WA State Cascadia Subduction Zone (CSZ) Tsunami Loss Estimate Study: Hazus User Guide

July 30, 2025
Washington Emergency Management Division, Camp Murray, Washington

Background

In July 2021, Washington Emergency Management Division (WA EMD), of the Washington Military Department, hired John M. Bauer of Bauer GIS Solutions, Portland, Oregon, to conduct Hazus-based impact estimates for buildings and people in the Cascadia Subduction Zone tsunami zone, for all 15 Washington state coastal counties that will likely be significantly impacted by a tsunami.

This is a methods document, with the intent for WA EMD or others to duplicate the work we have done – either with the intent to refine the initial estimates provided by the contractor, or to adapt their usage for understanding earthquake impacts outside of the tsunami zone.

The tsunami inundation zone is defined by Washington Geological Survey's (WGS) detailed tsunami modeling of a Cascadia Subduction Zone (CSZ) Extended L1 M9.0 Tsunami (Washington Geological Survey, 2024) which has been quantified in raster format for all affected Washington counties.

This document assumes a user has prepared the User-defined Facilities (UDF) pointfile for use in Hazus, as defined by the accompanying document *WA State Cascadia Subduction Zone (CSZ) Tsunami Loss Estimate Study: Dataset Development Guide*. This is a user guide for running the UDF through the Hazus Comprehensive Data Management System (CDMS) and in the Hazus earthquake and tsunami modules. This document does not summarize loss estimate study results, nor does it provide commentary or recommendations. Rather, it is intended to be a guide for use by others on the detailed mechanics of working with the Hazus tool chain.

Assumptions

- Users have access to ArcGIS 10.8.1, ArcGIS Spatial Analyst extension, Hazus 5.0, CDMS, and SQL Server Management Studio.
- Users are adept at making inquiries and database updates in the ArcGIS database and exporting out and summarizing tables for their own reporting purposes.
- Users have access to the "median scenario" and "84th Percentile scenario" grids from the CSZ 2020 update published by United States Geological Survey (link). FYI: for convenience, these grids in xml form are supplied as part of the GIS package delivered to WA EMD.
- Users have training in CDMS and Hazus and are aware of the terminology, tool limitations, and requirements.

Importing into CDMS

When constructing or updating the UDF file, the UDF file may be in a projection not usable by CDMS. This is due to various geoprocessing needs. Prior to import into CDMS, the point file projection **must** be in WGS84:

- GCS_WGS_1984
- WKID: 4326 Authority: EPSG

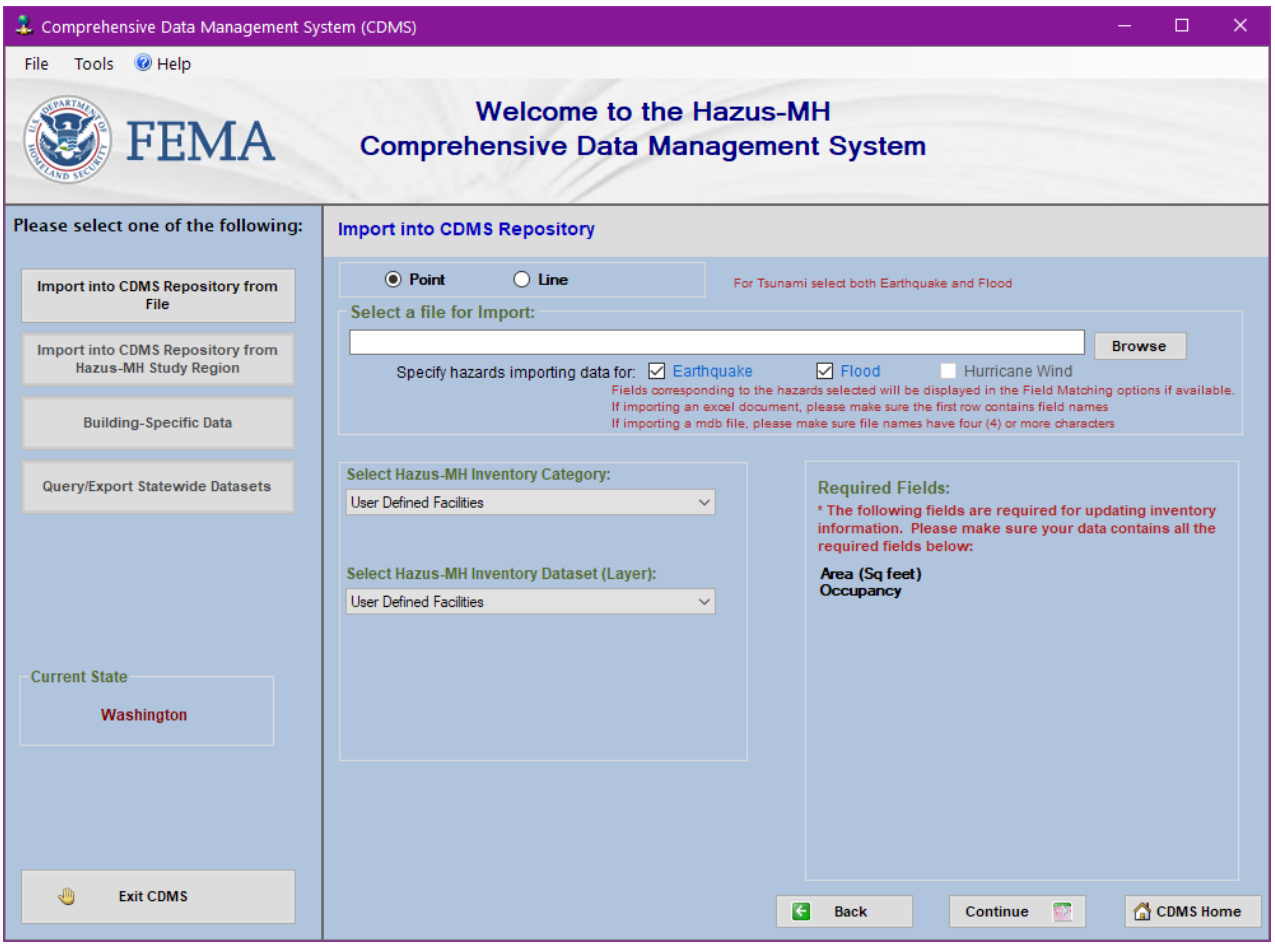
A good method for reprojection to create a feature dataset with this projection, is to export the UDF library into that feature dataset (using a different name), then exporting the file geodatabase feature dataset/feature class into a temporary personal geodatabase. (shapefile format, also acceptable to CDMS, truncates column names to 10 characters.)

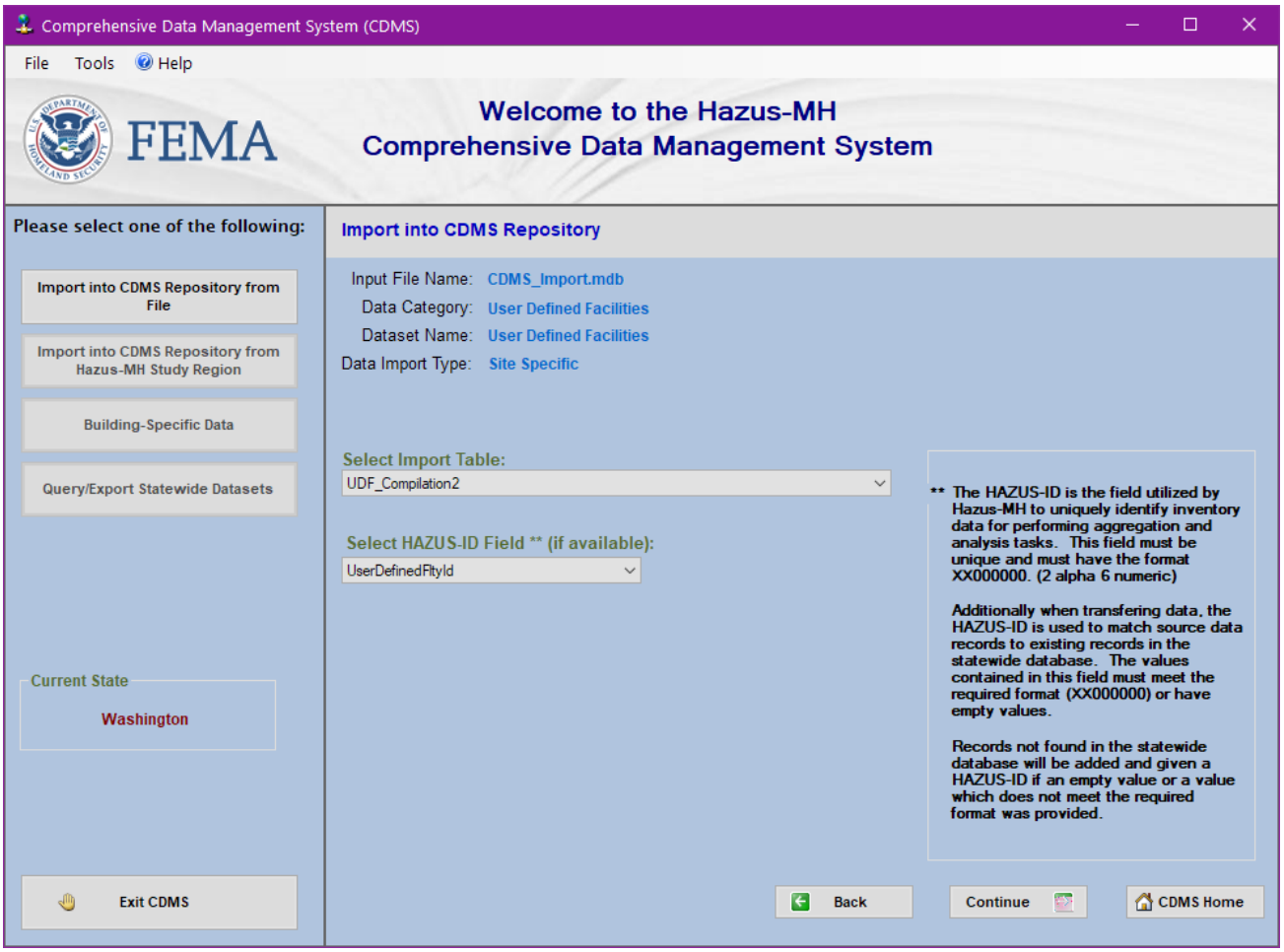
For processing efficiency purposes, be strategic about how many UDF points you try to import at the same time. **Do not try to import the entire state of Washington!**

CDMS => Import into CMDS Repository. Select both Earthquake and Flood, as there are flood-related attributes needed for the tsunami model (first floor height). You only need to click on Flood if you are using the tsunami module.

Browse to find the personal geodatabase that has the UDF file. Next.

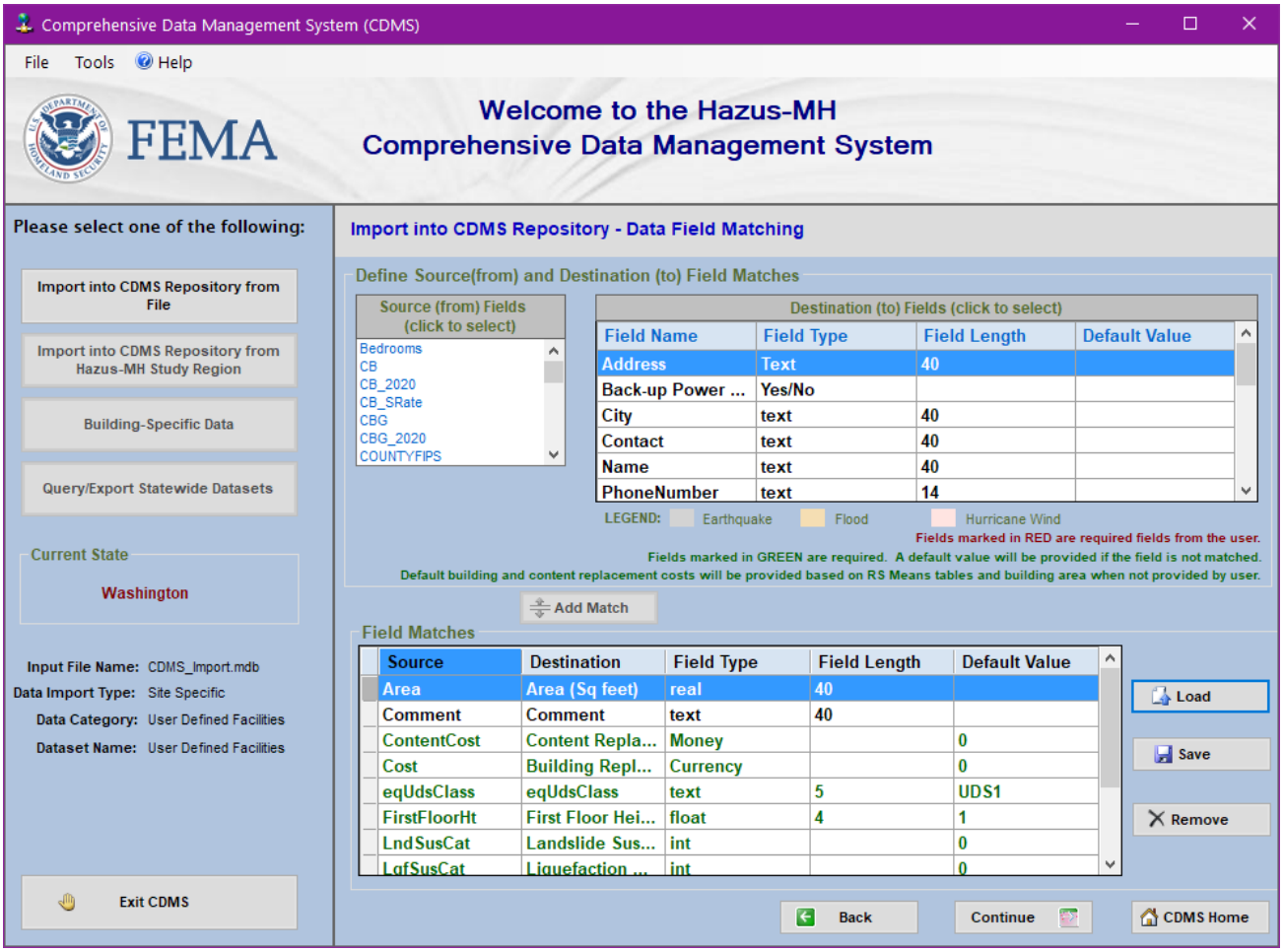
Select the specific UDF file (CDMS calls it a Table) – again, be smart about file size and number of records!





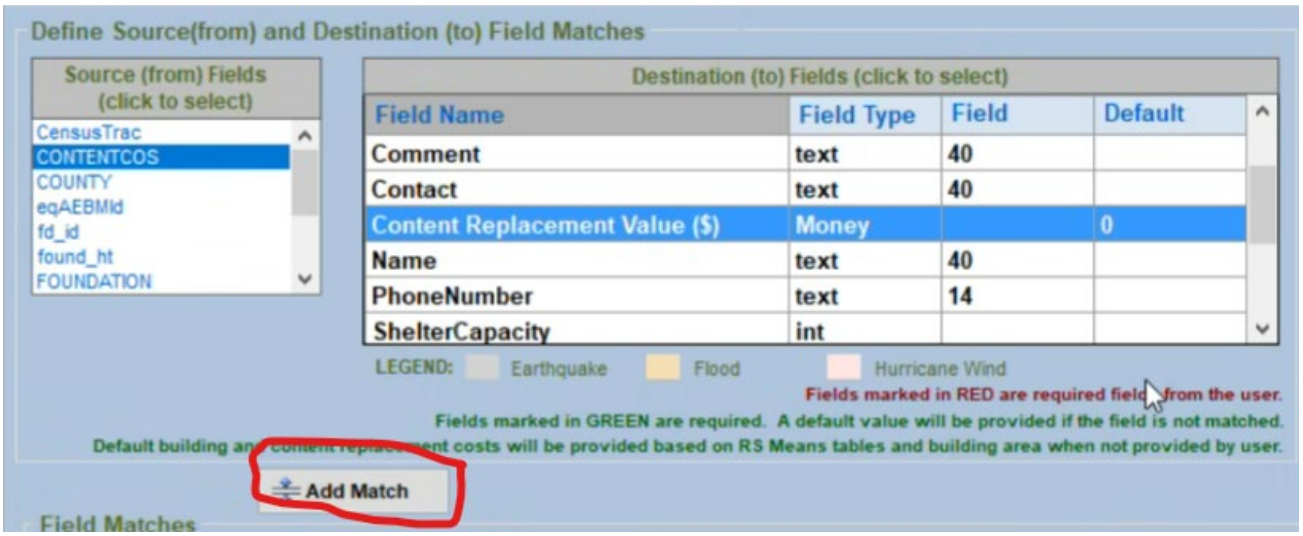
The “Select Import Table” will auto-fill. For the “Select HAZUS-ID Field” you want to select the field that contains the unique identification numbers (see text in right side box). For example, we used the “comment” field for where we put the unique identification numbers. Click “Continue.”

Now comes the mapping.

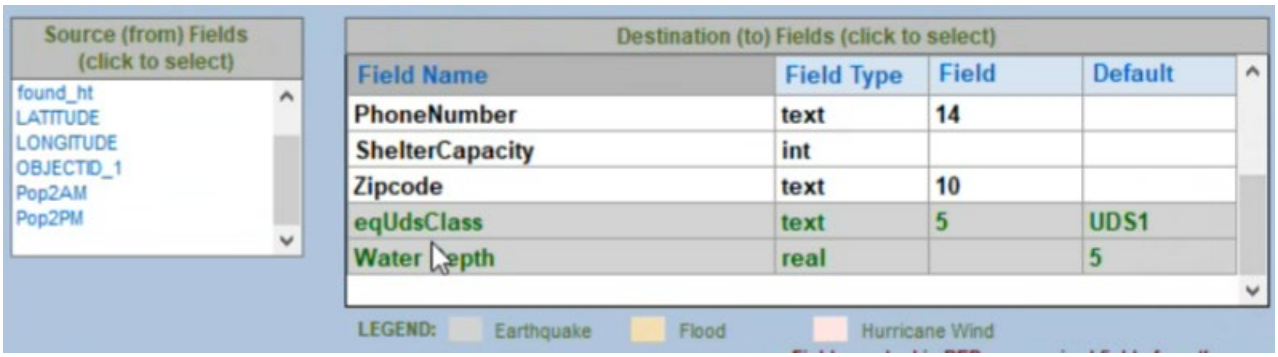


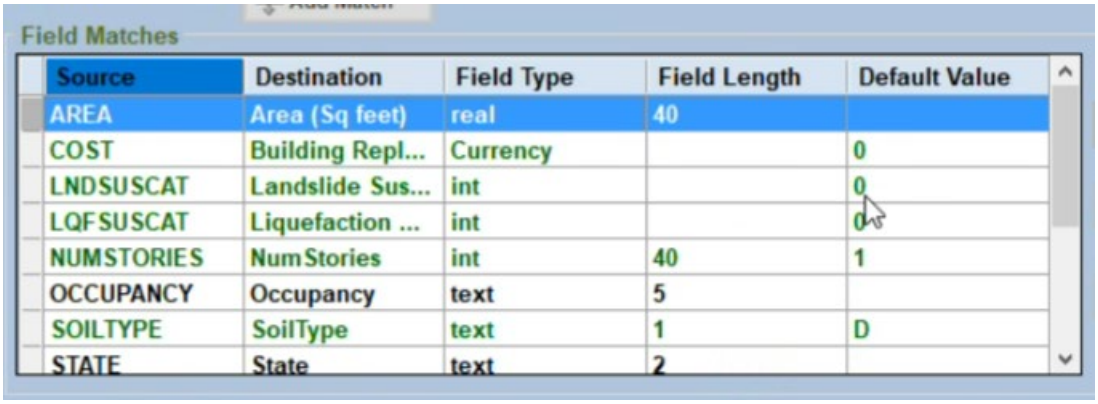
Now you need to manually match up the “Source” and “Destination” fields by clicking on the correct field in the “Source (from) Fields” box and the matching field in the “Destination (to) Fields” box. Then click the “Add Match” button below. Do this for each field that needs to be matched up. VERIFY ALL MAPPINGS.

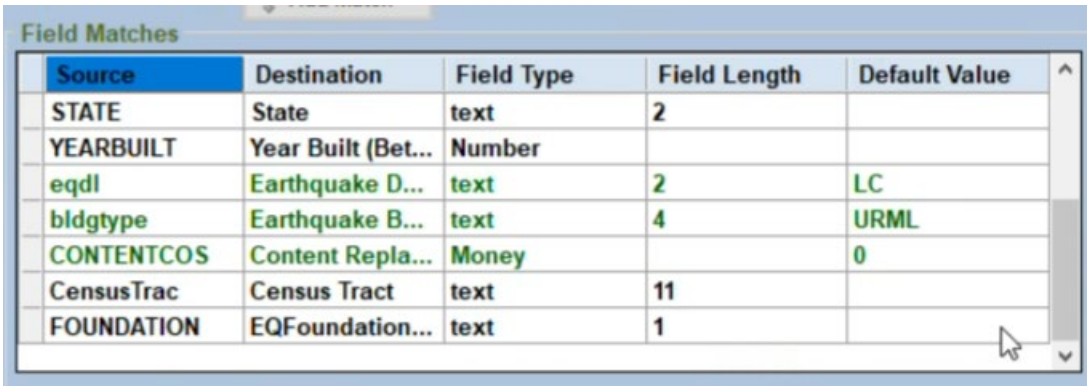
CDMS will automatically map fields that have the same name in the source and destination tables (Figure 3-10). The remaining fields must be mapped. Fields shown in red text in the destination table are required and must be supplied by the user. If the fields in green are not supplied by the user, CDMS will enter standard Hazus default values. Typically, the more data the user supplies, the more accurate the resulting dataset. To map the fields, select a value in the source and destination tables and click Add Match. Once the field mapping process is complete, click the Save button. If a mapping scheme has already been saved, it can be used by clicking the Load button. All mappings will be moved to the Field Matches table. Click Continue when finished.



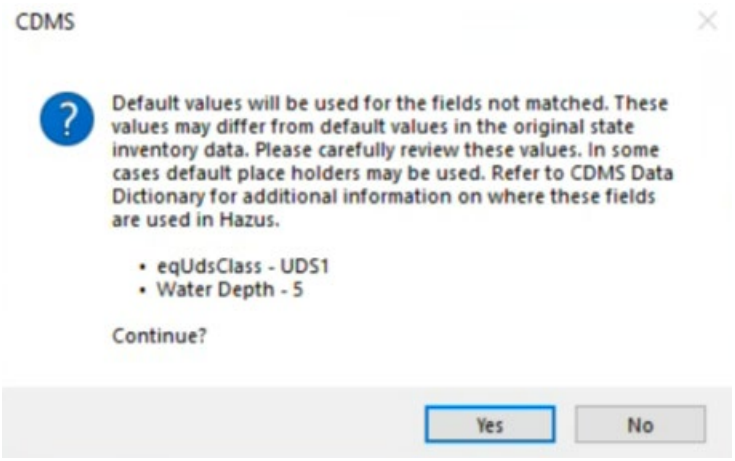
As an FYI, mapping a text field with more than 40 characters into the Comments field will result in a rejection by CDMS.







Continue results in this popup. Hit 'Yes'.

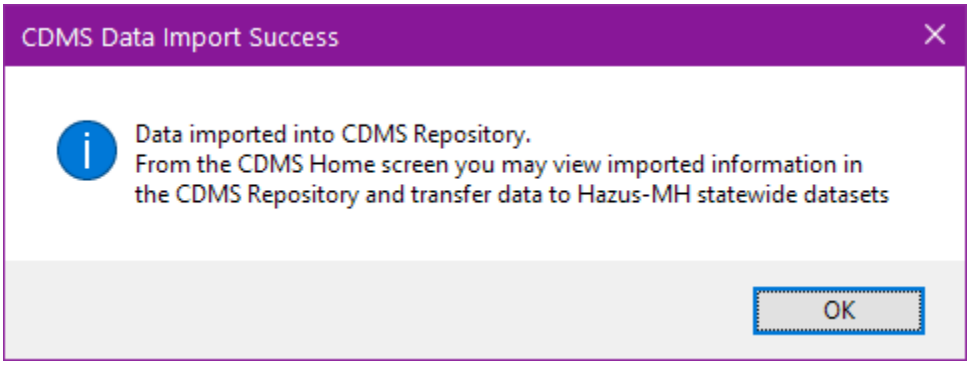


Proceed with OK, Continue, etc.

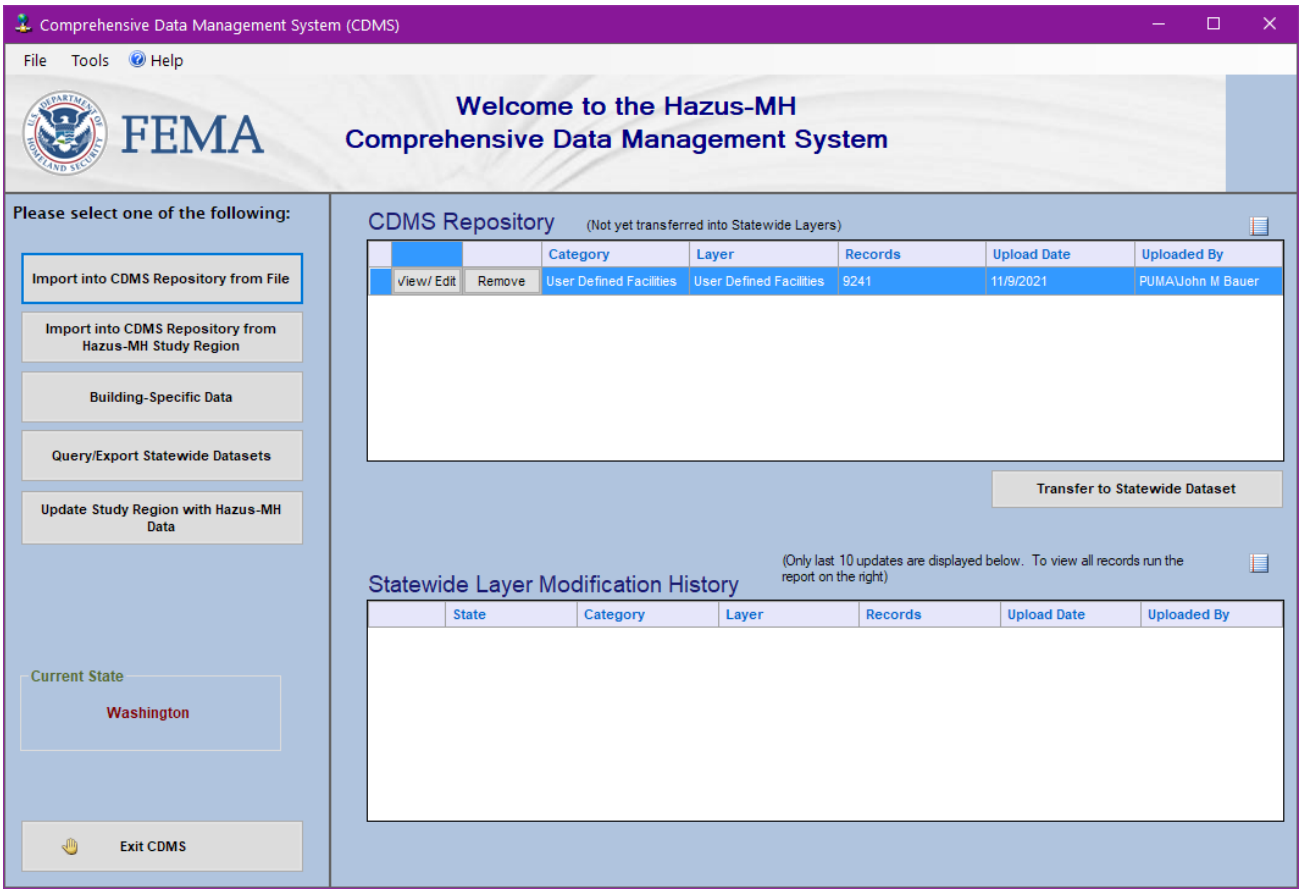
A Categorize Fields message will appear (Figure 3-12). Some of the fields that were supplied with data will need to be categorized into Hazus-specific data. If the data that have been imported already use Hazus-compatible attributes, the categorization will be automatic. Click OK to continue.

Hit Continue and **be prepared to wait. You may have to wait a long time.**

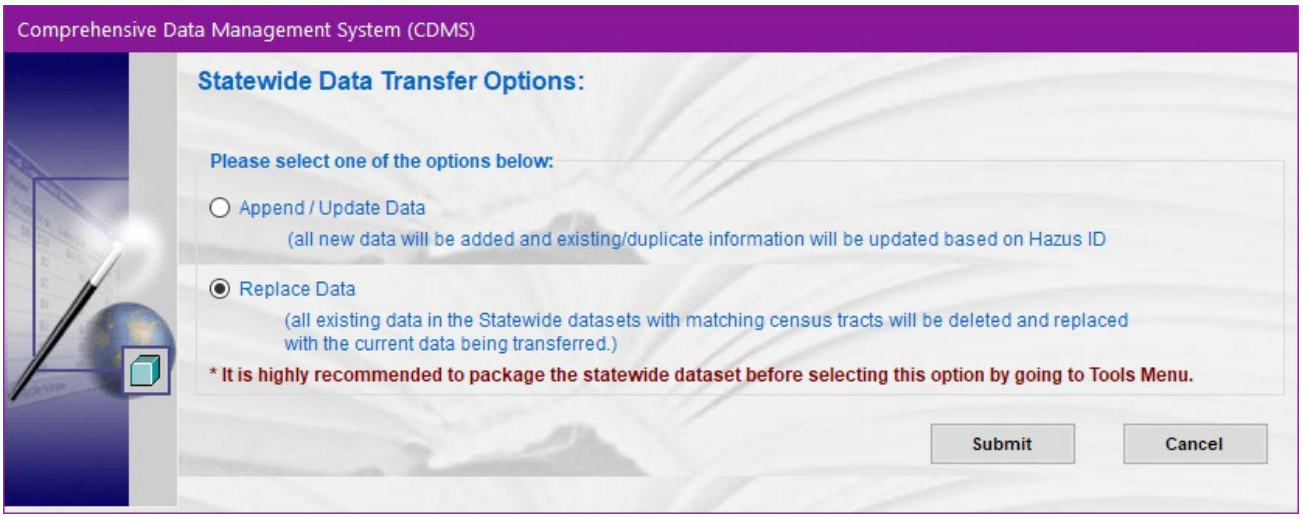
Finally – if all goes well:



But, it has yet to be transferred into the official Hazus inventory stored on your machine.

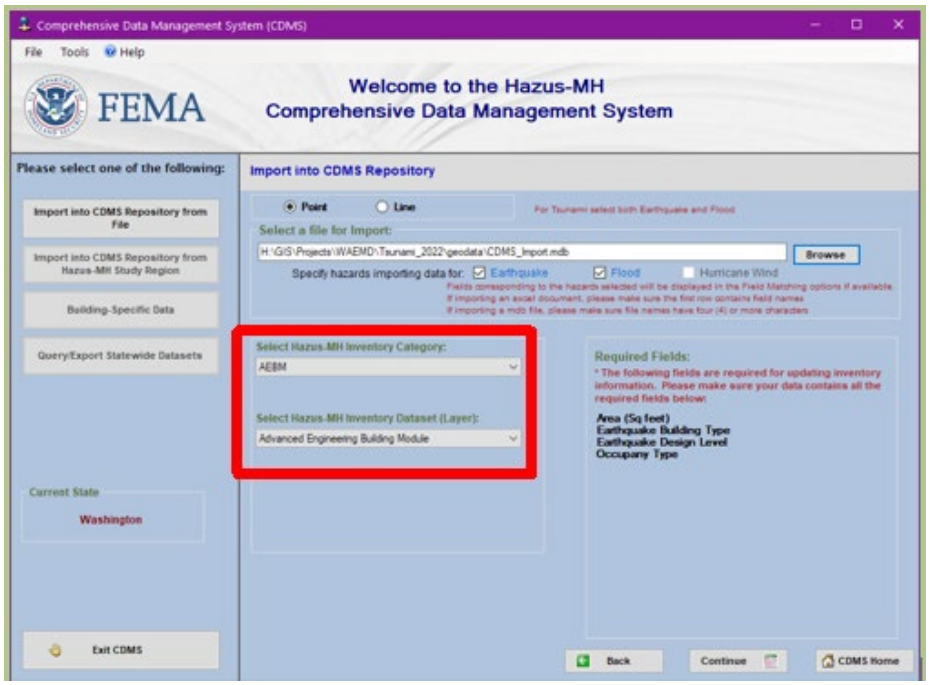


Hit “Transfer to Statewide Dataset”. To minimize confusion, Replace Data



Then hit Submit. This process should be pretty quick. A record of your transaction will then appear in the "Statewide Layer Modification History" section.

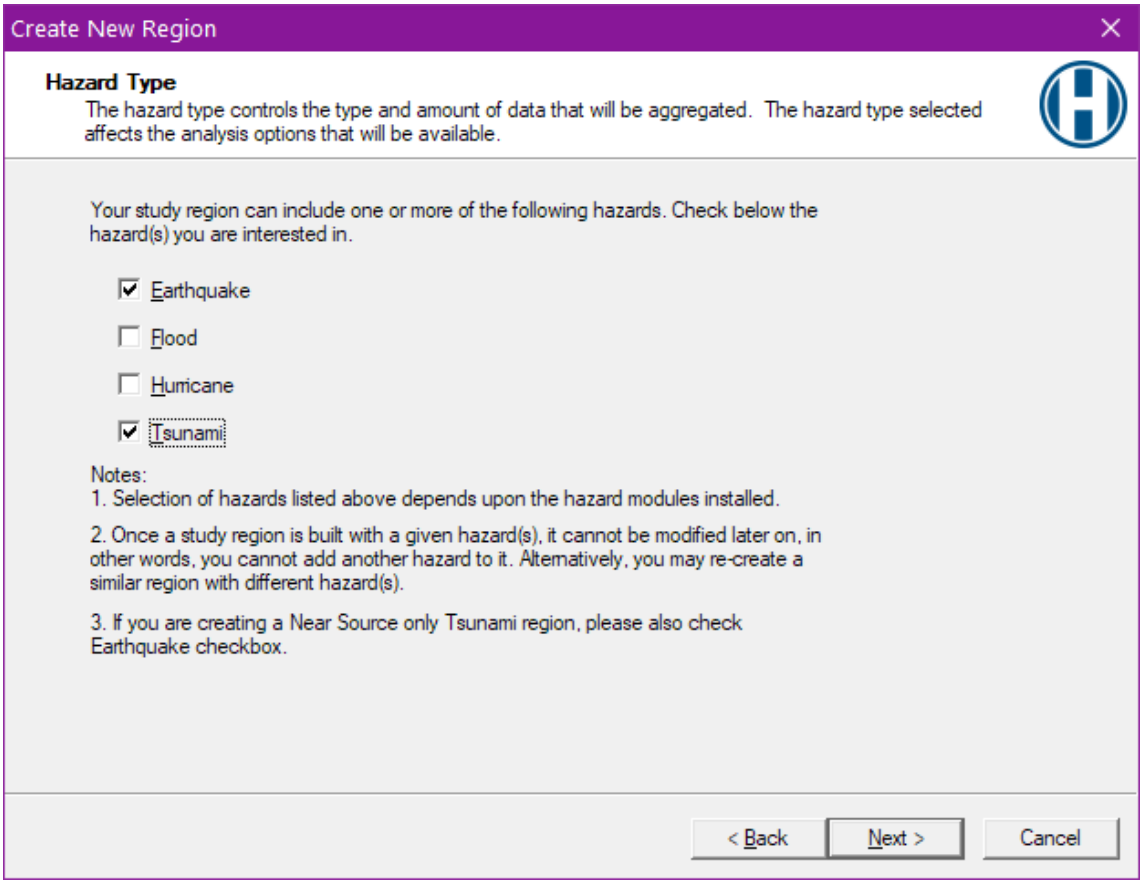
Repeat the above for populating the UDF Inventory Category (UDF is required for combined Hazus Earthquake-Tsunami. If you are doing only an earthquake run, depending on your plans, a UDF import may not be needed.) You need 2am/2pm population in order to conduct casualty estimates for earthquake runs.



Running the Hazus Earthquake-Tsunami model

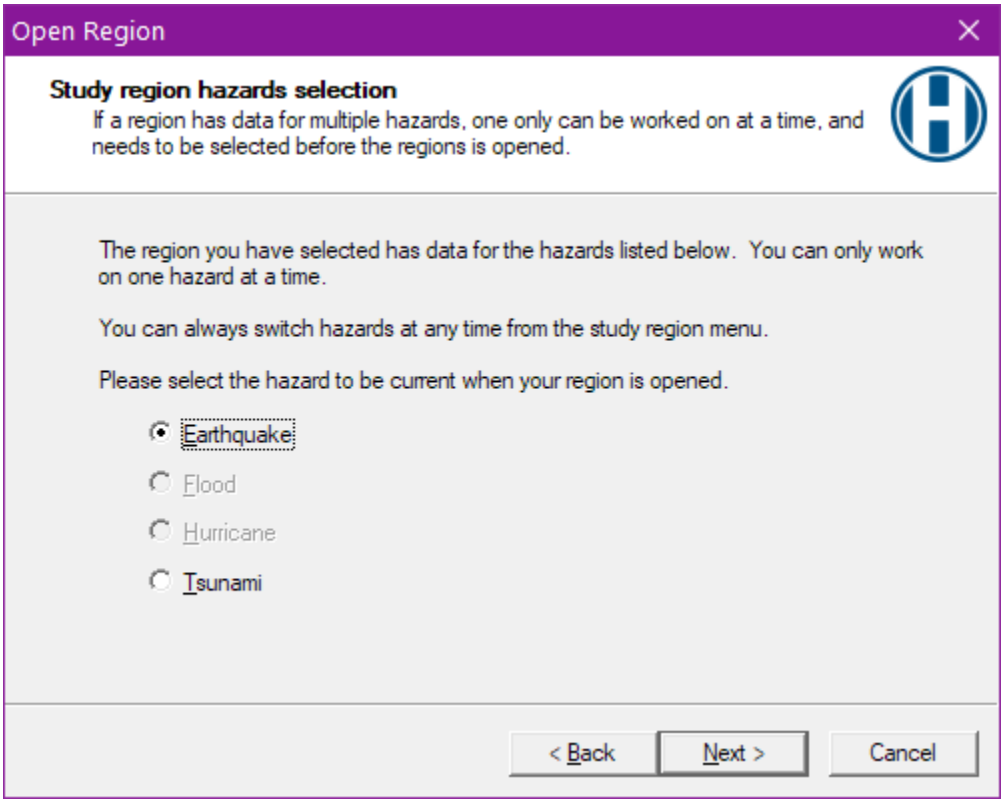
[If earthquake-only is desired, then ignore the tsunami model references below]

Open Hazus and "Create a new region". For efficiency's sake, we advise that this be run at a county level. The tsunami model becomes very slow with two or more counties. For tsunami, make sure both earthquake and tsunami are selected:

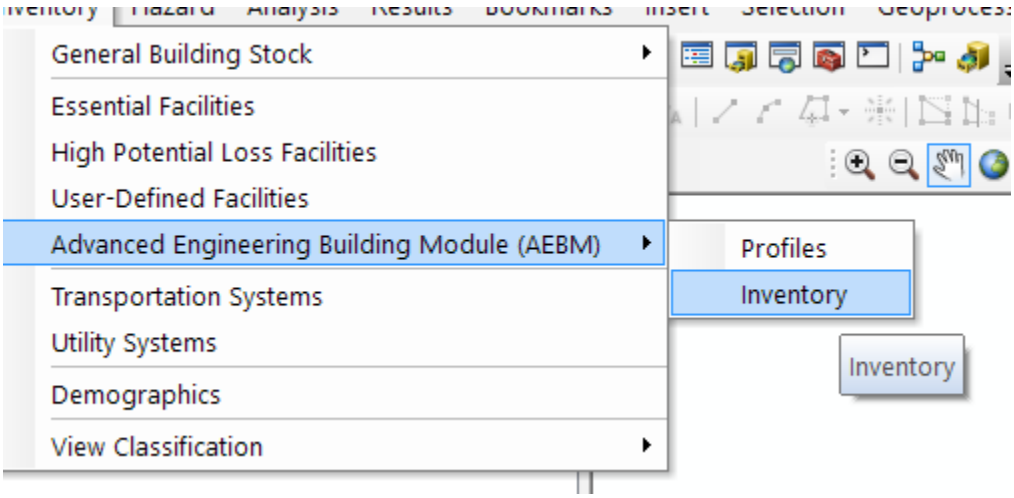


Depending on the county, this can take several minutes.

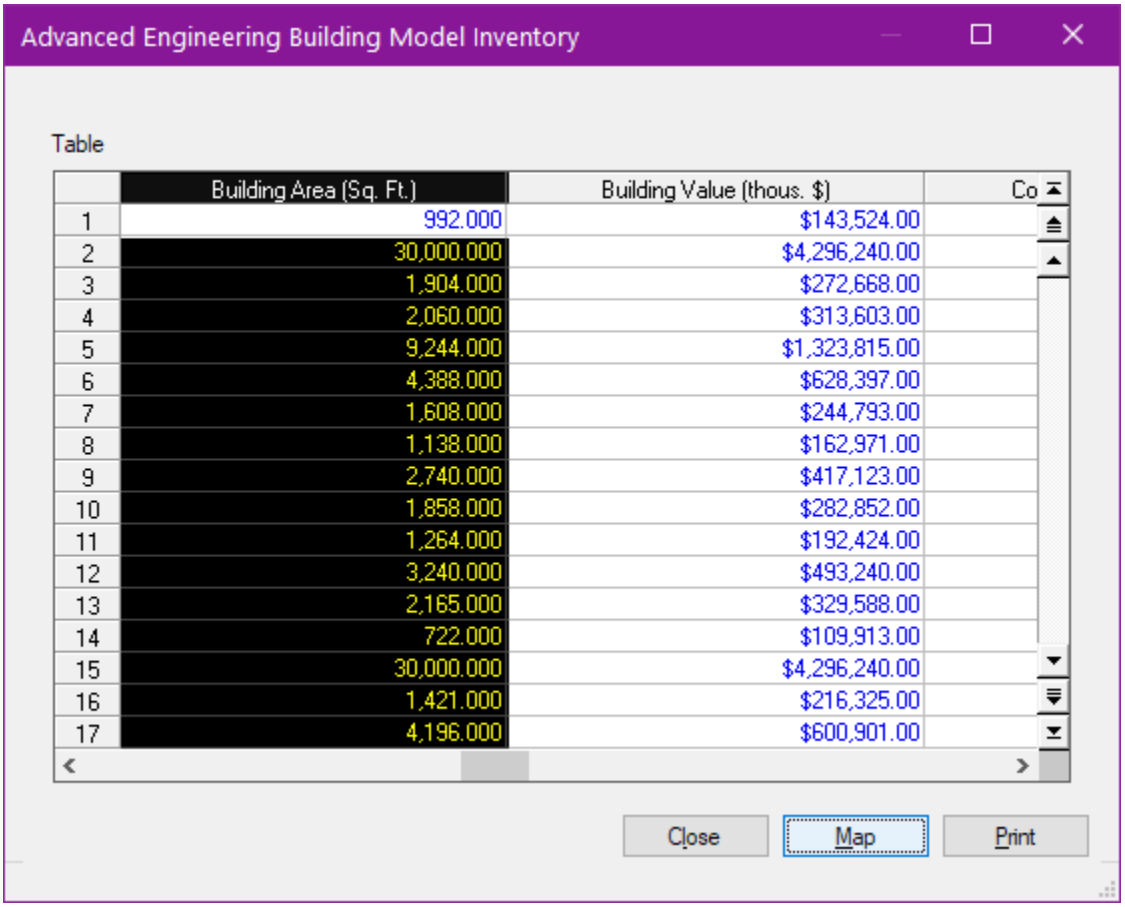
Open the region that was just created. For combined tsunami-earthquake analysis, open the Earthquake first, before proceeding with the tsunami.



Verify the inventory that was imported into CDMS is present in the Hazus database: (this example is for AEBM; for tsunami/earthquake, you want to view the User-Defined Facilities).

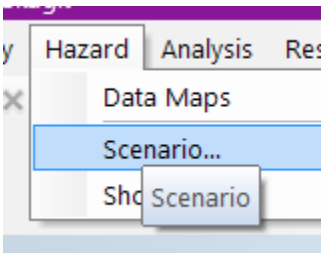


This may take several minutes while Hazus produces a table. You can select a column and map it:

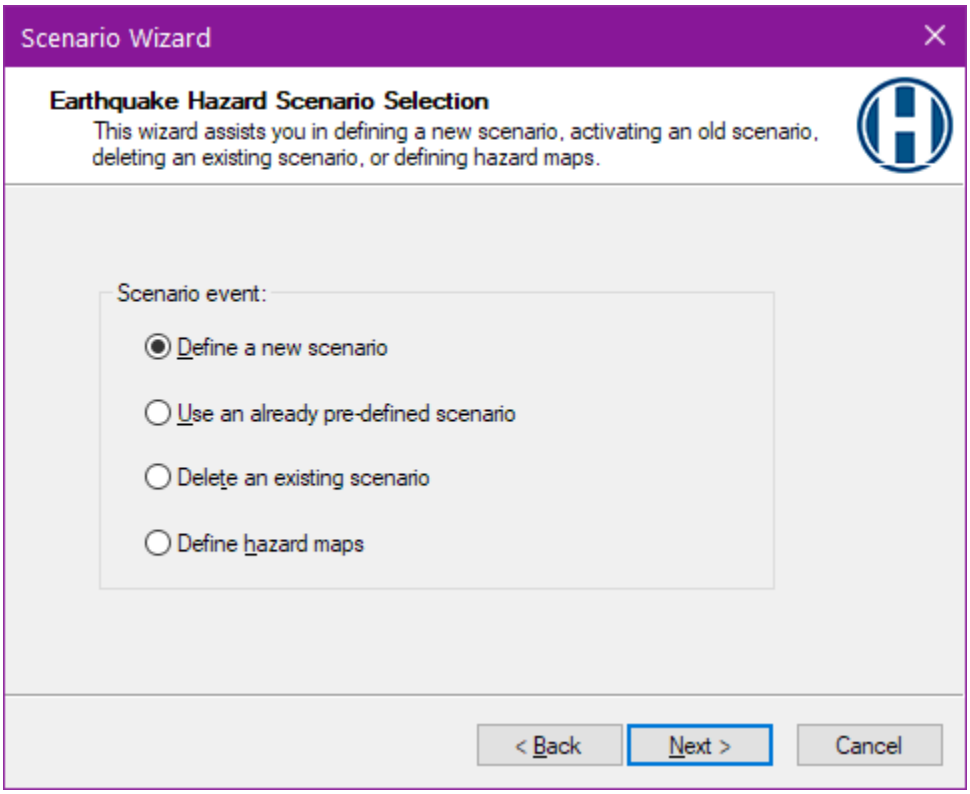


	Building Area (Sq. Ft.)	Building Value (thous. $)	Co
1	992.000	$143,524.00	
2	30,000.000	$4,296,240.00	
3	1,904.000	$272,668.00	
4	2,060.000	$313,603.00	
5	9,244.000	$1,323,815.00	
6	4,388.000	$628,397.00	
7	1,608.000	$244,793.00	
8	1,138.000	$162,971.00	
9	2,740.000	$417,123.00	
10	1,858.000	$282,852.00	
11	1,264.000	$192,424.00	
12	3,240.000	$493,240.00	
13	2,165.000	$329,588.00	
14	722.000	$109,913.00	
15	30,000.000	$4,296,240.00	
16	1,421.000	$216,325.00	
17	4,196.000	$600,901.00	

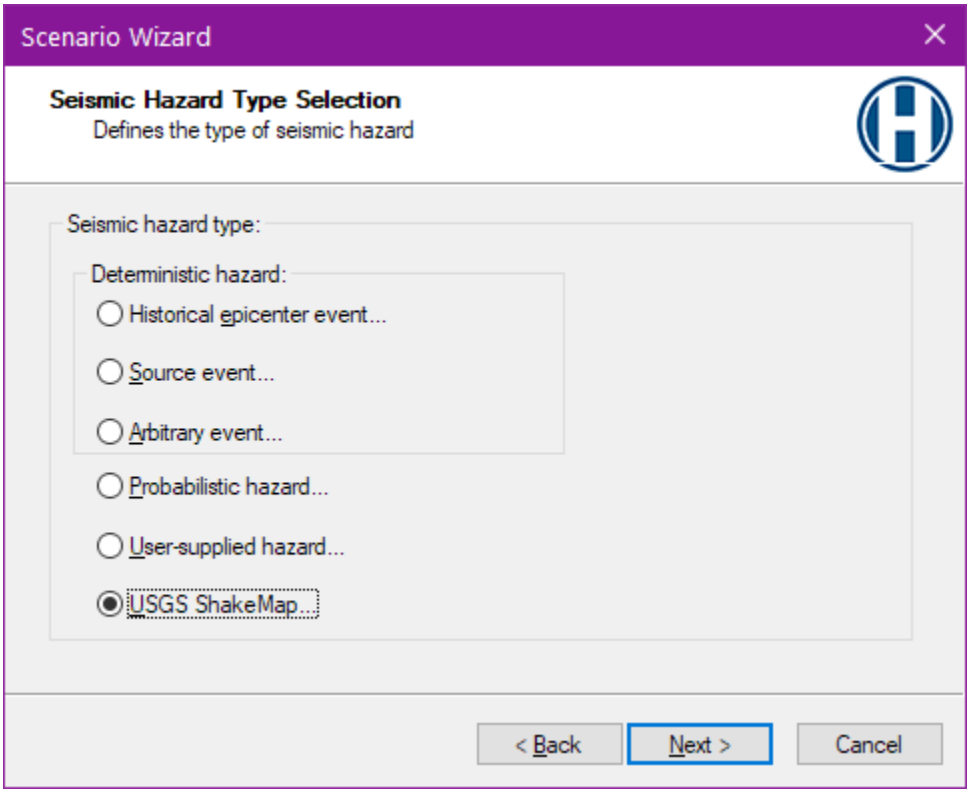
To run the earthquake model, define the scenario:



Next ->

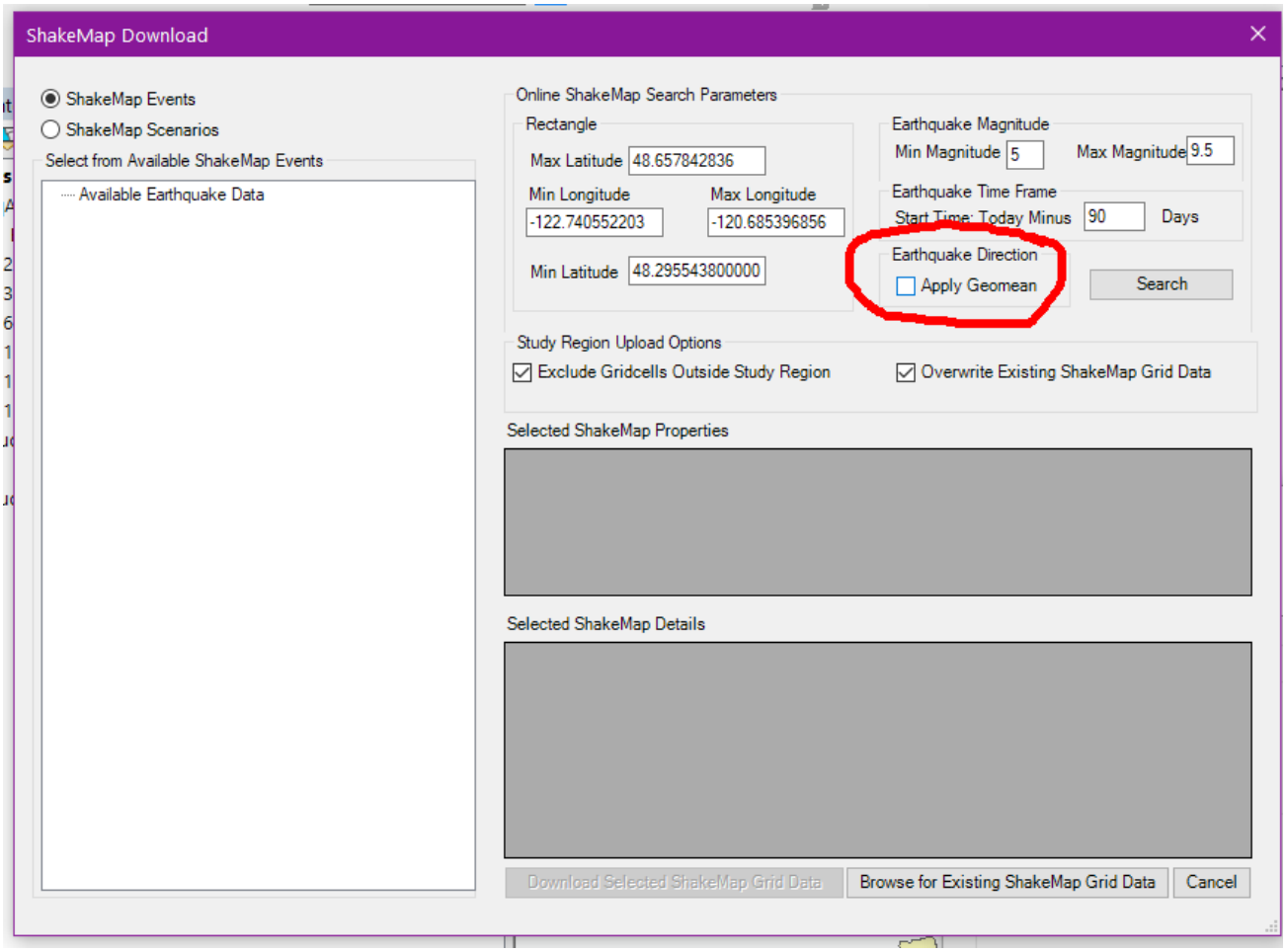


Don't try recycling old scenarios. Just do New Scenario each time. Next


Scenario Wizard
Seismic Hazard Type Selection
Defines the type of seismic hazard
Seismic hazard type:
Deterministic hazard:
Historical epicenter event...
Source event...
Arbitrary event...
Probabilistic hazard...
User-supplied hazard...
USGS ShakeMap...
< Back
Next >
Cancel

Next

Here, before proceeding, remember to uncheck the “Apply Geomean” box in the upper right

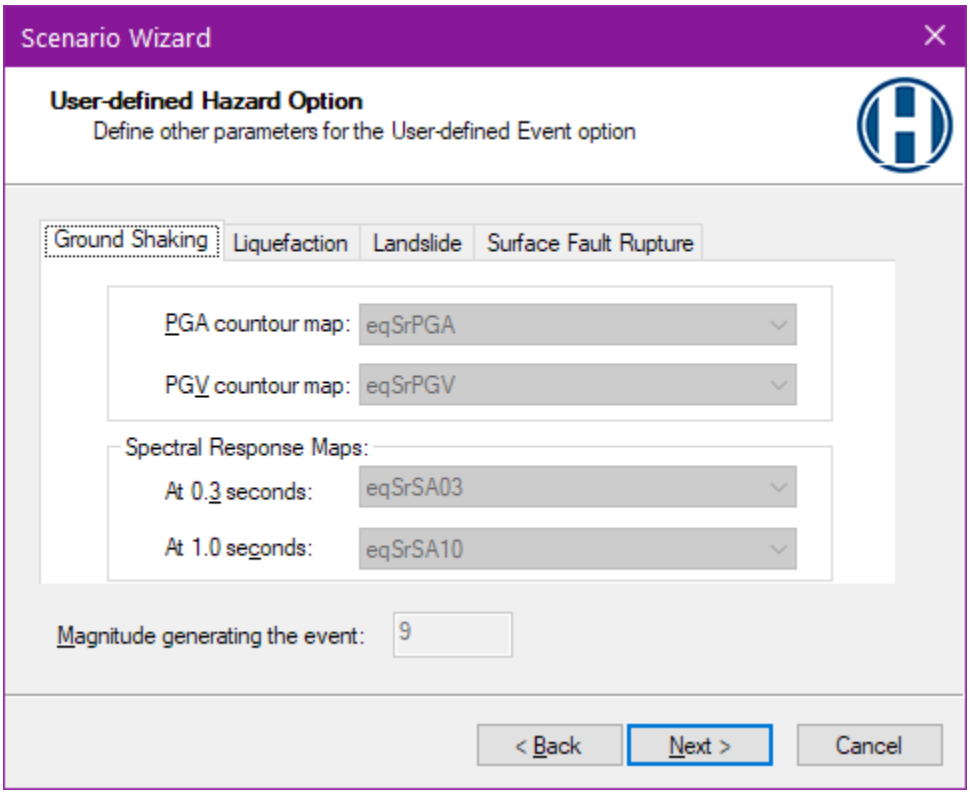


Then hit “Browse for Existing Shakemap Grid Data” (bottom right):

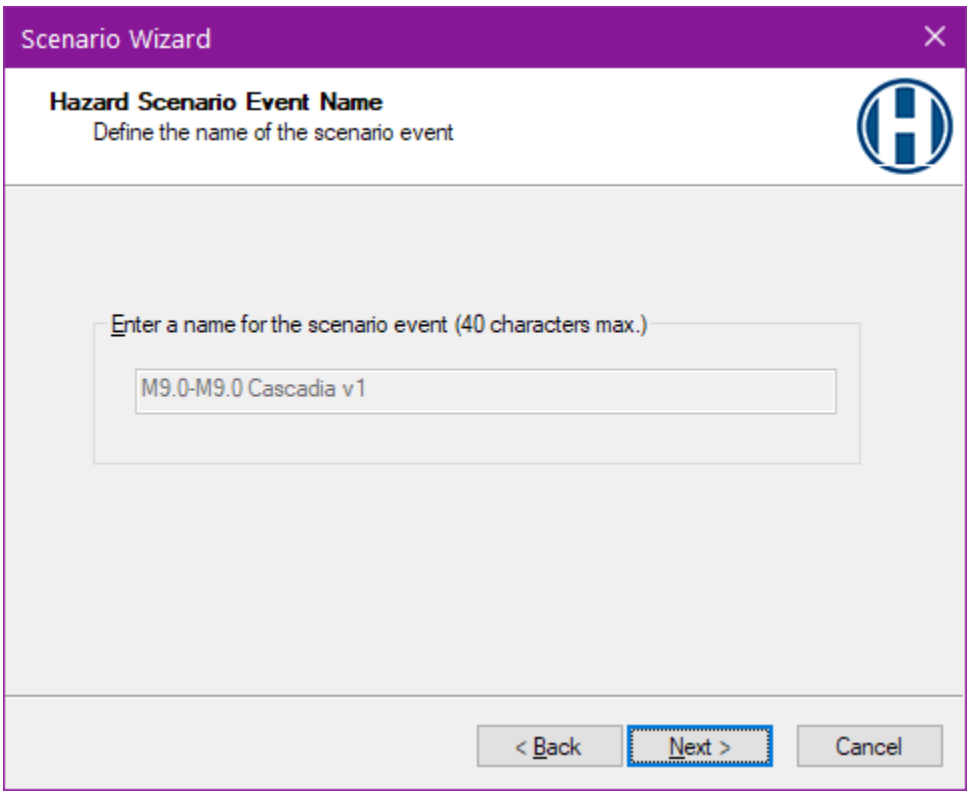
Navigate to where the USGS CSZ Shakemap median or 84th percentile file, and select the scenario of interest (folder geodata\CSZ ShakeMap):

- CSZ 2020 84th percentile.xml
- CSZ 2020 median.xml

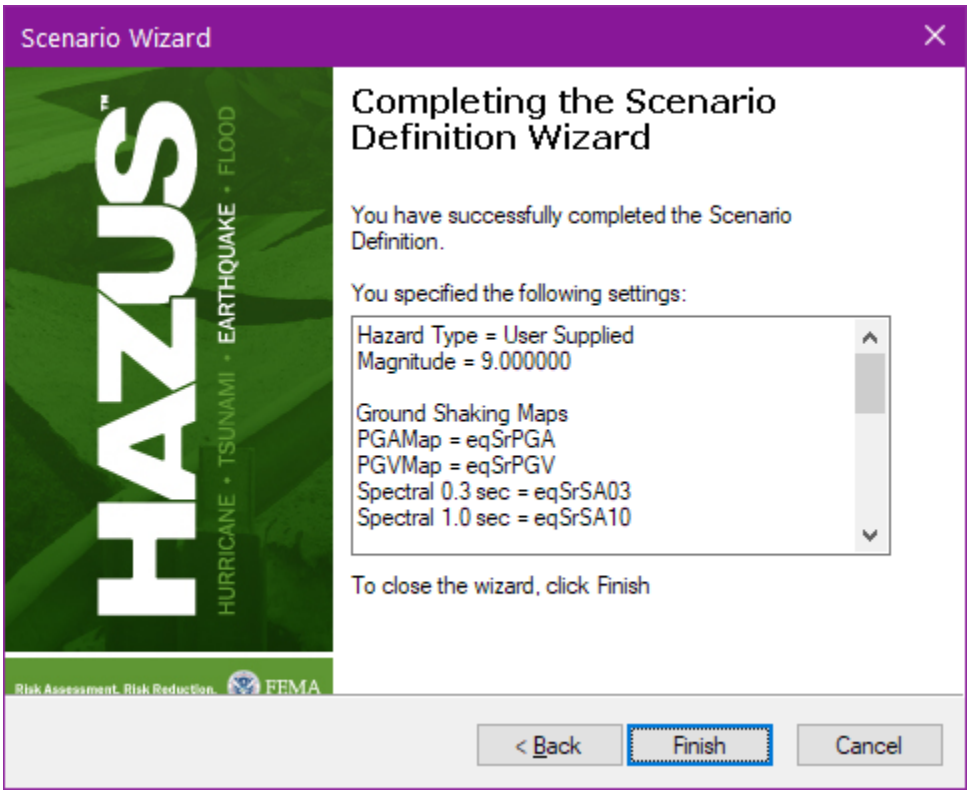
It should return the following:



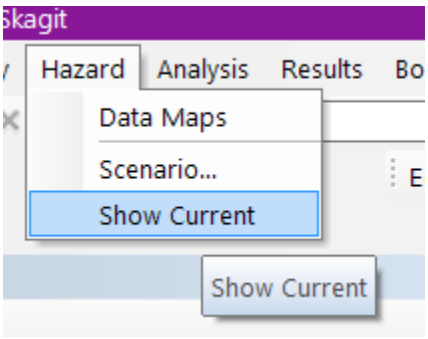
Next -> Nothing to select here below:



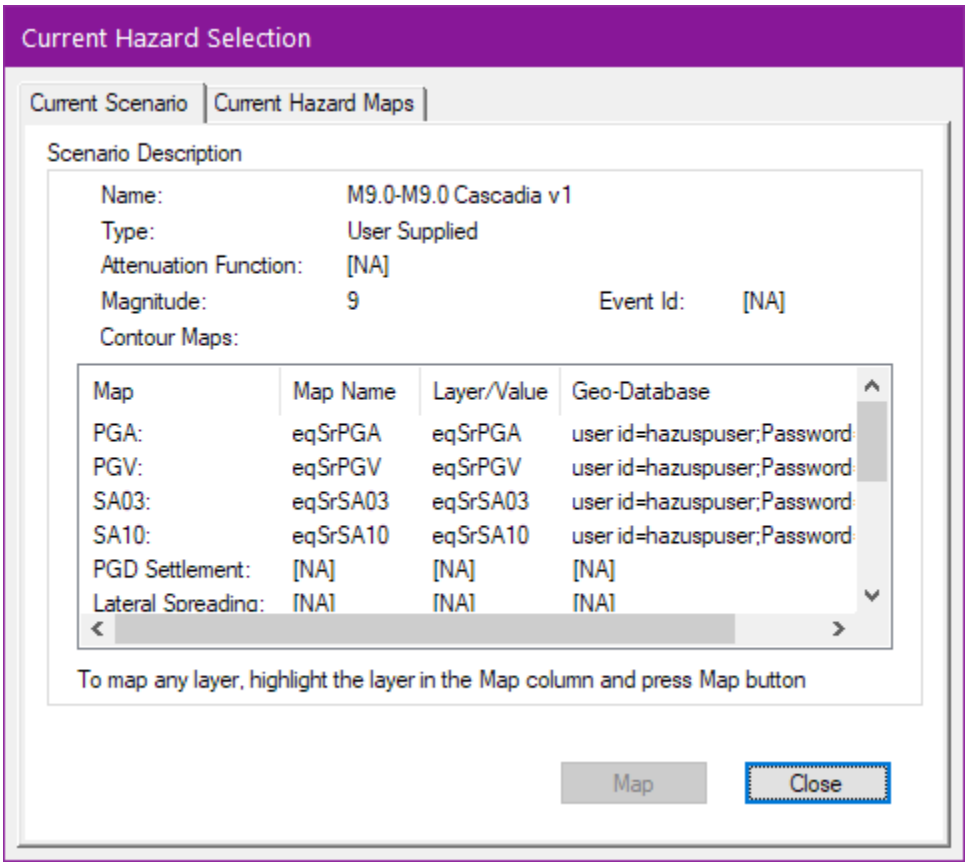
Next ->



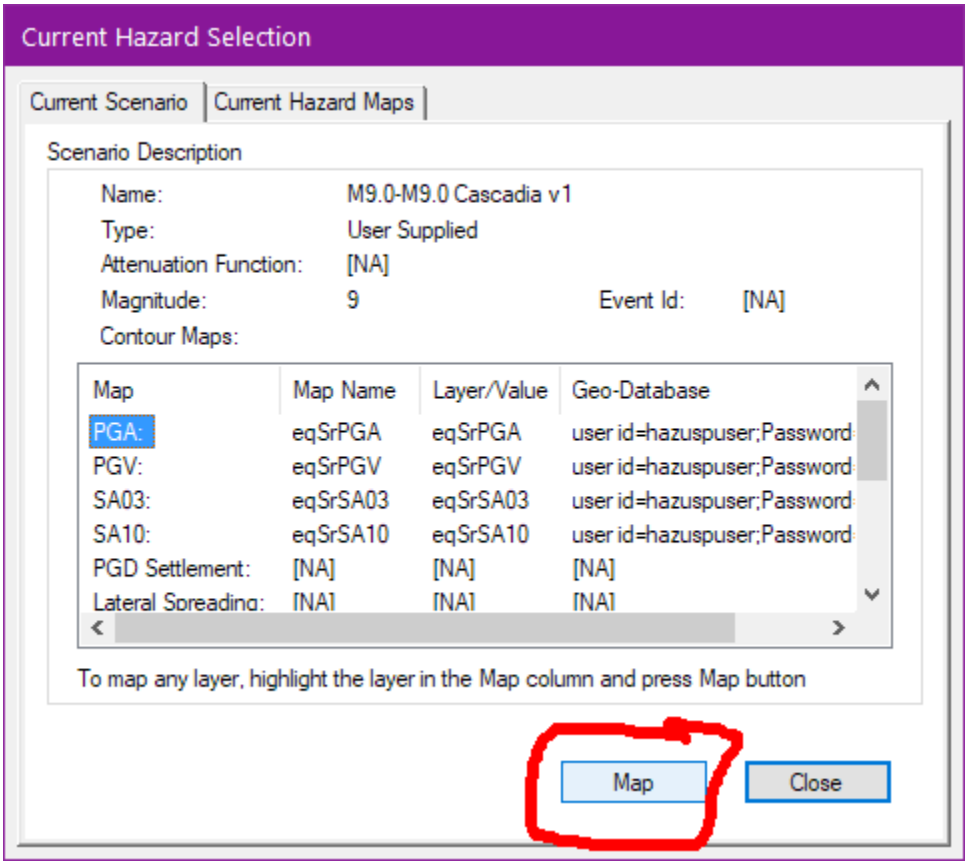
Finish. And there it is. To verify the grids are ready to go, do the following:



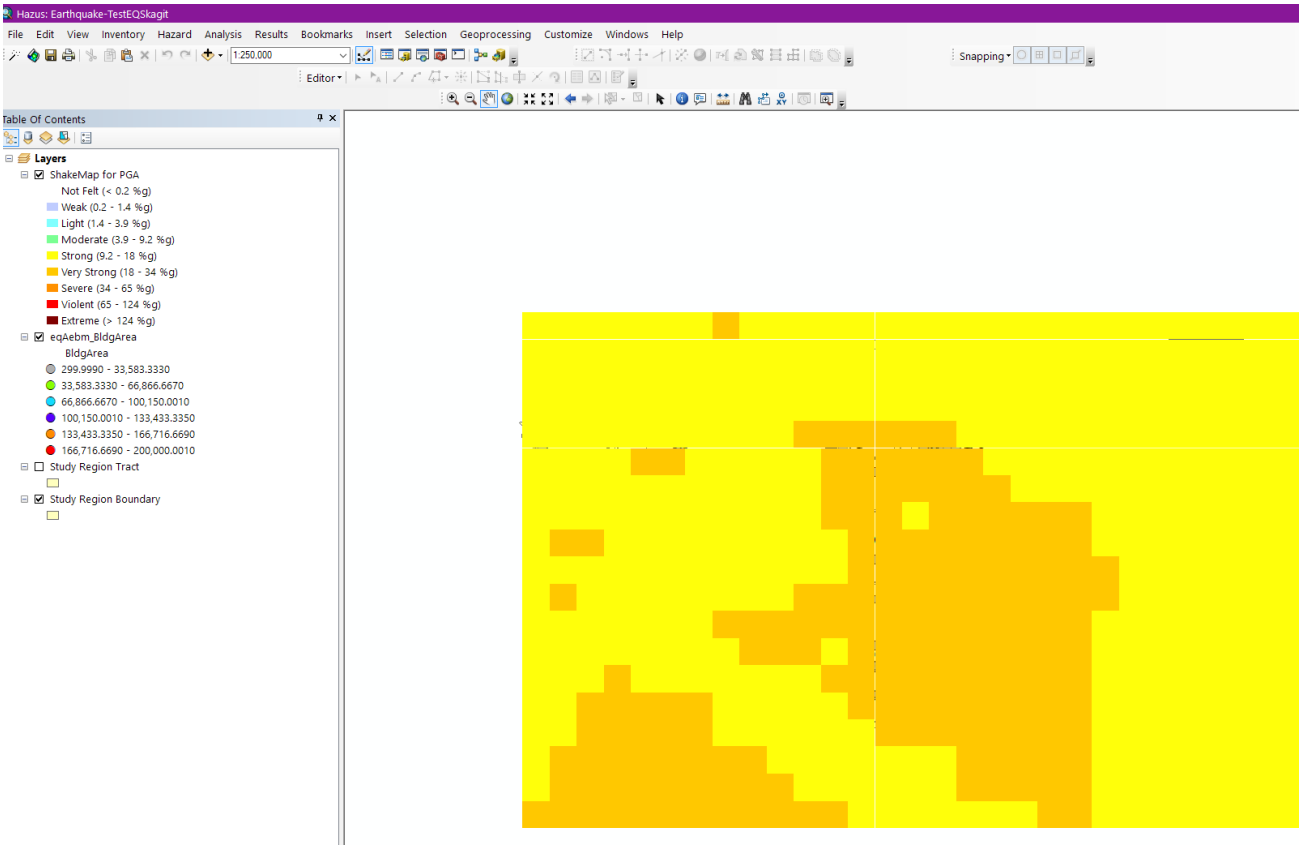
This should return the following:



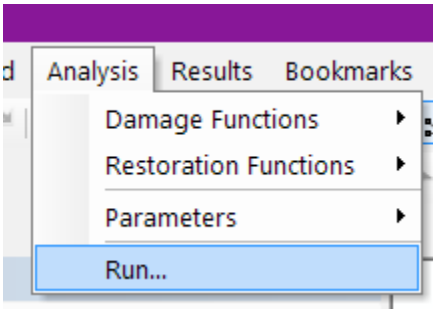
Click on “PGA” and hit “Map”



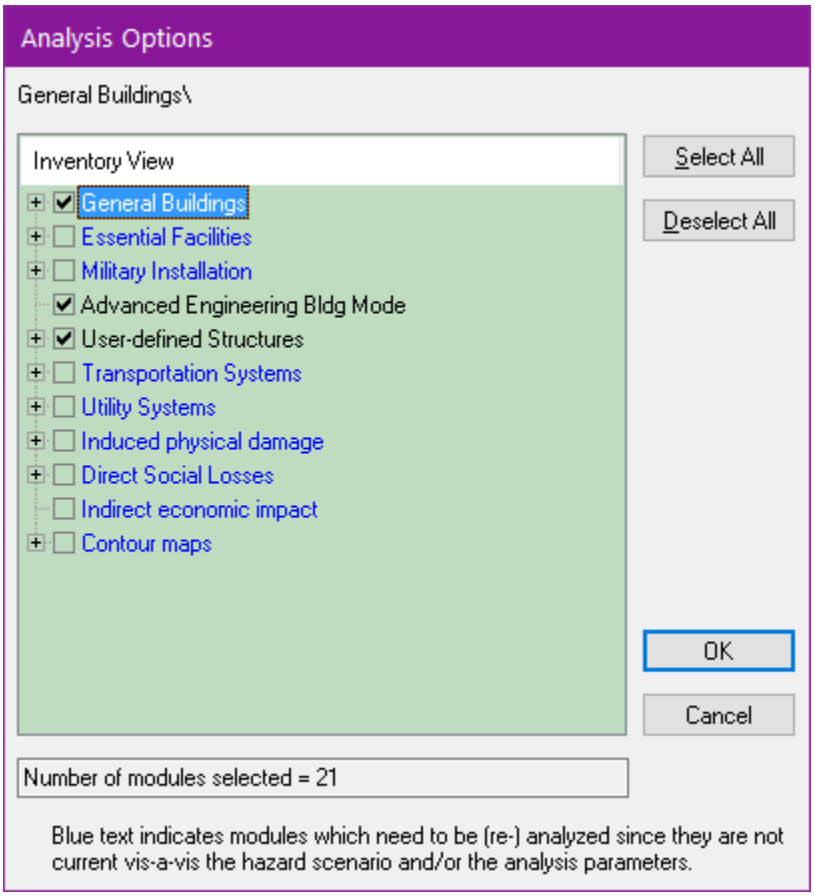
You should see a representation of “pga” (peak ground acceleration):

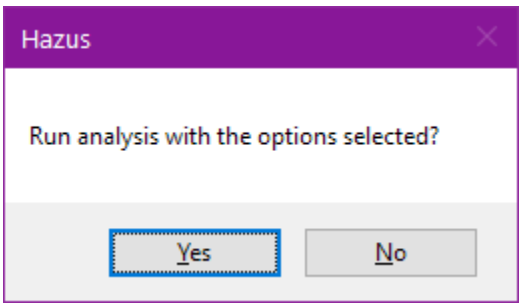


Then running Hazus itself:



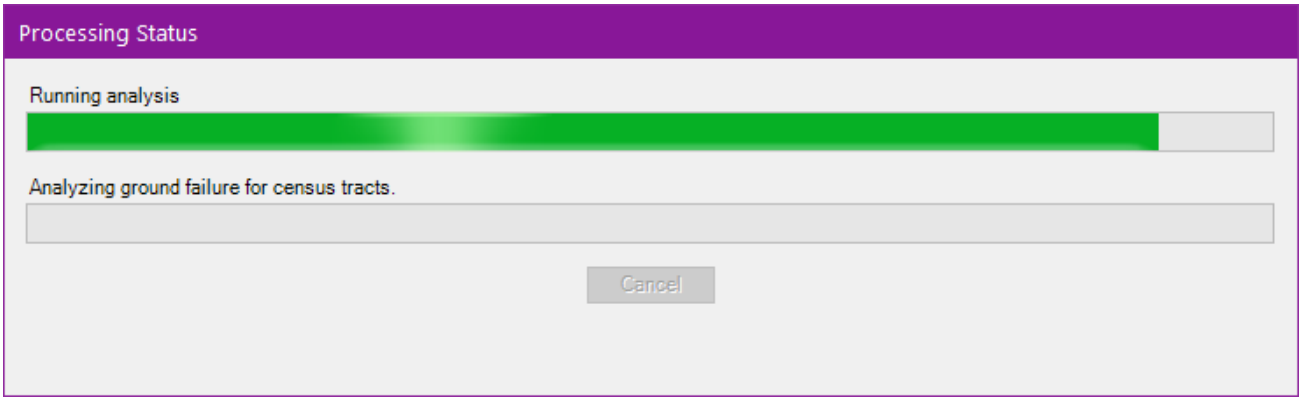
For a tsunami run, select





Select Yes

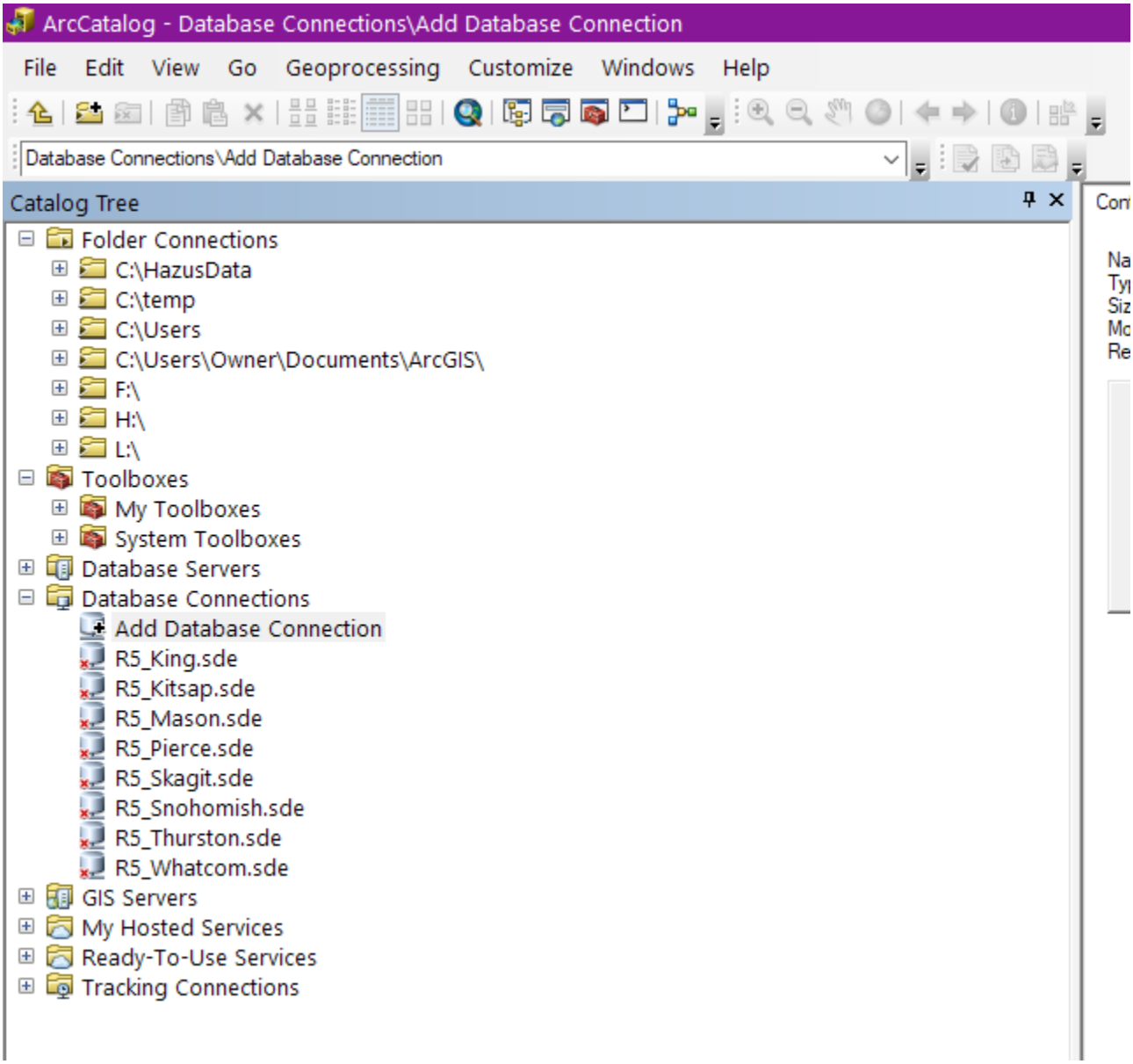
Depending on the UDF/AEBM dataset size, this step make take a while:

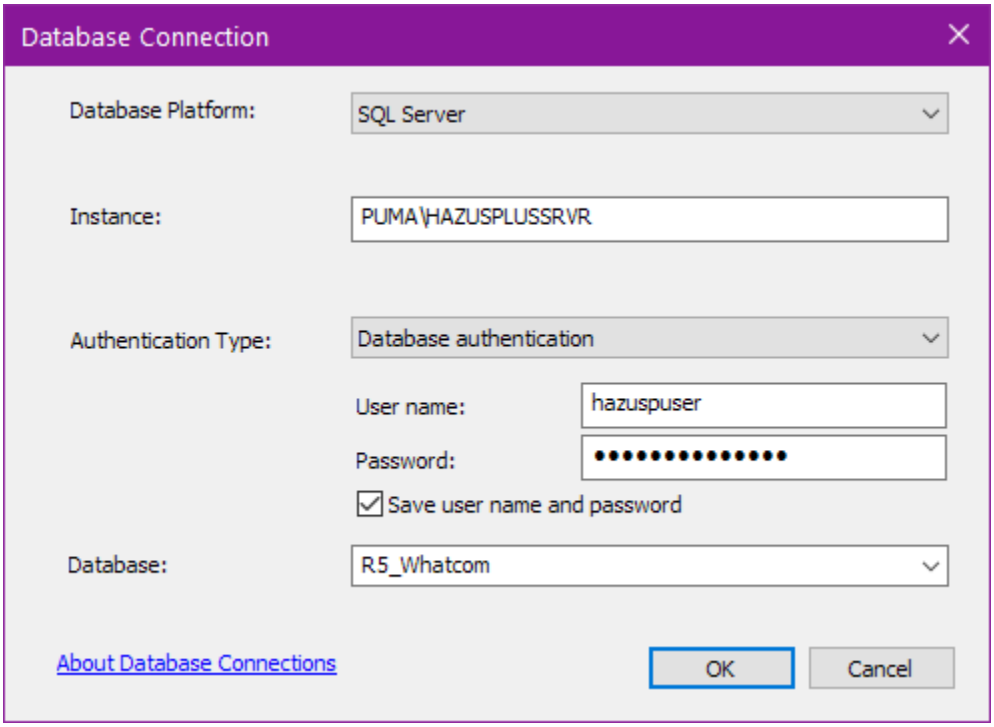


We are not reporting on earthquake-only data for buildings in the tsunami zone.

For earthquake only, exit Hazus and open ArcCatalog. If you are running the combined earthquake-tsunami, ignore the following.

Establish a connection to the SQL database. Double-click on the “Add Database Connection”

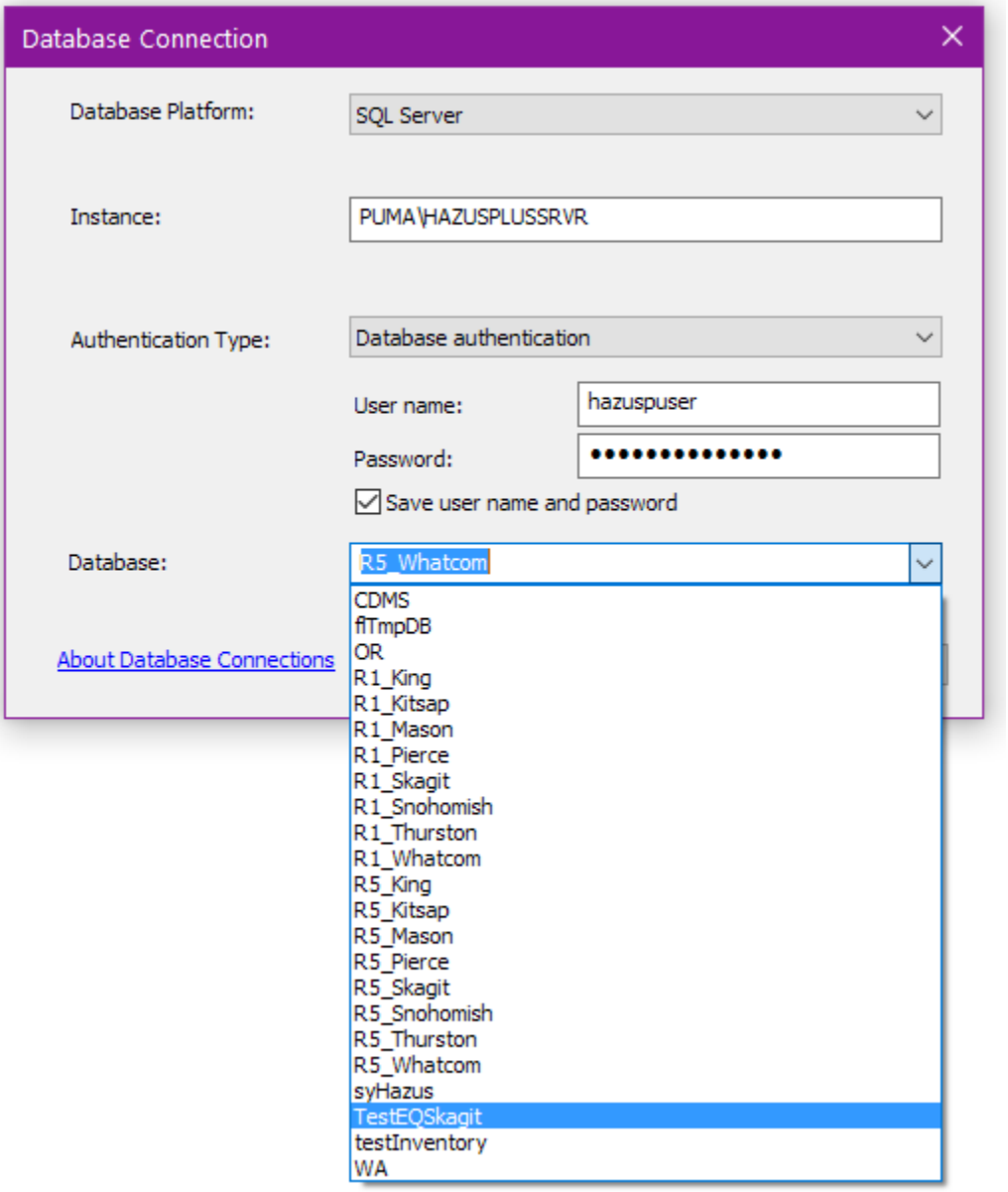

ArcCatalog - Database Connections\Add Database Connection
File Edit View Go Geoprocessing Customize Windows Help
Database Connections\Add Database Connection
Catalog Tree
Folder Connections
C:\HazusData
C:\temp
C:\Users
C:\Users\Owner\Documents\ArcGIS\
F:\
H:\
L:\
Toolboxes
My Toolboxes
System Toolboxes
Database Servers
Database Connections
Add Database Connection
R5_King.sde
R5_Kitsap.sde
R5_Mason.sde
R5_Pierce.sde
R5_Skagit.sde
R5_Snohomish.sde
R5_Thurston.sde
R5_Whatcom.sde
GIS Servers
My Hosted Services
Ready-To-Use Services
Tracking Connections



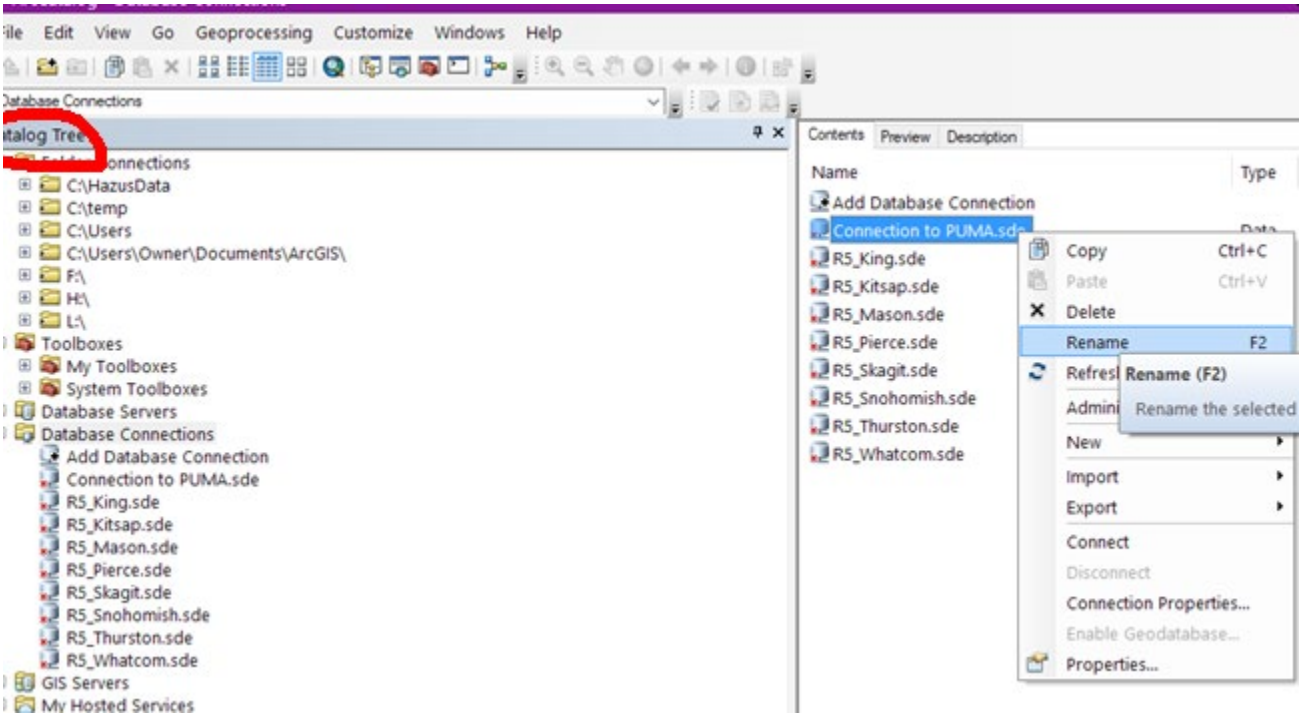
The password is: Gohazusplus_02

Your computer name will differ from “PUMA”.

Then via the pull-down, connect to the “Database” - which is your Hazus region name.



Hit “OK”. Immediately rename the “Connection to COMPUTER.sde” database connection to (ideally) the same region name you used in Hazus, so as to not avoid future confusion. Right-click on the item to rename it:



It will have a suffix of ".sde".

Then in the Catalog Tree window (circled in red, above), double click on the renamed connection, and have it expanded in full. There are a lot of files. The table you want for UDF loss is:

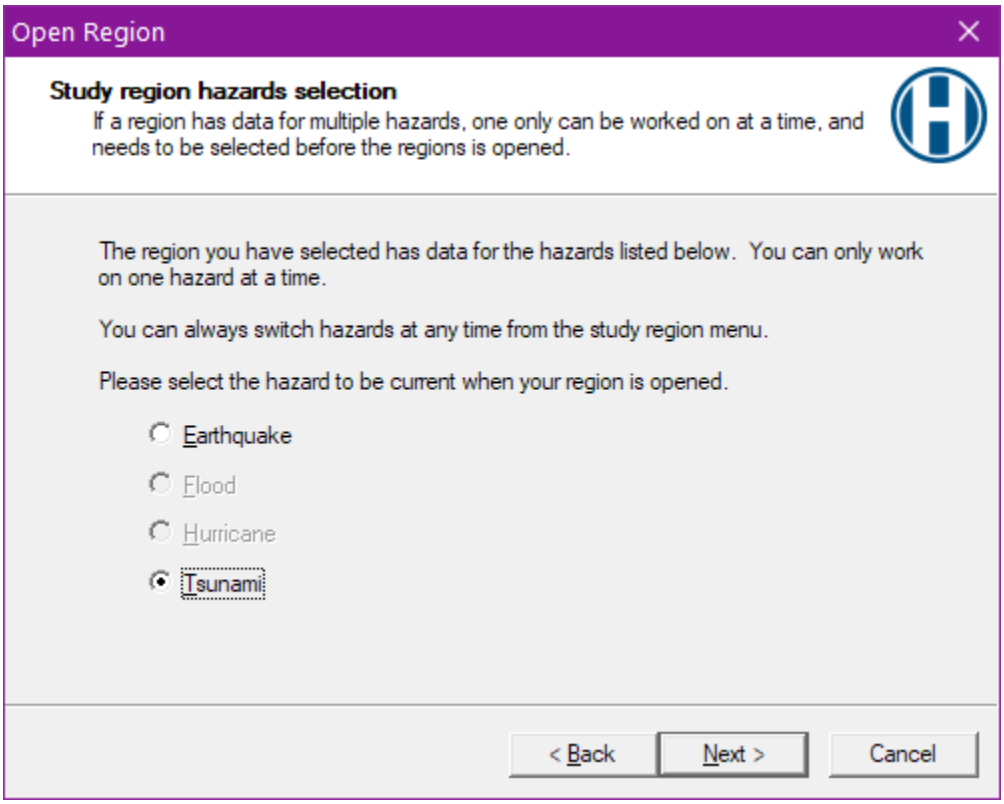
Database Connections\TestWhatcomEQ.sde\TestEQSkagit.dbo.eqUserDefinedFlty

To simplify future summaries, export this table to a standalone file geodatabase for use elsewhere.

The UDF earthquake economic loss numbers file for reference, and also to correct a major bug with the manufactured housing type (discussed below).

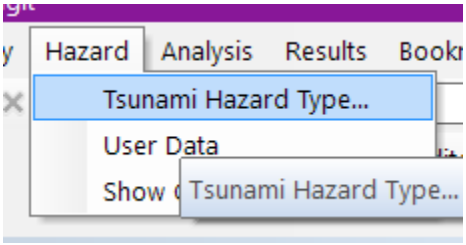
Combined Earthquake-Tsunami Building Loss

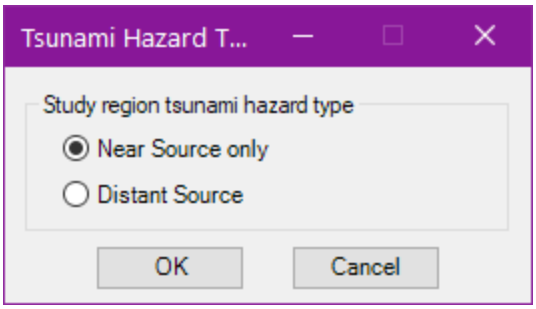
After running the earthquake analysis, quit Hazus (if you have not done so), open Hazus, select your region, and select Tsunami



Next, Finish. A Hazus/ArcMap should open. Note this warning window. Do not click buttons when these warning windows are displayed. Be patient.

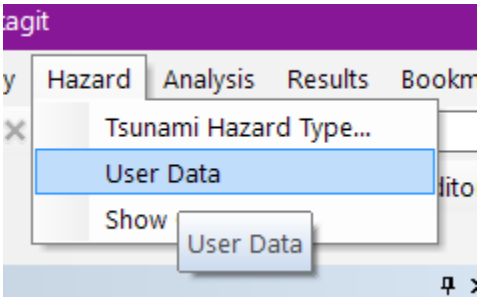
Define the Hazard as local. Hazard ->



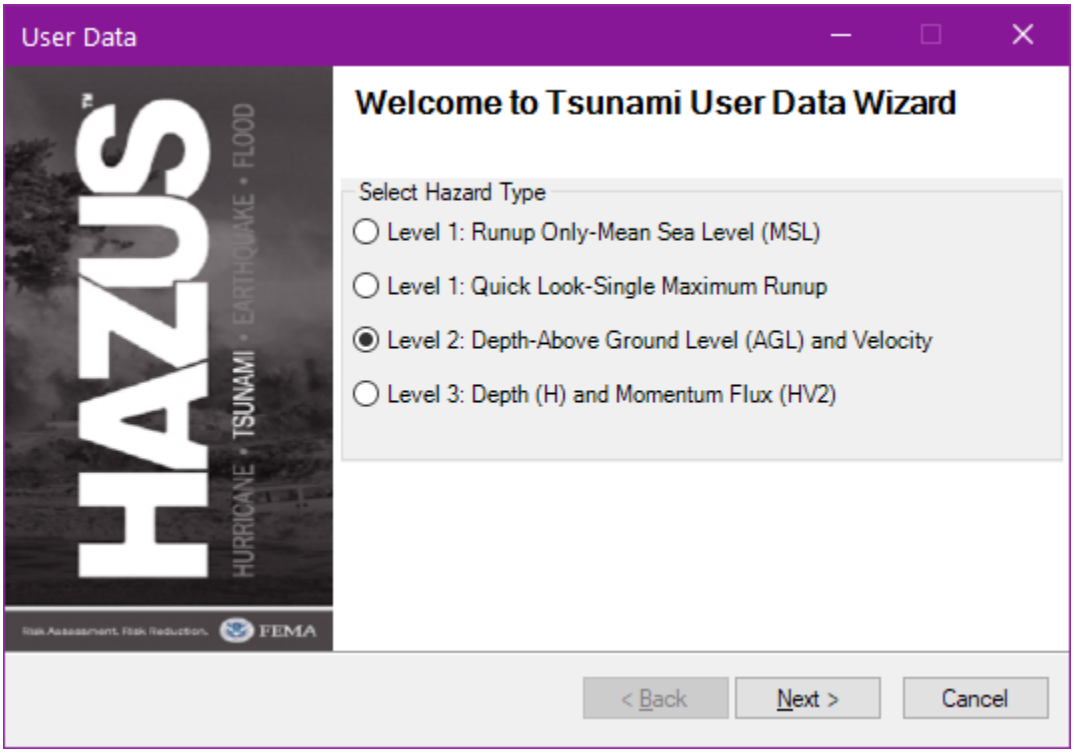


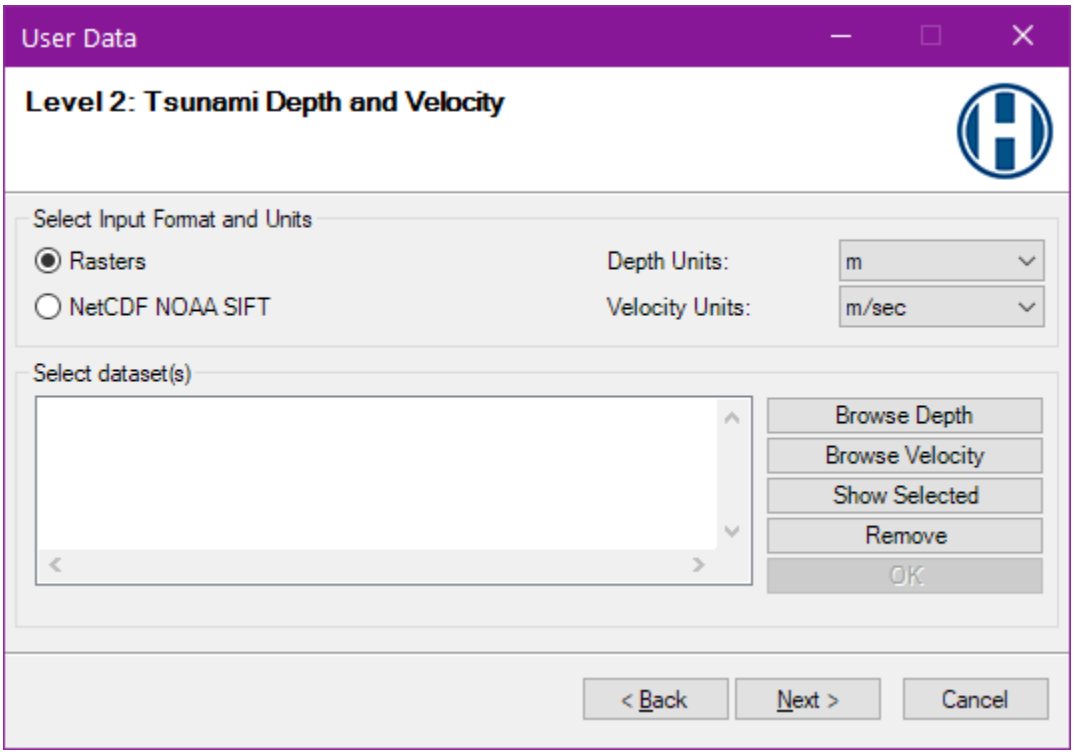
OK.

Provide the tool with the tsunami hazard data. Note that the derivation of these grids is discussed in the appendix.

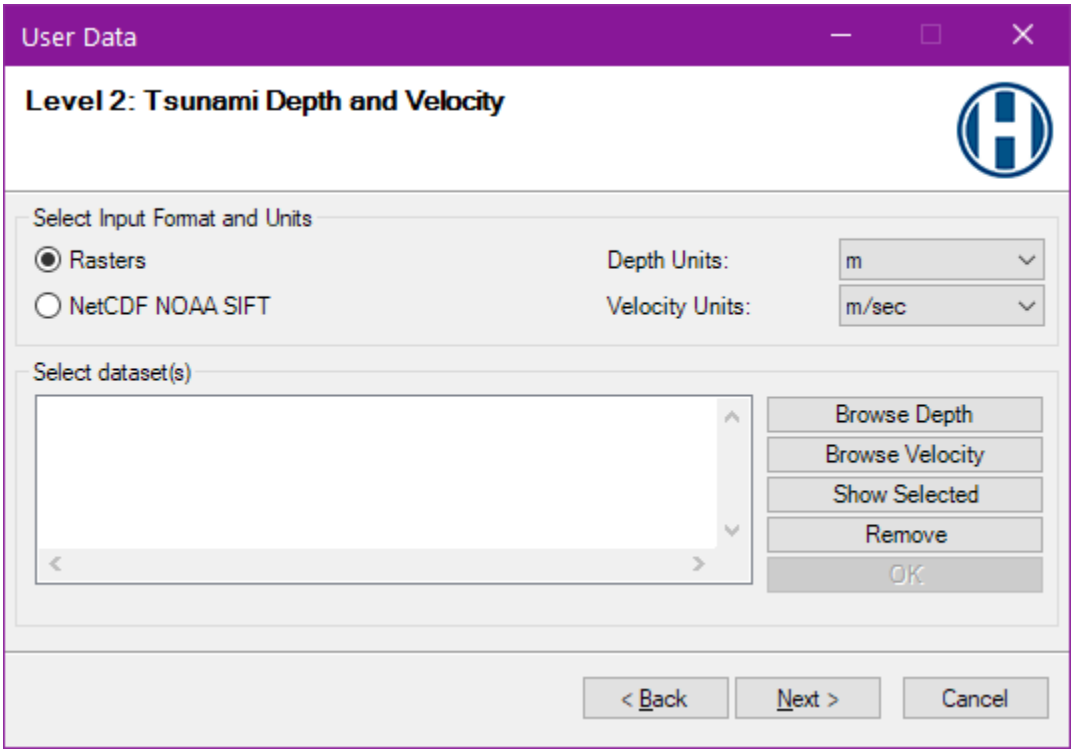


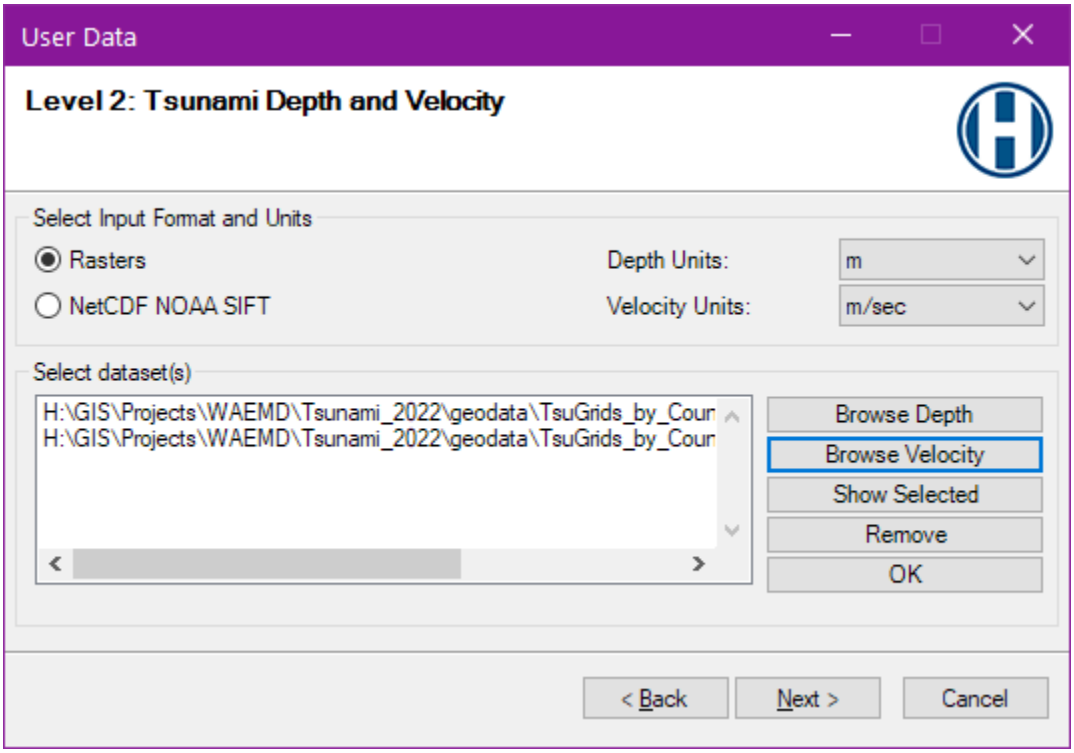
WGS has provided Level 2 data in meters and maximum units





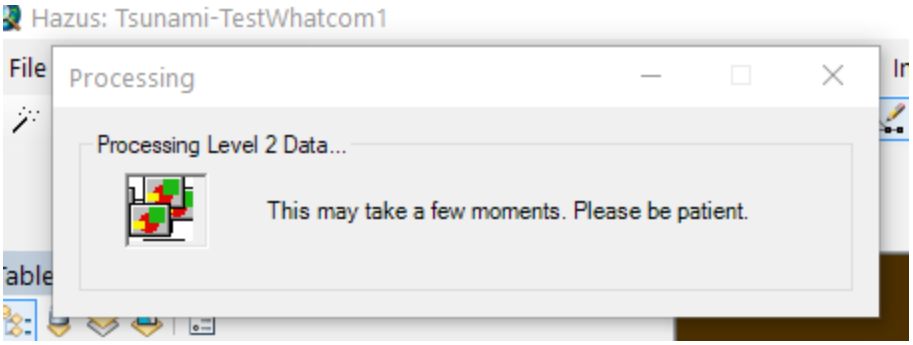
Browse to the TsuGrids_by_County.gdb file geodatabase location. Select the Depth_max_m_*county* grid for depth, the velocity grid (Velocity_max_ms_*county*) for the velocity. These must be done in order. Do depth first, then do velocity. Set units to m, m/s:



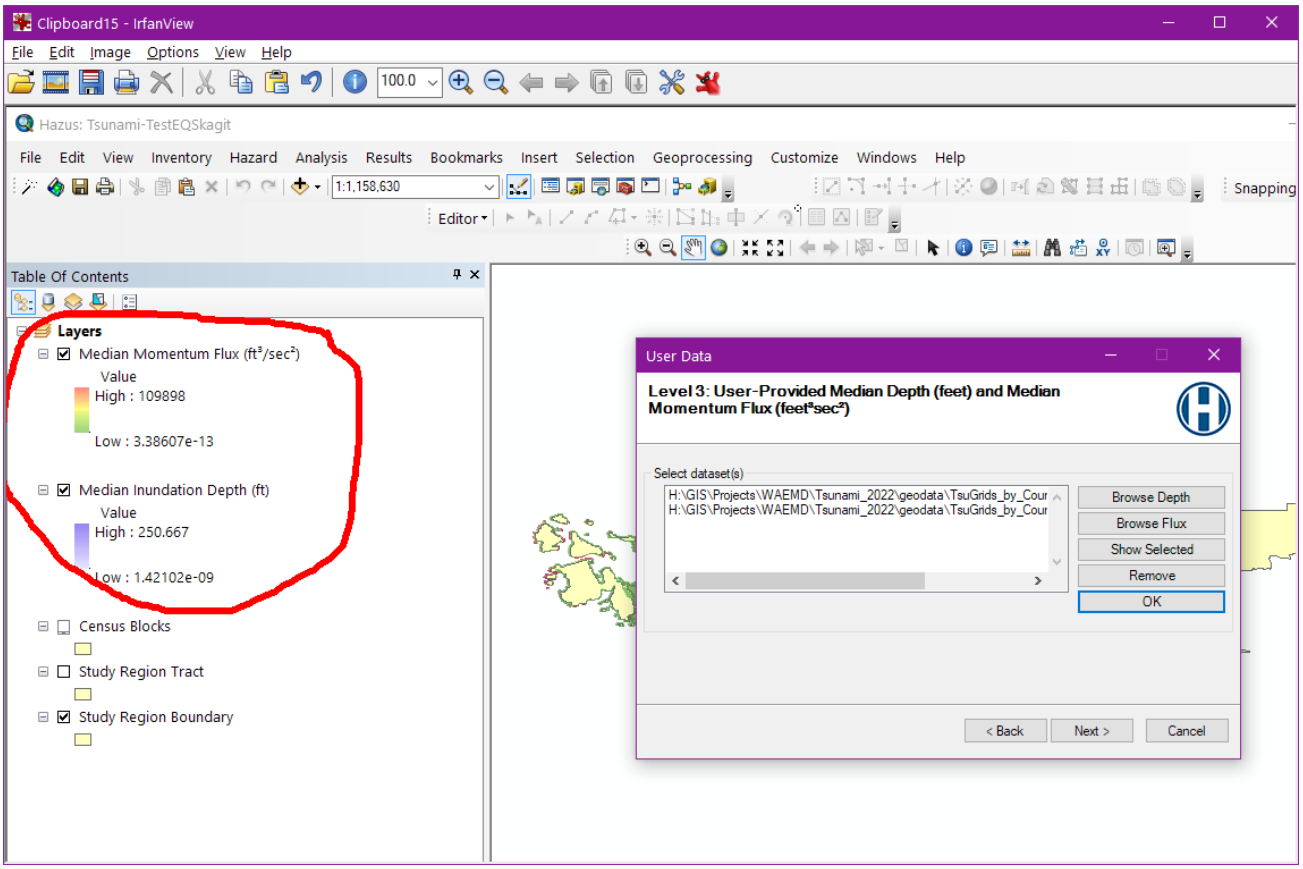


Now here is where patience is rewarded. Hit “OK” NOT “Next >”

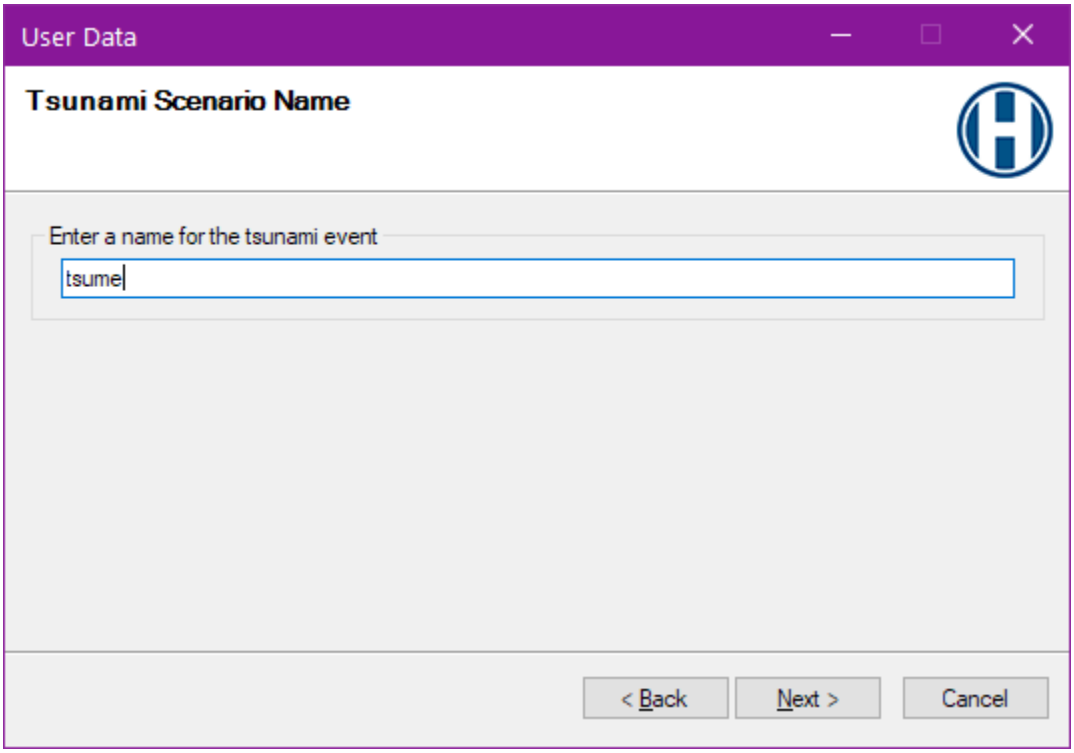
Expect this popup. Do not proceed until it goes away:



The display should show the imported depth and flux. Once you see both, then you can hit Next. Do NOT hit "OK" more than once.

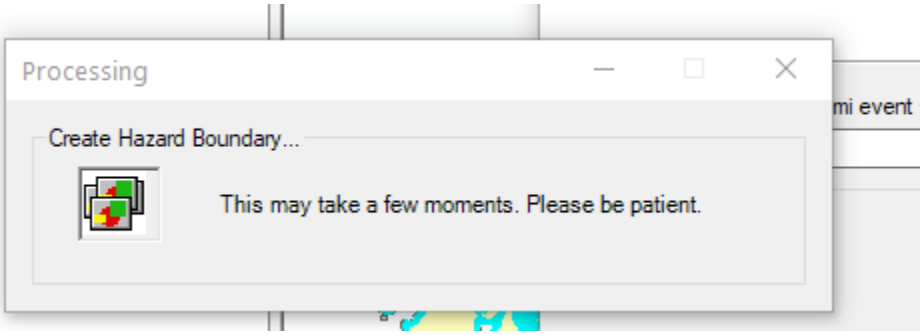


Next->

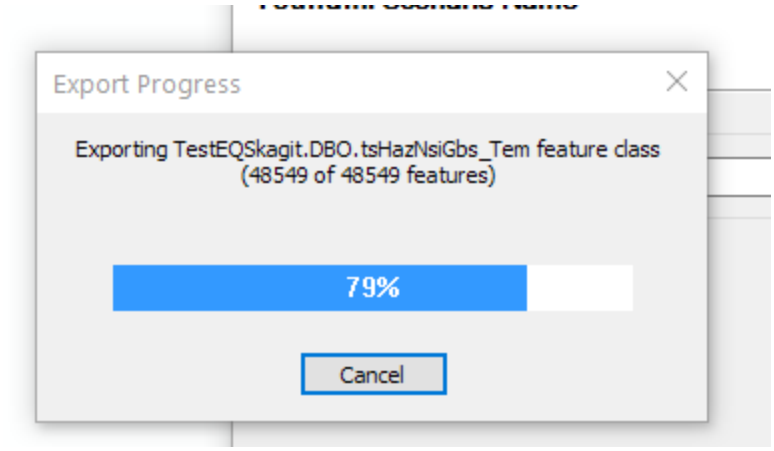


You can give it any arbitrary name. It won't impact the process. Next ->

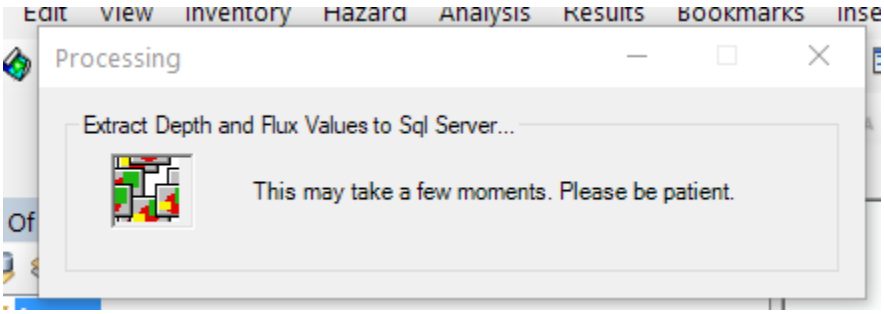
This may take some time. You will see this popup as it is doing various processing:



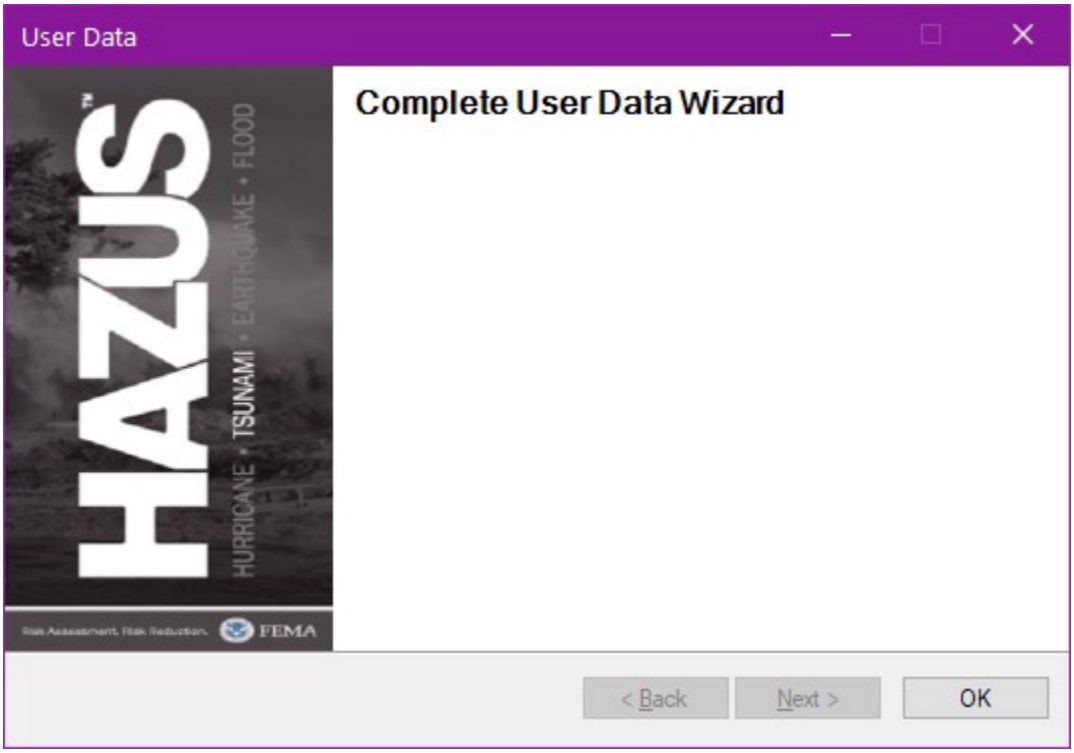
Followed by this window. Again, this can take a very long time, especially for heavily populated counties like King county.



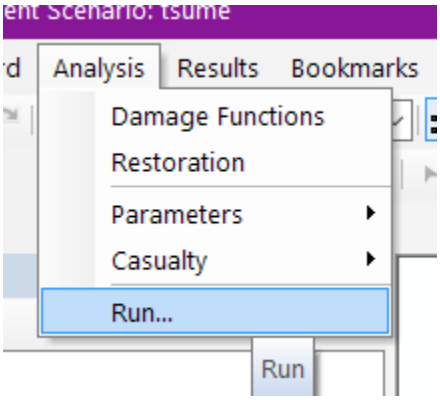
Yet another “in process” window:

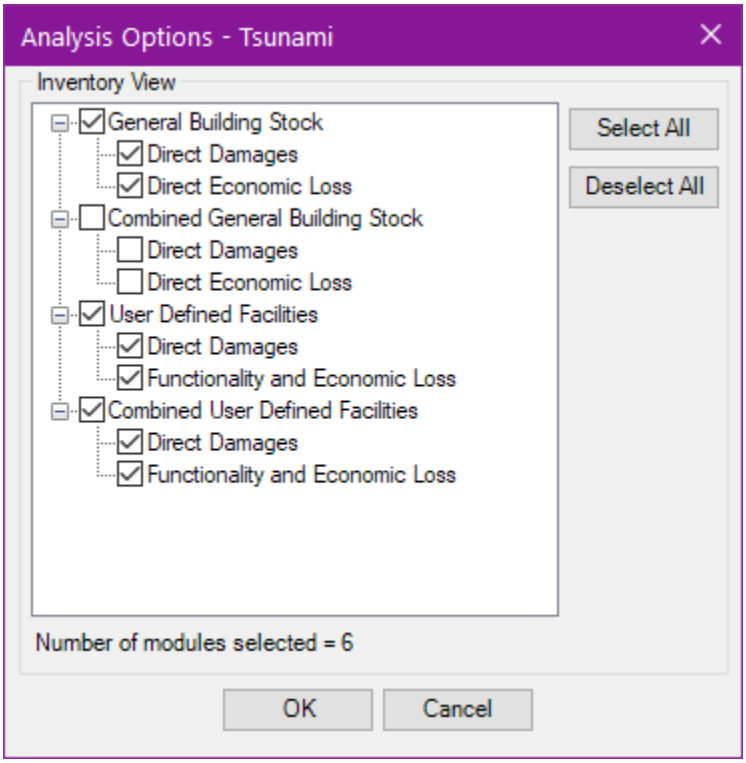


Finally, you should get this:



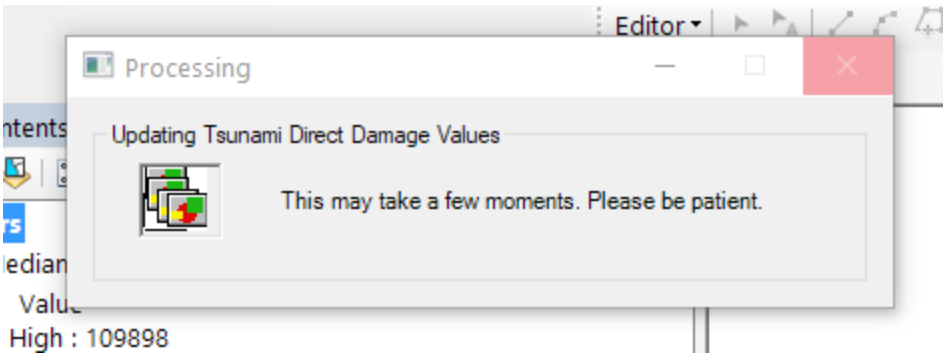
Run the combined earthquake-tsunami loss:



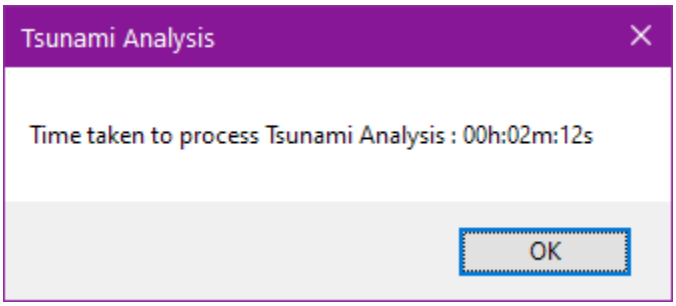


Hit OK. (the reason for running the GBS is that the tsunami casualty model sometimes does not work if the GBS was not run. There isn't a reason it shouldn't run but this is mentioned for quick reference).

Expect more processing windows:



Finally:



Hit OK.

Connect to the region SQL database as shown in the previous section. Export out the following two tables to your specific file geodatabase, for use later.

Database Connections\TestWhatcomEQ.sde\TestEQSkagit.dbo.**tsCombFRUserDefinedFlty**

Database Connections\TestWhatcomEQ.sde\TestEQSkagit.dbo.**tsCombUserDefinedFlty**

*Note the "FuncDayxx" columns are **not to be reported**. These estimates are **much too optimistic** for a regional disaster, and FEMA knows it (and has heard from me on this matter).*

Similar to earthquake loss, building repair cost = EconLossStruc + EconLossNonStruc

Optional datasets that may be of interest – if you are interested only in the tsunami damages:

- Database Connections\TestWhatcomEQ.sde\TestEQSkagit.dbo.tsUserDefinedFlty (OPTIONAL)
- Database Connections\TestClallam50.sde\TestClallam50.dbo.tsFRUserDefinedFlty (OPTIONAL)

Note the first is a point file. That is fine. #1 provides depth, velocity in structure, and PDS, but only for the tsunami damages. #2 provides economic impact and Loss Ratio for tsunami only.

With the additional field calculations, you can now join these tables with the original UDF file, and summarize losses, casualties, etc., over any spatial unit desired (typically, a county). Note, however, that **the number of buildings reported by the tsunami results may be less than earthquake results**. This is because all UDF points must intersect both tsunami grids. If neither or both are true, Hazus throws the result silently away.

Known Hazus Bugs

There are several known bugs present in Hazus 5.1. However, cumulatively, the end impact of all of these is judged to be minor on overall estimates at the state and county levels.

Restoration Times

This also influences other factors like economic impacts. The Hazus developers provided default "days to full functionality" estimates. Based on a cursory review of the estimates with experts, it was quickly determined that the Hazus estimates were simply not credible for a large-scale CSZ tsunami, and would be a major distraction if reported. We do not include these numbers or any derivatives in the final database deliverable.

Manufactured Housing

Manufactured houses (building type "MH") in the tsunami zone are estimated to be a complete loss regardless of depth or velocity of water (an overestimation). While the MH building type is very sensitive to water velocity, there are situations where the tsunami damage should be minimal, given its first-floor height/depth-in-structure and the relatively low water velocity. About one in five MH buildings are in areas of relatively low velocity and depth. However, it should be noted that the MH building type is very sensitive to earthquake ground motions and is likely to be moderately to significantly damaged from the antecedent earthquake. They can be identified using queries:

tsUserDefinedFlty.EqBldgTypeID=36 and tsUserDefinedFlty.EqDesignLevelID = 1 and flux <

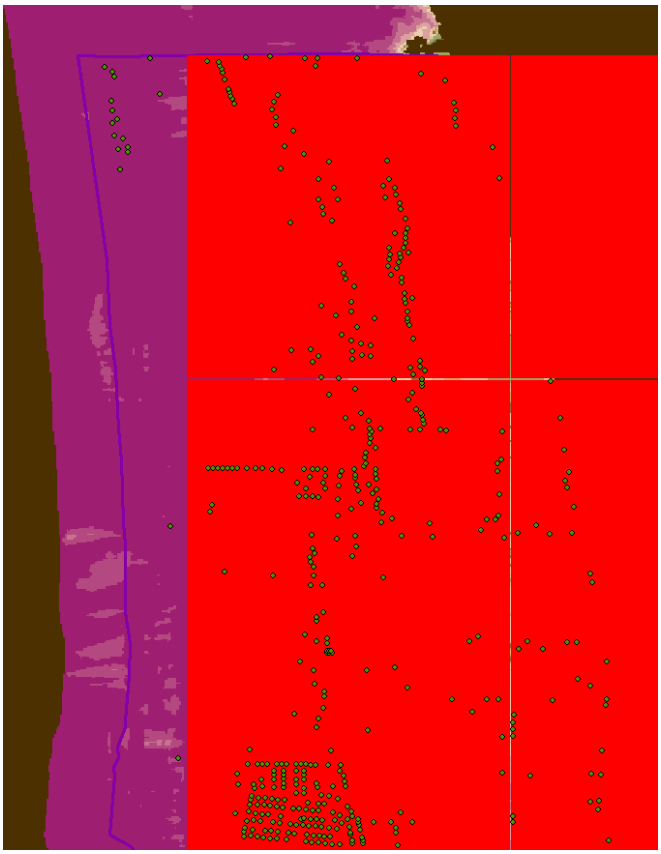
tsUserDefinedFlty.EqBldgTypeID=36 and tsUserDefinedFlty.EqDesignLevelID <> 1

Areas with Low Velocity (Momentum Flux) But High Depth

For buildings where the velocity is low enough that it does not cause structural damage, but the depth of water is significant (more than 3 feet of water above the first floor), the Hazus model underestimates the damage to the non-structural components of the building and to the building's contents. Such situations could be considered, in essence, a flooding event. This results in under-reporting of building and content repair costs in probably around 1 in 10 buildings. For instance, this situation occurs throughout the Aberdeen/Hoquiam area. On the outer coast, this situation does not occur given the destructive wave velocities generally present.

Earthquake ShakeMap Boundary Issues

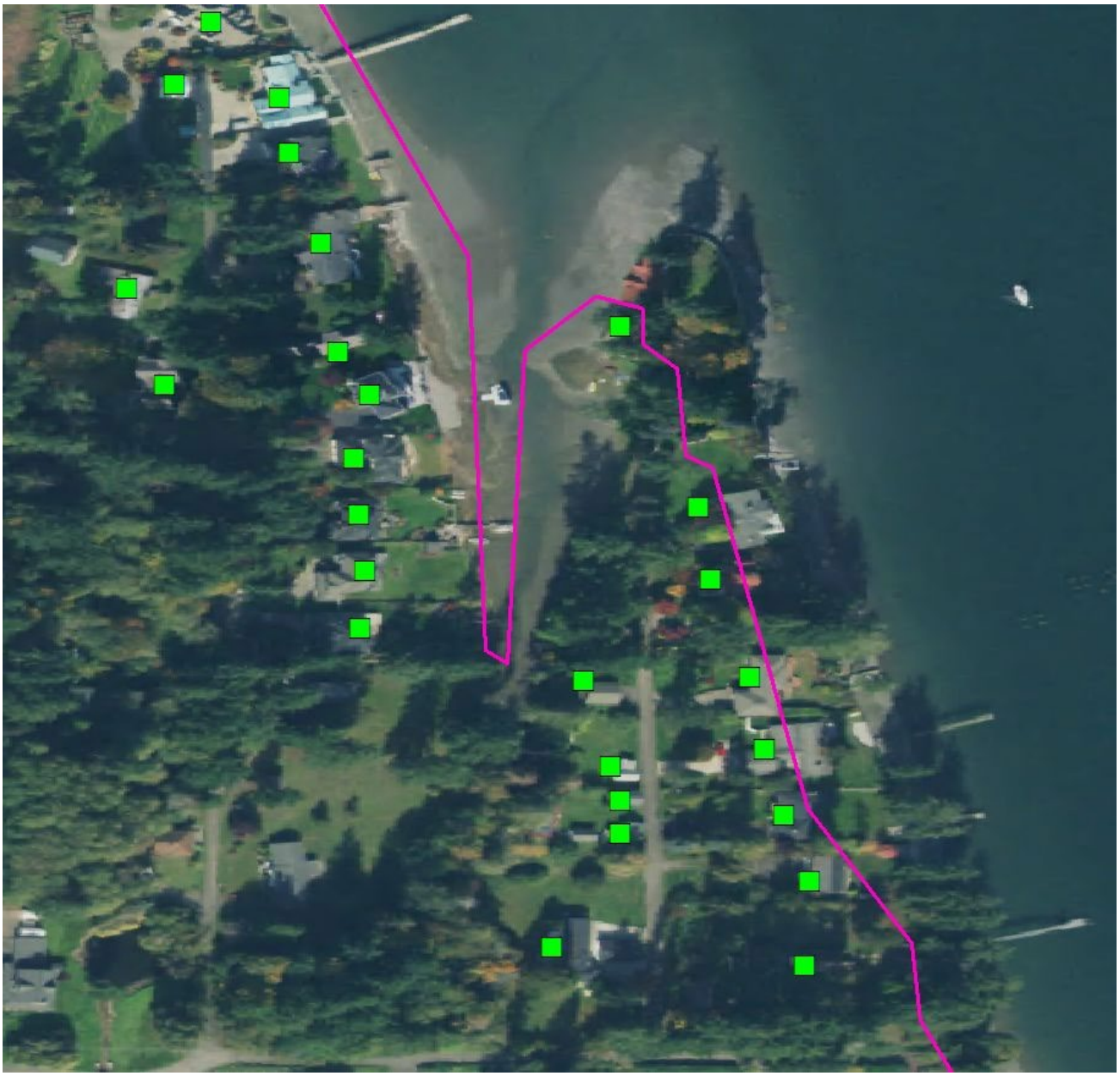
Hazus 5.1 does a mostly efficient job importing the USGS ShakeMap grids. However, a boundary condition occurs where the grid information gets translated into polygon rectangle form and can occasionally not completely cover the study area. A quick workaround was not identified. For example, in northwest Pacific County, about 17 buildings in the Study Area end up having zero ground motions, and thus zero damage, because the ShakeMap grid did not extend into the area. UDFs as dots, the county outline in purple, and the ShakeMap grid, interpreted from the USGS grid.xml file, is in red. Note that the grid does not fully extend westward. Hazus team knows about the bug. (The momentum flux grid is in the background. The deep magenta colors indicate where nearly no building will remain standing).



In practice, this affects relatively few points in this project. And for Pacific County, while the earthquake damage estimate for the excluded buildings will be zero, they will be completely destroyed anyway by the tsuanmi, and included as “completely damaged” in the final result.

Hazus County Boundary Imprecision

Hazus has an internal county boundary file, constructed from Census geometries. In some spots on Washington's rather contorted shorelines, this boundary does not quite match the reality. Any UDF point NOT within the boundary is ignored and discarded by Hazus.



In the above case, the pink line is the Hazus county boundary. We deliberately moved some of the UDF points (shown as green squares) within the boundary, to not lose the point all together. Note that they are not necessarily on the building footprint itself. It's acknowledged that moving the points so that they fall within the boundary will change the tsunami depth/velocity data, and thus may underestimate the building damage from the tsunami. This was determined to be the best course of action than to not represent the building at all. The above situation only impacts about 300 points.

Appendix D. Acronyms used in this report

AEBM	Advanced Engineering Building Module (Hazus)
CSZ	Cascadia Subduction Zone
Hazus	Hazards of the United States. FEMA-distributed software for estimating impacts from natural hazards.
HIFLD	Homeland Infrastructure Foundation-Level Data
PDS	Probability of Damage States
UDF	User-Defined Facility (Hazus)
WA EMD	Washington Emergency Management Division
WGS	Washington Geological Survey