



Performance-Based Earthquake Engineering Assessment Tool  
for Gas Storage and Transmission Systems



**Document:** *OpenSRA* User Manual

***OpenSRA* Version:** 1.0.0

**Author:**

- Slate Geotechnical Consultants:
  - Barry Zheng: [bzheng@slategeotech.com](mailto:bzheng@slategeotech.com)
  - Micaela Largent: [mlargent@slategeotech.com](mailto:mlargent@slategeotech.com)
- SimCenter @ UC Berkeley:
  - Stevan Gavrilovic: [gavrilovic@berkeley.edu](mailto:gavrilovic@berkeley.edu)

## Table of Contents

1	<i>OpenSRA</i> Application .....	1
2	Summary of Instructions for Users.....	1
	2.1 Additional Notes for First-Time Users.....	1
3	<i>OpenSRA</i> Installation.....	3
	3.1 Download Links .....	3
	3.2 Instructions for Installation.....	3
	3.2.1 Windows .....	3
	3.3 Instructions to Uninstall <i>OpenSRA</i> .....	8
	3.3.1 Windows .....	8
4	<i>OpenSRA</i> Functions and Location Definitions .....	9
5	Input Options .....	10
	5.1 Visualization Tab .....	10
	5.2 General Information .....	11
	5.3 Infrastructure.....	11
	5.3.1 Pipelines.....	12
	5.3.2 Wells and Caprocks .....	12
	5.3.3 Aboveground Infrastructure .....	12
	5.4 Decision Variable .....	12
	5.5 Damage Measure .....	13
	5.6 Engineering Demand Parameter.....	14
	5.7 Using Generic Models .....	19
	5.8 Intensity Measure .....	15
	5.9 GIS and CPT Data.....	17
	5.10 Input Variable .....	18
6	Running Built-In Examples.....	21
	6.1 Details to Built-in Examples .....	22
7	Constructing a New Scenario in <i>OpenSRA</i> .....	28
8	Glossary.....	30

## 1 *OpenSRA* Application

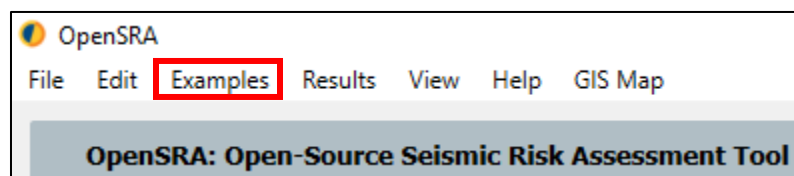
*OpenSRA* is an open-source seismic risk assessment tool designed as a desktop application that owners and regulators can use to evaluate the seismic performance of gas infrastructure and the potential effectiveness of system upgrades. *OpenSRA* has the capability to incorporate the Investor-Owned Utilities' (IOUs) proprietary data regarding their gas infrastructure systems for use with updated seismic demand models and methods, and fragility models developed in this research project. The tool provides a user-friendly interface to view results, including risk maps and exposure estimates.

*OpenSRA* enables a user to execute a scenario when the user provides information for the following parameters:

- General information
- Infrastructure
- Intensity Measure
- Engineering Demand Parameter
- Damage Measure
- Decision Variable

## 2 Summary of Instructions for Users

1. Follow Section 3 to download and install *OpenSRA*.
2. Run "OpenSRA.exe" to start the *OpenSRA* application (a shortcut of the executable is generated automatically on the desktop by the installer).
3. *OpenSRA* comes with pre-configured examples, which can be accessed through the "Examples" drop-down menu in the task-bar located at the top of the application window (see screenshot below).



### 2.1 Additional Notes for First-Time Users

1. If you experience errors while running *OpenSRA*, please contact the developers (listed on the first page of this manual).
2. It may take slightly longer to launch the *OpenSRA* application on the first run.

3. The default folder for outputs is the working directory, e.g., “.../[YourAccount]/Documents/OpenSRA/”. Users can change the output directory, i.e., the “Working Directory,” in the “General Information” tab.
4. A file named “debug.log” is created and stored under the working directory. If the user changes the working directory on the “General Information” tab, then the debug.log file will be stored in the user specified location. This file tracks the runtime messages and errors returned by the application.

### 3 *OpenSRA* Installation

*OpenSRA* is tested to work on Windows 10. Only 64-Bit computer architectures are supported. The *OpenSRA* installation requires about 3.3 GB of available hard disk space. The additional folder with prepackaged datasets requires about 8.7 GB of available hard disk space after decompression. This set of data is primarily used in the below ground infrastructure examples provided in *OpenSRA*. Users should expect a total of about 12 GB of disk space to fully run the examples in *OpenSRA*.

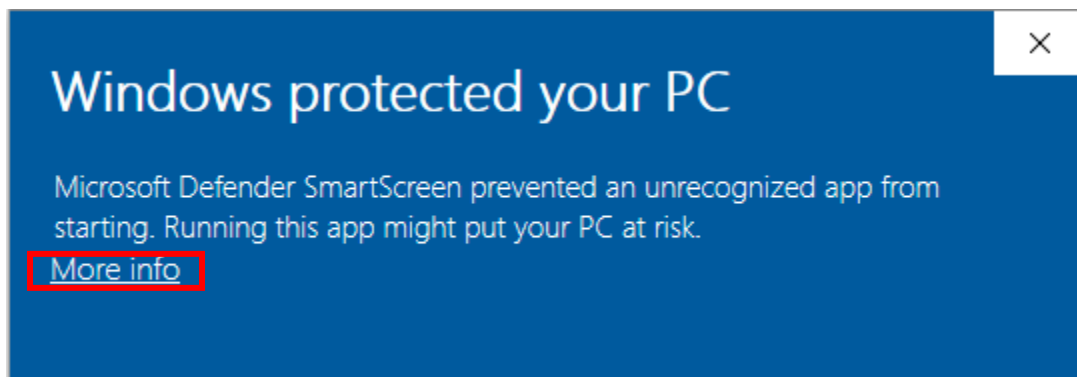
#### 3.1 Download Links

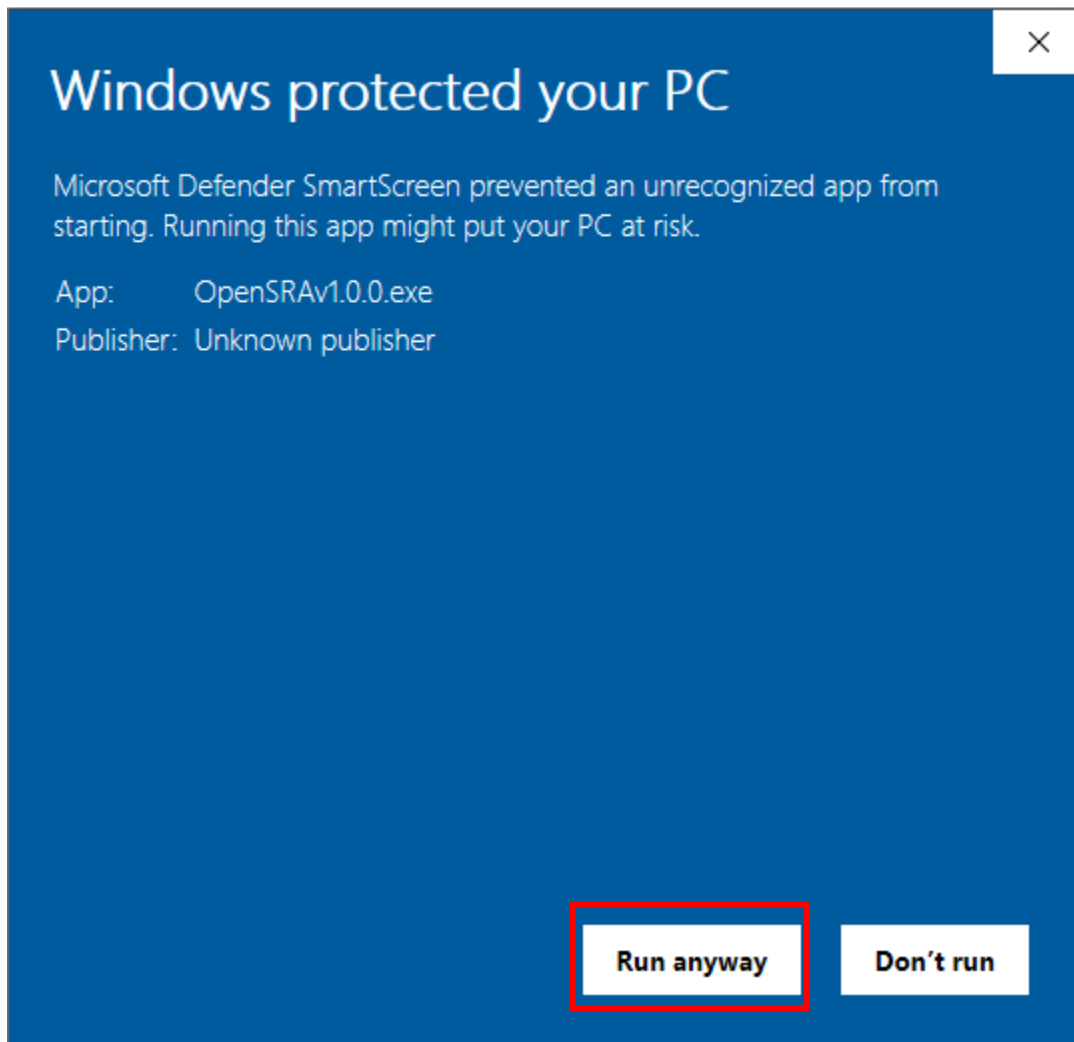
- Software Installer (Windows, 64-Bit): [OpenSRA for Windows](#)
- Compressed Folder with Datasets: [OpenSRA Datasets 230108.zip](#)

#### 3.2 Instructions for Installation

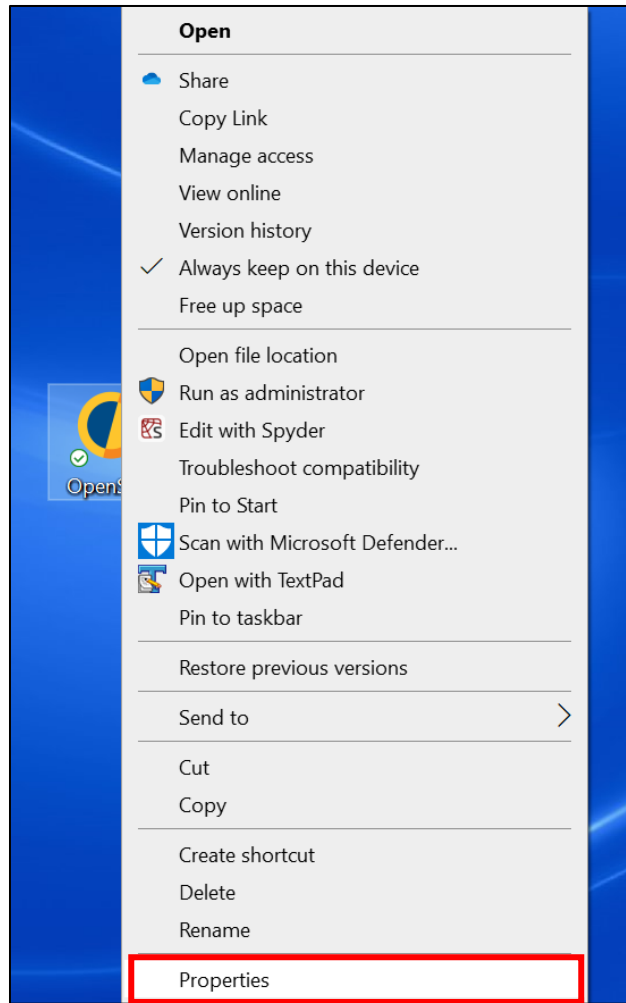
##### 3.2.1 Windows

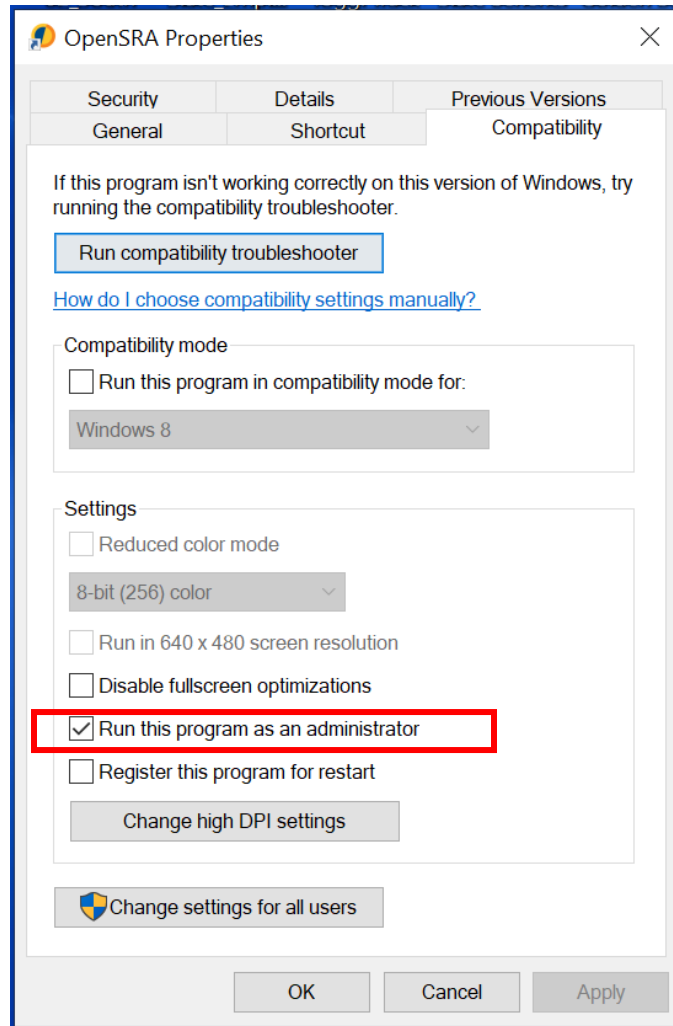
1. Download the installer from the link above. Note that users may encounter a security measure to block the download (see screenshots below).
  - a) Click on **More Info**
  - b) Then click on **Run Anyway**





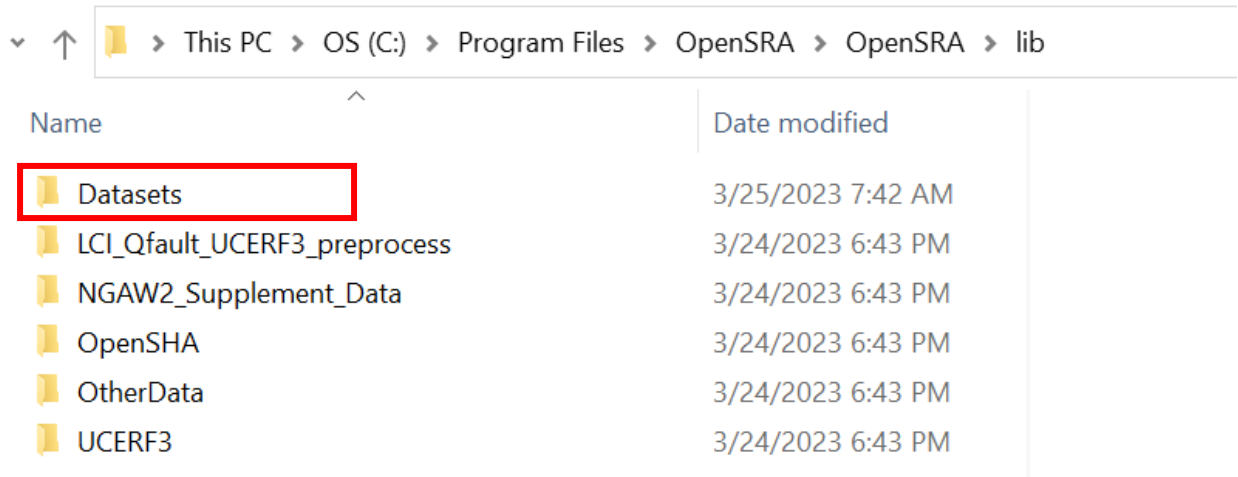
2. Run the executable and follow the on-screen instructions to install *OpenSRA*. It is recommended to install *OpenSRA* in the default location provided by the installer. *OpenSRA* can be run by double-clicking the “OpenSRA.exe” shortcut on the desktop.
3. Once a shortcut is made right click on the *OpenSRA* icon and select **Properties**
  - a. Under **Compatibility** check the box next to **Run this program as an administrator**



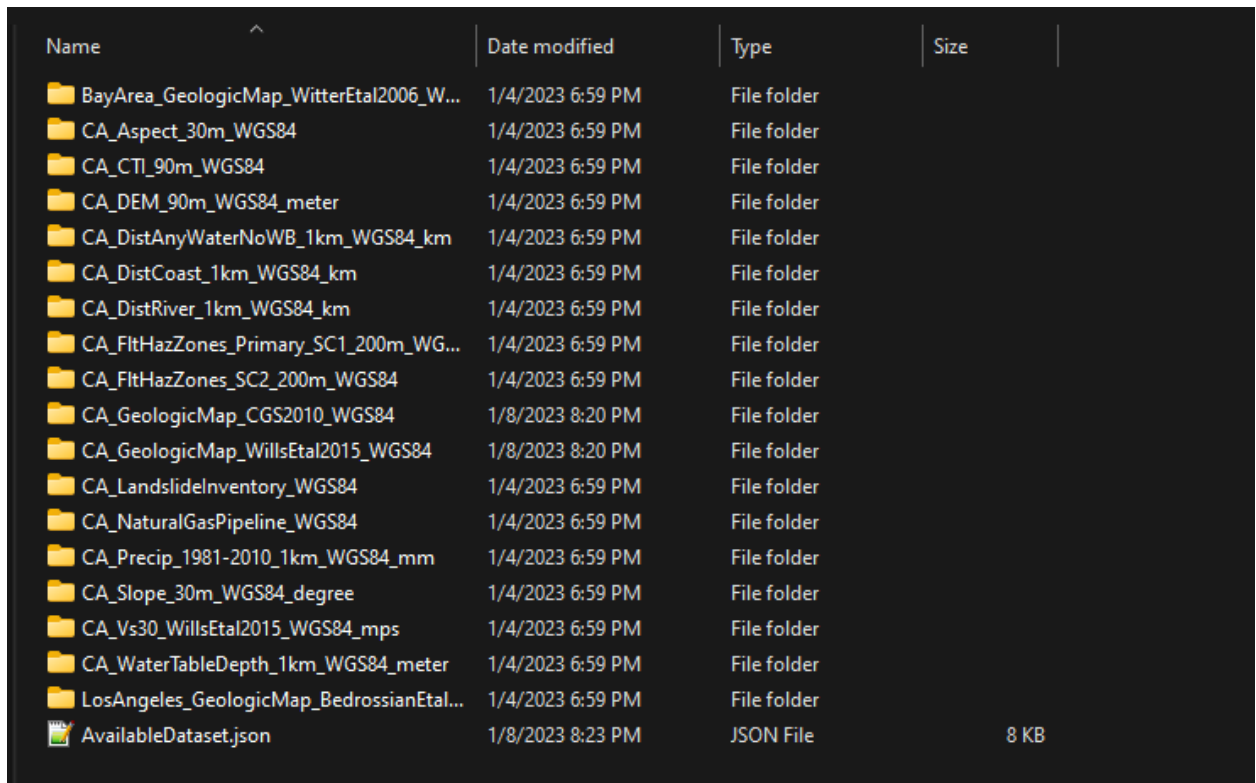


4. Next download the prepackaged datasets "OpenSRA\_Datasets\_230108.zip"
  - a. Unzip files, and rename folder "Datasets"
  - b. Next, move the unzipped folder to "Installation Directory/OpenSRA/OpenSRA/lib"  
(shown in the screenshot below)





- c. For the Datasets:
  - i. When you click into the folder, it should look like the following:



- 5. When you run *OpenSRA* as an administrator, you will be asked “Do you want to allow this app from an unknown publisher to make changes to your device?”
  - a. Select **Yes**

### 3.3 Instructions to Uninstall *OpenSRA*

#### 3.3.1 Windows

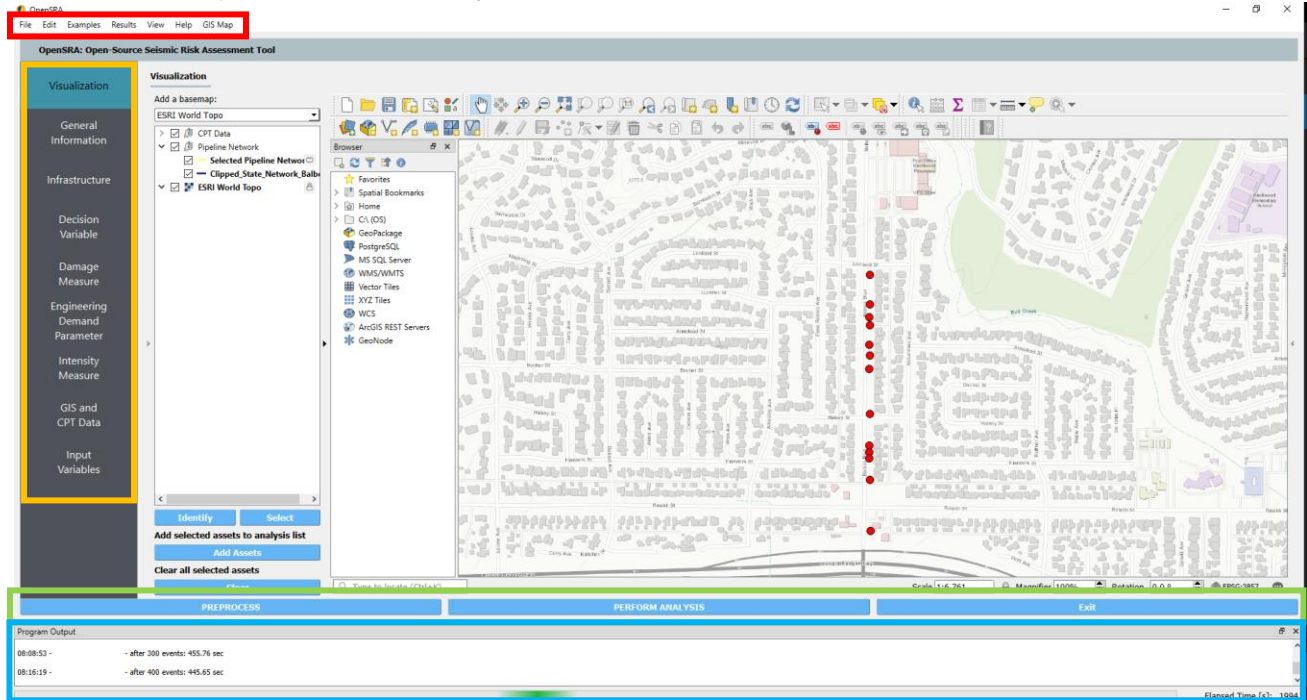
1. Click on the **Start** button
2. Find *OpenSRA* in the apps
3. Right-click on *OpenSRA* icon and click on **Uninstall**
4. Find *OpenSRA* in the Programs and Features dialog
5. Double click on the *OpenSRA* icon and select the **Remove all components** selection and click on **Next**
6. Click on the **Uninstall** button

If this does not work try the following:

1. Click on the **Start** button
2. Find "Add or Remove Programs"
3. Select *OpenSRA* in the list and click **Uninstall**
4. Once prompted select **Remove all components** and **Next**

## 4 OpenSRA Functions and Location Definitions

This section outlines the different components of the software interface that users will be using to run the examples and future analyses.



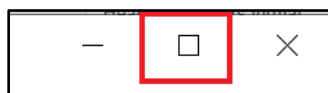
**Task-bar** - the horizontal bar with drop-down lists at the top of the *OpenSRA* window (outlined in red).

**Left Side-bar** - the vertical bar on the left side of the *OpenSRA* window where the user can switch between tabs including **General Information**, **Decision Variable**, **Damage Measure**, **Engineering Demand Parameter**, **Intensity Measure**, **GIS and CPT Data**, and **Input Variables**.

**Bottom Ribbon** - the three buttons at the bottom of the *OpenSRA* window (outlined in green). Sometimes the ribbon can become obstructed; to fix, adjust the size of the *OpenSRA* window.



To adjust the window, select the window reduction button in the top right-hand corner to shrink the window (see figure above); once shrunk, click the full-screen button (again in the upper right corner of the window, see figure below).



If resizing does not fix the problem, try completely minimizing the window and reopening.

**Project Output** – the bottom dialog widget that updates the user on the progress of preprocessing and analysis run (outlined in blue).

## 5 Input Options

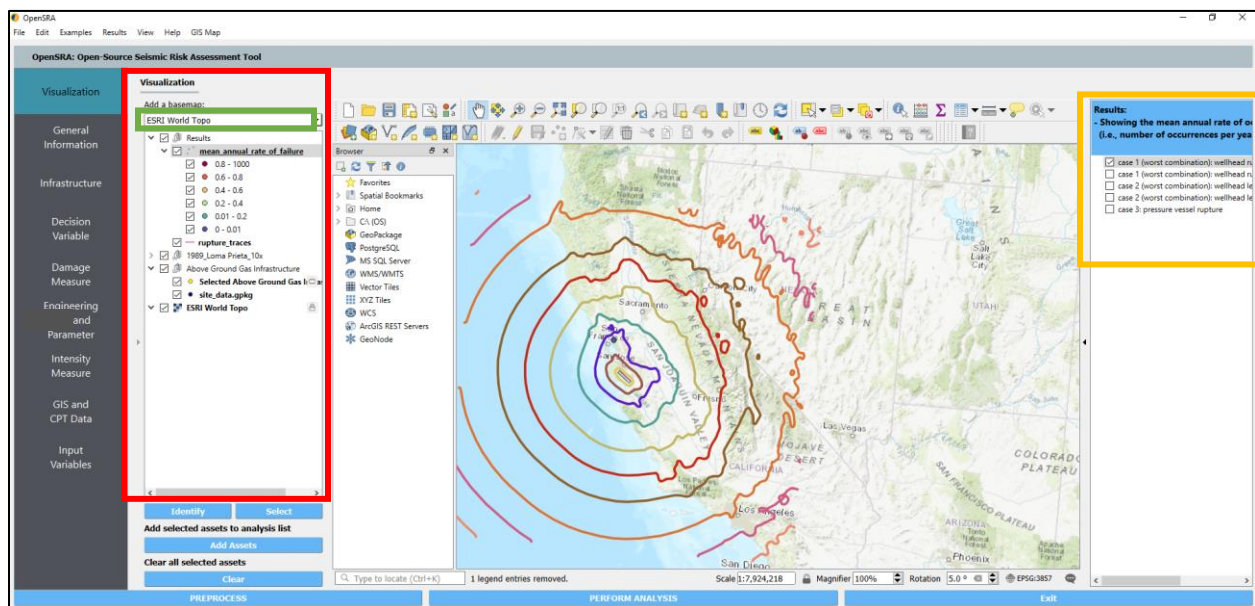
The following section outlines the available input options including data importing, models included in the software, and analysis options.

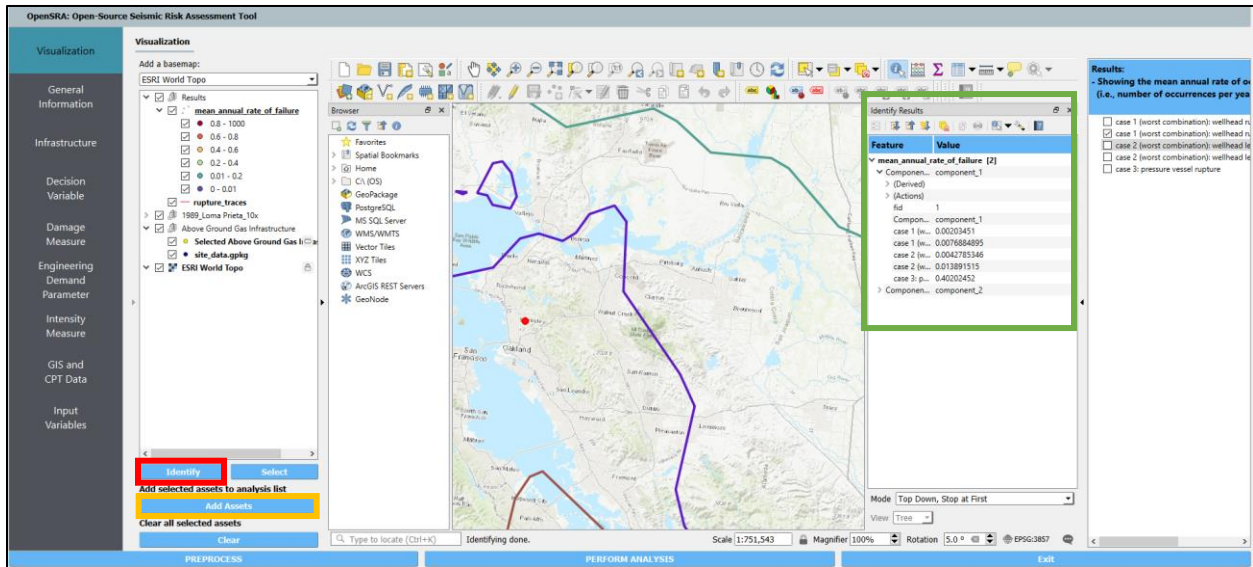
### 5.1 Visualization Tab

The **Visualization** tab (in the left side-bar) shows the assets that have already been imported (in the below picture the aboveground component Example 1 is loaded). The left portion of the screen (outlined in red) allows the user to toggle on and off different components of the map.

The top drop-down menu (outlined in green) allows multiple base maps to be imported and viewed in the viewport. In the figure below, the ESRI map is being viewed as well as the Loma Prieta ShakeMap. Once the user's analysis is complete, results will be shown in this tab.

On the lefthand side of the screen, a menu pops up (once the analysis is performed) where the user can toggle between scenarios, showing different failure mechanisms as well as leakage/rupture combinations.



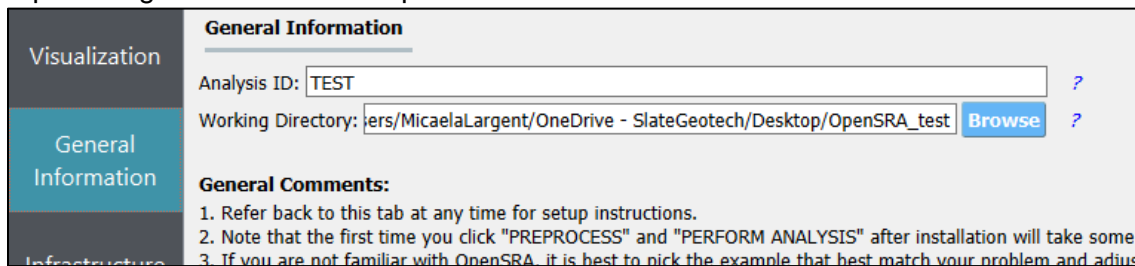


By clicking the **Identify** (above in red) button a secondary side-bar will pop up on the right (above in green). This secondary side-bar contains the results for the highlighted component.

The user can also click on assets shown in the viewport and select **Add Assets** (outlined in yellow); this will add the assets to the analysis.

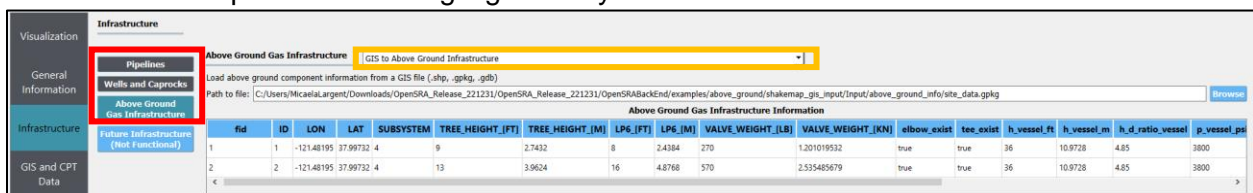
## 5.2 General Information

The **General Information** tab (in the left side-bar) allows the user to redirect where results will be output and gives the user an explanation of each of the other tabs.



## 5.3 Infrastructure

The **Infrastructure** tab (in the left side-bar) allows the user to import their infrastructure. They can select Pipelines, Wells and Caprocks, and Aboveground Infrastructure by clicking the buttons outlined in red below. The user simply selects whether they are importing CSV file or a GIS file in the drop-down menu highlighted in yellow.

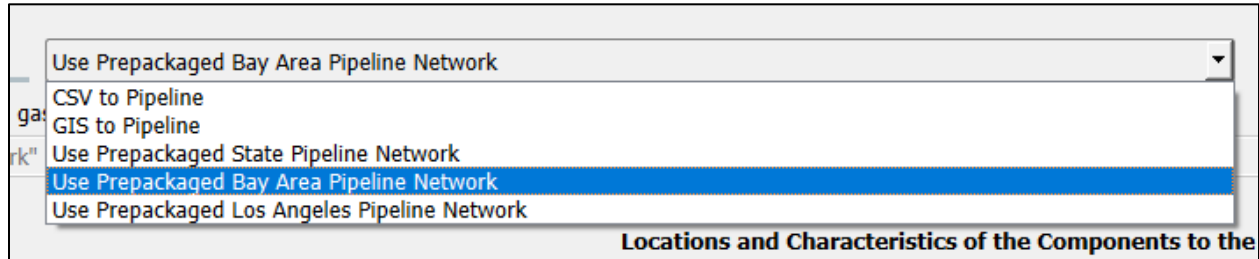


The imported assets will then be shown in the characteristic table which includes latitude and longitude points, and other characteristics specific to the asset type.



### 5.3.1 Pipelines

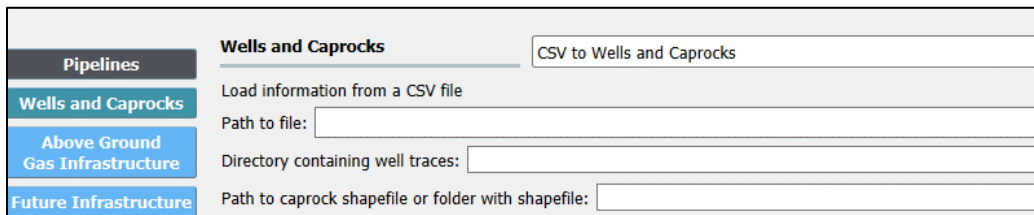
When **Pipelines** is selected, there are 5 options to upload infrastructure.



There are three prepackaged options, including a pipeline database containing transmission pipelines throughout California.

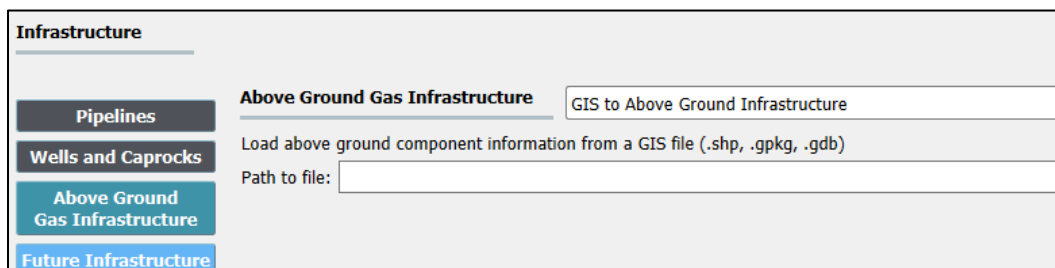
### 5.3.2 Wells and Caprocks

When **Wells and Caprocks** is selected, the user can either import a CSV file or a GIS file. It should be noted that either selection also needs a directory containing well traces, and path to caprock shapefile. Each trace file should contain a minimum of two points (top and bottom). If the actual trace is not known, then the user should assign the latitude and longitude point at the top of the well, provide an approximate depth to the bottom, and the program will assume a vertical well.



### 5.3.3 Aboveground Infrastructure

When **Aboveground Gas Infrastructure** is selected the user can import either a CSV file or a GIS file.



### 5.4 Decision Variable

The **Decision Variable** tab (in the left side-bar) allows the user to select the models to calculate the decision variable (typically leakage or rupture). The options within this tab change based on the asset selected in the **Infrastructure** tab.

Visualization	Decision Variable (DV)	Available Method(s)	Return
General Information	Pipe Compressive Rupture	Bain et al. (2022)	Return
Infrastructure	Pipe Tensile Leakage		Return
GIS and CPT Data	Pipe Tensile Rupture		Upstream
Decision Variable		1. d_p	2. t_pi

Visualization	Decision Variable (DV)	Available Method(s)	Return
General Information	Vessel Rupture	Pantoli et al. (2022)	Return
Infrastructure	Wellhead Leakage		Return
GIS and CPT Data	Wellhead Rupture		Upstream
Decision Variable		1. Non	

Visualization	Decision Variable (DV)	Available Method(s)	Return
General Information	Shear Induced Leakage on Caprocks	Zhang et al. (2022)	Return
Infrastructure	Shaking Induced Rupture on ...		Return
GIS and CPT Data	Shear Induced Rupture on Wells		Upstream
Decision Variable		1. Non	

**Pipe Compressive Rupture**

Available Method(s)  
Bain et al. (2022)  
Bain et al. (2022)

This method returns the critical strain at which 50% probability of compression-induced rupture is expected to occur pipeline segments.

**Return parameter labels used by OpenSRA backend (presented here for making generic model):**

1. eps\_comp\_crit\_rup

**Upstream dependencies:**

1. d\_p

**List of Cases to Run**

BainEtal2022 - weight=1

Each decision variable has a drop-down menu for “Available Method(s)” which currently has the models developed by the research teams within this project (red) listed. Once selected, the method and its weight will be shown in the right sidebar (outlined in yellow). Below the drop-down menu there are instructions on the model (green), including inputs that will need to be entered on the **Input Variable** tab described later.

Currently the models included are based on the research within this project, as such there is only one option for each decision variable.

### 5.5 Damage Measure

The **Damage Measure** tab (in the left side-bar) allows the user to select the models to calculate the damage measure (typically strain). Similar to the previous tab, the options within this tab change based on the asset selected in the **Infrastructure** tab.

Damage Measure (DM)	Available Method(s)	Return description	Return parameter labels	Upstream dependencies	Additional input parameters
Landslide Induced Pipe Strain	Hutabarat et al. (2022)	This method returns the critical strain at which 50% probability of compression-induced rupture is expected to occur pipeline segments.	1. eps_pipe_ten 2. eps_pipe_con	This method requires	1. d_pipe: [mm] pipe outside diameter
Pressure Vessel Moment Ratio	Pantoli et al. (2022)	This method returns the critical strain at which 50% probability of compression-induced rupture is expected to occur pipeline segments.	1. h_vesse		
Wellhead Strain					
Shaking Induced Moment on ...	Luu et al. (2022)	This method returns the critical strain at which 50% probability of compression-induced rupture is expected to occur pipeline segments.	1. mode_ 2. mode_		
Shear Induced Well Strain on Wells					

Similar to the **Decision Variable** tab, this tab has a drop-down menu to select available models (red), a list of selected models and weights (yellow), and instructions for each model (green).

**(DM)**

**Lateral Spread Induced Pipe Strain**

Available Method(s)  
Bain et al. (2022) and Hutabarat et al. (2022)

**Return description:**  
This method returns lateral spread induced tensile and compressive strain\* for pipeline segments.  
**Return parameter labels used by OpenSRA backend (presented here for making generic model):**  
No return parameters  
**Upstream dependencies:**  
This method requires a method for permanent ground deformation from the "Engineering Demand Parameter - Lateral Spread" tab.  
**Additional input parameters (visit the "Input Variables" tab to modify the variable values):**

- d\_pipe:**  
[mm] pipe outside diameter - required for "level 2 and 3" analysis
- t\_pipe:**

**List of Cases to Run**

BainEta2022\_and\_HutabaratEta2022 - weight=1

Each damage measure only has one model. Most of the damage measures simply need the model to be selected. However, when **Aboveground Structures** is selected in the **Infrastructure** tab, the damage measure of **Wellhead Strain** also needs a high-pressure weight (weight to apply to high pressure model, ((1-weight) will be the low pressure weight).

**Additional input parameters (visit the "Input Variables" tab to modify the variable values):**

- high\_pressure\_weight:**   
weight to apply to high pressure model; for low pressure model, weight = 1 - high\_pressure\_weight, default: 0.7
- sys\_type:**

## 5.6 Engineering Demand Parameter

The **Engineering Demand Parameter** (in the left side-bar) allows the user to select the model to calculate the engineering demand parameter (usually probability of deformation or probability of a geohazard occurring). Similar to the models on the **Decision Variable** and **Damage Measure** tabs, the options within this tab change based on the asset selected in the **Infrastructure** tab. Unlike the other two tabs, each engineering demand parameter has multiple models to choose from. However, Polynomial Chaos assumes a (log)normal distribution, if models are combined with different weights this assumption may not be true. It is suggested that only one model be used at a time.



Engineering Demand Parameter (EDP)	
Landslide	<b>Landslide</b> Available Method(s) Bray and Macedo (2019) <b>Return description:</b> This method <b>Return parameter l</b> 1. pgdef <b>Upstream dependen</b> This method <b>Additional input pa</b> 1. <b>slope:</b> [deg] slope 2. <b>t_slope:</b> [m] slope th 3. <b>gamma_soil:</b> [kN/m <sup>3</sup> ] ut
Wellhead Rotation	<b>Wellhead Rotation</b> Available Method(s) Pantoli et al. (2022) <b>Return descr</b> This n <b>Return paran</b> 1. rot 2. rot 3. rot 4. rot 5. rot 6. rot 7. rot 8. rot 9. rot 10. r
Surface Fault Rupture	<b>Surface Fault Ruptur</b> Available Method(s) Thompson (2021) <b>Return desc</b> This <b>Return para</b> 1. pg <b>Upstream de</b> This <b>Additional in</b> 1. <b>None:</b> This

Most engineering demand parameters simply need the model to be selected however, when analyzing pipelines for probability of landslide there is the option to utilize a landslide inventory. The California landslide inventory is included as the default, or the user can upload their own polygon shapefile.

Use a shapefile with deformation polygons?

First check the box, then either leave as "CA\_LandslideInventory\_WGS84" or browse and locate the shapefile

### 5.7 Intensity Measure

The **Intensity Measure** tab (in the left side-bar) allows the user to choose how the ground motion is being predicted. The user can either import a ShakeMap and select the intensity measure they would like to use (PGA or PGV), use the UCERF3 seismic source characterization with four of the NGA-West2 models, or import a user-defined rupture.

<b>Intensity Measure (IM)</b>	ShakeMap
<p>To import ShakeMap files, please download the files from the ShakeMap website and place them in the folder specified below:</p>	
<input type="text"/>	<input type="button" value="Browse"/> <input type="button" value="Load"/>
<p>At a minimum, the folder must contain the 'grid.xml' file. Click 'Load' to load the ShakeMap. Multiple ShakeMaps can be added by selecting another folder containing a ShakeMap, and clicking 'Load' again. The list of loaded ShakeMaps will appear on the right.</p>	
<p>Select the type of Intensity Measure (IM) to visualize</p>	<input checked="" type="checkbox"/> PGA <input type="checkbox"/> PGV

<b>Intensity Measure (IM)</b>	UCERF3 (Preferred)
<b>Seismic Source Model:</b>	Mean UCERF3 FM3.1
<b>Filters</b>	<input type="checkbox"/> Distance (km) <input type="checkbox"/> Magnitude <input type="checkbox"/> Mean Annual Rate
<b>Ground Motion Model:</b>	NGAWest2 2014 Averaged, No Idriss
Vs30 (m/s); preferred: default values used in OpenSHA	Preferred
Source for Vs30, inferred or measured; preferred: inferred	Preferred
Depth to Vs of 1.0 km/s (km), preferred: default values used in OpenSHA	Preferred
Depth to Vs of 2.5 km/s (km), preferred: default values used in OpenSHA	Preferred

**Intensity Measure (IM)** User-defined Rupture

---

**This tab allows you to provide the user-defined CSV file. Please see the example**  
 CSV file with user-defined fault ruptures

**Note: the user-defined rupture CSV file must contain the following columns**

<b>Column 1 label: EventID</b>	Desc: User-specified IDs (e.g., 1, 2, 3)
<b>Column 2 label: EventName</b>	Desc: User-specified event names
<b>Column 3 label: Magnitude</b>	Desc: Moment magnitude
<b>Column 4 label: AnnualRate</b>	Desc: Mean annual rate
<b>Column 5 label: Dip</b>	Desc: Dip angle (deg)
<b>Column 6 label: Rake</b>	Desc: Rake angle (deg)
<b>Column 7 label: DipDir</b>	Desc: Dip direction (deg)
<b>Column 8 label: UpperDepth</b>	Desc: Upper seismogenic depth (km)
<b>Column 8 label: LowerDepth</b>	Desc: Lower seismogenic depth (km)
<b>Column 8 label: FaultTrace</b>	Desc: List of fault traces (lat/lon,z), with commas (,)

### 5.8 GIS and CPT Data

When performing Level 3 analyses (site-specific), this tab allows the user to import GIS and site investigation data (currently CPT). Once imported, the characteristic table will be filled out with information on the CPT.

The drop-down menu, highlighted in red, allows the user to switch between site investigation data and GIS data. When “User Provided GIS Data” is selected, the user needs to enter a file path to import the GIS data.

**Geospatial Data** User Provided GIS Data

---

To import GIS files, please place them in the following folder:

Files must be in a valid GIS format (\*.geojson, \*.gpkg, \*.tif, or \*.shp) and in the WGS 84 (EPSG:4326) coordinate reference system.  
 The list of loaded GIS maps will appear on the right.

When “Site Investigation Data (currently supports CPTs only)” is selected, the user provides a file path to a summary file and a file path to the folder containing the CPT data. The user then will need to specify the column that includes groundwater (N/A if not included), assign weights for liquefaction/lateral spread models, if available, include a shapefile of the free-face feature

(for lateral spread analyses), and apply a method for use for the depth-weight factor for CPT processing (optional).

**Geospatial Data** Site Investigation Data (currently supporting CPTs only)

This tab allows you to enter CPT-related data to be used in CPT-based methods under "Liquefaction", "Lateral Spread", and "Settlement" in the "Engineering Demand Parameter" tab.

- CPT Summary file in csv format - must contain the columns "CPT\_FileName", "Longitude", and "Latitude":
- Folder containing CPT files in csv format - file names must match those in the "CPT\_FileName" column above:

**Geospatial Data** Site Investigation Data (currently supporting CPTs only)

This tab allows you to enter CPT-related data to be used in CPT-based methods under "Liquefaction", "Lateral Spread", and "Settlement" in the "Engineering Demand Parameter" tab.

- CPT Summary file in csv format - must contain the columns "CPT\_FileName", "Longitude", and "Latitude":
- Folder containing CPT files in csv format - file names must match those in the "CPT\_FileName" column above:

Note: each CPT datafile must contain the following columns

Column 1 label: z Desc: depth (m)	Column 2 label: qt Desc: tip resistance (MPa)	Column 3 label: fs Desc: sleeve friction (MPa)	Column 4 label: u2 Desc: pore pressure (MPa)						
ID	CPT_FileName	CPT_Date	Datum	Longitude	Latitude	Datum	Mean GWT	Mean GWT NR	Mean GWT SF
0	LAC041.csv	4/12/1995	NAD 27 UTM Zone 11 N	-118.501993	34.283897	WGS84	15	15	15
1	LAC042.csv	4/12/1995	NAD 27 UTM Zone 11 N	-118.501982	34.283302	WGS84	9.4	9.4	11.4
2	LAC043.csv	4/12/1995	NAD 27 UTM Zone 11 N	-118.501999	34.283049	WGS84	9.1	9.1	11.1
3	LAC044.csv	4/12/1995	NAD 27 UTM Zone 11 N	-118.501997	34.282896	WGS84	8.5	8.5	10.5
4	LAC047.csv	4/13/1995	NAD 27 UTM Zone 11 N	-118.502	34.282508	WGS84	8.2	8.2	10.2
5	LAC048.csv	4/13/1995	NAD 27 UTM Zone 11 N	-118.501997	34.2823	WGS84	7.9	7.9	9.9
6	LAC049.csv	4/13/1995	NAD 27 UTM Zone 11 N	-118.502003	34.28203	WGS84	7.9	7.9	9.9
7	LAC051.csv	4/13/1995	NAD 27 UTM Zone 11 N	-118.501987	34.281146	WGS84	7.2	7.2	9.2
8	LAC053.csv	4/14/1995	NAD 27 UTM Zone 11 N	-118.502009	34.280524	WGS84	7.6	7.6	9.6
9	LAC054.csv	4/14/1995	NAD 27 UTM Zone 11 N	-118.502006	34.28038	WGS84	8.2	8.2	10.2
10	LAC055.csv	5/12/1995	NAD 27 UTM Zone 11 N	-118.502004	34.280262	WGS84	8.4	8.4	10.4

- Column in summary file with mean groundwater depth in meters:
- Assign weights to use for "liquefaction" and "lateral spread" analysis of CPTs:  
 Liquefaction: weight for Robertson (2009):  , weight for Boulanger & Idriss (2016) = 1 - weight for Robertson (2009)  
 Lateral spread: weight for Zhang et al. (2004):  , weight for Idriss & Boulanger (2008) = 1 - weight for Zhang et al. (2004)
- (Optional) Path to folder with shapefile for free-face feature (must contain the attribute "Height\_m"):
- (Optional) Method to use for depth-weight factor for CPT processing:

## 5.9 Input Variable

The **Input Variable** tab (in the left side-bar) will change based on the analysis you are running. The variable will automatically update according to the fragility models selected within the **Decision Variable**, **Damage Measure**, and **Engineering Demand Parameter** tabs. There are a lot of components to this page, as such it is recommended that the instructions on the tab be referenced before use.

The variables can be manually adjusted or use the "Preferred" values. In the figure below, the drop-down menu under source allows the user to select "Preferred," "From the infrastructure table" which imports from the characteristic table imported in the "Infrastructure" tab, or "From user-provided GIS maps" which is also imported in the "Infrastructure" tab.

Name	Description	From Model	Source
coh_soil		Landslide-BrayMacedo2019	Preferred
gamma_soil		Landslide-BrayMacedo2019	Preferred
phi_soil		Landslide-BrayMacedo2019	From infrastruc... or enter valu
			From user-provided GIS maps

The distribution of certain parameters can be set to “Normal” or “Lognormal” and the mean/median and standard deviation can both be defined.

Distribution Type	Mean or Median	Sigma
Normal	DIAMETER	N/A
Lognormal		
Normal		

### 5.10 Using Generic Models

In each of the **Decision Variable**, **Damage Measure**, and **Engineering Demand Parameter** tabs has the option to use a “Generic Model.” This option allows the user to input coefficients for their own models.

The user first needs to define the distribution (normal or lognormal). Then assign an output variable label and any upstream dependencies. Finally, the user needs to define the aleatory variability and epistemic uncertainty.

Select model distribution type:	lognormal
Enter label for return parameter (limited to one for now):	eps_comp_crit_rup
Select upstream dependency:	EDP
Enter list of upstream parameters (use "," to separate labels and leave empty if none):	

Next, the user can click the **Add** button to add additional levels or variable to the analysis (outlined in red below). The user must define the variable, the level (integral number), coefficient, whether it is lognormally or normally distributed, as well as its power.

Select model distribution type:

Enter label for return parameter (limited to one for now):

Select upstream dependency:

Enter list of upstream parameters (use "," to separate labels and leave empty if none):

**Generic Model Definition**

Variable	Level	Coefficient	Apply Ln	Power
	1	-2.3	false	0
pga	1	0.5	true	1
mag	2	10	false	2
var_3	3	+2	false	1

**Generic Equation**

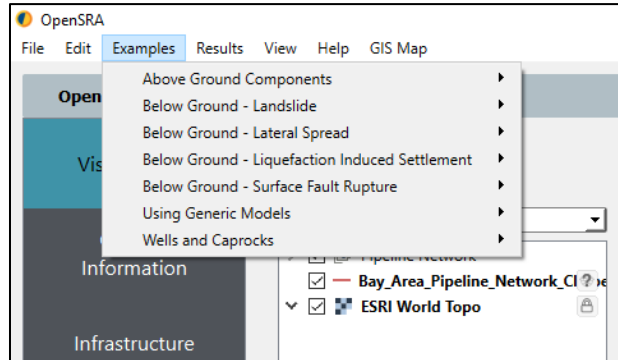
**Level 1:**  
 $\ln(Y) = -2.3 + 0.5 \cdot \ln(pga)$

**Level 2:**  
 $\ln(Y) = -2.3 + 0.5 \cdot \ln(pga) + 10 \cdot mag^2$

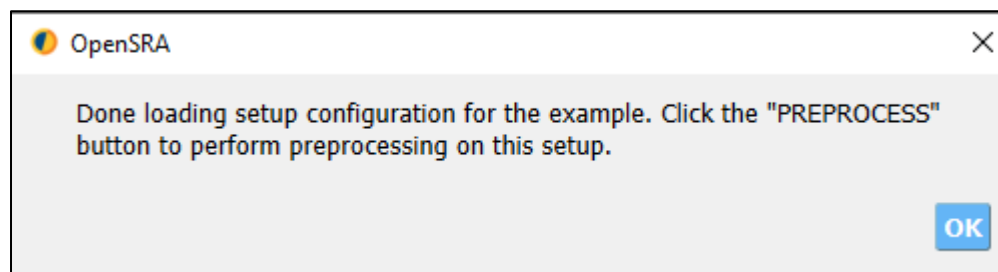
**Level 3:**  
 $\ln(Y) = -2.3 + 0.5 \cdot \ln(pga) + 10 \cdot mag^2 + +2 \cdot var_3$

## 6 Running Built-In Examples

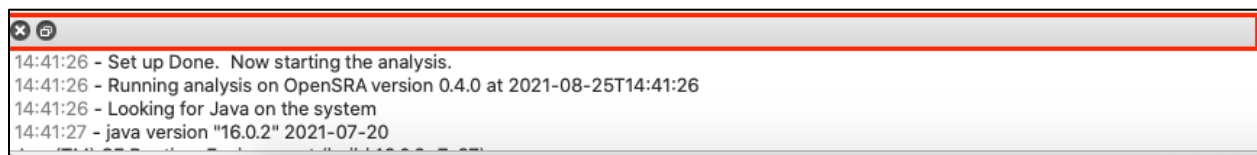
There are over twenty built in examples to demonstrate how to configure *OpenSRA* for various problems. These examples are listed under “Examples” in the task-bar. Selecting any of the examples will prompt *OpenSRA* to import the preconfigured settings. **Note that no edits need to be made when running the examples, the user should be able to load examples from the task-bar and click “Preprocess” and “Perform Analysis” located at the bottom ribbon of the *OpenSRA* window.**



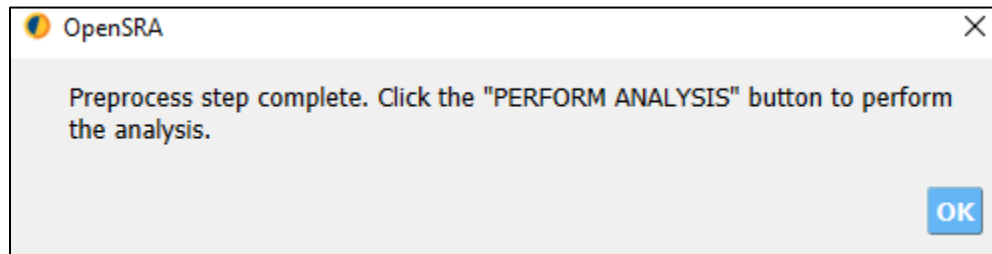
To run an example, choose one from the drop-down list in the task-bar, and the program will then prompt you to click “Preprocess” in the bottom ribbon.



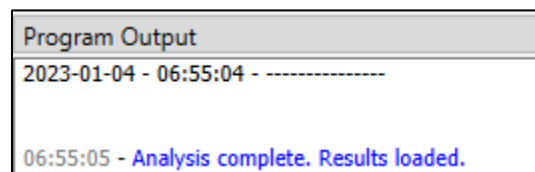
When *OpenSRA* is running, runtime dialogs will be displayed in the “Program Output” widget at the bottom of the window. The widget can be undocked by double clicking the top bar, this allows the user to move the widget.



Once preprocessing is finished, the program will direct the user to click “Perform Analysis,” also in the bottom ribbon of the *OpenSRA* window.



Once completed, the Program Output will show “Analysis complete, Results loaded”



## 6.1 Details to Built-in Examples

The following outlines the analysis being performed within each example. **Note that no edits need to be made when running the examples, the user should be able to load examples located in the tool-bar, click “Preprocess,” and then “Perform Analysis” located at the bottom ribbon of the *OpenSRA* window.** The locations of the example files are stored under “[InstallationDirectory]\OpenSRA\examples. It should be noted that some examples are built to fail at certain parts of the analysis as a check that the program is failing when the analysis is outside deformation boundaries or the example isn’t given enough information. The examples are also likely to change with future releases of the program. Note: It will take some time for the program to set up the first time you run both the “PREPROCESS” and “PERFORM ANALYSIS” commands (~1 minute for “PREPROCESS” and ~10 minutes for “PERFORM ANALYSIS”).

**Aboveground Components** – These examples are for different above ground components. The **Infrastructure** tab will automatically select “Aboveground Components” and the **Decision Variable, Damage Measure, and Engineering Demand Parameter** tabs will show the “Aboveground Component” layouts (shown in Sections 5.5 through 5.7).

- AG-1 – ShakeMap GIS Input – This example uses a GIS input file combined with the Loma Prieta ShakeMap to calculate the probability of well-head leakage, rupture, and pressure vessel rupture.
- AG-2 – UCERF CSV Input – This example uses a CSV input file combined with UCERF3 and the NGA-West2 models to calculate the probability of well-head leakage, rupture, and pressure vessel rupture.



- AG-3 – UCERF with Filters CSV Input – This example uses a CSV input file combined with UCERF3 (with magnitude and distance filters checked) and the NGAWest2 models to calculate the probability of well-head leakage, rupture, and pressure vessel rupture.

**Below Ground – Landslide** - These examples are for buried pipelines subjected to landsliding. The “Infrastructure” tab will automatically select “Pipelines” and the **Decision Variable**, **Damage Measure**, and **Engineering Demand Parameter** tabs will show the “Pipeline” layouts (shown in Sections 5.5 through 5.7).

- BG-L-1 – Level1 Balboa Blvd with CA Inventory ShakeMaps (Fails in Preprocess) – This example uses multiple pipelines on Balboa Boulevard combined with the South Napa ShakeMap to estimate the probability of pipeline rupture and leakage. Specifically, this example utilizes the landslide inventory (on the **Engineering Demand Parameter** tab).
- BG-L-2 – Level 1 Bay Area No Deformation Polygon UCERF – This example is using the publicly available pipeline network in the Bay Area combined with UCERF3 and NGAWest2 to estimate the probability of pipeline rupture and leakage. Specifically, this example does not utilize the landslide inventory (on the **Engineering Demand Parameter** tab).
- BG-L-3 – Level1 Bay Area with CA Inventory ShakeMaps - This example is using the publicly available pipeline network in the Bay Area combined with the Loma Prieta (both unscaled and scaled to  $PGA = 0.5g$ ), and the South Napa ShakeMaps to estimate the probability of pipeline rupture and leakage. Specifically, this example utilizes the landslide inventory (on the **Engineering Demand Parameter** tab).
- BG-L-4 – Level1 Bay Area with CA Inventory UCERF - This example is using the publicly available pipeline network in the Bay Area combined with UCERF3 and NGA-West2 to estimate the probability of pipeline rupture and leakage due to landsliding. Specifically, this example does utilize the landslide inventory (on the **Engineering Demand Parameter** tab).

**Below Ground – Lateral Spread** - These examples are for buried pipelines subjected to lateral spreading. The “Infrastructure” tab will automatically select “Pipelines” and the **Decision Variable**, **Damage Measure**, and **Engineering Demand Parameter** tabs will show the “Pipeline” layouts (shown in shown in Sections 5.5 through 5.7).

- BG-LS-1 – Level1\_Balboa\_Blvd\_UCERF – This example uses the pipeline at Balboa Blvd combined with UCERF3 and NGA-West2 to predict the probability of pipeline leakage and rupture due to lateral spreading using Level 1 models in the **Engineering Demand Parameter**, **Decision Variable**, and **Damage Measure** tabs.
- BG-LS-2 – Level1 Bay Area ShakeMap 1989 Loma Prieta Scaled to  $PGA=0.5g$  – This example uses the prepackaged pipeline network in the Bay Area combined with the

Loma Prieta ShakeMap scaled to a PGA of 0.5g to predict the probability of pipeline leakage and rupture due to lateral spreading using Level 1 models in the **Engineering Demand Parameter, Decision Variable, and Damage Measure** tabs.

- BG-LS-3 – Level1 Bay Area ShakeMap 1989 Loma Prieta User Specified Maps – This example uses the prepackaged pipeline network in the Bay Area combined with the Loma Prieta ShakeMap to predict the probability of pipeline leakage and rupture due to lateral spreading using Level 1 models in the **Engineering Demand Parameter, Decision Variable, and Damage Measure** tabs.
- BG-LS-4 – Level1 Bay Area ShakeMap 2014 South Napa – This example uses the prepackaged pipeline network in the Bay Area combined with the South Napa ShakeMap to predict the probability of pipeline leakage and rupture due to lateral spreading using Level 1 models in the **Engineering Demand Parameter, Decision Variable, and Damage Measure** tabs.
- BG-LS-5 – Level 1 Bay Area UCERF – This example uses the prepackaged pipeline network in the Bay Area combined with UCERF3 and NGAWest2 to predict the probability of pipeline leakage and rupture due to lateral spreading using Level 2 models in the **Engineering Demand Parameter, Decision Variable, and Damage Measure** tabs.
- BG-LS-6 – Level2 Balboa Blvd ShakeMap 1971 San Fernando – This example uses the pipeline at Balboa Blvd combined with the San Fernando ShakeMap to predict the probability of pipeline leakage and rupture due to lateral spreading using Level 2 models in the **Engineering Demand Parameter, Decision Variable, and Damage Measure** tabs.
- BG-LS-7 – Level 2 Balboa Blvd ShakeMap 1994 Northridge – This example uses the pipeline at Balboa Blvd combined with the Northridge ShakeMap to predict the probability of pipeline leakage and rupture due to lateral spreading using Level 2 models in the **Engineering Demand Parameter, Decision Variable, and Damage Measure** tabs.
- BG-LS-8 – Level 2 Balboa Blvd UCERF - This example uses the pipeline at Balboa Blvd combined with UCERF3 and NGAWest2 to predict the probability of pipeline leakage and rupture due to lateral spreading using Level 2 models in the **Engineering Demand Parameter, Decision Variable, and Damage Measure** tabs.
- BG-LS-9 – Level 3 CPT Alameda UCERF (Fails in Preprocess) – This example uses the prepackaged pipeline network in the Bay Area combined with UCERF3 and NGAWest2 to predict the probability of pipeline leakage and rupture due to lateral spreading using CPT data and Level 3 models in the **Engineering Demand Parameter, Decision Variable, and Damage Measure** tabs. This example is supposed to fail in the

“Preprocess” phase, as the pipelines do not intersect the zone of deformation interpreted from the CPT’s.

- BG-LS-10 – Level 3 CPT Balboa Blvd ShakeMap 1971 San Fernando – This example uses the pipeline at Balboa Blvd combined the San Fernando ShakeMap to predict the probability of pipeline leakage and rupture due to lateral spreading using CPT data and Level 3 models in the **Engineering Demand Parameter**, **Decision Variable**, and **Damage Measure** tabs.
- BG-LS-11 – Level 3 CPT Balboa Blvd ShakeMap 1994 Northridge – This example uses the pipeline at Balboa Blvd combined with the Northridge ShakeMap to predict the probability of pipeline leakage and rupture due to lateral spreading using CPT data and Level 3 models in the **Engineering Demand Parameter**, **Decision Variable**, and **Damage Measure** tabs.
- BG-LS-12 – Level 3 CPT Balboa Blvd UCERF – This example uses the pipeline at Balboa Blvd combined with UCERF3 and NGAWest2 to predict the probability of pipeline leakage and rupture due to lateral spreading using CPT data and Level 3 models in the **Engineering Demand Parameter**, **Decision Variable**, and **Damage Measure** tabs.

**Below Ground – Liquefaction Induced Settlement** - These examples are for buried pipelines subjected to liquefaction induced settlement. The “Infrastructure” tab will automatically select “Pipelines” and the **Decision Variable**, **Damage Measure**, and **Engineering Demand Parameter** tabs will show the “Pipeline” layouts (shown in shown in Sections 5.5 through 5.7).

- BG-S-1 – Level 1 Bay Area ShakeMap – This example uses the prepackaged pipeline network in the Bay Area combined with Loma Prieta (both unscaled and scaled to  $PGA = 0.5g$ ), San Fernando, Northridge, and South Napa ShakeMaps to calculate the probability of failure due to liquefaction induced settlement, using Level 1 models in the **Engineering Demand Parameter**, **Decision Variable**, and **Damage Measure** tabs.
- BG-S-2 – Level 1 Bay Area UCERF – This example uses the prepackaged pipeline network in the Bay Area combined with UCERF3 and NGAWest2 to calculate the probability of failure due to liquefaction induced settlement, using Level 1 models in the **Engineering Demand Parameter**, **Decision Variable**, and **Damage Measure** tabs.
- BG-S-3 – Level 3 CPT Balboa Blvd ShakeMaps (Fails in Preprocess) – This example uses the pipelines at Balboa Blvd combined with the Loma Prieta (both unscaled and scaled to  $PGA = 0.5g$ ), San Fernando, Northridge, and South Napa ShakeMaps to calculate the probability of failure due to liquefaction induced settlement, using CPT data and Level 3 models in the **Engineering Demand Parameter**, **Decision Variable**, and **Damage Measure** tabs.

- BG-S-4 – Level 3 CPT Balboa Blvd UCERF (Fails in Preprocess) – This example uses the pipelines at Balboa Blvd with UCERF3 and NGA-West2 to calculate the probability of failure due to liquefaction induced settlement, using CPT data and Level 3 models in the **Engineering Demand Parameter**, **Decision Variable**, and **Damage Measure** tabs.

**Below Ground – Surface Fault Rupture** - These examples are for buried pipelines subjected to landsliding. The **Infrastructure** tab will automatically select “Pipelines” and the **Decision Variable**, **Damage Measure**, and **Engineering Demand Parameter** tabs will show the “Pipeline” layouts (shown in shown in Sections 5.5 through 5.7).

- BG-SFR-1 – Bay Area – This example uses the prepackaged pipeline network in the Bay Area combined with the fault rupture models included in *OpenSRA* to predict the probability of failure due to fault rupture.
- BG-SFR-2 – Los Angeles – This example uses the prepackaged pipeline network in Los Angeles combined with the fault rupture models included in *OpenSRA* to predict the probability of failure due to fault rupture.
- BG-SFR-3 – Pipe Near Hayward – This example uses a pipeline near the Hayward fault combined with the fault rupture models included in *OpenSRA* to predict the probability of failure due to fault rupture.

**Using Generic Model** – These examples are for buried pipelines subjected to lateral spreading. The **Infrastructure** tab will automatically select “Pipelines” and the **Decision Variable**, **Damage Measure**, and **Engineering Demand Parameter** tabs will show the “Pipeline” layouts (shown in Sections 5.5 through 5.7).

- GM-1 – Level 3 CPT Balboa Blvd ShakeMap 1994 Northridge Generic Model in DM DV – This example uses the pipeline at Balboa Blvd combined with the Northridge ShakeMap to predict the probability of pipeline leakage and rupture due to lateral spreading using CPT data and Level 3 methods in the **Engineering Demand Parameter** tab. In the **Damage Measure** and **Decision Variable** tabs, the “Generic Model” is selected and the inputs filled in.
- GM-2 – Level 3 CPT Balboa Blvd ShakeMap 1994 Northridge Generic Model in DV – This example uses the pipeline at Balboa Blvd combined with the Northridge ShakeMap to predict the probability of pipeline leakage and rupture due to lateral spreading using CPT data and Level 3 methods in the **Damage Measure** and **Engineering Demand Parameter** tabs. In the **Decision Variable** tab, the “Generic Model” is selected and the inputs filled in.
- GM-3 – Level 3 CPT Balboa Blvd ShakeMap 1994 Northridge Generic Model in DV Single Integral – This example uses the pipeline at Balboa Blvd combined with the Northridge ShakeMap to predict the probability of pipeline leakage and rupture due to

lateral spreading using CPT data and Level 3 methods in the **Damage Measure** and **Engineering Demand Parameter** tabs. In the **Decision Variable** tab, the “Generic Model” is selected and the inputs filled in, forcing the program to only calculate one integral intensity measure to decision variable.

- GM-4 – Level 3 CPT Balboa Blvd ShakeMap 1994 Northridge Generic Model in EDP DV – This example uses the pipeline at Balboa Blvd combined with the Northridge ShakeMap to predict the probability of pipeline leakage and rupture due to lateral spreading using CPT data and Level 3 methods in the **Damage Measure** tab. In the **Decision Variable**, and **Engineering Demand Parameter** tabs, the “Generic Model” is selected and the inputs filled in.

**Wells and Caprocks** – These examples are for wells and caprocks subjected to ground shaking and fault displacement. The “Infrastructure” tab will automatically select “Wells and Caprocks” and the **Decision Variable**, **Damage Measure**, and **Engineering Demand Parameter** tabs will show the “Wells and Caprocks” layouts (shown in shown in Sections 5.5 through 5.7).

- WC-1 – UCERF CSV Input – This example uses wells and caprocks at Honor Rancho combined with UCERF3, NGAWest2, and Quaternary Faults and Folds traces to predict the probability of failure due to ground shaking and fault displacement.
- WC-2 – Userdef Rupture GIS Input – This example uses wells and caprocks at Honor Rancho combined with a user defined rupture input through a GIS file to predict the probability of failure due to ground shaking and fault displacement

## 7 Constructing a New Scenario in *OpenSRA*

To construct a brand-new analysis in *OpenSRA*, follow the instructions below and refer to examples for specific file structure

1. Create a folder on your computer. This folder will be referred to as the working directory.
2. Prepare any infrastructure or site data
  - a. The data file(s) should be located anywhere on the user's computer except in the working directory
3. In the **General Information** tab on the side-bar
  - a. Select **Browse** next to "Working Directory", locate, and add the folder from Step 1
4. In the **Infrastructure** tab on the side-bar
  - a. Select type of infrastructure by selecting one of the following buttons **Pipelines**, **Wells and Caprocks**, or **Aboveground Gas Infrastructure**
  - b. Browse and locate the site data file created in Step 2.
5. In the **Decision Variable** tab on the side-bar
  - a. For each decision variable you want to assess:
    - i. Pick a method to use
    - ii. Assign the weight
    - iii. Select or fill in and of the available options (epistemic uncertainty, landslide inventory etc.)
    - iv. Click "Add run to list"
    - v. Repeat for additional methods
    - vi. If using the Generic Model see Section 5.10
6. In the **Damage Measure** tab on the side-bar
  - a. For each demand you want to assess:
    - i. Pick a method to use
    - ii. Assign the weight
    - iii. Select or fill in and of the available options (epistemic uncertainty, landslide inventory etc.)
    - iv. Click "Add run to list"
    - v. Repeat for additional methods
    - vi. If using the Generic Model see Section 5.10
7. In the **Engineering Demand Parameter** tab on the side-bar
  - a. For each demand you want to assess:
    - i. Pick a method to use
    - ii. Assign the weight
    - iii. Select or fill in and of the available options (epistemic uncertainty, landslide inventory etc.)
    - iv. Click "Add run to list"
    - v. Repeat for additional methods
    - vi. If using the Generic Model see Section 5.10



8. In the **Intensity Measure** tab on the side-bar
  - a. Select **UCERF3 (Preferred)**, **ShakeMap**, or **User-defined Rupture** from the drop-down menu at the top.
  - b. If using UCERF3 –
    - i. Select if you would like filters applied for magnitude, distance, or mean annual rate
    - ii. If you have site-specific data specify the column in the “Infrastructure” table for  $V_{s30}$ ,  $Z_{1.0}$ , or  $Z_{2.5}$ .
  - c. If using ShakeMap –
    - i. Select **Browse** and navigate to the location of the ShakeMap file
    - ii. Select the type of Intensity Measure to visualize (PGA or PGV)
    - iii. Click **Load**
    - iv. Repeat for additional ShakeMaps
9. If available import GIS or CPT data in the **GIS and CPT Data** tab
  - a. Select which type of data you would like to import in the drop-down menu
  - b. Select **Browse** and navigate to the location of the file you wish to import
10. In the **Input Variables** tab on the side-bar
  - a. Assess each of the inputs listed, under source select “From Infrastructure table or enter value” or “From user-defined maps” if applicable
11. Click **Preprocess**
12. Once prompted select **Perform Analysis**
13. To load previously run results:
  - a. Click **Results** on the task-bar at the top
  - b. Click **Load Results** from the drop-down menu
  - c. Click **Browse**
  - d. Navigate to the “analysis” folder under the working directory you specified under “Step b” (2 steps above).
  - e. Click **Select folder** at the bottom
  - f. Click **Load Results**

## 8 Glossary

### **Damage Measure (DM)**

Parameters that quantify the physical damage caused by engineering demand parameters. DMs currently available in *OpenSRA* include transient pipe strain.

### **Decision Variables (DV)**

Parameters that quantify the consequences of damages, engineering demands, and/or ground-shaking intensities. DVs currently available in *OpenSRA* include ground-shake and deformation induced repair rates.

### **Engineering Demand Parameters (EDP)**

Parameters that quantify the effect that intensity measures have on the system response. EDPs currently available in *OpenSRA* include liquefaction, lateral spread, ground settlement, landslide, surface fault rupture, subsurface fault rupture, and transient ground strain.

### **Intensity Measures (IM)**

Parameters that quantify the intensity of ground-shaking at a site. IMs currently available in *OpenSRA* include Peak Grounds Acceleration (PGA) and Peak Ground Velocity (PGV).

**Task-bar** - the horizontal bar with drop-down lists at the top of the *OpenSRA* window (outlined in red).

**Left Side-bar** - the vertical bar on the left side of the *OpenSRA* window where the user can switch between tabs including **General Information, Decision Variable, Damage Measure, Engineering Demand Parameter, Intensity Measure, GIS and CPT Data, and Input Variables.**

**Bottom Ribbon** - the three buttons at the bottom of the *OpenSRA* window (outlined in green). Sometimes the ribbon can become obstructed; to fix, adjust the size of the *OpenSRA* window.

**Project Output** – the bottom dialog widget that updates the user on the progress of preprocessing and analysis run (outlined in blue).