Hazus Tsunami Model User Guidance

Revision 1

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Document History

Affected Section or Subsection	Date	Description
First Publication	November 2017	Initial version of new *Hazus Tsunami Model User Guidance* for Hazus version 4.0.
First Revision	August 2020	Adjusted formatting to match *Hazus Format and Style Guide* and updated to reflect Hazus 4.2 Service Pack 3 and November 2019 Data and Tools Release functionality.

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Acronyms and Abbreviations

Acronym/ Abbreviation	Definition
AGL	Above ground level
CDMS	Hazus Comprehensive Data Management System
DEM	Digital Elevation Model
EOC	Emergency Operation Center
FAQ	Frequently Asked Questions
FEMA	Federal Emergency Management Agency
FIPS	Federal Information Processing Standards
GBS	General Building Stock
GIS	Geographic Information System
GUI	Graphical User Interface
HPLF	High Potential Loss Facilities
HV2	Momentum Flux
MSL	Mean sea level
NED	National Elevation Dataset
NFIP	National Flood Insurance Program
NIBS	National Institute of Building Sciences
NOAA	National Oceanic and Atmospheric Administration
NSI	National Structure Inventory
NTHMP	National Tsunami Hazard Mitigation Program
PMEL	Pacific Marine Environmental Laboratory
SIFT	Short-term Inundation Forecasting for Tsunamis
SLTT	State, Local, Tribal, and Territorial
TIGER	Topologically Integrated Geographic Encoding and Referencing
UDF	User-Defined Facility
URM	Unreinforced masonry
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey

Section 1. Introduction to FEMA Tsunami Loss Estimation Methodology

1.1 Background

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

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

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

The Hazus Tsunami Model provides the capability to quantify potential building impacts and losses, as well as casualties. The model analyzes the potentially catastrophic tsunami scenarios associated with near-source tsunamis by combining tsunami and earthquake losses, as well as distant-source tsunamis.

The current capability addresses High to Very High Tsunami Risk States and U.S. territories, as defined by the National Tsunami Hazard Mitigation Program (NTHMP). The Tsunami Model itself was developed and implemented from the Tsunami Methodology developed by FEMA in 2013, but is not completely congruous with that methodology, having been modified based on newer developments or for software development. Estimates can also help guide the allocation of federal resources to stimulate risk mitigation efforts and to plan for a federal tsunami response.

The Hazus Tsunami Model is currently available for the five Very High Risk U.S. states and the five High Risk U.S. territories.

- Alaska
- Washington
- Oregon
- California
- Hawaii
- Northern Mariana Islands (Tsunami only)
- American Samoa (Tsunami only)
- Guam (Tsunami only)
- Puerto Rico
- U.S. Virgin Islands

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

The *Hazus Tsunami Model Technical Manual* (FEMA, 2021) documents the methods used in calculating losses. A companion document, the *Hazus Inventory Technical Manual* (FEMA, 2021), provides more detailed methodology and data descriptions for the inventory shared by each hazard model. Together, 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 a wide range of informational needs. A state, local, tribal, or territorial 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. 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 tsunami scenarios. 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. Emergency planners may want estimates of temporary shelter requirements for different tsunami scenario events. Federal and state government agencies may conduct a loss analysis to obtain quick estimates of impacts in the hours immediately following a tsunami to best direct resources to the disaster area. Insurance companies may be interested in the estimated monetary losses so they can determine asset vulnerability.

Tsunami 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 study results.

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

- Development of tsunami hazard mitigation strategies that outline policies and programs for reducing tsunami 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 tsunami inundation zones, and the adoption of advanced building codes.
- Development of preparedness (contingency) planning measures that identify alternate transportation routes, planning tsunami preparedness, and education seminars.
- Anticipation of the nature and extent of response and recovery efforts including the identification of alternative housing; the location, availability and scope of required medical services; and the establishment of a priority ranking for restoration of water and power resources.

Post-tsunami applications of the outputs include:

- Projection of immediate economic impact assessments for state and federal resource allocation, and support for state and/or federal disaster declarations by calculating direct economic impact on public and private resources, local governments, and the functionality of facilities in 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 that include 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 assessment of land use planning principles and practices.

1.3 Assumed User Expertise

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

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

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

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

If a state, local, tribal, or territorial agency is performing the analysis, some of the expertise may be found in-house. Experts are generally found in several departments: building 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 the external participation of individuals from academic institutions, citizen organizations, and private industry cannot be underestimated.

1.4 When to Seek Help

The results of a loss estimation analysis should be interpreted with caution because baseline values have a great deal of uncertainty. Baseline inventory datasets are the datasets that are provided with Hazus. Further information on these can be found in the *Hazus Inventory Technical Manual* (FEMA, 2021). 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 an expert is not available to assist in the selection of tsunami flood depth, velocity, and momentum flux, the user should defer to readily available data provided by the USGS. This will allow users to take advantage of USGS subject matter expertise when defining their deterministic tsunami scenario.

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

1.5 Technical Support

Technical Support contact information is provided in the Hazus application at **Help|Obtaining Technical Support**; technical assistance is available via the Hazus Help Desk by email at FEMA-Hazus-support@fema.dhs.gov (preferred) or by phone at 1-877-FEMA-MAP (1-877-336-2627). The FEMA Hazus website also provides answers to Frequently Asked Questions, and information on software updates 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. Since Hazus was built as an extension to ArcGIS functionality, knowing how to use ArcGIS and ArcGIS Help Desk will help Hazus users.

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

1.6 Uncertainties in Loss Estimates

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

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 tsunamis to determine precise estimates of damage based on known momentum flux and tsunami depths, even for specific buildings and other structures. To deal with this complexity and lack of data, buildings and components of infrastructure systems are grouped into categories based upon key characteristics. The relationships between key tsunami features and average degree of damage with associated losses for each building category are based on current data and available theories.

The results of a tsunami 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 tsunami events are infrequent or where recorded data is scarce.

Section 2. Introduction to Tsunami Loss Estimation Methodology

This brief overview of the Tsunami Methodology is intended for SLTT officials contemplating a tsunami analysis.

The Hazus Methodologies will generate an estimate of the consequences of a scenario tsunami event to a coastal 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 tsunami event. The following information can be obtained:

- *Quantitative estimates of losses* in terms of direct costs for repair and replacement of damaged buildings, direct costs associated with loss of function (e.g., loss of business revenue, relocation costs), and casualties.
- *Functionality losses* in terms of loss of function and restoration times for user-defined facilities provided by the user.

To generate this information, the Methodology includes:

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

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

The Hazus software uses GIS technologies for performing analyses with inventory data and displaying losses and consequences on applicable tables and maps. The Methodology permits estimates to be made at several levels of complexity, based on the level of inventory 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 graphic representation of the modules that the Hazus Tsunami Model Methodology is comprised of, and their interrelation in deriving estimates.

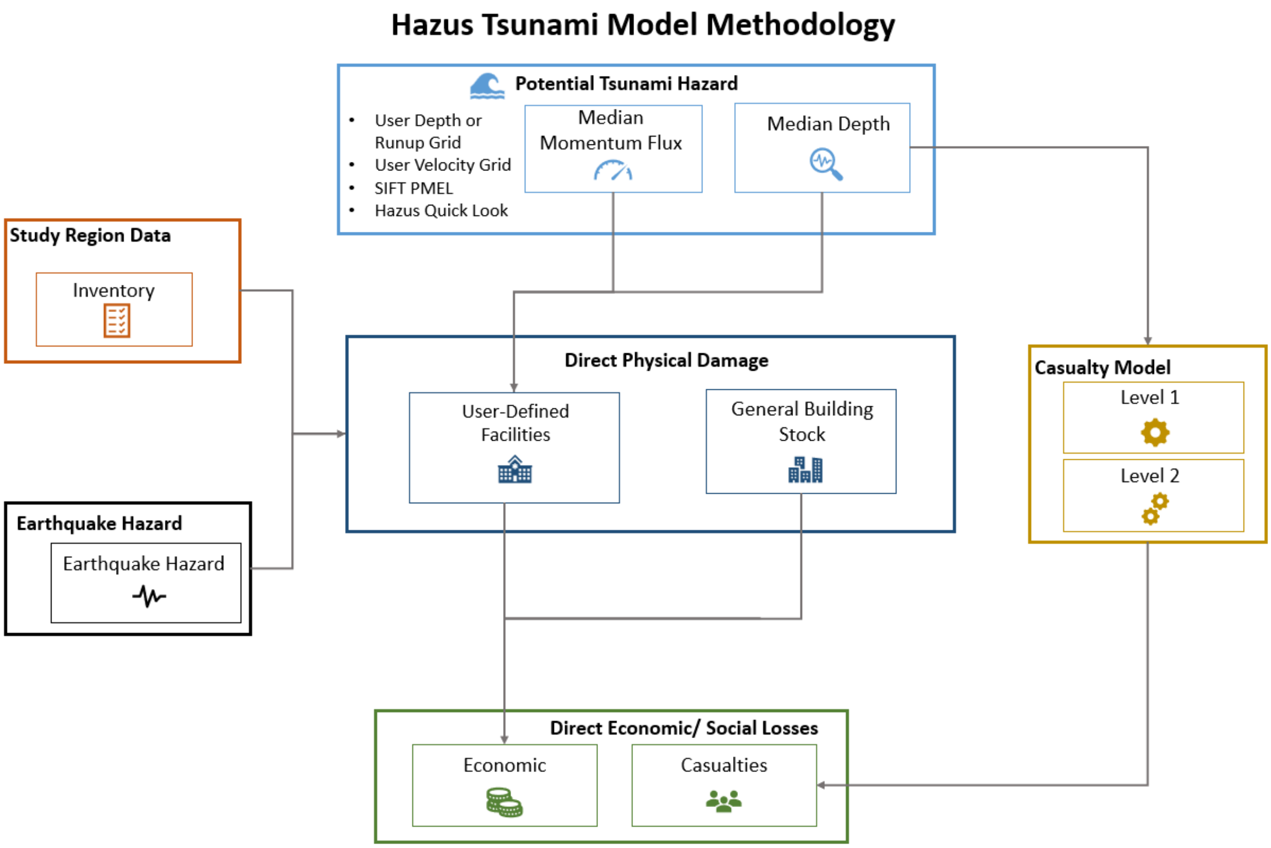


Figure 2-1 Hazus Tsunami Model Methodology Schematic

While Figure 2-1 shows the conceptual relationships, the steps used in the Hazus Tsunami Model are as follows:

- *Select the area to be studied:* The Hazus Study Region (the region of interest) is created based on Census block, tract, or county 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 tsunami hazard scenario:* In developing the scenario tsunami, consideration should be given to the availability of data including median momentum flux, median depth, and median velocity grids using NOAA and other datasets, or subject matter experts.
- *Integrate local inventory data:* Include user-defined facilities and updates to GBS characteristics.
- *Use the formulas embedded in Hazus*: Compute probability distributions for damage to different classes of buildings, facilities, and infrastructure system components. Then, estimate the loss of function.
- *Compute estimates of direct economic loss and casualties using the damage and functionality information.*

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 Tsunami Hazards Considered in the Methodology

The Hazus Tsunami Methodology consists of three basic analytical processes: hazard analysis, damage assessment, and impact analysis. In the hazard analysis phase, source characteristics, and bathymetry data are used to model the spatial variation in flood depth, velocity, and momentum flux. During the damage assessment phase, structural, nonstructural, and content damage is calculated based on the results of the hazard analysis using fragility curves. The impact phase translates the severity of tsunami and damage assessment into social and economic losses.

The tsunami-related hazards considered by the Hazus Methodology in evaluating damage, resultant losses, and casualties are collectively referred to as potential tsunami hazards (PTH). Most damage and loss caused by a tsunami is directly or indirectly the result of water velocity and depth. Thus, Hazus evaluates the geographic inundation as a result of a specific tsunami scenario and expresses tsunami characteristics using several quantitative parameters (e.g., median momentum flux, median velocity, and median depth). Most casualties result from drowning and trauma associated from being in the water.

The following two features of tsunamis can cause structural damage and loss of life:

- *Tsunami Momentum Flux*: The transport of momentum acting in the direction of the water flow and is equal to the force per unit area. This tsunami parameter drives the structural damage.
- *Tsunami Depth*: This is the median depth of the tsunami and drives the contents losses and casualty estimates.

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 General Building Stock (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 block 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, 2021). Degree of damage is computed for each grouped combination of model building type and occupancy class.
- *User-Defined Facilities (UDFs):* Destruction of critical coastal structures could cause significant increase in losses, even if residents were evacuated to safe areas. Critical

coastal structures can include schools, hospitals, fire and police stations, shelters and Emergency Operation Center's (EOC). Since Hazus Tsunami does not yet provide an Essential Facility loss model, these facilities can be modeled as UDFs. Modeling as UDFs will provide the user with direct economic losses for both tsunami only, as well as combined earthquake and tsunami losses.

Specific data can be used to estimate potential damage and hazard effects using the UDF module, which is addressed in Section 9.

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 provides a graphic representation of the various levels of analysis. These are generally defined in the Hazus Tsunami Model based on the quality of the input hazard data, although improvement of inventory data should always be considered. The hazard data available for tsunami loss modeling frequently does not include velocity data, which is the critical driver of all structural losses in tsunami. Therefore, if the input hazard data lack user supplied velocity, the term Level 1 (Basic) is used. Level 2 (Advanced) is used where both inundation depth and velocity data exist, and Level 3 (Advanced) when momentum flux and depth are provided directly by the user. In addition, the casualty model (Section 6) provides only two levels of analysis, Level 1 (Basic) and Level 2 (Advanced).

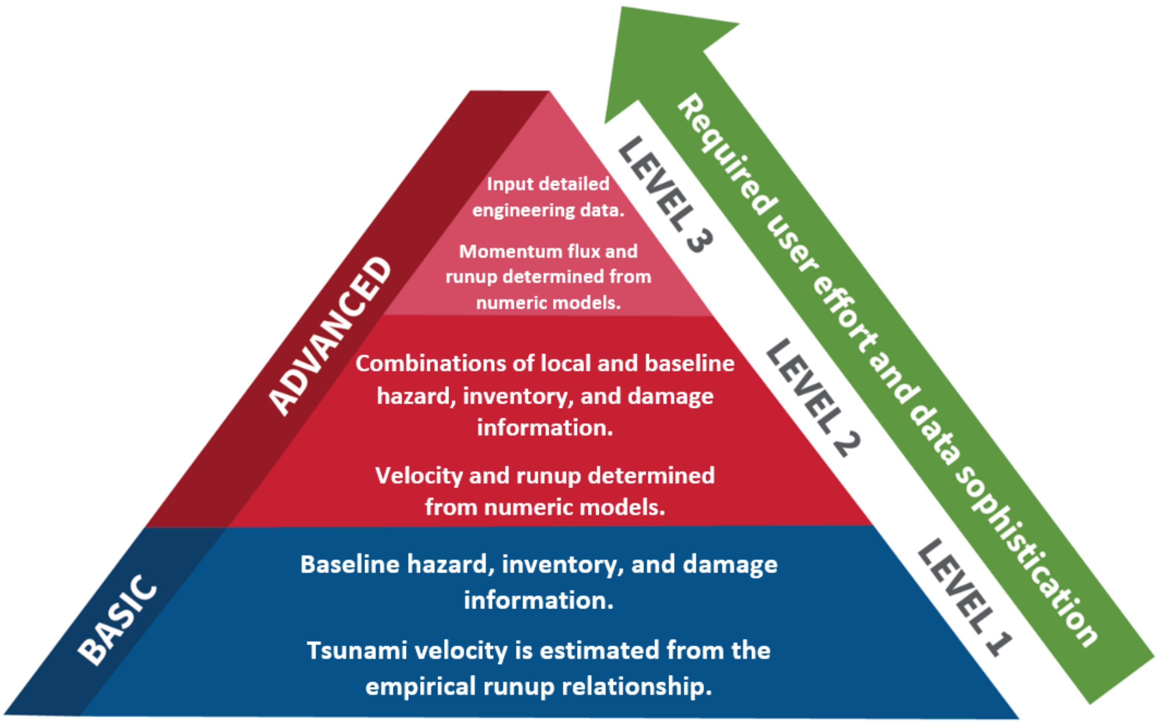


Figure 2-2 Levels of Analysis

2.3.1 Analysis Based on Baseline Information

Level 1 (Basic) 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. In a Level 1 (Basic) analysis, tsunami hazard velocity grid data are developed using an empirical relationship, and as little as a single observation of runup height may be used. This is an important limitation to note with Level 1 (Basic) data, since in Hazus tsunami all building structural losses are driven based on velocity information (non-structural and content losses are based on inundation depth alone). The user is not expected to have extensive technical knowledge. While the methods require some user-supplied input to run, the type of input required could be gathered by referring to published information. At this level, estimates will have much greater uncertainty than Levels 2 or 3 (Advanced) and will likely be appropriate only as initial loss estimates to determine where more detailed analyses are warranted.

2.3.2 Analysis with User-Supplied Inventory

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 or Level 3 (Advanced) analysis. The following inventory improvements impact the accuracy of Level 2 and Level 3 (Advanced) analysis results:

- Use of locally available data or estimates of the square footage of buildings in different occupancy classes.
- Use of local expertise to modify 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 (integrated as user-defined facilities).
- Use of locally available data concerning construction costs or other economic parameters.

The Level 2 (Advanced) tsunami hazard analysis is defined by having both velocity as well as runup grid information provided from an external hazard model. The purpose of this type of analysis is to provide the user with the best estimates of tsunami damage/loss that can be obtained using the methods included in the Methodology. All components of the Hazus Methodology can be performed at this level. In addition, loss estimates based on user-developed local inventories could further improve this level of analysis. As the user provides more complete data, the quality of the analysis and results improve. Depending on the size of the region and the level of detail desired by the user, as well as user experience, the required input for this type of analysis could take weeks to months to develop.

The Level 3 (Advanced) tsunami hazard analysis is defined by including both momentum flux, as well as runup grid provided from an external numeric tsunami hazard model. At this level, one or more technical experts could further improve the analysis by acquiring data, performing detailed analyses, assessing damage/loss, and assisting the user in gathering more extensive inventory. It is anticipated that at this level there will be extensive participation by local utilities and owners of at-risk facilities that could provide more accurate inventories and attributes.

There are no standardized procedures for conducting an advanced data and models analysis study. The quality and detail of the results depend upon the level of effort. Advanced data development and models analysis studies could take six months to two years to complete. Each subsequent level builds on and adds to the data and analysis procedures available in previous levels.

2.4 Model Limitations

The current version of the Hazus Tsunami Model does not estimate the following:

- Damage, loss, and functionality estimations for Essential Facilities and Lifeline Infrastructure
- Shelter Requirements
- Debris
- Indirect economic losses

Note that, at this time, the standalone earthquake model analysis is not complete for the U.S. Pacific territories, and will not run independently of the tsunami analysis. The functionality to run the standalone earthquake hazard analysis is available for these territories, but the building and infrastructure inventory tables specific to earthquake have not been completed.

For Combined Earthquake and Tsunami Losses Global Report, casualties are calculated and presented separately for earthquake and tsunami at this time, so there is some potential for double counting. However, it is possible that injuries as a result of the earthquake would slow evacuation times for those persons and anyone who remains to assist them, which could result in an increase in casualties caused by the tsunami.

Section 3. Getting Started: Hazus Start-Up Screen

The start-up screen is the first screen the user sees when Hazus is launched. Before running a loss estimation analysis, users must define a Study Region. The Study Region, in Hazus terminology, is the geographic extent for which data are aggregated, the hazard is defined, and the analysis is carried out. Hazus will prompt the user to create a new region or import a previously created region. Users also can open, delete, duplicate, backup, or export an existing region.

3.1 Hazus Startup

The first option in the Hazus Startup (Figure 3-1) is to define a Study Region. For this example, we will be creating a new region. Clicking **OK** activates the window seen in Figure 3-2. In this wizard, the user selects the Study Region's tsunami hazard type for the analysis.

Click **Next** to start. This will activate the window seen in Figure 3-3, where the user can name the Study Region and create a description. Click **Next**, which will activate the window in Figure 3-4. Select **Tsunami** and click **Next**. For users who wish to create combined earthquake and tsunami results, **Earthquake** should also be selected. Additional information regarding the combined earthquake and tsunami scenario in Section 11.

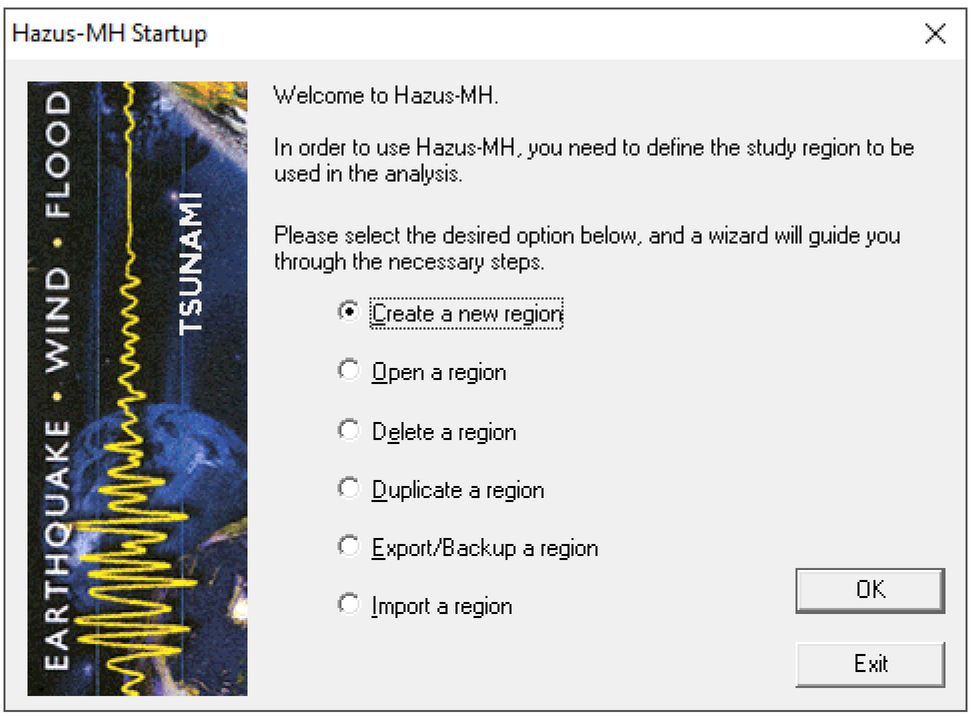


Figure 3-1 Hazus Startup Menu - Create a New Region

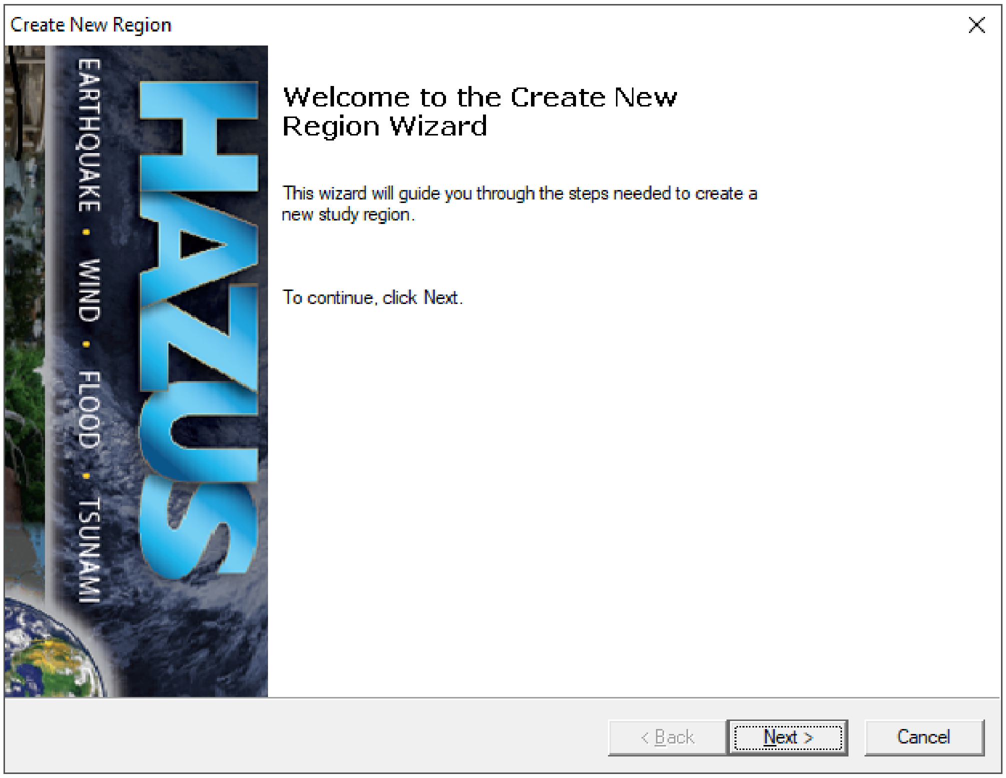


Figure 3-2 Create New Region Wizard

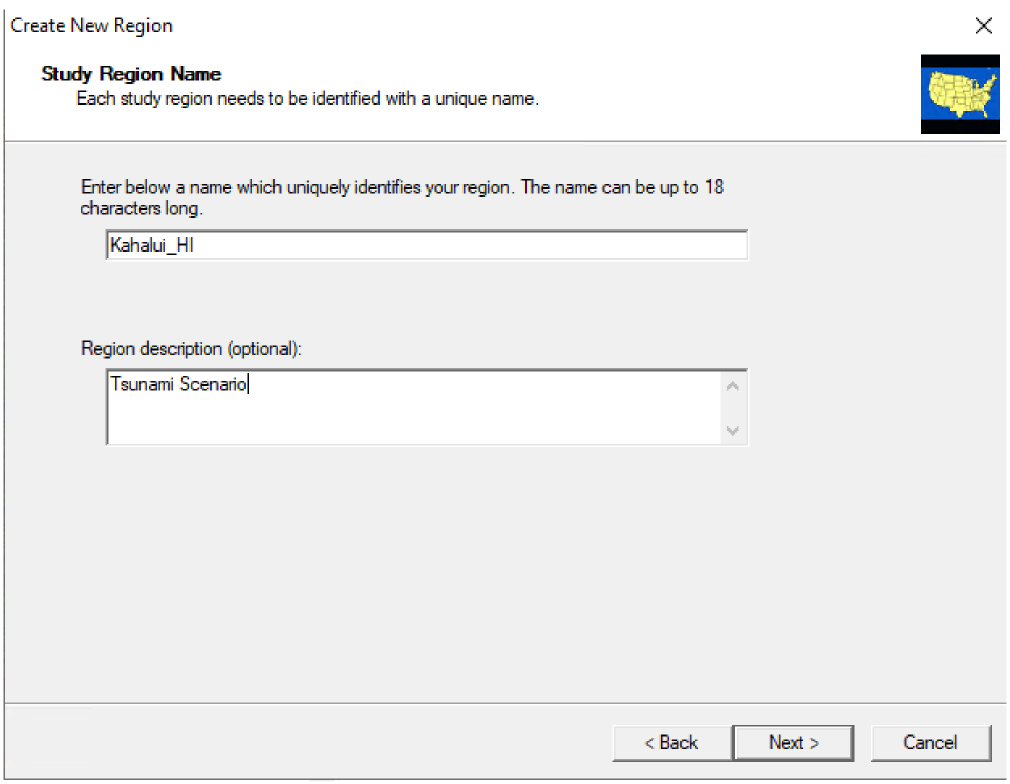


Figure 3-3 Study Region Name

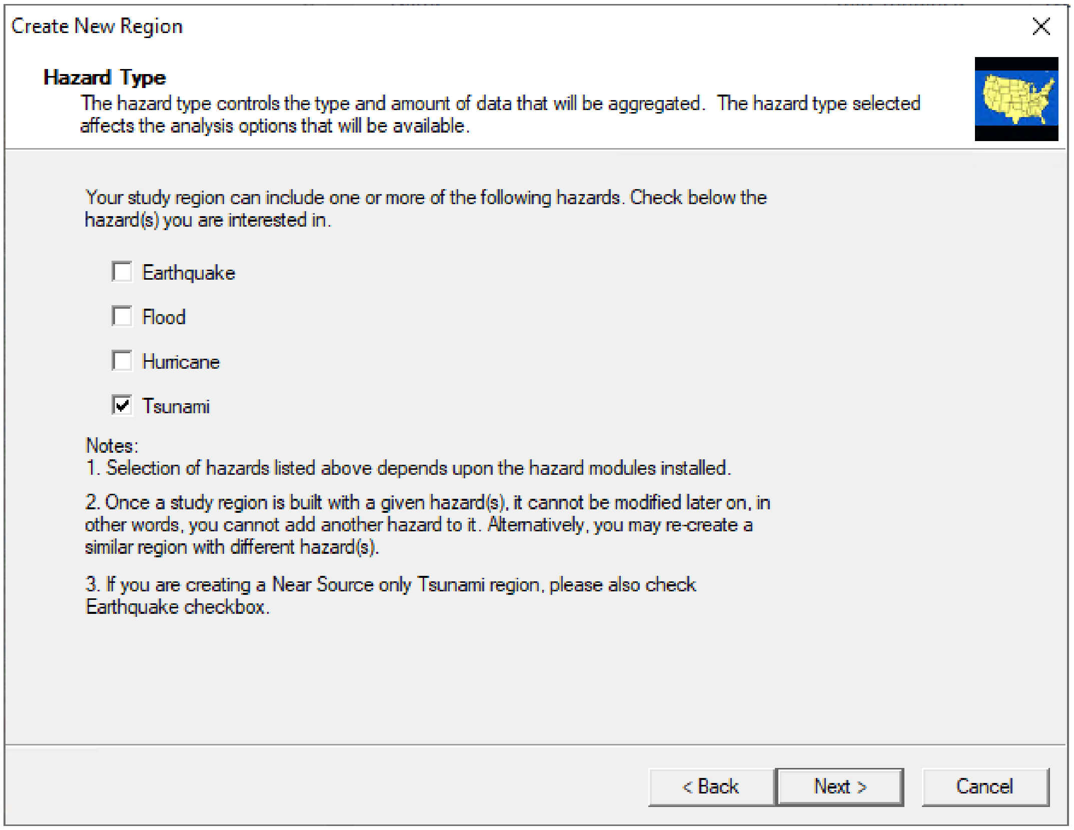


Figure 3-4 Hazard Type

3.2 Create New Study Region

Next, the user can create a new Study Region by state, county, Census tract, Census block, or Community levels, as seen in Figure 3-5. To create a Study Region at the county level, the user first selects the state of the new Study Region found in Figure 3-6. This will prompt the **County Selection** window found in Figure 3-7.

Once a county is selected, click **Finish**. The program will process until the Study Region has been created. Click **OK**. The program will not automatically open the Study Region at the end of this process.

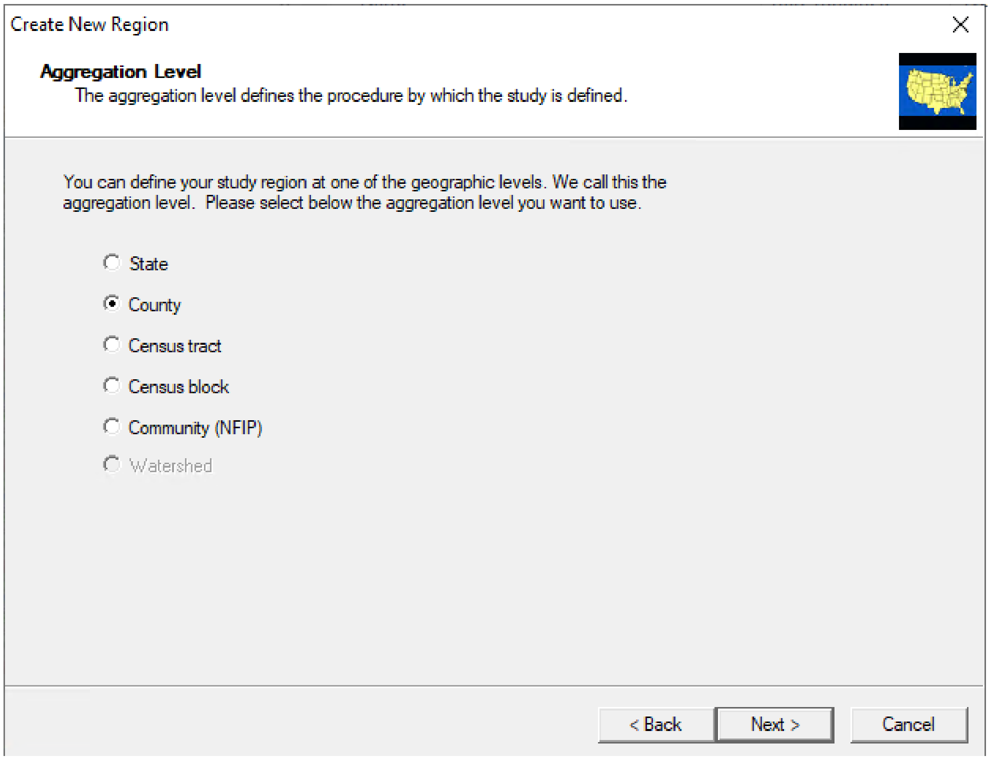


Figure 3-5 Create New Study Region Selection

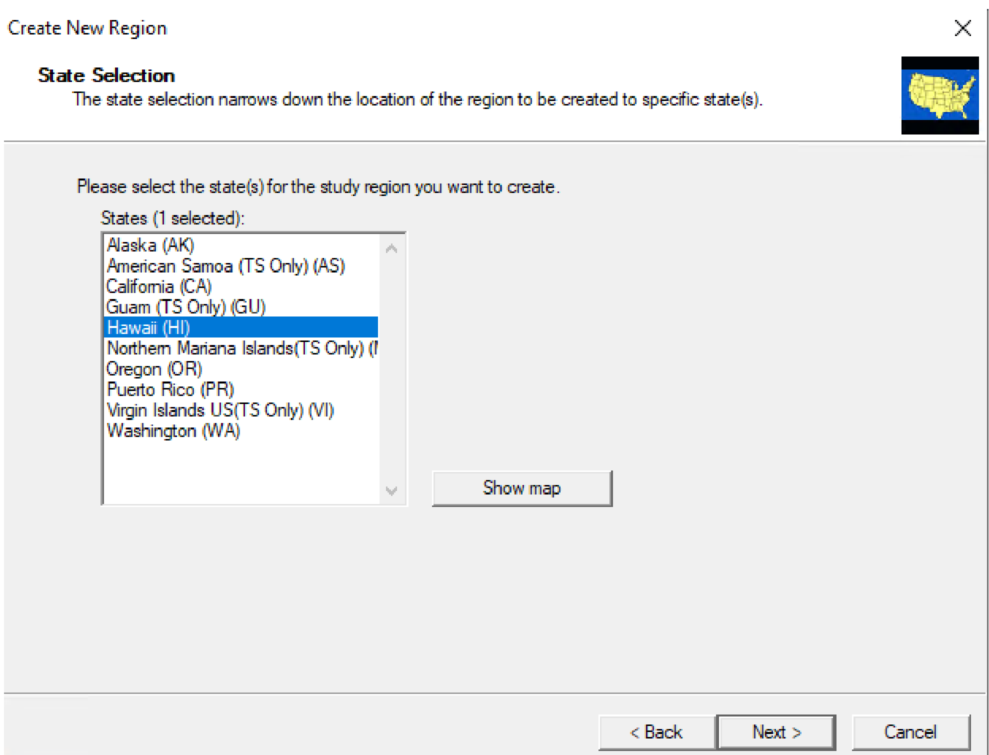


Figure 3-6 Create New Study Region State Selection

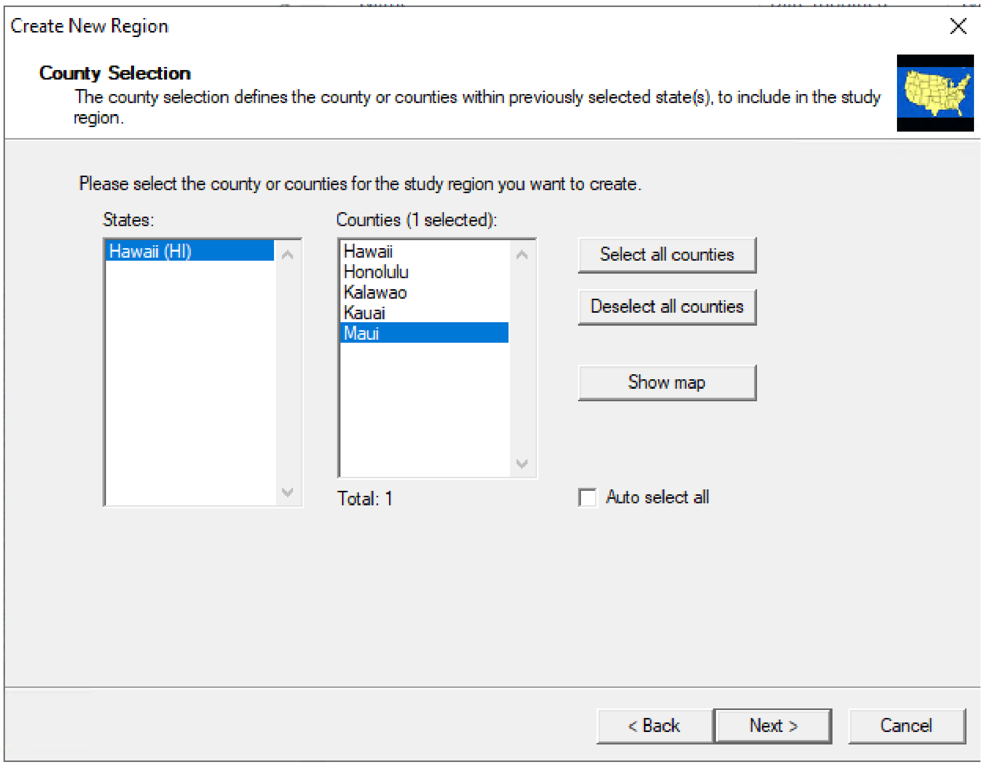


Figure 3-7 Create New Study Region County Selection

3.3 Open Region

Open the newly created Study Region under the **Hazus Startup** screen in Figure 3-8 by selecting **Open a region** and then clicking **OK.** This will allow the user to select the Study Region created in the previous steps. Click **Next** at the **Open Region** window (Figure 3-9). Select the Study Region that was created in the previous section**.** Click **Next**. Then click **Finish**. The Study Region will then open.

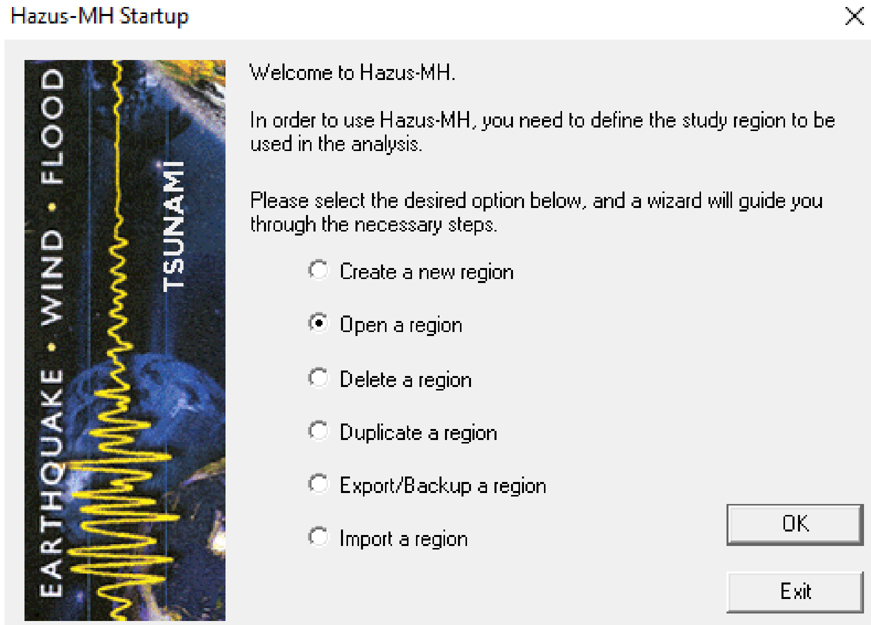


Figure 3-8 Hazus Startup Menu - Open a Region

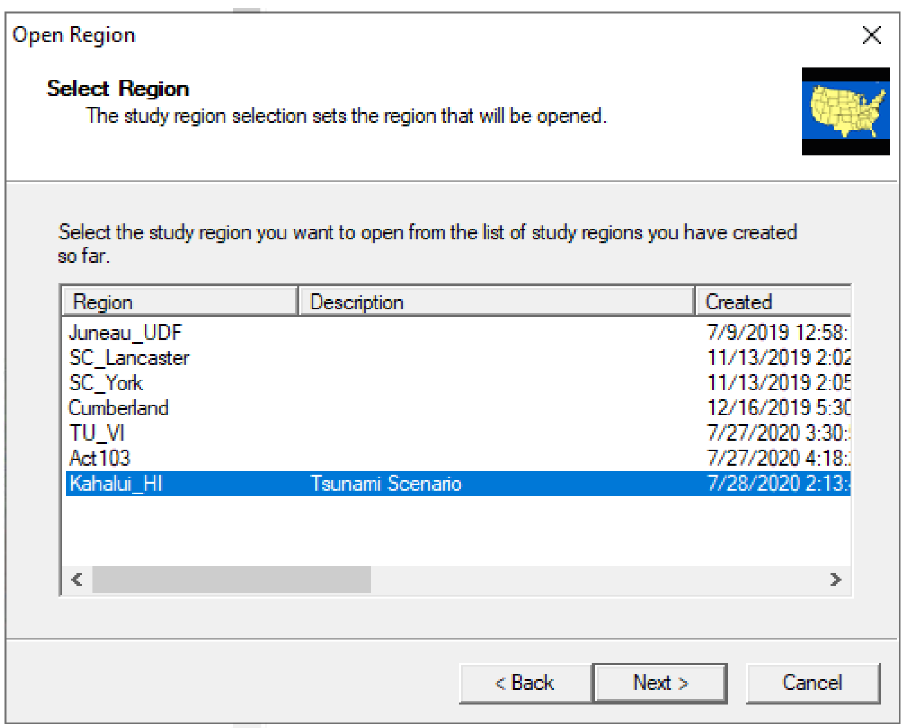


Figure 3-9 Select a Region

3.4 Delete Region

The **Delete a region** option seen in Figure 3-10 will not be available until a region has been created or imported. Select **Delete a region** and click **OK**, this will open the **Delete Region** window seen in Figure 3-11. Select a region from the list and click **Delete** to permanently delete the region.

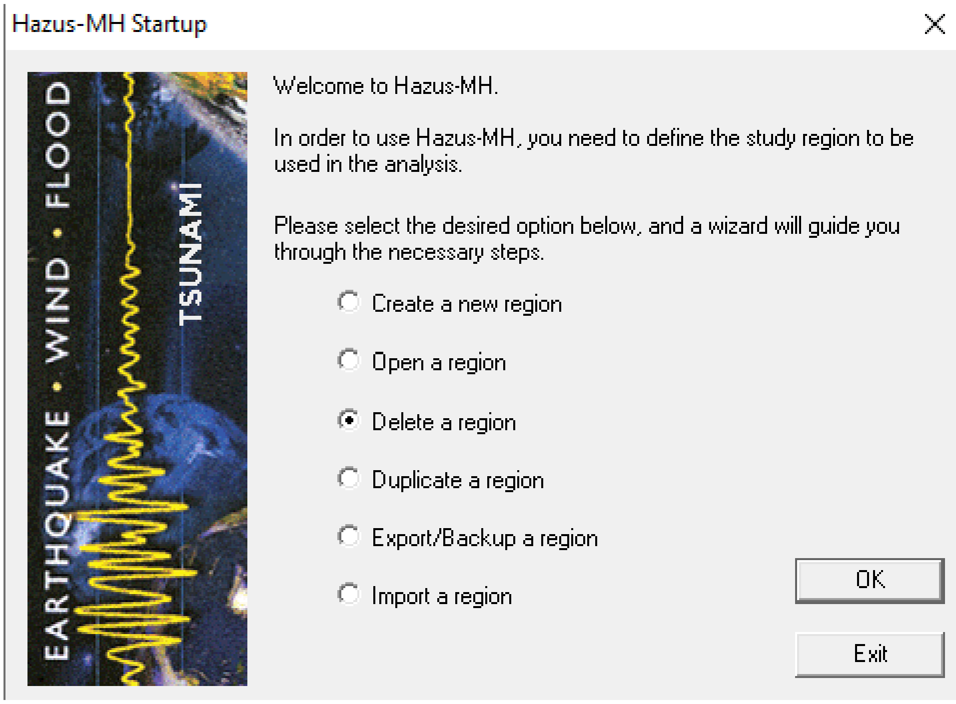


Figure 3-10 Hazus Startup Menu - Delete a Region

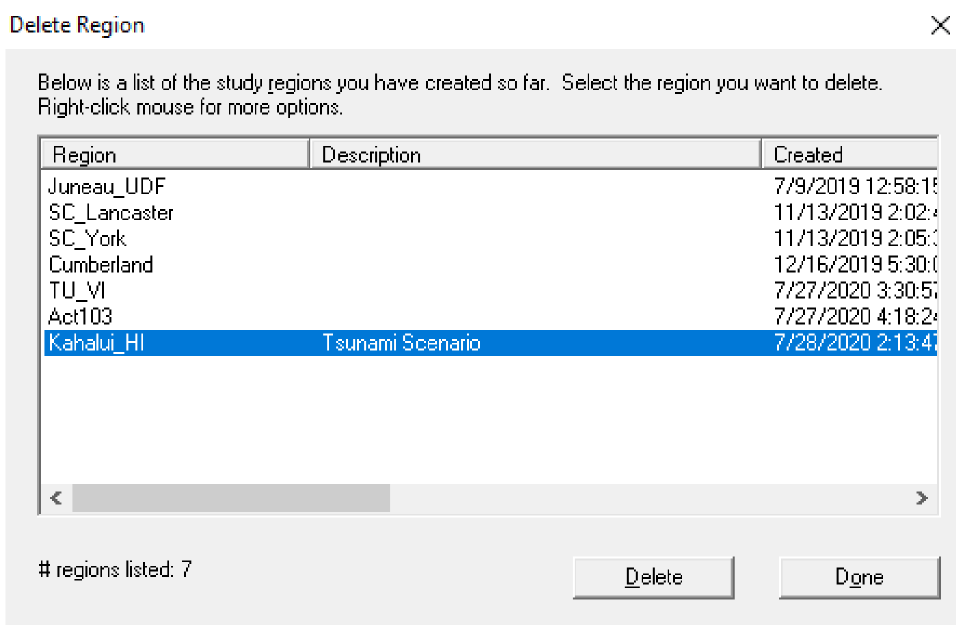


Figure 3-11 Delete a Region

3.5 Duplicate a Region

The **Duplicate a region** option seen in Figure 3-12 will not be available until a region has been created or imported. Select **Duplicate a region** and click **OK**. The selected region can be duplicated as seen in Figure 3-13**.** 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 seen in Figure 3-14. The **Duplicate Region Name** dialog will appear as seen in Figure 3-15. 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, see Figure 3-16. 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 3-17, will appear to notify the user that the region has been duplicated. Click **OK** to return to the **Duplicate Region** list as seen in Figure 3-18. Click **Done** to return to the **Hazus Startup** screen.

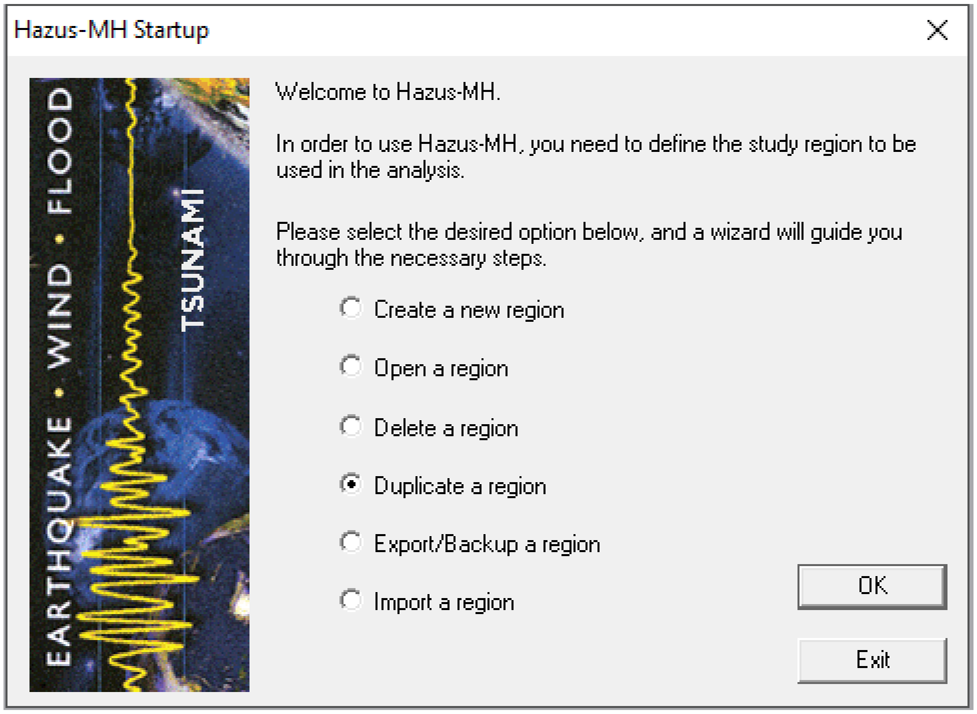


Figure 3-12 Hazus Startup Menu - Duplicate a Region

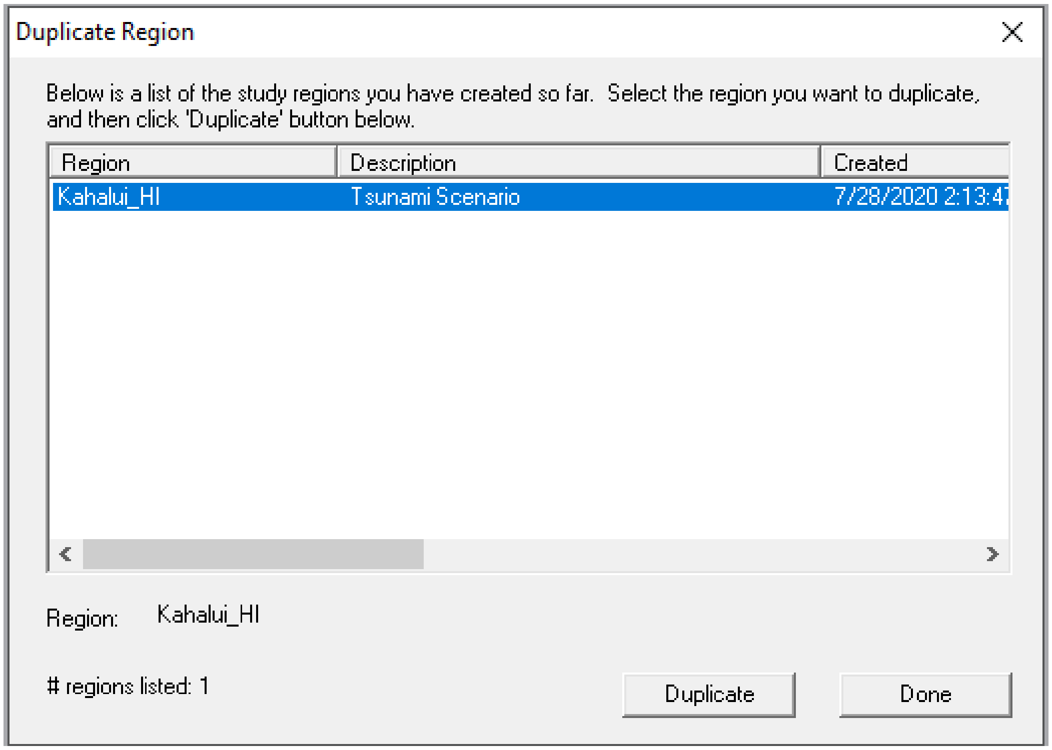


Figure 3-13 Duplicate a Region Selection

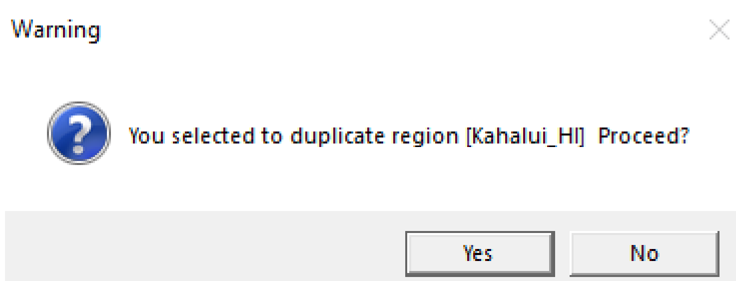


Figure 3-14 Duplicate Warning

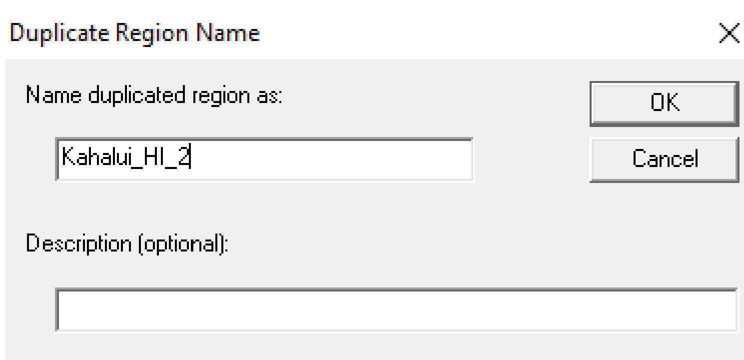


Figure 3-15 Duplicate Region Name

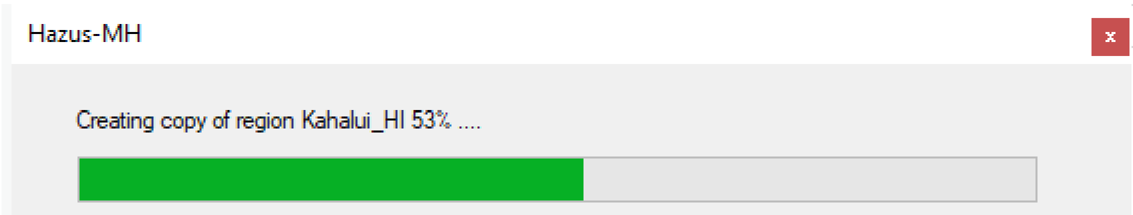


Figure 3-16 Duplicate Region Progress Bar

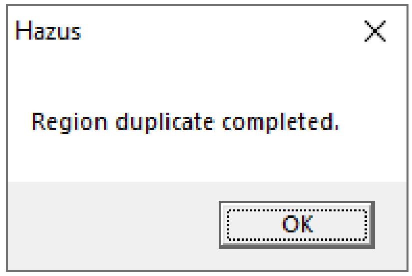


Figure 3-17 Duplication Complete

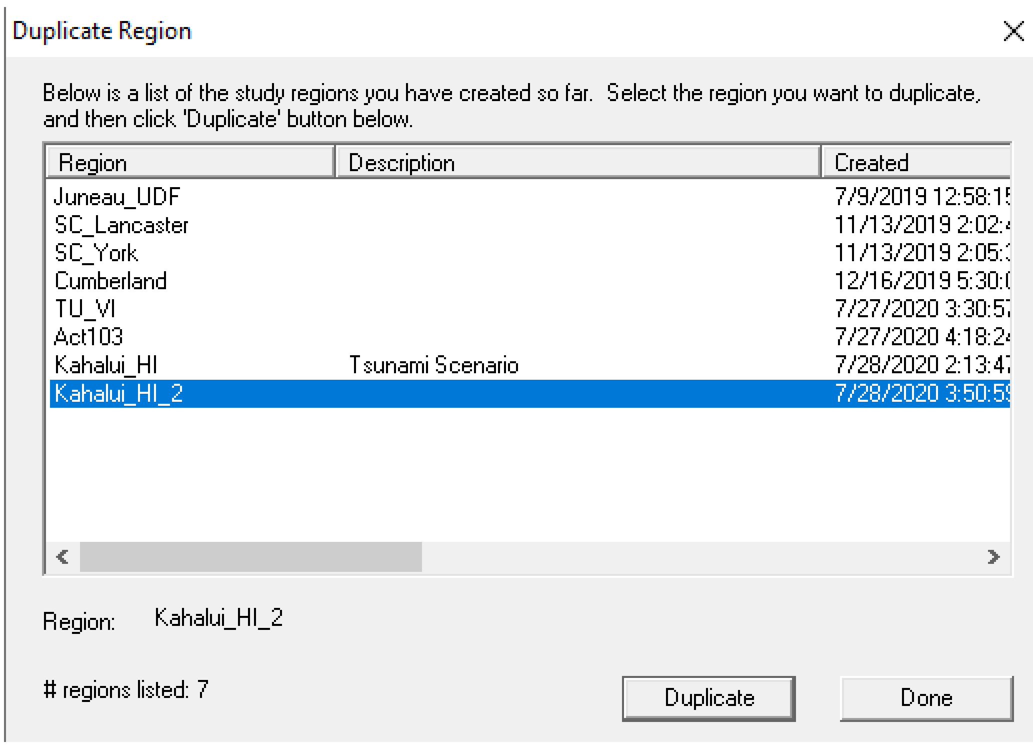


Figure 3-18 Duplicate Region

3.6 Export Region

The **Export/Backup a region** option seen in Figure 3-19 will not be available until a region has been created or imported. Select **Export/Backup a region** and click **OK**. The user can then export or backup a region by following the instructions at the top of the window seen in Figure 3-20.

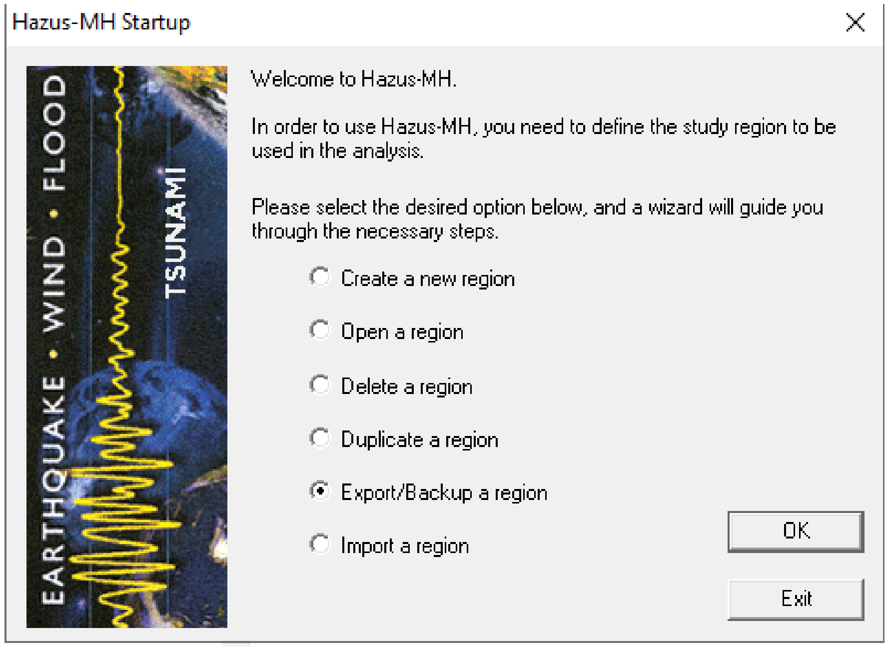


Figure 3-19 Hazus Startup Menu - Export/Backup a Region

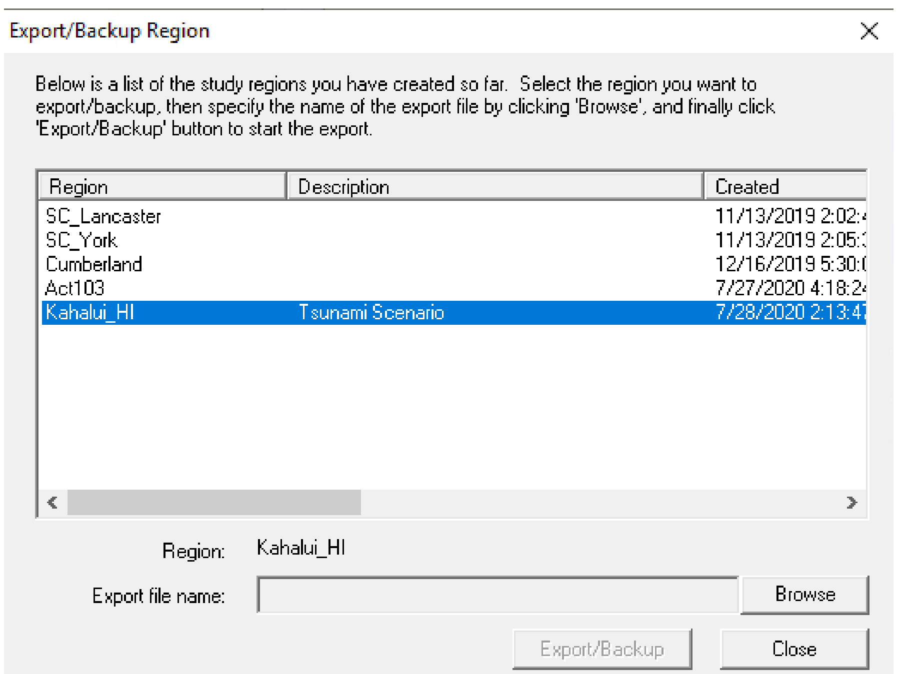


Figure 3-20 Export/Backup a Region

3.7 Import a Region

Select **Import a region** (Figure 3-21) and click **OK**. File explorer will open. Select an export Hazus file (.hpr)**.** The **Imported Region Name** window will open and prompt the user to name the imported region (Figure 3-22).

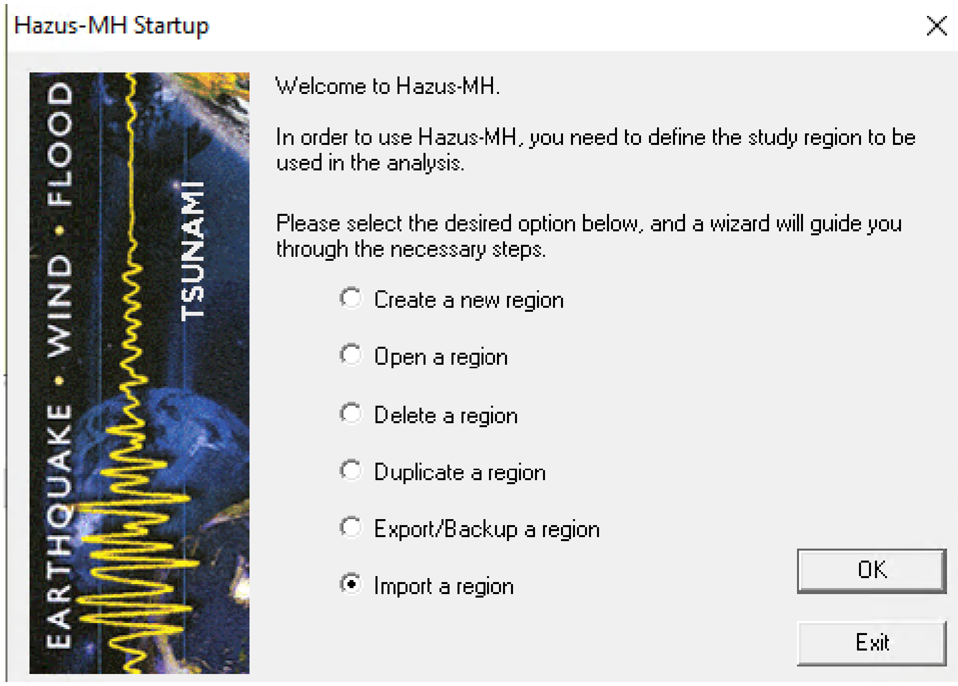


Figure 3-21 Hazus Startup Menu - Import a Region

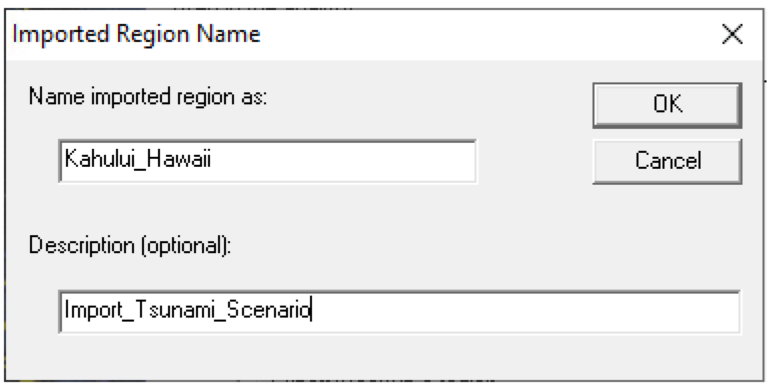


Figure 3-22 Imported Region Name

Section 4. Tsunami Model: Basic Hazus Analysis

The Hazus Tsunami Model allows practitioners to estimate the economic and social losses from tsunami impacts. The information provided by the model might assist state and local officials in evaluating, planning for, and mitigating the effects of tsunami impacts. The Hazus Tsunami Model provides practitioners and policy makers with a tool to help reduce tsunami damage, reduce disaster payments, and make wise use of the nation's emergency management resources. The following example will allow the user to run a Basic Tsunami GBS Analysis and Basic Casualty Analysis.

4.1 Steps to Create and Run a Basic Tsunami GBS Analysis

This section will involve opening a Study Region. Open Hazus (Figure 4-1). Information on all other options can be found in Section 3: Getting Started: Hazus Start-Up Screen. Select **Open a region** and click **OK**. This will open the **Open Region Wizard** (Figure 4-2).

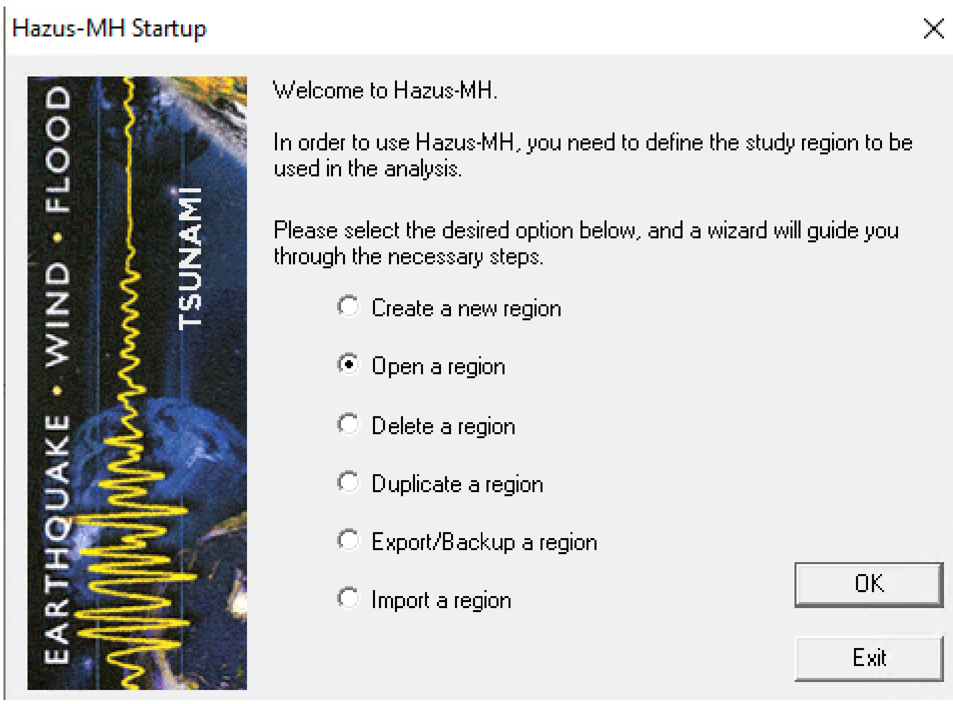


Figure 4-1 Open a Region

Figure 4-2 Open Region Wizard

Select **Next**. In the **Open Region > Select Region** window (Figure 4-3), choose the region. After choosing, click **Next**.

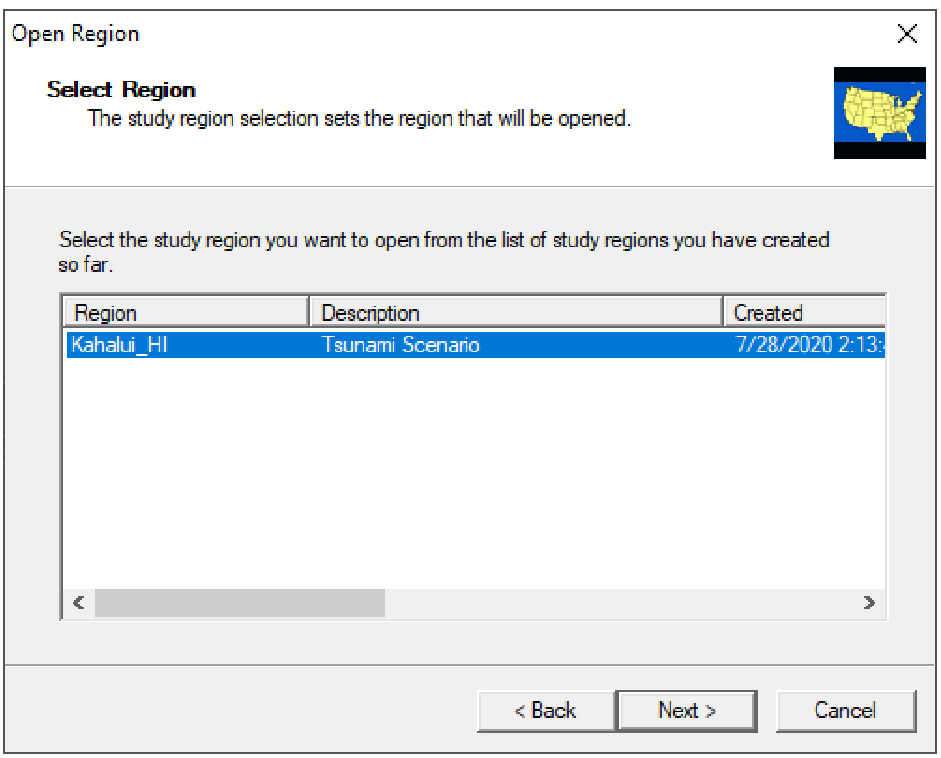


Figure 4-3 Select a Region

This will bring up a review window (Figure 4-4). Here the user can check that the Study Region and hazard selected are as intended. Select **Finish**. ArcMap will open the selected region, as seen in Figure 4-5.

Figure 4-4 Region Review

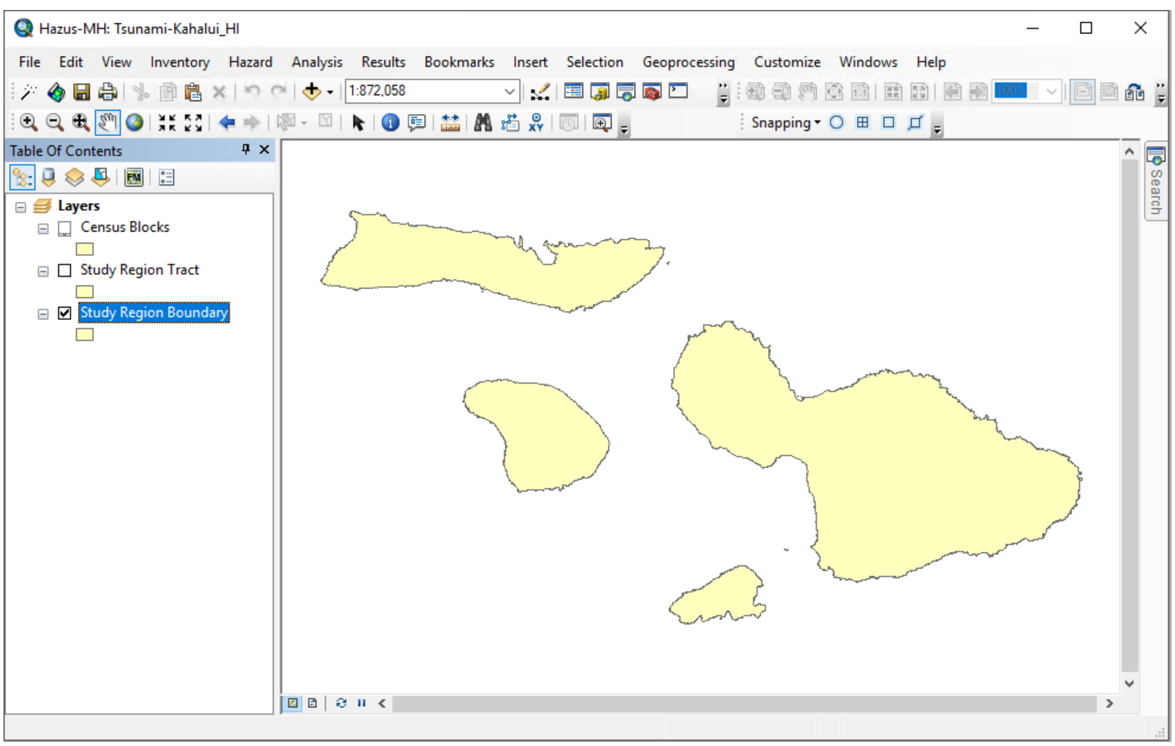


Figure 4-5 ArcMap

Choose the **Hazard** drop-down menu from the toolbar and select **Tsunami Hazard Type** (Figure 4-6).

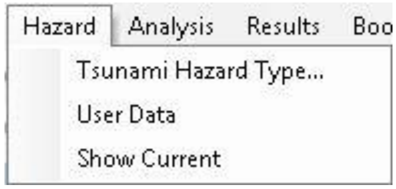


Figure 4-6 Hazard Menu

This opens the **Tsunami Hazard Type** dialog (Figure 4-7) where the user can choose between a **Near Source only** (tsunamigenic source nearby, earthquake impacts may be expected) or **Distant Source** (tsunamigenic source far away, no earthquake impacts). Select **Distant Source** and click **OK**. Return to the **Hazard** drop-down menu and select **User Data**. This will open the **User Data Wizard** (Figure 4-8). Choose the **Level 1: Runup Only-Mean Sea Level (MSL)** option and click **Next**.

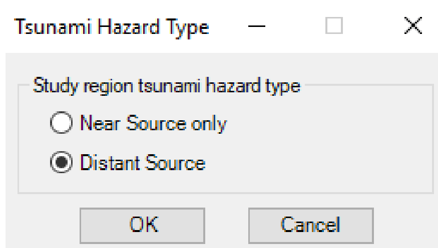


Figure 4-7 Tsunami Hazard Type

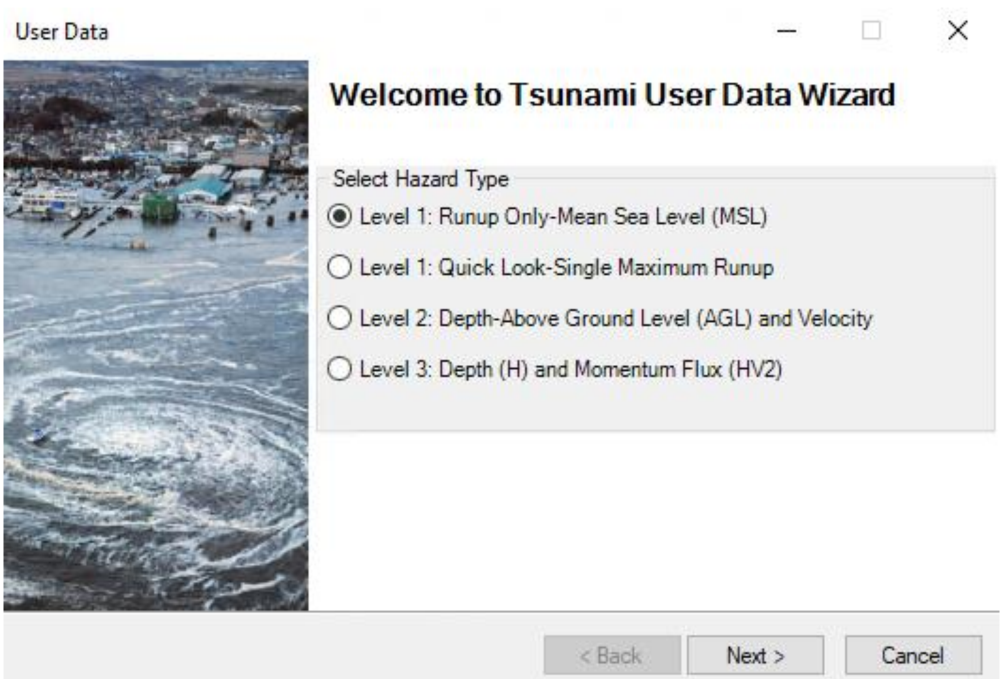


Figure 4-8 User Data Wizard

In the **Level 1: Runup Height Only** window (Figure 4-9), click the **Determine required DEM extent** button. This step will locate and extract a digital elevation model (DEM) for the Study Region. It may take a few moments.

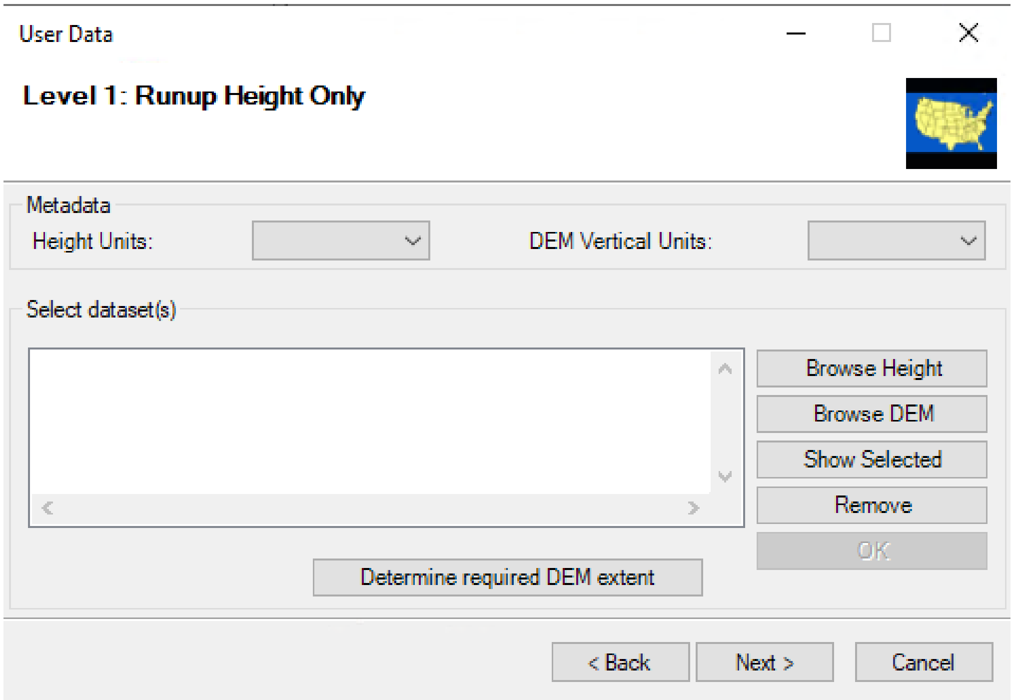


Figure 4-9 Level 1 (Basic) DEM Extraction

When the **DEM Extent** window appears, click the **Download DEM** option to save the DEMs (Figure 4-10). The **NED Resolution** menu allows the user to select the resolution of the DEMs (vertical units for NED data will be meters). When complete, a dialog will pop up with the location of the saved DEM (Figure 4-11).

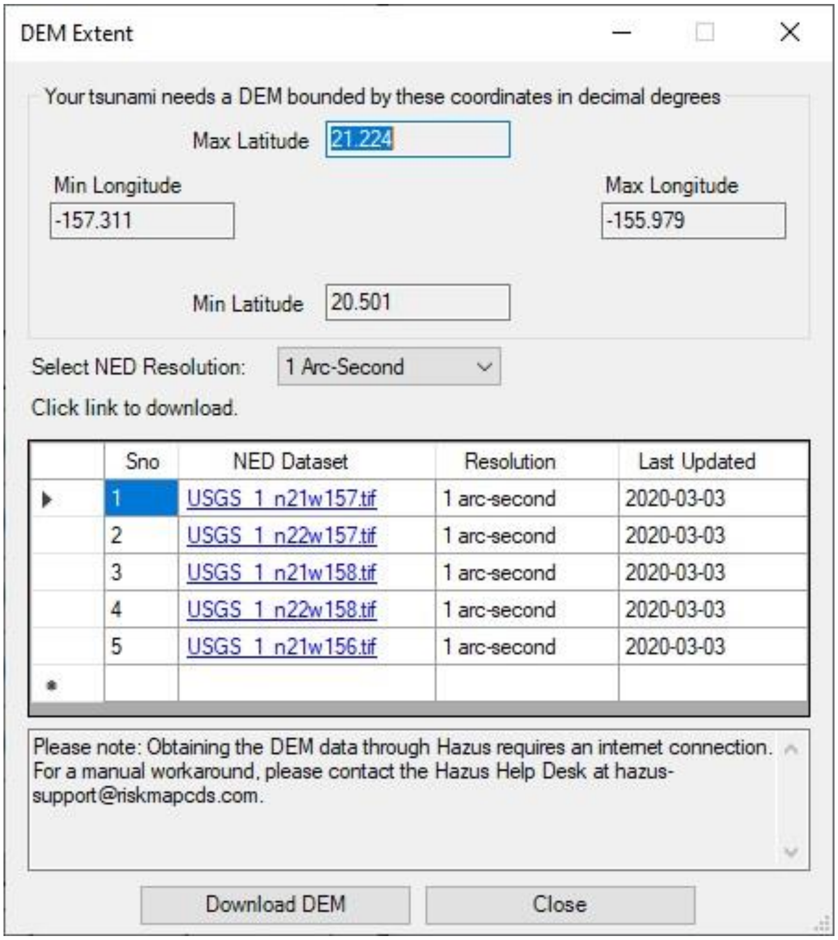


Figure 4-10 DEM Extent

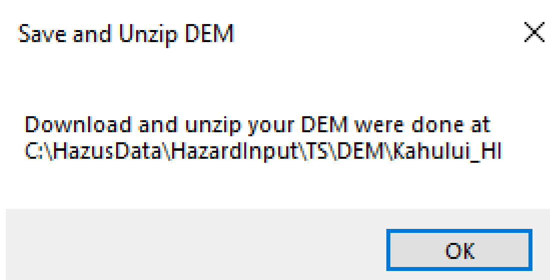


Figure 4-11 Save and Unzip DEM

Once the files have been downloaded and unzipped, the DEMs should be merged into a single DEM which will be easier to process. Additionally, the model works best if the DEM is 'clipped' to the on-land inundation areas where the Hazus modeled losses will occur in the Study Region. This can be done in two steps using two ArcGIS raster geoprocessing tools in Arc Toolbox. Note that the Spatial Analyst extension is required to use the following two tools.

The first step is to mosaic all the discrete DEM rasters into one raster. The tool used is the Mosaic to New Raster found in Arc ToolBox under Data Management Tools > Raster > Raster Dataset > Mosaic to New Raster (see Figure 4-12). Add all downloaded DEM files to this tool as input and give it a new name with .tif as the file extension.

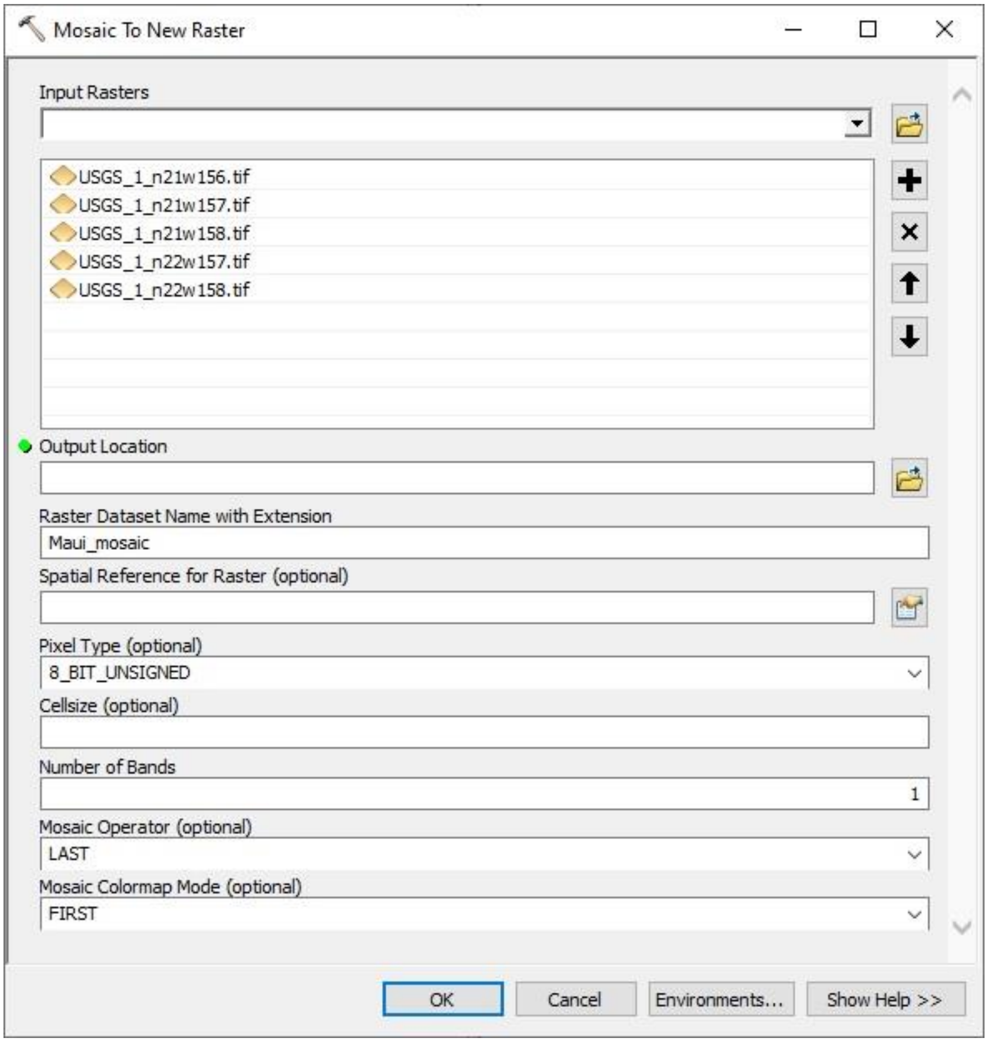


Figure 4-12 Mosaic to New Raster Tool

The second step is to 'clip' the DEM generated in the previous step to the land area of the Study Region. This step helps to reduce processing time. The tool used is Extract by Mask, which extracts the cells of a raster that correspond to the areas defined by a mask, in this case the Study Region boundary. The tool can be found in Arc Toolbox under Spatial Analyst Tools > Extraction > Extract by Mask (see Figure 4-13). The tool takes two datasets as inputs (the raster created in the previous step and the Study Region boundary file) and creates one output raster with .tif as the file extension. The result should look like the example in Figure 4-14.

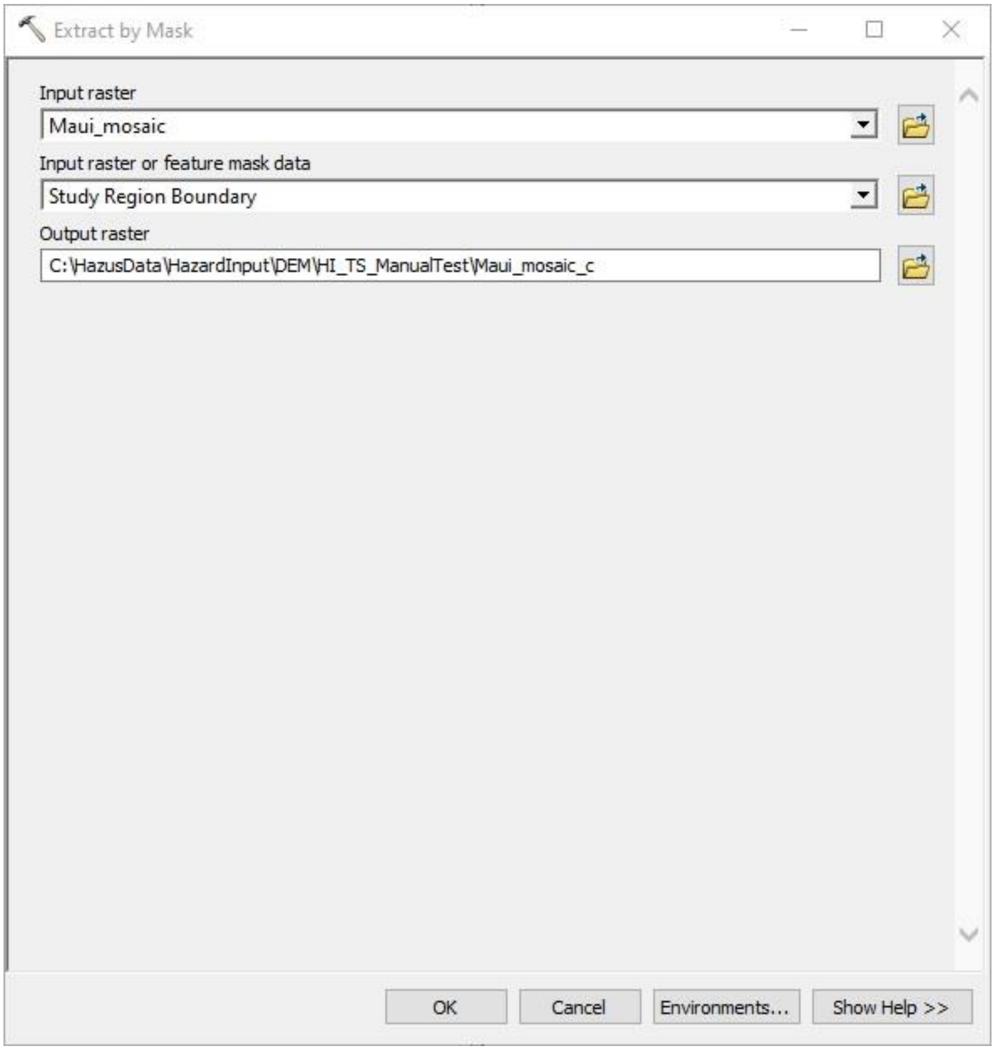


Figure 4-13 Extract by Mask Tool

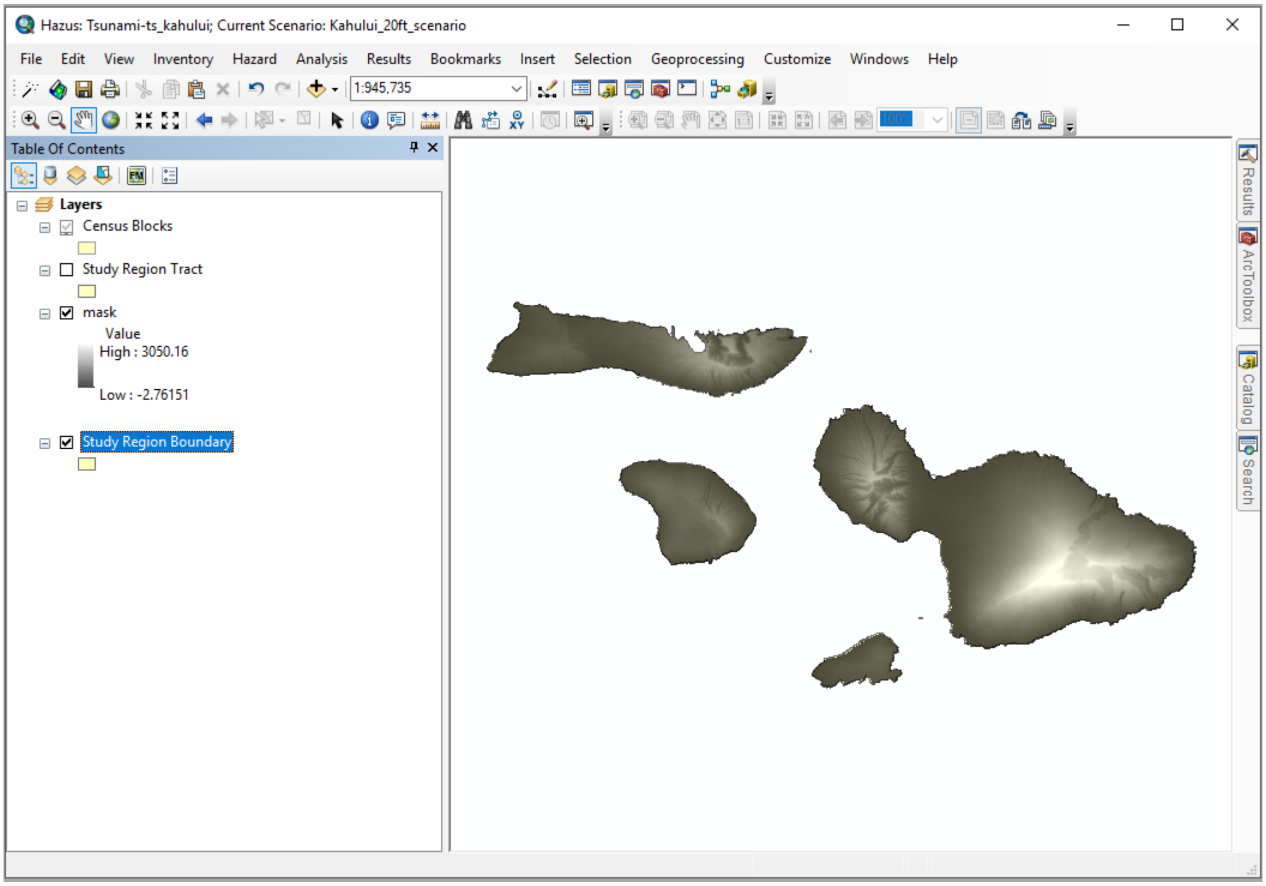


Figure 4-14 Mask DEM to Study Region

Return to the **Hazard** drop-down menu, select **User Data** again. Choose the **Level 1: Quick Look-Single Maximum Runup** option and click **Next** (Figure 4-15).

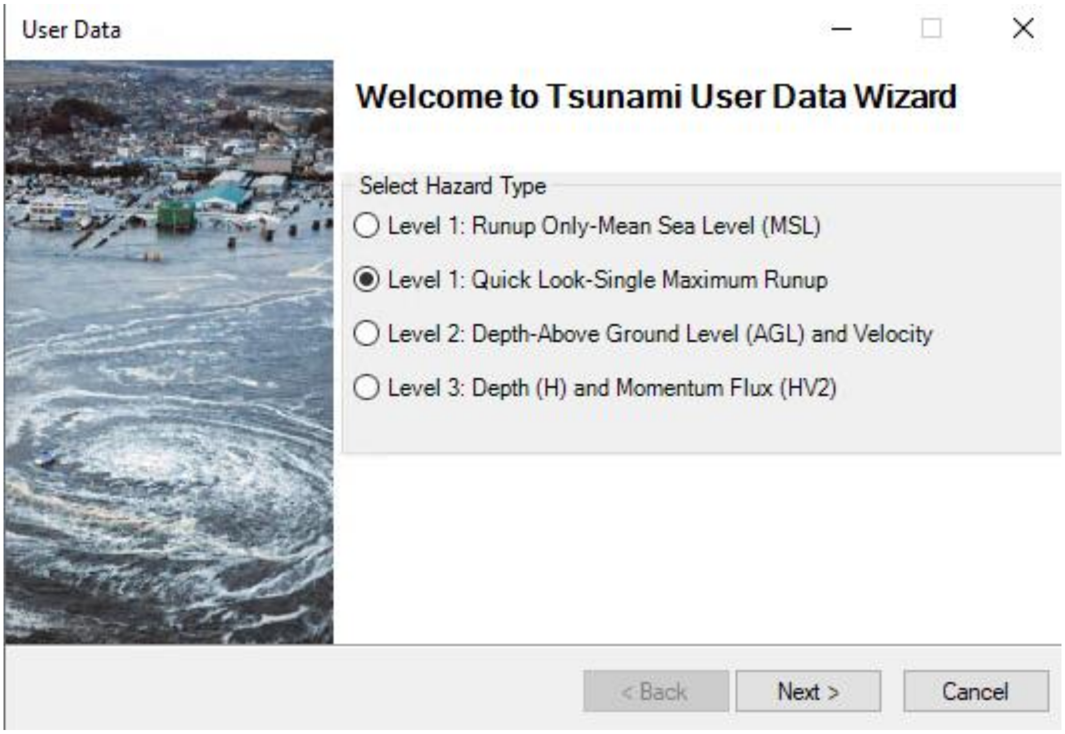


Figure 4-15 Level 1 Quick Look Option

In the **Quick Look** window (Figure 4-16), select the **DEM Vertical Units and Maximum Runup Units** from the dropdown menus, please note that USGS DEM vertical units are in meters. Enter a Maximum Runup Height Value (vertical elevation of the furthest inundation of the tsunami with respect to the initial sea level – see *Hazus Tsunami Model Technical Manual* (FEMA, 2021), Section 4 and **Browse DEM** to select the masked DEM from Figure 4-14. Click **OK**. A processing notification will popup (Figure 4-17). When it vanishes, click **Next**.

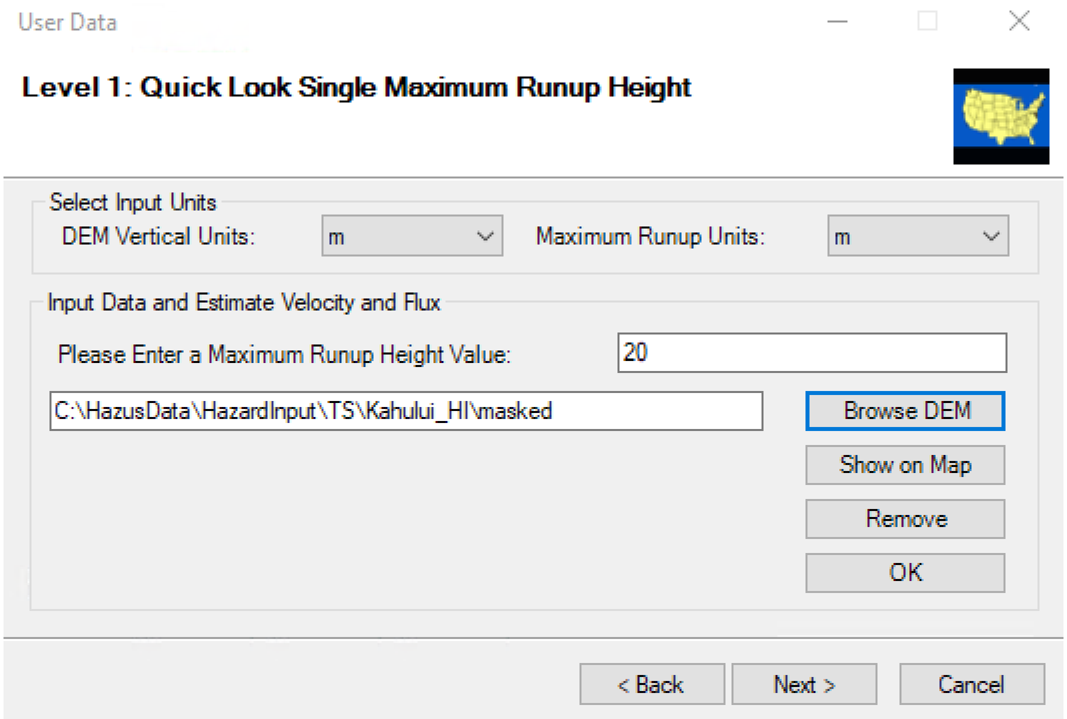


Figure 4-16 Quick Look Window

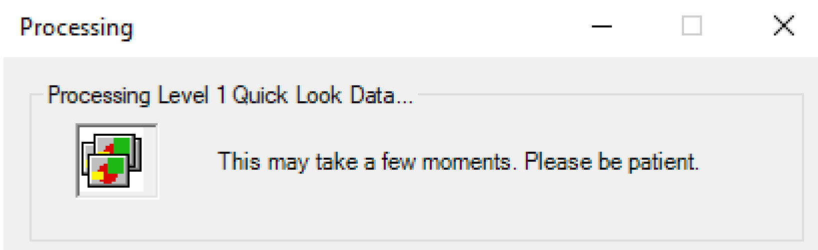


Figure 4-17 Processing Window

Enter the tsunami scenario name (Figure 4-18), click **Next**. The model will now use the DEM and the entered maximum runup height value to create a hazard boundary (Figure 4-19) for the analysis. The boundaries include a median inundation depth (ft) and a median momentum flux (ft^3/sec^2) (Figure 4-20). The layers are added to the Study Region (Figure 4-21). Click **OK** in the next window to complete.

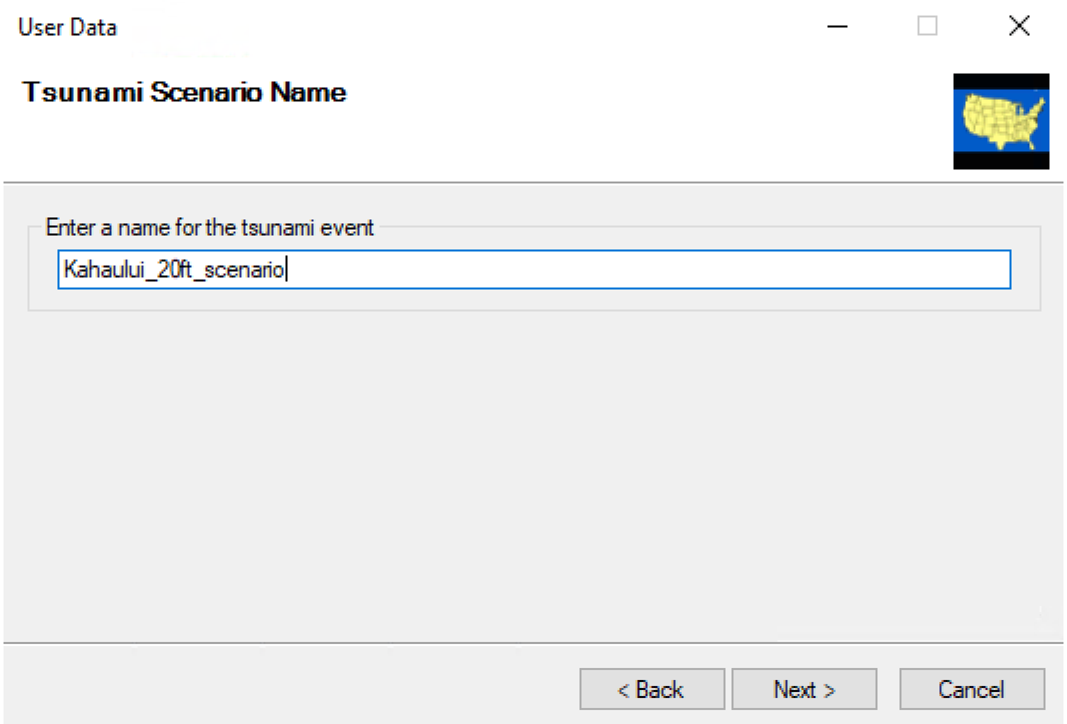


Figure 4-18 Tsunami Scenario Name

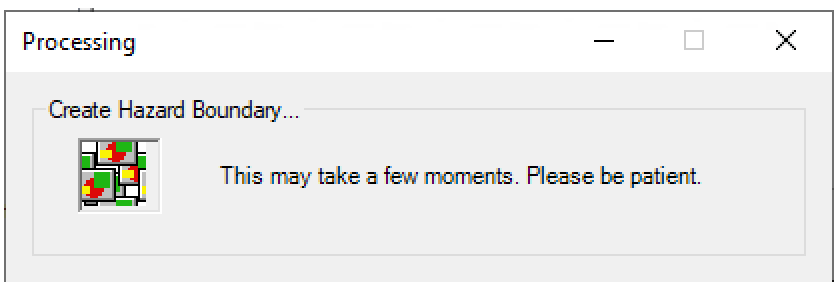


Figure 4-19 Hazard Boundary Creation

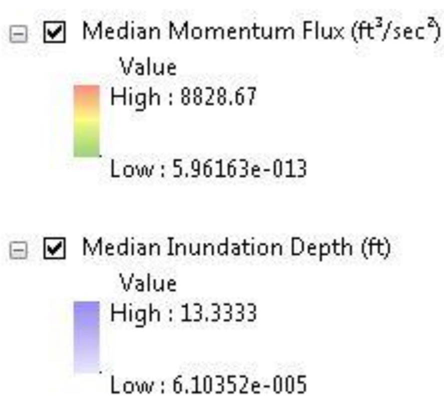


Figure 4-20 Hazard Layers

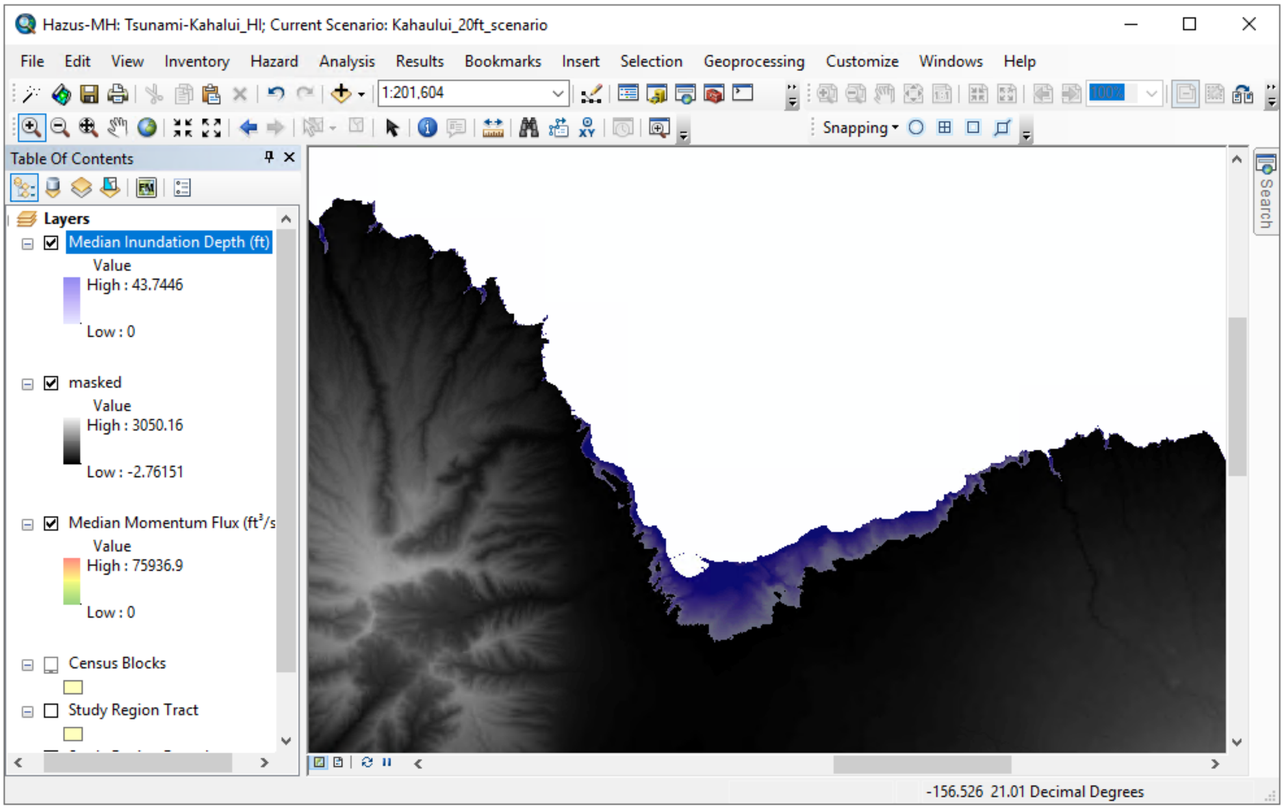


Figure 4-21 Median Inundation Depth (ft)

On the **Analysis** drop-down menu, select **Run** (Figure 4-22). Click **OK** on the **Combined Analysis** notice (Figure 4-23). The notice refers to the Combined Earthquake and Tsunami Analysis for Near Source events only. If a Distant Source event tsunami is selected, no earthquake damages will be modeled. See Section 11 for more information.

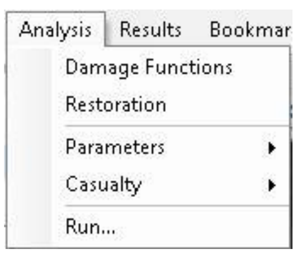


Figure 4-22 Analysis Menu

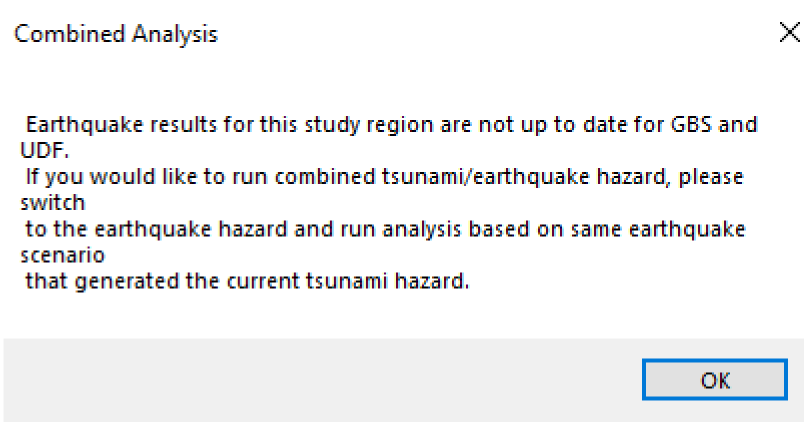


Figure 4-23 Combined Analysis Window

In the **Analysis Option – Tsunami** window, click **Select All** (Figure 4-24), then **OK**. A processing notification will appear (Figure 4-25). This may take a few moments.

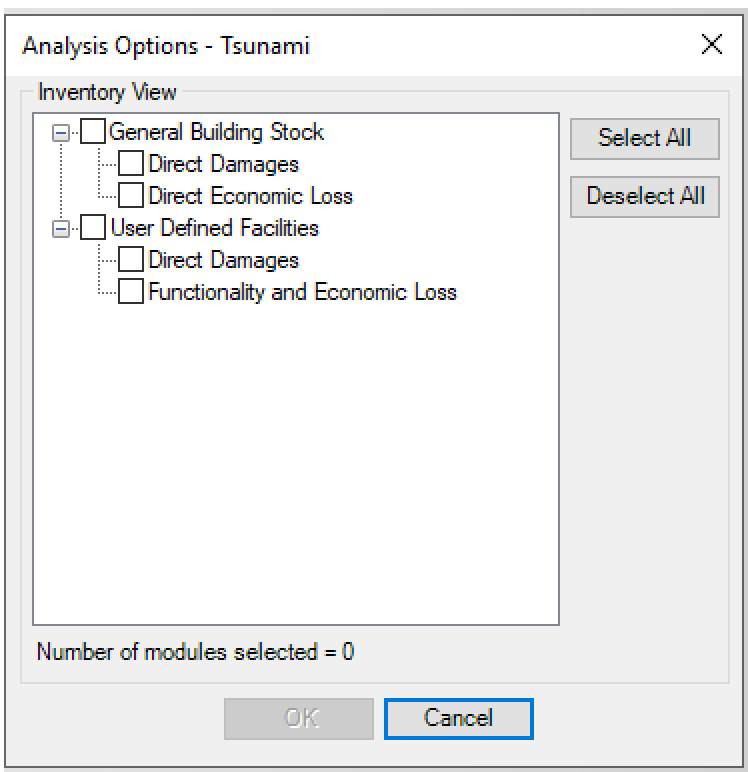


Figure 4-24 Analysis Option – Tsunami Window

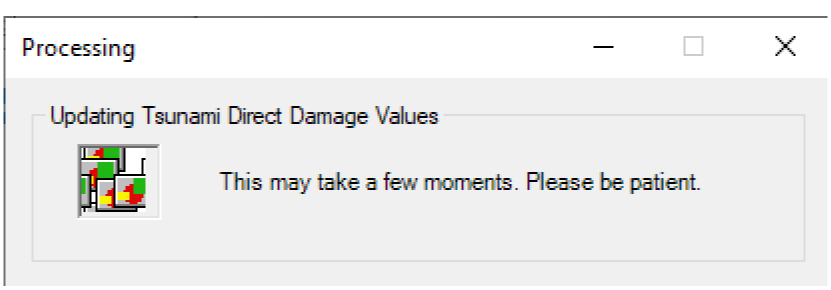


Figure 4-25 Processing Window

When the analysis is complete, a notice will appear (Figure 4-26). Click **OK**. Results are viewable under the **Results** heading on the toolbar. See Section 8 for more information.

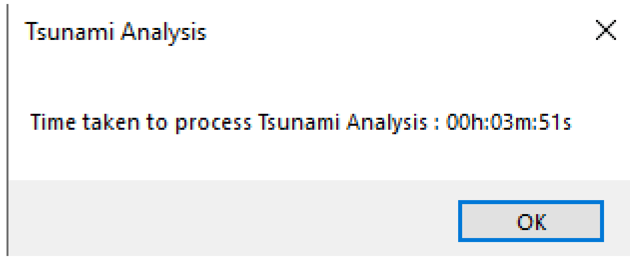


Figure 4-26 Analysis Completion Notice

4.2 Steps to Create and Run a Level 1 (Basic) Casualty Analysis

Level 1 (Basic) casualty estimates can be calculated after the tsunami GBS analysis is complete. On the **Analysis** drop-down menu, choose **Casualty** (Figure 4-27). On the **Casualty** submenu, choose **Download TIGER Roadway Network** to download the road data[1]. The model will save the road network data to the C:\HazusData\HazardInput\TS\TIGER\Roads folder under the county FIPS code for the Study Region.

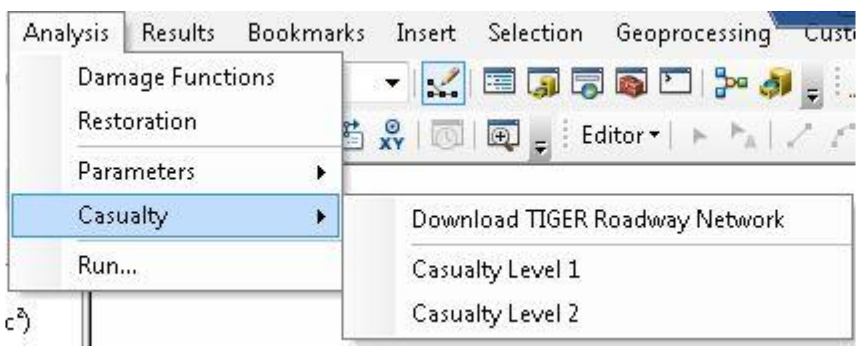


Figure 4-27 Casualty Menu

Select the **Analysis** drop-down menu, choose **Casualty** again, and then **Casualty Level 1 (Basic)**. In the **Casualty Level 1 (Basic)** window (Figure 4-28), load the DEM, the roads data, the hazard boundary and fatality boundary data.

[1] Note: If a download error occurs, the road network can be obtained from the TIGER data website based on County FIPS.

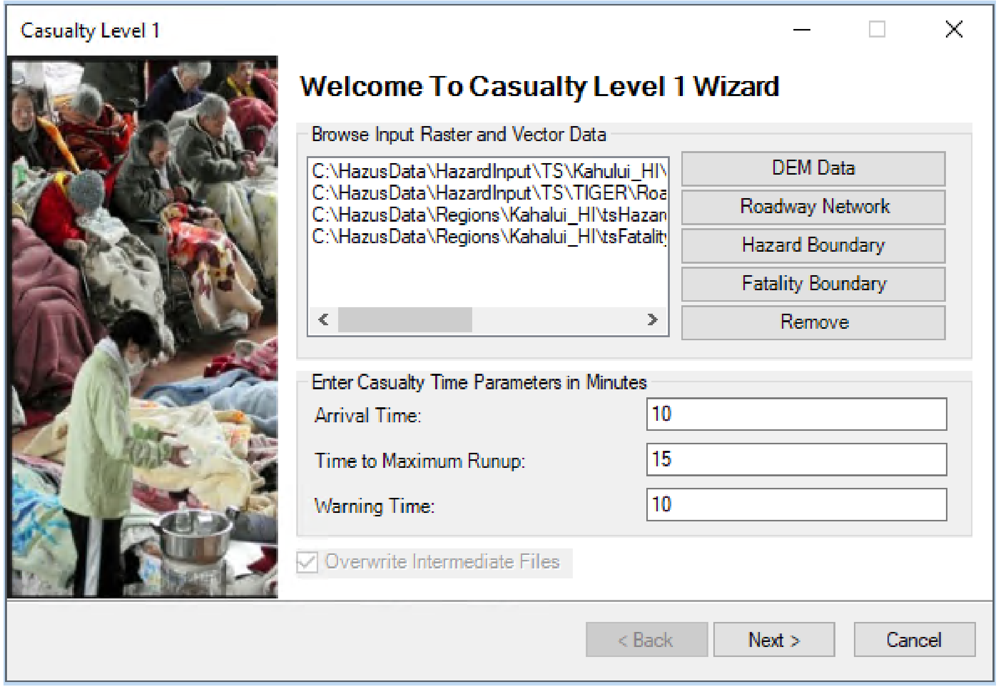


Figure 4-28 Casualty Level 1 Window

The hazard boundary and fatality boundary are processed by the model and can be located in the **Regions** folder under the **Study Region** folder (Figure 4-29). The hazard boundary is the inundation hazard boundary (depth > 0), and the fatality boundary is the portion of the inundation hazard where the flood depths are expected to be 2 meters or greater in depth (Fatality Rate = 99%). Users should review the boundaries to determine whether slivers along the coast or other small pockets that intersect the road network might result in areas that would not be considered safe for evacuation, (where the slivers intersect roadways) and remove them. If the sliver does not intersect a roadway, the user does not have to remove it, as it will not be identified by the model.

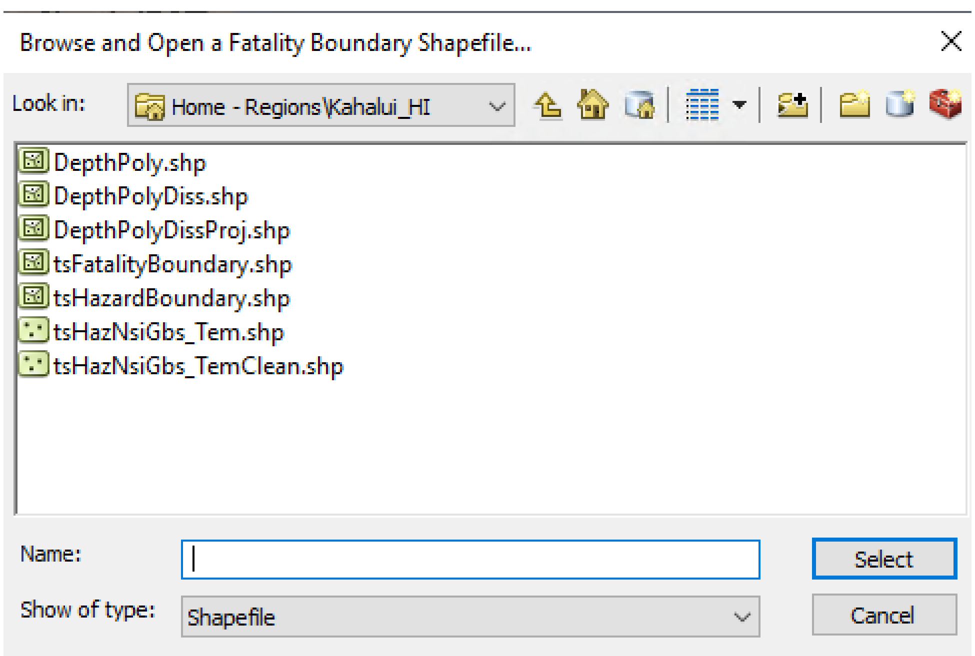


Figure 4-29 Study Region Folder

To assist in evaluation analysis, the USGS developed the Pedestrian Evacuation Analyst software to aid in pedestrian evacuation from sudden-onset hazards. The software assists in evacuation analysis by managing the data files and providing an orderly path through the processing. The goal is to provide a research tool for exploratory analysis of evacuation potential on the landscape. Results are intended to initiate risk-reduction and preparedness discussions within communities. The USGS Pedestrian Evacuation Analyst methodology document is available online.

To determine if slivers exist, add the **Hazard Boundary** and **Fatality Boundary** layers to the ArcMap and compare with the TIGER roads data from the step above.

If gaps overlap with the road data, the model will read this as a safe place for evacuation (represented in the image – see blue arrow in Figure 4-30). If the gap does not overlap with a road, it will not be considered in the calculation. For this scenario, there are gaps at the Kahului Harbor. To fix the layer, use the **Editor** toolbar. In the drop-down menu, select **Start Editing**. Select the **Fatality Boundary** layer and use the **Edit Vertices** option. Click on the **green square** and drag the polygon to cover the road. When finished elect **Stop Editing** from the drop-down menu and click **Save** to save the edits. Repeat these steps with the Hazard Boundary layer.

Figure 4-30 shows a point along the coast intersecting a road segment that would be identified as "safe" if left within the hazard boundary. Road segments are represented as polygons in the figure. Note that the model did run with this sliver left in the hazard boundary but produced erroneously low evacuation times for the area denoted by the arrow, which is shown in the figure for polygon segments for that portion of the roadway.

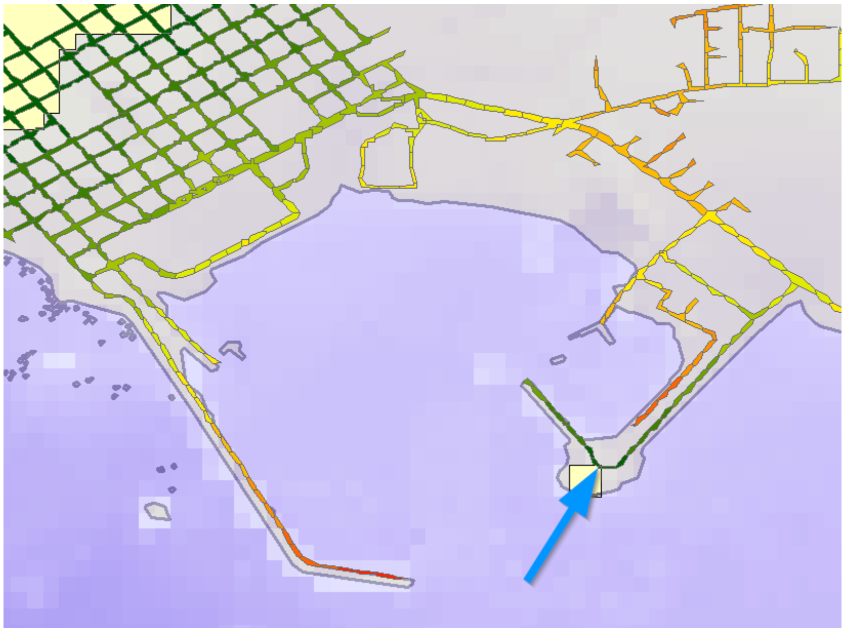


Figure 4-30 Hazard Boundary Error Checking

Once the input data is selected, enter the casualty time parameters in the boxes below. The model will enter baseline values once there is a value for **Arrival Time** (see back to Figure 4-28). However, the user should review these and modify as needed. This data is able to be viewed and opened (see back to Figure 4-29). *Note: Warning time cannot exceed arrival time; if values are entered that are inconsistent with this, Hazus will prompt the user to change them. In addition, for a near source event where the ground shaking provides the trigger for warning, a warning time value of 0 minutes (recommended) may be entered.* Click **Next**.

The next few steps are processed by the model, beginning with the processing of the Level 1 Casualty Input. This step projects the data into the same projected coordinate system (Figure 4-31). Click **Next**. The model then preprocesses the DEM, roads and hazard boundaries to ensure consistent projections and reproject if necessary (Figure 4-32)**.** The default output cell size is 10 meters. The Speed Conservation Value (SCV) default is 1, which assumes that road networks have no reduction in the capability to support evacuation. SCV less than 1 reduces the capability of the road network to support evacuation (see USGS Pedestrian Evacuation Analyst Tool for more information). Click **Next**.

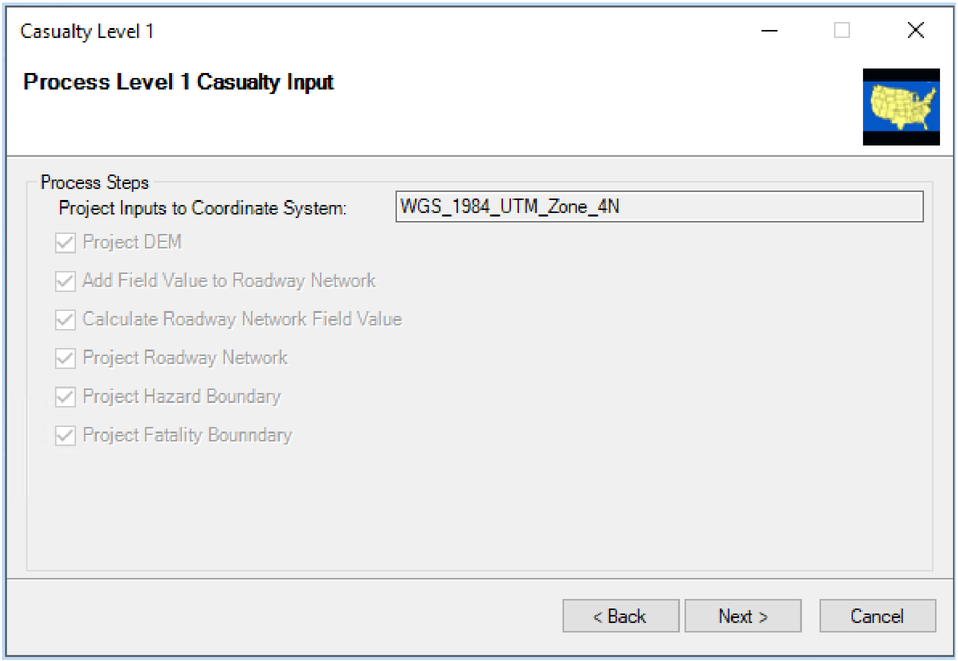


Figure 4-31 Process Level 1 Casualty Input

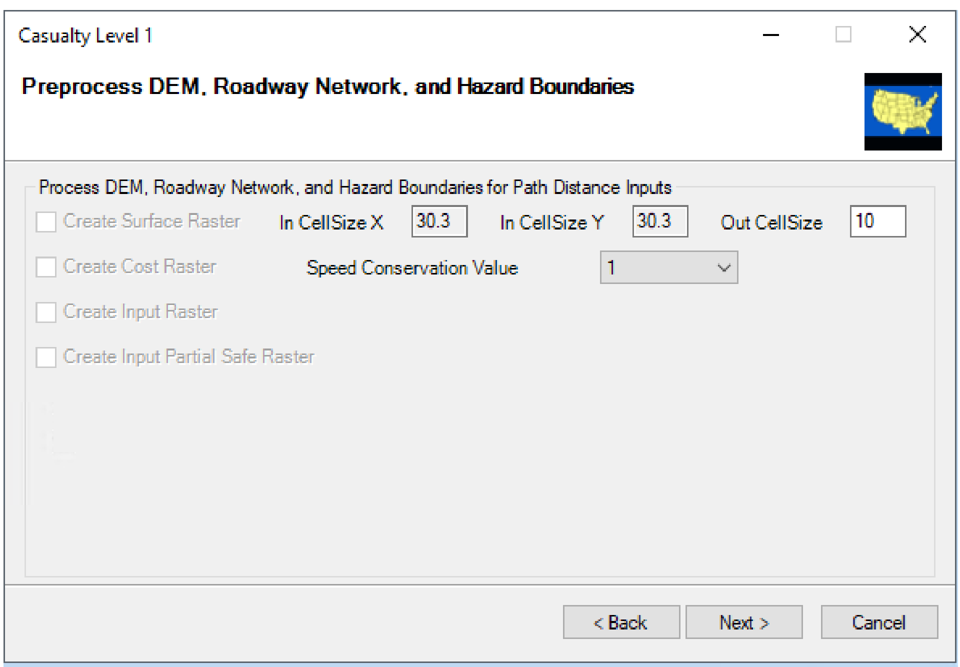


Figure 4-32 Preprocess Data

Next, the model calculates the evacuation time required at the selected travel speed (Figure 4-33). The baseline speed is **Average Walk**. The **Maximum Travel Time in Minutes**, by default, is blank. The maximum travel time available for pedestrian evacuation will set all values in the travel time map raster that exceed the maximum. This could be useful if longer pedestrian travel times do not impact the results of the analysis, such as a local tsunami with very little travel time available before maximum inundation. Click **Next**.

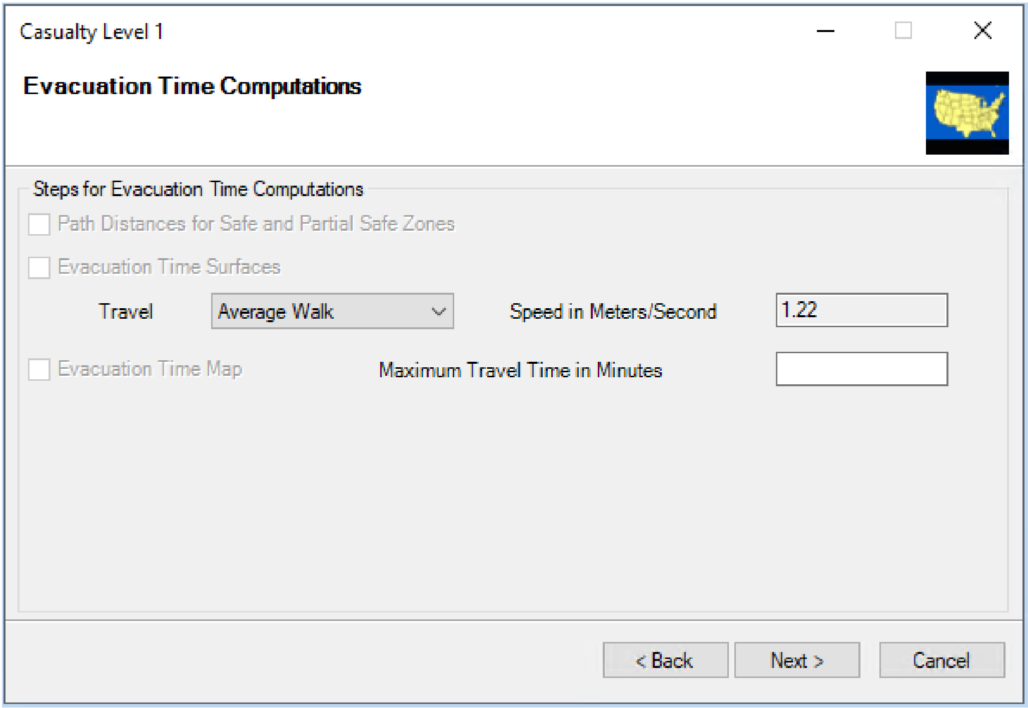


Figure 4-33 Evacuation Time

Next, the model computes travel time and the probability of casualties (Figure 4-34). Click **Next**.

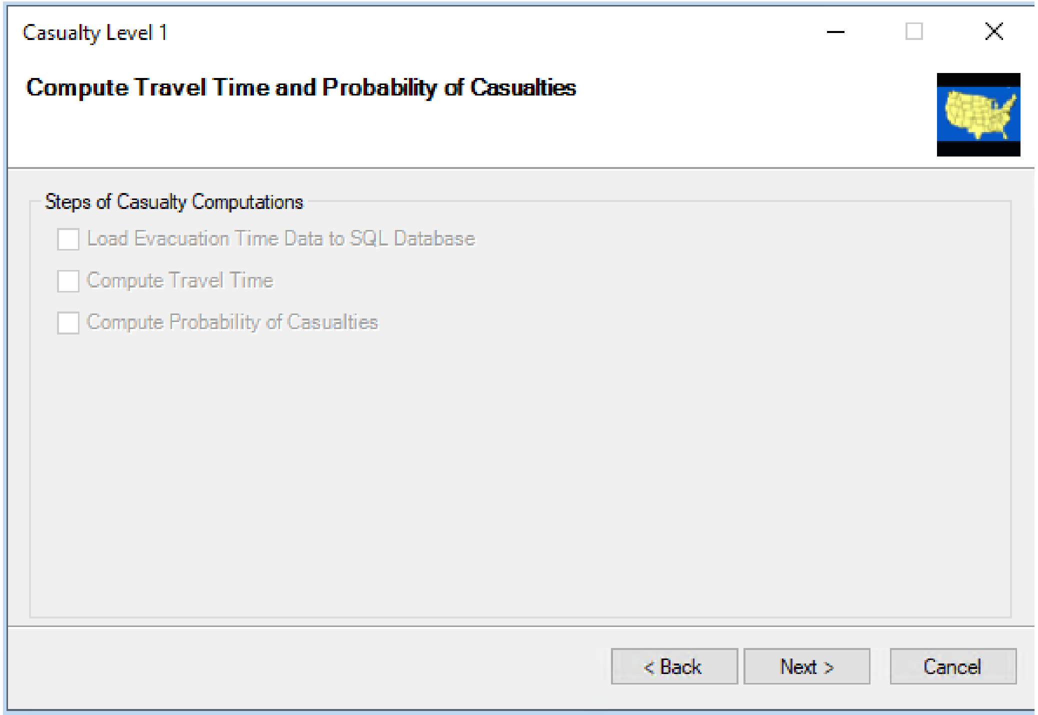


Figure 4-34 Travel Time and Probability of Casualties

This completes the **Casualty Level 1 Estimate** (Figure 4-35). Click **OK**. The results and reports are accessible under the **Results** drop-down menu (see Section 8 for more information).

Figure 4-35 Complete Casualty Level 1 Wizard

Section 5. Tsunami Model: Inventory Menu

5.1 Inventory Menu

The **Inventory** menu (Figure 5-1) has several inventory types and submenus from which to choose. These options enable the user to estimate the amount of exposure or potential damage in the Study Region. This section explains each selection and submenu to further the user's understanding of these options. Additional information can be found in the *Hazus Inventory Technical Manual* (FEMA, 2021).

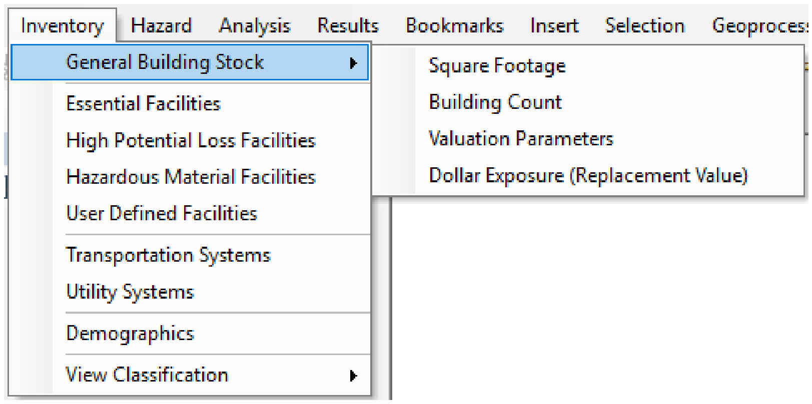
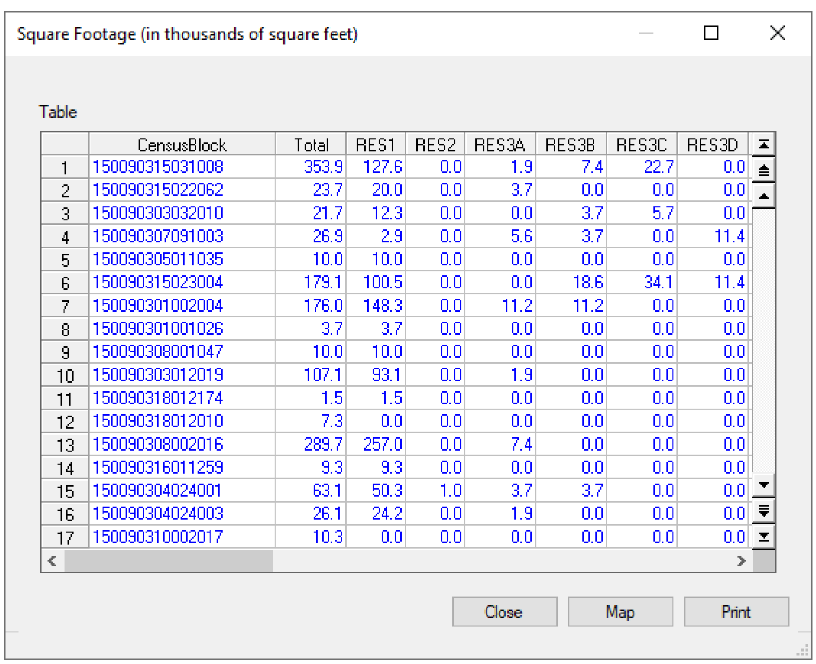


Figure 5-1 Hazus Inventory Menu

5.2 General Building Stock (GBS)

The first option within the **Inventory** menu is **General Building Stock**. The first submenu option allows the user to see the square footage distribution (in thousands of square feet) by specific occupancy type per Census block (or tract) as seen in Figure 5-2.



Square Footage (in thousands of square feet)

Table

	CensusBlock	Total	RES1	RES2	RES3A	RES3B	RES3C	RES3D
1	150090315031008	353.9	127.6	0.0	1.9	7.4	22.7	0.0
2	150090315022062	23.7	20.0	0.0	3.7	0.0	0.0	0.0
3	150090303032010	21.7	12.3	0.0	0.0	3.7	5.7	0.0
4	150090307091003	26.9	2.9	0.0	5.6	3.7	0.0	11.4
5	150090305011035	10.0	10.0	0.0	0.0	0.0	0.0	0.0
6	150090315023004	179.1	100.5	0.0	0.0	18.6	34.1	11.4
7	150090301002004	176.0	148.3	0.0	11.2	11.2	0.0	0.0
8	150090301001026	3.7	3.7	0.0	0.0	0.0	0.0	0.0
9	150090308001047	10.0	10.0	0.0	0.0	0.0	0.0	0.0
10	150090303012019	107.1	93.1	0.0	1.9	0.0	0.0	0.0
11	150090318012174	1.5	1.5	0.0	0.0	0.0	0.0	0.0
12	150090318012010	7.3	0.0	0.0	0.0	0.0	0.0	0.0
13	150090308002016	289.7	257.0	0.0	7.4	0.0	0.0	0.0
14	150090316011259	9.3	9.3	0.0	0.0	0.0	0.0	0.0
15	150090304024001	63.1	50.3	1.0	3.7	3.7	0.0	0.0
16	150090304024003	26.1	24.2	0.0	1.9	0.0	0.0	0.0
17	150090310002017	10.3	0.0	0.0	0.0	0.0	0.0	0.0

Close Map Print

Figure 5-2 Square Footage Table

The **Square Footage** data dialog (Figure 5-2 Square Footage Table) 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.
  - 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. Adding new block data is disabled because the link between the tabular data and their geospatial attributes would be missing. The new block 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 block 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[2].

- 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[3].

5.2.1 GBS Building Count

The **Building Count** inventory in the **General Building Stock** submenu option (Figure 5-3) allows the user to review building count per Census block by occupancy for both specific occupancy and general occupancy, as well as by general building type, as seen in Figure 5-4.

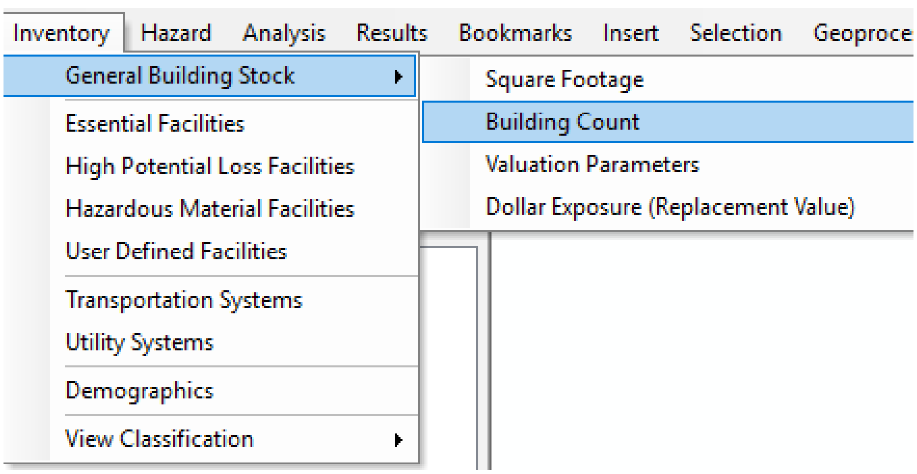
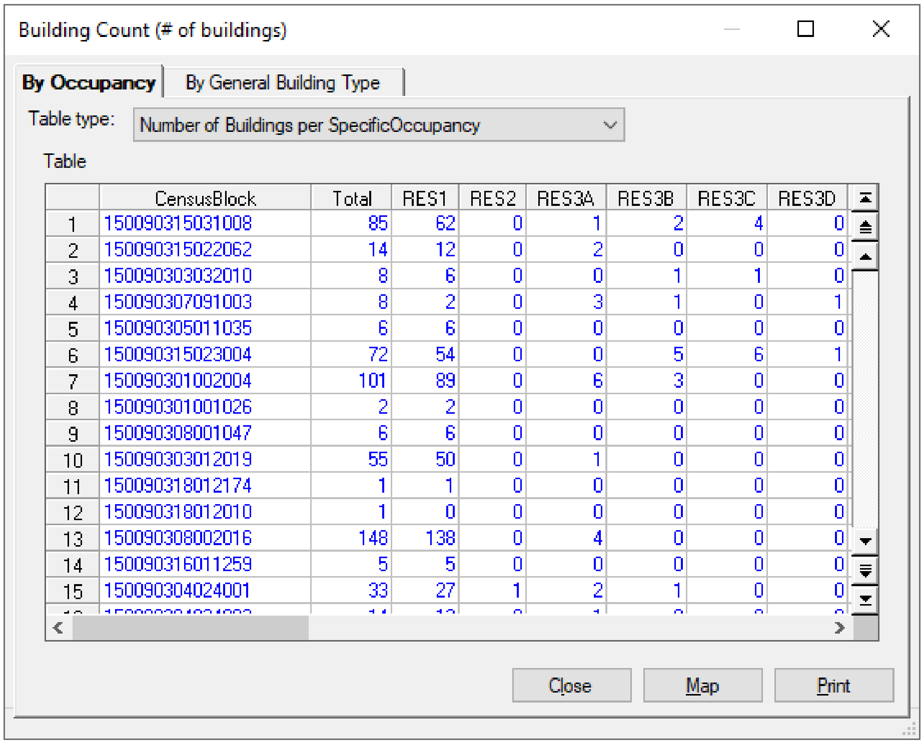


Figure 5-3 General Building Stock Building Count Menu

[2] 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.

[3] 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.



	CensusBlock	Total	RES1	RES2	RES3A	RES3B	RES3C	RES3D
1	150090315031008	85	62	0	1	2	4	0
2	150090315022062	14	12	0	2	0	0	0
3	150090303032010	8	6	0	0	1	1	0
4	150090307091003	8	2	0	3	1	0	1
5	150090305011035	6	6	0	0	0	0	0
6	150090315023004	72	54	0	0	5	6	1
7	150090301002004	101	89	0	6	3	0	0
8	150090301001026	2	2	0	0	0	0	0
9	150090308001047	6	6	0	0	0	0	0
10	150090303012019	55	50	0	1	0	0	0
11	150090318012174	1	1	0	0	0	0	0
12	150090318012010	1	0	0	0	0	0	0
13	150090308002016	148	138	0	4	0	0	0
14	150090316011259	5	5	0	0	0	0	0
15	150090304024001	33	27	1	2	1	0	0

Figure 5-4 General Building Stock Building Count Table

5.2.2 Valuation Parameters

The **Valuation Parameters** option (Figure 5-5) allows the user to review the estimated replacement cost per square foot for each type of building occupancy (Figure 5-6).

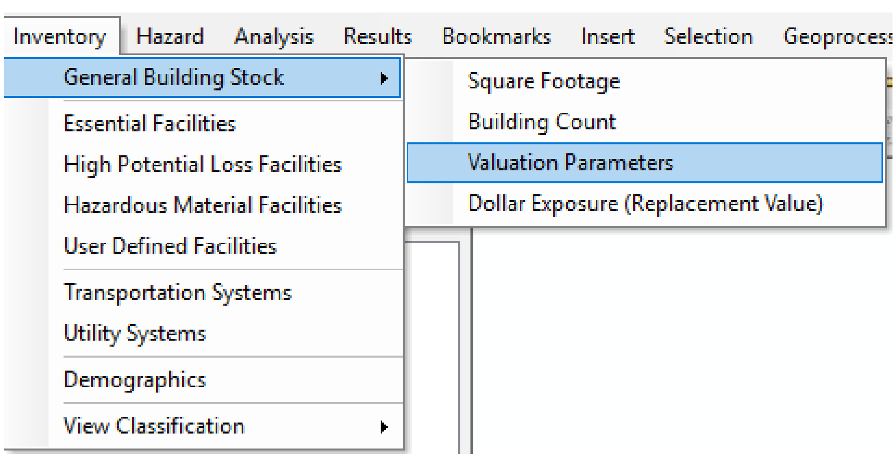
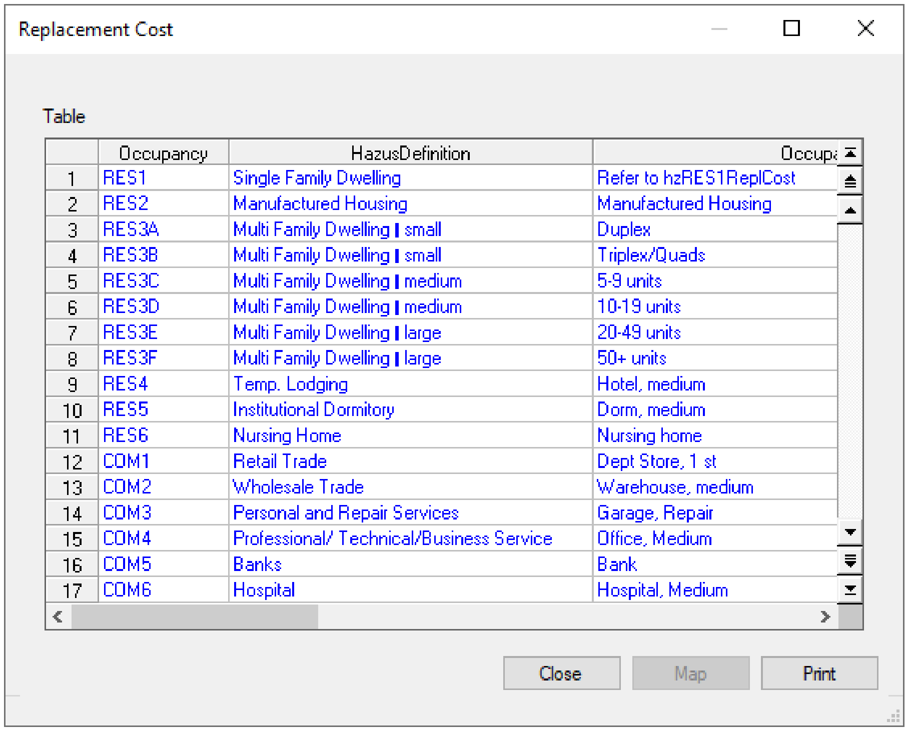


Figure 5-5 General Building Stock Valuation Parameters Menu



Replacement Cost

Table

	Occupancy	HazusDefinition	Occupa
1	RES1	Single Family Dwelling	Refer to hzRES1ReplCost
2	RES2	Manufactured Housing	Manufactured Housing
3	RES3A	Multi Family Dwelling I small	Duplex
4	RES3B	Multi Family Dwelling I small	Triplex/Quads
5	RES3C	Multi Family Dwelling I medium	5-9 units
6	RES3D	Multi Family Dwelling I medium	10-19 units
7	RES3E	Multi Family Dwelling I large	20-49 units
8	RES3F	Multi Family Dwelling I large	50+ units
9	RES4	Temp. Lodging	Hotel, medium
10	RES5	Institutional Dormitory	Dorm, medium
11	RES6	Nursing Home	Nursing home
12	COM1	Retail Trade	Dept Store, 1 st
13	COM2	Wholesale Trade	Warehouse, medium
14	COM3	Personal and Repair Services	Garage, Repair
15	COM4	Professional/ Technical/Business Service	Office, Medium
16	COM5	Banks	Bank
17	COM6	Hospital	Hospital, Medium

Close Map Print

Figure 5-6 General Building Stock Replacement Cost Table

5.2.3 GBS Dollar Exposure

The **Dollar Exposure (Replacement Value)** inventory option (Figure 5-7) allows the user to review building exposure, content exposure, or total exposure per Census block in thousands of dollars. The user can view exposure values by **General Occupancy**, **Specific Occupancy**, and **General Building Type** as seen in Figure 5-8**.**

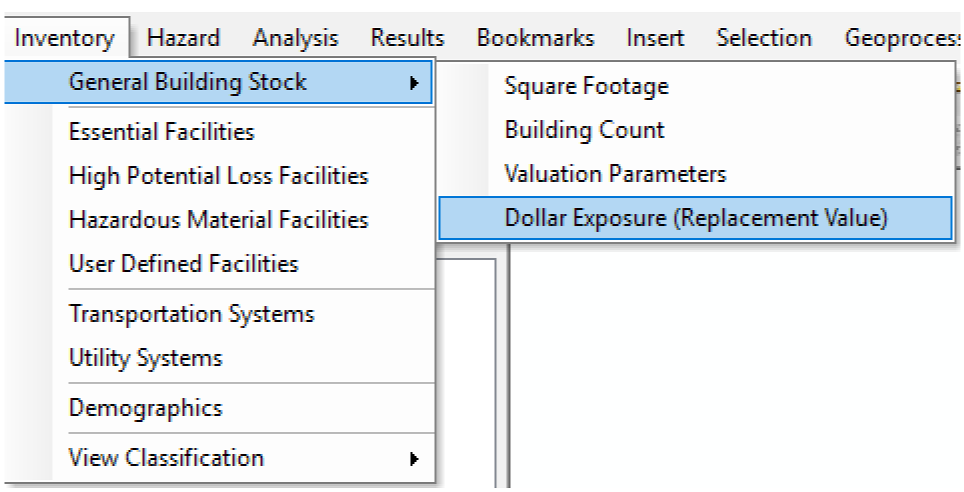
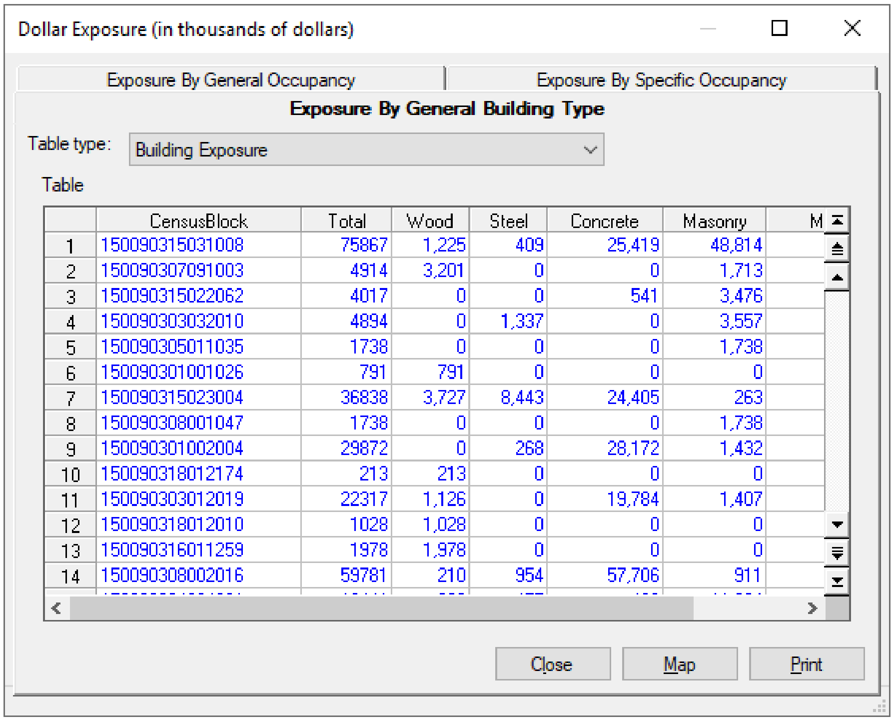


Figure 5-7 General Building Stock Dollar Exposure Menu



	CensusBlock	Total	Wood	Steel	Concrete	Masonry	M
1	150090315031008	75867	1,225	409	25,419	48,814	
2	150090307091003	4914	3,201	0	0	1,713	
3	150090315022062	4017	0	0	541	3,476	
4	150090303032010	4894	0	1,337	0	3,557	
5	150090305011035	1738	0	0	0	1,738	
6	150090301001026	791	791	0	0	0	
7	150090315023004	36838	3,727	8,443	24,405	263	
8	150090308001047	1738	0	0	0	1,738	
9	150090301002004	29872	0	268	28,172	1,432	
10	150090318012174	213	213	0	0	0	
11	150090303012019	22317	1,126	0	19,784	1,407	
12	150090318012010	1028	1,028	0	0	0	
13	150090316011259	1978	1,978	0	0	0	
14	150090308002016	59781	210	954	57,706	911	

Figure 5-8 General Building Stock Dollar Exposure Table

5.3 Essential Facilities

The **Essential Facilities** inventory menu selection (Figure 5-9) allows the user to view the essential facilities found in Hazus for a Study Region. These include **Medical Care Facilities**, **Emergency Response** facilities (i.e., police stations, fire stations, EOCs), and **Schools**. Please note that damage and loss are not computed for essential facilities in the present version of the Tsunami Model. Selecting this option will open the table seen in Figure 5-10.

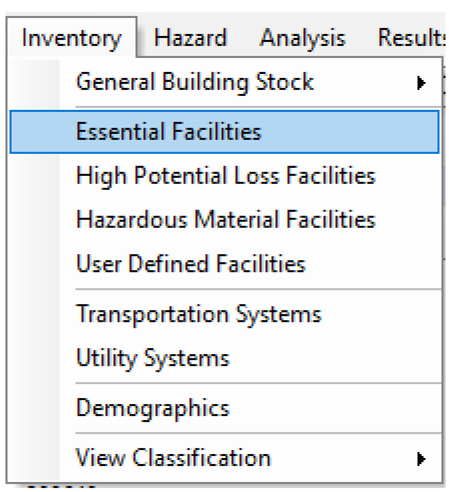
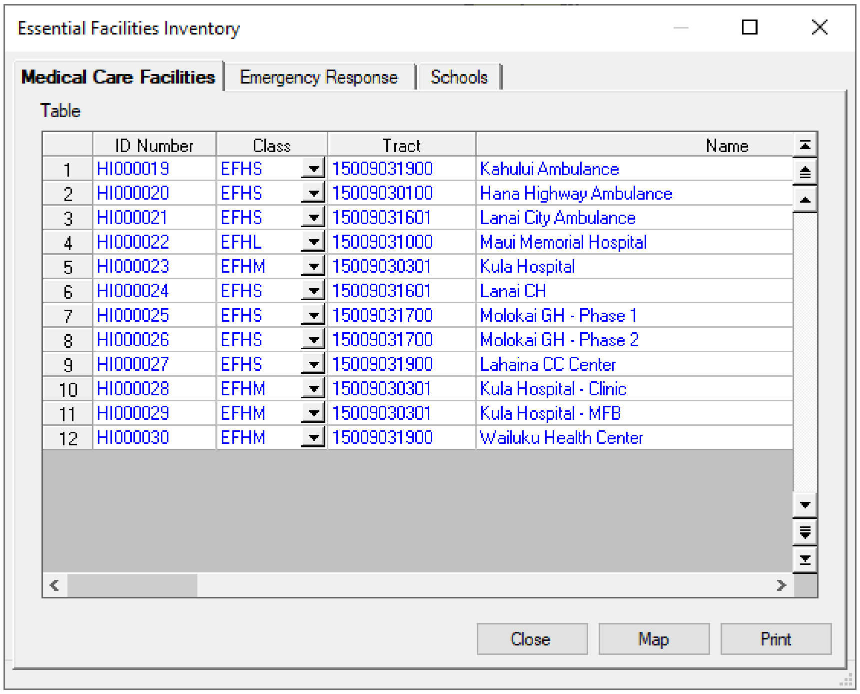


Figure 5-9 Essential Facilities Inventory Menu



	ID Number	Class	Tract	Name
1	HI000019	EFHS	15009031900	Kahului Ambulance
2	HI000020	EFHS	15009030100	Hana Highway Ambulance
3	HI000021	EFHS	15009031601	Lanai City Ambulance
4	HI000022	EFHL	15009031000	Maui Memorial Hospital
5	HI000023	EFHM	15009030301	Kula Hospital
6	HI000024	EFHS	15009031601	Lanai CH
7	HI000025	EFHS	15009031700	Molokai GH - Phase 1
8	HI000026	EFHS	15009031700	Molokai GH - Phase 2
9	HI000027	EFHS	15009031900	Lahaina CC Center
10	HI000028	EFHM	15009030301	Kula Hospital - Clinic
11	HI000029	EFHM	15009030301	Kula Hospital - MFB
12	HI000030	EFHM	15009031900	Wailuku Health Center

Figure 5-10 Essential Facilities Inventory Table

5.4 High Potential Loss Facilities

The **High Potential Loss Facilities** (HPLF) menu selection (Figure 5-11) allows the user to import, view and map the data for the Study Region. Selecting the **High Potential Loss Facilities** option will open the table seen in Figure 5-12. These include **Dams and Levees**, **Nuclear Power Facilities**, and **Military Installations**. Damage and loss are not computed for HPLFs in the Tsunami Model.

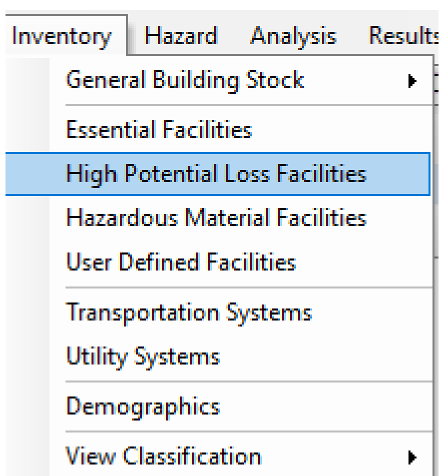


Figure 5-11 High Potential Loss Facilities Inventory Menu

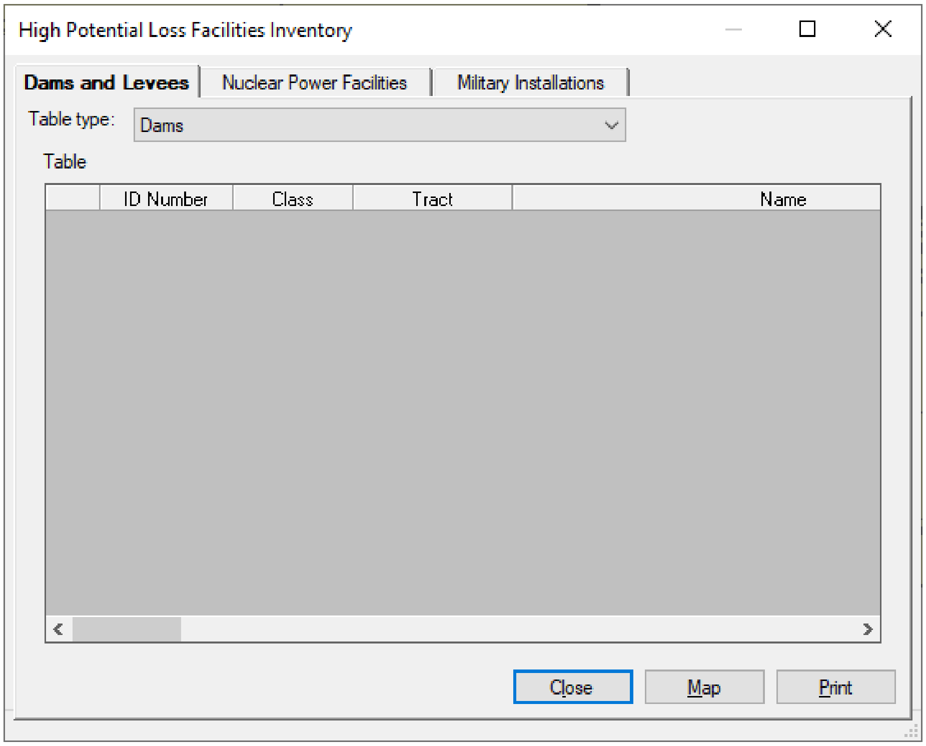


Figure 5-12 High Potential Loss Facilities Inventory Table

5.5 Hazardous Materials Facilities

The **Hazardous Materials** menu selection (Figure 5-13) allows the user to view and map the baseline database of the Study Region. Selecting the **Hazardous Materials Facilities** option will open the table seen in Figure 5-14. Each row in the table represents a separate hazardous material at a site, so several rows may have the same latitude and longitude. Damage and loss are not computed for hazardous materials sites in the Tsunami Model.

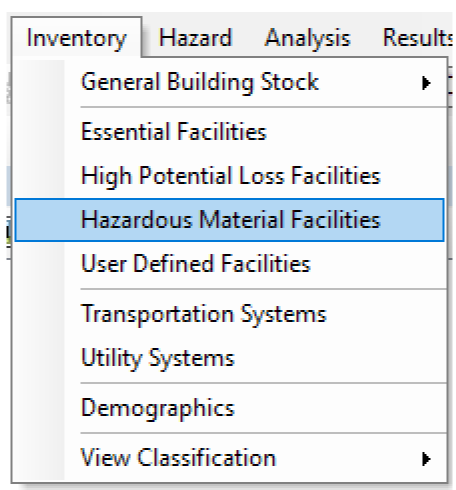
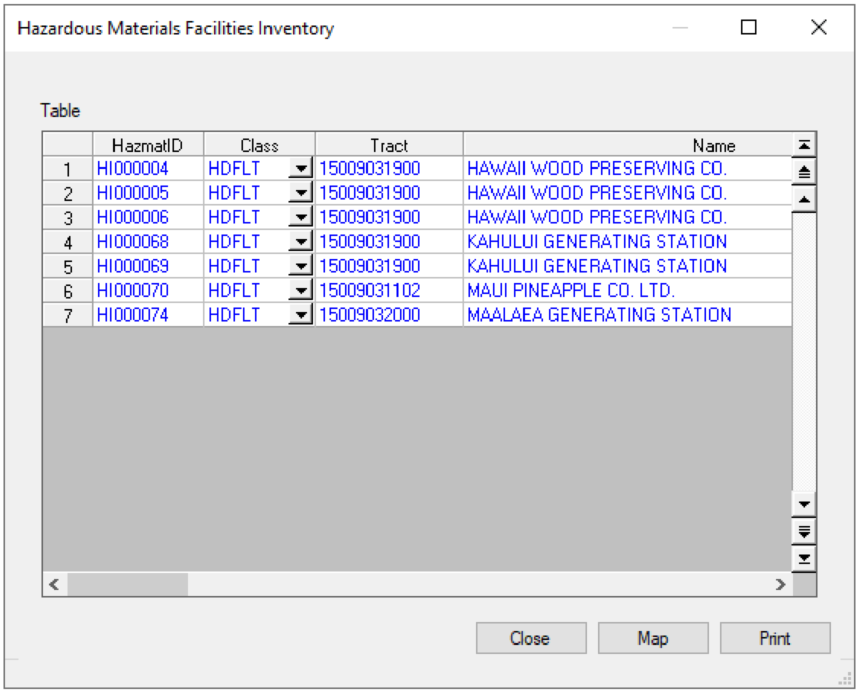


Figure 5-13 Hazardous Materials Facilities Inventory Menu



	HazmatID	Class	Tract	Name
1	HI000004	HDFLT	15009031900	HAWAII WOOD PRESERVING CO.
2	HI000005	HDFLT	15009031900	HAWAII WOOD PRESERVING CO.
3	HI000006	HDFLT	15009031900	HAWAII WOOD PRESERVING CO.
4	HI000068	HDFLT	15009031900	KAHULUI GENERATING STATION
5	HI000069	HDFLT	15009031900	KAHULUI GENERATING STATION
6	HI000070	HDFLT	15009031102	MAUI PINEAPPLE CO. LTD.
7	HI000074	HDFLT	15009032000	MAALAEA GENERATING STATION

Figure 5-14 Hazardous Materials Facilities Inventory Table

5.6 User-Defined Facilities

User-Defined facilities are buildings at specific locations that the user adds to the inventory. Damage and loss are evaluated on a building-by-building basis for this class of structures. Selecting the **User Defined Facilities** option (Figure 5-15) will open the window seen in Figure 5-16.

Section 9 discusses Advanced Hazus Analysis: User-Defined Inventory Data, which allows custom data to be imported into Hazus.

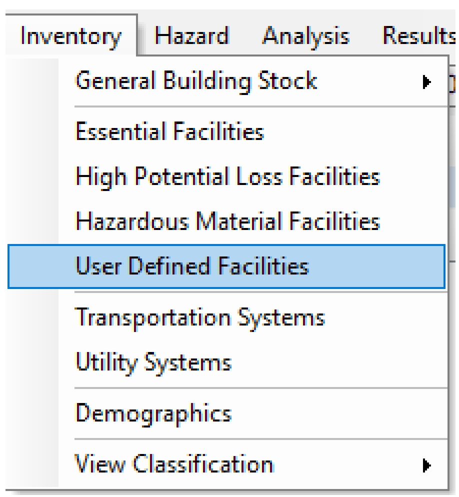
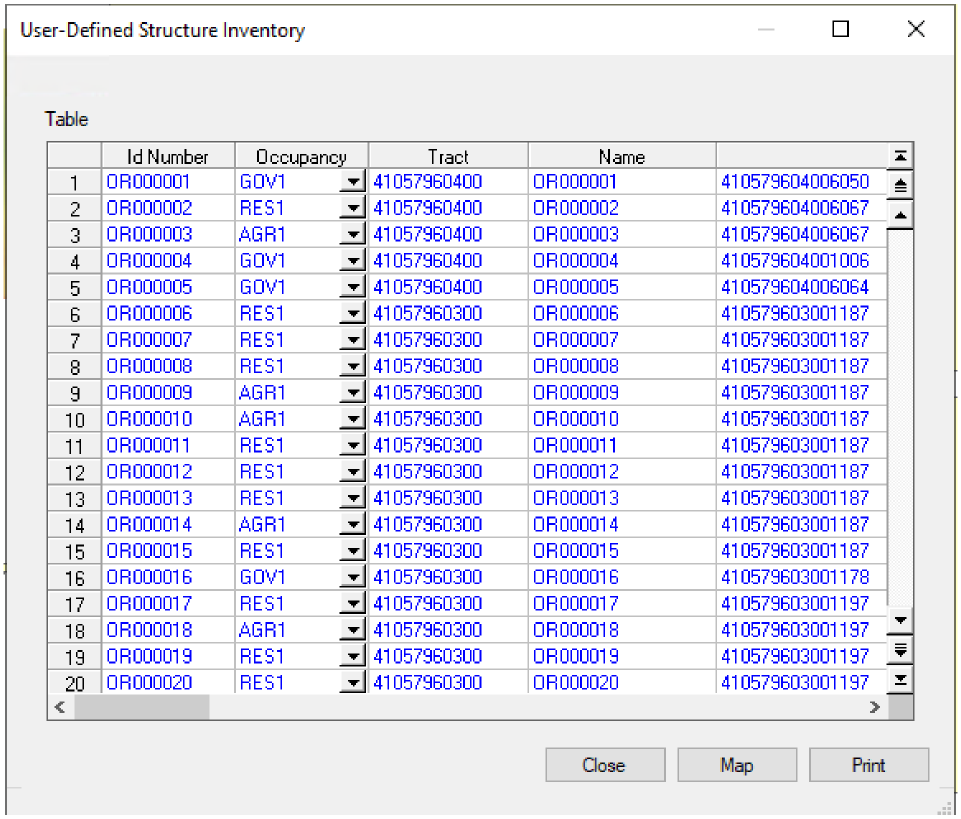


Figure 5-15 User-Defined Facilities Inventory Menu



	Id Number	Occupancy	Tract	Name	
1	OR000001	GOV1	41057960400	OR000001	410579604006050
2	OR000002	RES1	41057960400	OR000002	410579604006067
3	OR000003	AGR1	41057960400	OR000003	410579604006067
4	OR000004	GOV1	41057960400	OR000004	410579604001006
5	OR000005	GOV1	41057960400	OR000005	410579604006064
6	OR000006	RES1	41057960300	OR000006	410579603001187
7	OR000007	RES1	41057960300	OR000007	410579603001187
8	OR000008	RES1	41057960300	OR000008	410579603001187
9	OR000009	AGR1	41057960300	OR000009	410579603001187
10	OR000010	AGR1	41057960300	OR000010	410579603001187
11	OR000011	RES1	41057960300	OR000011	410579603001187
12	OR000012	RES1	41057960300	OR000012	410579603001187
13	OR000013	RES1	41057960300	OR000013	410579603001187
14	OR000014	AGR1	41057960300	OR000014	410579603001187
15	OR000015	RES1	41057960300	OR000015	410579603001187
16	OR000016	GOV1	41057960300	OR000016	410579603001178
17	OR000017	RES1	41057960300	OR000017	410579603001197
18	OR000018	AGR1	41057960300	OR000018	410579603001197
19	OR000019	RES1	41057960300	OR000019	410579603001197
20	OR000020	RES1	41057960300	OR000020	410579603001197

Figure 5-16 User-Defined Facilities Inventory Table

5.7 Transportation Systems

Transportation systems, including highways, railways, light rail, bus systems, ports, ferry systems, and airports are broken into components such as bridges, stretches of track, terminals, and facilities. Selecting the **Transportation System** option from the **Inventory** menu (Figure 5-17) will open the window seen in Figure 5-18. Damage and loss are not computed for transportation systems in the Tsunami Model.

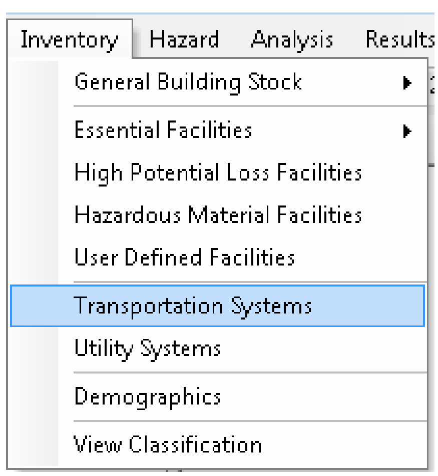


Figure 5-17 Transportation Systems Inventory Menu

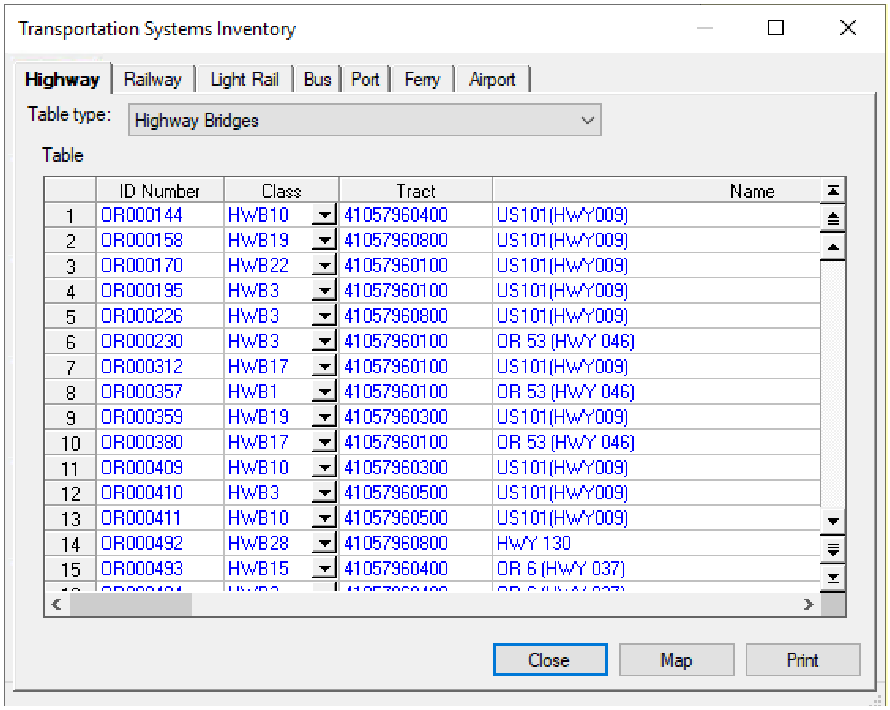


Figure 5-18 User Transportation Systems Inventory Table

5.8 Utility Systems

Utility systems, including potable water, wastewater, liquid fuels (oil and gas), electric power, and communication facilities, are treated in a manner similar to transportation systems. Examples of components are electrical substations, water treatment plants, tank farms, and pumping stations. Selecting the **Utility Systems** option from the **Inventory** menu (Figure 5-19) will open the window seen in Figure 5-20**.** Damage and loss are not computed for utility systems in the Tsunami Model.

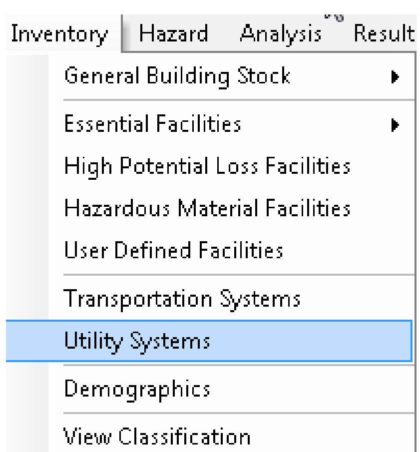


Figure 5-19 Utility Systems Inventory Menu

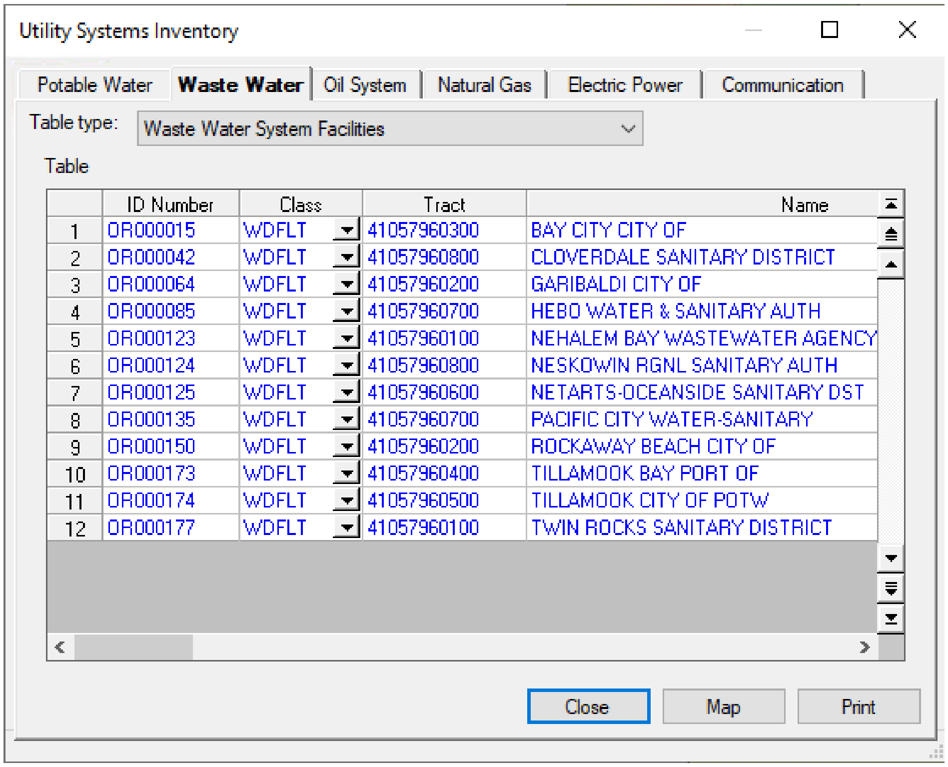


Figure 5-20 Utility Systems Inventory Table

5.9 Demographics

In the Hazus Tsunami Model, the population statistics are used to estimate casualties. The combined Hazus Tsunami and Earthquake Models can also estimate losses for displaced households and shelter needs. Population location, as well as ethnicity, income level, age, and home ownership are needed to make these estimates. The 2010 Census data are included within Hazus. The user may be able to obtain updated information from the Census Bureau or from a regional planning agency. The present version of the Tsunami Model uses the demographic data and NSI location in calculating evacuation travel time and casualties (USGS Pedestrian Evacuation Analyst Tool). Selecting this option from the Inventory menu (Figure 5-21) will open the window seen in Figure 5-22.

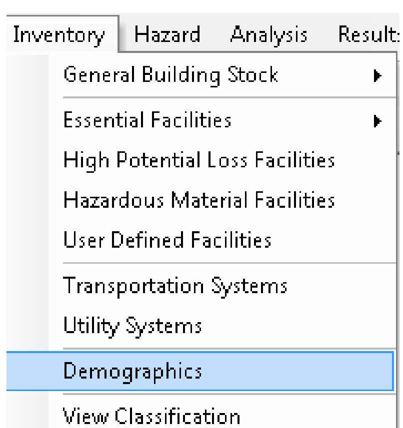
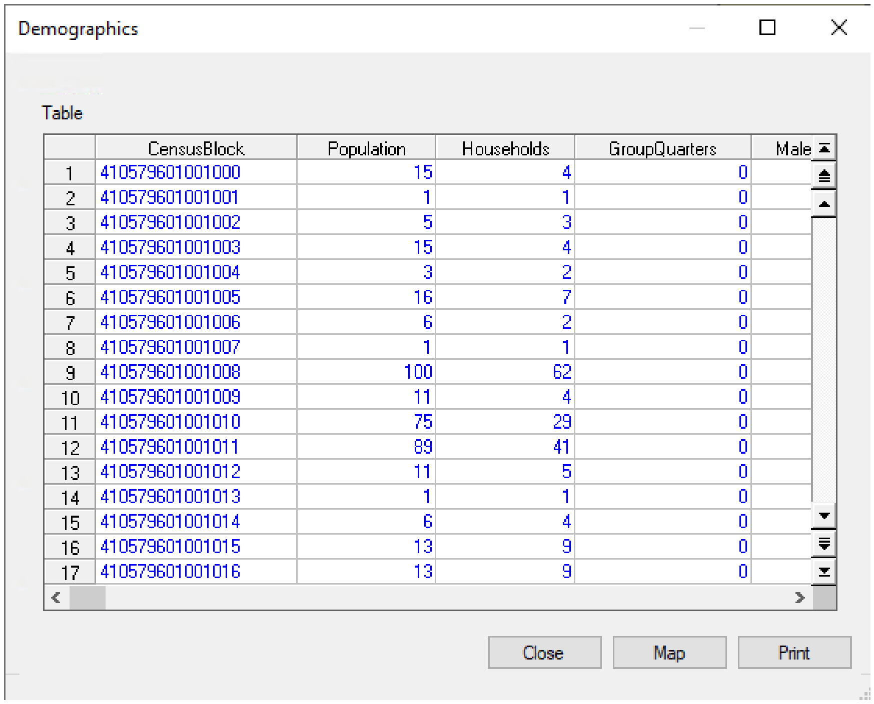


Figure 5-21 Demographics Inventory Menu



	CensusBlock	Population	Households	GroupQuarters	Male
1	410579601001000	15	4	0	
2	410579601001001	1	1	0	
3	410579601001002	5	3	0	
4	410579601001003	15	4	0	
5	410579601001004	3	2	0	
6	410579601001005	16	7	0	
7	410579601001006	6	2	0	
8	410579601001007	1	1	0	
9	410579601001008	100	62	0	
10	410579601001009	11	4	0	
11	410579601001010	75	29	0	
12	410579601001011	89	41	0	
13	410579601001012	11	5	0	
14	410579601001013	1	1	0	
15	410579601001014	6	4	0	
16	410579601001015	13	9	0	
17	410579601001016	13	9	0	

Figure 5-22 Demographics Inventory Table

5.10 View Classification

The **View Classification** option (Figure 5-23) allows the user to view definitions of the classification categories. Selecting this option will open the window seen in Figure 5-24.

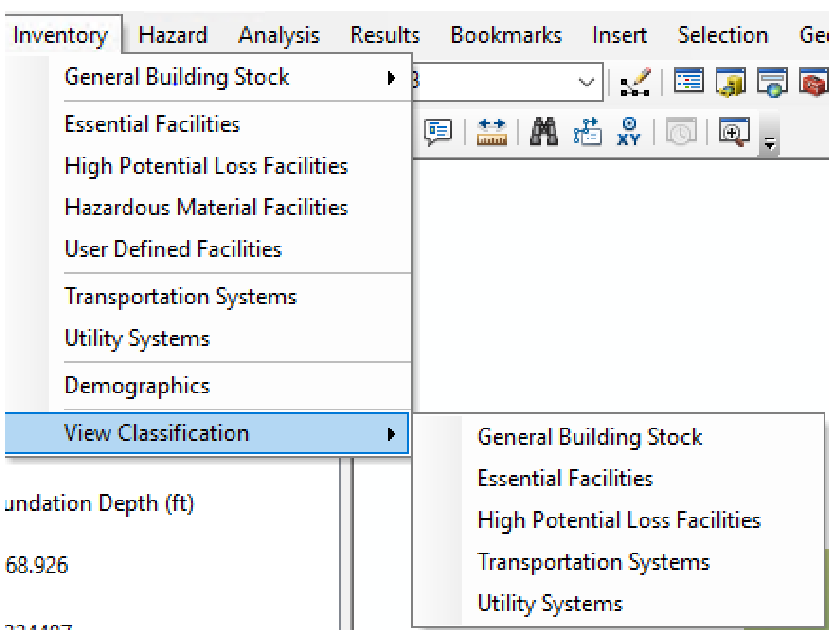
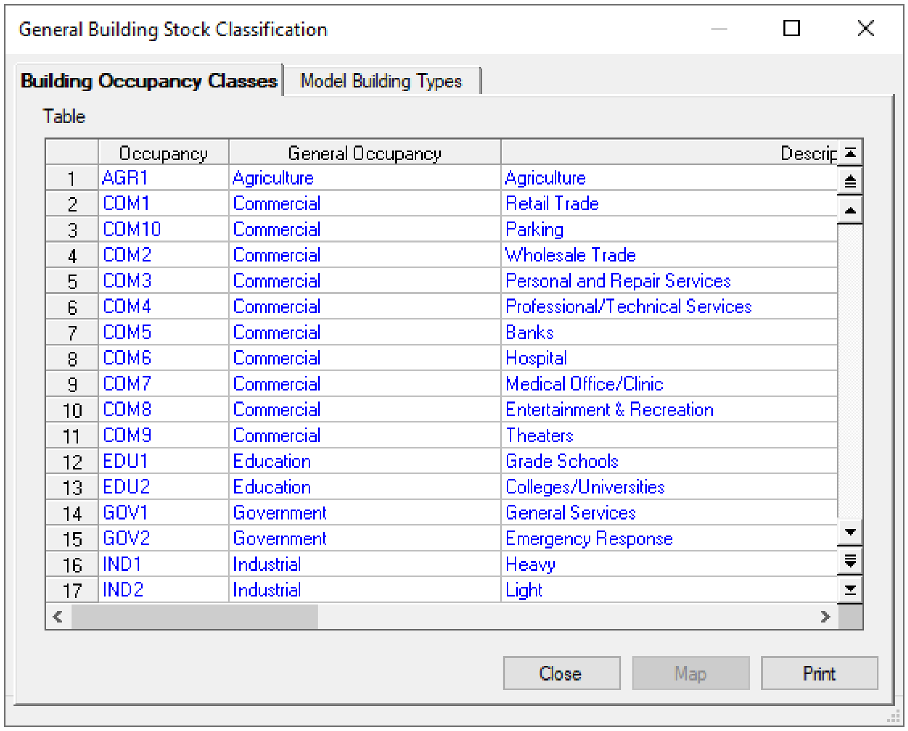


Figure 5-23 View Classification Menu



	Occupancy	General Occupancy	Descrip
1	AGR1	Agriculture	Agriculture
2	COM1	Commercial	Retail Trade
3	COM10	Commercial	Parking
4	COM2	Commercial	Wholesale Trade
5	COM3	Commercial	Personal and Repair Services
6	COM4	Commercial	Professional/Technical Services
7	COM5	Commercial	Banks
8	COM6	Commercial	Hospital
9	COM7	Commercial	Medical Office/Clinic
10	COM8	Commercial	Entertainment & Recreation
11	COM9	Commercial	Theaters
12	EDU1	Education	Grade Schools
13	EDU2	Education	Colleges/Universities
14	GOV1	Government	General Services
15	GOV2	Government	Emergency Response
16	IND1	Industrial	Heavy
17	IND2	Industrial	Light

Figure 5-24 General Building Stock Inventory Classifications

Section 6. Tsunami Model: Hazard Menu

The Hazus Tsunami Model relies on varying levels of user input for the hazard, much like the Hazus Flood Model. This section summarizes the **Hazard** menu, including **Tsunami Hazard Type** and **User Data** input under the **Hazard** menu.

6.1 Tsunami Hazard Type

The **Tsunami Hazard Type** submenu (Figure 6-1) allows the user to select **Near Source only** (required for a combined earthquake + tsunami scenario) or **Distant Source** (tsunami scenario only) tsunamigenic event. It is accessible under the **Tsunami Hazard Type** menu (Figure 6-2). Select **Tsunami Hazard Type** in the menu. Choose source type. Click **OK**.

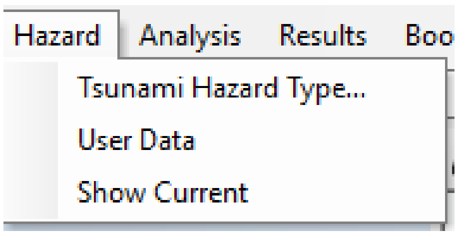


Figure 6-1 Hazard Menu

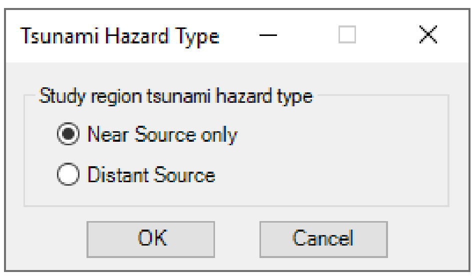


Figure 6-2 Tsunami Hazard Type Menu

6.2 Tsunami User Data Wizard

The **Tsunami User Data Wizard**, accessible under the **Hazard** menu (Figure 6-3), allows the user to select a **Hazard Type** (Figure 6-4) based on the level of data available to the user. This section will provide a brief description of each. The first two (both with names beginning with "Level 1") are basic level tsunami model scenarios and the last two are advanced level tsunami model scenarios (Table 6-1).

Table 6-1 Hazus Tsunami Data Requirements

	Hazard Data Required	Input Data Files and Formats
Level 1	Runup Only - Mean Sea Level (MSL)	Maximum Runup height grid in raster format ---AND--- DEM raster (download option for USGS provided)
Level 1	Quick Look - Single Maximum Runup	DEM raster and single maximum runup value (MSL)

	Hazard Data Required	Input Data Files and Formats
Level 2	Depth Above Ground Level (AGL) and Velocity	Maximum Depth grid and Velocity grid in raster format ---OR--- Maximum Depth and Velocity NetCDF NOAA SIFT (.nc) files
Level 3	Depth AGL (ft) and Momentum Flux (ft3 sec2)	Median Depth grid in raster format ---AND--- Median Momentum Flux grid in raster format

In the **Tsunami User Data Wizard**, users have the flexibility to specify the units for the files they import, depending on analysis level. Level 3 (Advanced) assumes user-provided data are already in the required units. No system validation of units is performed by Hazus.

Sample data are available for small, selected cities in the five U.S. states. See Section 10 for more information.

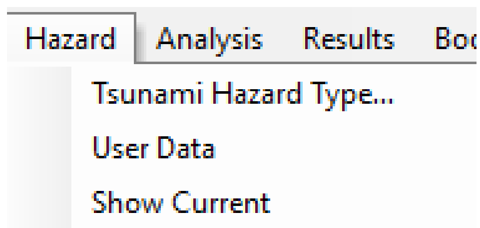


Figure 6-3 Hazard Scenario Menu

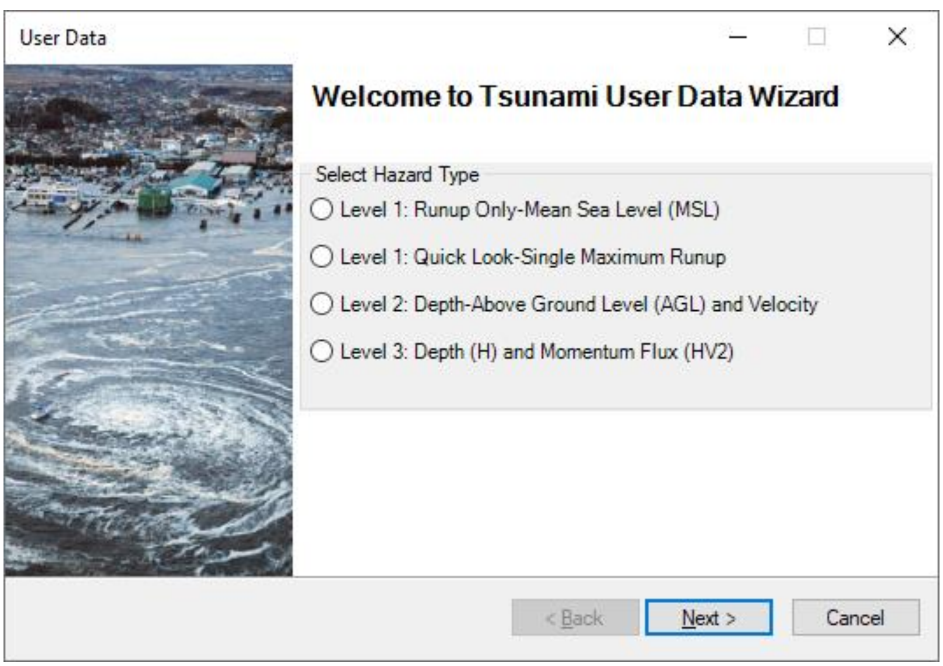


Figure 6-4 Tsunami User Data Wizard

6.2.1 Level 1 (Basic): Runup Only-Mean Sea Level

Select the first option, **Level 1: Runup Only-Mean Sea Level (MSL)** (Figure 6-5). Click **Next**.

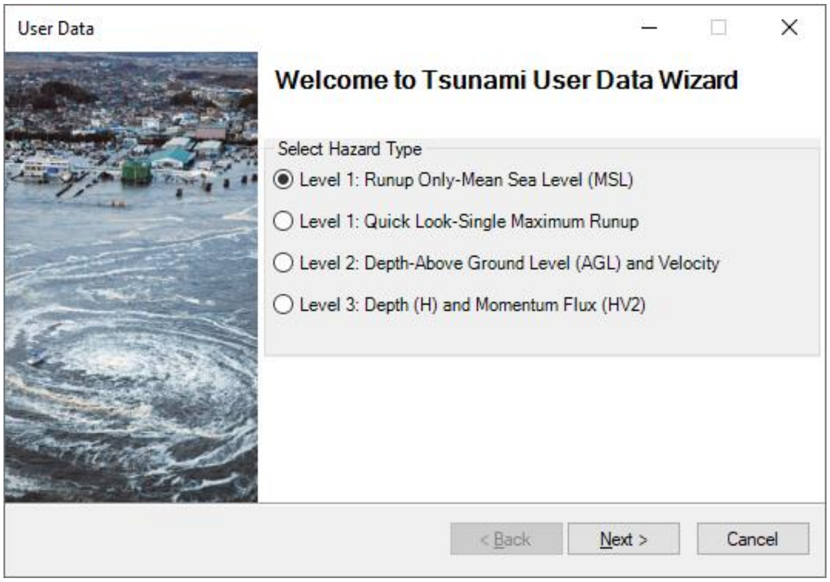


Figure 6-5 Tsunami Wizard Level 1 Runup Only

The **Level 1: Runup Height Only** scenario (Figure 6-6) requires a maximum runup height grid in raster format and a DEM. A download option for USGS DEMs is available (similar to the Hazus Flood Model). Click **Determine required DEM extent** to access the DEM download. USGS DEMs are typically in height and vertical units of meters. If using a DEM from another source, ensure the correct height and vertical units are used. These can usually be found in the metadata for the DEM.

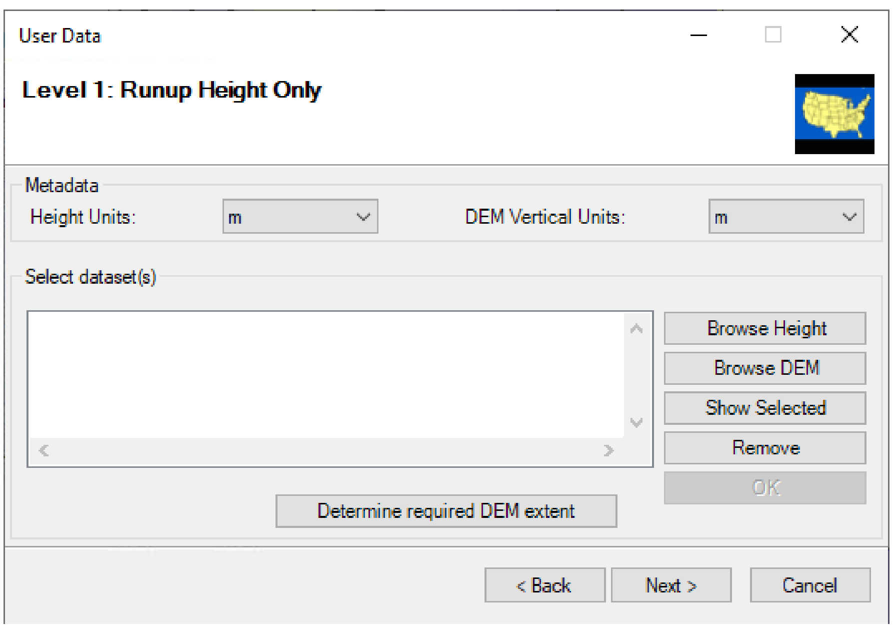


Figure 6-6 Level 1 Runup Height Only Scenario

The **DEM Extent** window will appear with a list of related datasets from the National Elevation Dataset (NED) (Figure 6-7). Click **Download and Unzip All** to download the data to the **Hazard Input** folder (Figure 6-8)**.**

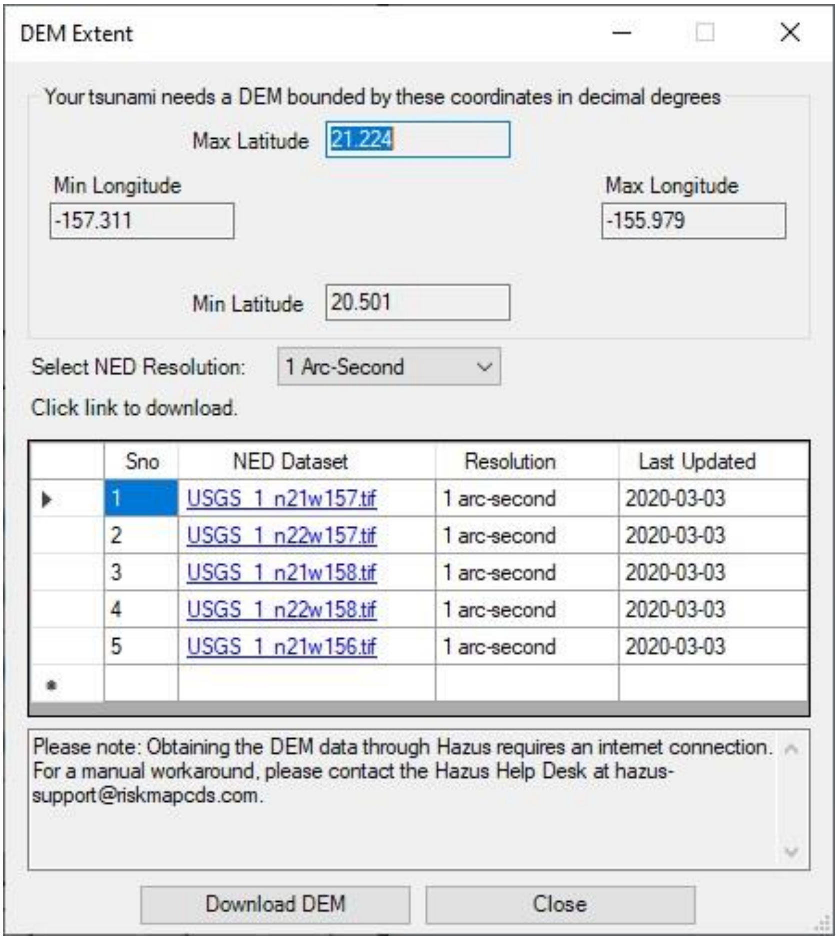


Figure 6-7 USGS DEM import tool

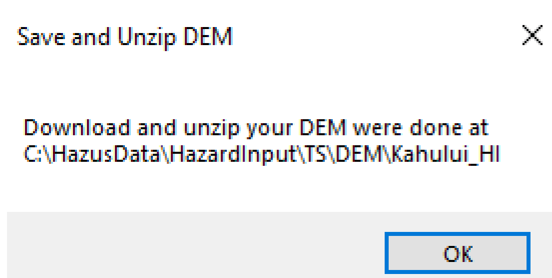


Figure 6-8 DEM Download Location

The metadata drop-down menus are used to identify the units for each dataset. (Note: The USGS NED vertical units are always in meters.) The user-defined tsunami height grid is added using the **Browse Heigh**t button (Figure 6-6). The DEM is added using the **Browse** DEM button. The **Show Selected** button will map the imported user rasters. Click **OK** to create the velocity grid, and hazard and fatality boundaries.

6.2.2 Level 1 (Basic): Quick Look-Single Maximum Runup

Select the second option, **Level 1: Quick Look-Single Maximum Runup** (Figure 6-9). Click **Next**.

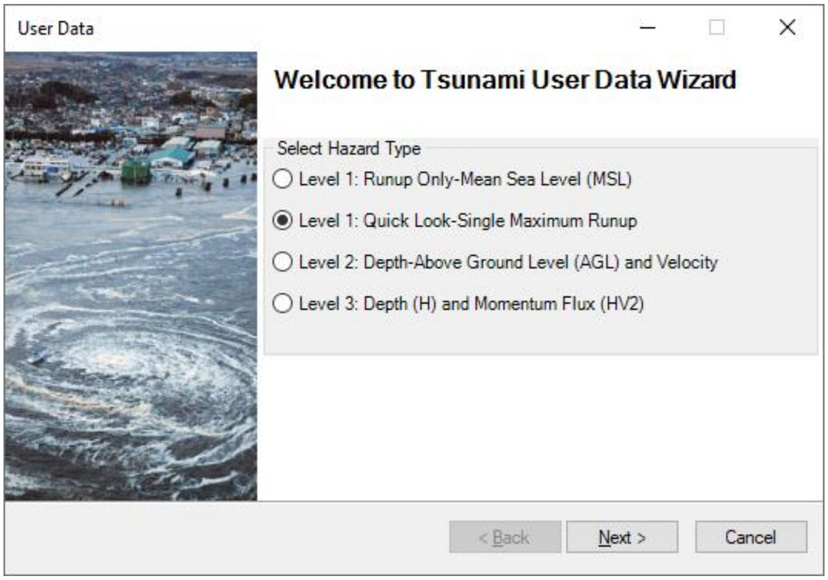


Figure 6-9 Tsunami Wizard - Level 1: Quick Look-Single Maximum Runup

The **Level 1: Quick Look-Single Maximum Runup Height** (Figure 6-10) requires a DEM (download option available in the previous section), and a single maximum runup value. The **Select Input Units** drop-drown menus are used to identify the units of the DEM and the height value. Refer to Section 4.1 for the remaining steps.

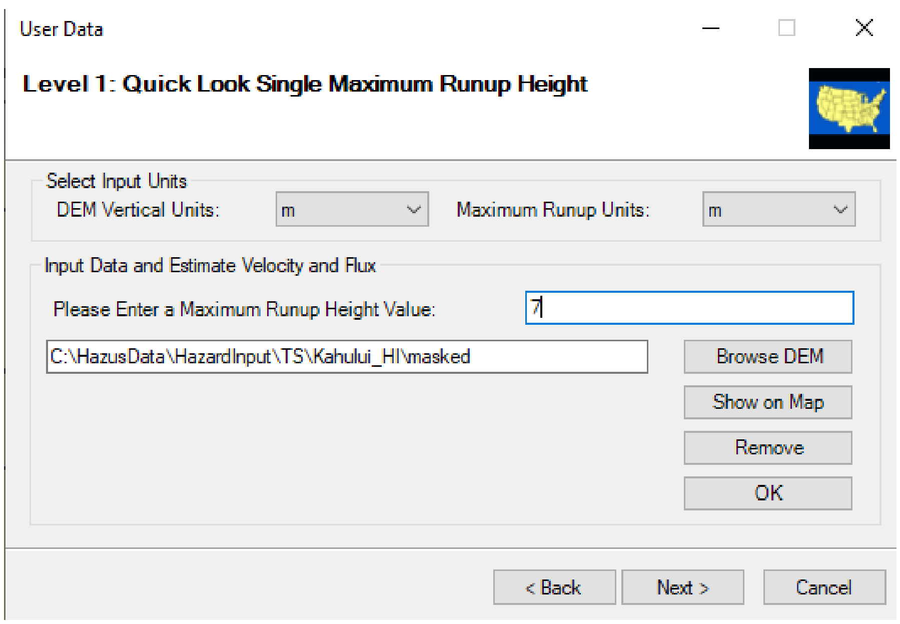


Figure 6-10 Level 1 Quick Look Single Maximum Runup Height

6.2.3 Level 2 (Advanced): Depth-Above Ground Level (AGL) and Velocity

The next two options are advanced level options. The first is **Level 2: Depth-Above Ground Level (AGL) and Velocity** (Figure 6-11).

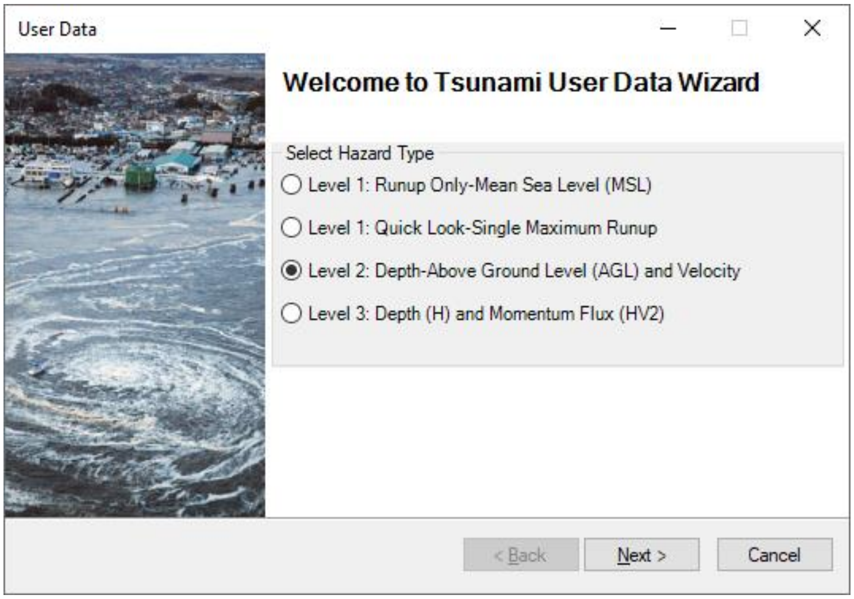


Figure 6-11 Tsunami Wizard - Level 2: Depth-Above Ground Level (AGL) and Velocity

The **Level 2: Depth-Above Ground Level (AGL) and Velocity** (Figure 6-12) enables users to enter maximum depth grid and velocity grid data in raster format, or maximum depth and velocity NetCDF NOAA SIFT (.nc) files. (Sample data are provided by NOAA. See Section 10 for more information.) The units are defined using the drop-down menus.

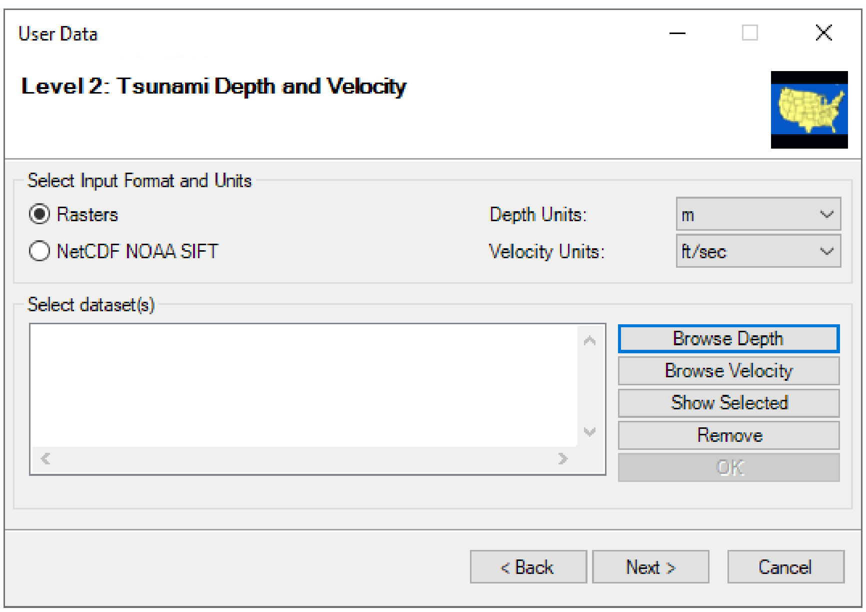


Figure 6-12 Level 2 Depth-Above Ground Level (AGL) and Velocity

6.2.4 Level 3 (Advanced): Depth (H) and Momentum Flux (HV2)

The last option is **Level 3: Depth (H) and Momentum Flux (HV2)** (Figure 6-13). This option requires a median depth grid in raster format and a median momentum flux grid in raster format. Level 3 (Advanced) assumes user-provided data are already in required units (Figure 6-14).

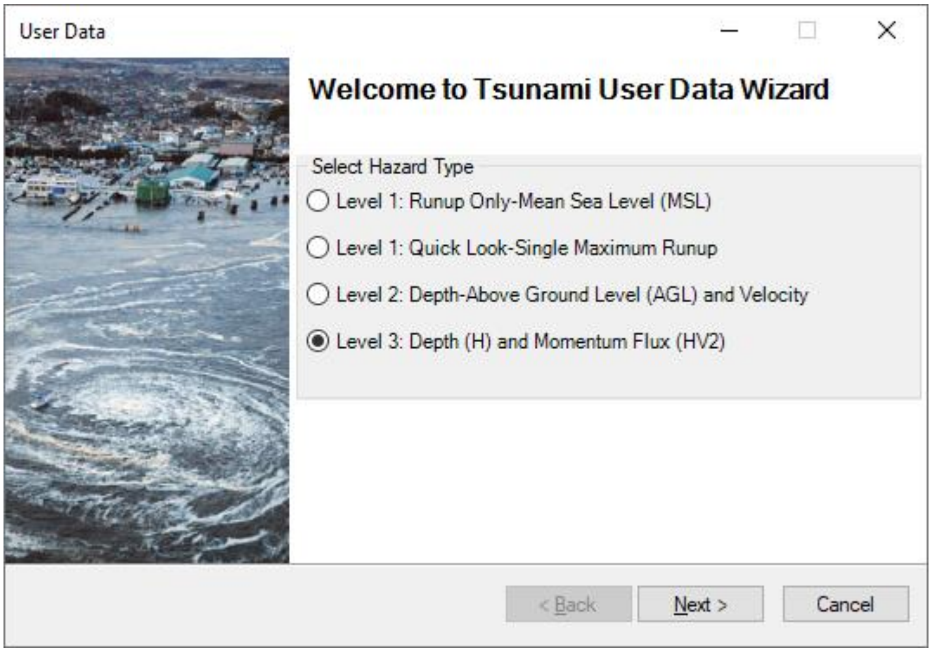


Figure 6-13 Tsunami Wizard - Level 3: Depth (H) and Momentum Flux (HV2)

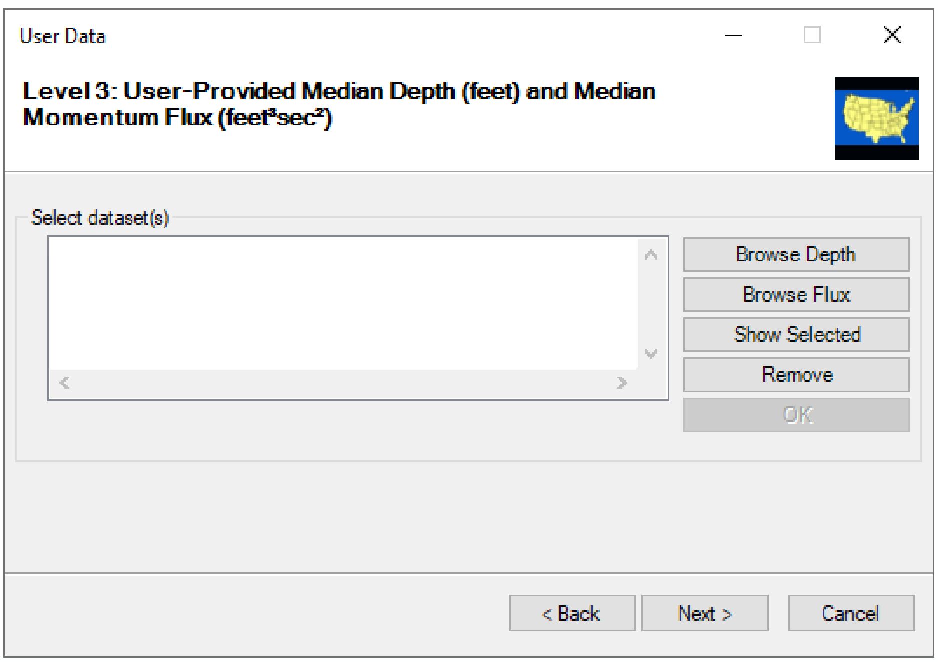


Figure 6-14 Level 3 (Advanced) Depth (H) and Momentum Flux (HV2)

Section 7. Tsunami Model: Analysis Menu

There are three basic classes of analysis functions used in the Hazus Tsunami Model:

- Damage Functions
- Restoration
- Casualty

There are also two types of parameters in the Tsunami Model:

- Casualty
- Building economic

The menu in Figure 7-1 shows each option in the **Analysis** selection. Functions are described in the following sections.

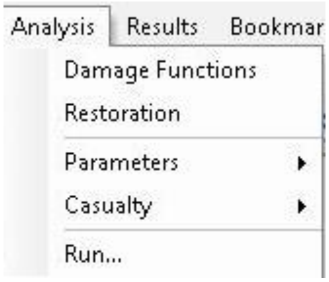


Figure 7-1 Analysis Menu

7.1 Damage Functions

The **Analysis > Damage Functions** option displays tables of the probabilities of damage states for building type as a function of tsunami inundation depth (for contents) and flux (for structural) (Figure 7-2). The structural, nonstructural, and content tsunami damage functions are based on the median rather than maximum hazard values. See the *Hazus Tsunami Model Technical Manual* (FEMA, 2021) document for details of the Hazus Methodology.

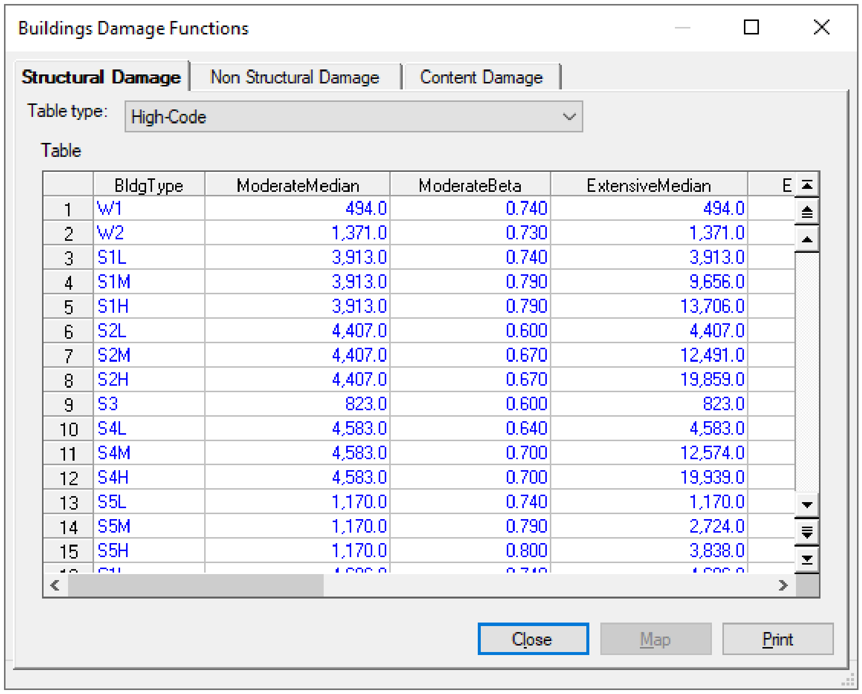


Figure 7-2 Building Damage Functions Viewer

7.2 Restoration

The **Analysis > Restoration** option displays tables of the expected number of days to restore the function of each building type as a function of tsunami inundation depth and velocity (Figure 7-3).

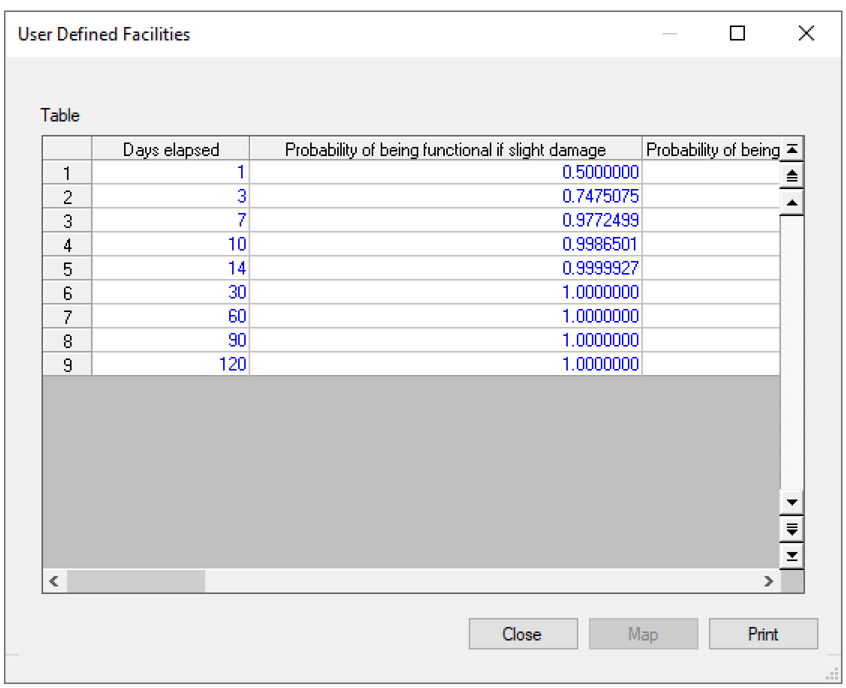


Figure 7-3 User-Defined Facilities Functionality

7.3 Parameters

The **Analysis > Parameters** menu (Figure 7-4) allows the user to define **Casualties** and **Building Economic** parameters.

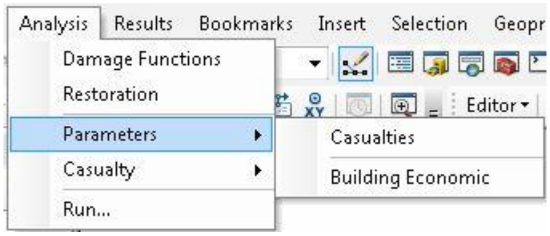


Figure 7-4 Analysis Parameters Menu

See Section 12 for detailed information on each parameter.

7.4 Casualties

The **Analysis > Casualty** menu (Figure 7-5) allows the user to download TIGER road data and set up **Casualty Level 1 and Casualty Level 2** scenarios.

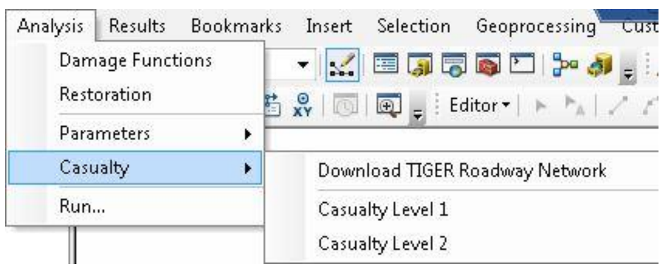


Figure 7-5 Casualty Menu

The Hazus Tsunami Model makes use of a USGS methodology (see USGS Pedestrian Evacuation Analyst Tool) for estimating pedestrian evacuation times, arrival, warning times, and community preparedness levels to estimate potential loss of life and injuries. Prior to running the casualty module, the user must first run the tsunami GBS analysis. Hazus will prompt the user to do this if it is not already done. See Section 12 for detailed information.

7.5 Run

When the Study Region inventory, hazard, and analysis parameters have been specified, the user is ready to run an analysis. Select the **Analysis > Run** menu (Figure 7-6) option to display the **Analysis Options - Tsunami** window shown in Figure 7-7.

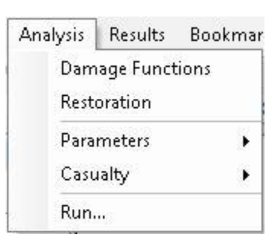


Figure 7-6 Analysis Run Menu

The **Analysis Options - Tsunami** window (Figure 7-7) allows the user to select inventory items. Once satisfied with inventories, click **OK** to run the analysis.

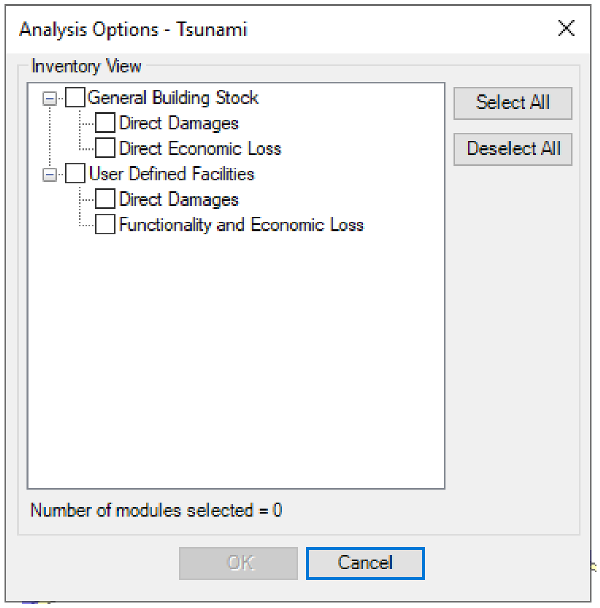


Figure 7-7 Analysis Options

After the analysis is completed, the user can access the results under the **Results** menu outlined in Section 8.

Section 8. Tsunami Model: Results Menu

The output from the analysis is available in the form of result tables, maps, and reports produced by the Hazus Tsunami Model. The items discussed are accessed via the **Results** menu (Figure 8-1) after running a tsunami GBS scenario and casualty analysis. This section will describe the outputs associated with each menu selection including: **Tsunami Inundation**, **General Building Stock**, **User-Defined Facilities**, **Combined General Building Stock**, **Combined User-Defined Facilities**, **Casualties**, and **Summary Reports**.

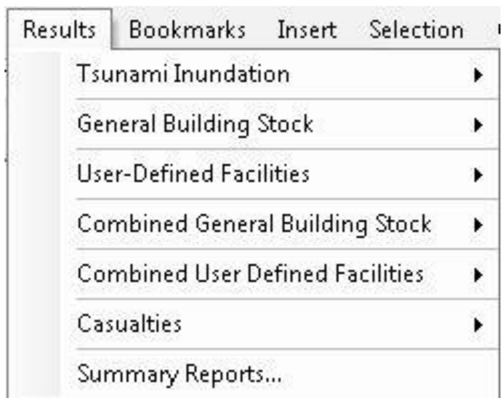


Figure 8-1 Results Menu

8.1 Model Outputs

Hazus provides the user with a series of outputs for each model. The outputs can be in a numerical or graphical form. Table 8-1 summarizes the outputs that can be obtained from an analysis using the Hazus Tsunami Model.

Table 8-1 Hazus Tsunami Model Output

Model Output	Description of Output
Maps of Tsunami Inundation	
General Building Stock Hazard	Hazus determines the depth of flooding in feet and the momentum flux in (ft^3/sec^2) at each NSI point.
User-Defined Facility Hazard	Hazus determines the depth of flooding in feet and the momentum flux in (ft^3/sec^2) at each UDF point.
Inundation Boundary	Hazus determines the area impacted by the tsunami.
General Building Stock	
Damage by Count (actual values)	Hazus determines how many buildings are in a specific damage state (None, Moderate, Extensive, Complete) by general occupancy, specific occupancy, general building type, and specific building type.
Damage by Square Footage (thousands)	Hazus determines how much square footage is in a specific damage state (None, Moderate, Extensive, Complete) by general occupancy, specific occupancy, general building type, and specific building type.
Direct Economic Loss (thousands $)	Hazus determines the loss (structural, non-structural, building, contents, inventory, relocation, income, rental, wage, output, total) by general occupancy, specific occupancy, general building type, and specific building type.

Model Output	Description of Output
User-Defined Facilities	
Building Damage State (% damaged)	Hazus determines the structural, non-structural, and content damage (none, moderately, extensive, complete, exceeds moderate, exceeds extensive) to a UDF.
Building Functionality (actual values)	Hazus determines the number of buildings that are functional on 1 day, 3 days, 7 days, 14 days, 30 days, and 90 days after the tsunami.
Building Economic Losses (dollars)	Hazus determines the economic losses (structural, no-structural, structural loss ratio, contents, content loss ratio and economic loss) for each UDF.
Combined User Defined Facilities	
Combined Building Damage State (% damaged)	Hazus determines the structural, non-structural, and content damage (none, moderately, extensive, complete, exceeds moderate, exceeds extensive) to a UDF.
Combined Building Functionality (actual values)	Hazus determines the number of buildings that are functional on 1 day, 3 days, 7 days, 14 days, 30 days, and 90 days after the tsunami.
Combined Building Economic Losses (dollars)	Hazus determines the economic losses (structural, no-structural, structural loss ratio, contents, content loss ratio and economic loss) for each UDF.
Combined General Building Stock	
Combined Damage by Count (actual values)	Hazus determines how many buildings are in a specific damage state (None, Moderate, Extensive, Complete) by general occupancy, specific occupancy, general building type, and specific building type.
Combined Damage by Square Footage (thousands)	Hazus determines how much square footage is in a specific damage state (None, Moderate, Extensive, Complete) by general occupancy, specific occupancy, general building type, and specific building type.
Combined Direct Economic Loss (thousands $)	Hazus determines the loss (structural, non-structural, building, contents, inventory, relocation, income, rental, wage, output, total) by general occupancy, specific occupancy, general building type, specific building type, and total.
Casualties	
Evacuation Travel Time	Hazus determines the travel times by category (Day population under 65, Day population over 65, Day population total, Night population under 65, Night population over 65, Night population total, Travel partially safe 65 (mins), Travel partially safe over 65 (mins), Travel safe under 65 (mins), Travel safe over 65 (mins)).
Probability of Casualties	Probability of injuries and fatalities based on community preparedness levels and times of day for different age groups.

Note: The two sections labeled "Combined" require both earthquake and tsunami results and can only be found in the Tsunami Model.

Examples of pre-event applications of the outputs are as follows:

- General Building Stock Loss and Damage Probability outputs can aid in the development of mitigation strategies that outline policies and programs for reducing tsunami losses and disruptions. Strategies can include upgrading existing buildings, the adoption of new building codes, and relocating essential facilities to areas outside the tsunami inundation area.
- Evacuation Travel Time and Casualties outputs can support preliminary investigations of the ideal location of vertical evacuation refuges to minimize the casualties from future tsunami events.

- Maps of Tsunami Inundation outputs can provide information to support the scope of response and recovery efforts including identifying safe zones for evacuations, locations of essential facilities, and areas where fatalities may occur.
- Casualties Based on Community Preparedness Levels and Pedestrian Evacuation Travel Time Maps (minutes) outputs can support development and implementation of community preparedness outreach programs to increase community readiness especially targeted in areas where longer pedestrian evacuation times occur, and populations may be concentrated.

Examples of post-event applications of the outputs would include:

- Business Inventory and Income Loss outputs can be used to project immediate economic impact assessments for state and federal resource allocation and support for actions including 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.
- Day and Night Population Exposure outputs can be used in immediate emergency recovery efforts including provision of emergency housing shelters.
- Business related outputs can be used in the application of long-term reconstruction plans including the identification of long-term reconstruction goals, the institution of appropriate wide-range economic development plans for the entire area, allocation of permanent housing needs, and the application of land-use planning principles and practices.
- Any of the model outputs can be used in the application of lessons learned to improve community response and preparedness.

8.2 Tsunami Inundation

Tsunami Inundation results (Figure 8-2) include the Median Tsunami Depth, Median Momentum Flux, and Inundation Boundary for the scenario. The Tsunami Depth is mapped in feet (Figure 8-3). The dots represent the depth at each structure. The Tsunami Momentum Flux is mapped in ft^3/sec^2 (Figure 8-4). The dots represent the momentum flux at each structure. Each map shows similar patterns with the highest depth and flux values are along the coastline, with progressively lower values going inland from the coast until the values go to zero at the limit of the Tsunami Inundation. The Tsunami Hazard Boundary is the extent of the tsunami inundation and is mapped as shown in Figure 8-5. The layer can be exported as a shapefile or geodatabase feature class.

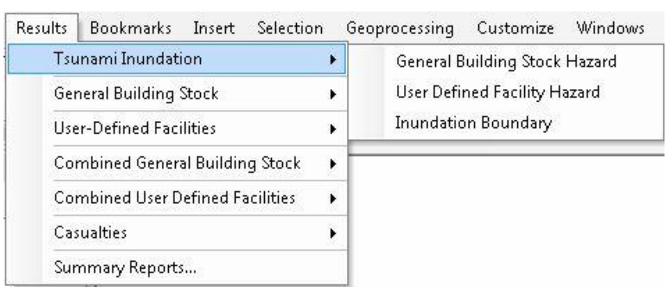


Figure 8-2 Results Tsunami Inundation Menu

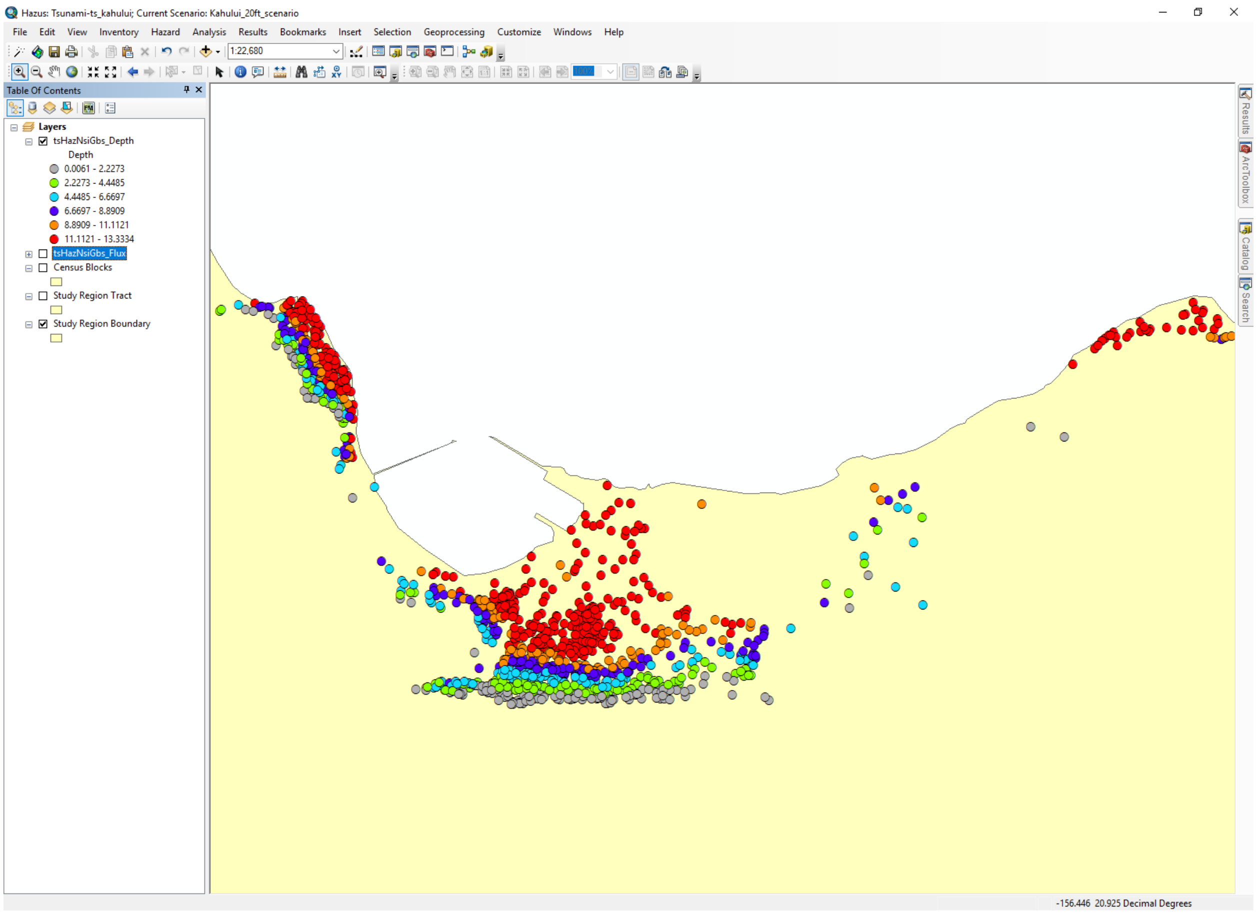


Figure 8-3 Tsunami Depth Results Example

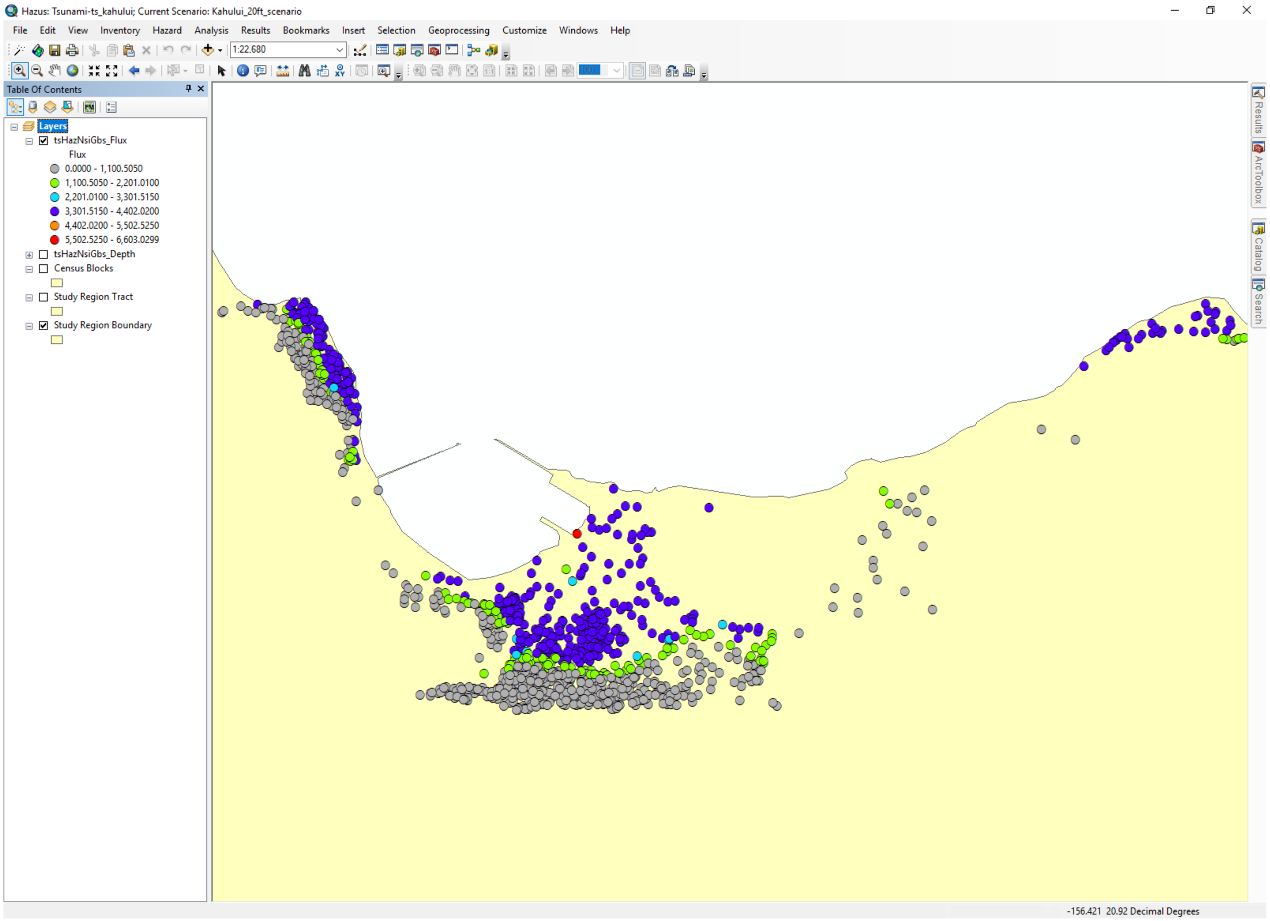


Figure 8-4 Tsunami Momentum Flux Results Example

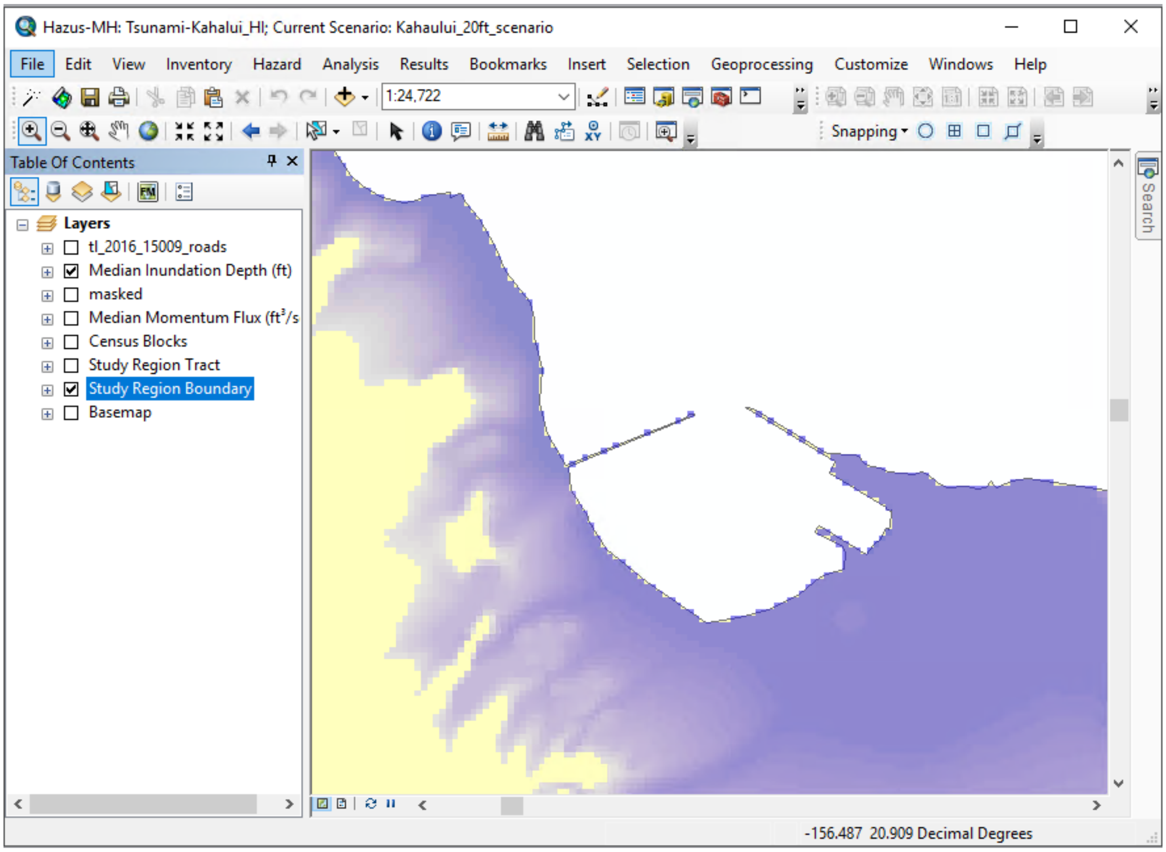


Figure 8-5 Tsunami Inundation Boundary Results Example

8.3 General Building Stock Results

The **Results > General Building Stock** menu (Figure 8-6) allows the user to view and map the general inventory damage results (by Census block) either by occupancy or building type.[4]

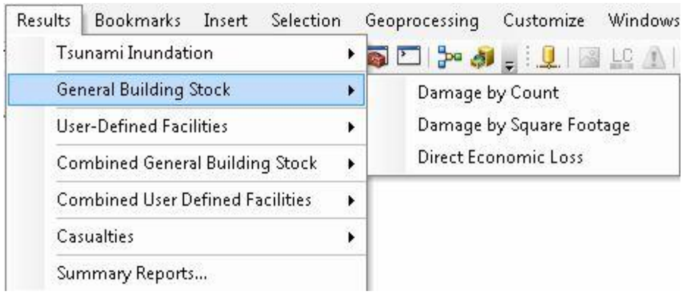


Figure 8-6 General Building Stock Menu

[4] Note: the values for damage are building counts aggregated by damage state probabilities. This may lead to "counts" of damaged buildings with decimals, giving the appearance that fractions of buildings were counted. This provides more accurate aggregated damage counts since no fractions are discarded

8.3.1 GBS Building Damage Count

Figure 8-7 shows the **Building Damage Count by Occupancy Class** table, allowing the user to view and map the general inventory damage results either by general or specific occupancy class. The values in the table represent the expected number of buildings in each damage state. Fractions are used to provide more accurate aggregated building counts.

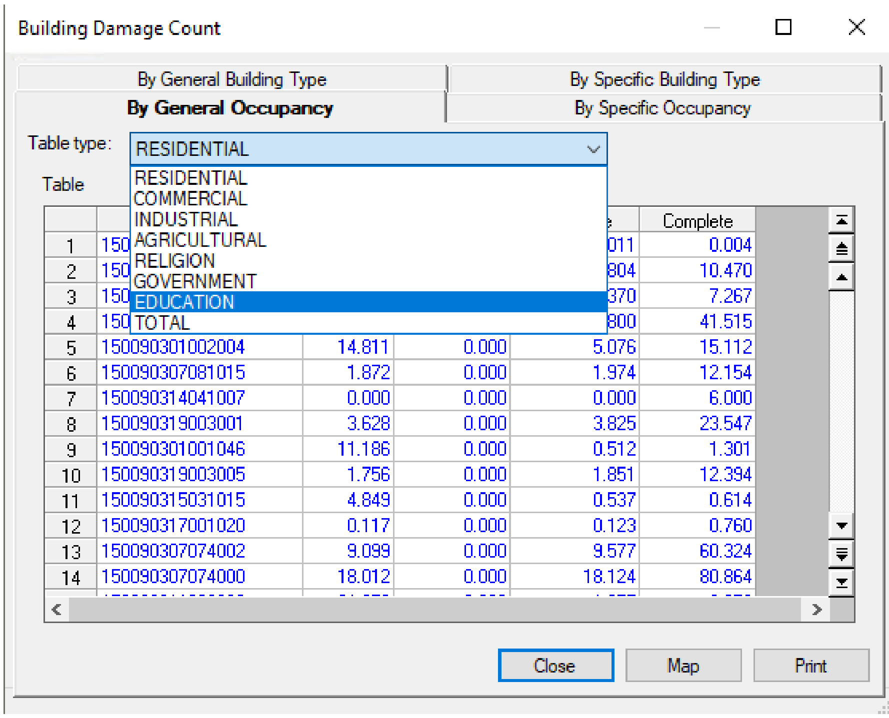


Figure 8-7 Damage Count by Occupancy Class

Figure 8-8 shows **Building Damage Count by General Building Type**, which allows the user to view results by the **General Building Type** and **Specific Building Type**. The values in the table represent the expected number of buildings in each damage state.

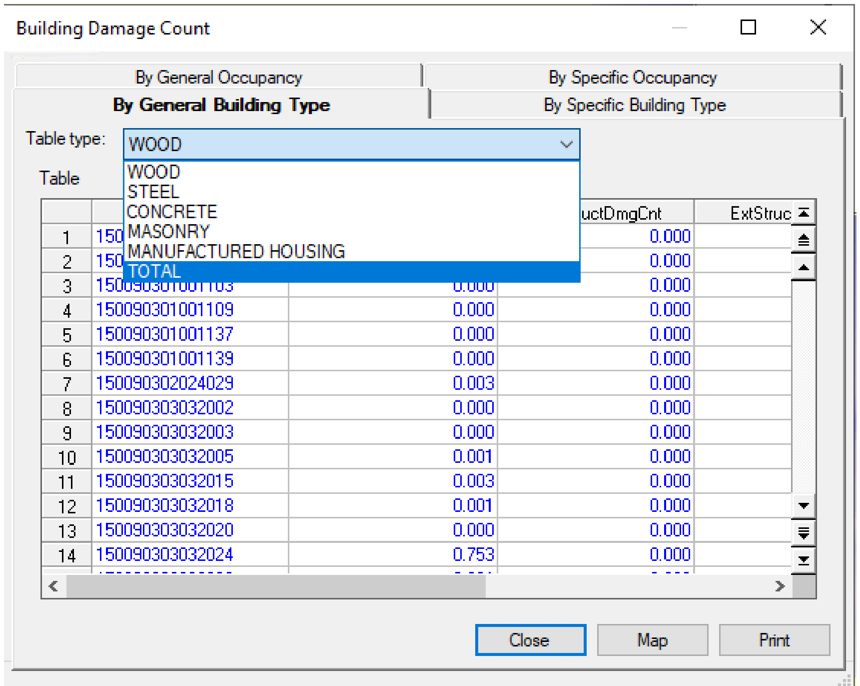


Figure 8-8 Building Damage Count by Building Type

8.3.2 GBS Building Stock Damage by Square Footage by Occupancy

Figure 8-9 shows the **Building Damage Count by Square Footage by Occupancy** class results table, which allows the user to view and map the general inventory damage results either by **General Occupancy** or **Specific Occupancy** class. The values in the table represent the expected damage by square footage (in thousands of square feet) by occupancy class.

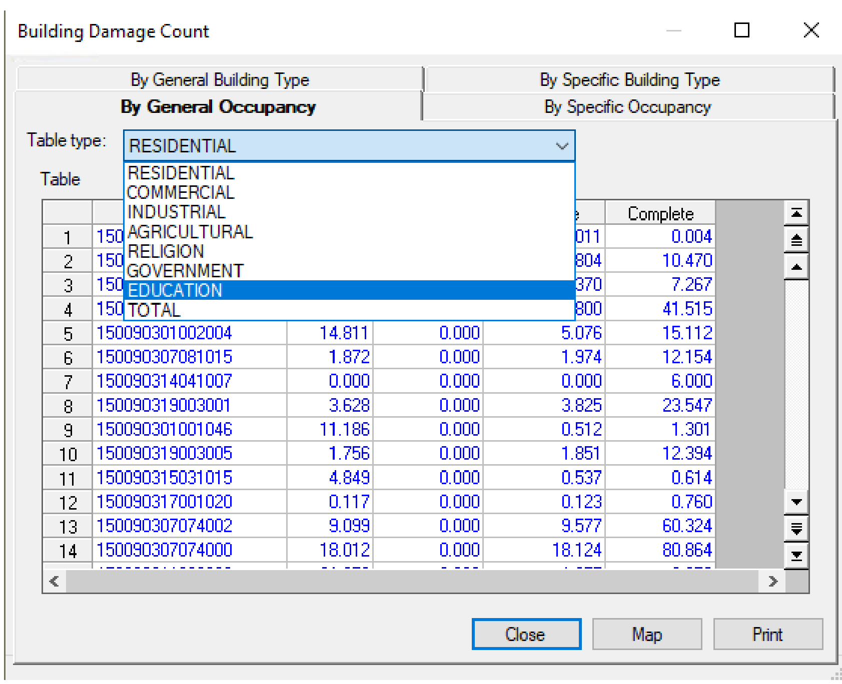


Figure 8-9 Damage by Square Footage by Occupancy Class

8.3.3 GBS Damage by Square Footage by Building Type

Figure 8-10 shows the **Damage by Square Footage by Building Type** table, which allows the user to view and map the general inventory damage results either by **General Building Type** or by **Specific Building Type**. The values in the table represent the expected damage in square footage for each damage state (in thousands of square feet) by general and specific occupancy class.

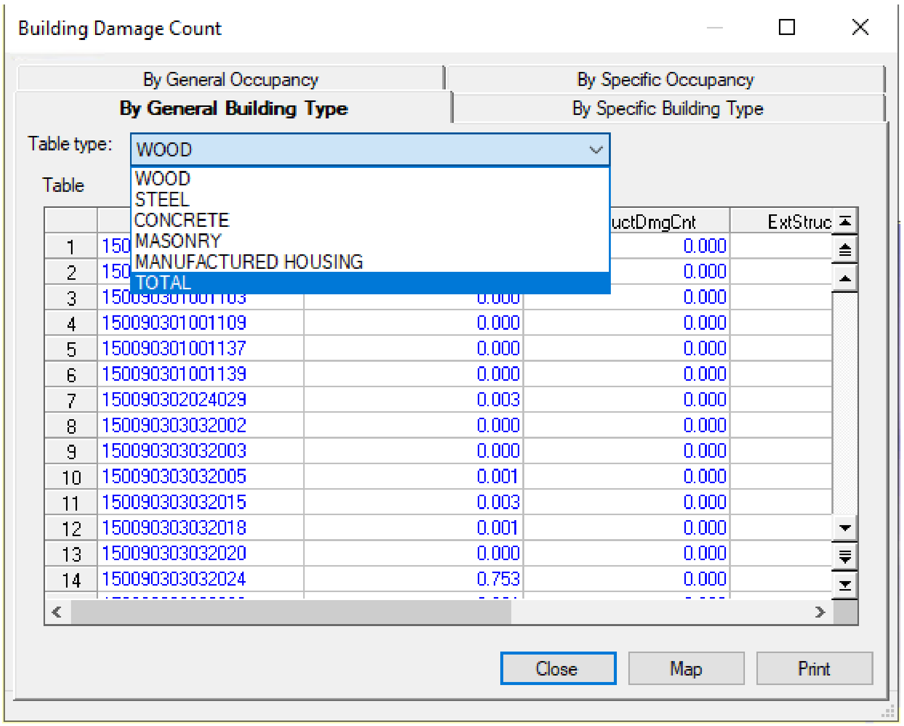


Figure 8-10 Damage by Square Footage by Building Type

8.3.4 GBS Direct Economic Loss by Occupancy

Figure 8-11 shows GBS **Direct Economic Loss by Occupancy** . The user can select and view direct economic loss values by general and specific occupancy classes in thousands of dollars (US). Hazus determines the losses to structural components, non-structural components, building, contents, inventory, relocation costs, income, rental, wage, output, and total of all of these.

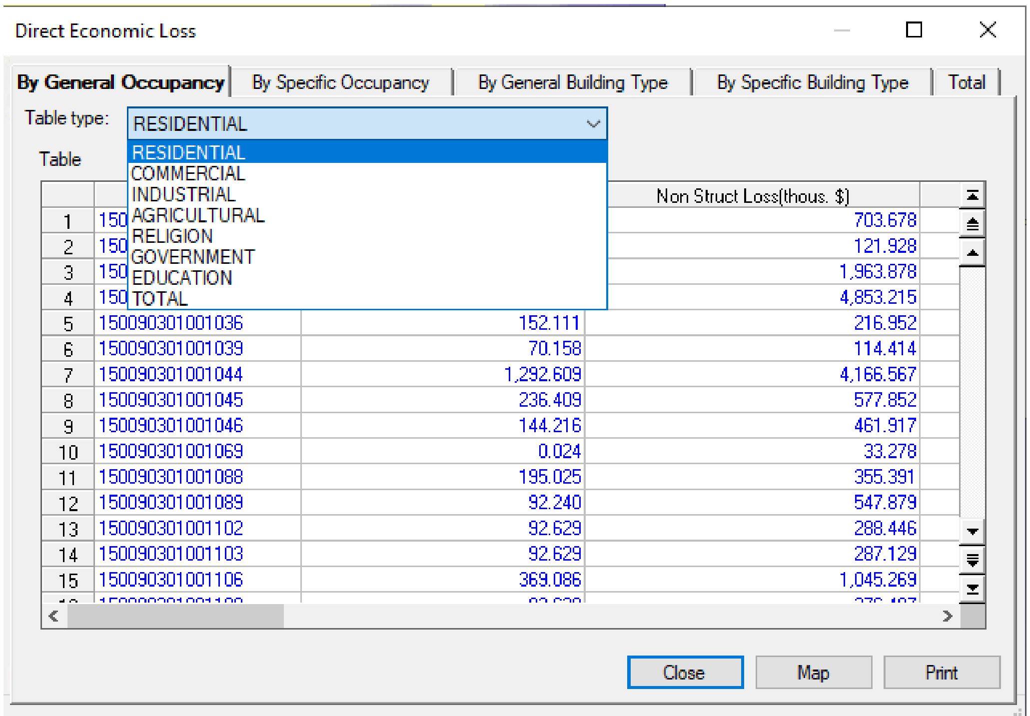


Figure 8-11 Direct Economic Loss by Occupancy

8.3.5 GBS Direct Economic Loss by Building Type

Figure 8-12 shows GBS **Direct Economic Loss by Building Type**. The user can select and view direct economic loss values by general and specific building types in thousands of dollars (US).

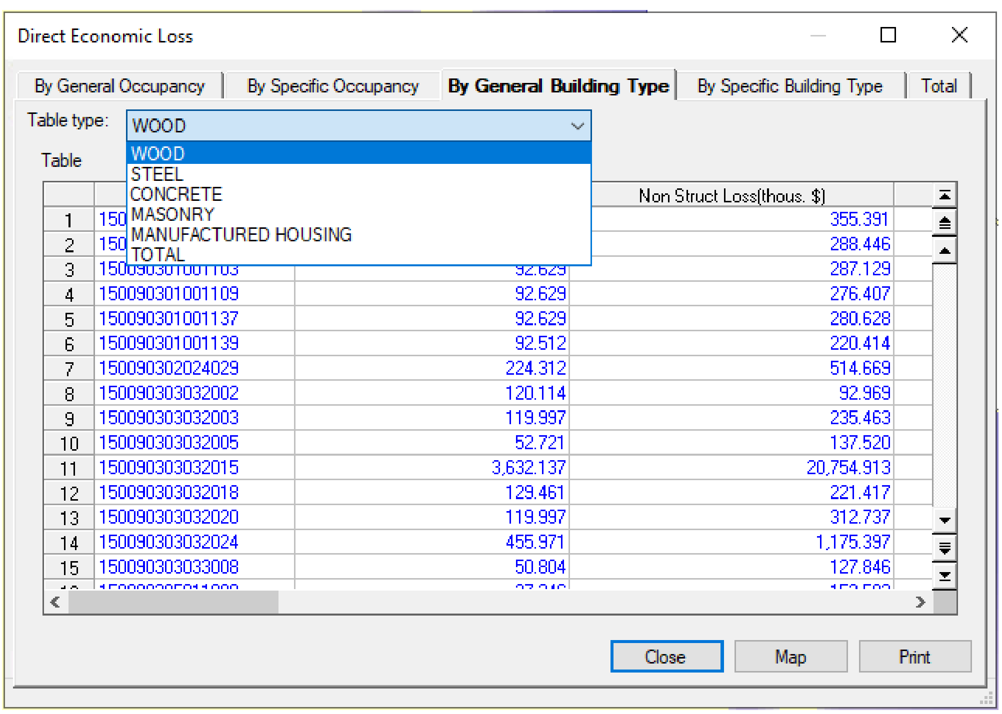
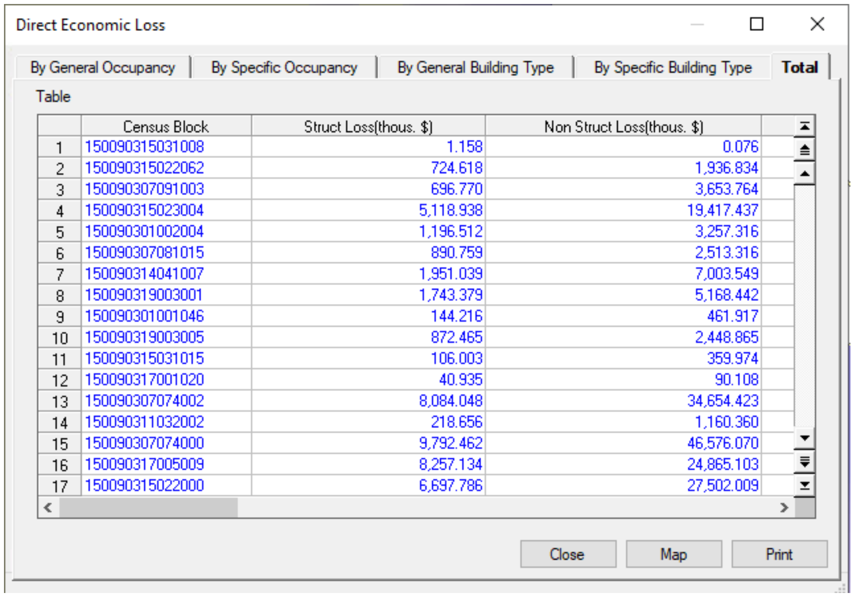


Figure 8-12 Direct Economic Loss by Building Type

8.3.6 GBS Total Direct Economic Loss

Figure 8-13 shows Total Direct Economic Loss for the scenario, in thousands of dollars (US).



	Census Block	Struct Loss(thous. $)	Non Struct Loss(thous. $)
1	150090315031008	1.158	0.076
2	150090315022062	724.618	1,936.834
3	150090307091003	696.770	3,653.764
4	150090315023004	5,118.938	19,417.437
5	150090301002004	1,196.512	3,257.316
6	150090307081015	890.759	2,513.316
7	150090314041007	1,951.039	7,003.549
8	150090319003001	1,743.379	5,168.442
9	150090301001046	144.216	461.917
10	150090319003005	872.465	2,448.865
11	150090315031015	106.003	359.974
12	150090317001020	40.935	90.108
13	150090307074002	8,084.048	34,654.423
14	150090311032002	218.656	1,160.360
15	150090307074000	9,792.462	46,576.070
16	150090317005009	8,257.134	24,865.103
17	150090315022000	6,697.786	27,502.009

Figure 8-13 Total Building Economic Loss

8.4 User-Defined Facilities

The **User-Defined Facilities** (Figure 8-14) submenu allows the user to view and map the damage results for individual, user-specified facilities. Results are available for **Building Damage State** (structure, nonstructural, and content), **Building Functionality** (probability that the structure is functional), and **Building Economic Losses**.

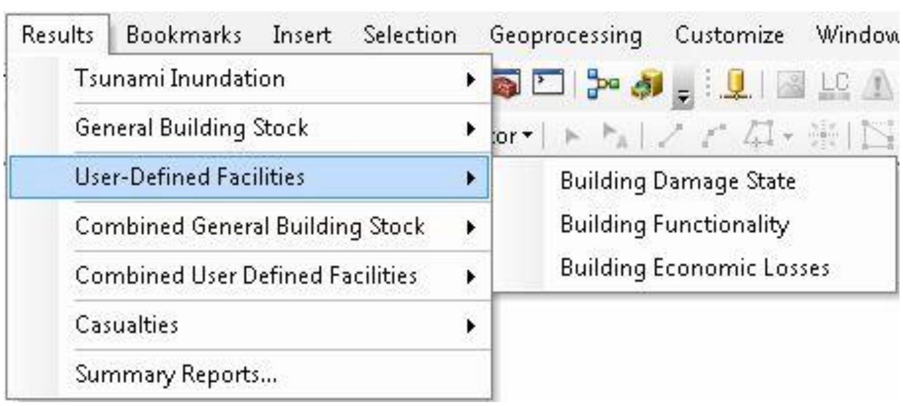


Figure 8-14 User-Defined Facilities Menu

8.5 Combined General Building Stock

The **Combined General Building Stock** (Figure 8-15) submenu allows the user to view and map combined earthquake and tsunami losses computed in the Hazus Tsunami Model incorporating results computed by the Hazus Earthquake Model. Results are available for **Damage by Count**, **Damage by Square Footage**, and **Direct Economic Losses**. Details on how to run a combined analysis are outlined in Section 11. For additional information on how results were derived, please refer to the combined methodology in the *Hazus Tsunami Technical Manual* (FEMA, 2021).

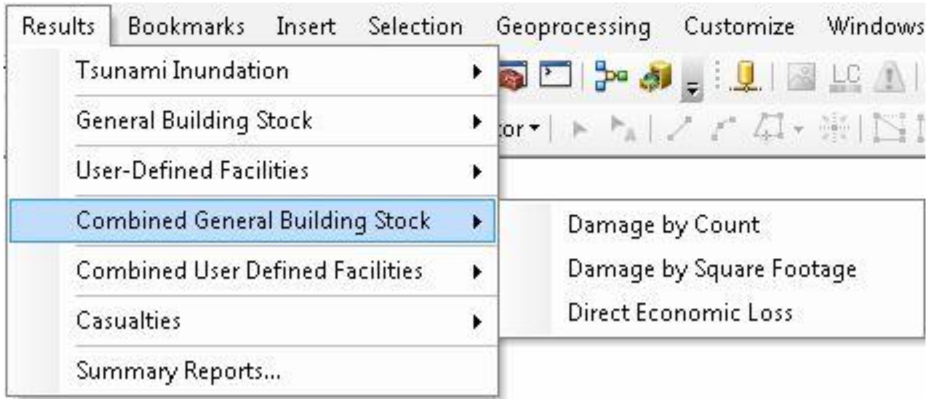


Figure 8-15 Combined General Building Stock Menu

8.6 Combined User-Defined Facilities

The **Combined User-Defined Facilities** (Figure 8-16) submenu allows the user to view and map combined earthquake and tsunami losses computed in the Hazus Tsunami Model incorporating results computed by the Hazus Earthquake Model. Results are available for **Combined Building Damage State**, **Combined Building Functionality**, and **Combined Building Economic Losses**. User-Defined Inventory Data is presented in Section 9. Details on how to run a combined analysis are outlined in Section 11.

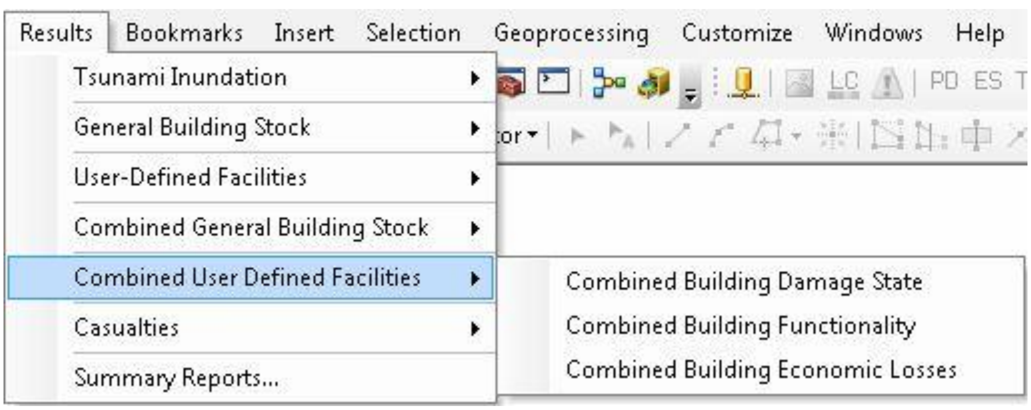


Figure 8-16 Combined User-Defined Facilities

8.7 Casualties

The **Casualties** (Figure 8-17) submenu allows the user to view and map results for **Evacuation Travel Time** and **Probability of Casualties**.

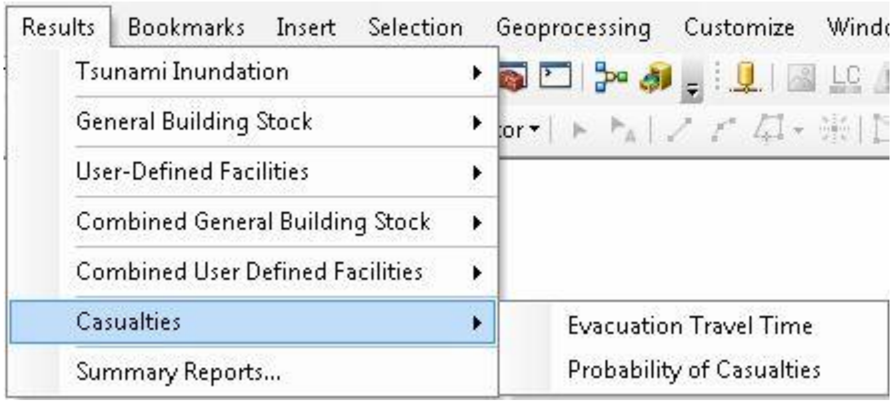
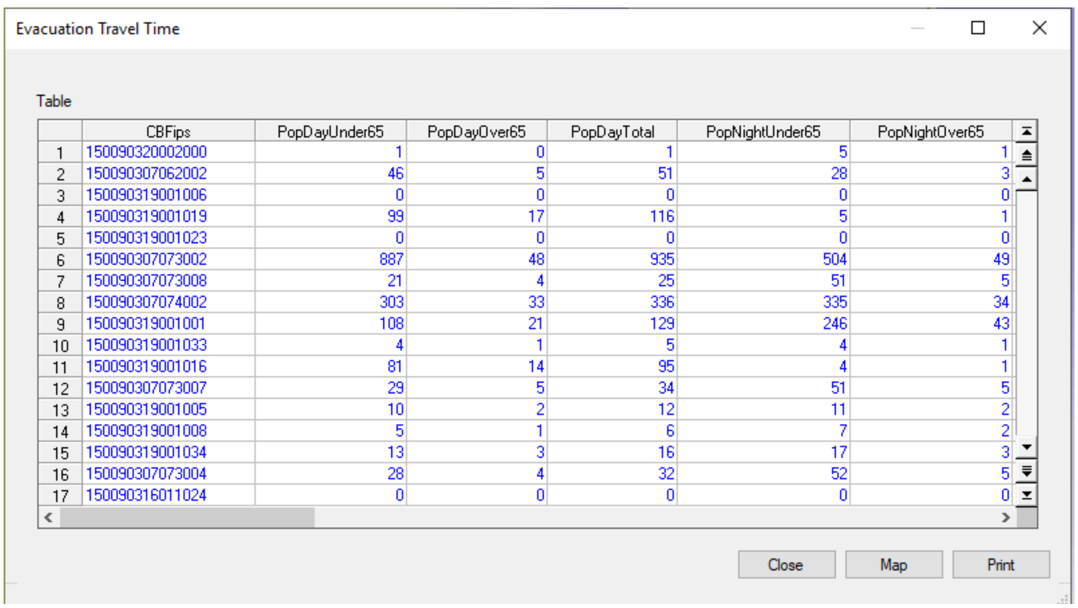


Figure 8-17 Casualty Menu

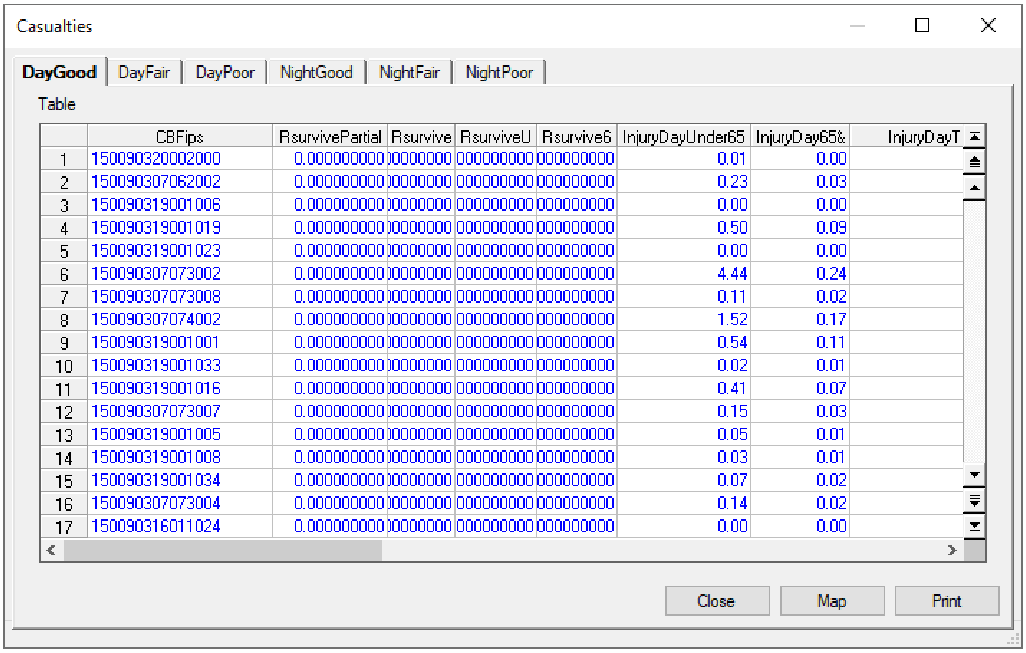
The **Evacuation Travel Time** (Figure 8-18) estimates the total population evacuated for Population Under 65, Population Over 65, and Total Population for Day (population at school, at work, and in commercial buildings); and Night (population at home). Estimates are also calculated in minutes for Travel to Partial Safety (water depth is <u><</u>2 meters), and Travel to Safety (out of inundation zone) for Population Under 65 and Population Over 65 and Total Population.



	CBFips	PopDayUnder65	PopDayOver65	PopDayTotal	PopNightUnder65	PopNightOver65
1	150090320002000	1	0	1	5	1
2	150090307062002	46	5	51	28	3
3	150090319001006	0	0	0	0	0
4	150090319001019	99	17	116	5	1
5	150090319001023	0	0	0	0	0
6	150090307073002	887	48	935	504	49
7	150090307073008	21	4	25	51	5
8	150090307074002	303	33	336	335	34
9	150090319001001	108	21	129	246	43
10	150090319001033	4	1	5	4	1
11	150090319001016	81	14	95	4	1
12	150090307073007	29	5	34	51	5
13	150090319001005	10	2	12	11	2
14	150090319001008	5	1	6	7	2
15	150090319001034	13	3	16	17	3
16	150090307073004	28	4	32	52	5
17	150090316011024	0	0	0	0	0

Figure 8-18 Evacuation Travel Time

The **Probability of Casualties** results (Figure 8-19) estimate the percentage of the Population Under 65 and Over 65 to survive by reaching Partial Safety (water depth <u><</u>2 meters) or Total Safety (water depth <0 meter). These results also provide an estimate of injuries for population Under 65, Over 65, and total number of injuries, as well as fatalities for population Under 65, over 65 and total fatalities. The estimates are provided for both Day (population at school, at work, and in commercial buildings); and Night (population at home), by the estimated level of preparedness of the community: Good, Fair, or Poor. See Section 12 for more information.



	CBFips	RsurvivePartial	Rsurvive	RsurviveU	Rsurvive6	InjuryDayUnder65	InjuryDay65&	InjuryDayT
1	150090320002000	0.000000000	)0000000	000000000	000000000	0.01	0.00	
2	150090307062002	0.000000000	)0000000	000000000	000000000	0.23	0.03	
3	150090319001006	0.000000000	)0000000	000000000	000000000	0.00	0.00	
4	150090319001019	0.000000000	)0000000	000000000	000000000	0.50	0.09	
5	150090319001023	0.000000000	)0000000	000000000	000000000	0.00	0.00	
6	150090307073002	0.000000000	)0000000	000000000	000000000	4.44	0.24	
7	150090307073008	0.000000000	)0000000	000000000	000000000	0.11	0.02	
8	150090307074002	0.000000000	)0000000	000000000	000000000	1.52	0.17	
9	150090319001001	0.000000000	)0000000	000000000	000000000	0.54	0.11	
10	150090319001033	0.000000000	)0000000	000000000	000000000	0.02	0.01	
11	150090319001016	0.000000000	)0000000	000000000	000000000	0.41	0.07	
12	150090307073007	0.000000000	)0000000	000000000	000000000	0.15	0.03	
13	150090319001005	0.000000000	)0000000	000000000	000000000	0.05	0.01	
14	150090319001008	0.000000000	)0000000	000000000	000000000	0.03	0.01	
15	150090319001034	0.000000000	)0000000	000000000	000000000	0.07	0.02	
16	150090307073004	0.000000000	)0000000	000000000	000000000	0.14	0.02	
17	150090316011024	0.000000000	)0000000	000000000	000000000	0.00	0.00	

Figure 8-19 Probability of Casualties

8.8 Summary Reports

Various summary reports are available for viewing and printing through the **Summary Reports** menu (Figure 8-20). After selecting a report click the **View** button and a sample report is shown (Figure 8-21), where the bars are shown as pairs where the day population under 65 is shown on the left (and is usually the greater value) and 65 and over is shown on the right. The combined reports are only available if a combined earthquake and tsunami scenario has been completed. See Section 11 for more information.

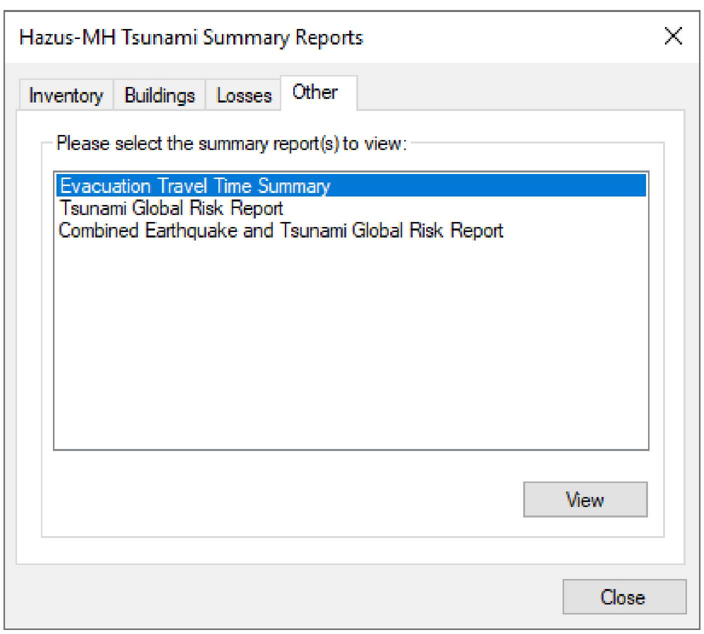


Figure 8-20 Summary Reports Menu

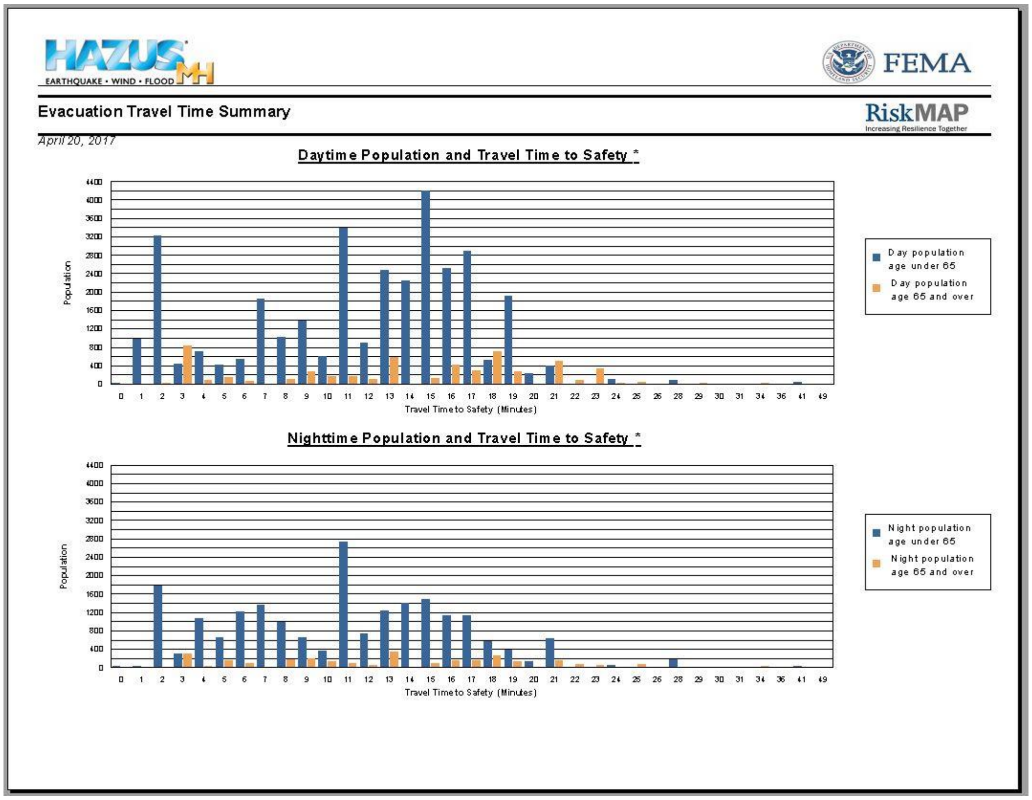


Figure 8-21 Summary Reports Output Example

Section 9. Advanced Hazus Analysis: User-Defined Inventory Data

The Hazus baseline data inventory provides datasets that can be used for immediate assessment, but in certain areas (particularly for tsunamis) there may be the need to use a custom data set that is more relevant to the Study Region being analyzed. **User-Defined Facilities**, accessible via the option **Inventory > User-Defined Facilities**, enables user-specific datasets to be analyzed through the Hazus methodologies providing more accurate results. Users should utilize the Hazus Comprehensive Data Management System (CDMS) to import their User-defined point data into the State Database before building their Study Region. This also allows the combination of tsunami and earthquake loss potential in the case of near-source earthquakes (where the region is impacted by both earthquake ground shaking, and the earthquake generated tsunami).

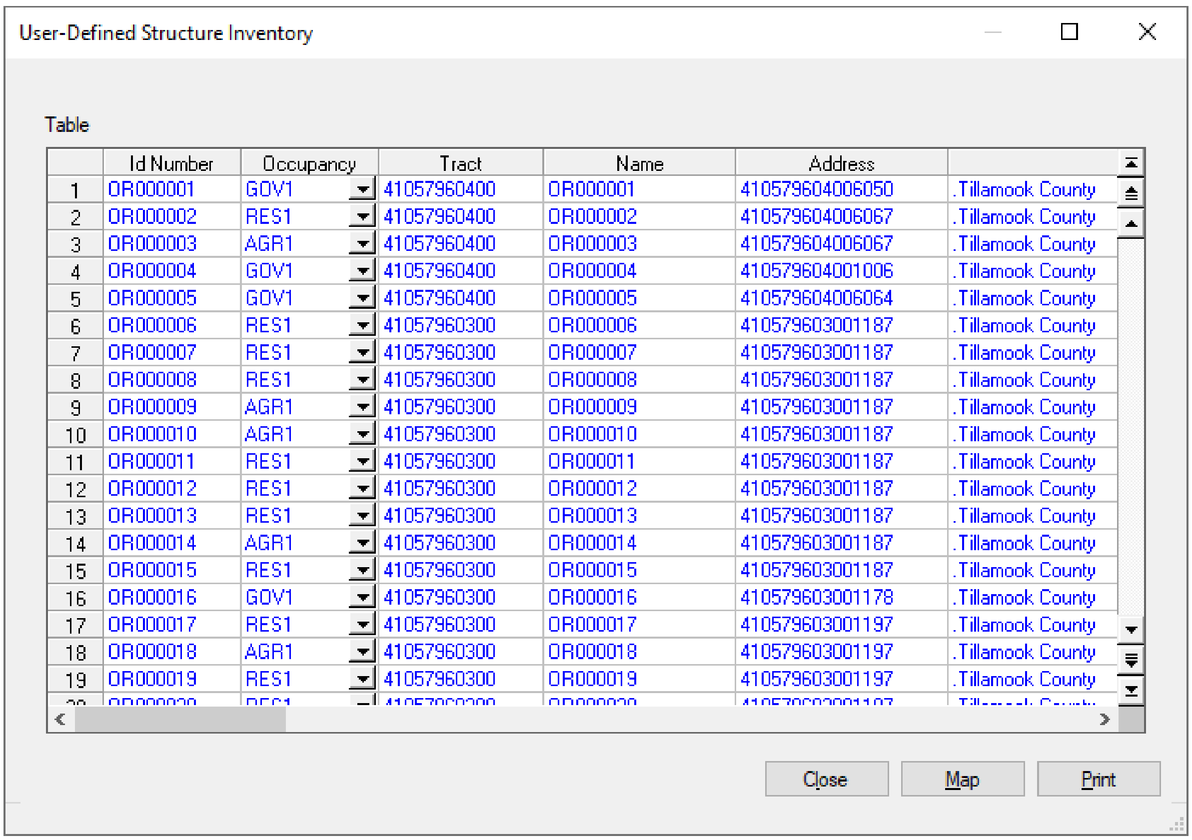
Within Hazus, the UDF table is empty and it is the responsibility of the user to populate the table with data specific to the area being analyzed using the CDMS. The assumption is that the user will obtain custom data from another source, such as parcel data, organize it into the format seen in Table 9-1**,** and add it to the UDF tables (hzUserDefinedFlty, eqUserDefinedFlty, and flUserDefinedFlty) in the State Database in Hazus, using the enhanced CDMS UDF interface. The design of tsunami UDF utilizes attributes that are already part of the earthquake- and flood-specific UDF tables.

Table 9-1 State Database User-Defined Facility Tables and Required Attributes

User-Defined Facility	Note	Required for Tsunami Losses
General Table (hzUserDefinedFlty)		
[UserDefinedFltyId]	A unique ID	Yes
[Occupancy]	Specific Occupancy Type	Yes
[Tract]		No
[Name]		No
[Address]		No
[City]		No
[Statea]		No
[Zipcode]		No
[Contact]		No
[PhoneNumber]		No
[YearBuilt]		No
[Cost]	Structural Replacement Cost ($USD)	Yes
[BackupPower]		No
[NumStories]		No
[Area]	Building Area (sqft)	Yes
[ContentCost]	Content Replacement Cost ($USD)	Yes
[ShelterCapacity]		No
[Latitude]		Yes
[Longitude]		Yes
[Comment]		No
[Shape]		No

User-Defined Facility	Note	Required for Tsunami Losses
Earthquake Specific Table (eqUserDefinedFlty)		
[eqBldgType]	Specific Earthquake Building Type	Yes
[DesignLevel]	Seismic Design Level	Yes
[eqUdsClass]		No, but required for EQ model functionality loss
Flood Specific Table (flUserDefinedFlty)		
[FirstFloorHt]	Top of Finished Floor Relative to Adjacent Grade (feet)	Yes
[foundationtype]		No, but useful in estimating FirstFloorHt

On aggregation, the data will be added to a new tsunami UDF table (tsUserDefinedFlty) as seen in Figure 9-1.



	Id Number	Occupancy	Tract	Name	Address	
1	OR000001	GOV1	41057960400	OR000001	410579604006050	.Tillamook County
2	OR000002	RES1	41057960400	OR000002	410579604006067	.Tillamook County
3	OR000003	AGR1	41057960400	OR000003	410579604006067	.Tillamook County
4	OR000004	GOV1	41057960400	OR000004	410579604001006	.Tillamook County
5	OR000005	GOV1	41057960400	OR000005	410579604006064	.Tillamook County
6	OR000006	RES1	41057960300	OR000006	410579603001187	.Tillamook County
7	OR000007	RES1	41057960300	OR000007	410579603001187	.Tillamook County
8	OR000008	RES1	41057960300	OR000008	410579603001187	.Tillamook County
9	OR000009	AGR1	41057960300	OR000009	410579603001187	.Tillamook County
10	OR000010	AGR1	41057960300	OR000010	410579603001187	.Tillamook County
11	OR000011	RES1	41057960300	OR000011	410579603001187	.Tillamook County
12	OR000012	RES1	41057960300	OR000012	410579603001187	.Tillamook County
13	OR000013	RES1	41057960300	OR000013	410579603001187	.Tillamook County
14	OR000014	AGR1	41057960300	OR000014	410579603001187	.Tillamook County
15	OR000015	RES1	41057960300	OR000015	410579603001187	.Tillamook County
16	OR000016	GOV1	41057960300	OR000016	410579603001178	.Tillamook County
17	OR000017	RES1	41057960300	OR000017	410579603001197	.Tillamook County
18	OR000018	AGR1	41057960300	OR000018	410579603001197	.Tillamook County
19	OR000019	RES1	41057960300	OR000019	410579603001197	.Tillamook County

Figure 9-1 User-Defined Facility Inventory

The intent is to begin to prioritize facilities requiring further study, as well as to prioritize mitigation strategies for the impacted communities. Losses and performance by building types are based on averages across large sets of buildings. Care should be used when reporting site specific results since the actual losses and performance for each could vary significantly. The UDF results should not been used as a substitute for a detailed engineering analysis performed with the agreement of the facility owner. The general approach is to call attention to these facilities, include their locations in the inventory, and indicate a potential for loss in the final report.

9.1 UDF Required Attributes

The minimum attributes required for analysis of UDF are presented in Table 9-2. It is recommended that CDMS be utilized to import the UDF data into the Hazus State database. If any of the attributes are not part of the user's dataset, then Hazus will populate them with default values using the CDMS tool provided that the user supplies occupancy type and building area. While it is possible to edit those values later through the Hazus interface, it is not practical to edit for larger datasets; therefore, it is more time-efficient to have the correct values in the imported file.

Table 9-2 UDF Required Attributes

Attribute	Description	Why is it needed?
Record Identifier (ID)	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 field that is not used: The COMMENT field is a good field to use to populate this attribute.	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 OCCUPANCY.	Analyses are based on the occupancy and/or building type.
Building Type	Building type per the Hazus classification. Map it to BLDGTYPE.	Analyses are based on the occupancy and/or building type.
Design Level	Seismic Design Level. Map to DesignLevel. CDMS default is PC.	To assess lateral strength of structure – for building damage
First floor height	Top of Finished Floor Relative to Adjacent Grade (ft). Map to FirstFloorHt. CDMS default is 1 foot.	To assess content damage
Building replacement cost	Cost ($) to replace the building in case of damage. Used by economic loss model. Map it to COST. CDMS will estimate based on RSMeans table (Section 12).	To assess building economic loss
Content replacement cost	As above (in Building replacement cost) relating to building content. Map to Content Cost. CDMS will estimate based on percent of building replacement.	To assess content economic loss
Location	The location of the structure/facility can be supplied as latitude/longitude (in that case, Hazus will create the geospatial points), or directly when the table imported is a feature class.	Hazus needs location of structure to calculate the hazard. Hazus uses the location at import time to filter the points that do not fall within the Study Region (i.e., discarding any point that falls outside the Study Region).

9.2 User-Defined Facilities Inventory

User-Defined inventory can require significant dedicated work to prepare. The extent of preparation and data compilation work involved depends on the condition and completeness of existing information, required data conversions, and the contributions of subject expertise. The greatest impact from enhanced inputs are produced both by editing 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.

The most detailed type of analysis incorporates the results from completed loss studies. For example, it is possible to include the output of loss estimates performed using locally developed assessments. Reviews and updates to the vulnerability ratings for each model building type will also produce more accurate analysis results.

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

Data collected may need to be adjusted so the inventory is classified appropriately. The inventory should align to the systems defined in the methodology, including replacement values and locations as points rather than polygons. In addition, a school may have two building wing additions that were constructed over the forty-year lifetime of the structure. Each era of construction used improved materials, but the best materials were used to construct the smallest addition. The individual responsible for assigning the building type of the school according to 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., two separate records. Refer to the *Hazus Tsunami Model Technical Manual* (FEMA, 2021) and *Hazus Inventory Technical Manual* (FEMA, 2021) for more information.

Section 10. Advanced Hazus Analysis: User-Defined Hazard Data

10.1 User-Defined Tsunami Grids

Since the Hazus Tsunami Model utilizes authoritative hazard datasets from external providers, sample data from NOAA's Pacific Marine Environmental Laboratory (PMEL) are provided so that users can review and understand input requirements for all three levels of analysis.

Sample data (Table 10-1) are prepared for each level of analysis based on data provided for five of the PMEL forecast inundation model communities.

Table 10-1 NOAA PMEL Sample Data

Community	County	Scenario	Level 1 (Basic)	Level 2 (Advanced)	Level 3 (Advanced)
Homer, AK	Kenai	M 9.2 1964 Alaska	hom_dem_ft hom_maxR_ft	hom_maxdg_ft hom_maxv_ftsec	hom_dg_ft_median hom_flux_ft3sec2_median
Crescent City, CA	Del Norte	M 9.0 Cascadia	crc_dem_ft crc_maxR_ft	crc_maxdg_ft crc_maxv_ftsec	crc_dg_ft_median crc_flux_ft3sec2_median
Kahului, HI	Maui	M 9.0 Cascadia	kah_dem_ft kah_maxR_ft	kah_maxdg_ft kah_maxv_ftsec	kah_dg_ft_median kah_flux_ft3sec2_median
Garibaldi, OR	Tillamook	M 9.0 Cascadia	gar_dem_ft gar_maxR_ft	gar_maxdg_ft gar_maxv_ftsec	gar_dg_ft_median gar_flux_ft3sec2_median
Westport, WA	Grays Harbor	M 9.0 Cascadia	wes_dem_ft wes_maxR_ft	wes_maxdg_ft wes_maxv_ftsec	wes_dg_ft_median wes_flux_ft3sec2_median

In the table above:

- *Level 1 (Basic):* DEMs include post-earthquake ground deformation (ft) for near-source scenarios; Max runup (maxR, ft) relative to MSL
- *Level 2 (Advanced):* Depth grids are maximum depths (maxdg) in feet above ground level; maximum velocity (maxv) in ft/sec.
- *Level 3 (Advanced):* Depth grids are median depths in feet above ground level; momentum flux is median values in $ft^3 sec^2$.

The levels of analysis noted above are not the same levels of analysis denoted in other Hazus models (refer to Section 2 for more information).

The hazard data (runup and velocity) were developed using NOAA's Short-term Inundation Forecasting for Tsunamis (SIFT) system. For additional information, including access to SIFT products visit the PMEL website.

In addition, each state and territory supported by the Hazus Tsunami Model has also developed or are actively working on the development of tsunami hazard data. Many of these datasets are available online or can be obtained through state contacts. A summary of some of the state efforts is available online. Note that each state provides hazard data in different GIS formats and units. Although the Hazus GUI helps provide the ability to convert units, the input needs to be in either ArcGRID or NetCDF NOAA SIFT output format.

The National Tsunami Hazard Mitigation Program (NTHMP) provides a comprehensive list of state agency partners as well as official NTHMP Coordinating Members.

10.2 User-Defined Casualty Data

The Level 2 (Advanced) Casualty Analysis leverages the output from the USGS Pedestrian Evacuation Analyst ArcGIS tool (Figure 10-1), which assesses evacuation times to high ground. The preparation of Level 2 (Advanced) input and use of the USGS tool requires review and input of available land use data, imagery and could require mapping in the field. Unlike Level 1 (Basic) that includes a road only approach, Level 2 (Advanced) supports the ability of providing pedestrian evacuation travel times across fields or other more direct routes to safety. However, development of the Level 2 (Advanced) data needs to incorporate a more detailed data analysis to ensure that no obstructions, such as fencing, or canals are ignored in providing the most expedient routes for evacuation. In addition, the Level 2 (Advanced) analysis can better incorporate current or proposed vertical evacuation structures. Detail on the USGS Pedestrian Evacuation Tool Methodology is available from the USGS.

The tool can be found online.

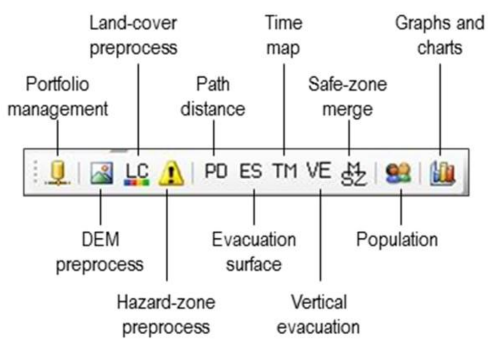


Figure 10-1 USGS Pedestrian Evacuation Analyst ArcGIS tool

Input data required for the Hazus Level 2 (Advanced) Casualty Analysis include:

- Travel Time to Safe Zone (depth = 0)
- Travel Time to Partially Safe Zone (depth <2 meters)

10.3 Advanced: Post-Earthquake Ground Deformation DEM

In the case of a tsunami analysis involving a Near Source earthquake, it is recommended that the DEM used in the scenario be based on deformed (post-earthquake) topography. This will allow for more accurate inundation modeling by factoring in any ground deformation caused by the earthquake. For numerical modeling, such as that performed by PMEL, the deformed DEM is usually available. The deformed DEM is available in the FEMA MSC sample data for the local Cascadia scenario. It can be a critical input if the ground surface elevations relative to sea-level have decreased, the inundation and losses could be more extensive. See the *Hazus Tsunami Model Technical Manual* (FEMA, 2021) document discussion of hydrodynamic models combined with seafloor deformation and coastal topography for more information.

Section 11. Advanced Hazus Analysis: Combined Earthquake and Tsunami Scenario with Level 2 Casualty Analysis

In order to run a combined earthquake and tsunami analysis, the user needs to build a multi-hazard (earthquake and tsunami) Study Region that includes a shoreline (i.e., must be a coastal region) following the workflow outlined in Table 11-1.

Table 11-1. Combined Earthquake and Tsunami Scenario – User Workflow

Build Multi-Hazard Study Region: Hazus Earthquake Model	Build Multi-Hazard Study Region Hazus Tsunami Model
• Define/Select Earthquake Scenario (using same scenario source that creates the Tsunami hazard) • Run Analysis • Display Earthquake-Only Losses	• Select Tsunami Scenario • Define Tsunami Type as Near Source • Define Scenario – Level 2 or 3 (Advanced) • Run Tsunami Analysis • Define Casualty Level 2 (Advanced) • Display Combined Earthquake and Tsunami Losses

11.1 Steps to Create and Run a Combined Earthquake and Tsunami Analysis

The combined earthquake and tsunami scenarios are available for Near Source tsunami hazards, where the earthquake ground shaking impacts the Study Region for the following locations:

- Alaska
- Oregon
- Washington
- California
- Hawaii
- US Virgin Islands
- Puerto Rico

Sample data for all levels of analysis have been provided for a selected community for each of the five U.S. states and is accessible from the PMEL website (See Section 10 for more information). The following example uses the data for Garibaldi, Oregon (in Tillamook County), for a Level 2 (Advanced) Analysis based on a Magnitude 9.0 Cascadia Subduction Zone earthquake.

To run a combined analysis, the Study Region must be created for both earthquake and tsunami hazard analysis. Start with **Create a New Region** wizard (Figure 11-1). Select both **Earthquake** and **Tsunami** and click **Next**.

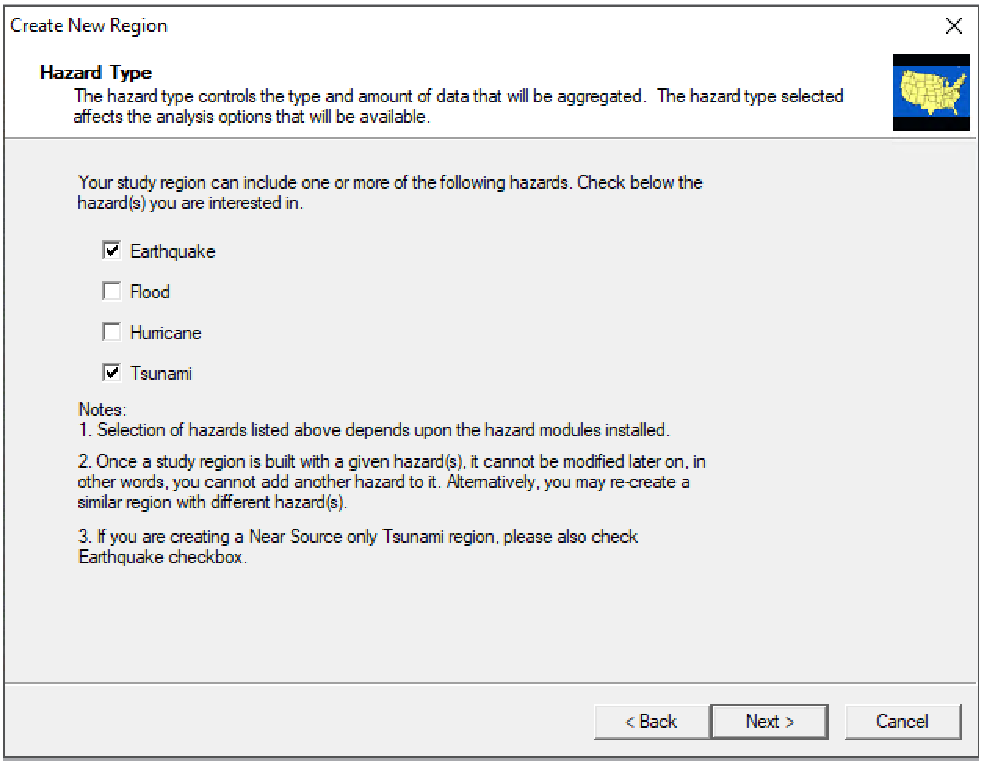


Figure 11-1 Create New Region Multi-hazard

Specify the Study Region for Tillamook, Oregon, and finish the **Create New Region** wizard. Open a region and select the new multi-hazard region (created above). When prompted, select **Earthquake** to run first as shown in Figure 11-2.

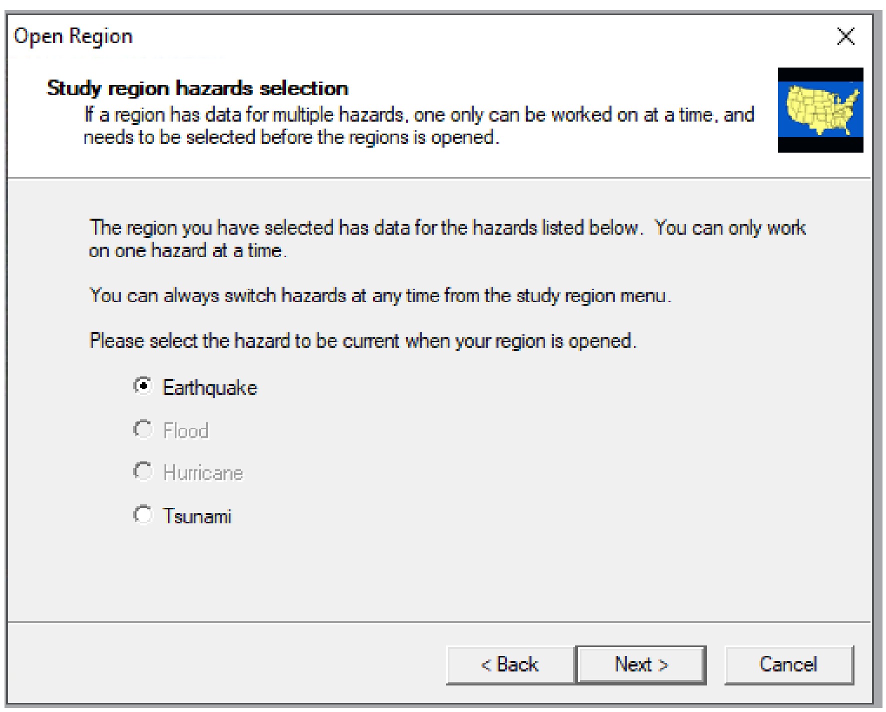


Figure 11-2 Open Region Earthquake Model

In the **Seismic Hazard Type Selection** menu, choose to run a scenario using **USGS ShakeMap** as the seismic hazard type (Figure 11-3).

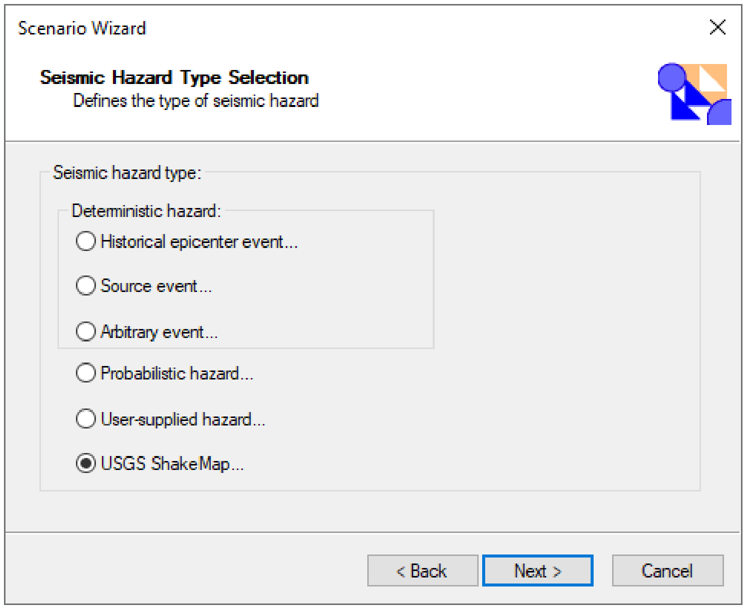


Figure 11-3 Scenario Wizard – Seismic Hazard Type Selection

Use the **ShakeMap Download** window (Figure 11-4) to search for available USGS ShakeMaps or use the **Browse for Existing ShakeMap Grid Data** button to search for a previously downloaded ShakeMap (See *Hazus Earthquake Model User Guidance* (FEMA, 2020) for instructions on downloading USGS ShakeMaps).

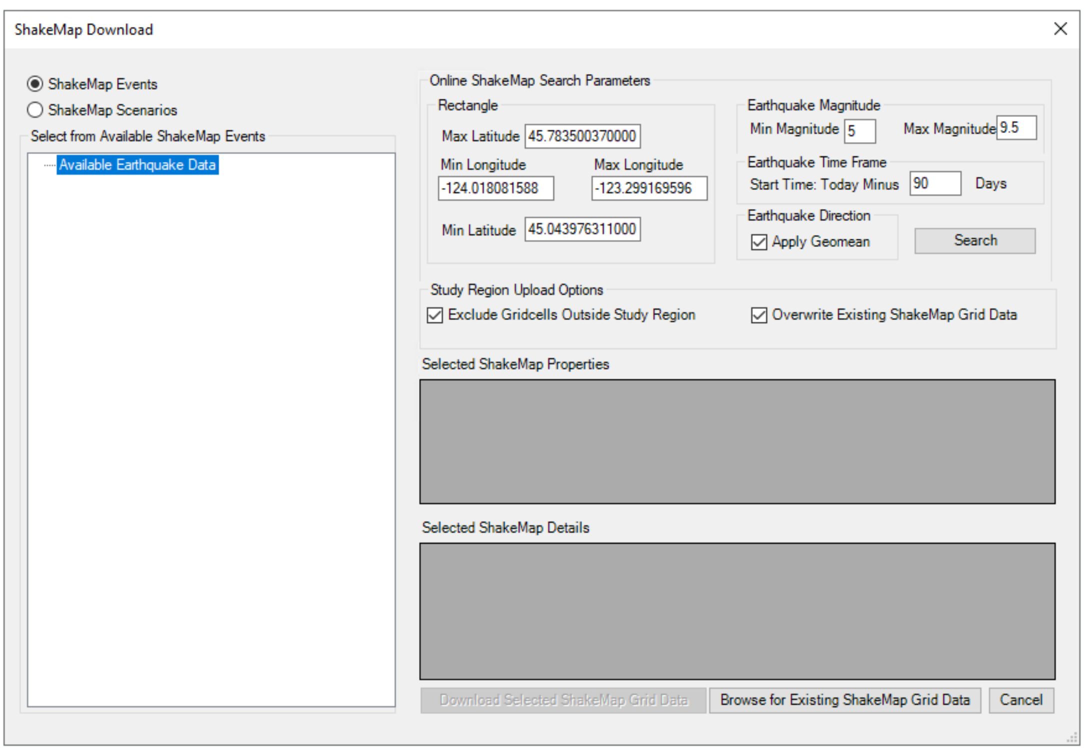


Figure 11-4 ShakeMap Download

Complete the scenario setup and run the analysis (Figure 11-5).

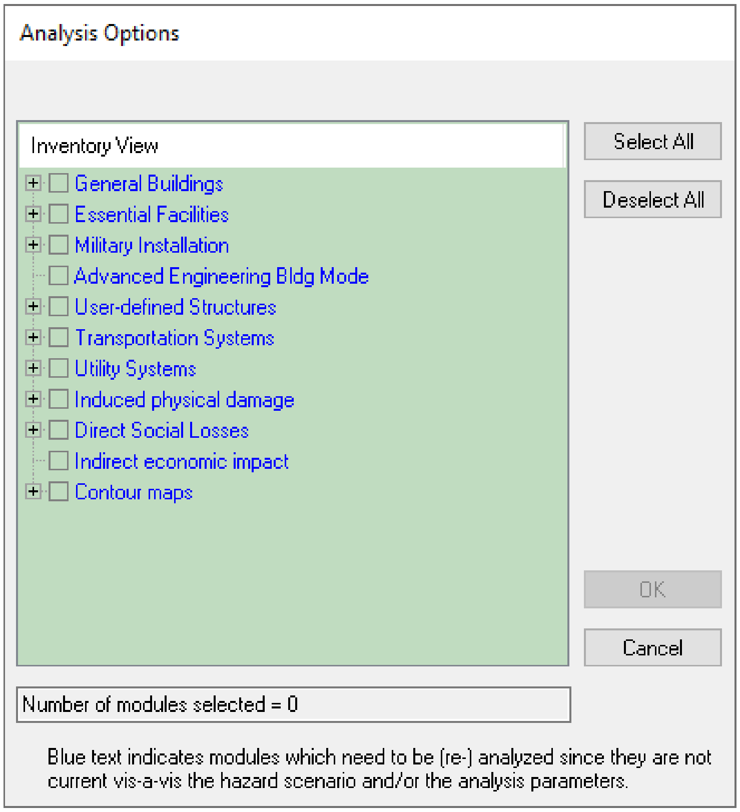


Figure 11-5

When the run is complete, choose **Switch Hazard** under **File** on the toolbar. Select **Tsunami** (Figure 11-6) to switch to the Tsunami Model.

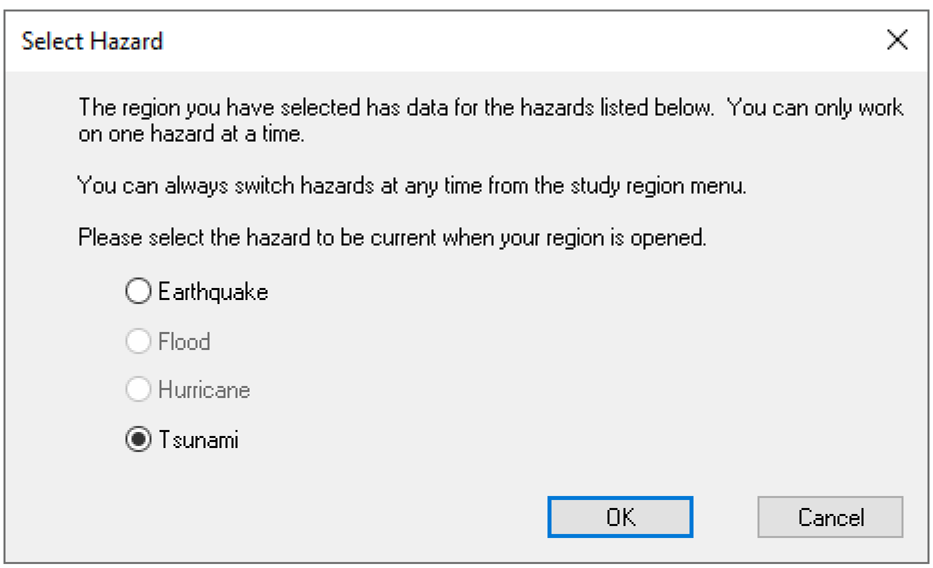


Figure 11-6 Select Hazard Model

In the Hazus Tsunami Model, select **Tsunami Hazard Type** (Figure 11-7) from the **Hazard** menu. Choose **Near Source only** (Figure 11-8). Click **OK**.

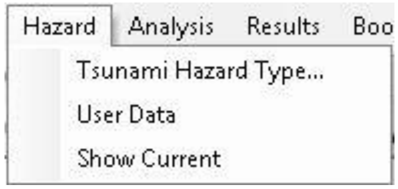


Figure 11-7 Hazard Menu

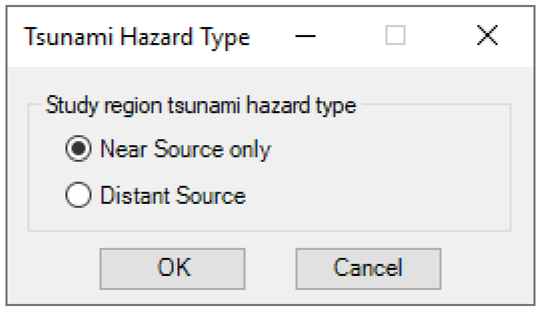


Figure 11-8 Tsunami Hazard Type

From the **Hazard** menu, select **User Data**. Then, choose **Level 2: Depth-Above Ground Level (AGL) and Velocity** (Figure 11-9).

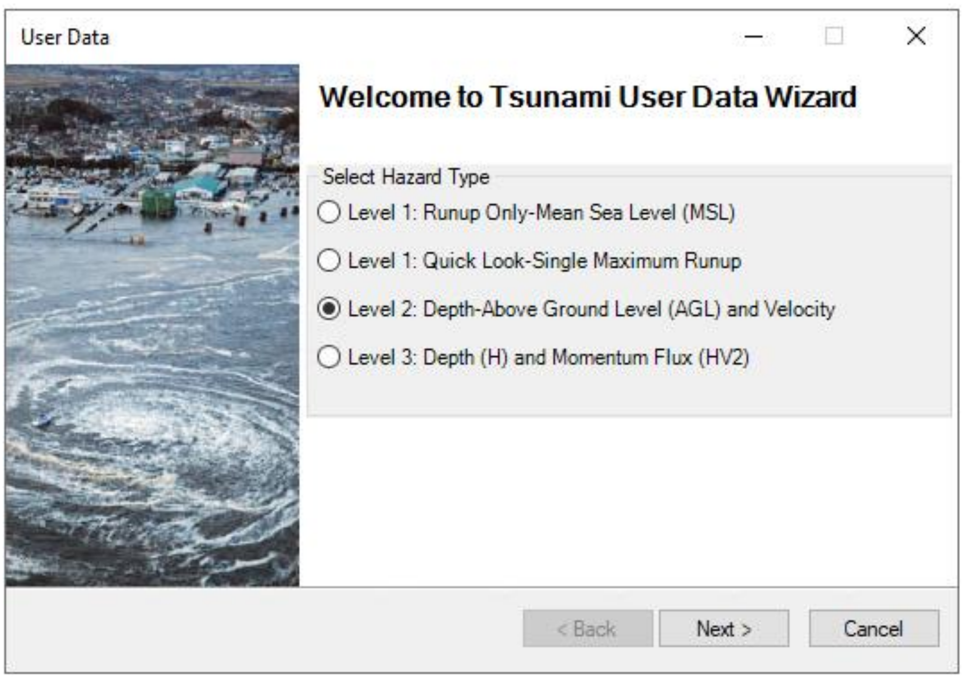


Figure 11-9 User Data Menu

As seen in Figure 11-10, under Select Input Format and Units, choose **Rasters** and set the units to depth = ft and velocity = ft/sec. Use the **Browse Depth** and **Browse Velocity** buttons to load the Level 2 (Advanced) sample data for Garibaldi, Oregon. Click **OK** to load the data into the analysis. Then click **Next**.

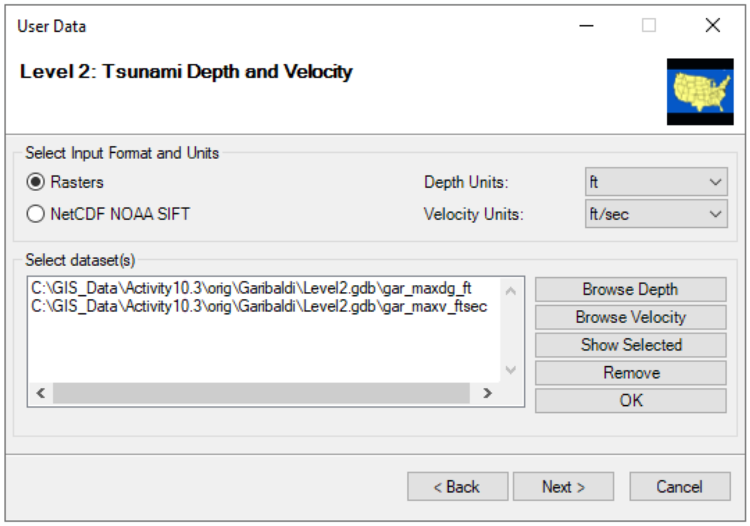


Figure 11-10 Level 2 (Advanced) Tsunami Depth and Velocity

Enter the scenario name and click **Next** (Figure 11-11). Click **OK** to continue.

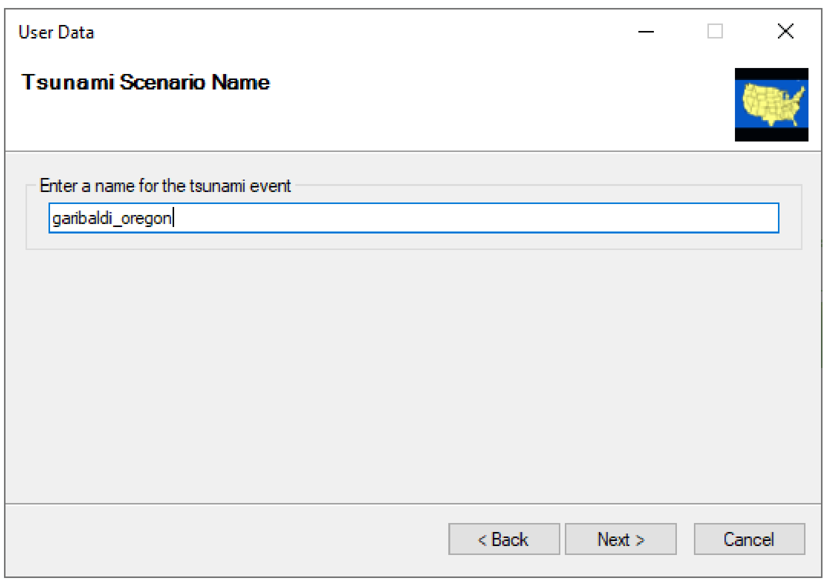


Figure 11-11 Tsunami Scenario Name

In the **Analysis** menu, choose **Run**. In the **Analysis Option–Tsunami** window (Figure 11-12), click **Select All**. Note that the Study Region for Tillamook, Oregon, has a user-defined facility (UDF) database included in Hazus. Click **OK**.

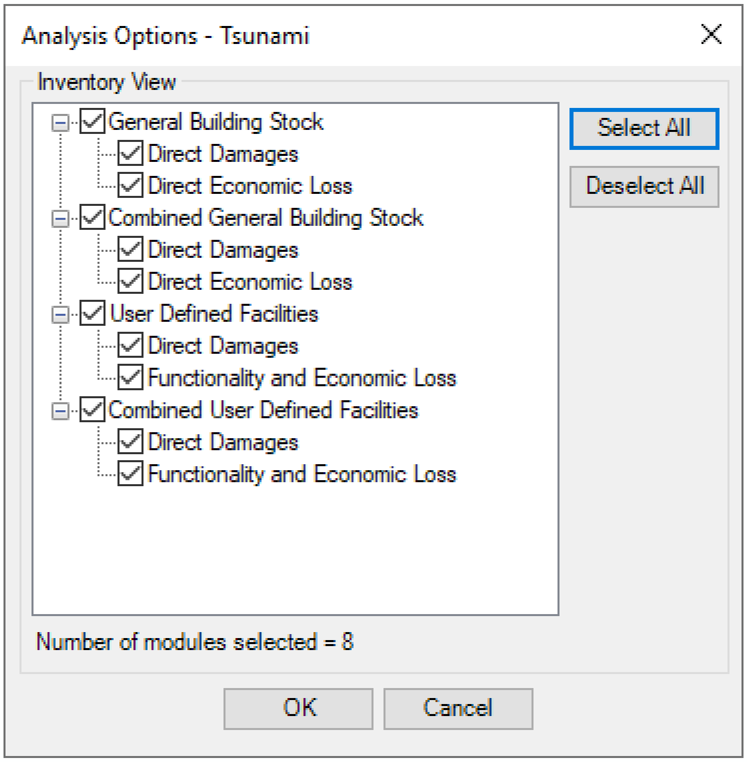


Figure 11-12 Analysis Option - Tsunami

The next step requires output data from the USGS Pedestrian Evacuation Model. The USGS model includes the capability for more detailed analysis using land-use layers, and safe-zone validation, as well as the ability to incorporate vertical evacuation. The Level 2 (Advanced) Hazus input is the Travel Time Map output to Safety and Partial Safety of the USGS model as shown in Figure 11-13.

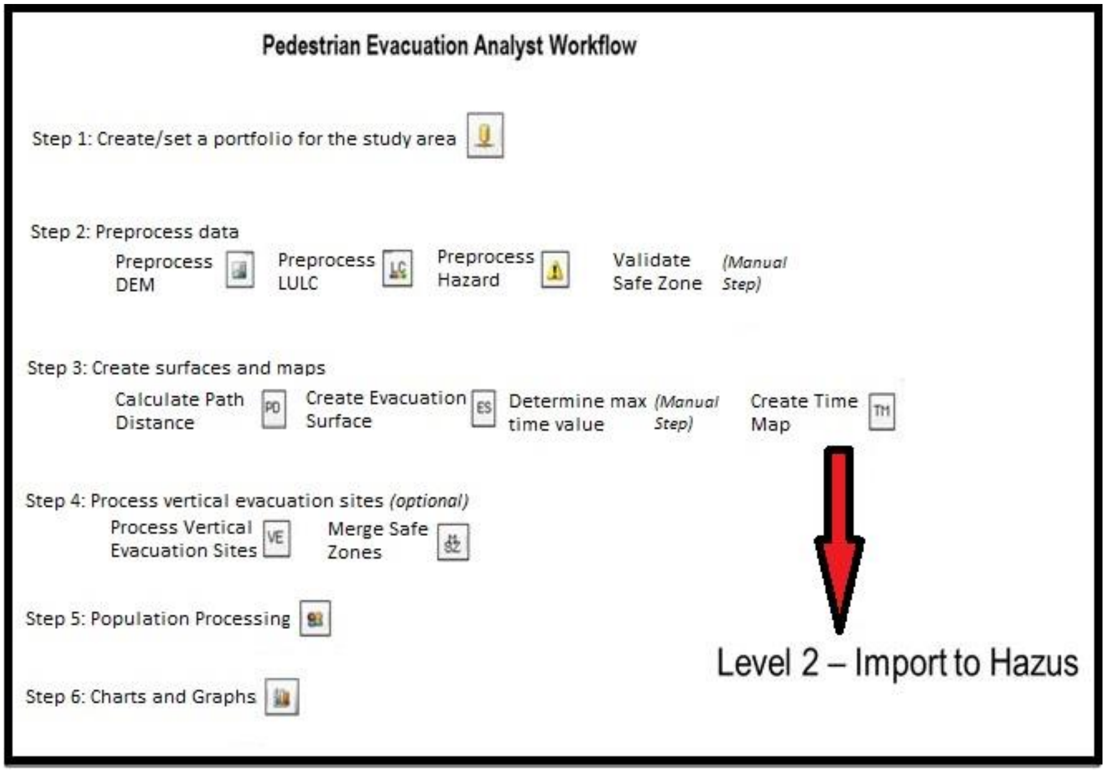


Figure 11-13 Pedestrian Evacuation Analyst Workflow Example

11.2 Casualty – Level 2 Analysis

In the **Analysis** menu, in the **Casualty** submenu (Figure 11-14) choose **Casualty Level 2**.

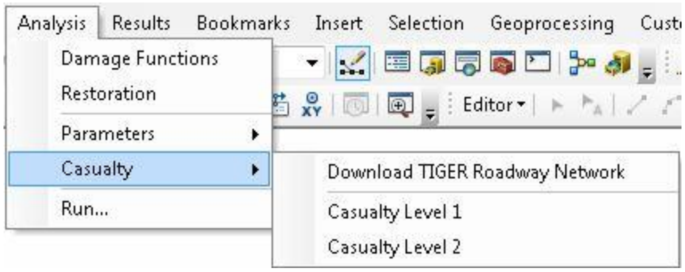


Figure 11-14 Casualty Menu

In the **Casualty Analysis** window (Figure 11-15), load the **Safe Zone** data and the **Partially Safe Zone** data from the USGS Pedestrian Evacuation Analyst Tool. Click on **Load to SQL Database** to add to Hazus. Enter an Arrival Time of 20 minutes. The rest will fill in with default values of a Time to Maximum Runup of 25 minutes and a Warning Time of 10 minutes. Click on **Analysis**.

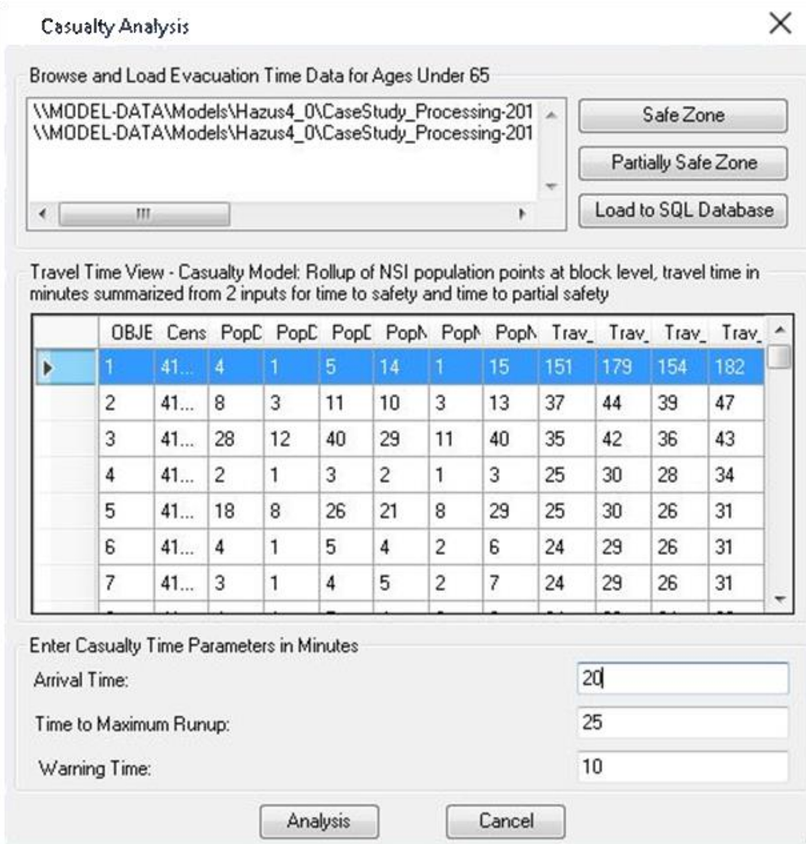


Figure 11-15 Casualty Analysis – Level 2 (Advanced)

The output will be available to view as tables, map layers, and reports. The next section will focus on the combined reports (earthquake and tsunami). See Section 8 for additional information regarding the result reporting options.

11.3 Reports

Tsunami losses that occur with near-source earthquakes occur typically in narrow coastal zones. In Hazus, the smaller tsunami region losses are incorporated into the larger earthquake Study Region losses. The entire Study Region will likely be affected by a near source earthquake, compared to the narrow coastal zone for tsunami. The results of a combined earthquake and tsunami analysis can be viewed only in the Tsunami Model.

Table 11-2 Tsunami Summary Reports

Tsunami Summary Reports	Description of Output
Inventory	
Building Stock Exposure by General Occupancy	Hazus displays the inventory by general occupancy and total (all occupancies combined) for the study region in thousands of dollars.
Buildings	
Building Damage by Count by General Occupancy	Hazus displays the number of buildings damaged by state (none, moderate, extensive, complete and total) by general occupancy.

Tsunami Summary Reports	Description of Output
Building Damage by General Occupancy	Hazus displays the square footage distribution by damage state (none, moderate, extensive, and complete) by square footage (thousands square feet).
Losses	
Direct Economic Losses for Buildings	Hazus displays the direct economic loss (in thousands) by capital stock losses (structural, non-structural and contents damage, inventory loss) loss ratio, and income losses (relocation, capital related, wages, and rental income) and total losses.
User Defined Facility Economic Loss Report by Building Type	Hazus displays the UDF economic losses (in US $) by capital stock exposure (building and contents) capital stock losses (structural, non-structural, contents, and total) and loss ratio (building % and content %).
User Defined Facility Economic Loss Report by General Occupancy	Hazus displays the UDF economic losses (in US $) by capital stock exposure (building and contents) capital stock losses (structural, non-structural, contents, and total) and loss ratio (building % and content %).
Casualties - All	Hazus displays the potential casualties by community preparedness level (good, fair, poor) by night and day.
Combined Direct Economic Losses for Buildings	Hazus displays economic losses (thousands $) by capital stock losses (structural, non-structural and contents damage, inventory loss) loss ratio, and income losses (relocation, capital related, wages, and rental income) and total losses.
Combined User Defined Facility Economic Loss Report by General Occupancy	Hazus displays the UDF economic losses (in US $) by capital stock exposure (building and contents) capital stock losses (structural, non-structural, contents, and total) and loss ratio (building % and content %).
Combined User Defined Facility Economic Loss Report by Building Type	Hazus displays the UDF economic losses (in US $) by capital stock exposure (building and contents) capital stock losses (structural, non-structural, contents, and total) and loss ratio (building % and content %).
Other	
Evacuation Time Travel Summary	Hazus displays the daytime population and travel time to safety and nighttime to safety by age under 65 and over 65. It also displays the nigh time population and travel time to safety for ages 65 and over and 65 and under.
Tsunami Global Risk Report	Hazus displays a report consisting of a description of the region, tsunami scenario parameters, direct tsunami damage, social impact (evacuation travel time and casualties), economic losses (building losses), an appendix for county data and regional population and building value data.
Combined Earthquake and Tsunami Global Risk Report	Hazus displays a report that contains a building and lifeline inventory, earthquake and tsunami scenario parameters, combined earthquake and tsunami damage, induced earthquake damage, social impact, economic loss and two appendixes.

The output can be viewed in the form of results tables, maps, and reports. The tables and map layers are accessible from the **Results** menu (Figure 11-16) on the toolbar for **Combined General Building Stock**, **Combined User-Defined Facilities**, and **Casualties**. See Section 8 for additional information.

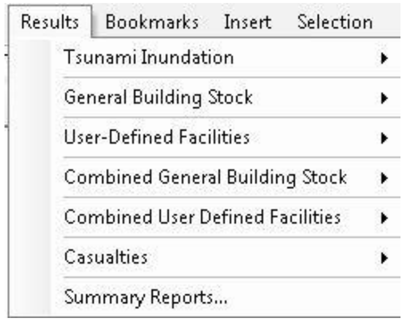


Figure 11-16 Results Menu

This section will review the reports, which are located under **Hazus MH Tsunami Summary Reports** (Figure 11-17) on the **Results** menu. The Combined Analysis reports are available under the following tabs in the **Summary Report** window:

- Losses
  - Combined Direct Economic Losses for Building
  - Combined User-Defined Facility Economic Loss Report by General Occupancy
    - These results will only appear if there are UDF inventory in the Study Region.
  - Combined User-Defined Facility Economic Loss Report by Building Type
- Other
  - Combined Earthquake and Tsunami Global Risk Report

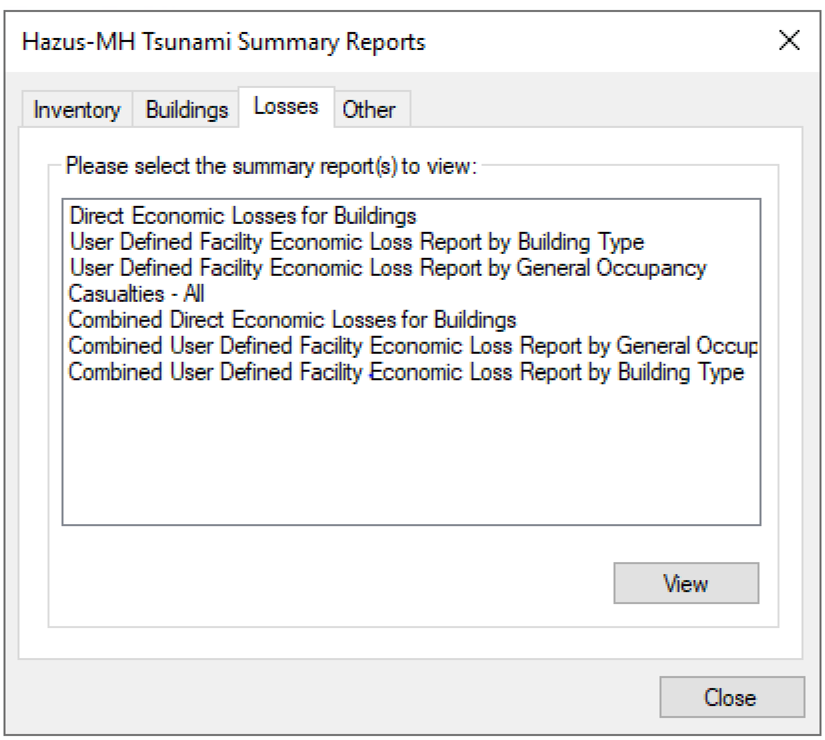
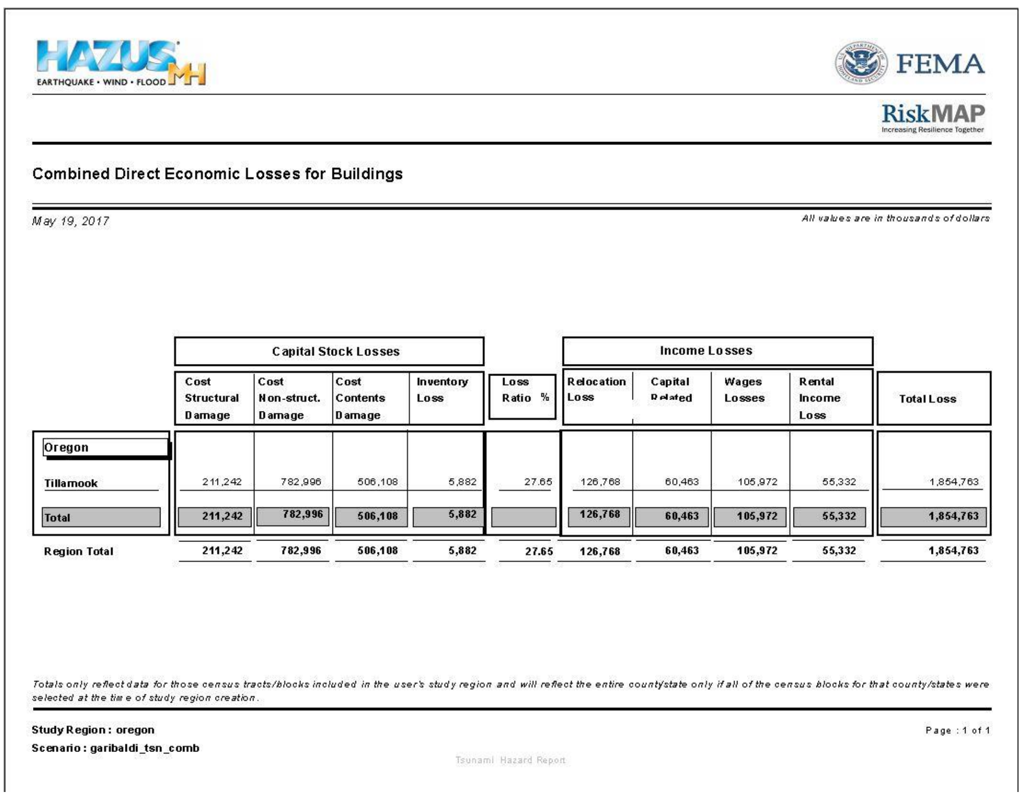


Figure 11-17 Hazus MH Tsunami Summary Reports

11.3.1 Combined Direct Economic Losses for Buildings

The Combined Direct Economic Losses for Buildings (Figure 11-18) displays the combined losses (in thousands of dollars US) for:

- Capital Stock Losses
  - Structural Damage
  - Nonstructural Damage
  - Contents Damage
  - Inventory Loss
- Income Losses
  - Relocation Losses
  - Capital Related Losses
  - Wage Losses
  - Rental Income Loss
- Total Loss



Combined Direct Economic Losses for Buildings

May 19, 2017

All values are in thousands of dollars

	Capital Stock Losses					Income Losses				
	Cost Structural Damage	Cost Non-struct. Damage	Cost Contents Damage	Inventory Loss	Loss Ratio %	Relocation Loss	Capital Related	Wages Losses	Rental Income Loss	Total Loss
Oregon										
Tillamook	211,242	782,996	506,108	5,882	27.65	126,768	60,463	105,972	55,332	1,854,763
Total	211,242	782,996	506,108	5,882		126,768	60,463	105,972	55,332	1,854,763
Region Total	211,242	782,996	506,108	5,882	27.65	126,768	60,463	105,972	55,332	1,854,763

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 : oregon
Scenario : garibaldi_tsn_comb

Page : 1 of 1

Tsunami Hazard Report

Figure 11-18 Combined Direct Economic Losses for Buildings

11.3.2 Combined User-Defined Facility Economic Loss Report by General Occupancy

The Combined User-Defined Facility Economic Loss Report by General Occupancy (Figure 11-19) displays the combined exposure and losses by general occupancy. These results will only appear if there are UDF inventory in the Study Region.

- Capital Stock Exposure
- Building Exposure
    - Content Exposure
- Capital Stock Losses
    - Building Loss
    - Nonstructural Loss
    - Content Loss
- Total Loss
    - Loss Ratio
    - Building %
    - Content %

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Combined User Defined Facility Economic Loss(USD$) Report by General Occupancy

Friday, May 19, 2017

General Occupancy	Capital Stock Exposure		Capital Stock Losses				Loss Ratio	
	Building Exposure	Contents Exposure	Building Loss	Non Structural Loss	Contents Loss	TOTAL Loss	Building %	Content %
Agriculture	1,884,680	1,879,400	744,628	889,843	1,664,153	3,298,624	86.72%	88.55%
Commercial	8,837,862	8,835,000	2,299,504	5,842,431	8,189,964	16,331,900	92.13%	92.70%
Education	695,900	695,800	130,806	564,375	695,800	1,390,981	99.90%	#######
Government	8,577,890	8,620,600	928,596	4,753,477	6,428,974	12,111,046	66.24%	74.58%
Industrial	3,528,296	5,291,550	267,101	1,509,831	2,742,352	4,519,284	50.36%	51.83%
Religion/Non-Profit	5,678,194	5,676,400	885,710	3,850,012	4,999,612	9,735,335	83.40%	88.08%
Residential	187,134,677	93,522,700	36,112,878	137,808,644	87,260,389	261,181,911	92.94%	93.30%
Scenario Total	**216,337,499**	**124,521,450**	**41,369,224**	**155,218,612**	**111,981,244**	**308,569,081**	**90.87%**	**89.93%**

Study Region: oregon
Scenario: garibaldi_tsn_comb

Page : 1 of 1

Tsunami Hazard Report

Figure 11-19 Combined User-Defined Economic Loss Report by General Occupancy

11.3.3 Combined User-Defined Facility Economic Loss Report by General Building Type

The Combined User-Defined Facility Economic Loss Report by General Building Type (Figure 11-20) displays the combined exposure and losses by general building type for:

- Capital Stock Exposure
    - Building Exposure

- Contents Exposure
- Capital Stock Losses
  - Structural Loss
  - Non-Structural Loss
  - Contents Loss
  - Total Loss
- Loss Ratio
  - Building %
  - Content %

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FEMA

Combined User Defined Facility Economic Loss(USD$) Report by General Building Type

RiskMAP Increasing Resilience Together

Tuesday, July 28, 2020

	Capital Stock Exposure		Capital Stock Losses				Loss Ratio	
General Building Type	Building Exposure	Contents Exposure	Structural Loss	NonStructural Loss	Contents Loss	TOTAL Loss(USD$)	Building %	Content %
C = Concrete	10,709,789	10,214,650	1,521,620	7,102,921	8,719,995	17,344,536	80.53%	85.37%
C = Concrete	82,620	123,900	11,245	69,649	123,900	204,793	97.91%	100.00%
C = Concrete	863,620	737,550	201,941	661,016	737,550	1,600,506	99.92%	100.00%
h = Manufactured Housing	10,392,493	5,189,800	2,467,466	7,921,171	5,189,800	15,578,437	99.96%	100.00%
C = Concrete	245,087	245,000	39,527	200,308	245,000	484,835	97.86%	100.00%
C = Concrete	2,160,506	3,067,750	257,052	1,139,890	2,157,082	3,554,023	64.66%	70.31%
m = Masonry	1,488,577	1,484,050	264,680	1,184,157	1,472,471	2,921,308	97.33%	99.22%

Study Region: Act103
Scenario: Cascadia

Page : 1 of 2

Tsunami Hazard Report

Figure 11-20 Combined User-Defined Economic Loss Report by General Building Type

11.3.4 Combined Earthquake and Tsunami Global Report

The Combined Global Report (Figure 11-20) provides a 25-page report with text, tables, and graphics displaying earthquake and tsunami losses for the scenario. The sections unique to earthquake or tsunami are labeled to show that the losses refer to the specific hazard only.

Combined earthquake and tsunami losses include:

- Combined Building Damage
- Combined Building Losses

Earthquake specific losses include:

- Earthquake Scenario Parameters

- Essential Facilities Damage from Earthquake
- Transportation and Utility Lifeline Damage from Earthquake
- Debris Generation from Earthquake
- Shelter Requirements from Earthquake
- Casualties from Earthquake
- Transportation and Utility Lifeline Losses from Earthquake

Tsunami specific losses include:

- Tsunami Scenario Parameters
- Tsunami Evacuation (Travel Time)
- Casualties from Tsunami

Combined Building Damage

Combined Earthquake and Tsunami Building Damage

Hazus estimates that about 26,961 buildings will be at least moderately damaged. This is over 80.00 % of the buildings in the region. There are an estimated 9,467 buildings that will be damaged beyond repair. The definition of the 'damage states' is provided in Volume 1: Chapter 5 of the Hazus technical manual. Table 3 below summarizes the expected damage by general building type.

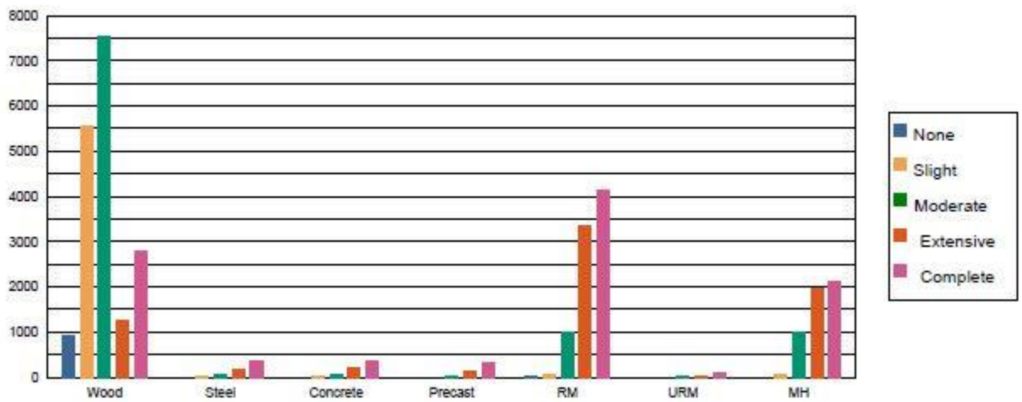


Table 3: Expected Building Damage by Building Type (All Design Levels)

	None		Slight		Moderate		Extensive		Complete	
	Count	(%)	Count	(%)	Count	(%)	Count	(%)	Count	(%)
Wood	929	97.54	5563	97.23	7,551	77.73	1,258	17.74	2,787	27.44
Steel	0	0.05	3	0.05	40	0.41	162	2.29	375	3.70
Concrete	1	0.06	5	0.09	69	0.71	205	2.89	373	3.68
Precast	0	0.02	2	0.03	31	0.32	135	1.90	306	3.01
RM	20	2.07	77	1.35	1,001	10.30	3,329	46.95	4,119	40.56
URM	0	0.00	1	0.01	11	0.11	37	0.53	93	0.92
MH	3	0.26	70	1.23	1,012	10.42	1,965	27.71	2,103	20.70
Total	952		5,721		9,714		7,091		10,156	

*Note:

RM Reinforced Masonry
URM Unreinforced Masonry
MH Manufactured Housing

Combined Earthquake and Tsunami Global Risk Report   Page 9 of 26

Figure 11-20 Combined Global Report

Section 12. Advanced Hazus Analysis: Modifying Analysis Factors

The **Analysis > Parameters** menu (Figure 12-1) allows the user to define casualty and building economic loss parameters.

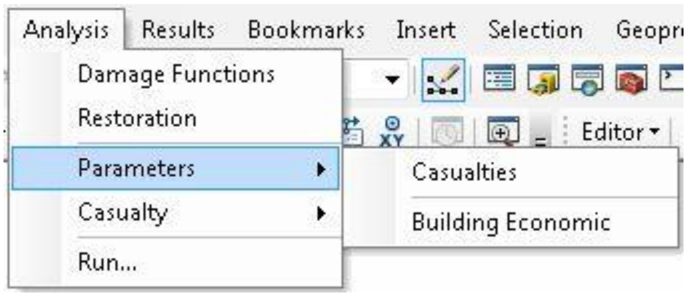


Figure 12-1 Analysis Parameters Menu

12.1 Casualty Parameters

The **Casualties** window allows the user to view and edit the parameters that effect the casualty analysis. These include:

- Community Preparedness Level
- Walking Speed
- Walking Speed Reduction

The Community Preparedness Level parameters (Figure 12-2) are based on FEMA's methodology, concerning the time required between the warning and the evacuation of the community. The classifications of Good, Fair, or Poor are based on tsunami hazard preparedness level. This can be determined based, for example, on the condition of shore-protection structures, emergency loudspeakers, preparation of evacuation routes and signs, a community's risk management level, and/or the education level for tsunami awareness. A community rated "good," for example, could be one that is designated "Tsunami Ready" by the National Weather Service. See the *Hazus Tsunami Model Technical Manual* (FEMA, 2021) for more information.

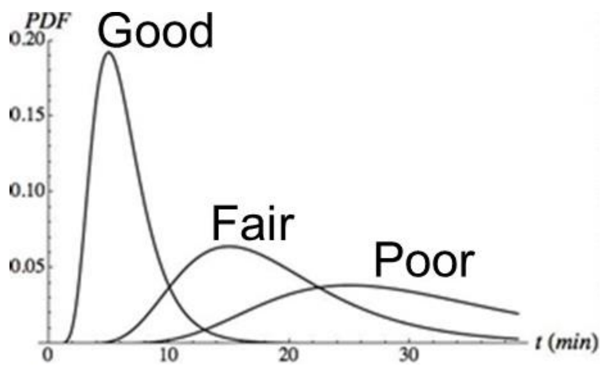


Figure 12-2 Community preparation times following warning based on Community Preparedness Levels

In Figure 12-3, Cprep refers to the amount of preparation time needed after the initial warning is given (including the natural cue = ground shaking). The Community Preparedness Level (Good, Fair, or Poor) grading defaults are 0.2, 0.6 and 1.0 respectively. Cprep is used as a multiplier to the time available (i.e., travel time – warning time) and represents the median where half the community has begun evacuating and half have not. Using 0.2 for a well-prepared community implies that the community median will need one-fifth the time available to react to the warning compared with a community with Poor grading. The model also considers Community Preparedness Level standard deviation values with defaults of 0.3, 0.5 and 0.8 representing the shape of the curves shown in Figure 12-2.

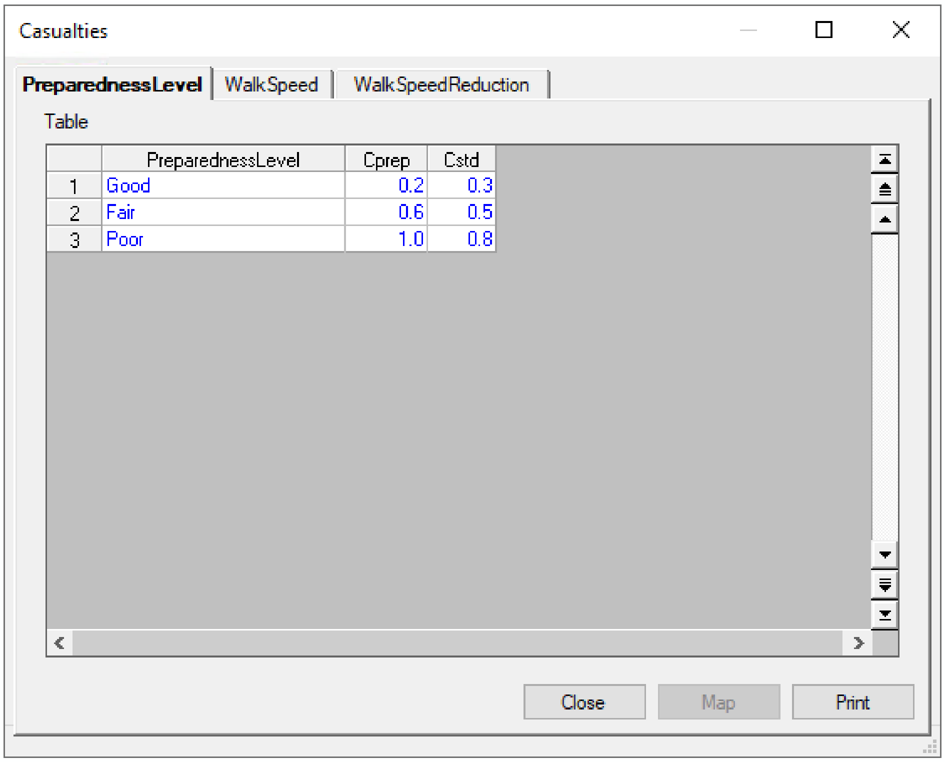


Figure 12-3 Casualty Preparedness Level Parameters

The average Walking Speeds are based on the USGS Pedestrian Evacuation Analyst Tool for populations under 65 (Figure 12-4).

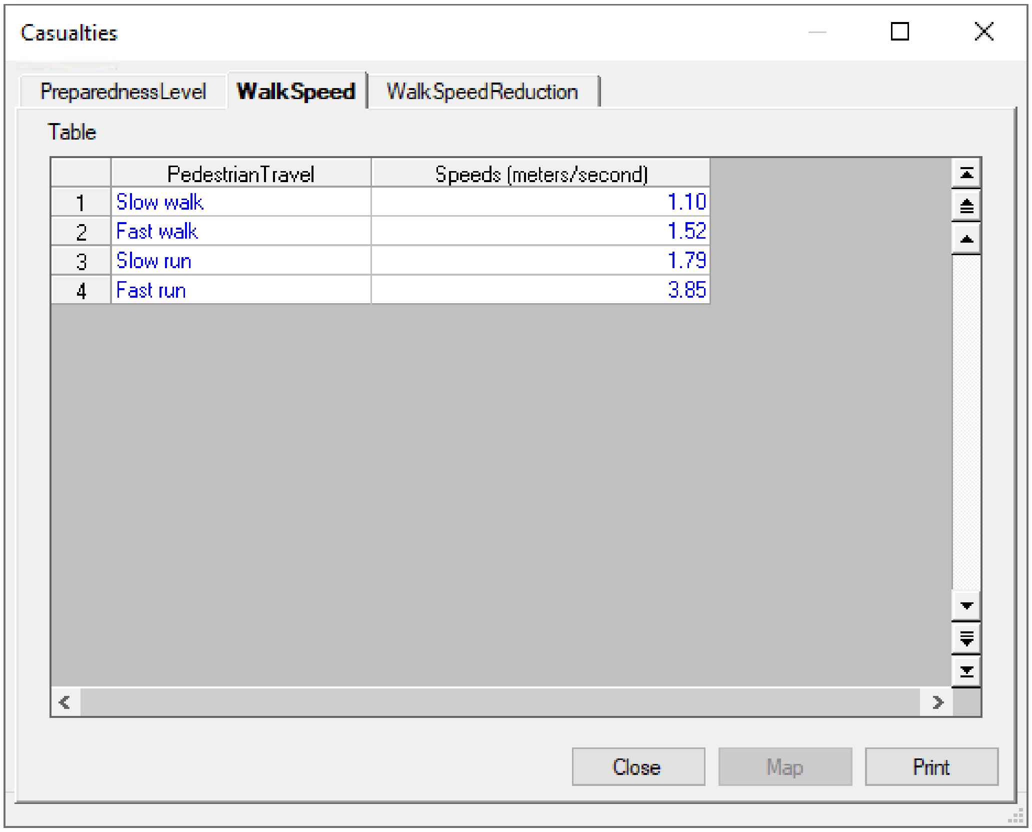


Figure 12-4 Casualty Walking Speed Parameters

A Walking Speed Reduction parameter is included to account for the difference in evacuation walking speed for population over 65 years old (Figure 12-5). These can be used to reduce walking speeds for either category to represent local or post-earthquake conditions. Various local and post-earthquake conditions could potentially impact walking speed such as potential dispersion of evacuees, safety conditions of sidewalks or roadways, roadway segments defined as impassable areas, rendering aid to the injured, or age of local population. Additional details related to potential walking speed reductions are discussed in detail within the *Hazus Tsunami Model Technical Manual* (FEMA, 2021).

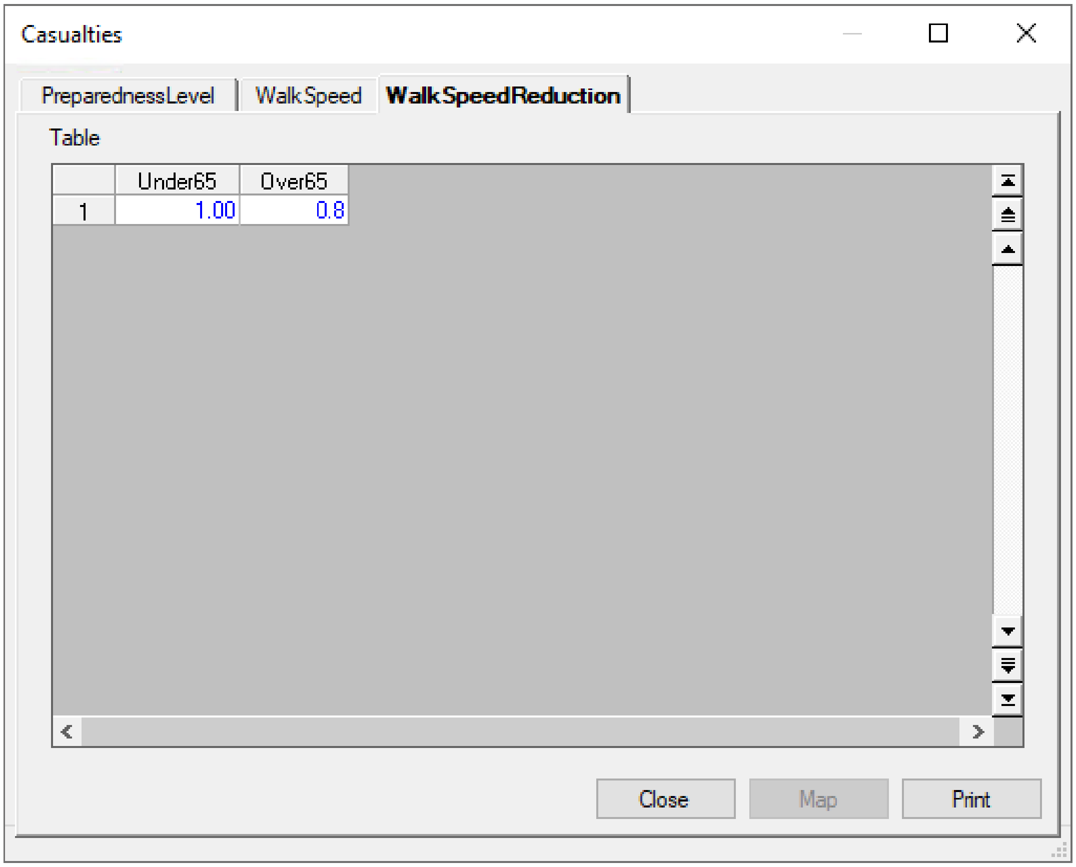


Figure 12-5 Walking Speed Reduction Parameters

12.2 Building Economic Parameters

Economic losses are based on a summation of the damage state probabilities and repair cost ratio. This methodology closely follows the earthquake methodology, except that the “Slight” category is not used for Tsunami only losses. In the case of Combined Earthquake and Tsunami losses, the Slight category is considered. Estimates of damage to the built environment are converted to dollar loss in this model. 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.

Losses that are directly derived from building damage:

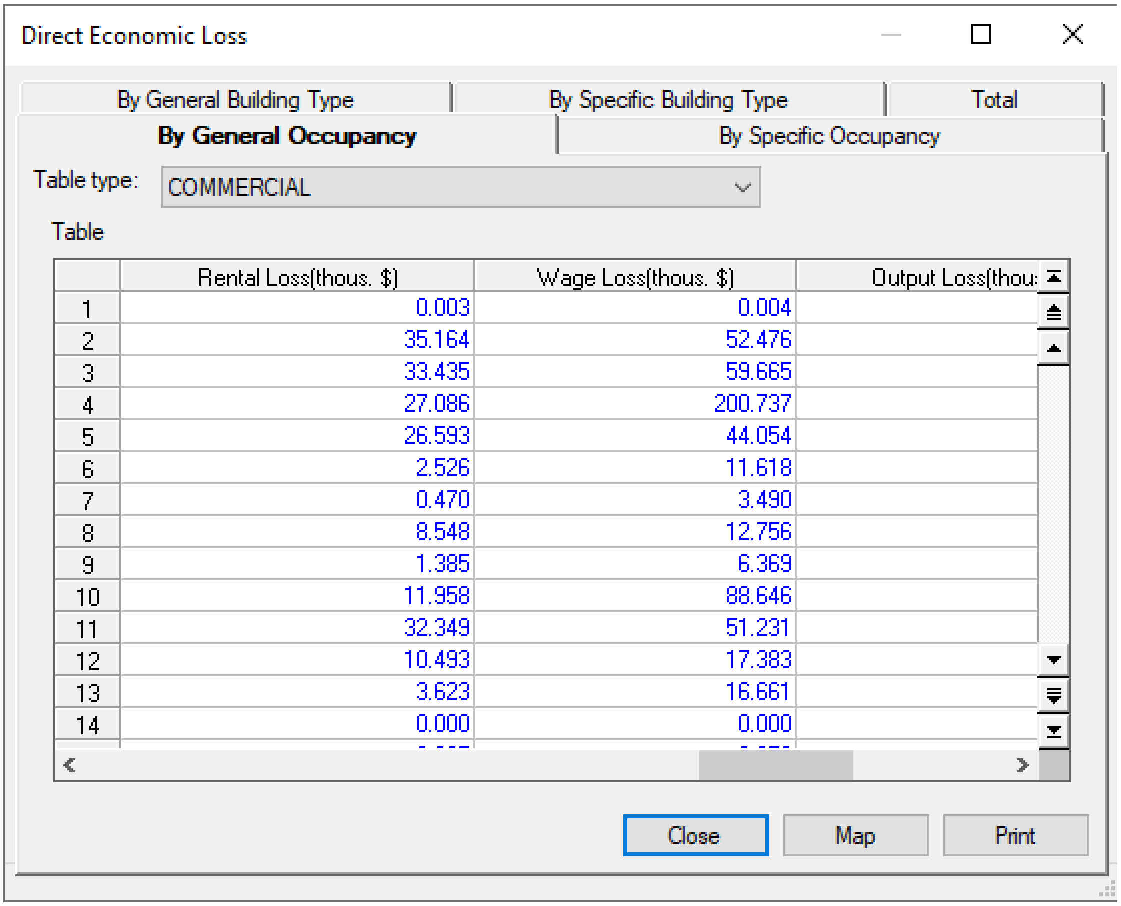
- Cost of repair and replacement of damaged and destroyed buildings
- Costs of damage to building contents
- Losses of building inventory (contents related to business activities)

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)

The baseline economic data can be viewed and modified from within the **Building Economic Loss Parameters** window (Figure 12-6).



	Rental Loss(thous. $)	Wage Loss(thous. $)	Output Loss(thou:
1	0.003	0.004	
2	35.164	52.476	
3	33.435	59.665	
4	27.086	200.737	
5	26.593	44.054	
6	2.526	11.618	
7	0.470	3.490	
8	8.548	12.756	
9	1.385	6.369	
10	11.958	88.646	
11	32.349	51.231	
12	10.493	17.383	
13	3.623	16.661	
14	0.000	0.000	

Figure 12-6 Building Economic Loss Parameter

12.2.1 Percent Loss

The replacement costs (e.g., where damage state = complete) were derived from “RSMeans Square Foot Costs for Residential, Commercial, Industrial, and Institutional Buildings.” The RSMeans publication is a nationally accepted reference on building construction costs, which is published annually. This publication provides cost information for a number of low-rise residential model buildings, and for 70 other residential, commercial, institutional, and industrial buildings. These are presented in a format that shows typical costs for each model building, showing variations by size of building, type of building structure, and building enclosure. One of these variations is chosen as “typical” for this typical model, and a breakdown is provided that shows the cost and percentages of each building system or component. A description of how to estimate losses based on replacement costs from the RSMeans publication is found in the *Hazus Tsunami Model Technical Manual* (FEMA, 2021). Since RSMeans is published annually, fluctuations in typical building cost can be tracked and the user can insert the most up to date RSMeans typical building cost into the baseline database. For more information on replacement cost values see Section 6 in the *Hazus Inventory Technical Manual* (FEMA, 2021).

In Hazus, selected RSMeans models have been chosen from the 70 plus models that represent the 33 occupancy types. The wide range of costs shown, even for a single model, emphasize the importance of understanding that the dollar values shown should only be used to represent costs of large aggregations of building types. If costs for single buildings or small groups (such as a college campus) are desired for more detailed loss analysis, local building-specific cost estimates should be used. Since a building has both structural and nonstructural repair costs, those are provided for each occupancy type by damage state (Figure 12-7). Complete Structural Damage and Complete Non Structural Sensitive Damage is equal to 100% loss.

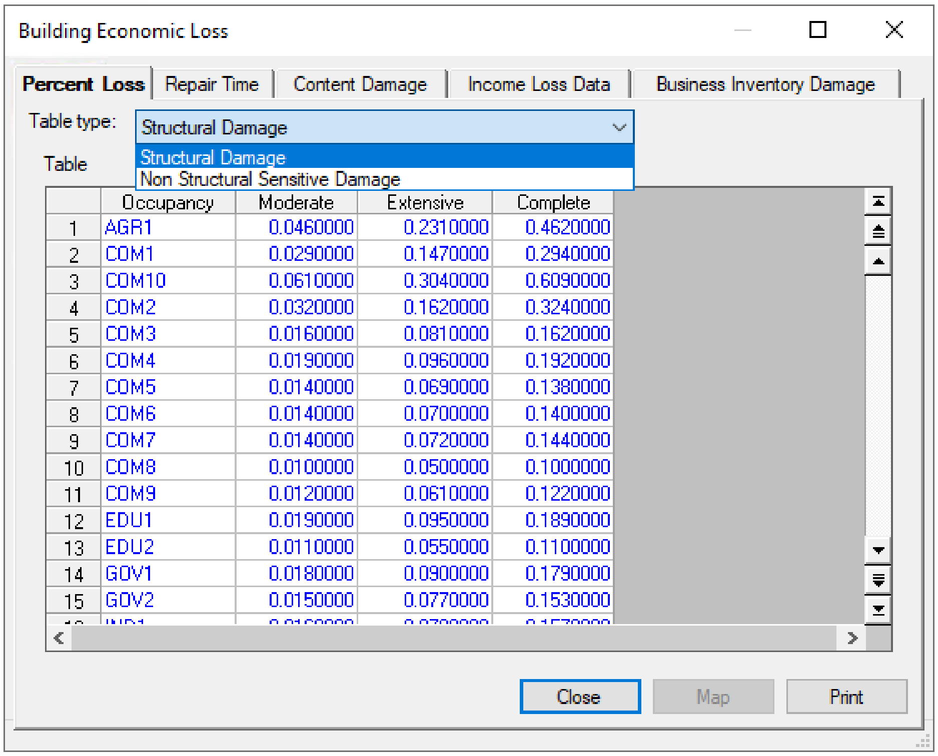


Figure 12-7 Percent Loss Parameters

12.2.2 Repair Time

The time to repair a damaged building can be divided into two parts: construction time (including clean-up) and additional tasks that increase repair time (i.e. obtain financing, 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 levels, a number of additional tasks must be undertaken that typically will considerably increase that actual repair time. These tasks, which may vary considerably in scope and time between individual projects, include:

- Decision-making (related to businesses of institutional constraints, plans, financial status, etc.)
- Negotiation with FEMA (for public facilities), Small Business Administration, etc.
- Negotiation with insurance company, if insured
- Obtaining financing
- Contract negotiation with design firm(s)

- Detailed inspections and recommendations
- Preparation of contract documents
- Obtaining building and other permits
- Bidding/negotiating construction contract
- Start-up and occupancy activities after construction completion

Baseline building repair and clean-up times are provided within Hazus. These 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 of the additional delays described above. The discussion of these values is found in the *Hazus Tsunami Model Technical Manual* (FEMA, 2021). Baseline values can be viewed and modified using the window shown in Figure 12-8.

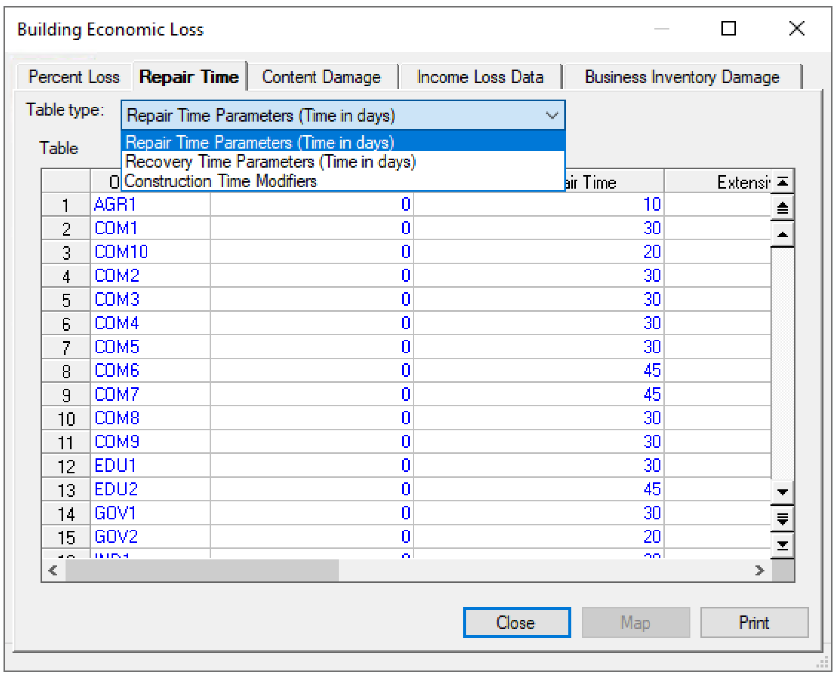


Figure 12-8 Repair Time Parameters

Repair times are presented as a function of both amount of damage and occupancy class. Clearly there can be a great deal of variability in repair times, but these represent estimates of the median times for actual cleanup and repair. This window is accessed from the **Analysis Parameters – Building Economic** menu. To modify these values, right click inside the menu and choose **Start Editing**. Enter new values and then right click and choose **Stop Editing**. A prompt will request that changes be confirmed.

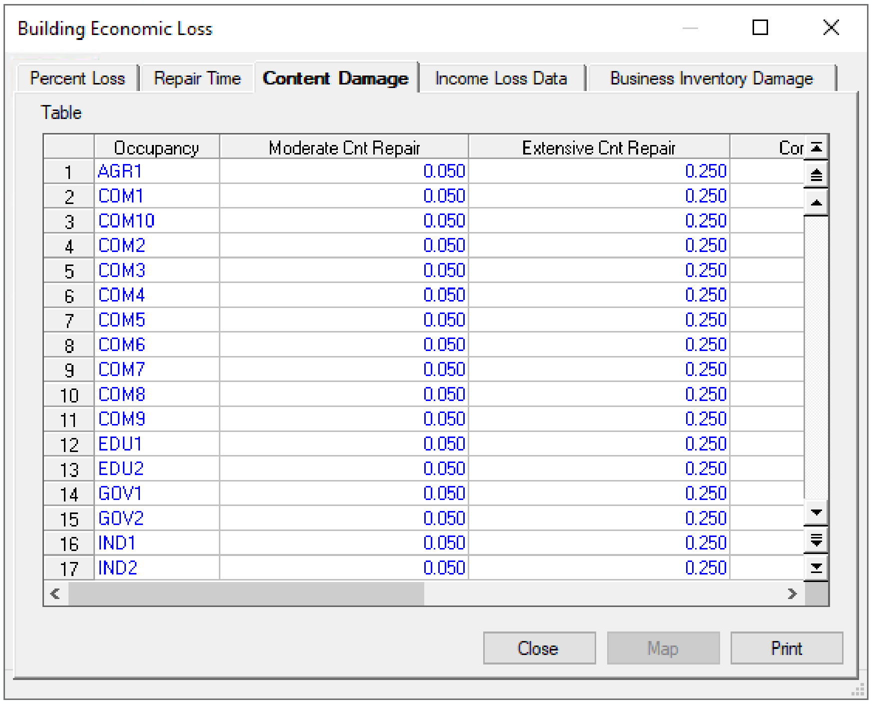
Baseline values of the extended building cleanup and repair times that account for delays in decision-making, financing, inspection, etc., are viewed by clicking on the desired table. Baseline extended estimates also can be modified.

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

The median value of repair time applies 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 a number of others will close or be demolished. For example, one might reasonably assume that an unreinforced masonry (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.

12.2.3 Content Damage

Building Contents are defined as furniture, equipment that is not integral with the structure, computers, and supplies. Contents (Figure 12-9) do not include inventory or nonstructural components such as lighting, ceilings, or mechanical and electrical equipment and other fixtures. The damage to contents is expressed in terms of the percentage of damage to the contents based upon the depth of water at the building relative to the finished floor. The contents-damage percentages are based upon the assumption that for the complete damage state some percentage of contents, 50%, can be retrieved in the event of an earthquake. For tsunamis, as the saturated or washed away contents are less likely to be salvaged, it is assumed that 100% of the contents for complete damage states are lost. The baseline-contents-damage percentages are the same for all occupancies.



	Occupancy	Moderate Cnt Repair	Extensive Cnt Repair	Cor
1	AGR1	0.050	0.250	
2	COM1	0.050	0.250	
3	COM10	0.050	0.250	
4	COM2	0.050	0.250	
5	COM3	0.050	0.250	
6	COM4	0.050	0.250	
7	COM5	0.050	0.250	
8	COM6	0.050	0.250	
9	COM7	0.050	0.250	
10	COM8	0.050	0.250	
11	COM9	0.050	0.250	
12	EDU1	0.050	0.250	
13	EDU2	0.050	0.250	
14	GOV1	0.050	0.250	
15	GOV2	0.050	0.250	
16	IND1	0.050	0.250	
17	IND2	0.050	0.250	

Figure 12-9 Content Damage Parameters

12.2.4 Income Loss Data

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 several 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 per square foot per month. A renter who has been displaced from a property due to earthquake damage will cease to pay rent to the owner of the damaged property and will only pay rent to the 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 his renter. If the damaged property is owner occupied, the owner will have to pay for his own disruption costs in addition to the cost of rent while he is repairing his building. Relocation expenses are therefore 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.

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, and 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 U.S. Department of Commerce's Bureau of Economic Analysis reports regional estimates of capital-related income by economic sector. Capital-related income per square foot of floor space can then be derived by dividing income by the floor space occupied by a specified sector. Income will vary considerably depending on regional economic conditions. Therefore, baseline values need to be adjusted for local conditions. For more information on methodology refer to Section 7.5 of the *Hazus Tsunami Technical Manual* (FEMA, 2021). Baseline values derived from information in Table 4.7 of ATC-13. Income Loss Data are summarized in Figure 12-10.

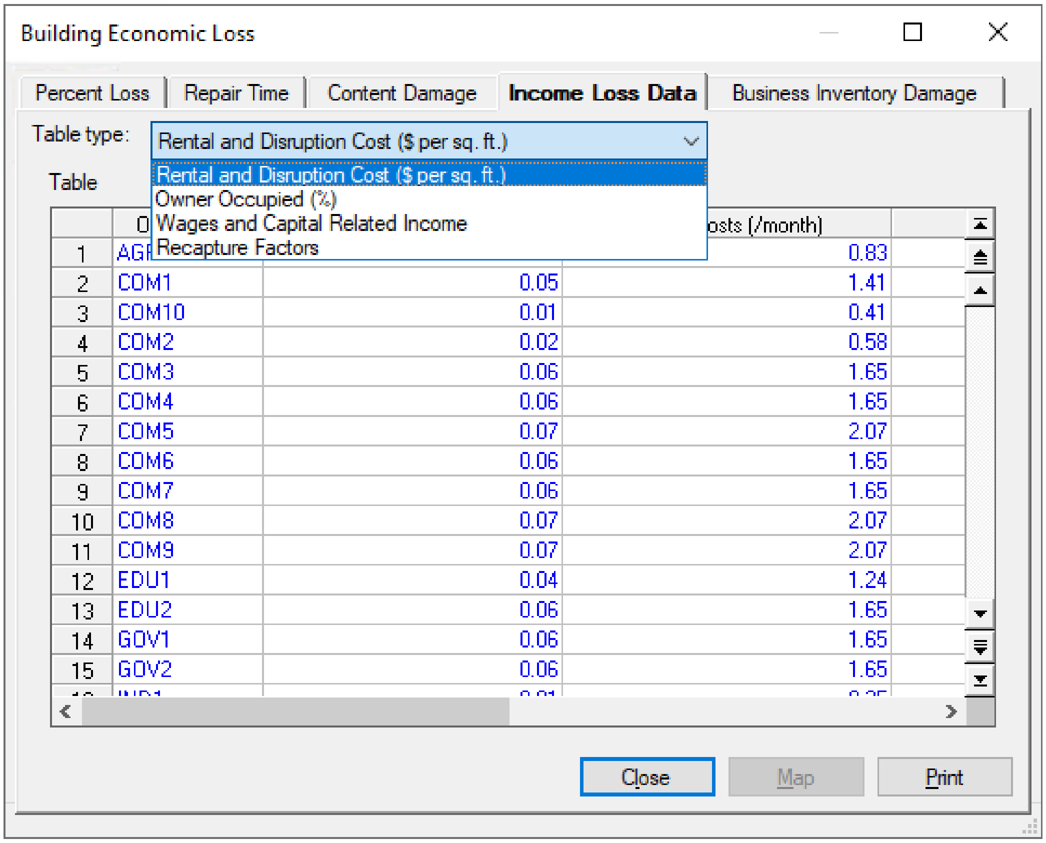
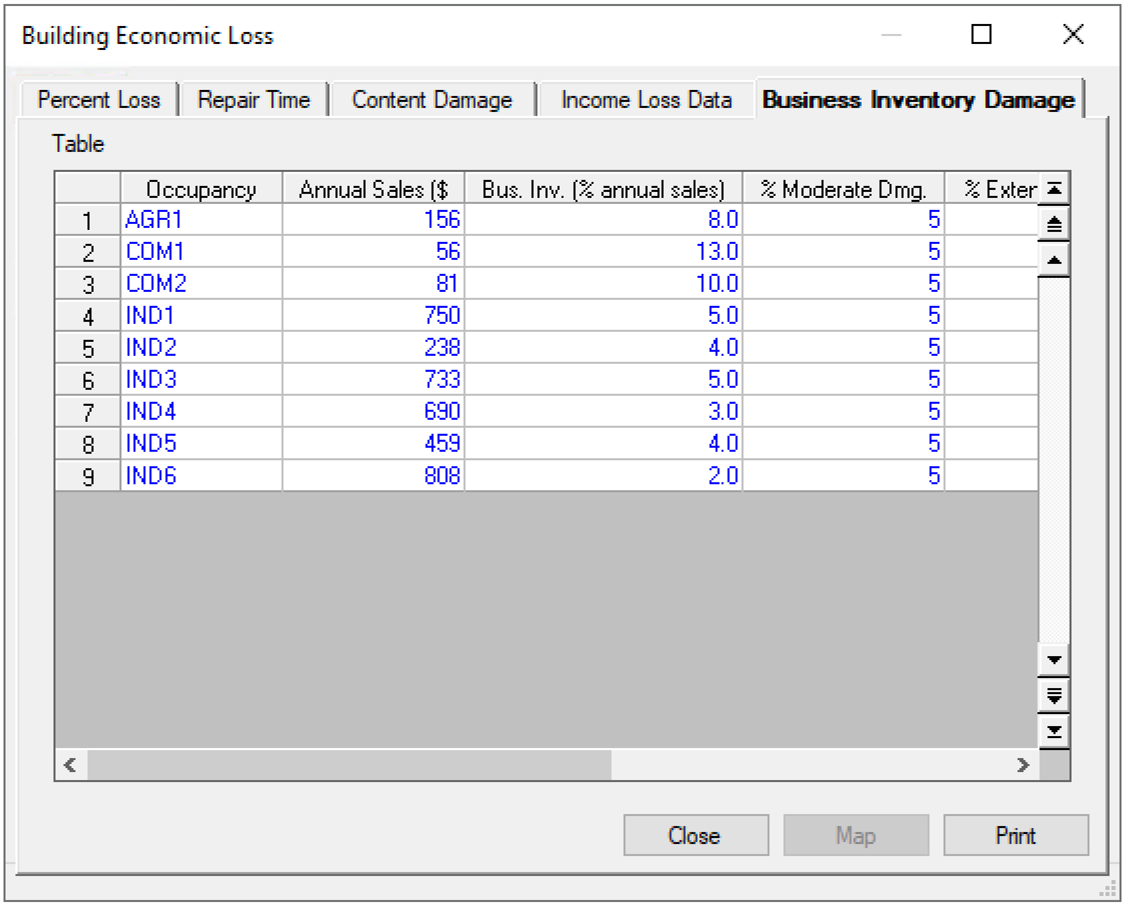


Figure 12-10 Income Loss Data

12.2.5 Business Inventory Damage

Business inventories vary considerably with occupancy. For example, the value of inventory for a high-tech manufacturing facility would be very different from that of a retail store. Thus, the baseline values of business inventory for this model are derived from annual gross sales by assuming that business inventory is some percentage of annual gross sales. These baseline values are based on judgement as displayed in Figure 12-11.



	Occupancy	Annual Sales ($	Bus. Inv. (% annual sales)	% Moderate Dmg.	% Exter
1	AGR1	156	8.0	5	
2	COM1	56	13.0	5	
3	COM2	81	10.0	5	
4	IND1	750	5.0	5	
5	IND2	238	4.0	5	
6	IND3	733	5.0	5	
7	IND4	690	3.0	5	
8	IND5	459	4.0	5	
9	IND6	808	2.0	5	

Figure 12-11 Business Inventory Damage