard

The Hazard parameter menu enables users to adjust the baseline values for Soils Amplification, Liquefaction and Landslide, Users can adjust the soil amplification factors by soil type for PGA, PGV, 0.3 seconds and 1.0 seconds spectral acceleration (Figure 7-16). For liquefaction and landslide, the proportion values by susceptibility (proportion of the mapped area that is considered susceptible to either liquefaction or landslide, i.e., the likelihood of susceptible conditions existing at any given location within the unit) can be adjusted by the user.

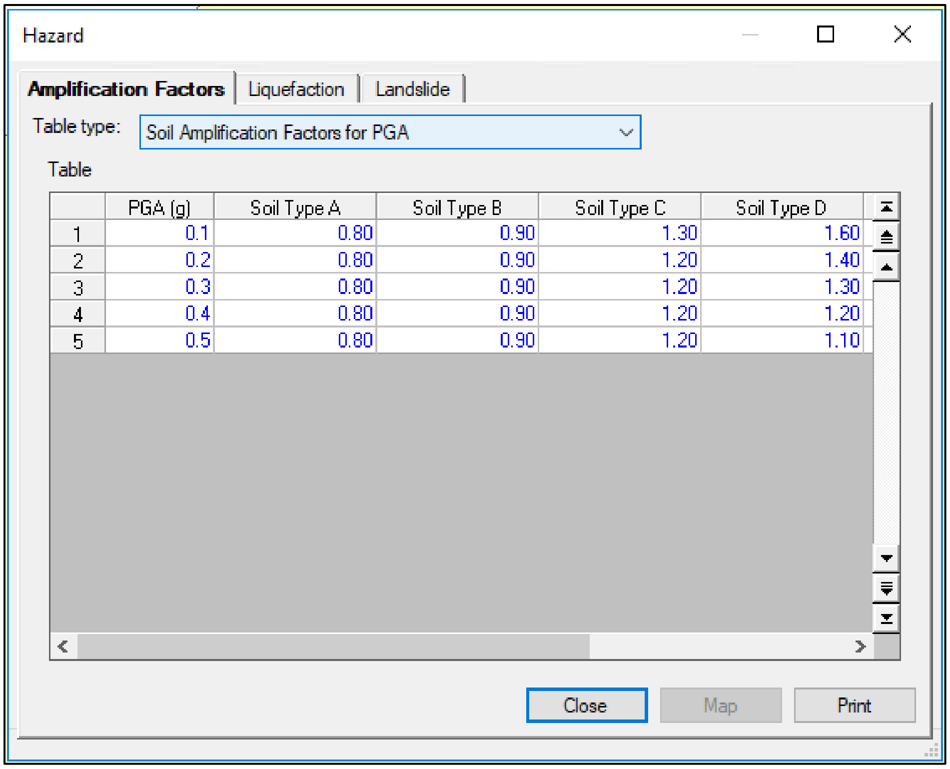


Figure 7-16 Hazard Parameter Menu

When a scenario is defined without using USGS ShakeMaps or probabilistic ground motions, ground motions are calculated by Hazus when direct losses are estimated. Baseline ground motion and ground failure parameters can be modified using the windows shown in Figure 7-17 and Figure 7-18. These windows can be accessed through the **Analysis > Parameters > Hazard** option on the Hazus menu bar. The window shown in Figure 7-17 is used to modify soil amplification factors. Soil amplification factors include factors for peak ground acceleration (PGA), peak ground velocity (PGV), and amplification for spectral accelerations at 0.3 second and 1.0 second periods. These factors are discussed in the *Hazus Earthquake Model Technical Manual (FEMA, 2024)*. It should be noted, however, that these parameters should not be modified unless users have expertise in seismology and geotechnical engineering.

As discussed in the *Hazus Earthquake Model Technical Manual (FEMA, 2024)*, soil does not behave uniformly, and in an area with very high susceptibility to liquefaction, it is unlikely that the entire area will actually liquefy. In fact, liquefaction may appear in pockets with a large portion of the area remaining unaffected. A parameter is used to define the proportion of a geologic map unit that is likely to liquefy, or landslide given its relative susceptibility. The window in Figure 7-18 is used to modify the baseline map proportions for liquefaction and landslide. These factors are described in the *Hazus Earthquake Model Technical Manual (FEMA, 2024)*.

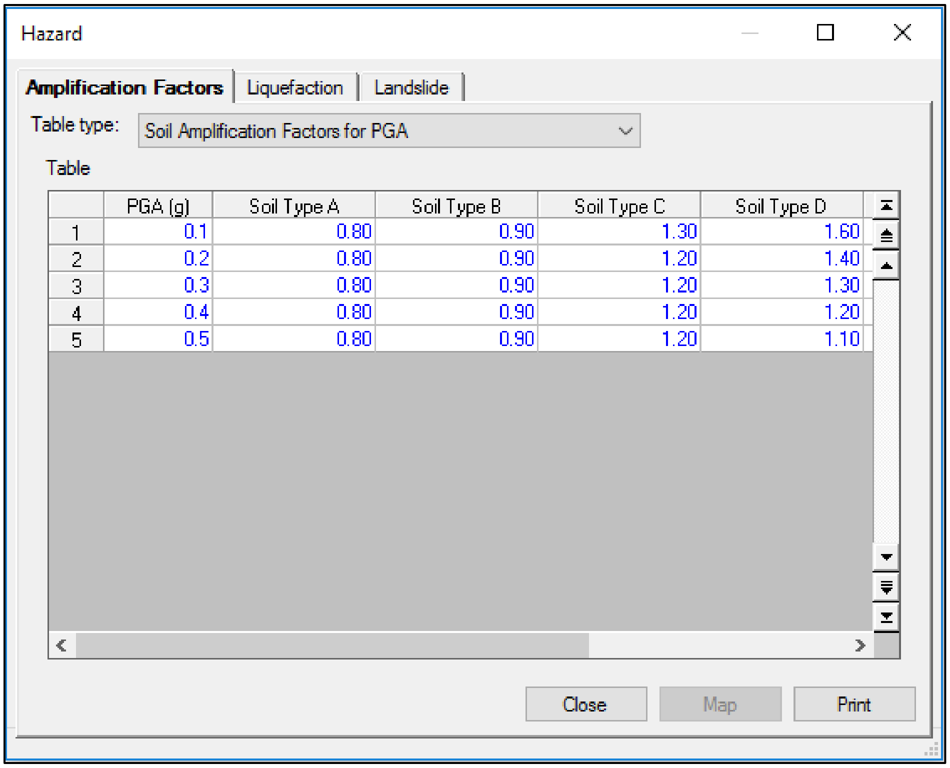


Figure 7-17 Modifying Soil Amplification Factors

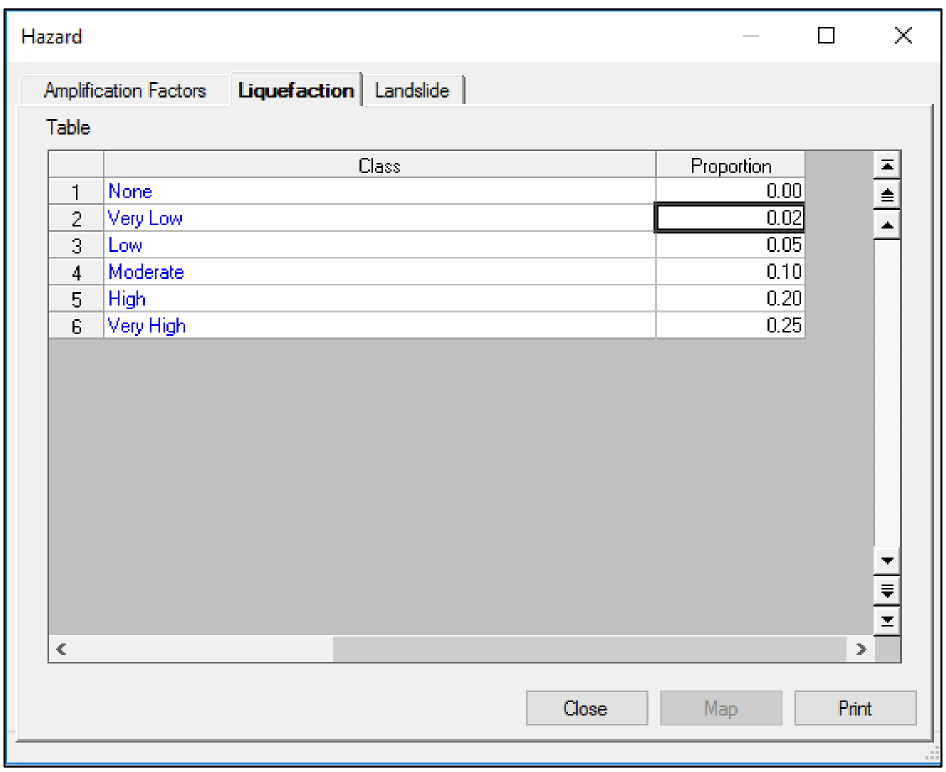


Figure 7-18 Modifying Map Proportions Susceptible to Liquefaction

Contour maps that are generated by Hazus are for display purposes only. The baseline setting is 100 x 100 number of grid cells (Figure 7-19). This parameter can be updated by the user to create a more refined or a coarser grid.

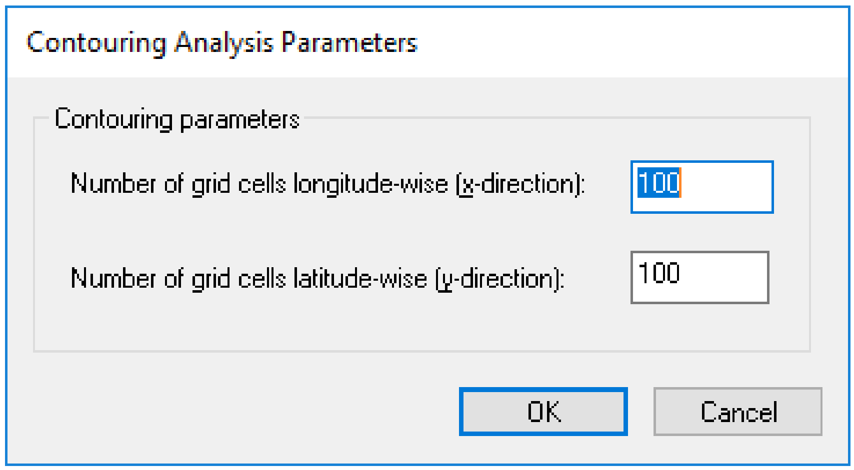


Figure 7-19 Contouring Analysis Parameters

7.3.2 Inundation Data Files

To assess potential exposure due to inundation, an inundation map must be loaded into Hazus under the **Hazard > Data Maps** menu, and then activated from the **Analysis > Parameters > Inundation Data Files** menu as shown in Figure 7-20 (noted as Inundation Data Maps in GUI).

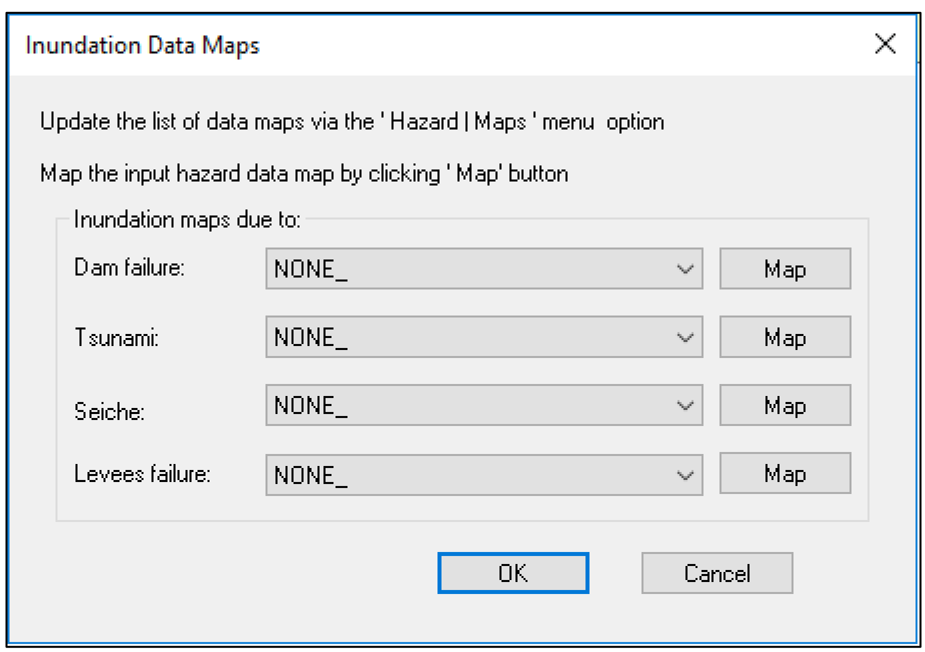


Figure 7-20 Specifying Inundation Maps

7.3.2.1 Dam or Levee Failure

In general, unless inundation maps already exist, the treatment of inundation due to dam failure is limited to identifying dams whose failure has a high potential of causing damage. User-input dam and levee data can be mapped to consider their locations. Users are responsible for developing their own inventory of dams and levees because no baseline inventory exists. If inundation maps exist, they can be input using the menu **Hazard > Data Maps**. Hazus does not model dam or levee failures and riverine damage functions may not accurately reflect damage.

7.3.3 Fire Following Earthquake Parameters

Users can analyze fire damage by adjusting simulation parameters following an earthquake. Aside from the locations of fire stations and the number of fire trucks that should be available from fire departments or regional emergency response organizations, there is little inventory information available to estimate fire following earthquake. Parameters for the Hazus fire-following earthquake module can be accessed via the **Analysis > Parameters > Fire Following** menu, as shown in Figure 7-21. Typical wind speeds and wind directions can be obtained from the weather service, and average fire engine speeds should be available from the fire department.

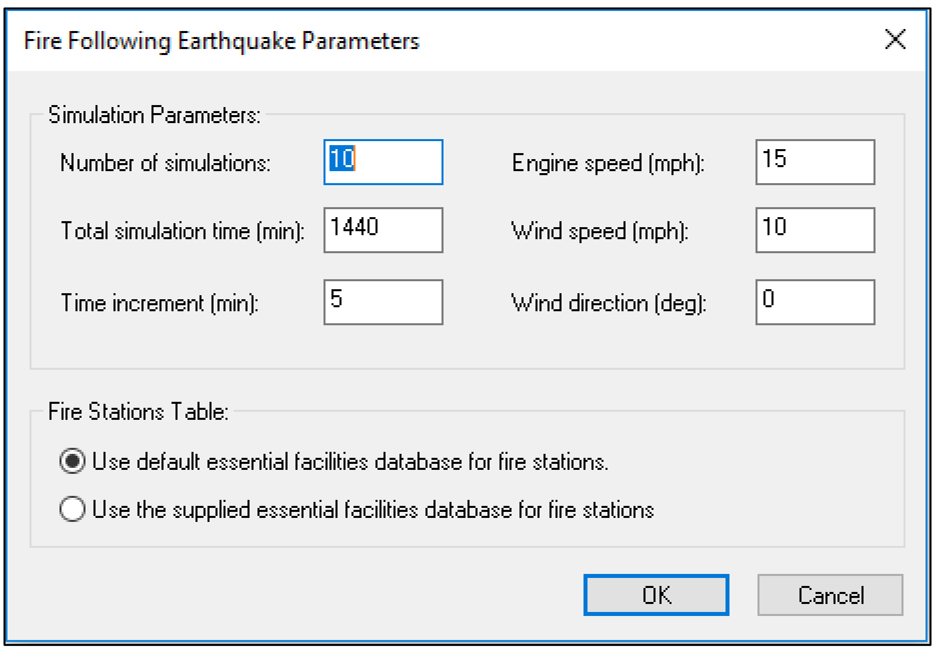


Figure 7-21 Fire Following Earthquake Parameters

7.3.4 Debris Parameters

A major source of debris after an earthquake event is structures that have been significantly damaged or have collapsed. Debris estimates include values for reinforced concrete and steel (heavy debris), as well as brick, wood and other materials (light debris) to help planners determine the types and quantity of debris removal and storage resources that may be needed. Completely damaged buildings may still be standing, but the cost of repair could be so high that these buildings will be torn down and rebuilt. However, even buildings that do not suffer extensive damage can be sources of debris. Examples of nonstructural debris are suspended ceilings, light fixtures, and partition walls made of plaster or hollow clay tile.

Different types of buildings generate different types of debris. Unreinforced masonry structures tend to generate piles of bricks that result from a collapse of a wall or from damage to some nonstructural element such as an unbraced parapet. In single-family dwellings of wood construction, chimneys may separate from the rest of the structure, causing them to be torn down and rebuilt. Many steel and concrete frame buildings that were built in the first half of the 20th century have exterior cladding made of brick or terra cotta that may fall off when subjected to earthquake motion. Non-ductile concrete buildings may collapse in a pancake fashion, resulting in a stack of concrete slabs that are not broken up. In a tilt-up building, concrete wall panels, which are usually on the exterior of the structure, may fall outward and remain essentially intact. When the walls fall, the roof (typically of wood or light metal deck) will also collapse. In modern high-rise structures, precast panels used for exterior cladding may come loose and fall to the ground or windows may break. If a steel structure collapses, as one did in Mexico City in 1985, large pieces of twisted steel would result.

The types of building debris that are generated from an earthquake can be divided into two types:

- Light debris - Brick, wood, and other debris
- Heavy debris - Reinforced concrete and steel members.

The first type of debris includes everything except reinforced concrete and steel members. It includes glass, equipment, and plaster walls, as well as brick and wood. The difference in the two types of debris is that light debris can be moved and broken up with a bulldozer or hand-held tools. Heavy debris requires special treatment to break up the long steel members or the large pieces of concrete before they can be transported. Cranes and other heavy equipment are likely to be needed.

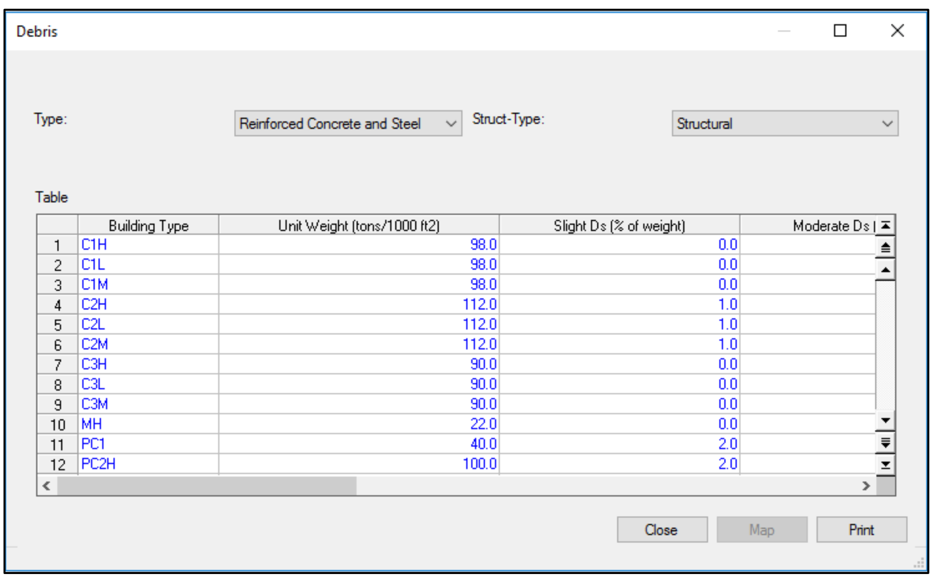
Hazus debris estimates are limited to debris resulting from building damage; debris from bridge and overpass damage is not included. Due to the simplifications that are introduced in the modeling of transportation systems, and in particular the lack of inventory detail regarding dimensions of individual bridges, any estimate of quantities of bridge debris would contain large uncertainties and may be misleading.

Very little research has been done to determine the amount of debris generated from earthquakes and other natural disasters. However, anecdotal evidence suggests that removal of debris can be a significant part of the cleanup process and as such, can be costly for a municipality. After Hurricane Hugo in 1989, the City of Charleston disposed of so much debris that the life of its landfill was shortened by 17 years (Leonard, 2014). Debris can also hinder emergency operations immediately after an earthquake if it is blocking streets, sidewalks, or doorways. Where collapses or partial collapses of buildings occur, rescue of victims can be difficult if the walls or floors of the structure come down essentially intact.

The Hazus debris module provides an estimate of the amount of light and heavy debris (in thousands of tons) that will be generated for each Census tract. Estimates of debris are based on the structural and nonstructural damage states that are output from the building damage module. Square footage of each specific building type is also required but is available from the building inventory module. Two additional sets of data are required to estimate the amount of debris that is generated from damaged buildings:

- Weight in tons of structural and nonstructural elements per square foot of floor area for each specific building type
- The amount of debris generated for each structural and nonstructural damage state in terms of percent of weight of elements

Estimates of debris can be generated using the baseline data supplied with Hazus. Baseline values of debris weight for each specific building type can be shown by clicking the **Analysis > Parameters > Debris** menu. For each specific building type, there are two-unit weight tables. The first table includes light materials such as brick, wood, and other debris, while the second includes the heavy materials such as reinforced concrete and steel. Both tables provide the number of tons of material per 1,000 square feet of building area. For example, Figure 7-22 shows that for each 1,000 square feet of high-rise concrete moment frame (C1H) buildings, there are 98.0 tons of heavy structural material. These values are based on assumptions of "typical buildings." The values can be modified to more accurately reflect the buildings in a specified area if such data are available.



	Building Type	Unit Weight (tons/1000 ft2)	Slight Ds (% of weight)	Moderate Ds
1	C1H	98.0	0.0	
2	C1L	98.0	0.0	
3	C1M	98.0	0.0	
4	C2H	112.0	1.0	
5	C2L	112.0	1.0	
6	C2M	112.0	1.0	
7	C3H	90.0	0.0	
8	C3L	90.0	0.0	
9	C3M	90.0	0.0	
10	MH	22.0	0.0	
11	PC1	40.0	2.0	
12	PC2H	100.0	2.0	

Figure 7-22 Debris Weights
(in Terms of Tons per 1,000 Square Feet of Building Area)

Baseline values are also provided for debris weight fractions by damage state (i.e., the percentage of weight of elements considered to be debris in each damage state). For example, for low-rise steel braced frame structures (S2L), one can expect to remove heavy debris (i.e., reinforced concrete and steel) equal to 30% of the building's structural weight if the damage state is extensive. These baseline values are based on observations of damage in past earthquakes but can be modified to more accurately reflect the buildings in a specified area if such data are available.

7.3.5 Casualty Parameters

The casualty (injuries and fatalities) module calculates the following estimates for each Census tract at three times of day (2 AM, 2 PM and 5 PM):

- Single-family dwelling (RES1) casualties
- Other Residential (other than RES1) casualties
- Commercial casualties
- Industrial casualties
- Education casualties
- Hotel casualties
- Commuting casualties
- Total casualties

The following inputs are needed to obtain estimates of casualties:

- Population distribution by Census tract
- Population distribution within occupancy types within the Census tract
- Building stock inventory
- Damage state probabilities
- Time of day of estimate (2 AM, 2 PM or 5 PM)
- Casualty rates by damage state of specific building type
- Collapse rates due to collapse of specific building/bridge type
- Number of commuters on or under bridges in the Census tract

All this information has already been provided by other models or is available as a baseline.

7.3.5.1 Injury Classification Scale

The output from the module consists of a casualty breakdown by injury severity, defined by a four-tier injury severity scale (Coburn, Spence, and Pomonis, 1992; Cheu, 2004).Table 7-7 defines the injury classification scale used in Hazus. Other more elaborate casualty scales are based on quantifiable medical parameters such as medical injury severity scores, coded physiologic variables, and similar issues. The selected four-tier injury scale used in Hazus is a compromise between the demands of the medical community (in order to plan its response) and the ability of the engineering community to provide the required data. Currently, available casualty assessment methodologies do not allow for a finer resolution in the casualty scale definition.

Table 7-7 Injury Classification Scale

Injury Severity	Description
Severity 1	Injuries requiring basic medical aid without requiring hospitalization
Severity 2	Injuries requiring a greater degree of medical care and hospitalization, but not expected to progress to a life-threatening status
Severity 3	Injuries that pose an immediate life-threatening condition if not treated adequately and expeditiously.
Severity 4	Instantaneously killed or mortally injured

7.3.5.2 Casualty Rates

In order to estimate the number and severity of the casualties, statistics from previous earthquakes were analyzed to develop relationships that reflect the distribution of injuries one would expect to see resulting from building and bridge damage. It should be noted that complete data do not exist for all specific building types and injury severity. Missing data were inferred from reviewing previous studies. Collection of better and more complete casualty statistics would involve a major research study. Casualty rates were developed for each specific building type, damage state and casualty severity and are multiplied by the exposed population to estimate the number of casualties. An example of a calculation of casualties follows:

Severity 1 casualty rate for low-rise unreinforced masonry buildings (URML) with slight structural damage = 1 in 2,000 (tabulated as 0.5 per 1,000 people)

Number of people in the Study Region who were in slightly damaged URML buildings = 50,000

Severity 1 casualties = 50,000 (1/2,000) = 25 people

The following baseline casualty rates are defined by Hazus and are discussed in the *Hazus Earthquake Model Technical Manual (FEMA, 2024)*:

- Casualty rates by specific building type for Slight structural damage (indoor rates only)
- Casualty rates by specific building type for Moderate structural damage (indoor and outdoor rates)

- Casualty rates by specific building type for Extensive structural damage (indoor and outdoor rates)
- Casualty rates by specific building type for Complete structural damage without collapse (indoor and outdoor rates)
- Casualty rates by specific building type for Complete structural damage with collapse (indoor only)
- Casualty rates by highway bridge type for complete structural damage.

Note that a separate set of casualty rates was developed for buildings suffering collapse and that collapse is only considered in the complete structural damage state (see Section 7.3.5.3). It is assumed that in slight, moderate, and extensive structural damage states, collapses do not occur. Casualty rates for both buildings and bridges can be viewed and modified in the window shown in Figure 7-23. Selecting the **Analysis > Parameters > Casualties** menu accesses this window. These baseline casualty rates can be modified if improved information is available. To modify values, right click to start editing, type in the new numbers and click the **Close** button. Users will be asked to confirm changes.

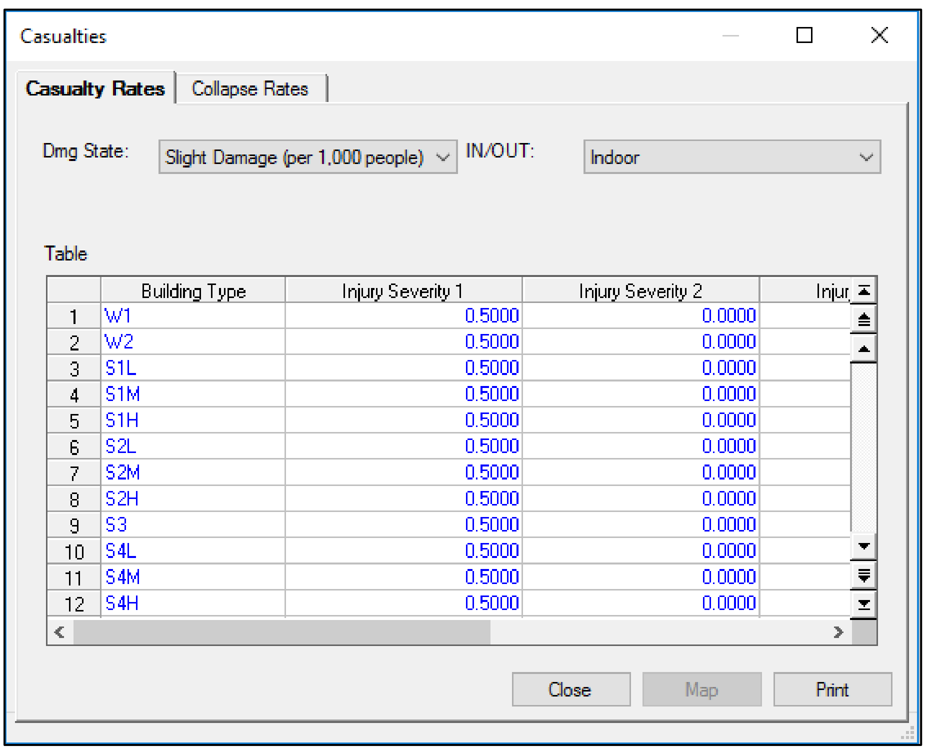


Figure 7-23 Casualty Rates (Number of Casualties per 1,000 Occupants) by Specific Building Type for the Slight Structural Damage State (Indoors)

7.3.5.3 Collapse Rates

When collapse or partial collapse occurs, individuals may become trapped under fallen debris or trapped in air pockets in the rubble. Casualties tend to be more severe in these cases, and a separate set of casualty rates was developed for collapsed buildings, along with collapse rates by specific building type for buildings in the Complete damage state. It should be noted that building collapse rates were developed only for the complete damage state because it is assumed that no collapses or partial collapses occur in the slight, moderate, or extensive damage states. Collapse rates by specific building type can be viewed from the **Analysis > Parameters > Casualties** menu, by clicking on the **Collapse Rates** tab as shown in Figure 7-24 and provided in the *Hazus Earthquake Model Technical Manual (FEMA, 2024)*. To modify values, right click to start editing, type in the new numbers and click the **Close** button. Users will be asked to confirm changes.

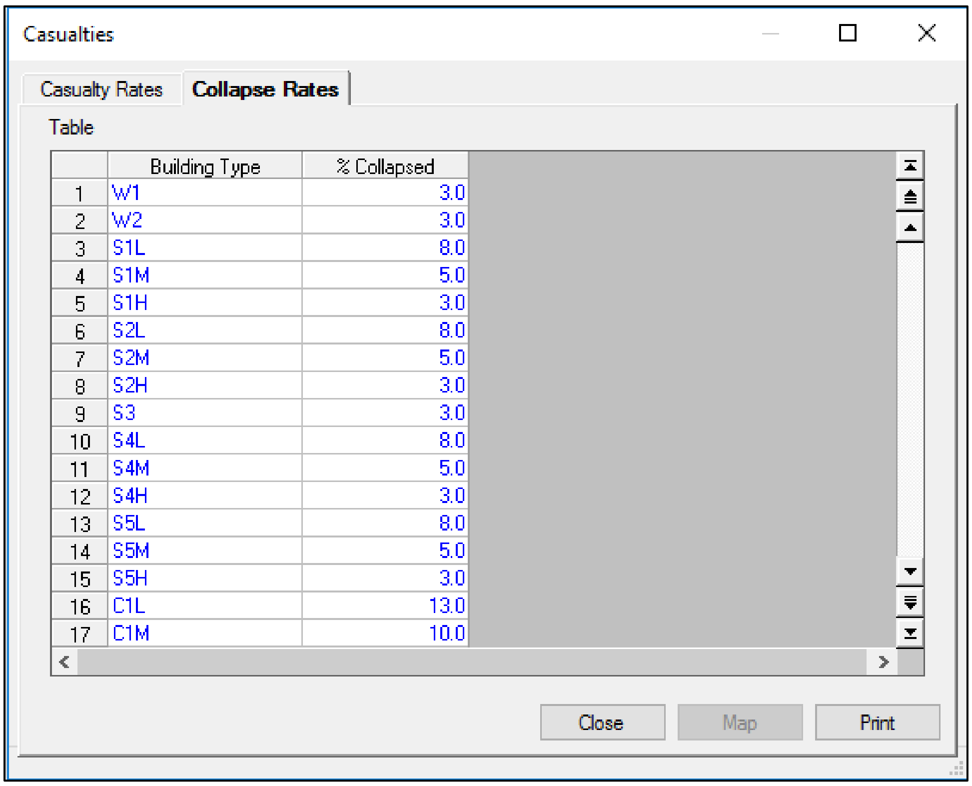


Figure 7-24 Collapse Rates for Buildings

7.3.6 Shelter Module Parameters

Earthquakes can cause loss of function or habitability of buildings that contain housing units resulting in predictable numbers of displaced households. These households will need alternative short-term shelter from family, friends, or public shelters provided by relief organizations such as the Red Cross and Salvation Army. For units where repair takes longer than a few weeks, long-term alternative housing can be achieved through importation of mobile homes, a reduction in vacant units, net emigration from the impacted area, and eventually by the repair or reconstruction of new public and private housing. While the number of people seeking short-term public shelter is of great concern to emergency response organizations, the longer-term impacts on the housing stock are of great concern to local governments. The shelter module provides two estimates:

- The total number of displaced households (due to loss of habitability)
- The number of people requiring short-term shelter

Loss of habitability is calculated directly from damage to the residential buildings. The methodology for calculating short-term shelter requirements recognizes that only a portion of those displaced from their homes will seek public shelter and that some may seek shelter even though their residence have experienced moderate damage and are technically habitable. For example, data from the 1994 Northridge earthquake indicate that approximately one-third of those in public shelters came from residences with no or insignificant structural damage (Petak, 2001).

Households may also be displaced as a result of fire following earthquake, inundation (or the threat of inundation) due to dam failure, and significant hazardous materials release. The Hazus shelter module does not specifically deal with these issues, but an approximate estimate of displacement due to fire or inundation can be obtained by multiplying the residential inventory in affected Census tracts by the areas of fire damage or inundation derived from other models. No methodology for calculations of damage or loss due to hazardous materials is provided, and the user is limited to identifying locations of sites where hazardous materials are stored. If the particular characteristics of the Study Region give cause for concern about the possibility of loss of housing from fire, inundation, or hazardous materials release, it would be advisable to initiate specific in-depth studies directed to the problem.

7.3.6.1 Parameters for Modeling Displaced Households

The fraction of dwelling units that are likely to be vacated if damaged is required to compute the number of uninhabitable dwelling units and the number of displaced households. The number of uninhabitable dwelling units is not only a function of the amount of structural damage but also a function of the number of damaged units that are perceived to be uninhabitable by their occupants. All dwelling units in buildings that are in the complete damage state are considered to be uninhabitable. In addition, dwelling units that are in moderately or extensively damaged multi-family structures can also be uninhabitable due to the fact that renters perceive some moderately damaged and most extensively damaged rental property as uninhabitable. On the other hand, those living in single-family homes are much more likely to tolerate damage and continue to live in their homes. Therefore, weighting factors have been developed that describe the fraction of dwellings likely be vacated if they are damaged. These baseline weighting factors can be viewed and modified as shown in Figure 7-25. To access this window, use the **Analysis > Parameters > Shelter** menu, and click on the **Damage State Factors** tab.

In Figure 7-25, based on these baselines, it is assumed that 90% of multi-family dwellings will be vacated if they are in the extensive damage state (shown as wMFE in Figure 7-25). Discussion of how the baseline values were developed is provided in the *Hazus Earthquake Model Technical Manual (FEMA, 2024)*.

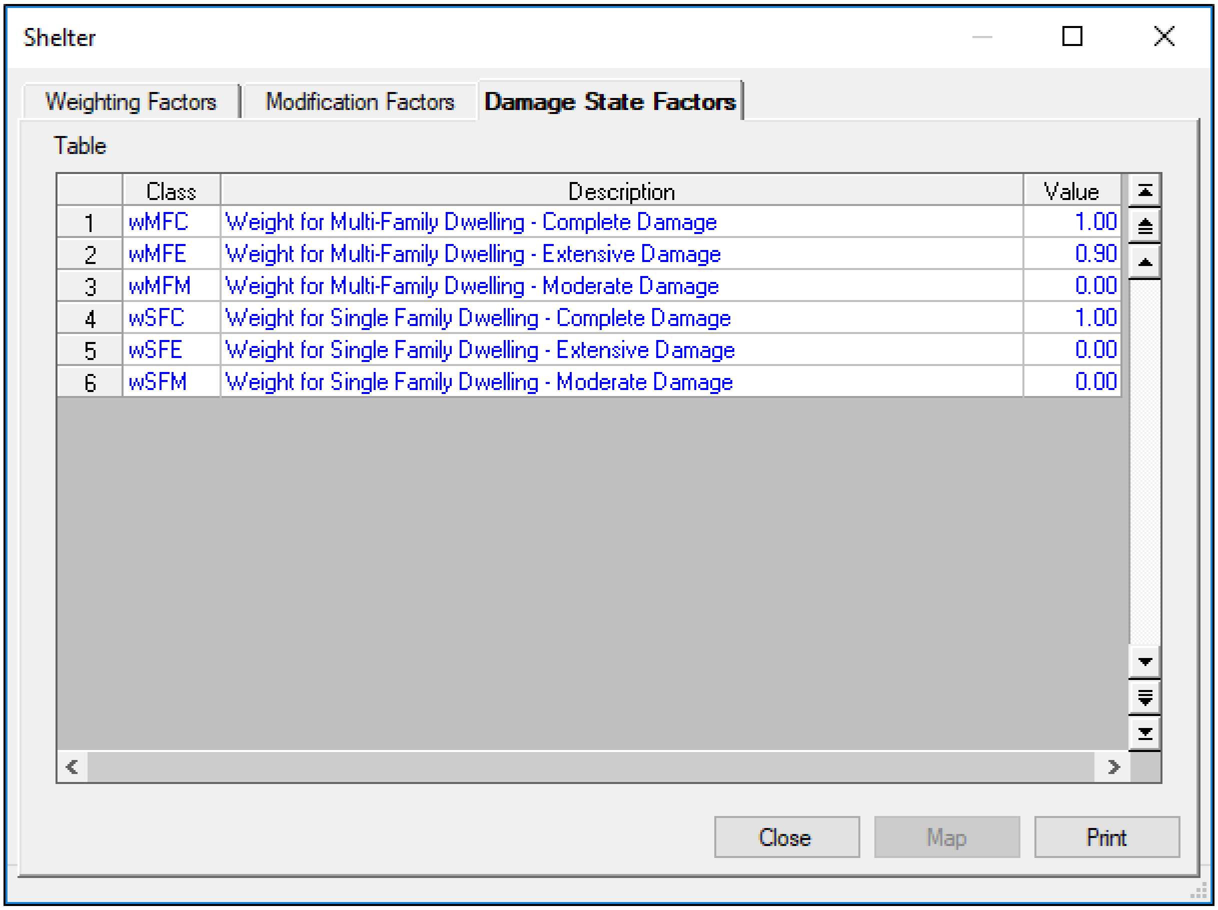


Figure 7-2 Displaced Households Model Damage State Factors

7.3.6.2 Parameters for Modeling Number of People Requiring Short-term Shelter

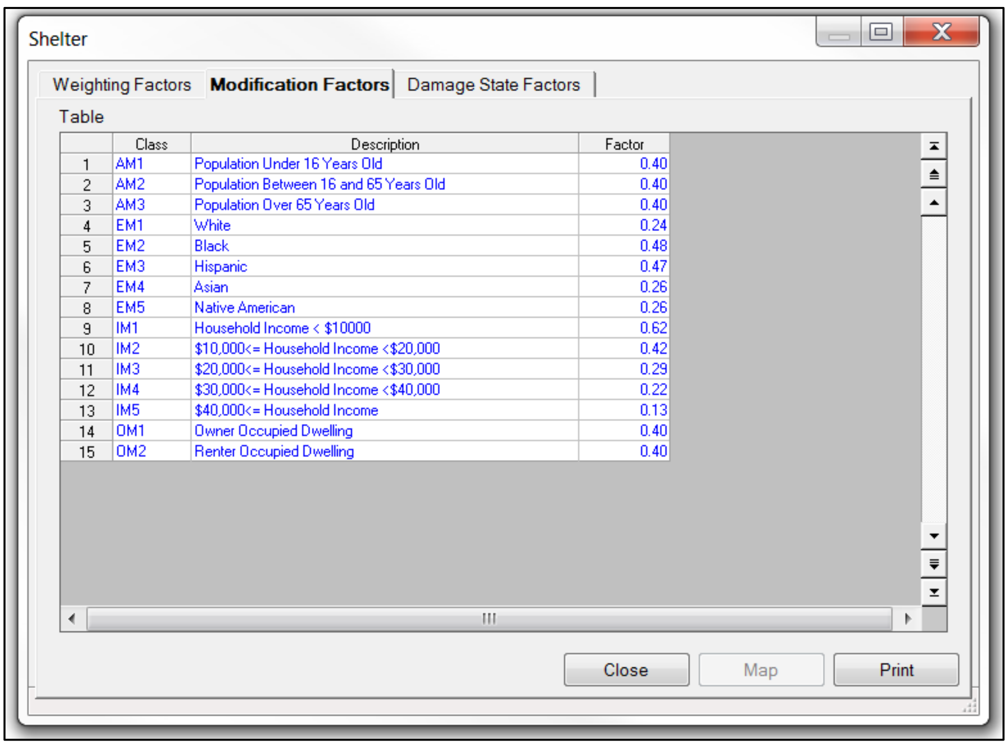
The estimated number of displaced households is combined with the following information to estimate short-term shelter needs:

- Number of people in the Census tract
- Number of households in Census tract
- Age breakdown of population in the Census tract
- Ethnicity of population in the Census tract
- Income breakdown of households in Census tract
- Percentage of homeowners and renters in the Census tract

All this information is provided in the baseline demographic database (see Section 5.7).

As documented in the *Hazus Earthquake Model Technical Manual (FEMA, 2024)*, the baseline assumptions in the methodology are that the number of people who require short-term shelter is a function of income, ethnicity, ownership, and age. Based on experience in past disasters, including both hurricanes and earthquakes, those seeking shelter typically have very low incomes and, therefore, have fewer options. In addition, they tend to have young children or are over age 65. Finally, even given similar incomes, Hispanic populations from Central America and Mexico tend to be more concerned about reoccupying buildings than other groups. This tendency appears to be because of the fear of collapsed buildings instilled from past disastrous earthquakes.

To account for these trends, modification factors have been developed to represent the fraction of people in each category likely to seek public shelter if their dwellings become uninhabitable. The baseline values of these factors as shown in Figure 7-26 are based on data from the Northridge earthquake combined with expert opinion (see the *Hazus Earthquake Model Technical Manual (FEMA, 2024)* for more information). From this table, users can interpret that 62% of people from households with incomes less than $10,000 whose dwellings have become uninhabitable will seek public shelter. The factors can be viewed and modified in the **Analysis > Parameters > Shelter** window, on the **Modification Factors** tab, as shown in Figure 7-26.



	Class	Description	Factor
1	AM1	Population Under 16 Years Old	0.40
2	AM2	Population Between 16 and 65 Years Old	0.40
3	AM3	Population Over 65 Years Old	0.40
4	EM1	White	0.24
5	EM2	Black	0.48
6	EM3	Hispanic	0.47
7	EM4	Asian	0.26
8	EM5	Native American	0.26
9	IM1	Household Income < $10000	0.62
10	IM2	$10,000<= Household Income <$20,000	0.42
11	IM3	$20,000<= Household Income <$30,000	0.29
12	IM4	$30,000<= Household Income <$40,000	0.22
13	IM5	$40,000<= Household Income	0.13
14	OM1	Owner Occupied Dwelling	0.40
15	OM2	Renter Occupied Dwelling	0.40

Figure 7-26 Short-Term Shelter Module Weighting Factors

Users have the option to weight the importance of the four factors that affect the fraction of households seeking public shelter: age, ethnicity, income, and ownership. Baseline values of the importance factors are shown in Figure 7-27. The **Importance Factors** column values in Figure 7-27 must sum to one. The default importance factors are based income (73%), ethnicity (27%), ownership (0%), and age (0%), however the module allows users to adjust the default importance factors for all four factors based on external information.

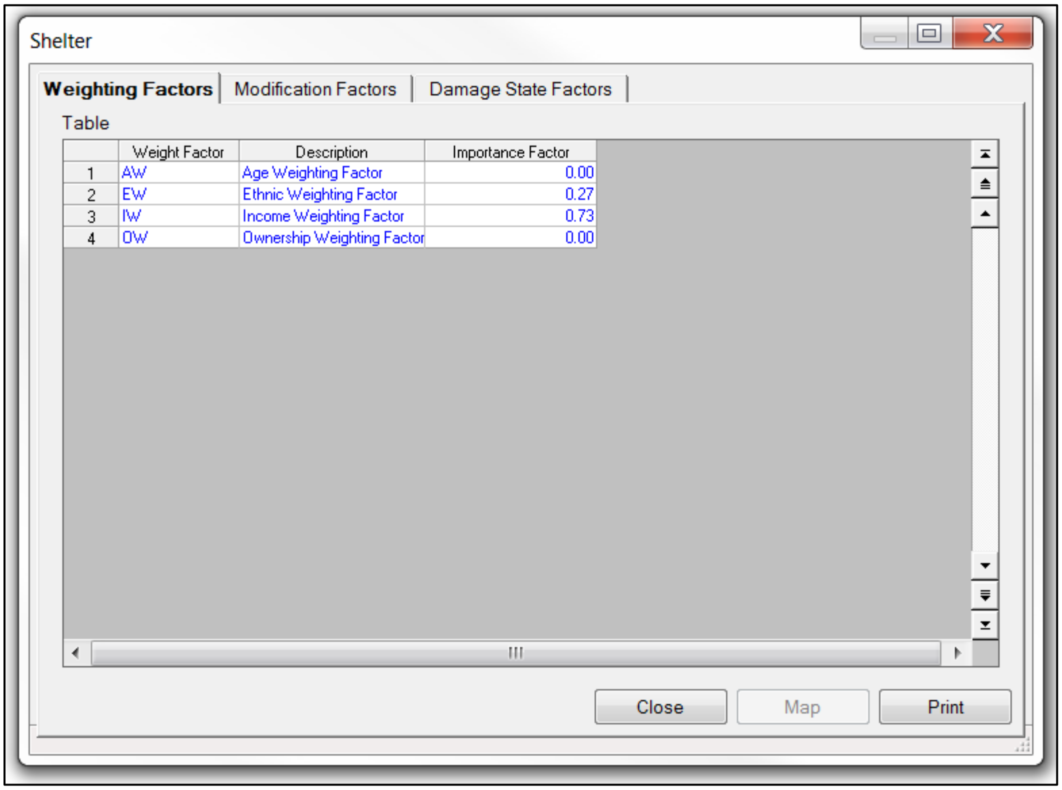


Figure 7-27 Short-Term Shelter Module Modification Factors

7.3.7 Building Economic Parameters

Direct economic losses begin with the cost of repair and replacement of damaged or destroyed buildings. However, building damage will result in a number of consequential losses that, in Hazus, are defined as direct economic losses. Building-related direct economic losses (which are all expressed in dollars) include two groups. The first group consists of losses that are directly derived from building damage:

- Cost of repair and replacement of damaged and destroyed buildings
- Cost of damage to building contents
- Loss of commercial inventory (contents related to business activities).

The second group consists of losses that are related to the length of time the facility is non-operational (or the immediate economic consequences of damage):

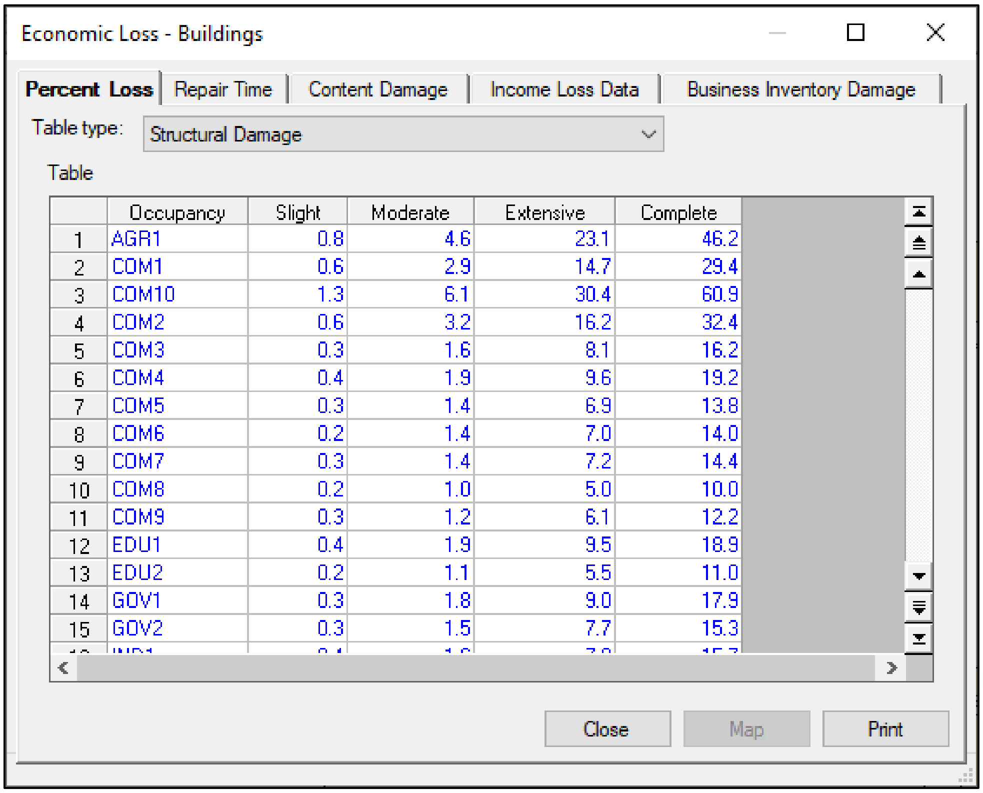
- Relocation expenses (for businesses and institutions)

- Capital-related income losses (a measure of the loss of productivity, services, or sales)
- Wage losses (consistent with income loss)
- Rental income losses (to building owners)

A great deal of baseline economic data is supplied with Hazus, and may be accessed via the **Analysis > Parameters > Building Economic** menu, including:

- Structural repair costs (expressed as a percent of total building replacement cost) for each of the damage states, and occupancies (Figure 7-28)
- Nonstructural repair costs (expressed as a percent of total building replacement cost) for each of the damage states for all occupancies (both acceleration-sensitive and drift-sensitive damage)
- Building cleanup and repair time (days) as a function of damage state and occupancy
- Building recovery time (days) as a function of damage state and occupancy
- Construction time modifiers as a function of damage state and occupancy
- Contents damage (percent) as a function of damage state
- Rental costs ($/square foot/day) by occupancy
- Disruption costs ($/square foot) by occupancy
- Percent of buildings that are owner occupied for each occupancy class
- Capital-related income and wage values in $/square foot/day for each occupancy
- Wage, employment, income and output recapture factors by occupancy
- Annual gross sales or production ($/square foot) for agricultural, selected commercial, and industrial occupancies
- Business inventory as a percentage of gross annual sales for agricultural, selected commercial, and industrial occupancies
- Business inventory damage (percent) as a function of damage state for agricultural, selected commercial, and industrial occupancies.

These data are described in detail in the *Hazus Earthquake Model Technical Manual (FEMA, 2024)*. Except for the underlying building replacement values, the baseline data represent typical values for the United States, and thus no regional variations are included. To best represent the region or project area, review the baseline data carefully and modify the data where applicable. The baseline data can be viewed and modified from within Hazus. The window that is used to view and modify economic baseline data is shown in Figure 7-28. This window is accessed from the **Analysis > Parameters > Building Economic** menu.



	Occupancy	Slight	Moderate	Extensive	Complete
1	AGR1	0.8	4.6	23.1	46.2
2	COM1	0.6	2.9	14.7	29.4
3	COM10	1.3	6.1	30.4	60.9
4	COM2	0.6	3.2	16.2	32.4
5	COM3	0.3	1.6	8.1	16.2
6	COM4	0.4	1.9	9.6	19.2
7	COM5	0.3	1.4	6.9	13.8
8	COM6	0.2	1.4	7.0	14.0
9	COM7	0.3	1.4	7.2	14.4
10	COM8	0.2	1.0	5.0	10.0
11	COM9	0.3	1.2	6.1	12.2
12	EDU1	0.4	1.9	9.5	18.9
13	EDU2	0.2	1.1	5.5	11.0
14	GOV1	0.3	1.8	9.0	17.9
15	GOV2	0.3	1.5	7.7	15.3

Figure 7-28 Building Economic Parameters: Building Repair Cost Ratios

7.3.7.1 Building Repair Costs

Building repair costs are determined relative to building replacement cost and are expressed as a percent of the building replacement cost.

7.3.7.2 Repair and Recovery Time Parameters

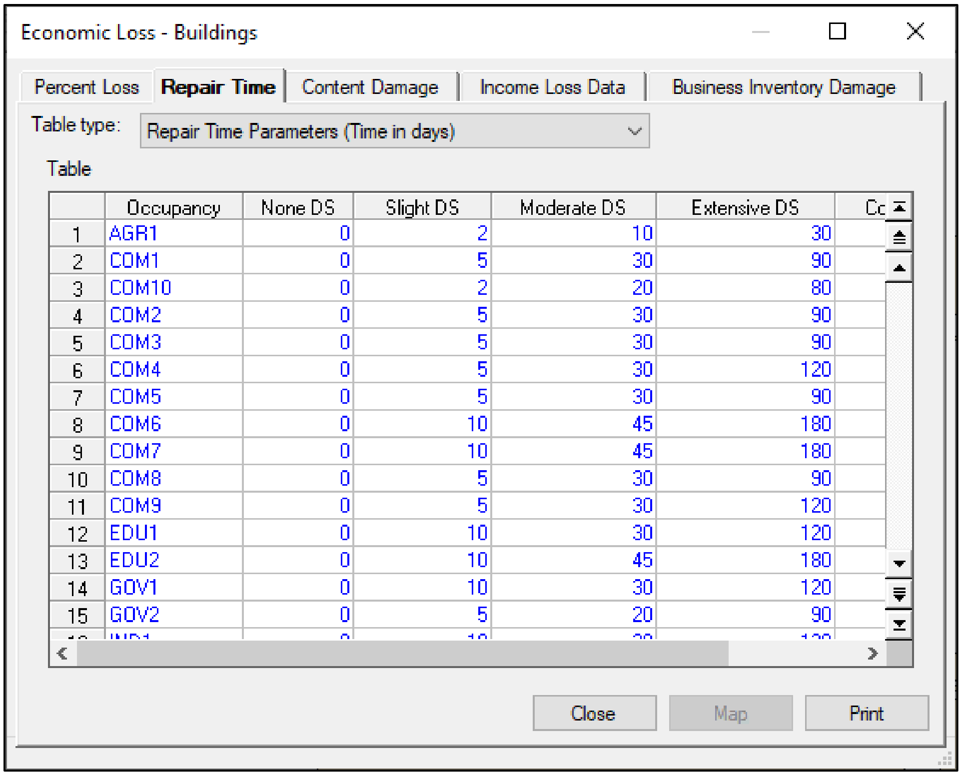
The time to repair a damaged building can be divided into two parts: (1) construction and cleanup time and (2) time to obtain financing and permits and complete a design. For the lower damage states, the construction time will be close to the real repair time. At the higher damage states, a number of additional tasks must be undertaken that typically will considerably increase the actual repair time. These tasks, which may vary considerably in scope and time between individual projects, include:

- Decision-making (related to institutional constraints, plans, financial status, and similar issues)
- Negotiations with FEMA (for public and non-profit), Small Business Administration, and other agencies

- Negotiation with insurance company, if insured
- Obtaining financing
- Contract negotiation with design firms(s)
- Detailed inspections and recommendations
- Preparation of contract documents
- Obtaining building and other permits
- Bidding/negotiating construction contract
- Startup and occupancy activities after construction completion.

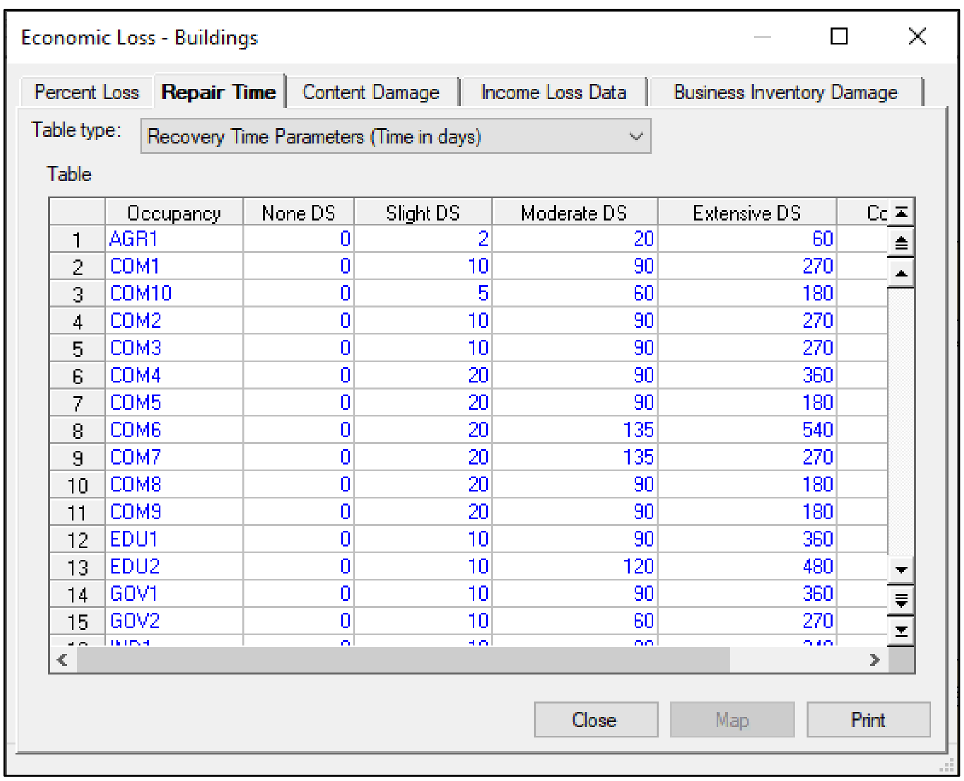
Baseline building repair and cleanup times are provided in Hazus. The baseline values are broken into two parts: construction time and extended time. The construction time is the time to do the actual construction or repair. The extended time includes construction plus all the additional delays described above. A discussion of these values is provided in the *Hazus Earthquake Model Technical Manual (FEMA, 2024)*. Baseline repair time parameter values can be viewed and modified using the window shown in Figure 7-29. Repair times are a function of both damage state and occupancy class. Clearly, there can be a great deal of variability in repair times, but the baselines represent estimates of the median times for actual cleanup and repair. This window is accessed from the **Analysis > Parameters > Buildings Economic** menu, by selecting the **Repair Time** tab and **Repair Time Parameters** table. To modify the baseline values, right click to start editing, type in the desired new values and click the **Close** button. Users will be asked to confirm changes.

Baseline values of the recovery times (the extended building cleanup and repair times that account for delays in decision-making, financing, inspection, and similar issues) are viewed by selecting the **Recovery Time Parameters** table as shown in Figure 7-30. Baseline recovery time estimates can also be modified.



	Occupancy	None DS	Slight DS	Moderate DS	Extensive DS	Cc
1	AGR1	0	2	10	30	
2	COM1	0	5	30	90	
3	COM10	0	2	20	80	
4	COM2	0	5	30	90	
5	COM3	0	5	30	90	
6	COM4	0	5	30	120	
7	COM5	0	5	30	90	
8	COM6	0	10	45	180	
9	COM7	0	10	45	180	
10	COM8	0	5	30	90	
11	COM9	0	5	30	120	
12	EDU1	0	10	30	120	
13	EDU2	0	10	45	180	
14	GOV1	0	10	30	120	
15	GOV2	0	5	20	90	

Figure 7-29 Baseline Building Repair Time Parameters

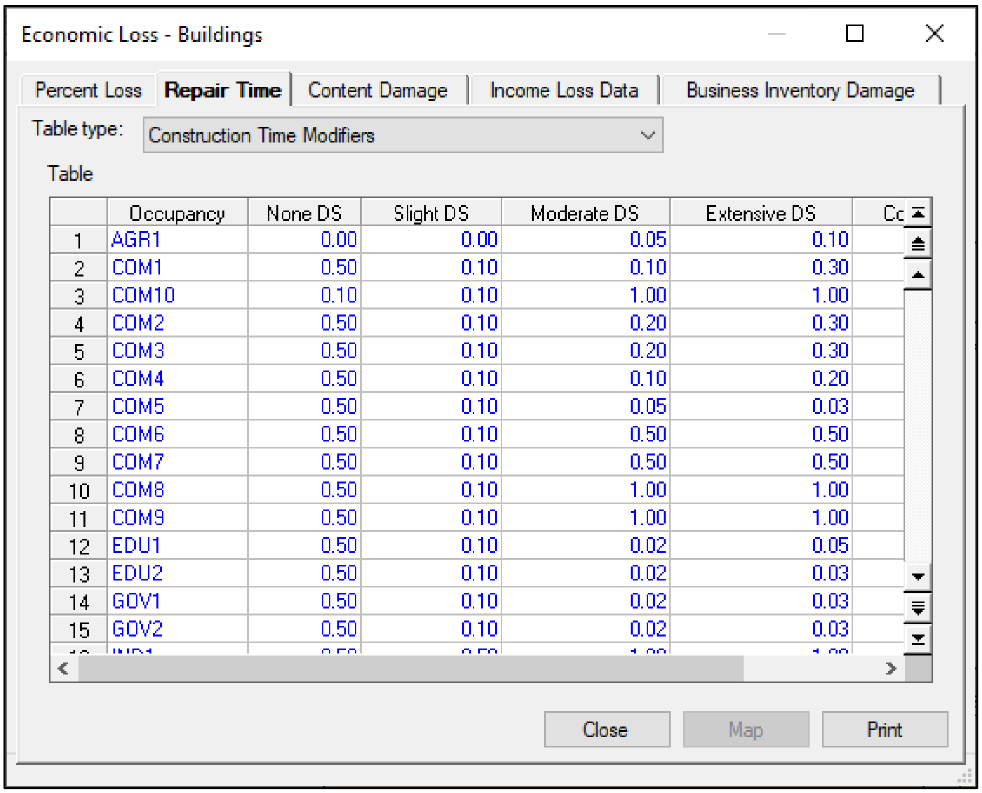


	Occupancy	None DS	Slight DS	Moderate DS	Extensive DS	Cc
1	AGR1	0	2	20	60	
2	COM1	0	10	90	270	
3	COM10	0	5	60	180	
4	COM2	0	10	90	270	
5	COM3	0	10	90	270	
6	COM4	0	20	90	360	
7	COM5	0	20	90	180	
8	COM6	0	20	135	540	
9	COM7	0	20	135	270	
10	COM8	0	20	90	180	
11	COM9	0	20	90	180	
12	EDU1	0	10	90	360	
13	EDU2	0	10	120	480	
14	GOV1	0	10	90	360	
15	GOV2	0	10	60	270	

Figure 7-30 Baseline Building Recovery Time Parameters

Repair times may differ for similar damage states depending on building occupancy. Simpler and smaller buildings take less time to repair than more complex, heavily serviced, or larger buildings. Large, well-financed corporations can sometimes accelerate the repair time compared to normal construction procedures.

However, establishment of a more realistic repair time does not translate directly into business or service interruption. For some businesses, building repair time is largely irrelevant because these businesses can rent alternative space or use spare industrial/commercial capacity elsewhere. Construction Time Modifiers for building and service interruption have been developed to estimate business interruption for economic purposes. These values are multiplied by the extended building cleanup and repair times (recovery times). Construction multipliers can be viewed by selecting the **Construction Time Modifiers** table as shown in Figure 7-31.



	Occupancy	None DS	Slight DS	Moderate DS	Extensive DS
1	AGR1	0.00	0.00	0.05	0.10
2	COM1	0.50	0.10	0.10	0.30
3	COM10	0.10	0.10	1.00	1.00
4	COM2	0.50	0.10	0.20	0.30
5	COM3	0.50	0.10	0.20	0.30
6	COM4	0.50	0.10	0.10	0.20
7	COM5	0.50	0.10	0.05	0.03
8	COM6	0.50	0.10	0.50	0.50
9	COM7	0.50	0.10	0.50	0.50
10	COM8	0.50	0.10	1.00	1.00
11	COM9	0.50	0.10	1.00	1.00
12	EDU1	0.50	0.10	0.02	0.05
13	EDU2	0.50	0.10	0.02	0.03
14	GOV1	0.50	0.10	0.02	0.03
15	GOV2	0.50	0.10	0.02	0.03

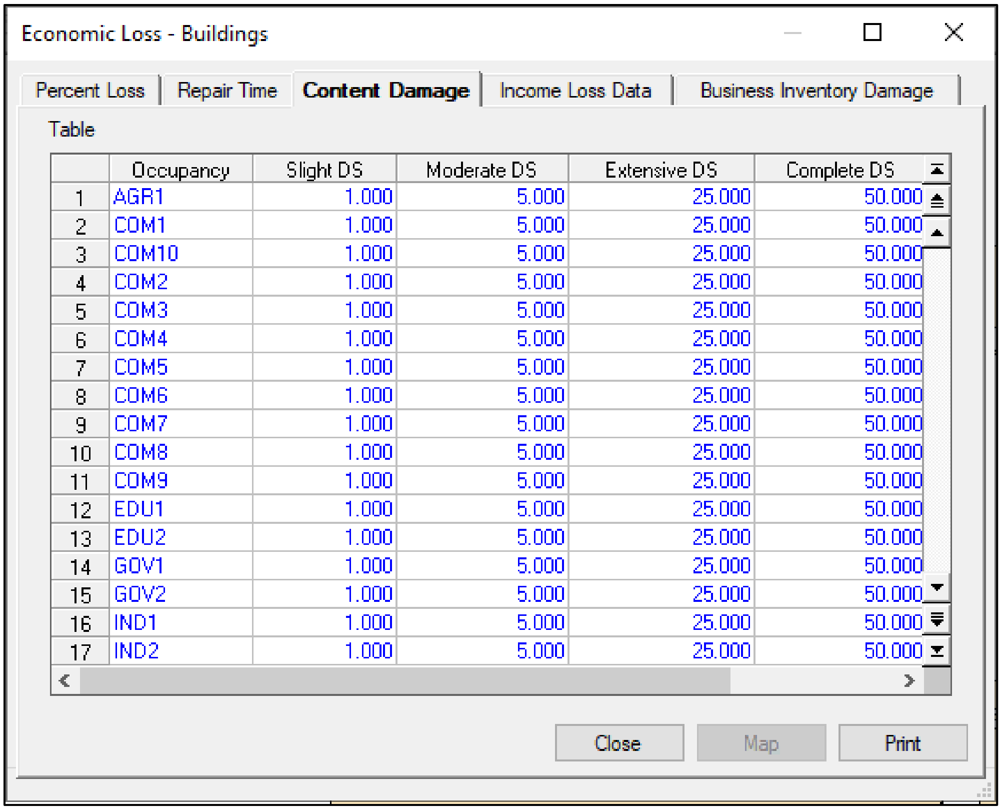
Figure 7-31 Baseline Construction Time Modifiers

Application of the interruption multipliers to the extended building cleanup and repair times (recovery times) results in average values for the business or service interruption. For the slight damage state, the time loss is assumed to be short, with cleanup by staff, and work can resume while repairs are being done. For many commercial and industrial businesses that suffer moderate or extensive damage, the baseline business interruption time is short based on the assumption that businesses will find alternate ways of continuing their activities. Churches generally find temporary accommodation quickly, and government offices also resume operating almost at once. It is assumed that hospitals and medical offices can continue operating, perhaps with some temporary rearrangement and departmental relocation, after sustaining damage. For residential, entertainment, theater, parking, and religious facilities whose revenue or continued service depends on the existence and continued operation of the facility, the interruption time is assumed to be equal to, or approaching, the recovery time.

The median value of repair time would apply to a large inventory of facilities. At moderate damage, some marginal businesses may close while others will open after a day's cleanup. Even with extensive damage, some businesses will accelerate repair while others will close or be demolished. For example, one might reasonably assume that an unreinforced masonry bearing wall, low-rise (URM) building that suffers moderate damage is more likely to be demolished than a newer building that suffers moderate or even extensive damage. If the URM building is a historic structure, its likelihood of survival and repair will probably increase. There will also be a small number of extreme cases: the slightly damaged building that becomes derelict or the extensively damaged building that continues to function for years with temporary shoring until an expensive repair is financed and executed.

7.3.7.3 Contents Damage Parameters

Building contents are defined as furniture, equipment that is not integral to the structure, computers, and supplies. Contents do not include commercial inventory or nonstructural components such as lighting, ceilings, mechanical and electrical equipment, and other fixtures. Contents values are expressed as a percent of structure value, by occupancy. The damage to contents is expressed in terms of the percentage damage based on the acceleration-sensitive nonstructural damage state of the building. The contents damage percentages assume that for the complete damage state, some percentage of contents can be retrieved, i.e., even in the complete damage state, contents are not expected to suffer a total loss. The baseline contents damage percentages are the same for all occupancies, as shown in Figure 7-32, accessible from the **Analysis > Parameters > Building Economic** menu, **Content Damage** tab. The values for Contents Damage Parameters can be edited by the user.

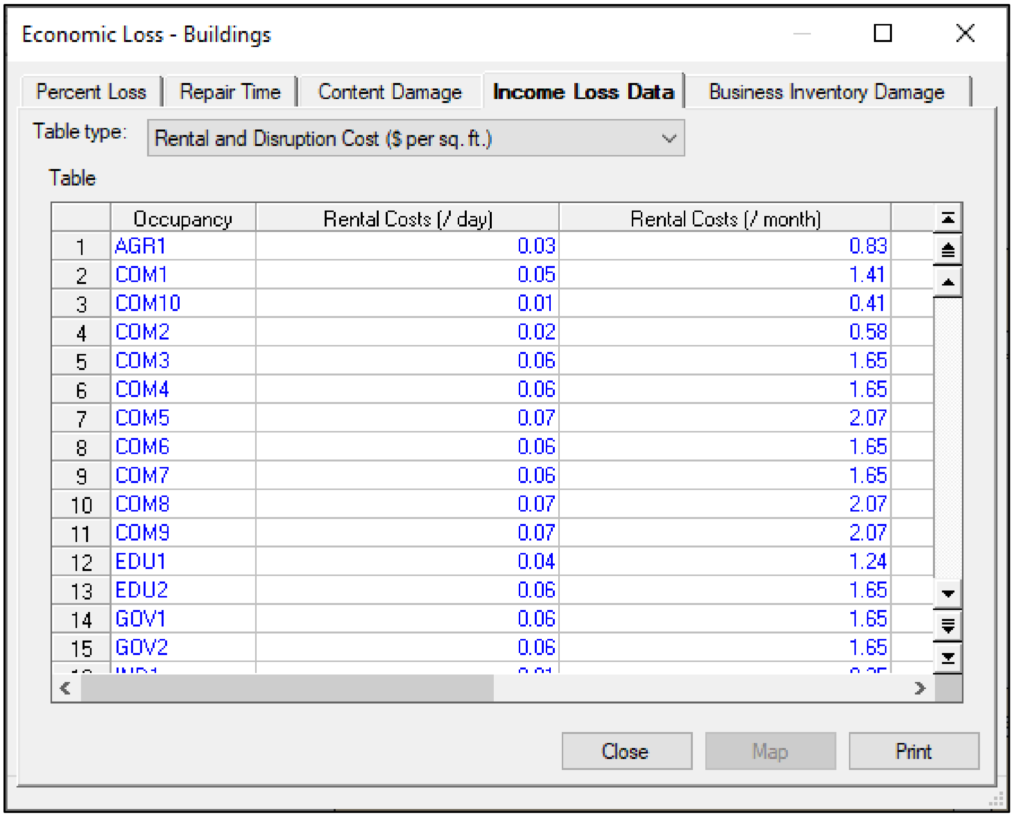


	Occupancy	Slight DS	Moderate DS	Extensive DS	Complete DS
1	AGR1	1.000	5.000	25.000	50.000
2	COM1	1.000	5.000	25.000	50.000
3	COM10	1.000	5.000	25.000	50.000
4	COM2	1.000	5.000	25.000	50.000
5	COM3	1.000	5.000	25.000	50.000
6	COM4	1.000	5.000	25.000	50.000
7	COM5	1.000	5.000	25.000	50.000
8	COM6	1.000	5.000	25.000	50.000
9	COM7	1.000	5.000	25.000	50.000
10	COM8	1.000	5.000	25.000	50.000
11	COM9	1.000	5.000	25.000	50.000
12	EDU1	1.000	5.000	25.000	50.000
13	EDU2	1.000	5.000	25.000	50.000
14	GOV1	1.000	5.000	25.000	50.000
15	GOV2	1.000	5.000	25.000	50.000
16	IND1	1.000	5.000	25.000	50.000
17	IND2	1.000	5.000	25.000	50.000

Figure 7-32 Content Damage Module

7.3.7.4 Income Loss Parameters – Rent and Relocation Expenses

Relocation costs may be incurred when the level of building damage is such that the building or portions of the building are unusable while repairs are being made. While relocation costs may include a number of expenses, Hazus only considers disruption costs that may include the cost of shifting and transferring and the rental of temporary space. Relocation expenses are assumed to be incurred only by building owners and measured in dollars (one-time disruption cost) and dollars per square foot per month (rent of alternate space). A renter who has been displaced from a property due to earthquake damage will stop paying rent to the owner of the damaged property and will only pay rent to a new landlord. Therefore, the renter has no new rental expenses. It is assumed that the owner of the damaged property will pay the disruption costs for the renter. If the damaged property is owner occupied, the owner will have to pay for his or her own disruption costs in addition to the cost of rent while the building is being repaired. Baseline values for percent owner-occupied by occupancy class are accessible from the **Analysis > Parameters > Building Economic** menu, **Income Loss Data** tab, **Owner Occupied (%)** table. Relocation expenses are then a function of the floor area, rental costs per day per square foot, disruption costs, and the expected days of loss of function for each damage state. As part of the Hazus 4.2 Service Pack 01 update, baseline rent, and disruption costs were updated to 2017 values. The updated baseline values are given in Figure 7-33, accessible from the **Analysis > Parameters > Building Economic** menu, **Income Loss Data** tab, **Rental and Disruption Cost** table. The values for Rent and Relocation Expenses can be edited by the user.



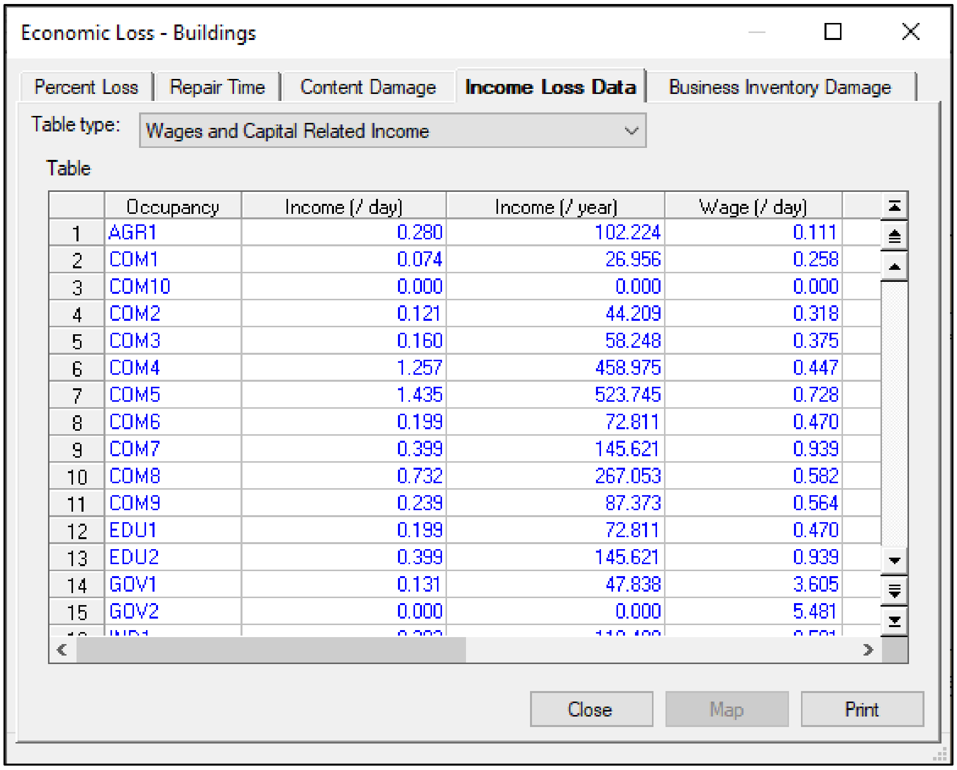
	Occupancy	Rental Costs (/ day)	Rental Costs (/ month)
1	AGR1	0.03	0.83
2	COM1	0.05	1.41
3	COM10	0.01	0.41
4	COM2	0.02	0.58
5	COM3	0.06	1.65
6	COM4	0.06	1.65
7	COM5	0.07	2.07
8	COM6	0.06	1.65
9	COM7	0.06	1.65
10	COM8	0.07	2.07
11	COM9	0.07	2.07
12	EDU1	0.04	1.24
13	EDU2	0.06	1.65
14	GOV1	0.06	1.65
15	GOV2	0.06	1.65

Figure 7-33 Rent and Relocation Cost Parameters

7.3.7.5 Capital-related Income Parameters

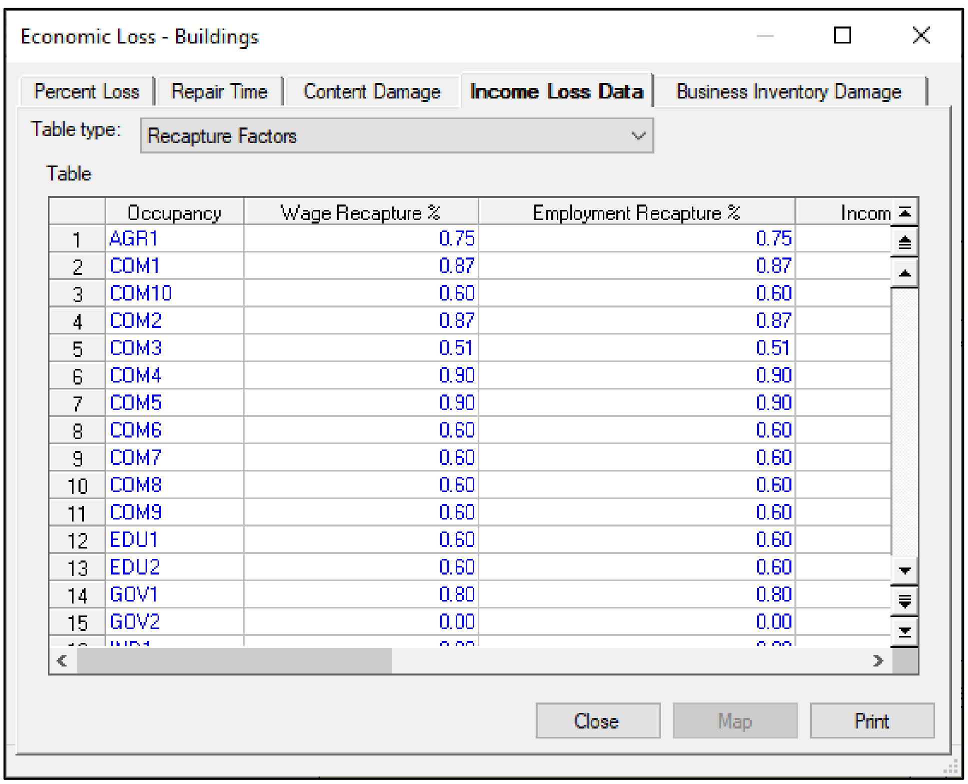
Capital-related income is a measure of the profitability of a commercial enterprise. Income losses occur when building damage disrupts commercial activity. Income losses are the product of floor area, income realized per square foot, the structural damage state of the building, the expected days of loss of function for each damage state, and a recapture factor reflecting the business' ability to make-up for lost production. The original Hazus baseline income values per square foot were derived from the U.S. Department of Commerce's Bureau of Economic Analysis reports of capital-related income per square foot of floor space by economic sector, divided by the floor space occupied by a specific sector. The values assumed for floor space were derived from information in Table 4.7 of ATC-13[1] (see *Hazus Earthquake Model Technical Manual (FEMA, 2024)).* As part of the Hazus 4.2 Service Pack 01 update, baseline income, wage and output values were updated to 2017 values. The updated baseline values are given in Figure 7-34, accessible from the **Analysis > Parameters > Building Economic** menu, **Income Loss Data** tab, **Wage and Capital Related Income** table. Baseline recapture factors, stored in the **Recapture Factors** table, are given in Figure 7-35. The values for Wage and Income Parameters can be edited by the user.

1 ATC-13, *Earthquake Damage Evaluation Data for California.*



	Occupancy	Income (/ day)	Income (/ year)	Wage (/ day)
1	AGR1	0.280	102.224	0.111
2	COM1	0.074	26.956	0.258
3	COM10	0.000	0.000	0.000
4	COM2	0.121	44.209	0.318
5	COM3	0.160	58.248	0.375
6	COM4	1.257	458.975	0.447
7	COM5	1.435	523.745	0.728
8	COM6	0.199	72.811	0.470
9	COM7	0.399	145.621	0.939
10	COM8	0.732	267.053	0.582
11	COM9	0.239	87.373	0.564
12	EDU1	0.199	72.811	0.470
13	EDU2	0.399	145.621	0.939
14	GOV1	0.131	47.838	3.605
15	GOV2	0.000	0.000	5.481

Figure 7-34 Wage and Income Parameters

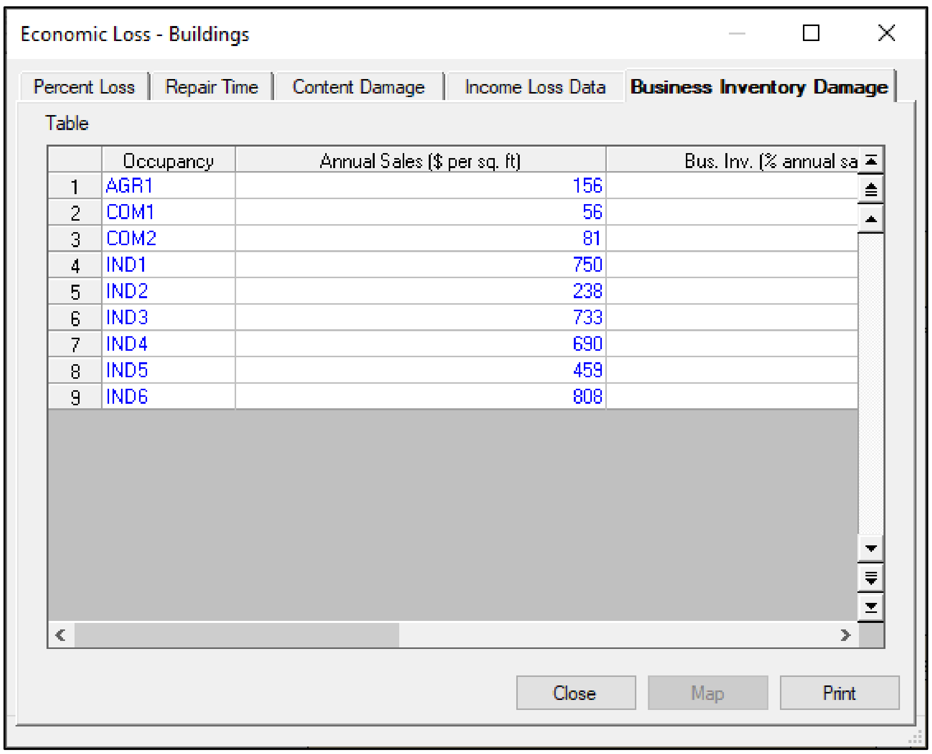


	Occupancy	Wage Recapture %	Employment Recapture %	Incom
1	AGR1	0.75	0.75	
2	COM1	0.87	0.87	
3	COM10	0.60	0.60	
4	COM2	0.87	0.87	
5	COM3	0.51	0.51	
6	COM4	0.90	0.90	
7	COM5	0.90	0.90	
8	COM6	0.60	0.60	
9	COM7	0.60	0.60	
10	COM8	0.60	0.60	
11	COM9	0.60	0.60	
12	EDU1	0.60	0.60	
13	EDU2	0.60	0.60	
14	GOV1	0.80	0.80	
15	GOV2	0.00	0.00	

Figure 7-35 Recapture Factors

7.3.7.6 Business Inventory Damage Parameters

Business inventories vary considerably with occupancy. For example, the value of inventory for a high-tech manufacturing facility (IND5) would be very different from that of a retail store (COM1). The baseline business inventory values for Hazus are derived from annual gross sales by assuming that business inventory value represents a fixed percentage of annual gross sales. For example, retail stores (COM1) are assumed to have inventory value equal to 8% of annual sales. As part of the Hazus 4.2 Service Pack 01 update, annual sales figures were updated to 2017 values. The baseline values are given in Figure 7-36, accessible from the **Analysis > Parameters > Building Economic** menu, **Business Inventory Damage** tab. Like contents damage, inventory damage is determined relative to the acceleration-sensitive nonstructural damage state of the building, assumes similar salvage values, and does not vary across occupancies. The values for Business Inventory Damage can be edited by the user.



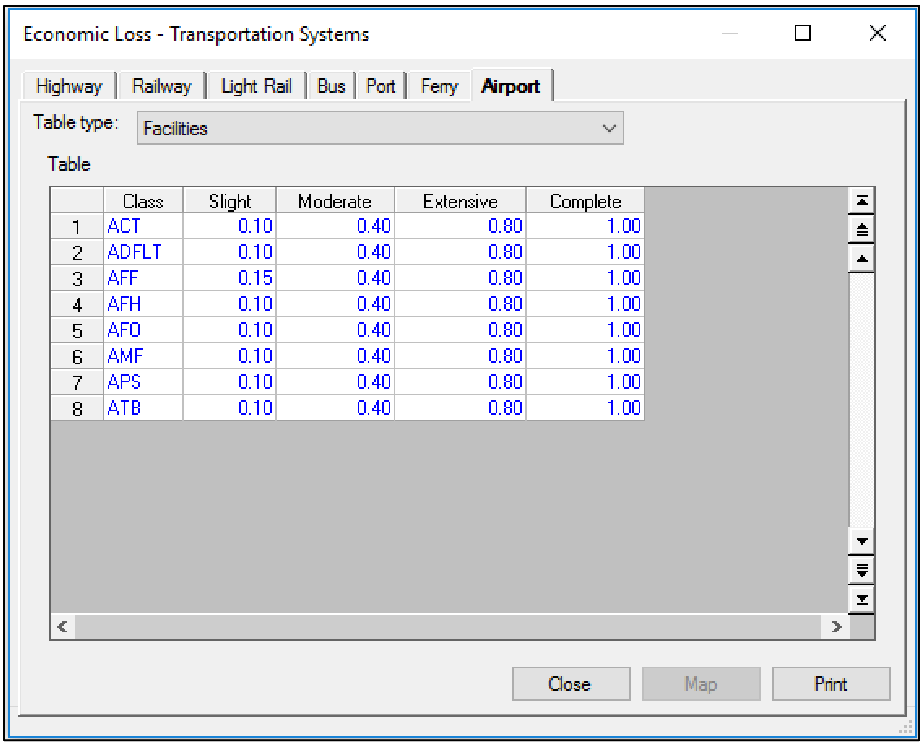
	Occupancy	Annual Sales ($ per sq. ft)	Bus. Inv. (% annual sa
1	AGR1	156	
2	COM1	56	
3	COM2	81	
4	IND1	750	
5	IND2	238	
6	IND3	733	
7	IND4	690	
8	IND5	459	
9	IND6	808	

Figure 7-36 Inventory Value Parameters and Damage Module

7.3.8 Transportation Systems Economic Parameters

For transportation and utility systems, estimates of economic losses are limited to the cost of repair. For each facility type and damage state, a baseline damage ratio (cost of repair as a fraction of replacement cost) has been defined. A sample of baseline damage ratios is shown in Figure 7-37, which can be accessed from the **Analysis > Parameters > Transportation Systems Economic** menu, **Airport** tab, **Facilities** table. For example, the cost to repair slight damage to an airport control tower (Class ACT) is 10% of the replacement cost. The definitions of the various transportation system classes may be found under the **Inventory > View Classification > Transportation Systems** menu, as shown for Airport Facilities in Figure 7-38. The damage ratios in Figure 7-37 are based on the model system components discussed in the *Hazus Earthquake Model Technical Manual (FEMA, 2024)*. Damage ratios can be modified to perform sensitivity analyses, but damage ratios should be kept in the ranges that are defined in the *Hazus Earthquake Model Technical Manual (FEMA, 2024)*.

To make estimates of losses to systems, damage ratios must be multiplied by replacement costs. Baseline replacement costs provided with the methodology are based primarily on values in ATC-13 (1985) and ATC-25-1 (1992). Replacement costs can be viewed and modified in the corresponding inventory table ("Replacement Cost" field). Figure 7-39 is an example for highway bridges. All cost fields are in thousands of dollars. Bridge data for the transportation systems was originally from 2001; however, the Hazus program is actively updating the data. Users should contact the [Hazus Support Team](#).



	Class	Slight	Moderate	Extensive	Complete
1	ACT	0.10	0.40	0.80	1.00
2	ADFLT	0.10	0.40	0.80	1.00
3	AFF	0.15	0.40	0.80	1.00
4	AFH	0.10	0.40	0.80	1.00
5	AFO	0.10	0.40	0.80	1.00
6	AMF	0.10	0.40	0.80	1.00
7	APS	0.10	0.40	0.80	1.00
8	ATB	0.10	0.40	0.80	1.00

Figure 7-37 Baseline Damage Ratios for Airport Facilities

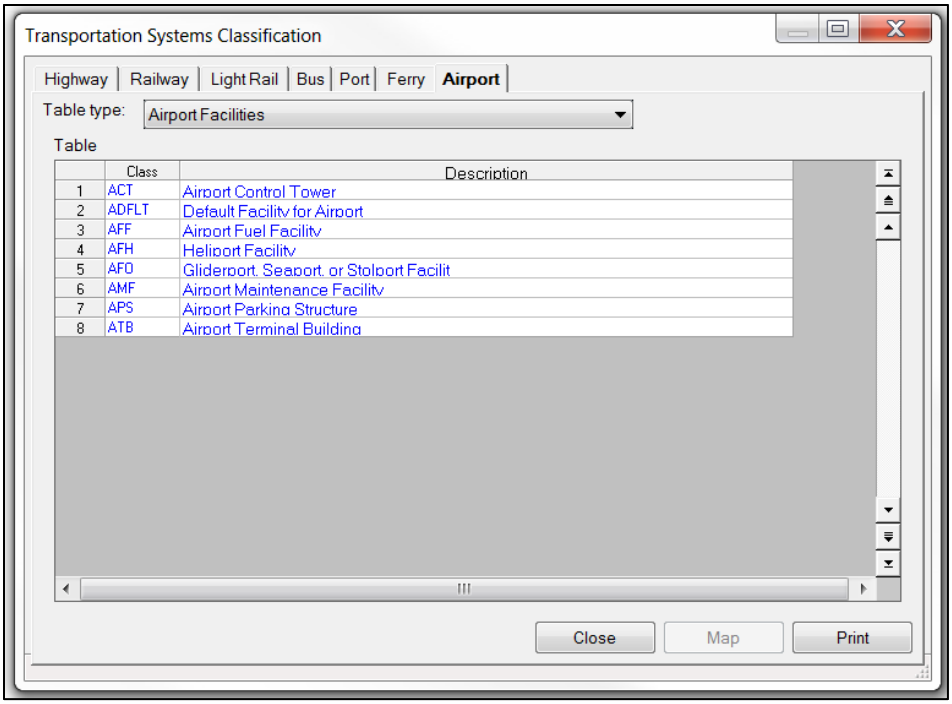


Figure 7-38 Airport Facility Classification Scheme

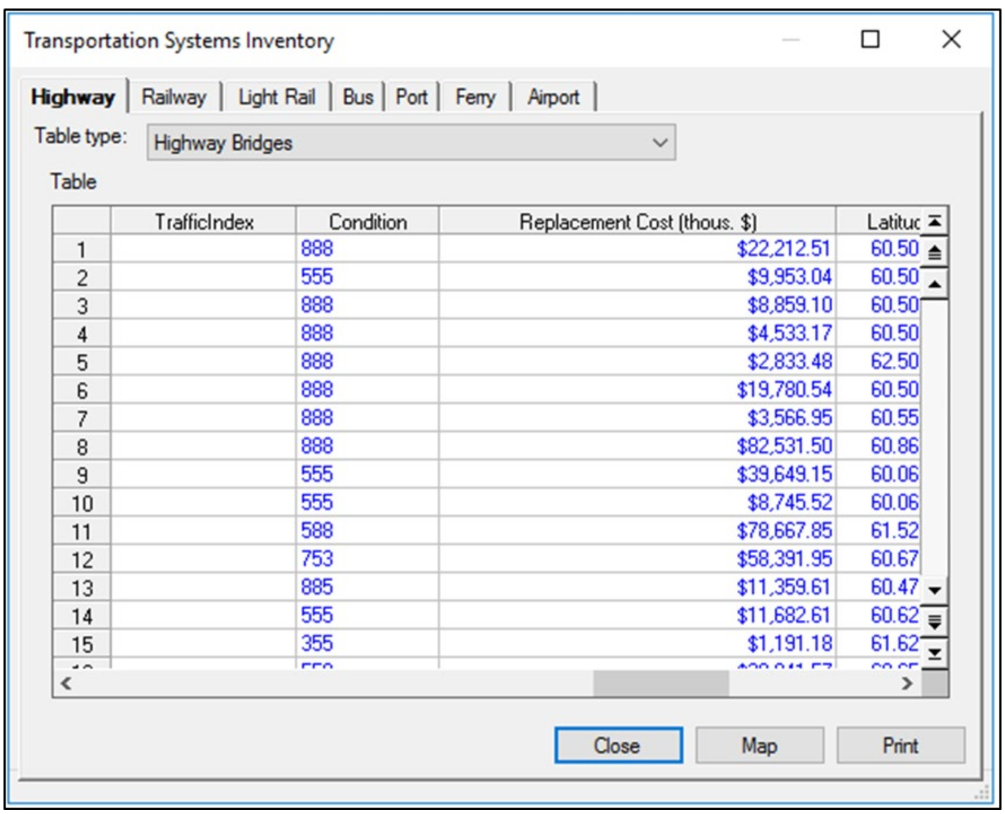


Figure 7-39 Replacement Costs for Highway Bridge Inventory

7.3.9 Utility Systems Economic Parameters

Functionality losses in terms of loss-of-function and restoration times contribute to the estimation of loss for utility systems. Utility systems include potable water, wastewater, oil, natural gas, electric power, and communication systems. Economic losses for utility systems as estimated like transportation systems as discussed in Section 7.3.8.

Baseline damage ratios can be accessed from the **Analysis > Parameters > Utility Systems Economic** menu: **Potable Water** tab, **Wastewater** tab**, Oil System** tab**, Natural Gas** tab**, Electric Power** tab, and **Communication** tab (Figure 7-40). The definitions of the various utility system classes may be found under the **Inventory > View Classification > Utility Systems** menu, as shown for Potable Water System Facilities in Figure 7-41. To make estimates of losses to systems, damage ratios must be multiplied by replacement costs. Replacement costs can be viewed and modified in the corresponding inventory table ("Replacement Cost" field). Figure 7-42 is an example for wastewater system facilities. All cost fields are in thousands of dollars.

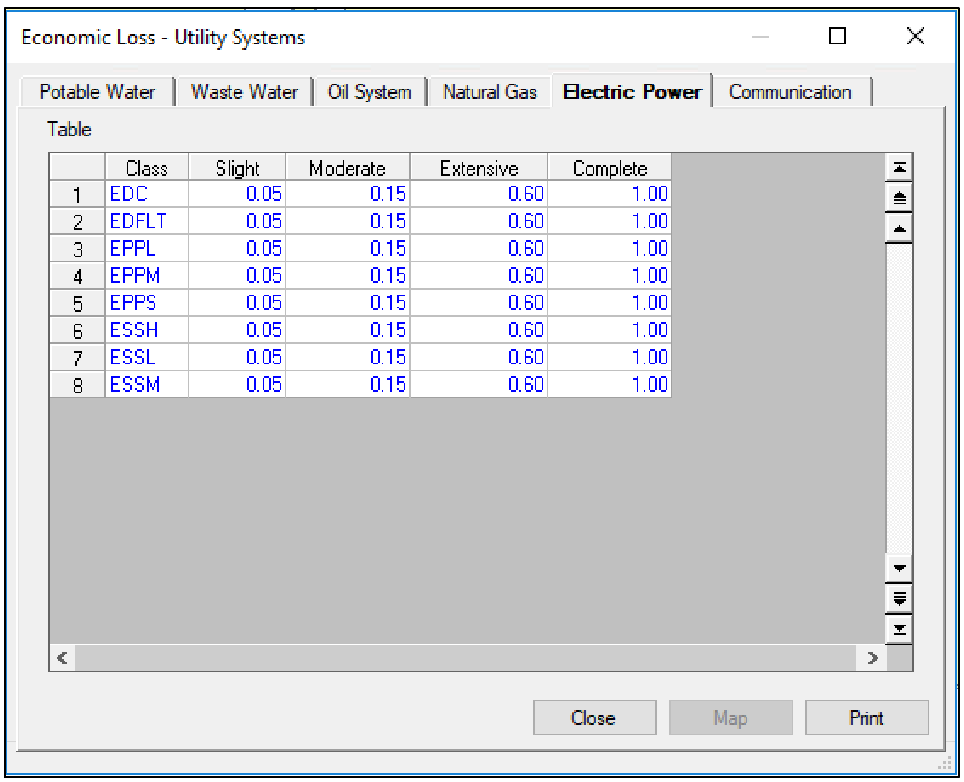


Figure 7-40 Baseline Damage Ratios for Utility Systems

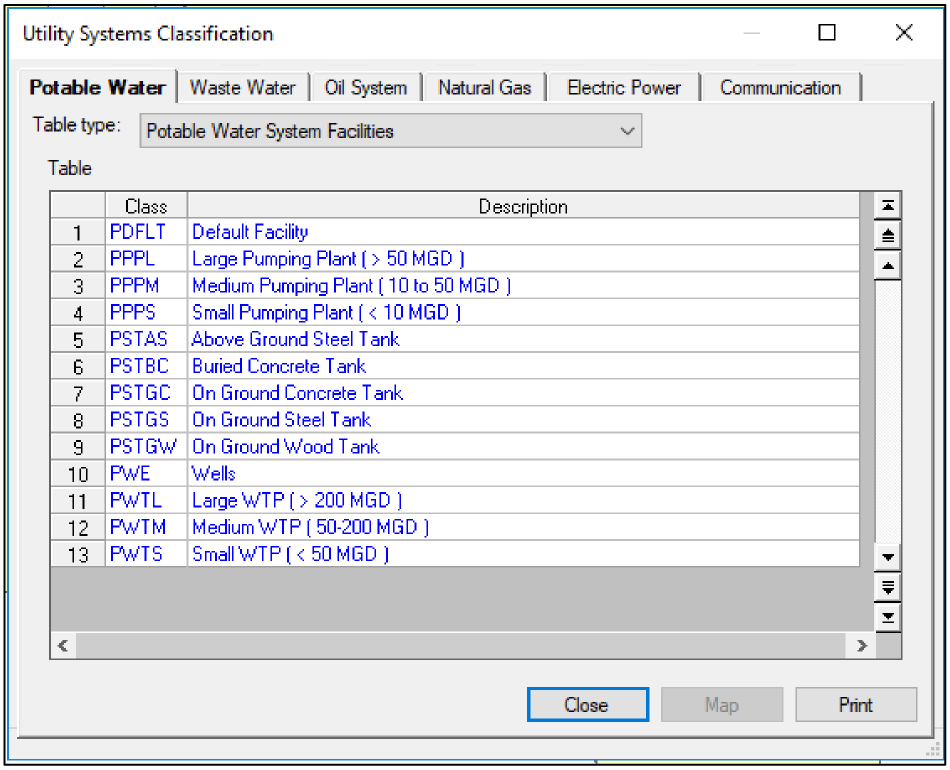


Figure 7-41 Utility Systems Classification Scheme

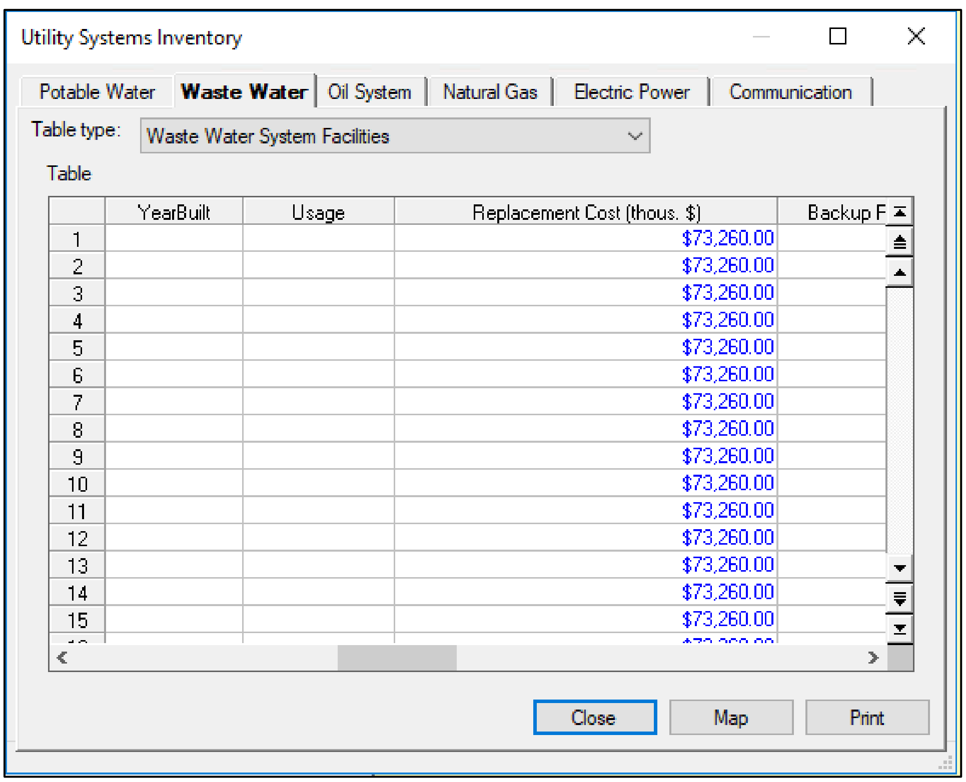


Figure 7-42 Replacement Costs for Utility System Inventory

7.3.10 Indirect Economic Loss Parameters

Earthquakes may produce dislocations in economic sectors not sustaining direct damage. All businesses are forward-linked (rely on regional customers to purchase their output) or backward-linked (rely on regional suppliers to provide their inputs) and are thus potentially vulnerable to interruptions in their operation. Such interruptions are called indirect economic losses. Note that these losses are not confined to immediate customers or suppliers of damaged enterprises. All of the successive rounds of customers of customers and suppliers of suppliers are impacted. In this way, even limited earthquake physical damage causes a chain reaction, or ripple effect, that is transmitted throughout the regional economy. The extent of indirect losses depends upon such factors as the availability of alternative sources of supply and markets for products, the length of the production disturbance, and deferability of production

Hazus provides information concerning the indirect economic effects of the scenario event to enable financial institutions and government planners to anticipate losses and develop programs to compensate for them. The indirect economic impact information can provide information to policymakers to consider cost-benefit implications of mitigation activities. Indirect economic loss parameters, accessible through the parameter specification wizard at **Analysis > Parameters > Indirect Economic** menu, include the analysis type (use of IMPLAN data files – see Section 8.3 - or modeling a synthetic economy), synthetic economy parameters (Figure 7-43), global factors (Figure 7-44), supplemental factors (Figure 7-45), restoration (Figure 7-46), rebuilding expenditure (Figure 7-47), and stimulus (Figure 7-48). For detailed information on these parameters please see the *Hazus Earthquake Model Technical Manual (FEMA, 2024)*– Indirect Economic Losses.

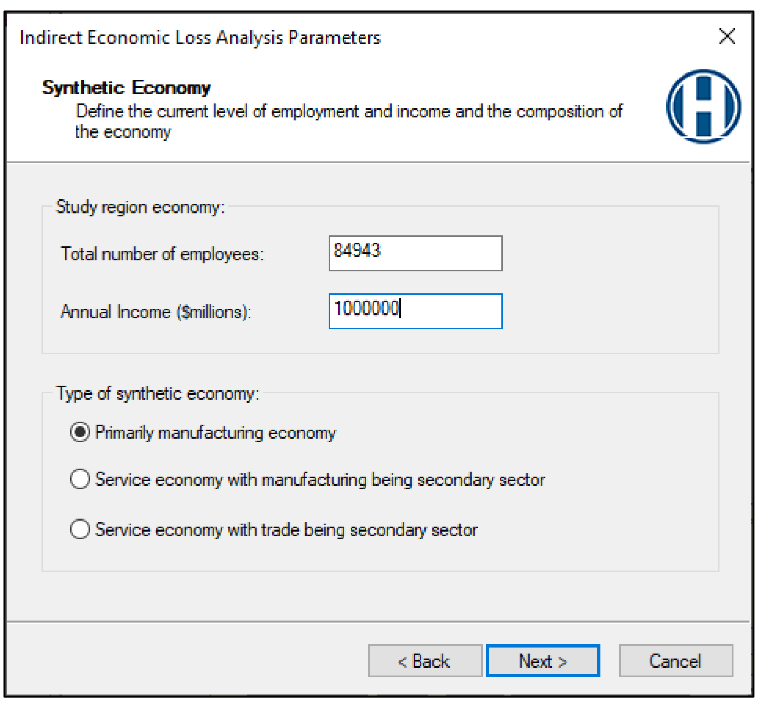


Figure 7-43 Indirect Economic Loss Parameters - Synthetic Economy

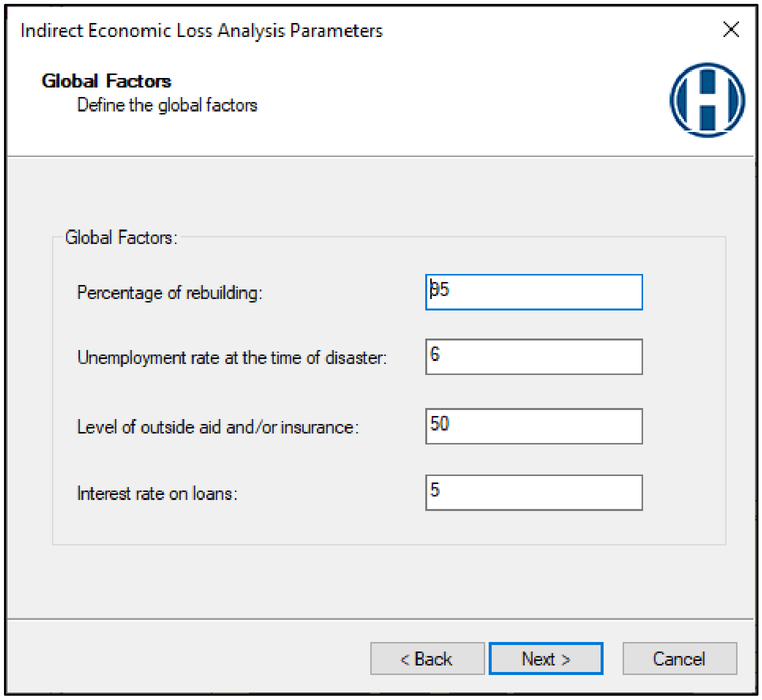


Figure 7-44 Indirect Economic Loss Parameters – Global Factors

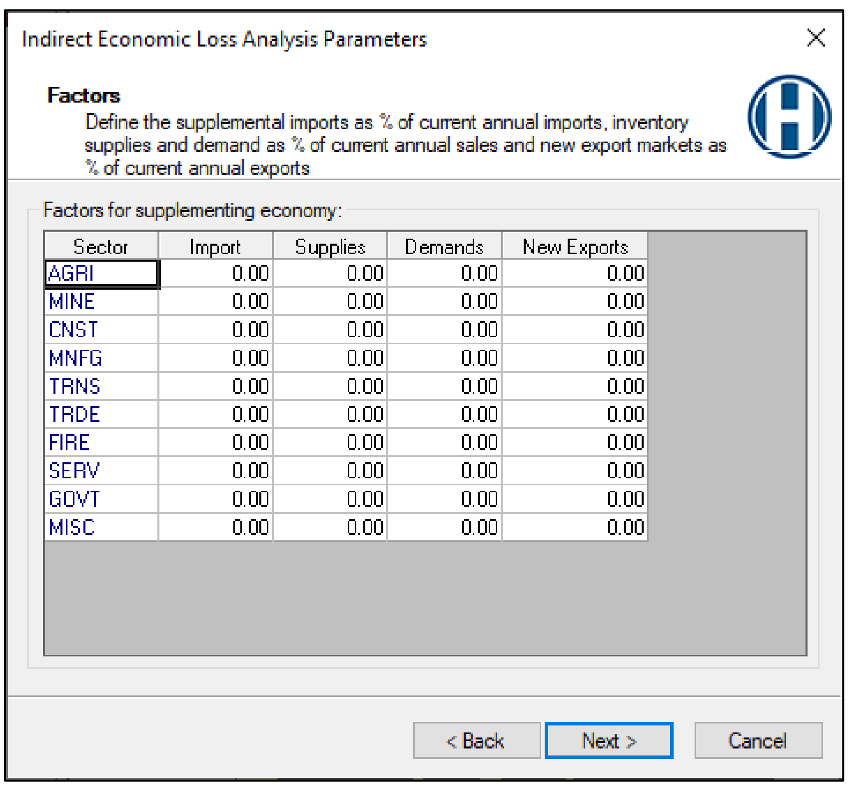


Figure 7-45 Indirect Economic Loss Parameters – Supplemental Factors

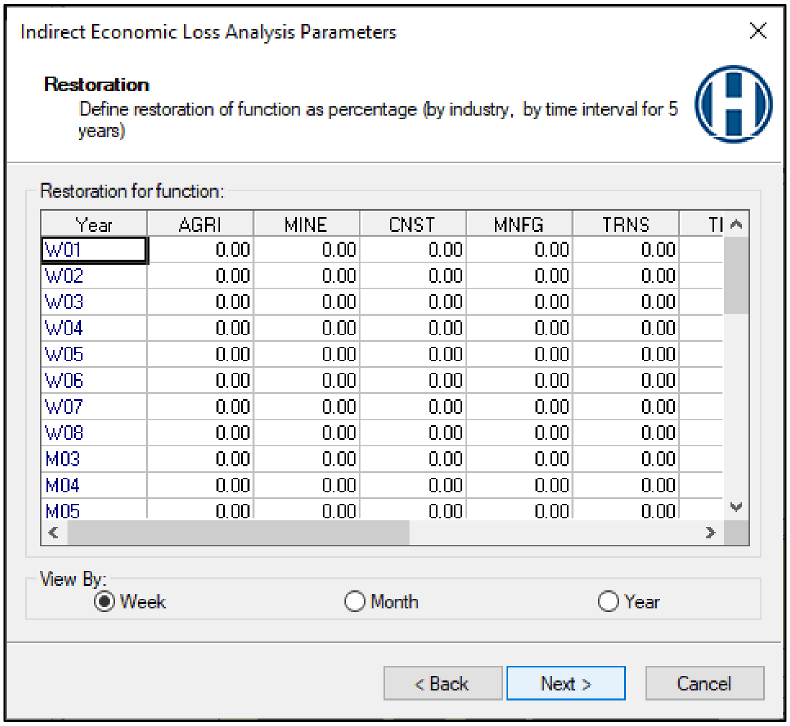


Figure 7-46 Indirect Economic Loss Parameters – Restoration

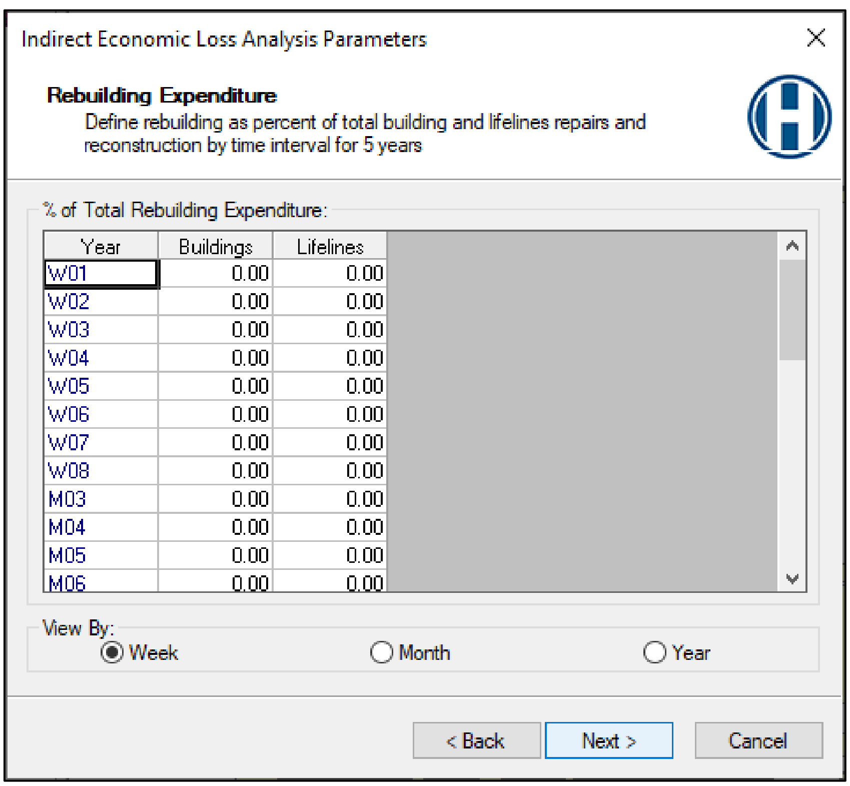


Figure 7-47 Indirect Economic Loss Parameters – Rebuilding Expenditure

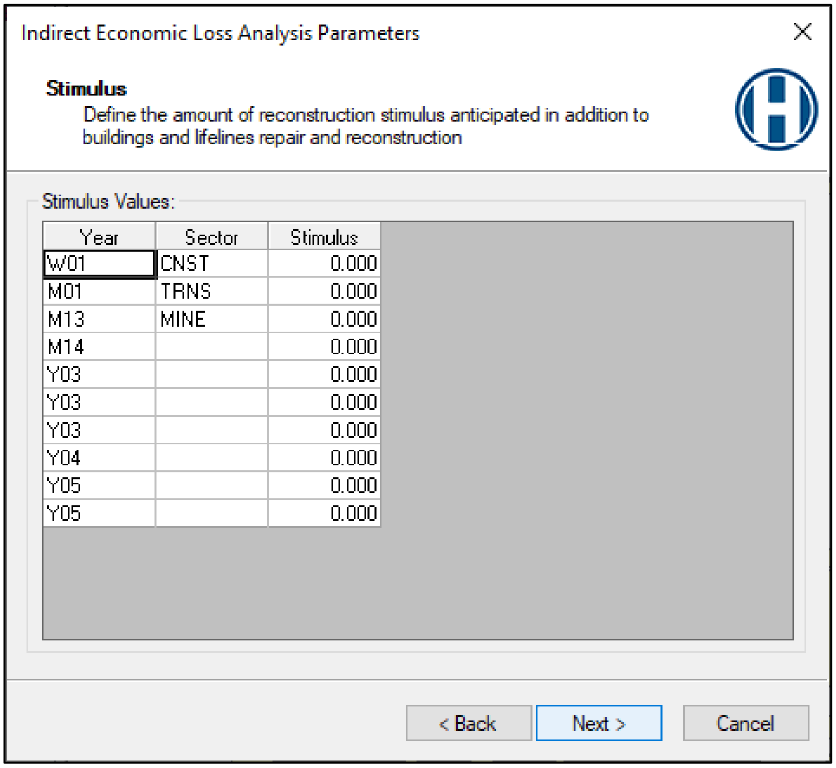


Figure 7-48 Indirect Economic Loss Parameters – Stimulus

For a more realistic analysis, the indirect economic module can use IMPLAN data for modeling the economy. Select **Use IMPLAN data** from the wizard accessed via the **Analysis > Parameters > Indirect Economic** menu to bring up **the Manage IMPLAN files** window shown in Figure 7-49. This menu allows the user to baseline import custom IMPLAN data files (see the *Hazus Earthquake Model Technical Manual (FEMA, 2024)*).

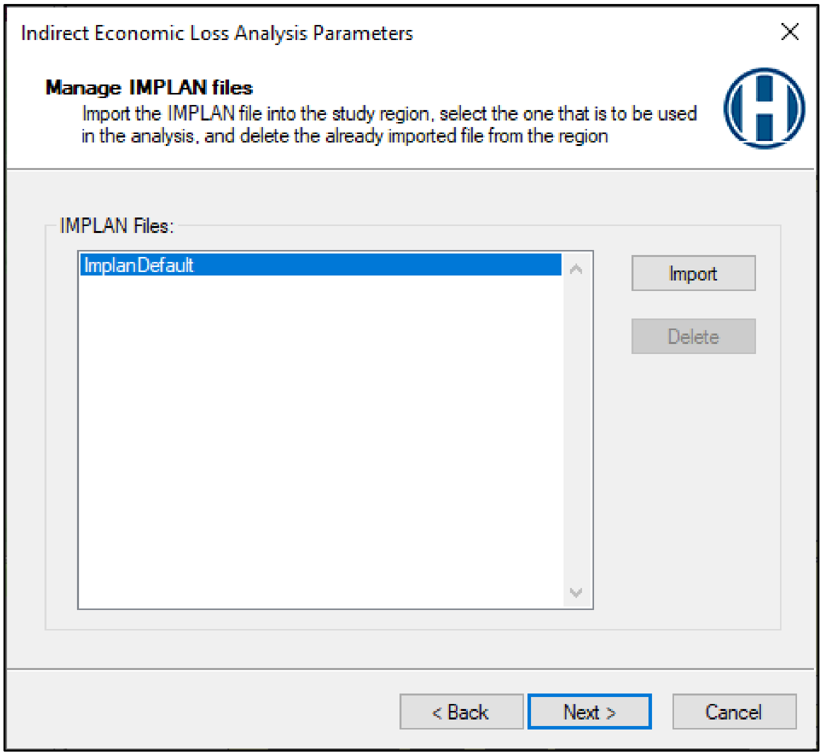


Figure 7-49 Indirect Economic Loss Parameters – Manage IMPLAN files

Figure 7-49 demonstrates browsing to the location of the available **IMPLAN** files and selecting the file. If the user has not imported any files, only one file labeled **ImplanDefault** is listed. This indicates the IMPLAN data for the baseline synthetic economy.

Click the **Import** button to import **IMPLAN** files into Hazus. Note that Hazus only prompts for the directory that contains the five required IMPLAN data files:

- Household Industry Demand (II031).txt
- Industry Output-Outlay Summary (II050).txt
- Institution Industry Demand (II030).txt
- Output, VA, Employment (SA050).txt
- Regional Industry x Industry (Text502).txt

All five files should be located in the same directory. The *Hazus Earthquake Model Technical Manual (FEMA, 2024)* provides detailed information regarding the files required by the model.

The newly imported **IMPLAN** file set name now appears underneath **ImplanDefault.** Use the mouse to highlight the new **IMPLAN** file, thus selecting it for use in the analysis. Click **OK** and the Indirect Economic Analysis Factors screen will appear.

If there are previously imported **IMPLAN** data files, the names will appear on the list. Remember to highlight the correct file each time before clicking **OK** to ensure that Hazus does not return to using the baseline **ImplanDefault** file.

7.4 Run

From the Hazus menu bar select **Analysis > Run** to launch the Analysis Options window, Figure 7-50. As noted at the bottom of the window, items listed as black text are current (i.e., have been run with the current scenario), and those in blue text are not current and need to be analyzed.

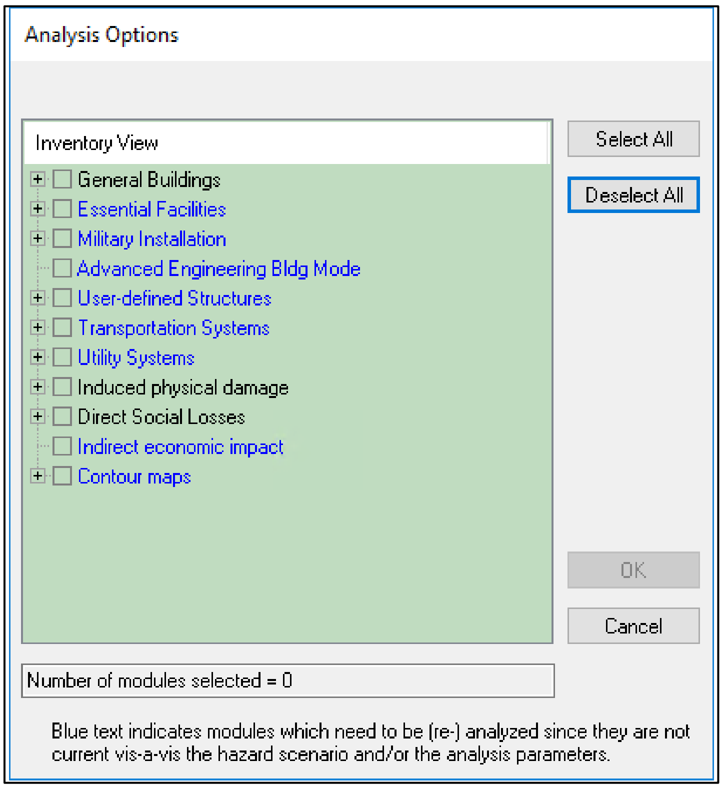


Figure 7-50 Analysis Options Menu

All analysis options can be run at the same time, or each can be run separately. If a Study Region is large (a few hundred to more than a thousand Census tracts), a complete analysis can take several hours. It is suggested that the analysis options are run one at a time while developing and modifying scenarios, inventories, and model parameters. This allows a review of intermediate results and check to determine if the results look reasonable or serve the required needs without waiting several hours to run a complete analysis. Once with the inventories and model parameters are complete, additional analyses may be performed with all options running simultaneously.

To run the analysis, there is the option of clicking **Select All** (which will select all modules except for Contour maps) or clicking one or more categories at a time, Figure 7-51.

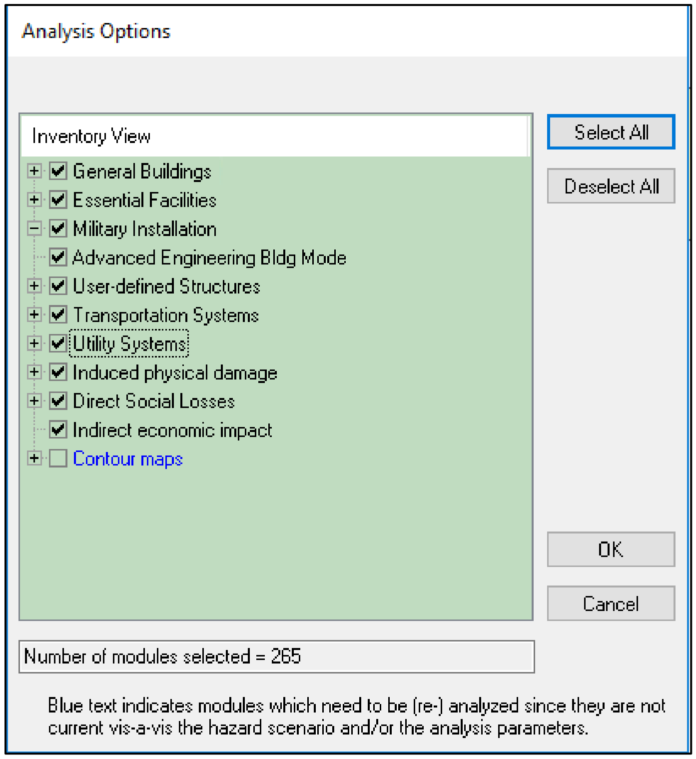


Figure 7-51 Analysis Options Menu – "Select All" Option

Some categories, such as General Buildings, have sub-categories that can be viewed by clicking the plus sign next to the category name, Figure 7-52.

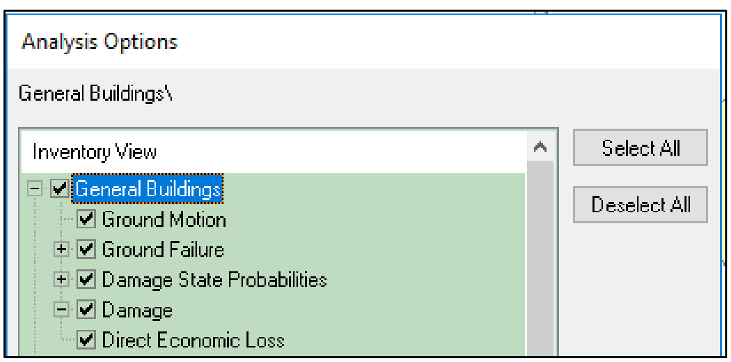


Figure 7-52 Analysis Options Menu Subcategories

Once the Analysis Options have been selected, click OK to begin the analysis.

Section 8. Earthquake Model: Results Menu

8.1 Results Menu Options

In the Earthquake Model, the **Results** menu includes the following options: Ground Motion or Ground Failure, General Building Stock, Essential Facilities, Military Installations, User-Defined Facilities, Advanced Engineering Building Model (AEBM), Transportation Systems, Utility Systems, Inundation, Fire Following Earthquake, Debris, Casualties, Shelter, Indirect Economic Loss, and Summary Reports, as shown in Figure 8-1.

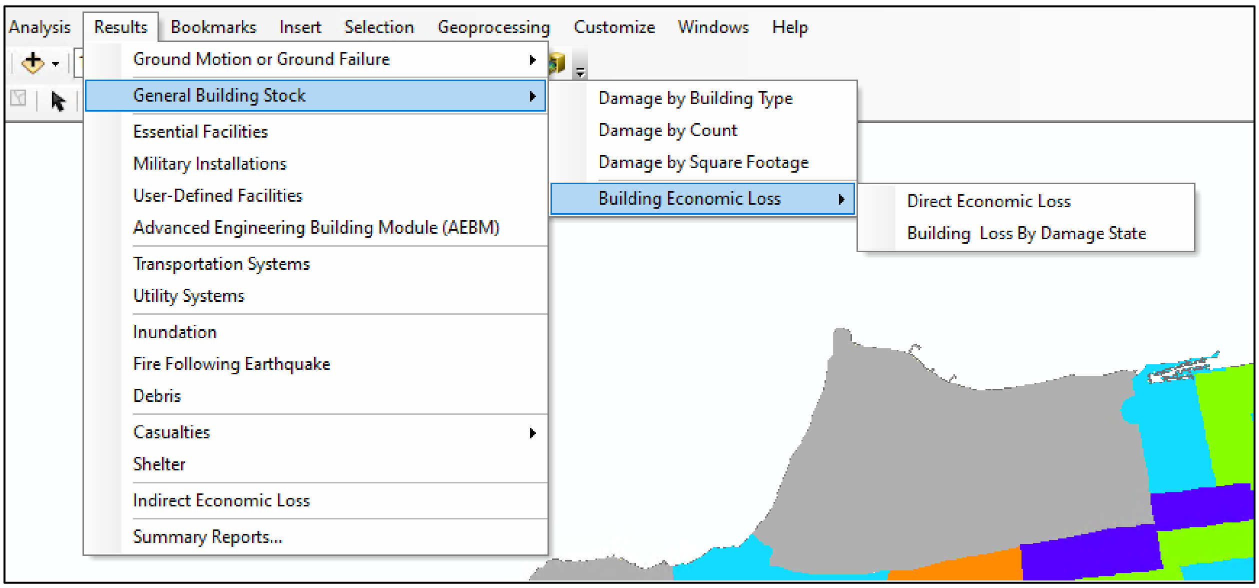


Figure 8-1 Hazus Results Menu

8.2 Module Outputs

Hazus provides users with a series of outputs for each module. The outputs can be in a numerical or map form. Table 1-1 (in Section 1.2) summarizes the outputs that can be obtained from an analysis using the Hazus Earthquake Model.

8.2.1 Ground Motion or Ground Failure

Table 8-1 summarizes the module I outputs for the four scenario hazard options. In all four cases, the user is provided with maps of ground shaking in the Study Region characterized by peak ground acceleration (PGA), peak ground velocity (PGV) and spectral accelerations (5% damping) at two structural periods (0.3 second and 1.0 second).

Table 8-1 Ground Motion/Site Effects Output

Input	Module Output	Description of Output
Deterministic Events: Historical Epicenter Events, Source Events, and Arbitrary Events	▪ Census Tract Ground Motions ▪ PGA, PGV and Spectral Acceleration Contour Maps	Hazus determines Census tract ground motion and develops region-wide ground motion contour maps based on a user-defined scenario event.
Probabilistic Hazard	▪ Census Tract Ground Shaking	Hazus includes two sets of gridded USGS probabilistic ground motion data for eight (8) return periods (100, 250, 500, 750, 1000, 1500, 2000 and 2500 years) which are used to determine Census tract ground motions. By baseline, the version of the gridded data that incorporates soil amplification is used. When the user brings in their own custom soils map, the gridded data without amplification is used, and ground motions are amplified based on the user's soils map.
User-Supplied Hazard	▪ Census Tract Ground Motions ▪ PGA, PGV and Spectral Acceleration Contour Maps	Hazus determines Census tract ground motion and develops region-wide ground motion contour maps based on the user-supplied hazard data.
USGS ShakeMap	▪ Census Tract Ground Motions ▪ PGA, PGV and Spectral Acceleration Contour Maps	Hazus determines area weighted average ground motions for Census tracts and develops region-wide ground motion contour maps based on the ShakeMap XML grid data.

For areas identified as susceptible to secondary hazards (i.e., where the user has input maps of landslide susceptibility, or liquefaction susceptibility and depth to groundwater), Hazus provides information concerning the expected level of permanent ground deformations (PGDs) due to the specified scenario event, along with their probability. In this methodology, permanent ground deformation is defined as liquefaction, landslide, and surface fault rupture. PGDs are important in estimating losses to and functionality of systems, in fact most of these module outputs will contribute to the economic losses and functionality of systems. Table 8-2 summarizes the ground deformation outputs. PGDs are reported in terms of Census tract maps of ground deformation (in inches) or site-specific PGDs.

Table 8-2 Ground Deformation Output

Input	Module Output
Liquefaction	▪ Census tract PGD map for both settlement and lateral spread ▪ Census tract map for liquefaction probability ▪ Location-Specific PGD and probability
Landslide	▪ Census tract PGD map ▪ Census tract map for landslide probability ▪ Location-Specific PGD and probability
Surface Fault Rupture	▪ Census tract PGD map ▪ Census tract map for rupture probability ▪ Location-Specific PGD

The user can access the hazard outputs from the **Results > Ground Motion or Ground Failure** menu (Table 8-2). Ground motion maps can be viewed in two forms: Census tract-based and contour maps. To generate Census tract-based maps, Hazus executes an area-weighted calculation of the ground motion across the Census tract and then assigns the value to the Census tract. The Census tract-based information is used to derive the damage and loss estimates for the GBS. Contour maps that are generated by Hazus are for display purposes only and serve as a regional view of the selected area.

From the **Ground Motion or Ground Failure** menu, the user can plot a variety of maps by choosing one of the two options**: Ground Motion (By Census Tracts)** or **Contours or Ground Failure Maps.** For the **Ground Motion (By Census Tracts)** option, as shown in Figure 8-2, a user can generate maps of spectral acceleration, spectral displacement, spectral velocity, PGV, or PGA by selecting the relevant tab, clicking the appropriate column of data, and then clicking the **Map** button. Examples of ground motion result values are shown in the output table in Figure 8-3. For the **Contours or Ground Failure Maps** option, a user may plot any of the maps shown in Figure 8-4, provided the user has already run the **Contour maps** analysis module. Click the appropriate category in Figure 8-5, followed by the **Map** button.

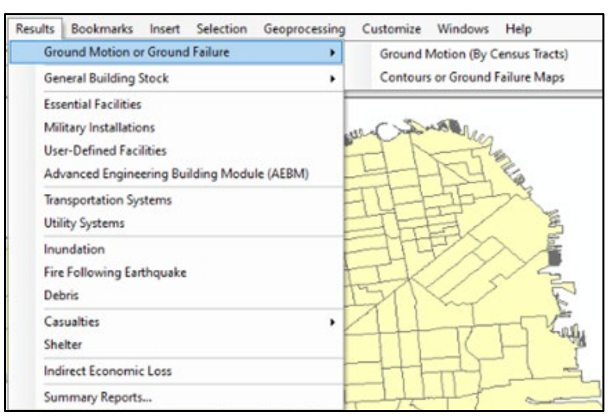
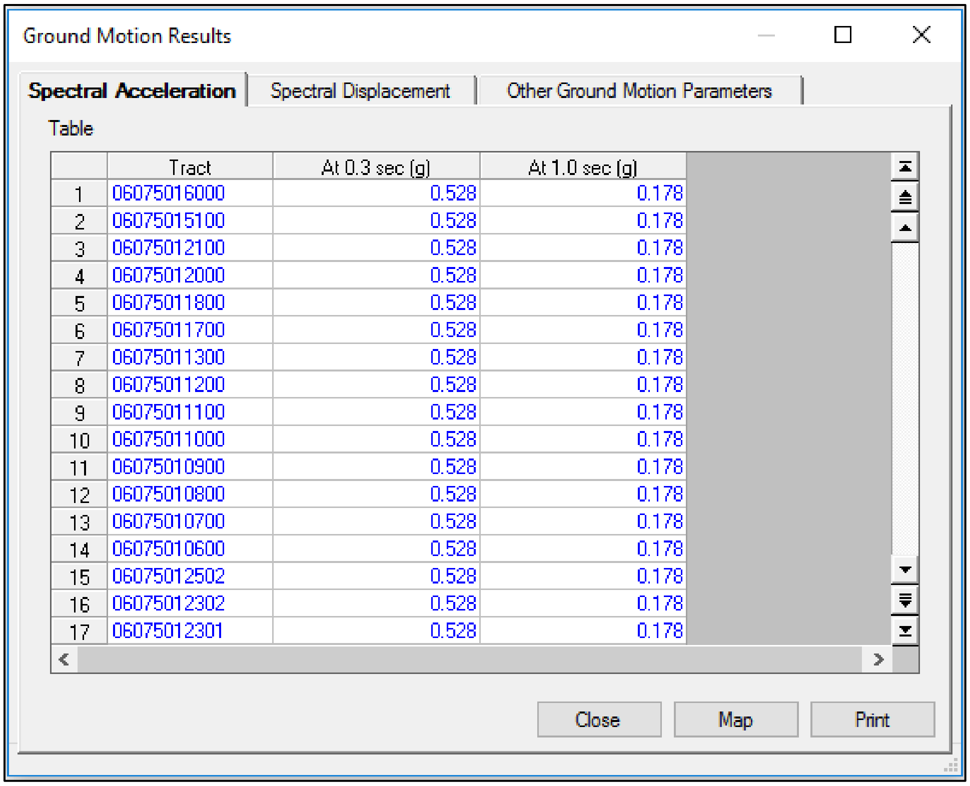


Figure 8-2 Ground Motion or Ground Failure Results Menu



	Tract	At 0.3 sec (g)	At 1.0 sec (g)
1	06075016000	0.528	0.178
2	06075015100	0.528	0.178
3	06075012100	0.528	0.178
4	06075012000	0.528	0.178
5	06075011800	0.528	0.178
6	06075011700	0.528	0.178
7	06075011300	0.528	0.178
8	06075011200	0.528	0.178
9	06075011100	0.528	0.178
10	06075011000	0.528	0.178
11	06075010900	0.528	0.178
12	06075010800	0.528	0.178
13	06075010700	0.528	0.178
14	06075010600	0.528	0.178
15	06075012502	0.528	0.178
16	06075012302	0.528	0.178
17	06075012301	0.528	0.178

Figure 8-3 Ground Motion Results by Census Tract

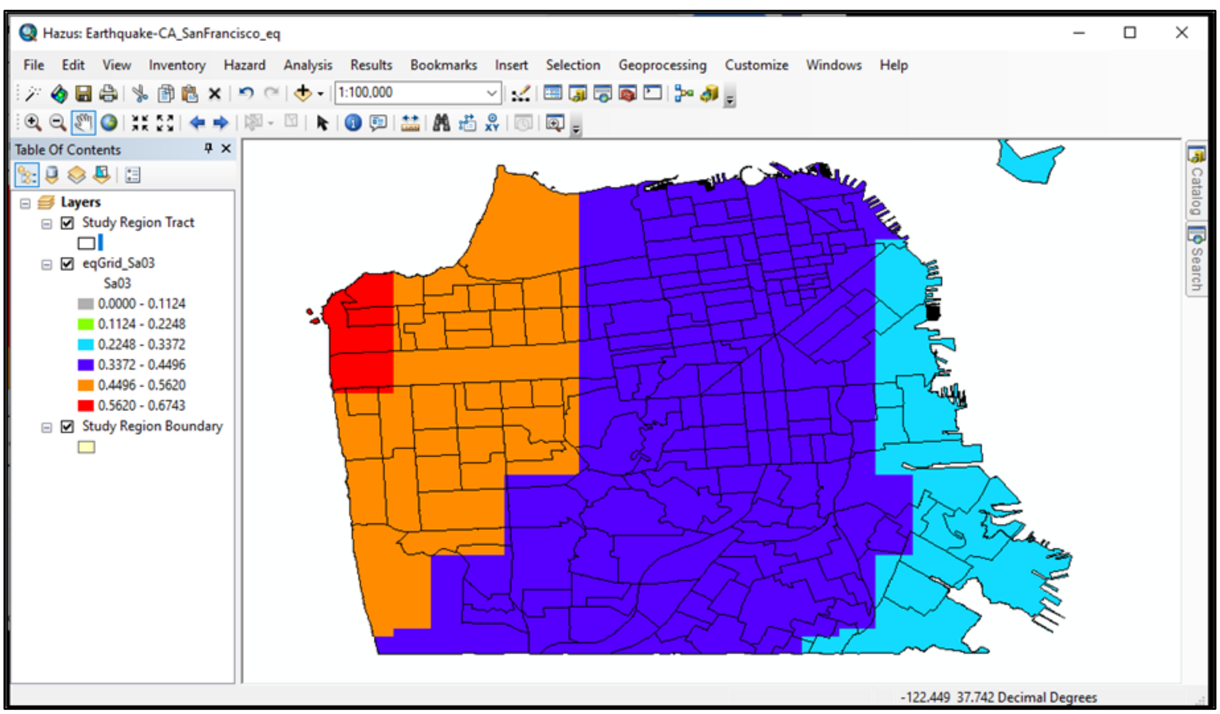


Figure 8-4 Map of 0.3 Second Spectral Acceleration by Census Tract

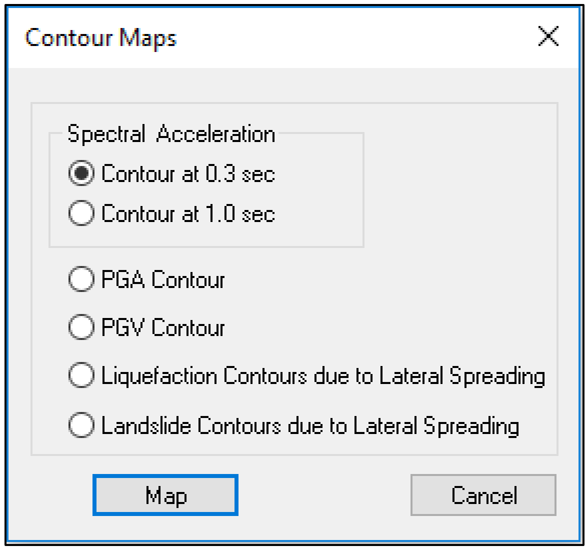


Figure 8-5 Contours or Ground Failure Maps Menu

8.2.2 General Building Stock: Direct Physical Damage

The direct physical damage module of Hazus provides information about the level of damage to the Study Region's GBS. Damage to the GBS is not evaluated on a building-by-building basis. Instead, damage is estimated and reported for groups of buildings in each Census tract. Damage to the GBS is defined in terms of the probability that a specific building type will reach or exceed a specified level of damage when subjected to a given level of ground motion. The General Building Stock damage estimates are used in other models in the methodology to estimate economic losses, social losses, and induced damages, such as debris (see Figure 8-6). Building damage is also used to determine estimates of the amount of debris that would need to be cleared.

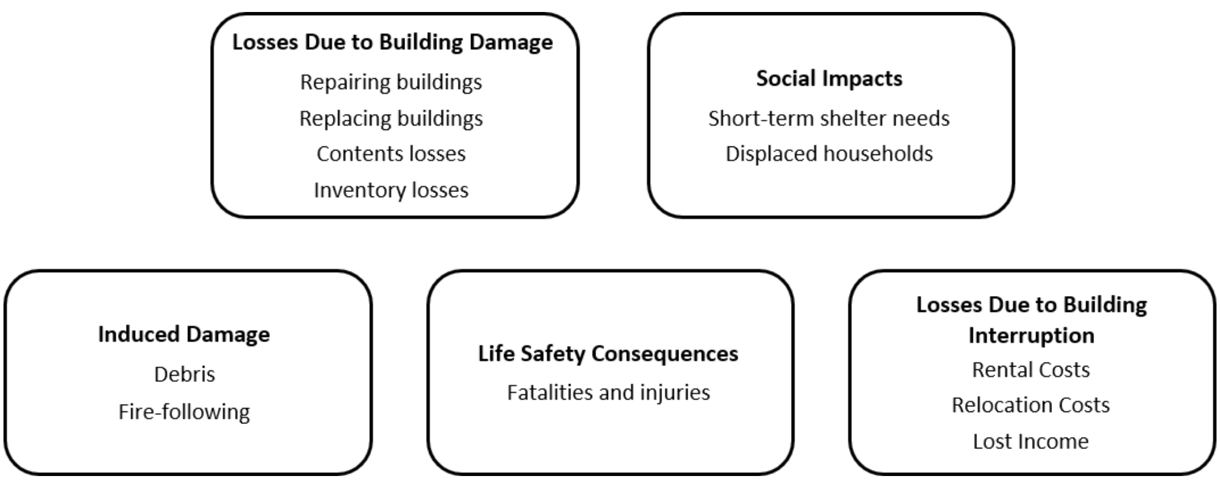


Figure 8-6 Losses Calculated from Damage Estimates

Losses such as the cost of reconstruction, length of business interruption, number of people needing shelter, and severity of injuries and number of casualties all depend on the severity of the damage. While estimating social and economic losses is the ultimate goal of a loss study, some knowledge of the geographical distribution of damage may be helpful in planning for post-earthquake response or in determining strategies for mitigation (e.g., if the scenario identifies a particular area where a large number of buildings are likely to collapse, planning for rescue efforts in this area may be important).

As discussed earlier in Section 7.1.1 damage is described by five damage states (none, slight, moderate, extensive, and complete). Estimates of earthquake damage are provided in terms of damage state probabilities, building count, or square footage, by specific building type and design level. That is, for a specified earthquake, the user is provided with the probability (or count or square footage) of a structural type experiencing a certain level of damage. For example, for a given earthquake, wood frame structures may have a probability of 0.9 (90%) of experiencing no damage and a probability of 0.1 (10%) of experiencing slight damage. Damage state probabilities are provided for structural as well as nonstructural damage, whereas building counts and square footages are only provided for structural damage. Results are available in a tabular or map format.

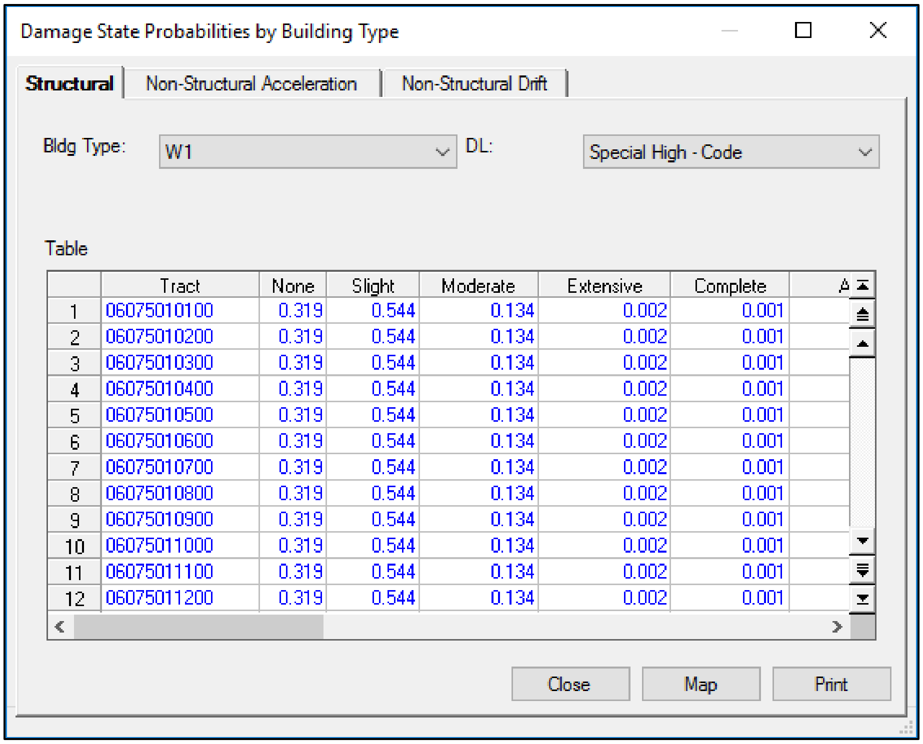
The **Results > General Building Stock** menu option is used to assess the output of the damage module. Results are provided in a tabular format (Figure 8-7 and Figure 8-8) which can also be mapped (Figure 8-9 and Figure 8-10). In the three sub-menus, the following information can be displayed:

- Damage by Building Type (Figure 8-7): Probability of None, Slight, Moderate, Extensive, or Complete damage by specific building type and design level in each Census tract, for structural, acceleration-sensitive nonstructural, or drift-sensitive nonstructural components Exceedance probabilities (probability of at least Slight damage, at least Moderate damage and at least Extensive damage) are also provided.

- Damage by Count: Count of buildings in each Census tract in the None, Slight, Moderate, Extensive, And Complete damage states by specific building type and design level, and in total.

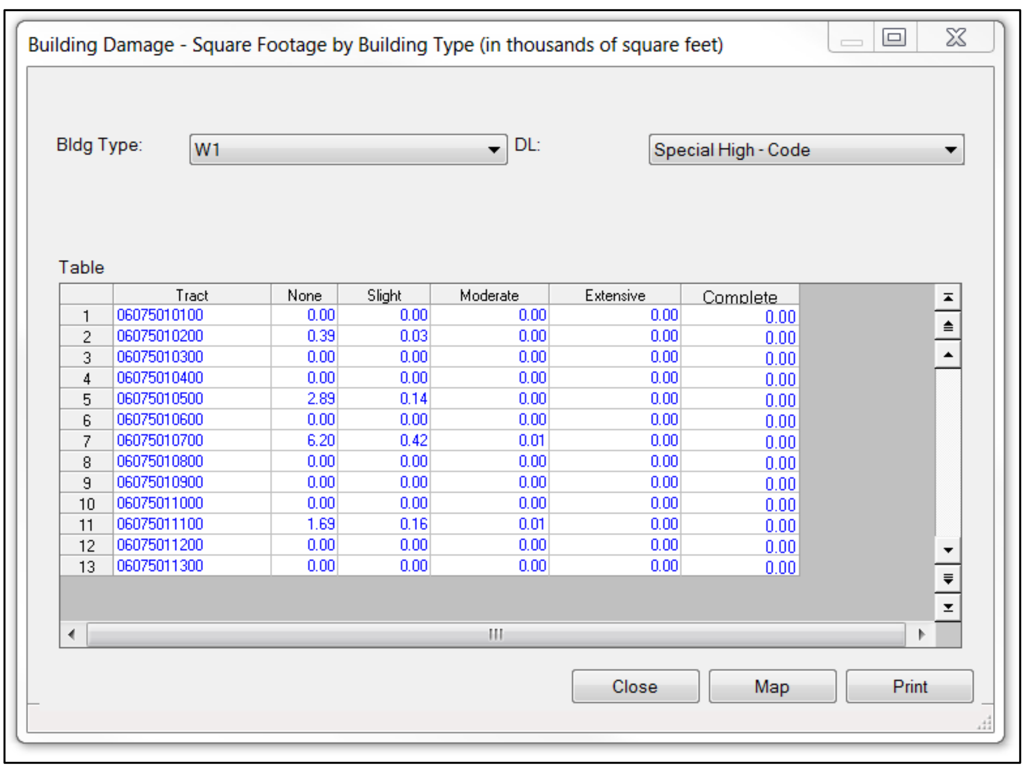
- Damage by Square Footage (Figure 8-8): Building square footage in each Census tract in the None, Slight, Moderate, Extensive, and Complete damage states by specific building type and design level.

To thematically map a given value, select its column by clicking the column header and then click **Map** and close the dialog.



	Tract	None	Slight	Moderate	Extensive	Complete
1	06075010100	0.319	0.544	0.134	0.002	0.001
2	06075010200	0.319	0.544	0.134	0.002	0.001
3	06075010300	0.319	0.544	0.134	0.002	0.001
4	06075010400	0.319	0.544	0.134	0.002	0.001
5	06075010500	0.319	0.544	0.134	0.002	0.001
6	06075010600	0.319	0.544	0.134	0.002	0.001
7	06075010700	0.319	0.544	0.134	0.002	0.001
8	06075010800	0.319	0.544	0.134	0.002	0.001
9	06075010900	0.319	0.544	0.134	0.002	0.001
10	06075011000	0.319	0.544	0.134	0.002	0.001
11	06075011100	0.319	0.544	0.134	0.002	0.001
12	06075011200	0.319	0.544	0.134	0.002	0.001

Figure 8-7 Damage by Building Type



	Tract	None	Slight	Moderate	Extensive	Complete
1	06075010100	0.00	0.00	0.00	0.00	0.00
2	06075010200	0.39	0.03	0.00	0.00	0.00
3	06075010300	0.00	0.00	0.00	0.00	0.00
4	06075010400	0.00	0.00	0.00	0.00	0.00
5	06075010500	2.89	0.14	0.00	0.00	0.00
6	06075010600	0.00	0.00	0.00	0.00	0.00
7	06075010700	6.20	0.42	0.01	0.00	0.00
8	06075010800	0.00	0.00	0.00	0.00	0.00
9	06075010900	0.00	0.00	0.00	0.00	0.00
10	06075011000	0.00	0.00	0.00	0.00	0.00
11	06075011100	1.69	0.16	0.01	0.00	0.00
12	06075011200	0.00	0.00	0.00	0.00	0.00
13	06075011300	0.00	0.00	0.00	0.00	0.00

Figure 8-8 Damage by Square Footage

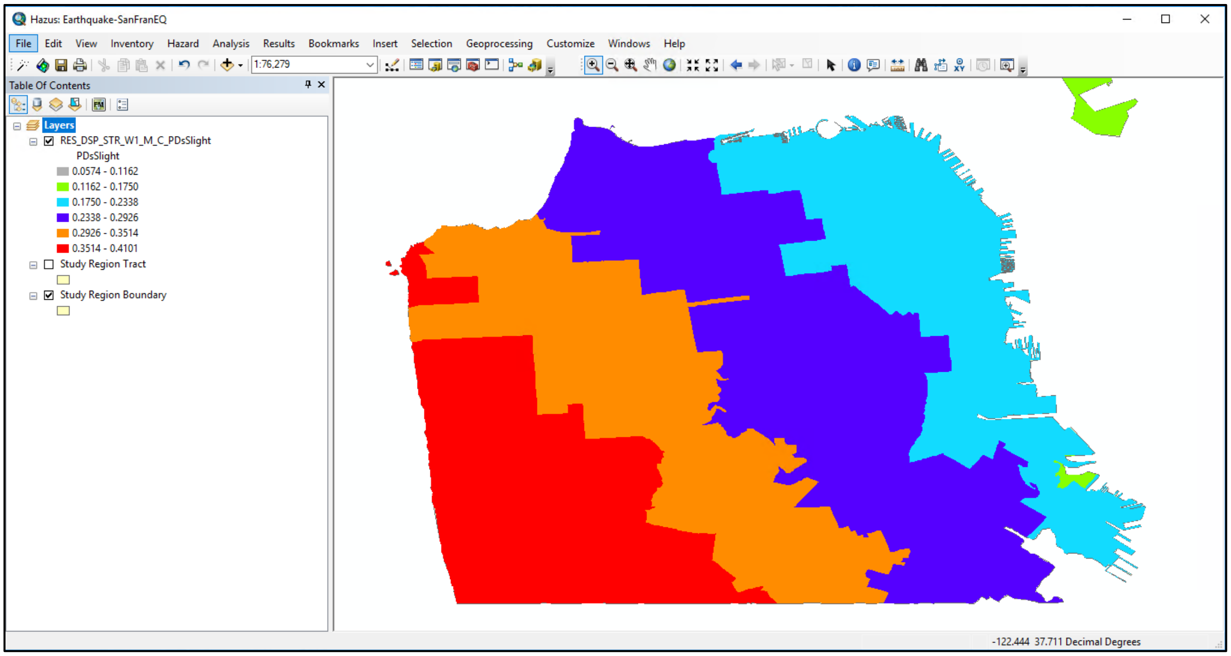


Figure 8-9 Map of Probability of Slight Structural Damage

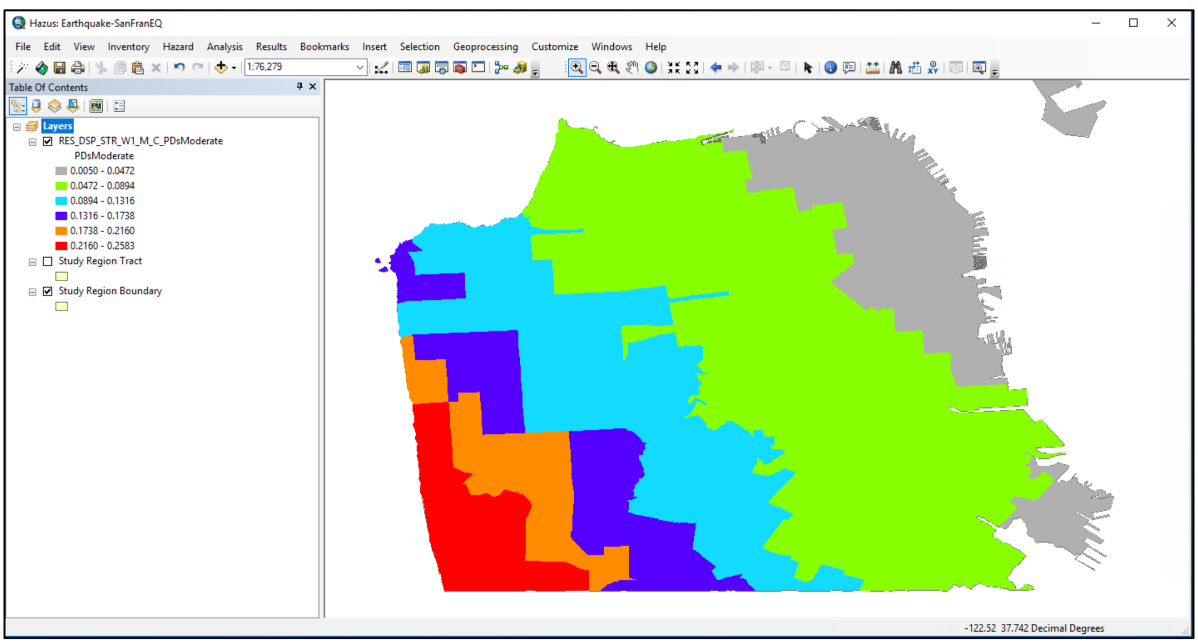


Figure 8-10 Map of Probability of Moderate Structural Damage

8.2.3 General Building Stock - Building Economic Loss

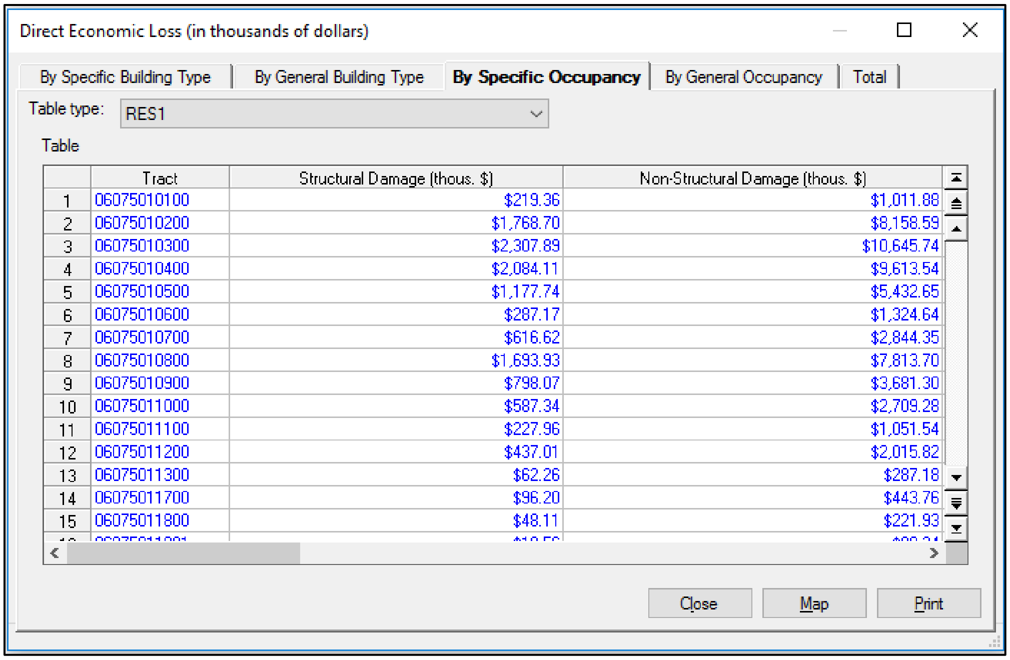
Building economic loss estimates, described in Table 8-3, can be viewed by clicking the **Results > General Building Stock > Building Economic Loss** menu. Two sub-menus are available – **Direct Economic Loss** and **Building Loss by Damage State.** From the **Direct Economic Loss** sub-menu

(Figure 8-11), the various building losses by Census tract are summarized on different tabs by specific (module) building type, general building type, specific occupancy, general occupancy, or as totals. Census tract economic losses broken down into structural and nonstructural components are also available by specific building type and design level from the **Building Loss by Damage State** sub-menu.

Table 8-3 Direct Economic Loss Module Outputs – Buildings

Component	Module Output	Description of Output
Structural Damage, Nonstructural Damage and Building Damage	Dollar Loss (in thousands of $)	Hazus determines the expected dollar loss due to the repair and replacement of structural and nonstructural damage to the GBS by Census tract for the Study Region. Total building damage (structural + nonstructural damage) is also tabulated.
Content Damage	Dollar Loss (in thousands of $)	Hazus determines the expected dollar loss due to contents damage by Census tract for the Study Region.
Commercial Inventory Loss	Dollar Loss (in thousands of $)	Hazus determines the expected dollar loss due to commercial inventory damage by Census tract for the Study Region.
Relocation Cost	Dollar Loss (in thousands of $)	Hazus determines the expected cost of business relocation by Census tract for the Study Region.
Capital-related Income Loss	Dollar Loss (in thousands of $)	Hazus determines the expected business income loss by Census tract for the Study Region.
Rental Income Loss	Dollar Loss (in thousands of $)	Hazus determines the expected loss of rental income resulting from building damage by Census tract for the Study Region.
Wage Loss	Dollar Loss (in thousands of $)	Hazus determines the expected wage loss by Census tract for the Study Region.
Total Loss	Dollar Loss (in thousands of $)	Hazus determines the sum of all building-damage related direct economic losses by Census tract for the Study Region.

As shown in Figure 8-11, direct economic losses for each Census tract are reported by Specific Occupancy class. Results for each individual Specific Occupancy class may be viewed by selecting the class from the **Table type** pull-down menu. The losses include structural and nonstructural repair, contents and inventory loss, relocation costs, proprietor's income loss, rental income loss and wage losses. As of the release of Hazus 4.2 Service Pack 01, loss estimates generated by Hazus are provided in 2018 dollars, in units of $1,000. The same types of losses are also reported by General Occupancy class, as shown in Figure 8-12.



Direct Economic Loss (in thousands of dollars)

By Specific Building Type | By General Building Type | **By Specific Occupancy** | By General Occupancy | Total

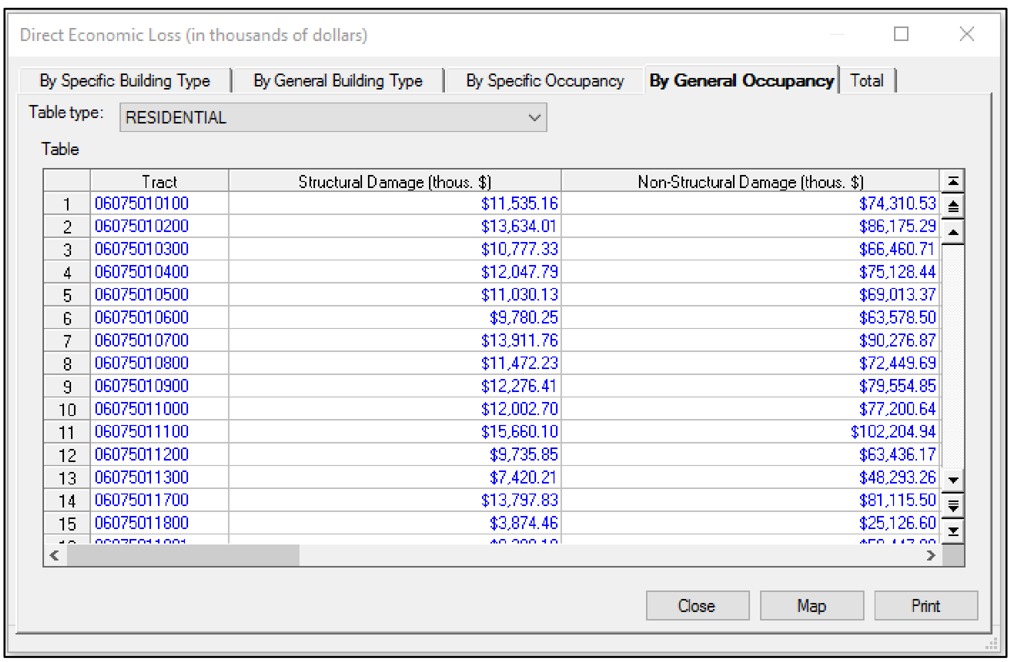
Table type: RES1

Table

	Tract	Structural Damage (thous. $)	Non-Structural Damage (thous. $)
1	06075010100	$219.36	$1,011.88
2	06075010200	$1,768.70	$8,158.59
3	06075010300	$2,307.89	$10,645.74
4	06075010400	$2,084.11	$9,613.54
5	06075010500	$1,177.74	$5,432.65
6	06075010600	$287.17	$1,324.64
7	06075010700	$616.62	$2,844.35
8	06075010800	$1,693.93	$7,813.70
9	06075010900	$798.07	$3,681.30
10	06075011000	$587.34	$2,709.28
11	06075011100	$227.96	$1,051.54
12	06075011200	$437.01	$2,015.82
13	06075011300	$62.26	$287.18
14	06075011700	$96.20	$443.76
15	06075011800	$48.11	$221.93

Close | Map | Print

Figure 8-11 Direct Economic Losses Reported by Specific Occupancy Class



Direct Economic Loss (in thousands of dollars)

By Specific Building Type | By General Building Type | By Specific Occupancy | **By General Occupancy** | Total

Table type: RESIDENTIAL

Table

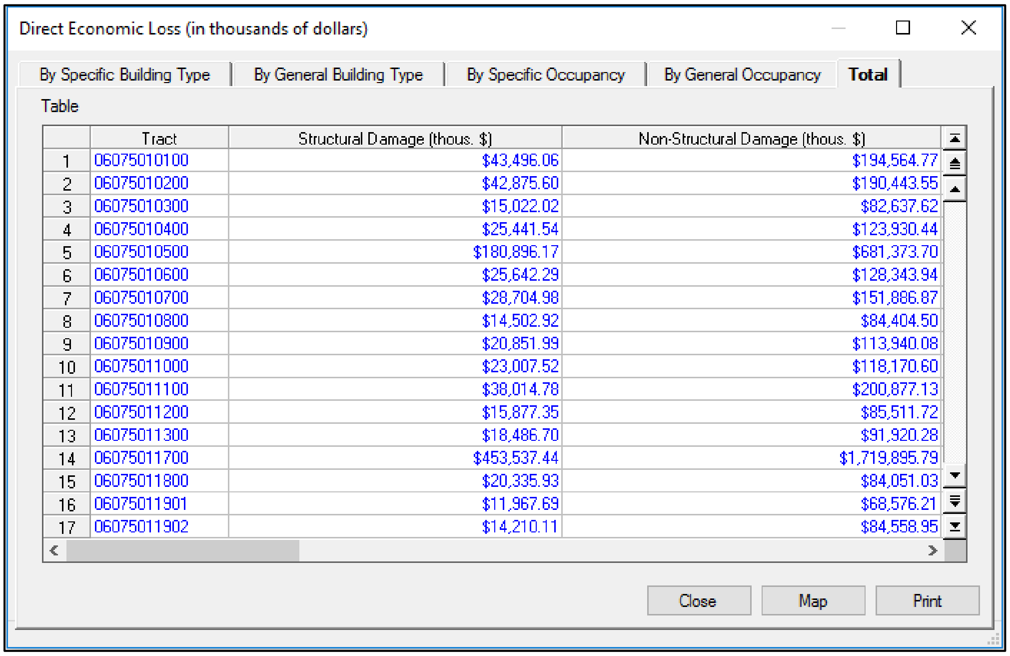
	Tract	Structural Damage (thous. $)	Non-Structural Damage (thous. $)
1	06075010100	$11,535.16	$74,310.53
2	06075010200	$13,634.01	$86,175.29
3	06075010300	$10,777.33	$66,460.71
4	06075010400	$12,047.79	$75,128.44
5	06075010500	$11,030.13	$69,013.37
6	06075010600	$9,780.25	$63,578.50
7	06075010700	$13,911.76	$90,276.87
8	06075010800	$11,472.23	$72,449.69
9	06075010900	$12,276.41	$79,554.85
10	06075011000	$12,002.70	$77,200.64
11	06075011100	$15,660.10	$102,204.94
12	06075011200	$9,735.85	$63,436.17
13	06075011300	$7,420.21	$48,293.26
14	06075011700	$13,797.83	$81,115.50
15	06075011800	$3,874.46	$25,126.60

Close | Map | Print

Figure 8-12 Direct Economic Losses Reported by General Occupancy Class

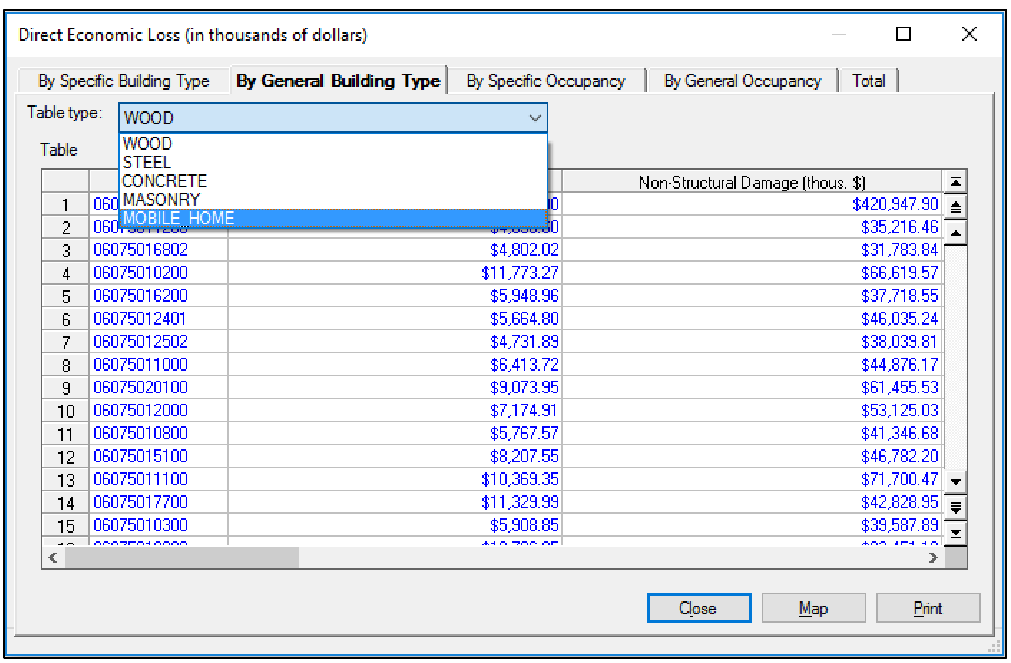
The total loss of each type for all occupancy classes by Census tract can be viewed from the **Total** tab as shown in Figure 8-13. Losses can also be reported for each of the 36 specific building types or the five general building types for each Census tract, as shown in Figure 8-14.

The window shown in Figure 8-13 differs from that shown in Figure 8-14 in that, for example, the total cost of structural damage is the sum of the structural damage for all of the five general building types.



	Tract	Structural Damage (thous. $)	Non-Structural Damage (thous. $)
1	06075010100	$43,496.06	$194,564.77
2	06075010200	$42,875.60	$190,443.55
3	06075010300	$15,022.02	$82,637.62
4	06075010400	$25,441.54	$123,930.44
5	06075010500	$180,896.17	$681,373.70
6	06075010600	$25,642.29	$128,343.94
7	06075010700	$28,704.98	$151,886.87
8	06075010800	$14,502.92	$84,404.50
9	06075010900	$20,851.99	$113,940.08
10	06075011000	$23,007.52	$118,170.60
11	06075011100	$38,014.78	$200,877.13
12	06075011200	$15,877.35	$85,511.72
13	06075011300	$18,486.70	$91,920.28
14	06075011700	$453,537.44	$1,719,895.79
15	06075011800	$20,335.93	$84,051.03
16	06075011901	$11,967.69	$68,576.21
17	06075011902	$14,210.11	$84,558.95

Figure 8-13 Total Direct Economic Building Losses Reported by Census Tract



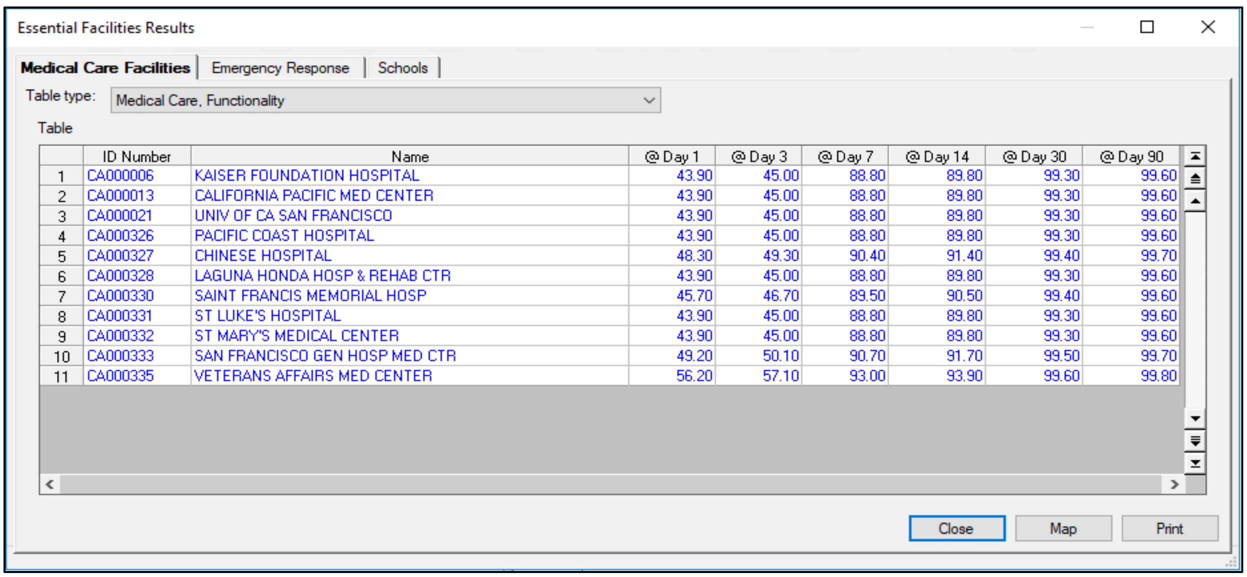
			Non-Structural Damage (thous. $)
1	060	0	$420,947.90
2	060	$4, 0	$35,216.46
3	06075016802	$4,802.02	$31,783.84
4	06075010200	$11,773.27	$66,619.57
5	06075016200	$5,948.96	$37,718.55
6	06075012401	$5,664.80	$46,035.24
7	06075012502	$4,731.89	$38,039.81
8	06075011000	$6,413.72	$44,876.17
9	06075020100	$9,073.95	$61,455.53
10	06075012000	$7,174.91	$53,125.03
11	06075010800	$5,767.57	$41,346.68
12	06075015100	$8,207.55	$46,782.20
13	06075011100	$10,369.35	$71,700.47
14	06075017700	$11,329.99	$42,828.95
15	06075010300	$5,908.85	$39,587.89

Figure 8-14 Types of Building Losses Reported by General Building Type

8.2.4 Essential Facilities

Hazus provides information about the structural damage state probabilities and functionality of the Study Region's essential facilities. In contrast to the GBS, where damage probabilities are calculated for groups of buildings, for essential facilities, the damage probabilities are estimated for each individual facility. For additional assistance with these results please refer to the [FEMA Earthquake Mapping SOP document](). As with the GBS, the damage states are none, slight, moderate, extensive, and complete. As can be seen in Figure 8-15, structural damage state probabilities are estimated for medical care facilities, police and fire stations, emergency operation centers, and schools. In addition, loss of beds is computed as a function of time for medical care facilities (these results are available on the **Medical Care, Functionality** summary report).

Output of the essential facilities damage module can be obtained by using the **Results > Essential Facilities** menu. Results are provided in a tabular format and can be mapped. An example of the percent of functionality by day of medical care facilities is shown in Figure 8-15. These results may help communities to understand how many days it will take to restore complete functionality to a specific facility. To thematically map a given value, select its column by clicking the header and then click **Map**.



	ID Number	Name	@ Day 1	@ Day 3	@ Day 7	@ Day 14	@ Day 30	@ Day 90
1	CA000006	KAISER FOUNDATION HOSPITAL	43.90	45.00	88.80	89.80	99.30	99.60
2	CA000013	CALIFORNIA PACIFIC MED CENTER	43.90	45.00	88.80	89.80	99.30	99.60
3	CA000021	UNIV OF CA SAN FRANCISCO	43.90	45.00	88.80	89.80	99.30	99.60
4	CA000326	PACIFIC COAST HOSPITAL	43.90	45.00	88.80	89.80	99.30	99.60
5	CA000327	CHINESE HOSPITAL	48.30	49.30	90.40	91.40	99.40	99.70
6	CA000328	LAGUNA HONDA HOSP & REHAB CTR	43.90	45.00	88.80	89.80	99.30	99.60
7	CA000330	SAINT FRANCIS MEMORIAL HOSP	45.70	46.70	89.50	90.50	99.40	99.60
8	CA000331	ST LUKE'S HOSPITAL	43.90	45.00	88.80	89.80	99.30	99.60
9	CA000332	ST MARY'S MEDICAL CENTER	43.90	45.00	88.80	89.80	99.30	99.60
10	CA000333	SAN FRANCISCO GEN HOSP MED CTR	49.20	50.10	90.70	91.70	99.50	99.70
11	CA000335	VETERANS AFFAIRS MED CENTER	56.20	57.10	93.00	93.90	99.60	99.80

Figure 8-15 Functionality of Medical Care Facilities

8.2.5 Military Installations

Hazus can be used to estimate potential damage and functionality of military installations if the user can develop and import appropriate inventory data. This can serve as a first step in developing mitigation and preparedness efforts regarding military facilities and their functionality. Results for military facilities can be viewed through the **Results > Military Installations** menu. The types of damage outputs can be viewed in Table 8-4.

Table 8-4 Direct Physical Damage Outputs – Military Installations

Component	Module Output	Description of Output
Military Facilities	▪ Structural Damage State Probabilities ▪ Facility functionality	Hazus determines the damage state probabilities and functionality for each facility in the Study Region.

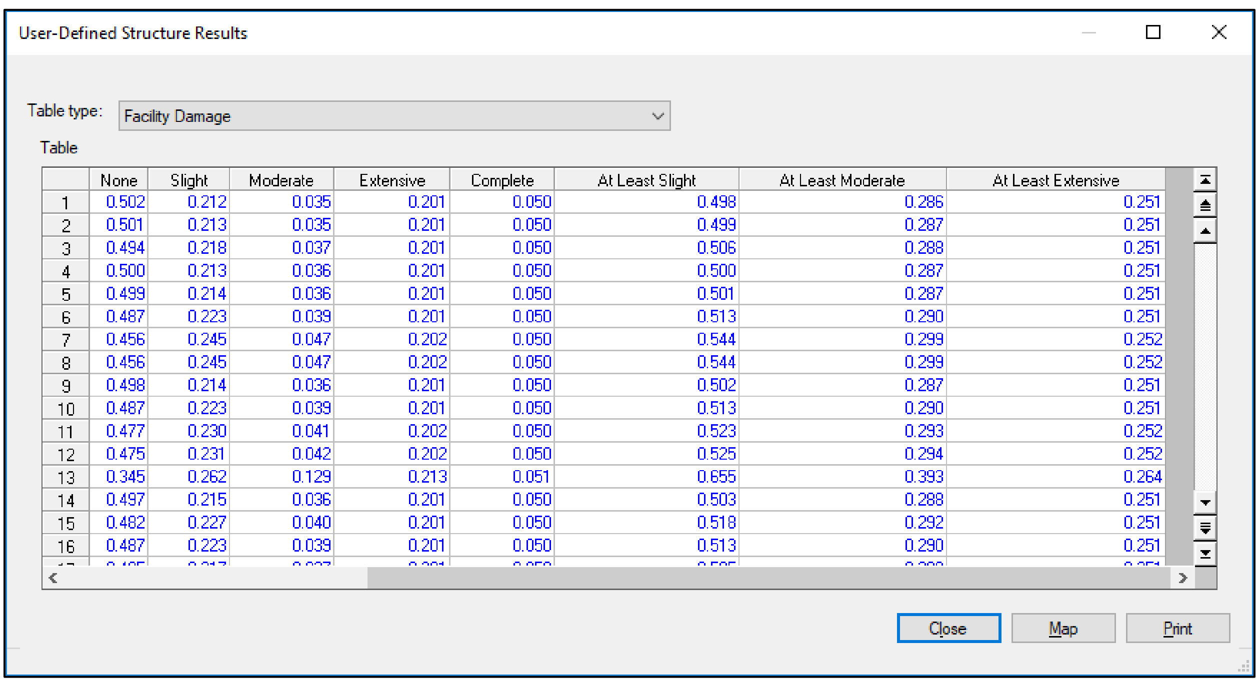
8.2.6 User-Defined Facilities

User-defined facilities are those structures, other than essential facilities or high potential loss facilities, which the user may wish to analyze on a site-specific basis. For example, if there is a need to identify all unreinforced masonry buildings or all the pharmacies in a community. See Section 9.1 to learn how to import user-defined facilities.

The user-defined facilities module returns results for each imported structure in two categories:

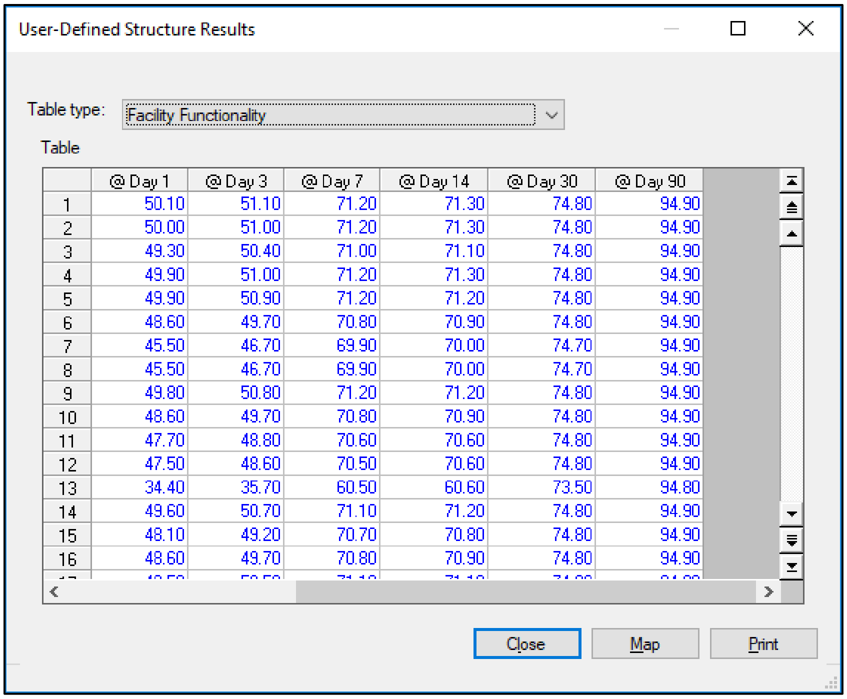
1. Facility Damage Percent (in eight categories) – None, Slight, Moderate, Extensive, Complete, At Least Slight, At Least Moderate, At Least Extensive (Figure 8-16). To thematically map a given value, select its column by clicking the header and then click **Map.**

2. Facility Functionality Percent (in six categories) – at Day 1, at Day 3, at Day 7, at Day 14, at Day 30, at Day 90 (Figure 8-17).



	None	Slight	Moderate	Extensive	Complete	At Least Slight	At Least Moderate	At Least Extensive
1	0.502	0.212	0.035	0.201	0.050	0.498	0.286	0.251
2	0.501	0.213	0.035	0.201	0.050	0.499	0.287	0.251
3	0.494	0.218	0.037	0.201	0.050	0.506	0.288	0.251
4	0.500	0.213	0.036	0.201	0.050	0.500	0.287	0.251
5	0.499	0.214	0.036	0.201	0.050	0.501	0.287	0.251
6	0.487	0.223	0.039	0.201	0.050	0.513	0.290	0.251
7	0.456	0.245	0.047	0.202	0.050	0.544	0.299	0.252
8	0.456	0.245	0.047	0.202	0.050	0.544	0.299	0.252
9	0.498	0.214	0.036	0.201	0.050	0.502	0.287	0.251
10	0.487	0.223	0.039	0.201	0.050	0.513	0.290	0.251
11	0.477	0.230	0.041	0.202	0.050	0.523	0.293	0.252
12	0.475	0.231	0.042	0.202	0.050	0.525	0.294	0.252
13	0.345	0.262	0.129	0.213	0.051	0.655	0.393	0.264
14	0.497	0.215	0.036	0.201	0.050	0.503	0.288	0.251
15	0.482	0.227	0.040	0.201	0.050	0.518	0.292	0.251
16	0.487	0.223	0.039	0.201	0.050	0.513	0.290	0.251

Figure 8-16 User-Defined Structure Results – Facility Damage



User-Defined Structure Results

Table type: Facility Functionality

Table

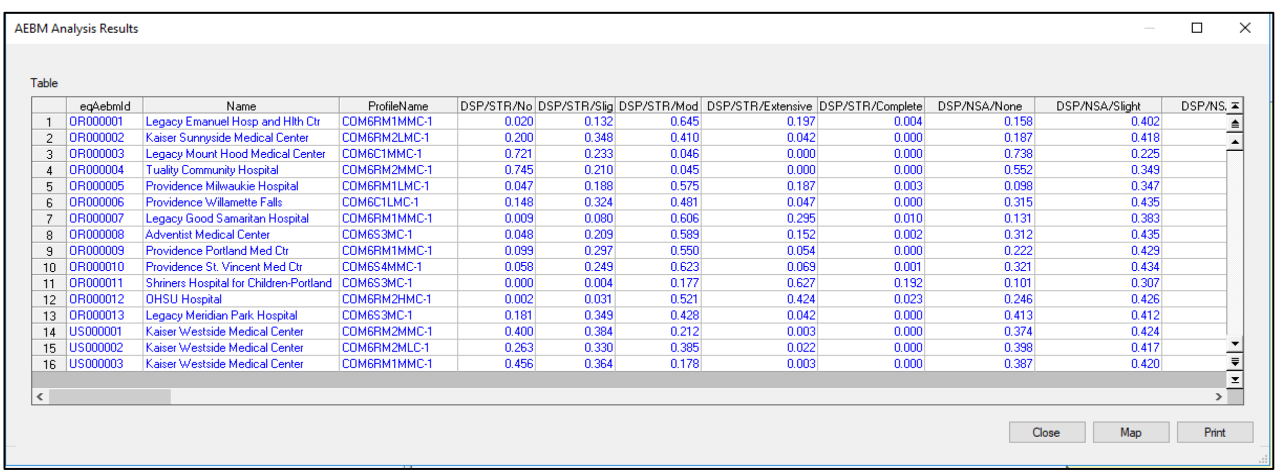
	@ Day 1	@ Day 3	@ Day 7	@ Day 14	@ Day 30	@ Day 90
1	50.10	51.10	71.20	71.30	74.80	94.90
2	50.00	51.00	71.20	71.30	74.80	94.90
3	49.30	50.40	71.00	71.10	74.80	94.90
4	49.90	51.00	71.20	71.30	74.80	94.90
5	49.90	50.90	71.20	71.20	74.80	94.90
6	48.60	49.70	70.80	70.90	74.80	94.90
7	45.50	46.70	69.90	70.00	74.70	94.90
8	45.50	46.70	69.90	70.00	74.70	94.90
9	49.80	50.80	71.20	71.20	74.80	94.90
10	48.60	49.70	70.80	70.90	74.80	94.90
11	47.70	48.80	70.60	70.60	74.80	94.90
12	47.50	48.60	70.50	70.60	74.80	94.90
13	34.40	35.70	60.50	60.60	73.50	94.80
14	49.60	50.70	71.10	71.20	74.80	94.90
15	48.10	49.20	70.70	70.80	74.80	94.90
16	48.60	49.70	70.80	70.90	74.80	94.90

Close Map Print

Figure 8-17 User-Defined Structure Results – Facility Functionality

8.2.7 Advanced Engineering Building Module

Results of AEBM analysis may be viewed by clicking the **Advanced Engineering Building Module (AEBM)** option of the **Results** pull-down menu. The results table includes structural and nonstructural damage state probabilities, casualties, and direct economic losses for each building in the AEBM Inventory, as shown in Figure 8-18. To thematically map a given value, select its column by clicking the header and then click **Map**. The results may also be viewed in Hazus summary reports.



AEBM Analysis Results

Table

	eqAebmId	Name	ProfileName	DSP/STR/No	DSP/STR/Slig	DSP/STR/Mod	DSP/STR/Extensive	DSP/STR/Complete	DSP/NSA/None	DSP/NSA/Slight	DSP/NS.
1	OR000001	Legacy Emanuel Hosp and Hlth Ctr	COM6RM1MMC-1	0.020	0.132	0.645	0.197	0.004	0.158	0.402	
2	OR000002	Kaiser Sunnyside Medical Center	COM6RM2LMC-1	0.200	0.348	0.410	0.042	0.000	0.187	0.418	
3	OR000003	Legacy Mount Hood Medical Center	COM6C1MMC-1	0.721	0.233	0.046	0.000	0.000	0.738	0.225	
4	OR000004	Tuality Community Hospital	COM6RM2MMC-1	0.745	0.210	0.045	0.000	0.000	0.552	0.349	
5	OR000005	Providence Milwaukie Hospital	COM6RM1LMC-1	0.047	0.188	0.575	0.187	0.003	0.098	0.347	
6	OR000006	Providence Willamette Falls	COM6C1LMC-1	0.148	0.324	0.481	0.047	0.000	0.315	0.435	
7	OR000007	Legacy Good Samaritan Hospital	COM6RM1MMC-1	0.009	0.080	0.606	0.295	0.010	0.131	0.383	
8	OR000008	Adventist Medical Center	COM6S3MC-1	0.048	0.209	0.589	0.152	0.002	0.312	0.435	
9	OR000009	Providence Portland Med Ctr	COM6RM1MMC-1	0.099	0.297	0.550	0.054	0.000	0.222	0.429	
10	OR000010	Providence St. Vincent Med Ctr	COM6S4MMC-1	0.058	0.249	0.623	0.069	0.001	0.321	0.434	
11	OR000011	Shriners Hospital for Children-Portland	COM6S3MC-1	0.000	0.004	0.177	0.627	0.192	0.101	0.307	
12	OR000012	OHSU Hospital	COM6RM2HMC-1	0.002	0.031	0.521	0.424	0.023	0.246	0.426	
13	OR000013	Legacy Meridian Park Hospital	COM6S3MC-1	0.181	0.349	0.428	0.042	0.000	0.413	0.412	
14	US000001	Kaiser Westside Medical Center	COM6RM2MMC-1	0.400	0.384	0.212	0.003	0.000	0.374	0.424	
15	US000002	Kaiser Westside Medical Center	COM6RM2MLC-1	0.263	0.330	0.385	0.022	0.000	0.398	0.417	
16	US000003	Kaiser Westside Medical Center	COM6RM1MMC-1	0.456	0.364	0.178	0.003	0.000	0.387	0.420	

Close Map Print

Figure 8-18 AEBM Analysis Results

8.2.8 Critical Systems

Critical systems are vital to the functionality of a community. Damage to these systems after an earthquake can be devastating in terms of the health and safety of the citizens. After Japan's Great Hanshin earthquake in 1995, the water supply system was so severely damaged that people had to rely on trucked-in water. Damage to railway and road systems prevented emergency response personnel from bringing food, water, and other supplies into the region. Over 900,000 households were without electricity and 800,000 households were without gas in the middle of winter. Damage to roads and blockages of roads due to collapsed buildings prevented police, firefighters, and rescuers from fighting fires and attending to the trapped and injured.

Losses to the community that result from damage to critical systems can be much greater than the cost of repairing the systems. For example, damage to the Port of Kobe, one of the busiest in Japan, stopped the import and export of materials that were essential to the operation of many manufacturing plants in Japan. Factories were forced to close for lack of materials. Recovery of a region will depend to a great degree on how quickly critical systems can be restored to full functionality. Therefore, assessment of the vulnerability of critical systems is an important part of developing regional emergency preparedness and response plans.

In Hazus, critical systems are divided into transportation systems and utility systems. Transportation systems are discussed in Section 8.2.8.1 and utility systems are discussed in Section 8.2.8.2.

8.2.8.1 Transportation Systems

Table 8-5 summarizes the outputs for each of the seven transportation systems: Highway, Railway, Light Rail, Bus, Ferry, Port, and Airport component systems.

Table 8-5 Results – Transportation Systems

Module Output	Description of Output
Damage State Probabilities	Hazus determines the damage state probability for each transportation system component or facility in the Study Region.
Loss	Hazus estimates the economic loss or cost to repair each damaged component or facility in the Study Region
Functionality	Hazus determines the functionality for each transportation system component or facility at discrete time intervals.

Damage to critical systems is described in terms of damage to individual facilities or system components. Detailed systems analyses are not performed, although simplified system analyses are performed for water systems and electric power. Damage is reported in terms of the probability of reaching or exceeding a specified damage state when subjected to a given level of ground motion or PGD. Associated with each damage state is a restoration curve that is used to evaluate the time required to bring the system back to full functionality. The functionality is defined as the probability of the component or facility operating at full capacity after a specified period of time, given an initial level of damage after the earthquake,

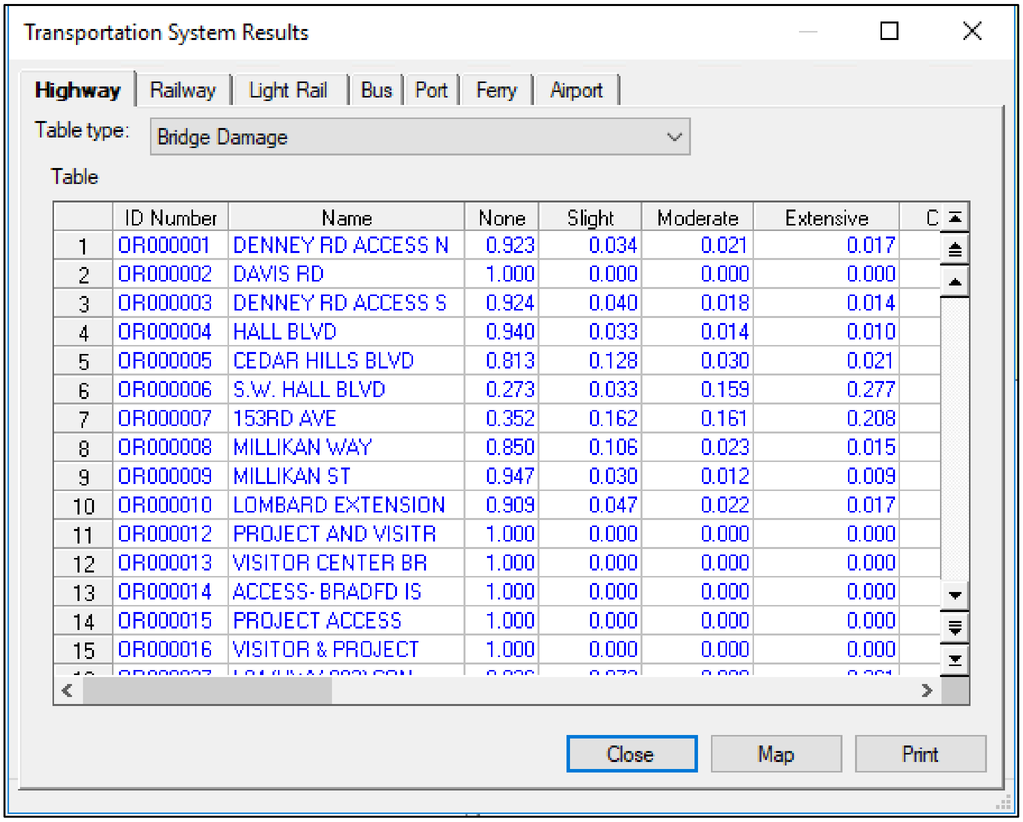
For example, a highway bridge experiencing 0.6g peak ground acceleration and 12 inches of permanent ground deformation might be found to have the following probabilities of damage:

- No damage: 3% chance
- Slight damage: 9% chance
- Moderate damage: 20% chance
- Extensive damage: 44%chance
- Complete damage: 24% chance

Based on this example estimate of damage, the expected functionality of the bridge would be:

- 14% functional after 1 day
- 26% functional after 3 days
- 34% functional after 7 days
- 36% functional after 14 days
- 39%t functional after 30 days
- 60% functional after a 3-month (90 day) restoration period

Another interpretation of these results is that after 1 day, 14% of the bridges of this type would be functional and after 3 months, 60% of these bridges would be functional. Interdependency of the components on the overall transportation system functionality is not addressed by the methodology. Critical transportation systems damage can be viewed in terms of damage state probabilities, repair cost or functionality, and can be displayed in a tabular or map format. Figure 8-19 shows a table of the damage state probabilities for highway bridges for the Study Region, accessed via the **Results > Transportation Systems** menu. For each of the bridges in the Study Region (identified by ID number), the probability of being in one of the five damage states is tabulated. For highway bridge id OR000001, the probability of no damage is 0.923 (92.3%), slight damage is 0.034, and moderate damage is 0.021. Refer to Table 7-5 for a description of the five damage states (See Table 7-5 in Section 7.1.3 for definitions of damage states). This information can be mapped, as shown in Figure 8-20, by selecting a column and clicking the **Map** button. Each highway bridge is identified by a circular symbol. The color of the symbol is associated with a range of probabilities.



	ID Number	Name	None	Slight	Moderate	Extensive	C
1	OR000001	DENNEY RD ACCESS N	0.923	0.034	0.021	0.017	
2	OR000002	DAVIS RD	1.000	0.000	0.000	0.000	
3	OR000003	DENNEY RD ACCESS S	0.924	0.040	0.018	0.014	
4	OR000004	HALL BLVD	0.940	0.033	0.014	0.010	
5	OR000005	CEDAR HILLS BLVD	0.813	0.128	0.030	0.021	
6	OR000006	S.W. HALL BLVD	0.273	0.033	0.159	0.277	
7	OR000007	153RD AVE	0.352	0.162	0.161	0.208	
8	OR000008	MILLIKAN WAY	0.850	0.106	0.023	0.015	
9	OR000009	MILLIKAN ST	0.947	0.030	0.012	0.009	
10	OR000010	LOMBARD EXTENSION	0.909	0.047	0.022	0.017	
11	OR000012	PROJECT AND VISITR	1.000	0.000	0.000	0.000	
12	OR000013	VISITOR CENTER BR	1.000	0.000	0.000	0.000	
13	OR000014	ACCESS- BRADFD IS	1.000	0.000	0.000	0.000	
14	OR000015	PROJECT ACCESS	1.000	0.000	0.000	0.000	
15	OR000016	VISITOR & PROJECT	1.000	0.000	0.000	0.000	

Figure 8-19 Damage State Probabilities for Highway Bridges

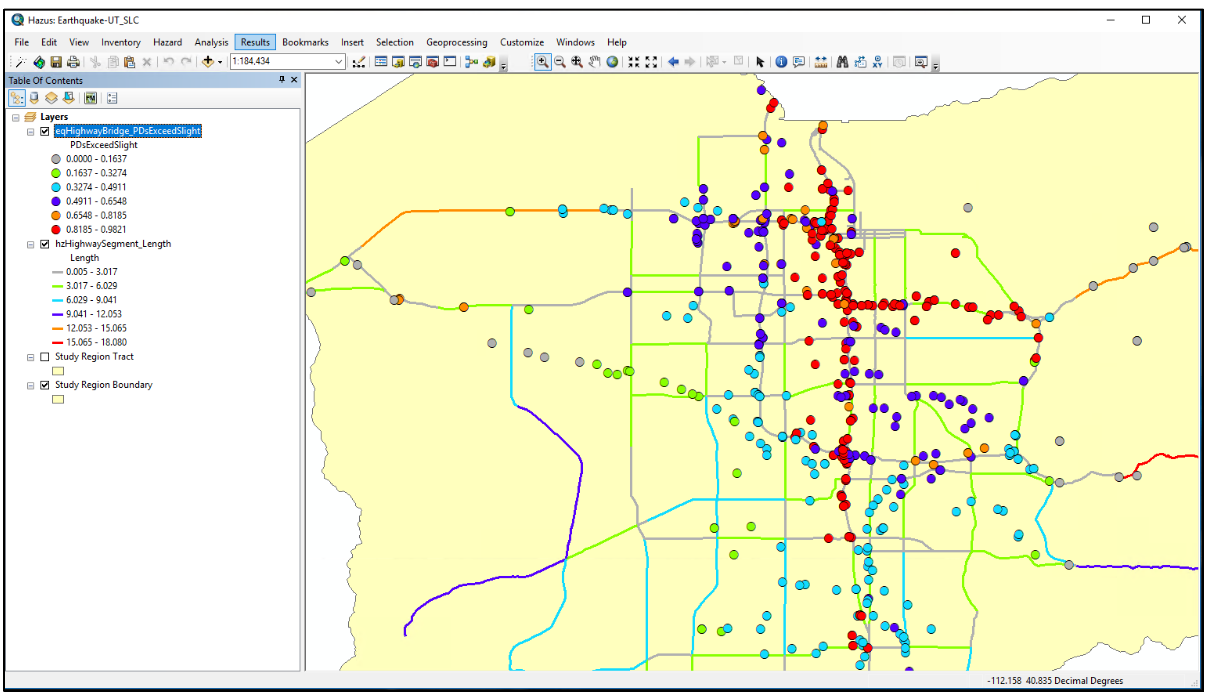
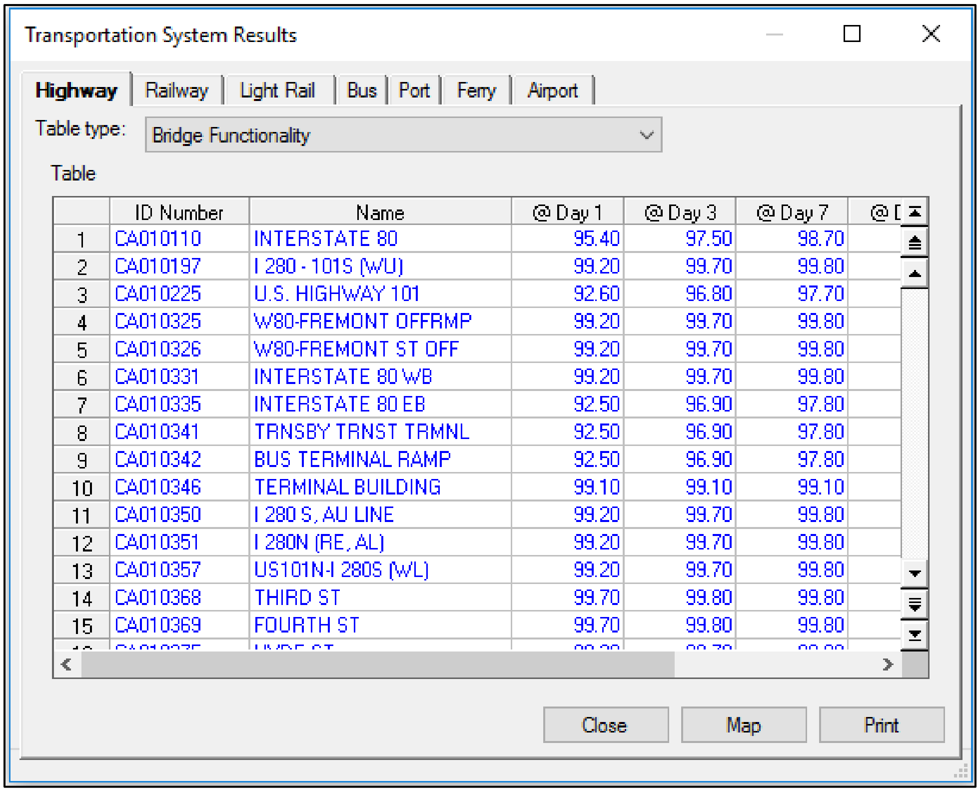


Figure 8-20 Map of Probability of Slight Damage for Highway Bridges

Figure 8-21 shows a table of the functionality of highway bridges at specified periods after the occurrence of the scenario earthquake. As shown in this table, the first bridge would be functional with a 95.4% probability immediately after the earthquake and functional with a 98.7% probability after 7 days. Functionality can be mapped by selecting a column and clicking the Map button. Facilities are mapped based on percent functionality.

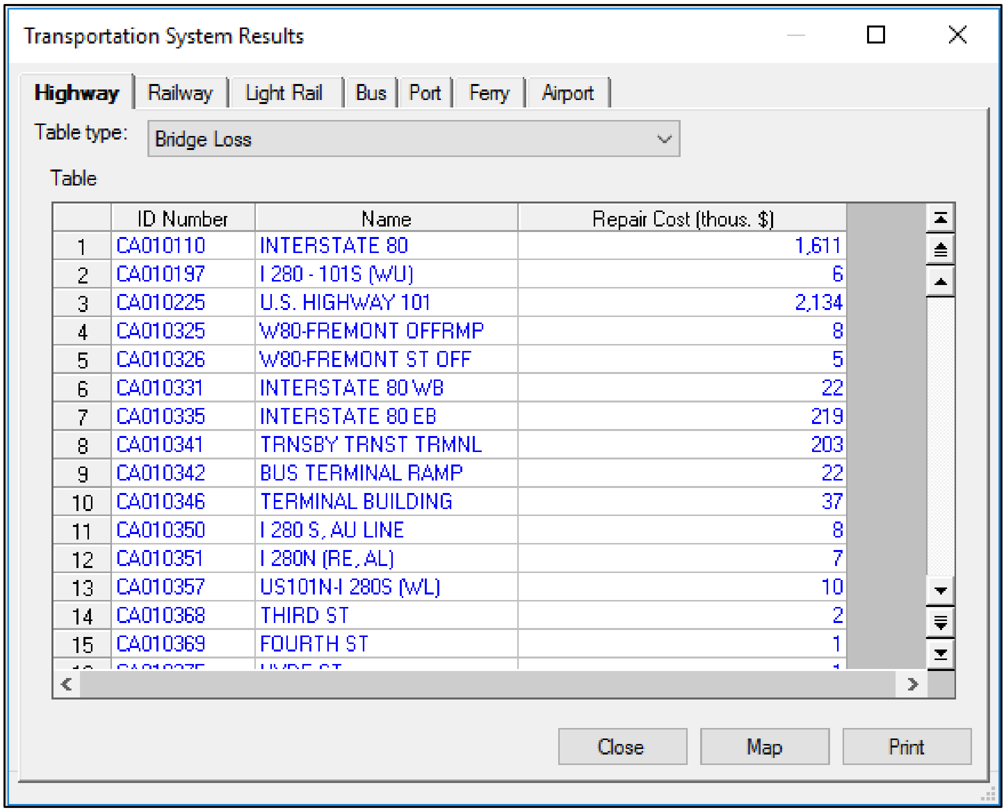


	ID Number	Name	@ Day 1	@ Day 3	@ Day 7	@ [
1	CA010110	INTERSTATE 80	95.40	97.50	98.70	
2	CA010197	I 280 - 101S (WU)	99.20	99.70	99.80	
3	CA010225	U.S. HIGHWAY 101	92.60	96.80	97.70	
4	CA010325	W80-FREMONT OFFRMP	99.20	99.70	99.80	
5	CA010326	W80-FREMONT ST OFF	99.20	99.70	99.80	
6	CA010331	INTERSTATE 80 WB	99.20	99.70	99.80	
7	CA010335	INTERSTATE 80 EB	92.50	96.90	97.80	
8	CA010341	TRNSBY TRNST TRMNL	92.50	96.90	97.80	
9	CA010342	BUS TERMINAL RAMP	92.50	96.90	97.80	
10	CA010346	TERMINAL BUILDING	99.10	99.10	99.10	
11	CA010350	I 280 S, AU LINE	99.20	99.70	99.80	
12	CA010351	I 280N (RE, AL)	99.20	99.70	99.80	
13	CA010357	US101N-I 280S (WL)	99.20	99.70	99.80	
14	CA010368	THIRD ST	99.70	99.80	99.80	
15	CA010369	FOURTH ST	99.70	99.80	99.80	

Figure 8-21 Functionality of Highway Bridges

The loss estimate outputs for transportation systems are summarized in Figure 8-22. These are accessed through the **Results > Transportation Systems**.

Losses are reported for each component of the system. For example, in this window, losses are reported for each highway bridge. Users can create similar reports for each type of component and each type of system by clicking the tabs at the top and using the list box next to the label “Table Type.” Like all the other results, the results in Figure 8-22 can also be mapped by clicking the **Map** button.



	ID Number	Name	Repair Cost (thous. $)
1	CA010110	INTERSTATE 80	1,611
2	CA010197	I 280 - 101S (WU)	6
3	CA010225	U.S. HIGHWAY 101	2,134
4	CA010325	W80-FREMONT OFFRMP	8
5	CA010326	W80-FREMONT ST OFF	5
6	CA010331	INTERSTATE 80 WB	22
7	CA010335	INTERSTATE 80 EB	219
8	CA010341	TRNSBY TRNST TRMNL	203
9	CA010342	BUS TERMINAL RAMP	22
10	CA010346	TERMINAL BUILDING	37
11	CA010350	I 280 S, AU LINE	8
12	CA010351	I 280N (RE, AL)	7
13	CA010357	US101N-I 280S (WL)	10
14	CA010368	THIRD ST	2
15	CA010369	FOURTH ST	1

Figure 8-22 Transportation System Results: Bridge Loss

8.2.8.2 Utility Systems

In addition to direct damage, loss and functionality of utility system facilities/components, the Hazus Utility module includes simplified systems analyses for potable water and electric power systems. These analyses use simplified assumptions regarding the serviceability of the systems. The serviceability is based upon the estimated number of potential pipe leaks and breaks, or the functionality of medium voltage substations. Results for the simplified systems models are reported at the County level, as the percent of households without water, or the percent of households without power (Figure 8-23).

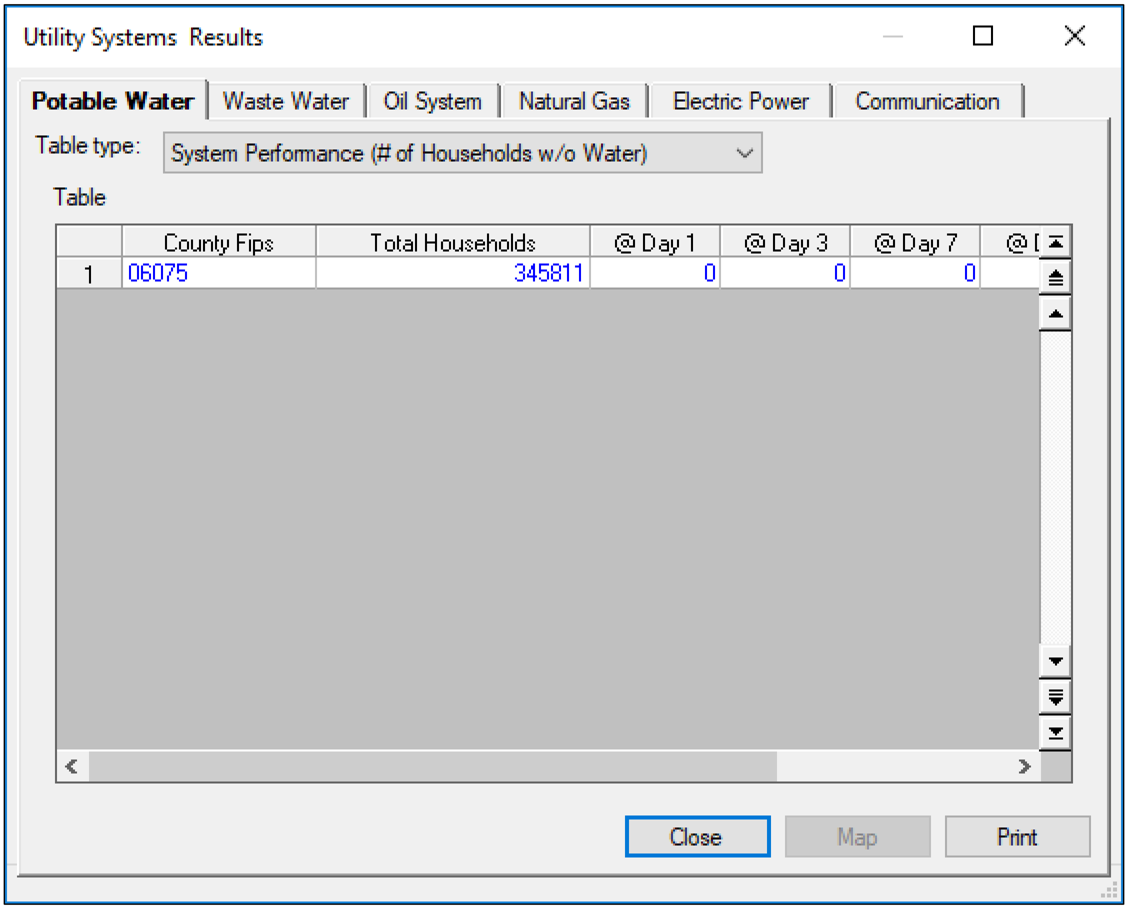


Figure 8-23 Utility Systems Results: System Performance, Households Without Water

Utility system damage results can be viewed in the same manner as the transportation system results, via the **Results > Utility Systems** menu. Results for each facility can be displayed for damage states, economic loss or functionality, in tabular or map format.

Table 8-6 summarizes the outputs of Hazus for the Study Region's utility system facilities and components.

Table 8-6 Results – Utility Systems

Component System	Module Output	Description of Output
Potable Water	Damage State Probabilities	Hazus determines the damage state probabilities for each potable water facility in the Study Region.
	Facility Loss	Hazus estimates the economic loss or cost to repair each damaged facility in the Study Region.
	Functionality	Hazus determines the functionality for each potable water facility at discrete time intervals.

Component System	Module Output	Description of Output
	Number of Households without Water	Hazus supports a simplified potable water system analysis for the Study Region.
	Pipeline damage, functionality and loss	For user-input pipeline data, Hazus estimates the number of leaks and breaks, repair times and cost.
Wastewater	Facility Damage State Probabilities	Hazus determines the damage state probabilities for each facility in the Study Region.
	Facility Loss	Hazus estimates the economic loss or cost to repair each facility in the Study Region.
	Facility Functionality	Hazus determines the functionality for each facility at discrete time intervals.
	Pipeline damage, functionality and loss	For user-input pipeline data, Hazus estimates the number of leaks and breaks, repair times and cost.
Oil System	Facility Damage State Probabilities	Hazus determines the damage state probabilities for each facility in the Study Region.
	Facility Loss	Hazus estimates the economic loss or cost to repair each facility in the Study Region.
	Facility Functionality	Hazus determines the functionality for each facility at discrete time intervals.
	Pipeline damage, functionality and loss	For user-input pipeline data, Hazus estimates the number of leaks and breaks, repair times and cost.
Natural Gas	Facility Damage State Probabilities	Hazus determines the damage state probabilities for each facility in the Study Region.
	Facility Loss	Hazus estimates the economic loss or cost to repair each facility in the Study Region.
	Facility Functionality	Hazus determines the functionality for each facility at discrete time intervals.
	Pipeline damage, functionality and loss	For user-input pipeline data, Hazus estimates the number of leaks and breaks, repair times and cost.
Electric Power	Facility Damage State Probabilities	Hazus determines the damage state probabilities for each electric power facility in the Study Region.
	Facility Loss	Hazus estimates the economic loss or cost to repair each electric power facility in the Study Region.
	Functionality	Hazus determines the functionality for each electric power facility at discrete time intervals.
	Number of Households without Power	Hazus supports a simplified electric power system analysis for the Study Region.
Communication	Facility Damage State Probabilities	Hazus determines the damage state probabilities for each communication facility in the Study Region.

Component System	Module Output	Description of Output
	Facility Loss	Hazus estimates the economic loss or cost to repair each communication facility in the Study Region.
	Probability of Functionality	Hazus determines the functionality for each communication facility at discrete time intervals.

8.2.9 Inundation

Hazus includes earthquake-related flooding information helpful for the design of programs to reduce the likelihood of dam or levee failure and to prepare for potentially occurring post-earthquake floods. Developing inundation maps requires an understanding of the downstream topography and the involvement of an experienced hydrologist.

The potential for tsunamis and seiches must be assessed by the user outside of Hazus. Table 8-7 summarizes the inundation outputs that are available from Hazus.

Table 8-7 Induced Physical Damage Outputs – Inundation

Component	Module Output	Description of Output
Tsunami	▪ Estimate Potential Threat ▪ Exposed Population ▪ Exposed Loss based on population ($1,000)	The methodology provides rules to determine whether tsunamis are a threat to the Study Region. The user can import existing tsunami inundation maps and overlay with population and economic value maps. More detailed analyses can be conducted using the Hazus Tsunami Model.
Seiche	▪ Estimate Potential Threat ▪ Exposed Population Exposed Value ($)	The methodology provides rules to determine whether seiches are a threat on any body of water in the Study Region. The user can import existing seiche inundation maps and overlay with population and economic value maps.
Dam Failure	▪ Exposed Population ▪ Exposed Value ($)	The user can import a dam inventory database. The user can import existing dam failure inundation maps and overlay with population and economic value maps.
Levee Failure	▪ Exposed Population ▪ Exposed Value ($)	The user can import a levee inventory database. Hazus displays the location of the levees in the Study Region. The user can import existing levee failure inundation maps and overlay with population and economic value maps.

For all four types of inundation, Hazus has the ability to import existing inundation maps. These can then be overlaid with population density maps or maps of inventory to estimate exposed population and exposed inventory. The output of the inundation module is a display of the inundation maps that are specified in the **Hazard > Data Maps** dialog.

Alternatively, users can view a table of population, value, and area exposure by Census tract using the **Results > Inundation** menu. This output is only available if an inundation map has been specified. Highlighting the appropriate column and clicking the **Map** button can map any one of the outputs.

8.2.10 Fire Following Earthquake

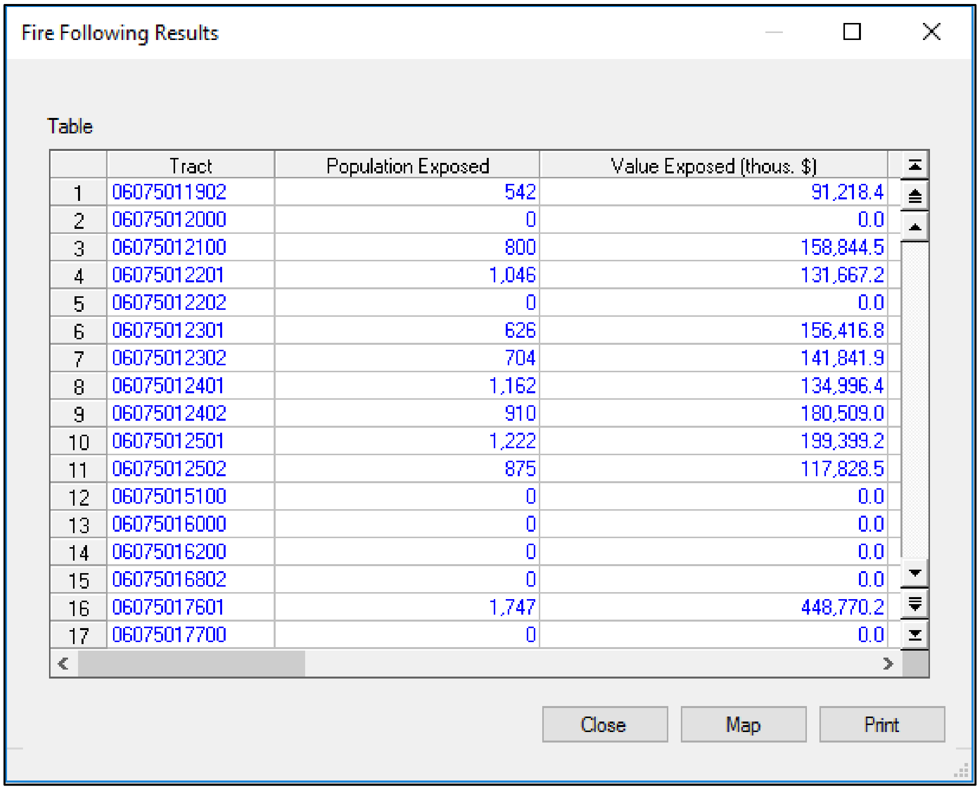
A comprehensive Fire Following Earthquake Model would require extensive input including the types and density of fuel, number of firefighting apparatuses, functionality of the water system, occurrence of hazardous materials releases, wind conditions, and others. To simplify the input, Hazus limits the analysis to an estimate of the number of ignitions, an estimate of the size of the potential burned area, and estimates of exposed population and exposed inventory, as described in (Table 8-8).

Table 8-8 Fire Following Earthquake Model Outputs

Component	Description of Output	Measure
Ignition	▪ Hazus determines the expected number of fire ignitions by Census tract for the Study Region; these are reported in aggregate in the Fire Following Earthquake summary report	▪ Number of ignitions
Burned Area	▪ Hazus determines the expected burned area by Census tract for the Study Region. ▪ Expected burned area is combined with population and economic value to estimate exposed population and value of exposed inventory. ▪ Hazus estimates the potential fire water demand by Census tract.	▪ Exposed Population ▪ Exposed Value ($) ▪ Fire demand (gpm)

The outputs from Fire Following Earthquake Model are accessible via the **Results > Fire Following Earthquake** menu and are presented in tabular form as shown in Figure 8-24. For each Census tract in the Study Region, the following results are displayed and can be mapped (Figure 8-25):

- Population in the Census tract that is exposed to fire (percent burned area X total population in Census tract).
- Value of inventory (in thousand dollars) in the Census tract fire exposed to fire (percent burned area X total building value in Census tract).
- Fire water demands, in gallons per minute (gpm).



	Tract	Population Exposed	Value Exposed (thous. $)
1	06075011902	542	91,218.4
2	06075012000	0	0.0
3	06075012100	800	158,844.5
4	06075012201	1,046	131,667.2
5	06075012202	0	0.0
6	06075012301	626	156,416.8
7	06075012302	704	141,841.9
8	06075012401	1,162	134,996.4
9	06075012402	910	180,509.0
10	06075012501	1,222	199,399.2
11	06075012502	875	117,828.5
12	06075015100	0	0.0
13	06075016000	0	0.0
14	06075016200	0	0.0
15	06075016802	0	0.0
16	06075017601	1,747	448,770.2
17	06075017700	0	0.0

Figure 8-24 Fire Following Results

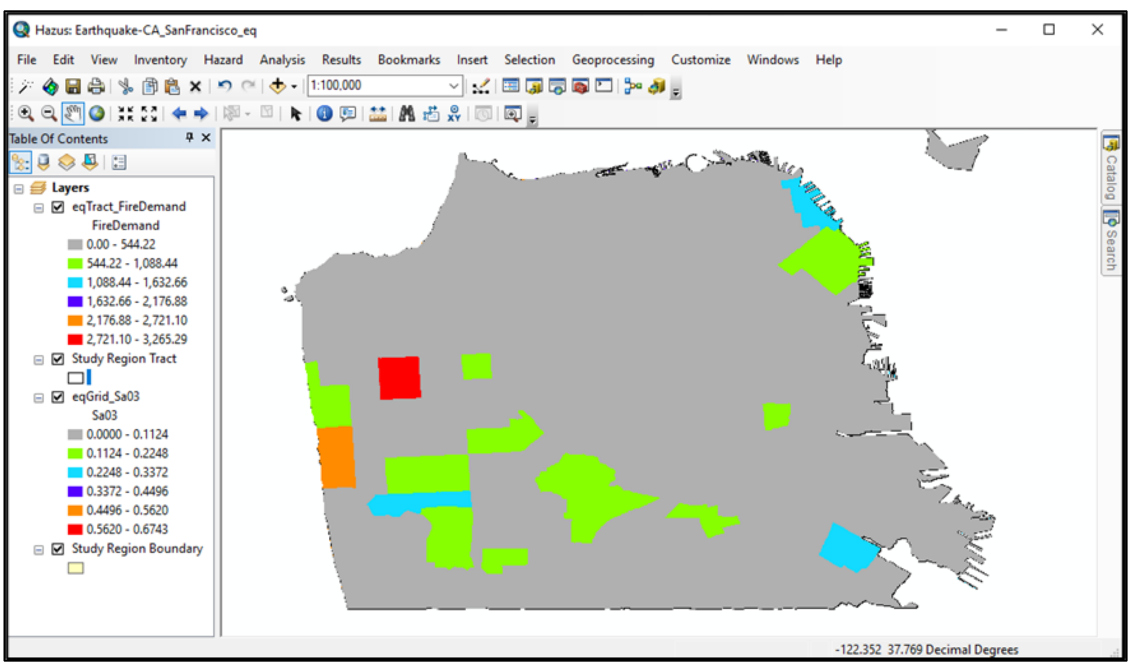


Figure 8-25 Map of Fire Demand by Census Tract

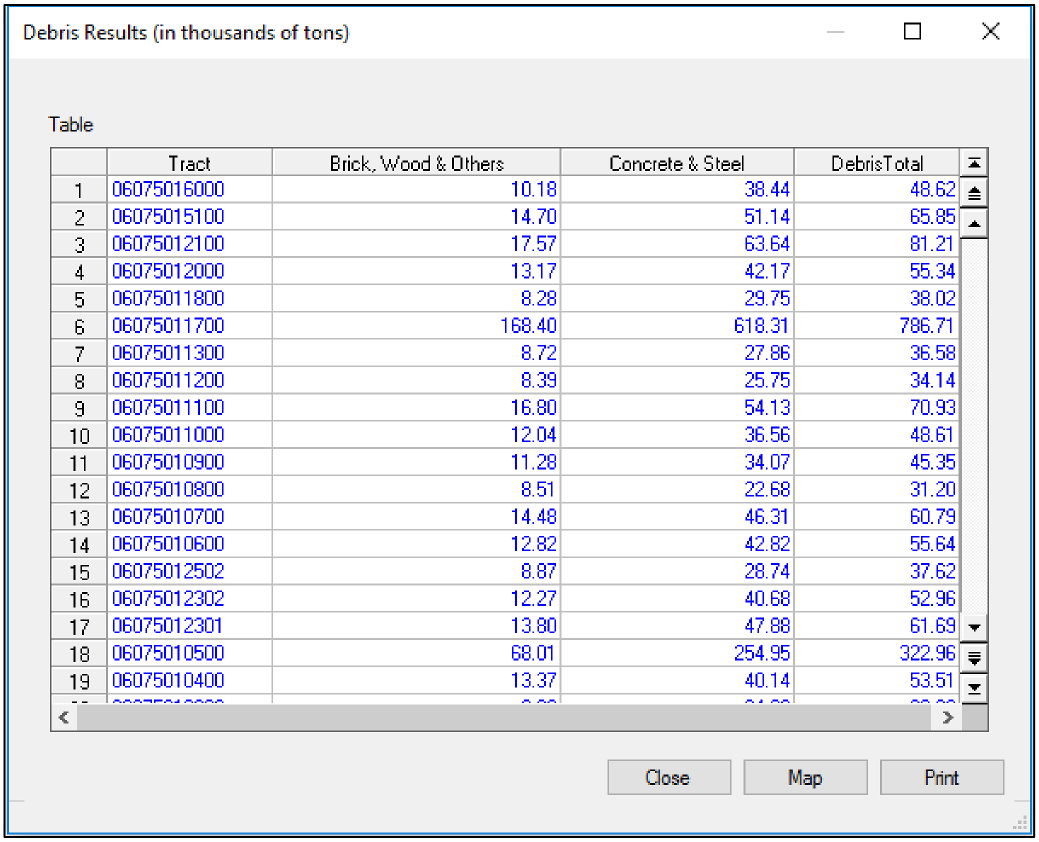
8.2.11 Debris

Hazus provides information about the building debris generated during the seismic event to enable users to prepare and rapidly and efficiently manage debris removal and disposal. As shown in Table 8-9, two types of debris are identified: (1) heavy debris - reinforced concrete and steel debris that requires special equipment to break it up before it can be transported and (2) light debris - brick, wood and other debris that can be loaded directly onto trucks with bulldozers. For each Census tract, Hazus determines the amount of debris of each type that is generated.

Table 8-9 Induced Physical Damage Module Outputs – Debris

Component	Module Output	Description of Output
Brick, Wood and Other Debris (Light Debris)	Weight of Debris Generated	Hazus determines the expected amount of brick, wood, and other debris generated in each Census tract of the Study Region.
Reinforced Concrete and Steel Debris (Heavy Debris)	Weight of Debris Generated	Hazus determines the expected amount of reinforced concrete and steel debris generated in each Census tract of the Study Region.

In Hazus, debris results are accessed via the **Results > Debris** menu and will appear as a table as shown in Figure 8-26. In addition, users will be able to map by Census tract the weight of generated debris using the **Map** button, as shown in Figure 8-27.



	Tract	Brick, Wood & Others	Concrete & Steel	DebrisTotal
1	06075016000	10.18	38.44	48.62
2	06075015100	14.70	51.14	65.85
3	06075012100	17.57	63.64	81.21
4	06075012000	13.17	42.17	55.34
5	06075011800	8.28	29.75	38.02
6	06075011700	168.40	618.31	786.71
7	06075011300	8.72	27.86	36.58
8	06075011200	8.39	25.75	34.14
9	06075011100	16.80	54.13	70.93
10	06075011000	12.04	36.56	48.61
11	06075010900	11.28	34.07	45.35
12	06075010800	8.51	22.68	31.20
13	06075010700	14.48	46.31	60.79
14	06075010600	12.82	42.82	55.64
15	06075012502	8.87	28.74	37.62
16	06075012302	12.27	40.68	52.96
17	06075012301	13.80	47.88	61.69
18	06075010500	68.01	254.95	322.96
19	06075010400	13.37	40.14	53.51

Figure 8-26 Debris Results in Thousands of Tons per Census Tract

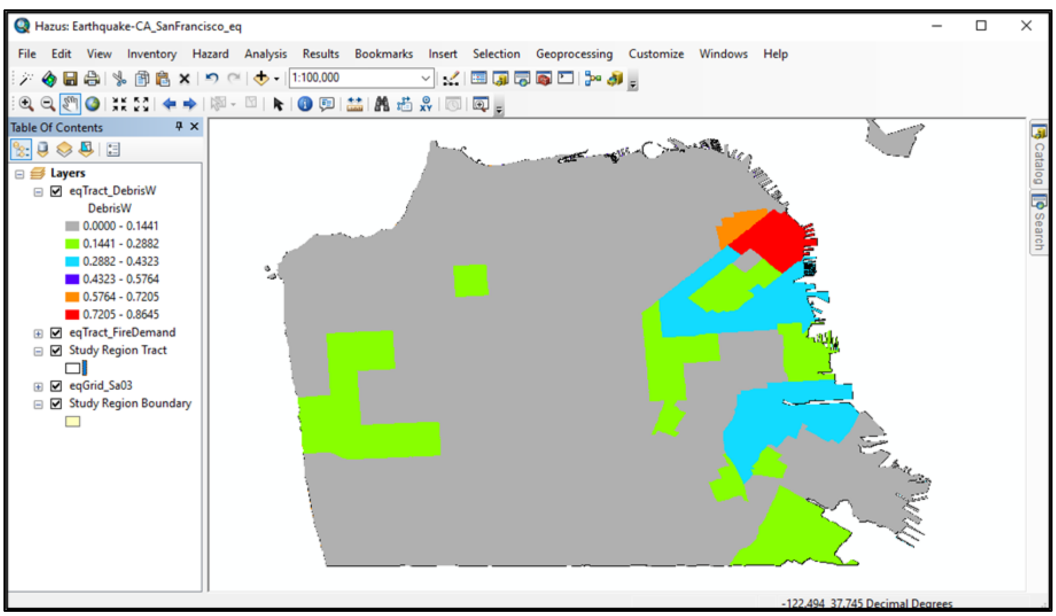


Figure 8-27 Weight of Brick, Wood and Other Light Debris by Census Tract

8.2.12 Casualities

The output of the casualty module is summarized in Table 8-10.

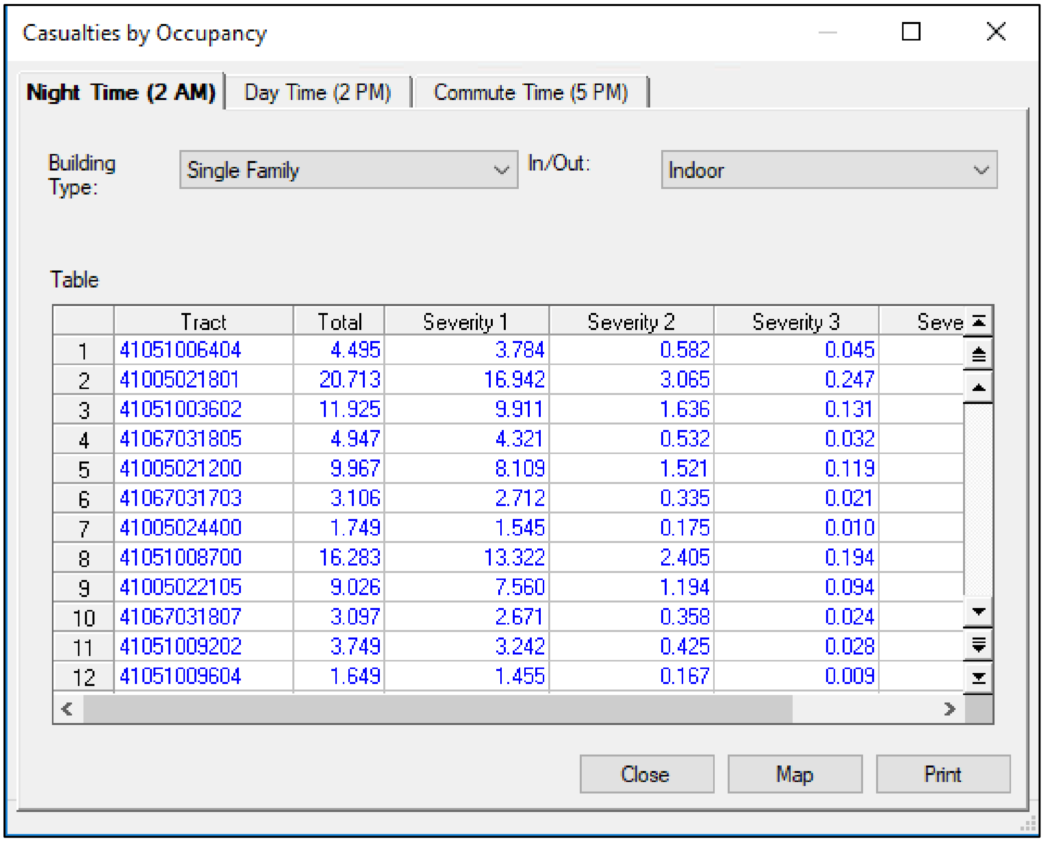
Table 8-1 Casualty Module Outputs

Component	Module Output	Description of Output
Casualties	Number of casualties for each of the four injury severities (medical aid, hospital treatment, life-threatening, death).	Hazus determines the expected number of casualties for each injury severity category by Census tract for the Study Region.

For each Census tract, the following results (use the **Results > Casualties > By Occupancy** menu, see Figure 8-28) are provided at three times of day (2 AM, 2 PM, and 5 PM) by occupancy type. Results are available for Indoor casualties, Outdoor Casualties or both (Total Casualties):

- Commuting casualties (severity 1, 2, 3, 4, and total)
- Hotel casualties (severity 1, 2, 3, 4, and total)
- Education casualties (severity 1, 2, 3, 4, and total)
- Industrial casualties (severity 1, 2, 3, 4, and total)
- Commercial casualties (severity 1, 2, 3, 4, and total)
- Single-family (RES1) casualties (severity 1, 2, 3, 4, and total)
- Other Residential (other than RES1) casualties (severity 1, 2, 3, 4, and total)
- Total casualties (severity 1, 2, 3, 4, and total)

Casualties results are also available by specific building type (**Results > Casualties > By Building Type**) and General Building Type (**Results > Casualties > By General Building Type**). As with the other output, highlighting the desired column and clicking the **Map** button will map the results (Figure 8-28).



	Tract	Total	Severity 1	Severity 2	Severity 3	Seve
1	41051006404	4.495	3.784	0.582	0.045	
2	41005021801	20.713	16.942	3.065	0.247	
3	41051003602	11.925	9.911	1.636	0.131	
4	41067031805	4.947	4.321	0.532	0.032	
5	41005021200	9.967	8.109	1.521	0.119	
6	41067031703	3.106	2.712	0.335	0.021	
7	41005024400	1.749	1.545	0.175	0.010	
8	41051008700	16.283	13.322	2.405	0.194	
9	41005022105	9.026	7.560	1.194	0.094	
10	41067031807	3.097	2.671	0.358	0.024	
11	41051009202	3.749	3.242	0.425	0.028	
12	41051009604	1.649	1.455	0.167	0.009	

Figure 8-28 Casualty Results by Occupancy - Indoor Residential Casualties at 2 AM

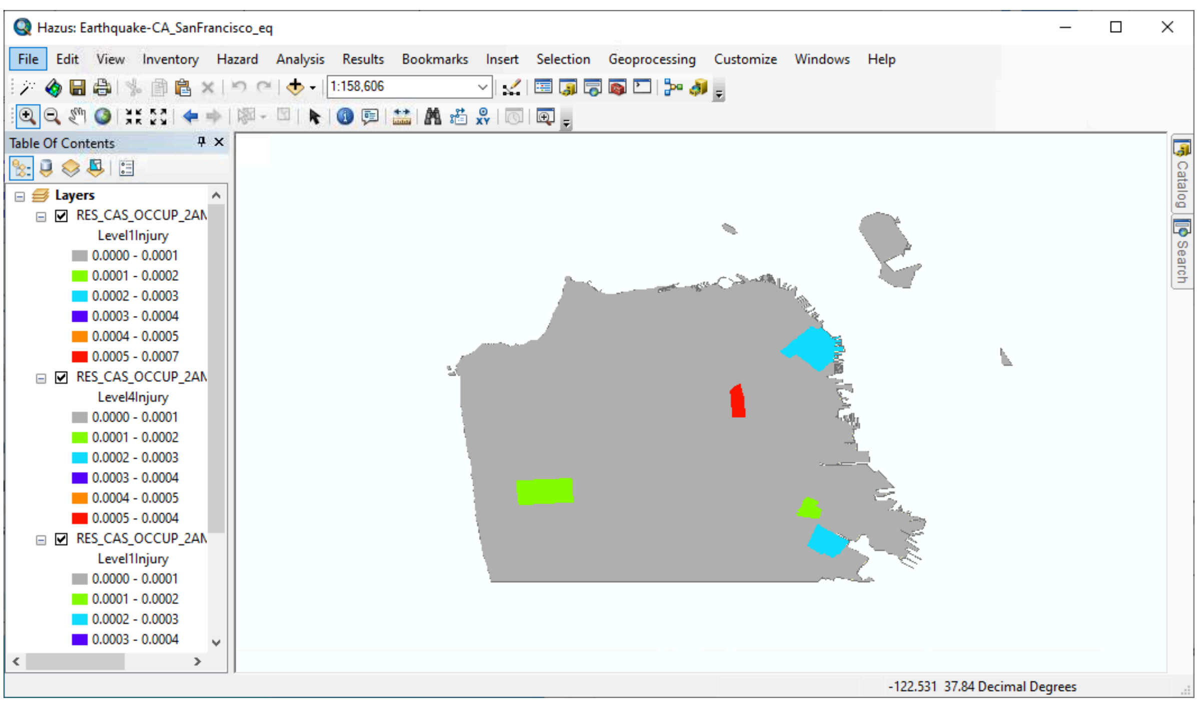


Figure 8-29 Casualty Results by Occupancy Across Census Tracts of Category Severity 1

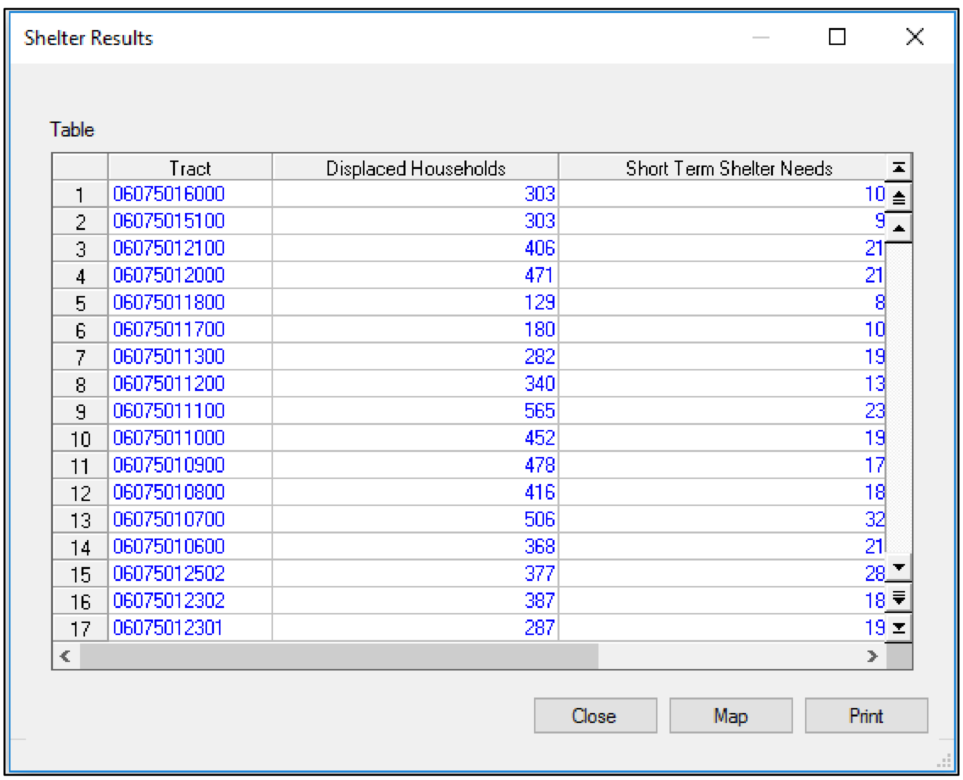
8.2.13 Shelter

Hazus provides information concerning the estimated number of displaced households and persons requiring temporary shelter to enable the design of programs to temporarily shelter victims. Outputs are described in Table 8-11.

Table 8-11 Shelter Module Outputs

Component	Module Output	Description of Output
Displaced Households	Number of Displaced Households	Hazus determines the expected number of displaced households by Census tract in the Study Region.
Short-term Shelter	Number of People Requiring Short-Term Shelter	Hazus determines the expected number of people requiring short-term or temporary shelter by Census tract in the Study Region.

The total number of displaced households for each Census tract of the Study Region is one output of the shelter module. The number of displaced households is used to estimate short-term shelter needs. Short-term shelter needs are reported as the number of people needing public shelter. The results, as displayed in Figure 8-, are retrieved using the **Results > Shelter** menu. As with all results, the results can be thematically mapped by highlighting a column and clicking the **Map** button.



	Tract	Displaced Households	Short Term Shelter Needs
1	06075016000	303	10
2	06075015100	303	9
3	06075012100	406	21
4	06075012000	471	21
5	06075011800	129	8
6	06075011700	180	10
7	06075011300	282	19
8	06075011200	340	13
9	06075011100	565	23
10	06075011000	452	19
11	06075010900	478	17
12	06075010800	416	18
13	06075010700	506	32
14	06075010600	368	21
15	06075012502	377	28
16	06075012302	387	18
17	06075012301	287	19

Figure 8-30 Shelter Results

8.3 Indirect Economic Loss

Hazus provides information concerning the indirect economic effects of the scenario event (Table 8-12) to enable financial institutions and government planners to anticipate losses and develop programs to compensate for them (**Results > Indirect Economic Loss**, as shown in Figure 8-30). The indirect economic impact information also enables users to motivate policymakers to consider cost-benefit implications of mitigation activities. The Hazus Model does not ship with any default data to support this module; however, users can input their own information to support the indirect economic loss functionality. For more information, please reach out to the Hazus Support Team.

Table 8-12 Indirect Economic Impacts Module Outputs

Component	Description of Output	Measure
Employment	Indirect employment loss with and without outside aid, expressed in terms of the number of people	Number of People
Income	Indirect income loss with and without outside aid in millions of dollars	$ Millions

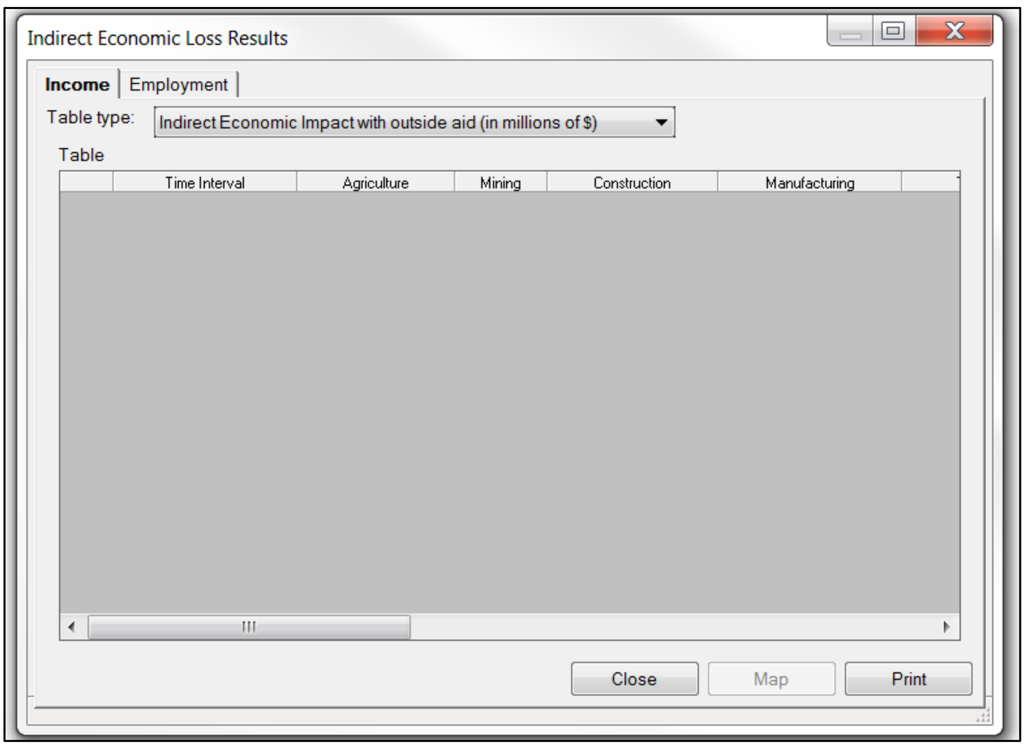


Figure 8-30 Indirect Economic Loss Results

8.4 Summary Reports

The options to view formatted, printable summaries of the outputs of each of the Hazus modules include **Inventory**, **Buildings**, **Utility/Transportation**, **Induced**, **Losses,** and **Other,** as shown in Table

8-13. From the **Results > Summary Reports** menu, users can select the summary report, as shown in Figure 8-31 and click the **View** button to generate the report. Sample summary reports of building damage by general occupancy and building stock exposure by building type are shown in Figure 8-32 and Figure 8-33. Clicking the **Print** or **Save** button allows the user to print or save reports in PDF or XLS format, among others.

Table 8-13 Summary Report Types and Uses

Summary Report (Number of Available Reports)	Results Reported	Data Uses
Inventory (3)	Identifies the building inventory exposure value by occupancy (in dollars), the transportation system exposure value (in dollars) and utility system exposure value (in dollars) within the Study Region. Note: all losses are reported in $1,000.	▪ Identify exposure by occupancy ▪ Identify exposure by building type ▪ Identify exposure by seismic design levels
Buildings (15)	▪ Building damage summaries for the GBS include nine reports which identify the number of structures by Damage State, Building Type, Design Level, and/or Occupancy. ▪ Essential Facilities functionality summaries are for hospitals, EOCs, fire stations, police stations and schools. ▪ There is also a report for military installations structural damage.	▪ Estimate reconstruction time for new or improved buildings by identifying which type(s) of facilities will experience complete loss. ▪ Focus mitigation actions on the relocation of at-risk critical facilities. ▪ Identify schools that will not be damaged during an event and can therefore be used as potential shelters/response facility. ▪ Generate mitigation actions to address building type or occupancy that produces the highest economic loss.
Utility/ Transportation (16)	Identifies damage, functionality and system performance associated with transportation and utility system components: ▪ Wastewater pipeline and facility, highway bridge, railroad bridge, potable water pipeline and facility, petroleum pipeline and light rail bridge damage ▪ Railroad bridge, airport runways, highway bridge and roads, communication facility and light rail bridge functionality Electric power and potable water system performance	▪ Designate potential detour routes post-disaster event. ▪ Arrange for air travel relocation to adjacent airfields during/post event. ▪ Identify public transportation routes that could be most affected and arrange for alternative transportation options. ▪ Estimate population that would experience utility loss and the duration of loss.

Summary Report (Number of Available Reports)	Results Reported	Data Uses
Induced (2)	The **Fire Following Earthquake** report provides the total number of ignitions, and total population and building value exposed to fire within the Study Region. The **Debris Generated** report summarizes the amount of debris (in thousands of tons) that will be generated from the projected hazard event. Hazus uses two general types of debris: Brick/Wood (Light Debris) and Reinforced Concrete/Steel (Heavy Debris)	▪ Allow municipalities to understand their potential risk to fires that occur following earthquake, including the demand for water in gallons per minute to battle fires ▪ Plan for how debris will be collected and discarded in specific locations. ▪ Identify how many trucks and equipment will be needed post-event. ▪ Identify the type of equipment needed can be based on debris type.
Losses (10)	▪ **Casualties** summary reports are available for each time of day (2 pm, 2 am and 5 pm), along with a comprehensive report providing all three sets of results. ▪ The **Shelter Requirements** report provides a summary of displaced households and people needing short-term shelter. Estimates of the financial loss associated with Buildings, Transportation Systems and Utilities are provided in the three Direct Economic Losses reports.	▪ Define budget line item(s) for safeguarding against potential economic impacts post-event. ▪ Planning for shelter needs/healthcare related needs.
Other (6)	Includes various loss reports including the **Global Summary Report**, AEBM building and portfolio reports, and quick assessment reports associated with the time of day of the hazard occurrence (2 am, 2 pm and 5 pm).	▪ These reports are a comprehensive accounting of the inventory and losses in your Study Region. ▪ Quick assessment reports present results for an earthquake striking at different times of the day, helpful for planning purposes.

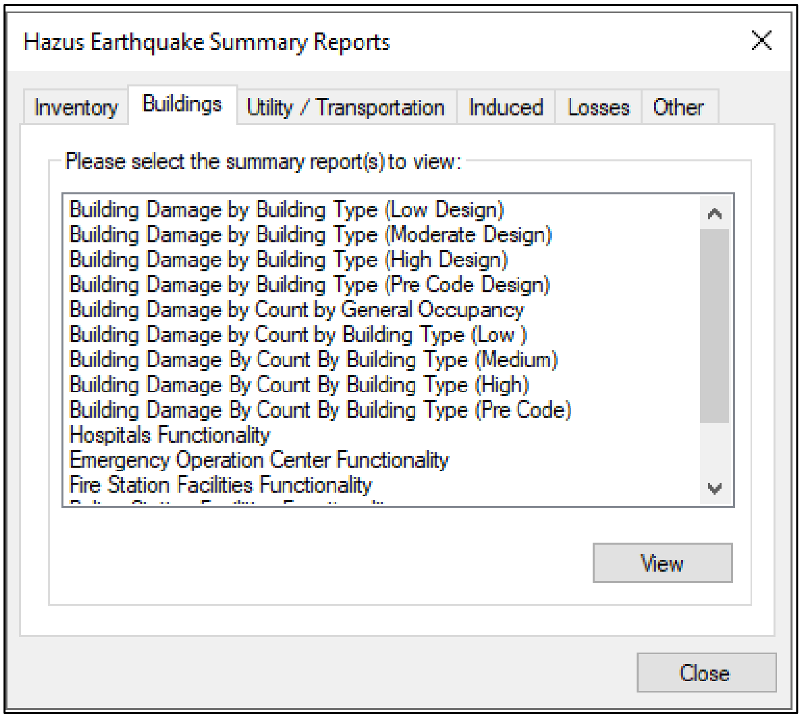
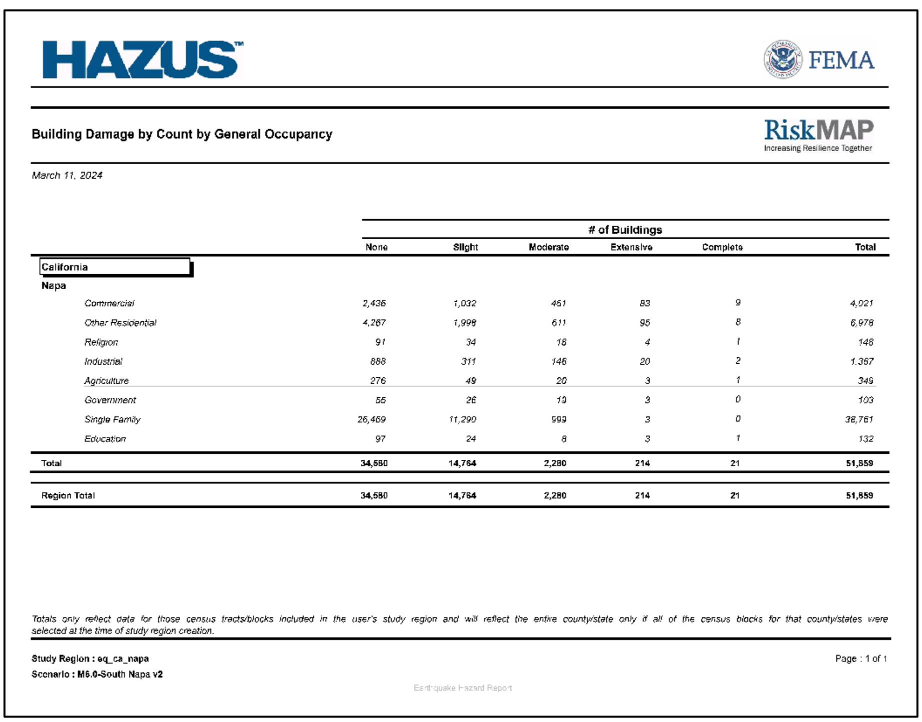


Figure 8-31 Summary Report Selection Window for Buildings Summary Reports



Building Damage by Count by General Occupancy

March 11, 2024

	# of Buildings					
	None	Slight	Moderate	Extensive	Complete	Total
California						
Napa						
Commercial	2,436	1,032	461	83	9	4,021
Other Residential	4,267	1,998	611	95	8	6,978
Religion	91	34	18	4	1	148
Industrial	888	311	146	20	2	1,367
Agriculture	276	49	20	3	1	349
Government	55	26	19	3	0	103
Single Family	26,469	11,290	999	3	0	38,761
Education	97	24	8	3	1	132
Total	**34,580**	**14,764**	**2,280**	**214**	**21**	**51,859**
Region Total	**34,580**	**14,764**	**2,280**	**214**	**21**	**51,859**

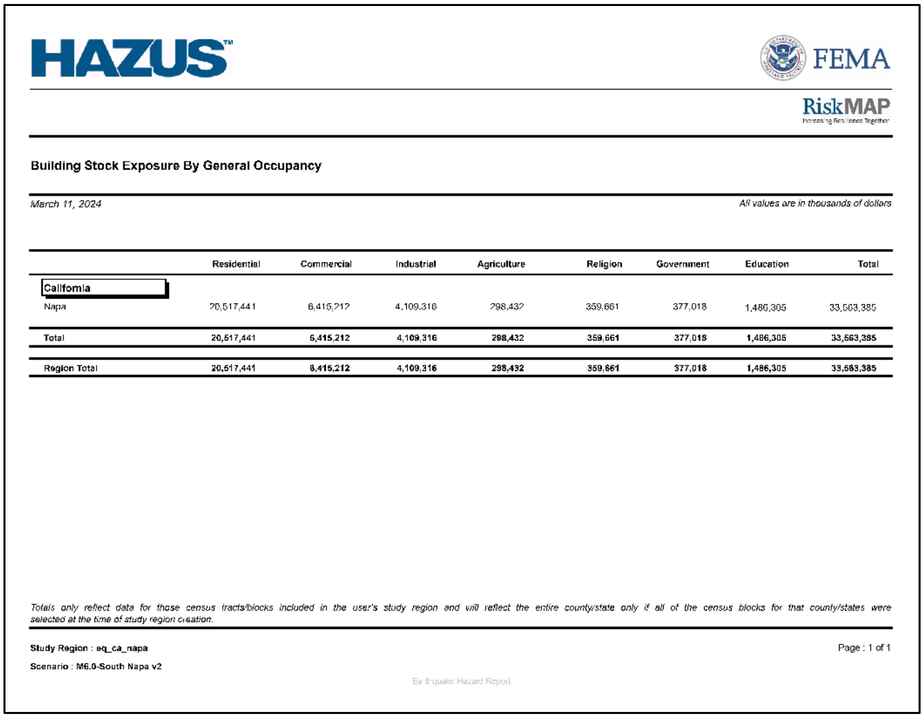
Totals only reflect data for those census tracts/blocks included in the user's study region and will reflect the entire county/state only if all of the census blocks for that county/states were selected at the time of study region creation.

Study Region : eq_ca_napa
Scenario : M6.0-South Napa v2

Page : 1 of 1

Earthquake Hazard Report

Figure 8-32 Sample Buildings Summary Report of Building Damage Count by General Occupancy



HAZUS™ FEMA RiskMAP

Building Stock Exposure By General Occupancy

March 11, 2024 *All values are in thousands of dollars*

	Residential	Commercial	Industrial	Agriculture	Religion	Government	Education	Total
California								
Napa	20,517,441	6,415,212	4,109,316	298,432	359,661	377,018	1,486,305	33,563,385
Total	**20,517,441**	**6,415,212**	**4,109,316**	**298,432**	**359,661**	**377,018**	**1,486,305**	**33,563,385**
Region Total	**20,517,441**	**6,415,212**	**4,109,316**	**298,432**	**359,661**	**377,018**	**1,486,305**	**33,563,385**

Totals only reflect data for those census tracts/blocks included in the user's study region and will reflect the entire county/state only if all of the census blocks for that county/states were selected at the time of study region creation.

Study Region : eq_ca_napa Page : 1 of 1

Scenario : M6.0-South Napa v2

Earthquake Hazard Report

Figure 8-33 Sample Inventory Summary Report of Building Stock Exposure by Occupancy Type

The 22-page **Global Summary Report** is a comprehensive standardized summary report that provides inventory, hazard, and analysis results related to the scenario event. Selecting the **Other** tab as shown in Figure 8-34 will access the window that contains the **Global Summary Report.**

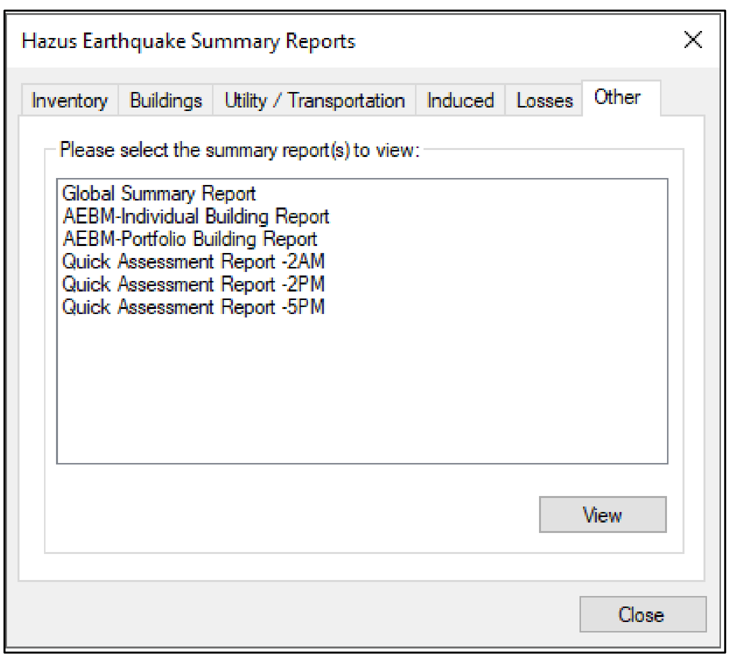


Figure 8-34 Global Summary Report Option

8.5 Guidance for Disseminating Hazus Loss Outputs

There is no single format that is appropriate for the presentation of loss study results to non-Hazus users. The format will depend on the use of the results and the intended audience. The audience can vary from the general public to technical experts. Decision-makers such as city council members, county commissioners, local and state emergency management staff, and other government officials may require only summaries of losses for a region. Emergency managers or response planners may want to see the geographical distribution of all losses and damage for several different earthquake scenarios. Hazus provides a great deal of flexibility in presenting results in either a tabular or map form, and which maps or tables are selected for reports will depend on the intended use of the results. In any case, the users of the results should be involved from the beginning in determining the types and formats of the results that best suit their needs.

Before Hazus, authors of reports had the difficult task of trying to combine the study results with the methodology used in their calculations. Consequently, reports often seemed overly technical, reducing their readability and usefulness for many audiences. Hazus users can refer to the *Hazus Earthquake Model Technical Manual (FEMA, 2024)* that describes the methodology and equations that provide the basis of any loss estimate. Thus, reports do not need to, and probably should not, include technical discussions of theory. Instead, reports should focus on describing results in non-technical language that is easily understood by the intended audience.

While no particular format for presenting results can be recommended, several general statements about reporting of results can be made:

- Reports should serve to **clarify the meaning** of the loss estimates. For example, the reporting of economic loss should indicate whether direct losses are included in the estimates. The report should indicate whether losses are due only to structural and nonstructural damage or whether they also include monetary losses resulting from loss of function. Casualty reports should indicate that casualties include only those that result from building damage and bridge collapse and do not include injuries and deaths from fires, flood, or hazardous material releases. It should be clarified that in most cases, losses are not calculated for specific buildings or facilities but instead are based on the performances of entire classes of buildings and systems. These are just a few examples of the types of clarifications that should appear in reports citing Hazus outputs.

- Reports should also **clarify the assumptions** that were made in developing the scenario and inventory and in calculating losses. For example, were losses based on baseline inventories or were baseline inventories augmented? Were baseline repair costs and repair times used? If not, what values were used? Were detailed soils maps provided or were results based on a baseline uniform soil type? What assumptions were made in selecting the scenario earthquake? Is it based on a historical event? Is it based on a specified probability of occurrence (e.g., 10% chance in 200 years)? What types of assumptions were made about design and construction quality?

A criticism of past studies is that there was little qualitative or quantitative treatment of uncertainty. Discussions with users of previous studies indicated that users need information about where errors in prediction are most likely to occur. While this methodology does not explicitly include a technique for carrying the uncertainty of each variable through the entire set of calculations, sensitivity analyses are useful for providing bounds on loss estimates. At a minimum, reports citing Hazus outputs should make some statement about the uncertainty of the input values.

Section 9. Advanced Hazus Analysis: User-Defined Facilities (UDF)

The Hazus baseline state inventory data provides data for immediate use, but there may be the need to use a custom dataset that is more relevant to the Study Region being analyzed. A UDF can be uploaded into Hazus through the Hazus CDMS. Imported UDF data would be available for viewing via the option **Inventory > User-Defined Facilities.** Hazus uses "user-defined facilities" and "user-defined structures" interchangeably. The User-Defined Facilities capability enables user-specific datasets to be analyzed through the Hazus methodologies, allowing for more accurate results.

In Hazus, it is the user's responsibility to populate this table, using CDMS, with data specific to the area being analyzed. The assumption is that the user will obtain custom data from another source and ensure that the data include the minimum required fields. It is highly recommended that the user utilizes CDMS to integrate UDF data for Hazus analysis. CDMS supports updating either the State Database so that all future Study Region contains the data, or it can update a selected, individual Study Region directly. CDMS assists the user in formatting the data and will help calculate required fields not provided by the user. In addition, CDMS can handle larger (>100,000) record sets not handled by direct Study Region import described below.

9.1 User-Defined Facilities Inventory

A user-supplied inventory may require months of dedicated work to prepare. The extent of preparation and data compilation work depends on the condition and completeness of existing information, required data conversions, and contributions of subject matter experts. The greatest impact from enhanced inputs are produced by editing both the basic inventory and updating the model parameters. Strategic planning is required to estimate and execute the level of effort required to produce the useful analysis outputs.

It is advisable that the user run a baseline analysis using the Hazus-supplied data for comparison with the results after introduction of user-supplied data. Sensitivity of the loss estimation methodology under local conditions is measured best by reviewing outputs after inclusion of each enhanced inventory. Good record-keeping and inventory of documentation are essential.

All user-defined inventory data need to be classified according to the various Hazus classification schemes, such as specific occupancy, specific building type and design level. For example, a school may have two building wing additions that were constructed over the 40-year lifetime of the structure. Each era of construction used improved materials, but the best materials may have been used to construct the smallest addition. The individual responsible for assigning the building type of the school per the Hazus methodology will need to define and document the criteria applied to classify the structure. The easiest approach is to break the facility into different entries (i.e., records).

It is important to note that Hazus will not include any inventory data that users have defined outside the limits of the Study Region. In fact, if users include facilities that are outside the defined Study

Region, Hazus will exclude those facilities from the Study Region. The region will always be defined by a Census tract boundary or boundaries within which population, demographics, and GBS values are aggregated.

9.2 Required User-Defined Facility Attributes

The full UDF data schema are provided in Table 9-1, and the minimum attributes required for analysis of UDF in the Hazus Earthquake model are listed in Table 9-2. While it is possible to edit the values later through the Hazus interface, it is not practical to edit for a large number of records; therefore, it is more time efficient to have the correct values in the imported file. More information specific to UDF and UDF requirements can be found in the *Hazus CDMS User Guidance (FEMA, 2019)*, specifically Section 3.3 User-Defined Facilities Data Import and Section 3.4 Developing UDF Data.

Table 9-1 Full CDMS Data Schema for UDF

Field Name	Type	Size
CONTACT	Text	40
NAME	Text	40
ADDRESS	Text	40
CITY	Text	40
STATE	Text	2
ZIPCODE	Text	10
PHONENUMBER	Text	14
OCCUPANCY	Text	5
YEARBUILT	Short	4
COST	Double	8
BACKUPPOWER	Short	1
NUMSTORIES	Short	1
AREA	Float	4
BLDGTYPE	Text	15
LATITUDE	Double	16
LONGITUDE	Double	16
COMMENT	Text	40
CONTENTCOST	Double	8
DESIGNLEVEL	Text	1
FOUNDATIONTYPE	Text	1
FIRSTFLOORHT	Double	8
SHELTERCAPACITY	Short	5
BLDGDAMAGEFNID	Text	10
CONTDAMAGEFNID	Text	10

Field Name	Type	Size
INVDAMAGEFNID	Text	10
FLOODPROTECTION	Long	4
SOILTYPE	Text	5
LQFSUSCAT	Short	
LNDSUSCAT	Short	
WATERDEPTH	Double	

**Size is based on type: text – character amount; numbers (float, double, short) – number of digits in the value*

Table 9-2 UDF Required Attributes

Attribute	Description	Why Is It Needed?
Record Identifier (ID)	Need a unique identifier for each record. Hazus will create its own primary key (it does not prompt the user for one since there is no guarantee it is unique). Map this identifier to any column that is not used: COMMENT is a good candidate	Hazus will output all results keyed by the ID it generates on import. If a join to the original data is needed, this attribute will be the only way to link the results to the original data.
Occupancy	Occupancy type per the Hazus classification. Map it to the OCCUPANCY field	Analysis functions are functions of the occupancy and/or building type.
Building Type	Specific Building Type per the Hazus classification. Map it to the EQBLDGTYPE field	As above
Building Design Level	Building design level per Hazus classification. Map it to the DESIGNLEVEL field	As above
Building Replacement Value	Value to replace the building in case of damage. Used by economic loss module. Map it to the COST field. While all dollar units in Hazus are in thousands of dollars, it makes sense to be consistent and use the same unit.	To assess building economic loss
Content Replacement Value	As above relating to building content	To assess content economic loss
Location	The location of the structure/facility is supplied directly from the personal geodatabase when the table is imported.	Hazus needs the location of structures to calculate the hazard. Hazus uses the location at import to filter the points that do not fall within the Study Region (discarding any point that falls outside the Study Region).

To estimate damage to the UDF buildings, the option to run the UDF analysis must be selected from the **Analysis** menu, as shown in Figure 9-1. See Section 8.2.6 for details of the UDF module results.

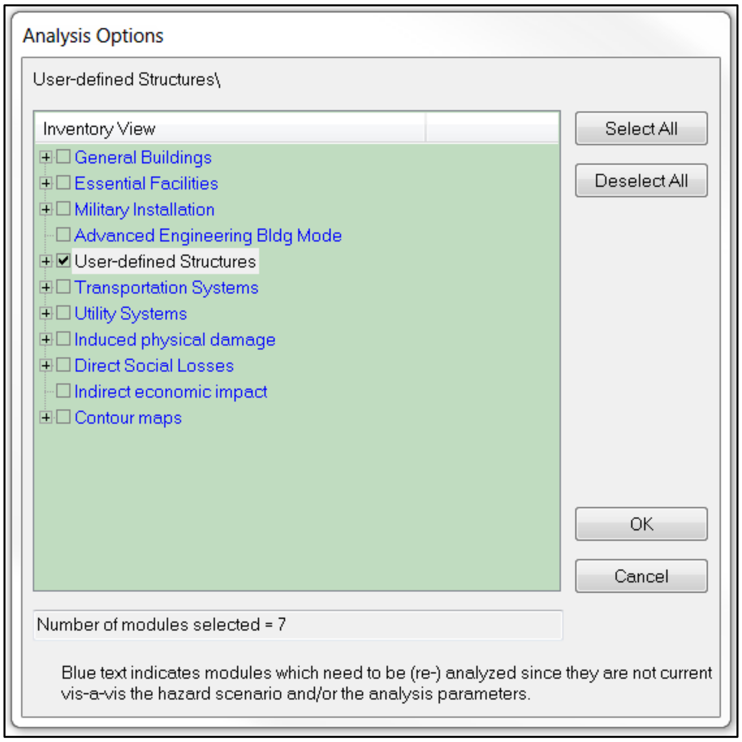


Figure 9-1 Run Menu - User-Defined Facilities Analysis

Section 10. Advanced Hazus Analysis: Advanced Engineering Building Model (AEBM)

The AEBM procedures are an extension of the more general methods of the Hazus Earthquake Model and provide building-specific loss estimation tools for use by experienced seismic/structural engineers or users with more detailed inventory data available. In addition to using the AEBM import methods described below, it is highly recommended that users integrate AEBM data into their State Databases using the CDMS application. CDMS will help the user prepare the data, including the creation of the AEBM profiles matching the over 16,000 profile options embedded in every Hazus earthquake Study Region, as well as estimates for building values (U.S. Dollars [USD]), maximum daytime and maximum nighttime occupants. For more information on the AEBM, users are referred to the *Hazus AEBM Technical and User's Manual (FEMA, 2002)*.

It is important to note that Hazus will not include any inventory data that users have defined outside the limits of the Study Region. In fact, if users include facilities that are outside the defined Study Region, Hazus will exclude those facilities from the Study Region. The region will always be defined by a Census tract boundary or boundaries within which population, demographics, and GBS values are aggregated.

10.1 Evaluation of Individual Building(s)

To evaluate an individual building, the user creates an AEBM Inventory record and identifies the AEBM Profile for each building of interest. These sets of linked inventory and profile data define unique properties for each building of interest.

10.2 Evaluation of a Group of Similar Buildings

To evaluate a group of similar buildings, the user creates an AEBM Inventory record for each building in the group, distributing them by location (latitude/longitude) throughout the Study Region and a single AEBM Profile record (linked to each building in the group). The profile data define properties that represent the collective performance of the group (e.g., building type).

An example "group" application of the AEBM is the evaluation of a "new" building type that is not well represented by an existing building type in Hazus (e.g., URM buildings seismically strengthened to meet certain performance criteria). The AEBM can be used to evaluate damage and loss to these buildings.

10.3 Building-Specific Data Provided by Users

The accuracy of building-specific loss estimates depends primarily on the extent and quality of the information provided by the user. The more effort the user puts into the determination of building-specific data, the more reliable the results will be. Conversely, not all input data have the same level of importance in terms of the reliability of the results. This section describes the required input data to be provided by the user and indicates, qualitatively, the likely relative importance of the data to loss estimates.

10.3.1 Inventory Data

It is expected that the user will have basic inventory data on each AEBM building (or group of buildings) of interest, including building location, size, occupancy, replacement value, and other financial data. In general, these data are known by building owners or are otherwise available to users performing detailed building-specific analyses. For individual buildings, inventory data include the following:

- *Building Location* – What is the geographical location of the building (e.g., name, address, and latitude/longitudinal coordinates of site)?
- *Building Occupants* – How many people use the building during the day and at night? What percentage of the building is owner occupied?
- *Building Size* – What is the gross square footage, and number of floors, of the building?
- *Replacement Value* – What is the replacement value of the building, contents, and/or business inventory?
- *Loss of Function Cost* – What are the financial data and costs associated with loss of building function, including business income, wages paid, and relocation costs due to disruption of operation and rental of temporary space?

10.3.2 Performance Data

Hazus provides an extensive set of over 16,000 AEBM profiles based on all possible combinations of Hazus occupancy, specific building type, and seismic design level, as well as a flag indicating whether baseline fragility curve betas (flag = 0) or reduced/ShakeMap betas (flag = -1) are applied (e.g., RES1W1HC0 or RES1W1HC-1). Refer to Section 7.1.2.1 for an explanation of fragility curves. The ShakeMap betas provide calibration of Hazus building fragility curves removing uncertainty against actual earthquake data and should always be used in the case of actual earthquakes. It is possible that the user will want to analyze their AEBM data using both a ShakeMap and another deterministic method. In this case, the user will need to develop two state databases using CDMS to contain their AEBM data. One database will store the baseline fragility curve betas (flag = 0) for use in any earthquake analysis except ShakeMap. The second database will store the reduced/ShakeMap betas (flag = -1) for use in a ShakeMap analysis.

Data describing the expected performance of the structural system and nonstructural components are required to select appropriate damage functions from the suite of available baseline functions or to develop improved building-specific damage functions. These data include an improved understanding of the structure’s response properties and damage to components and elements as a function of the amplitude of response. These data are best determined from a pushover analysis of the building using procedures in the *FEMA Guidelines* (FEMA, 2000) or ATC-40 (1996). The user who wants to develop new functions is expected to be familiar with these documents and will perform a pushover analysis to determine input data.

Users must provide inventory data to run the AEBM. In contrast, performance data that define building response properties, capacity curves and fragility (damage) functions, and loss data may be based entirely on built-in Hazus parameters.

The AEBM develops an initial "profile" of building response, damage, and loss parameters based on baseline Hazus values corresponding to the occupancy class, building type, and seismic design level of the building or group of buildings of interest. As a minimum, users must provide these three building characteristics to run the AEBM. These characteristics can be important to AEBM estimates of damage and loss if baseline values are not modified to incorporate building-specific data.

For more detailed information, please refer to the *Hazus AEBM Technical and User's Manual (FEMA, 2002)* , specifically regarding Building Failure Models, Pushover Analysis, and Element/Component Response Characteristics.

10.3.3 Occupant Data

The Hazus AEBM estimates indoor casualties at only two times of day: daytime (2 pm) and nighttime (2 am). The user will need to provide the number of daytime and nighttime occupants of individual buildings of the AEBM. If the user is using CDMS to prepare their AEBM inventory, the maximum day and maximum night populations will be estimated using methods from FEMA P-58and the relationships between numbers of persons by building area based on occupancy type. The user could also determine whether the distribution of the building population is significantly correlated with building failure (e.g., collapse). For example, suppose only a specific portion of a building is determined to be susceptible to collapse. Is this portion of the building densely populated, have an average building population, or perhaps have a very low population (e.g., storage area)?

10.3.4 Financial Data

Hazus estimates direct economic loss to buildings based on separate damage and loss estimates for the structural system, drift-sensitive nonstructural components, acceleration-sensitive nonstructural components, and contents (and business inventory). The repair or replacement cost of each damage state is expressed as a fraction of total replacement cost of the system of interest (i.e., loss ratio). Total building replacement value, including regional adjustment, is distributed between structural, nonstructural drift-sensitive, and nonstructural acceleration-sensitive systems. The value of contents is crudely based on a fraction (e.g., 50% for residential structures) of the building's replacement cost.

The user will need to provide the replacement cost of individual buildings, their contents, and business inventories (if applicable). The replacement costs of the last two items can be of particular importance for buildings or businesses that have special (expensive) contents or inventory items (e.g., laboratory or special process equipment). The user should also confirm (or revise accordingly) Hazus baseline values that distribute replacement cost of the building between structural, nonstructural drift-sensitive components, and nonstructural acceleration-sensitive components.

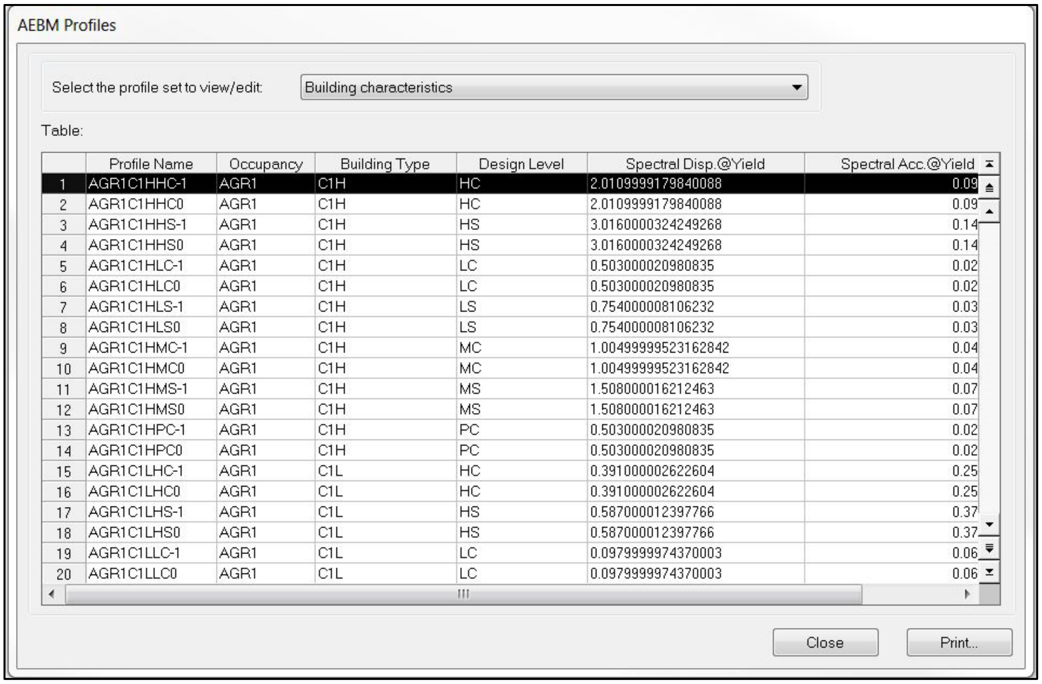
Hazus relates each damage state to an amount of financial loss as a fraction of replacement value. Users should confirm (or revise) the baseline values of Hazus parameters that relate damage states to financial loss, considering element/component damage as a function of building drift (e.g., spectral displacement). Users may choose to develop building-specific loss ratios for each damage state that better reflect construction costs associated with, for example, inspection, demolition, phasing, and unavoidable impact of repair on undamaged systems. Ideally, users would identify damage from a pushover analysis, describe the type and extent of repairs required to correct damage, and develop associated repair costs for each damage state.

In addition to repair and replacement costs, direct economic losses also include the financial effects of loss of building function on business income, wage income, relocation, and temporary space rental. Users should confirm (or revise) baseline values of Hazus for the time required for cleanup and repair (construction time) considering the extent of damage determined from pushover analysis and evaluation of damage to building components.

10.4 Advanced Engineering Building Model Menu Options

In the Earthquake Model, the **Inventory > AEBM** menu includes the following options: **Profiles** and **Inventory**. This section describes the inputs associated with each menu selection.

The AEBM Profiles describe an extensive set of building performance characteristics, including damage and loss function parameters. Each building in the AEBM Inventory must be linked to one of the AEBM Profiles to run the AEBM, but an AEBM Profile can be used for more than one building of the AEBM Inventory. Figure 10-1 shows the building characteristics that are listed when the AEBM Profile Menu is selected. As noted above, Hazus comes pre-populated with a profile for every combination of occupancy, building type, design level and event type (scenario vs. actual).



	Profile Name	Occupancy	Building Type	Design Level	Spectral Disp.@Yield	Spectral Acc.@Yield
1	AGR1C1HHC-1	AGR1	C1H	HC	2.0109999179840088	0.09
2	AGR1C1HHC0	AGR1	C1H	HC	2.0109999179840088	0.09
3	AGR1C1HHS-1	AGR1	C1H	HS	3.0160000324249268	0.14
4	AGR1C1HHS0	AGR1	C1H	HS	3.0160000324249268	0.14
5	AGR1C1HLC-1	AGR1	C1H	LC	0.503000020980835	0.02
6	AGR1C1HLC0	AGR1	C1H	LC	0.503000020980835	0.02
7	AGR1C1HLS-1	AGR1	C1H	LS	0.754000008106232	0.03
8	AGR1C1HLS0	AGR1	C1H	LS	0.754000008106232	0.03
9	AGR1C1HMC-1	AGR1	C1H	MC	1.00499999523162842	0.04
10	AGR1C1HMC0	AGR1	C1H	MC	1.00499999523162842	0.04
11	AGR1C1HMS-1	AGR1	C1H	MS	1.508000016212463	0.07
12	AGR1C1HMS0	AGR1	C1H	MS	1.508000016212463	0.07
13	AGR1C1HPC-1	AGR1	C1H	PC	0.503000020980835	0.02
14	AGR1C1HPC0	AGR1	C1H	PC	0.503000020980835	0.02
15	AGR1C1LHC-1	AGR1	C1L	HC	0.391000002622604	0.25
16	AGR1C1LHC0	AGR1	C1L	HC	0.391000002622604	0.25
17	AGR1C1LHS-1	AGR1	C1L	HS	0.587000012397766	0.37
18	AGR1C1LHS0	AGR1	C1L	HS	0.587000012397766	0.37
19	AGR1C1LLC-1	AGR1	C1L	LC	0.0979999974370003	0.06
20	AGR1C1LLC0	AGR1	C1L	LC	0.0979999974370003	0.06

Figure 10-1 AEBM Profiles Window

The AEBM **Inventory** menu enables users to import their own custom datasets to be analyzed by Hazus. The functionality of the menu can be accessed by right-clicking to access the context menu. There are two ways to add data using the menu. Records can be added one at a time, using **Add New Record**, or in a bulk manner using **Import.** If using the bulk import, it is important that the data types used in the import personal geodatabase match the AEBM schema (Figure 10-2). It is also important that the profile name of the data being imported matches a profile name in the full list of AEBM profiles. The data types for this schema can be found from the AEBM **Inventory** window by right-clicking to access the context menu and selecting **Data Dictionary.** Once imported, the AEBM **Inventory** Menu lists the imported data for each facility, such as name and address, as illustrated in Figure 10-3.

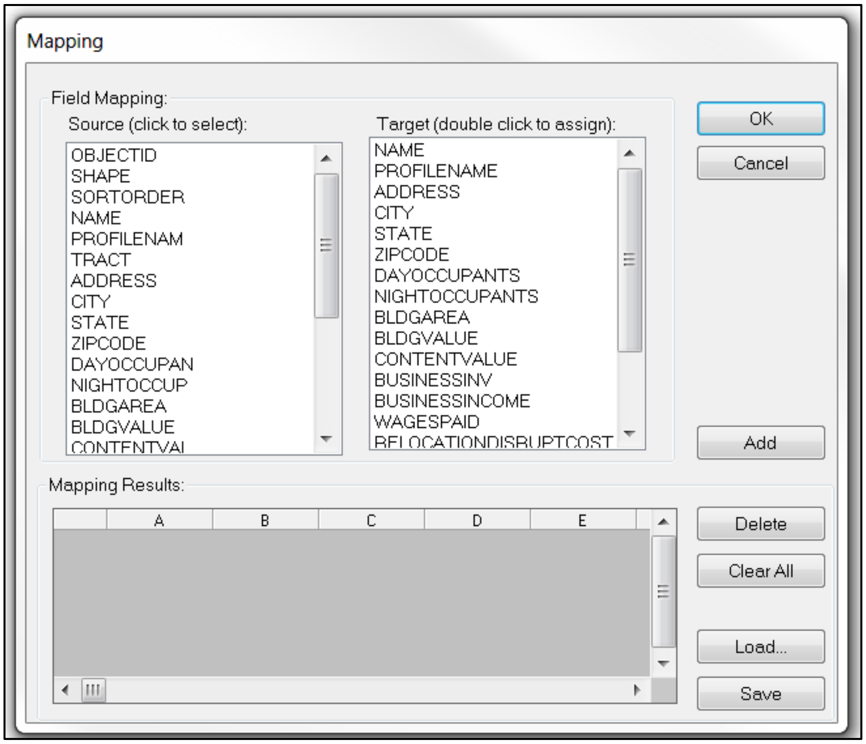


Figure 10-2 AEBM Inventory Import - Field Mapping

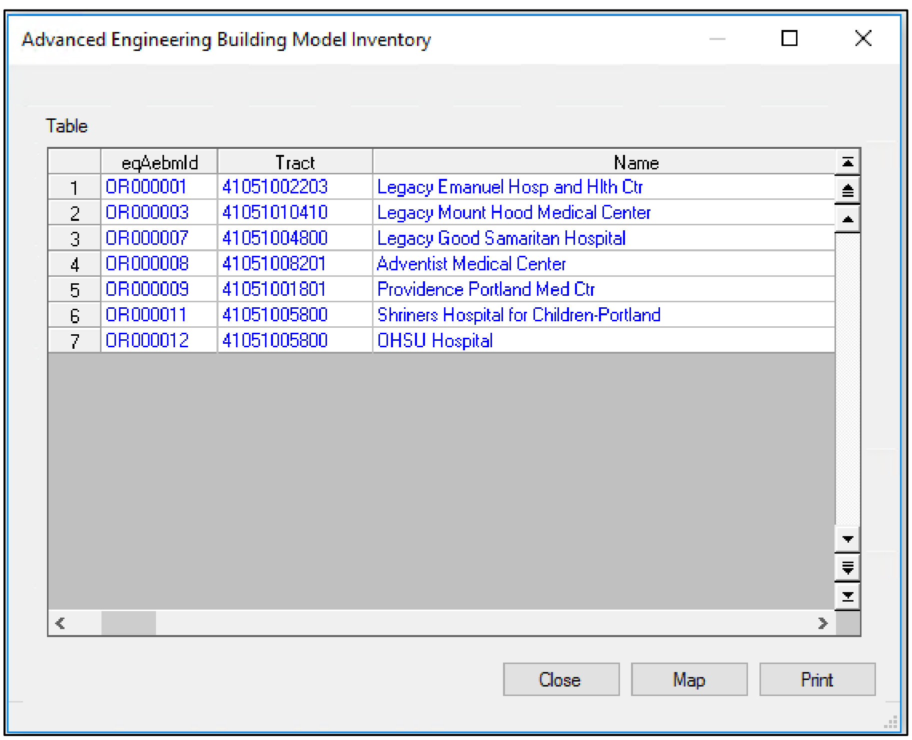


Figure 10-3 AEBM Inventory Menu

To estimate damage to the AEBM buildings, the option to run the AEBM analysis must be selected from the **Analysis** menu, as shown in Figure 10-4. See Section 8.2.7 for details of the AEBM model results.

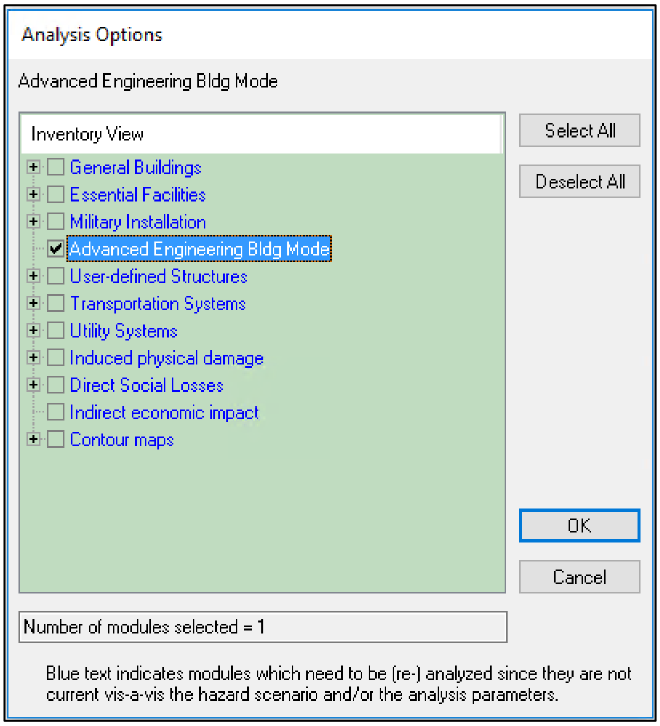


Figure 10-4 Run Menu - AEBM Analysis

Section 11. References

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