***RapidLiq* User Manual**

v.1.0.

Summary

RapidLiq is a Windows software program for predicting liquefaction-induced ground failure using geospatial models, which are particularly suited for regional scale applications such as: (i) loss estimation and disaster simulation; (ii) city planning and policy development; (iii) emergency response; and (d) post-event reconnaissance (e.g., to remotely identify sites of interest). *RapidLiq* v1.0 includes four such models. One is a logistic regression model developed by Rashidian and Baise (2020), which has been adopted into United States Geological Survey (USGS) post-earthquake data products, but which is not often implemented by individuals owing to the geospatial variables that must be compiled. The other three models are machine and deep learning models proposed by Geyin et al. (2021). All necessary predictor variables are compiled within *RapidLiq*, making user implementation trivial. The only required input is a ground motion raster easily downloaded within minutes of an earthquake, or available for enumerable future earthquake scenarios. This gives the software near-real-time capabilities, such that ground failure can be predicted at regional scale within minutes of an earthquake. The software outputs geotiff files mapping the probabilities of liquefaction-induced ground failure. These files may be viewed within the software or explored in greater detail using GIS or one of many free geotiff web explorers (e.g., http://app.geotiff.io/). The software also allows for tabular input, should a user wish to enter specific sites of interest and ground-motion parameters at those sites, rather than study the regional effects of an earthquake. *RapidLiq* v.1.0 operates in the contiguous U.S. and completes predictions within 10 seconds for most events.

Installation and Running *RapidLiq*

Install *RapidLiq* using "RapidLiqv1_Installer.exe." If prompted to do so, extract all zipped contents prior to continuing the installation. In addition, you may be warned by the Windows OS that .exe files from unknown sources could be harmful. Please ignore any such message and click "run anyways." There are no specific system requirements. 4GB of RAM will be enough for most scenarios, but if high resolution rasters with a large land domain will be used (2 million + pixels), at least 8 GB of RAM is recommended. Please note that the software will initiate slowly the first time it is used, since some of the installation process occurs during first use of the software. The software will thereafter open more quickly.

Using *RapidLiq*

The *RapidLiq* user interface has 2 main tabs that perform the same analyses with different types of inputs. Both use a simple 3-step process wherein: (1) an input file is loaded; (2) model parameters are extracted; (3) analyses are performed.

The first tab (Raster) requires a raster file in either .xml (Extensible Markup Language) or .tif (GeoTagged Image File) format. This option is best for studying the regional effects of an earthquake. The first format can be downloaded from the USGS earthquake catalog (https://earthquake.usgs.gov/earthquakes/search/) minutes after an event, or from the USGS scenario catalog (https://earthquake.usgs.gov/scenarios/catalog/) for future scenario events. The second format (.tiff) is a more general, flexible format, allowing for motions from various sources to be analyzed. In either case, the software extracts predictor variables across the ShakeMap extents and outputs geotiff files mapping the probabilities of liquefaction-induced ground failure. These output files (saved in the same directory as the input file) may be viewed within the software or explored in greater detail using GIS or one of many free geotiff web explorers (e.g., http://app.geotiff.io/).

The second tab (tabular) allows for tabular input, should a user wish to enter specific sites of interest and ground-motion parameters at those sites, rather than study the regional effects of an earthquake. With this option, an .xlsx input file is required with the following ordered columns: (1) Latitude (WGS84); (2) Longitude (WGS84); (3) Moment Magnitude (*Mw*); (4) Peak Ground Acceleration, *PGA*, in g; and (5) Peak Ground Velocity, *PGV*, in cm/sec. With this option, the software creates an .xlsx output file within the same directory where the input file is located.

Use of the software is next demonstrated via two examples.

Example 1. Input type: .xml Raster

Extensible Markup Language (.xml) ground motion rasters are available from the USGS for past earthquakes (https://earthquake.usgs.gov/earthquakes/search/) and future scenario events (https://earthquake.usgs.gov/scenarios/catalog/). These files contain all necessary seismic data, including earthquake magnitude and the regional distribution of shaking intensities. Once on an event page, navigate to the event's "ShakeMap."

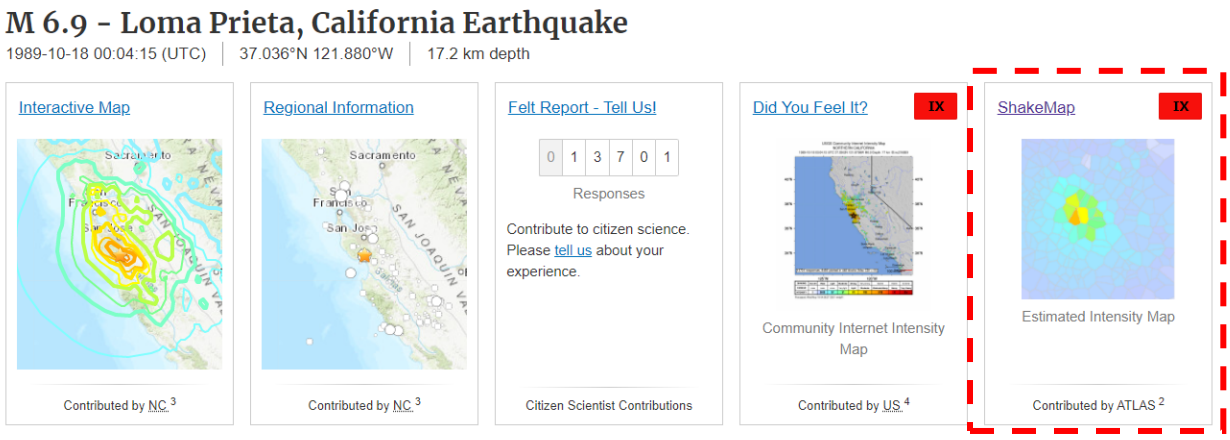


Figure 1. Navigating to ShakeMaps within the USGS event catalogs.

Next, below the map of ShakeMap information, select "Downloads."

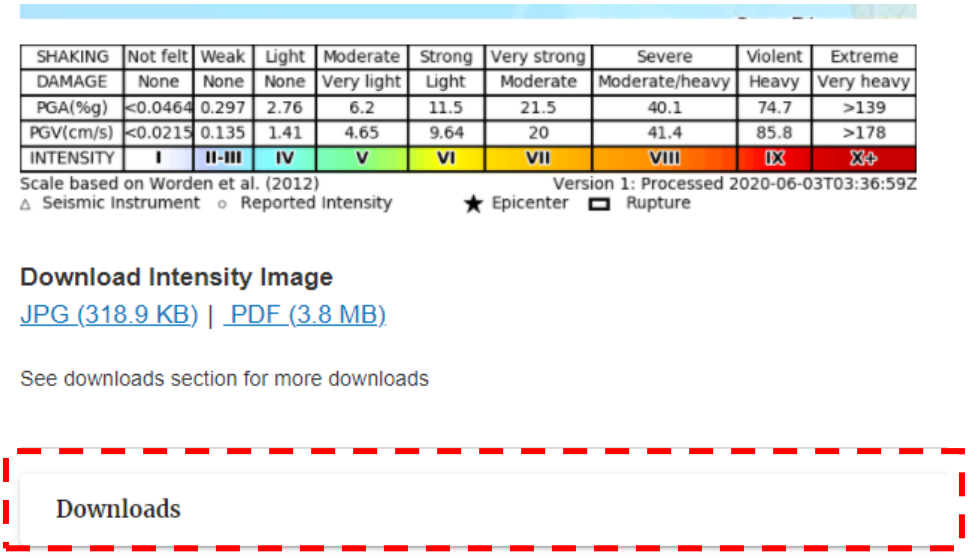


Figure 2. Select the Downloads dropdown menu within a given ShakeMap.

From the dropdown menu, a multitude of download options will appear. The exact position and title of the .xml file may change with time. For the 1989 Loma Prieta earthquake, for example, it appears as:

Figure 3. Location and name of XML grid file for 1989 Loma Prieta, CA, earthquake.

For the 2020 Stanley, Idaho earthquake, it appears as:

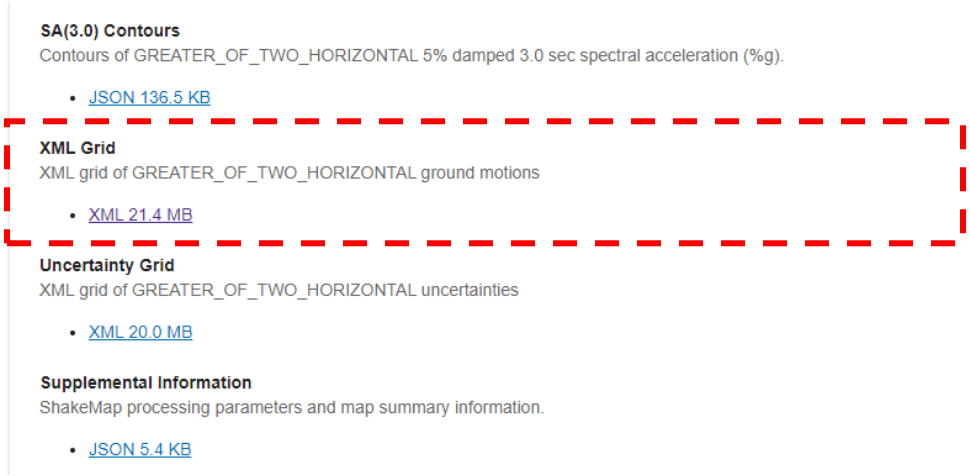


Figure 4. Location and name of XML grid file for 2020 Stanley, ID, earthquake.

Open and save the .xml file to any desired file directory. Please note that an "OutFiles" subfolder will be created in the same directory. Here, the program outputs will be saved.

In *RapidLiq*, under the "Raster" tab, select the "Input ShakeMap" button. Specify the input type as .xml and direct *RapidLiq* to the .xml file of your choosing. Please wait several seconds as the file is loaded. *RapidLiq* will inform the user whether the input was successful. Press OK to continue.

An interactive map of the *PGA* raster with a scalebar will appear on the screen, as shown in Figure 5.

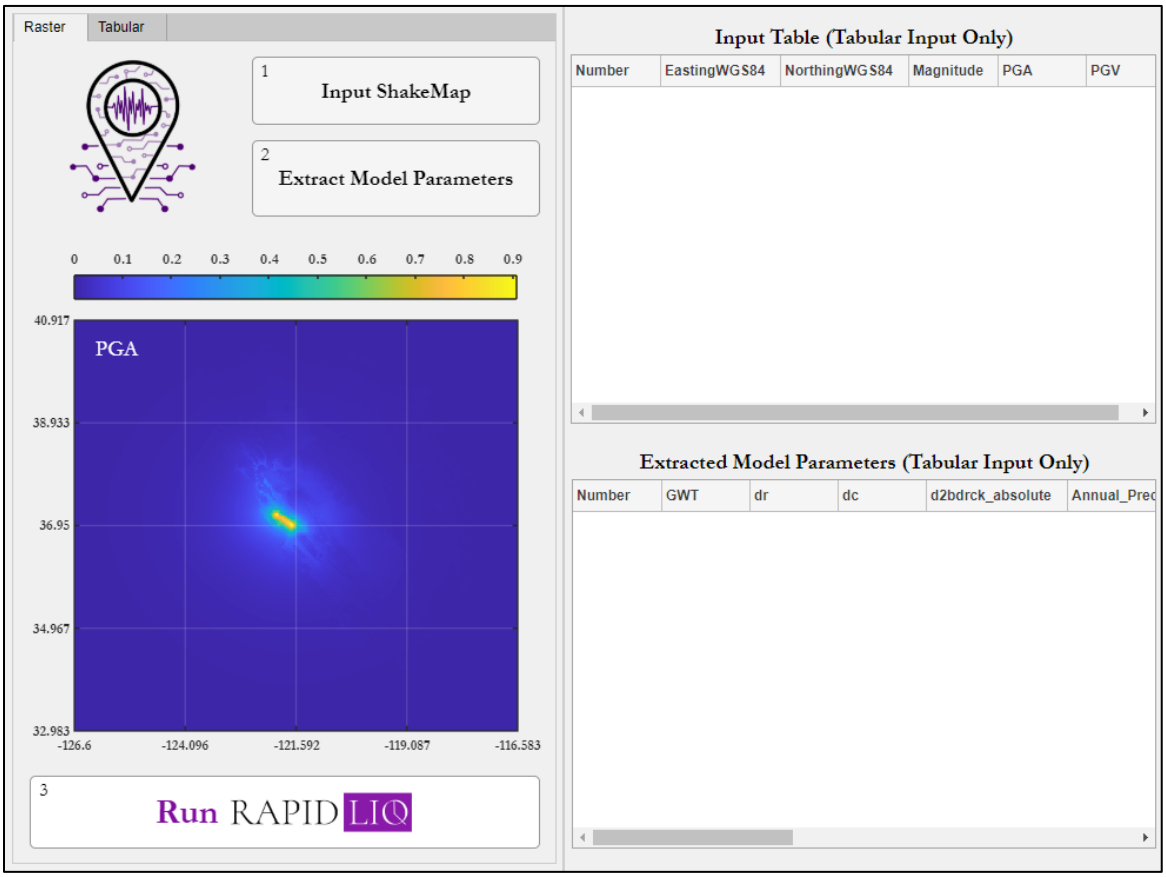


Figure 5. *RapidLiq* interface after Raster input

Next, select the "Extract Model Parameters" button to gather all model variables over the ShakeMap extents. In *RapidLiq* v1.0, these include predicted V_{S30} (Heath et al., 2020); predicted ground water depth (Fan and Miguez-Macho, 2020); measured distance to river (Lehner et al., 2006) and measured distance to coast (NASA, 2012); predicted depth to bedrock (Shangguan et al. 2017); measured annual precipitation (Fick and Hijmans, 2017); and the predicted (binomial) presence of unconsolidated soil, sandy soil, clayey soil, and silty soil, as obtained from the USGS National Geologic Map compilation (Horton et al. 2017). Please wait several seconds until extraction is complete. After the process finishes, a pop-up window should inform the user whether the parameter extraction was successful. Press OK to continue.

To compute predictions of liquefaction-induced ground failure using all available models, select the "Run *RapidLiq*" button. Rapidliq v.1.0 contains four models. These include the logistic regression model of Rashidian and Baise (2020) and the Deep Learning (DL), Machine Learning (ML), and Ensemble (ENS) models proposed by Geyin et al. (2021). All four models are described in detail by Geyin et al. (2021).

All calculations should be performed within several seconds After the predictions are made, a pop-up window informs the user whether the calculation process was successful. Press OK to plot the model predictions on the screen, as shown below in Figure 6. Results from each model, by default, are also saved to the aforementioned "OutFiles" folder as separate geotiff (.tiff) files.

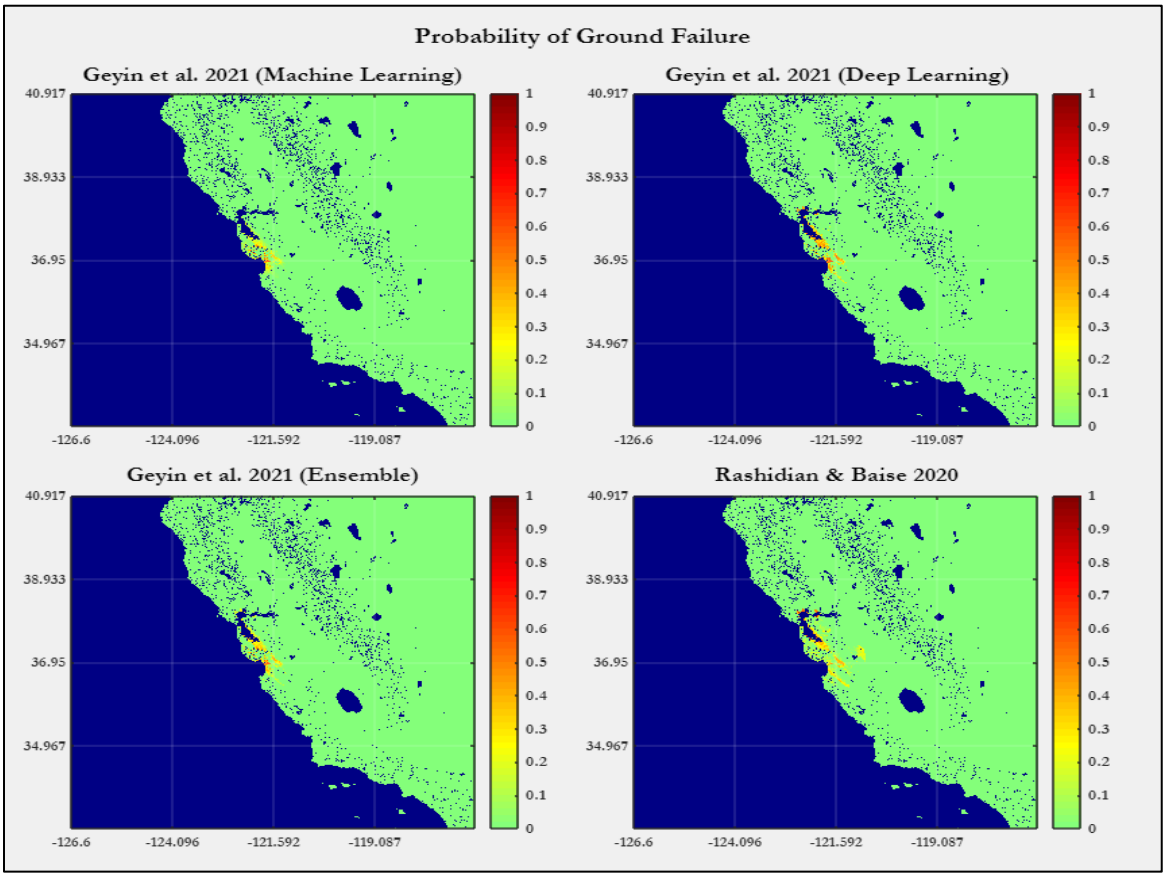


Figure 6. *RapidLiq* output from all 4 models.

To explore the outputs in greater detail (e.g., to make custom maps, or to further explore and study the predictions), the output files are easily opened in GIS or one of many free geotiff web explorers (e.g., http://app.geotiff.io/). As an example, results for the 2011 Mineral, VA, earthquake are shown in Figure 7 using the geotiff.io web explorer, which has several simple statistical analysis tools built in.

Alternatively, but following a very similar process, *RapidLiq* allows for geotiff (.tiff) input files, which might be obtained from various sources (e.g., ground motion simulations). Using this approach, .tiff files containing *PGA* and *PGV* are separately input, and the earthquake magnitude is entered in a text window.

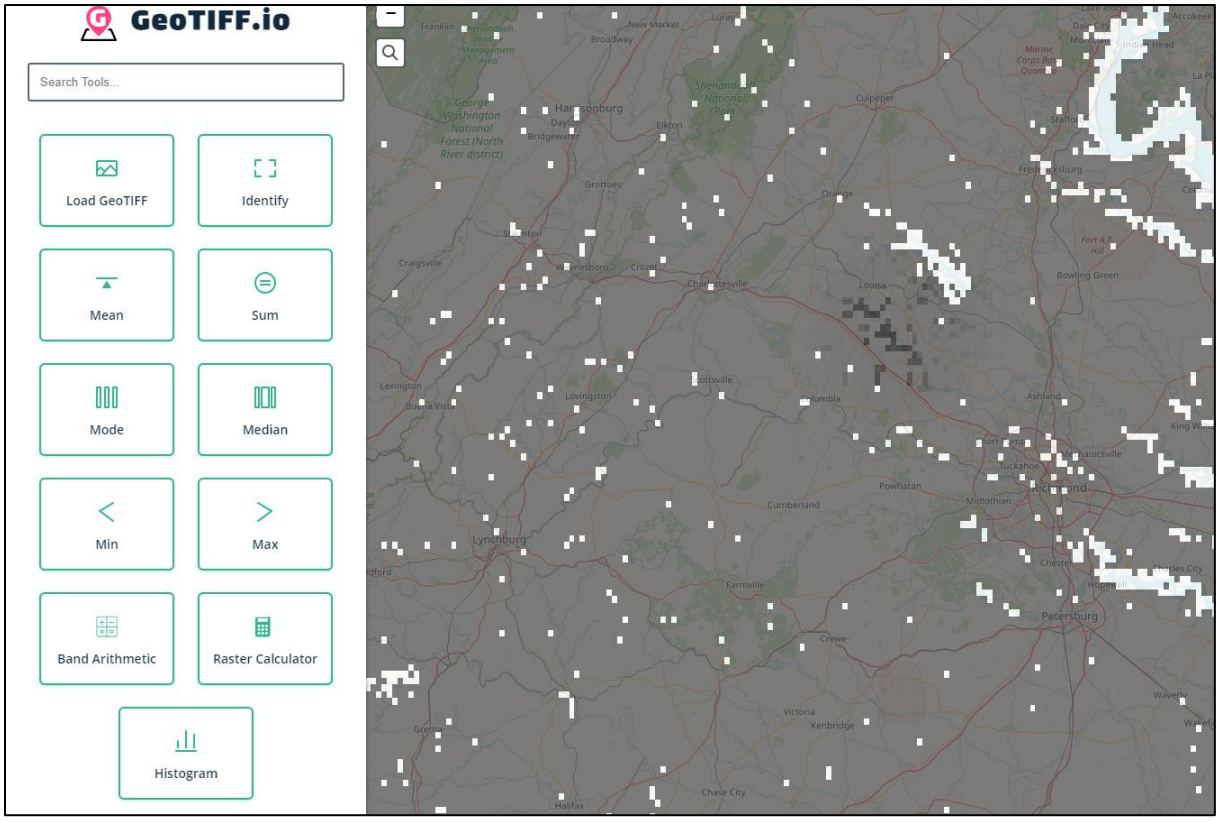
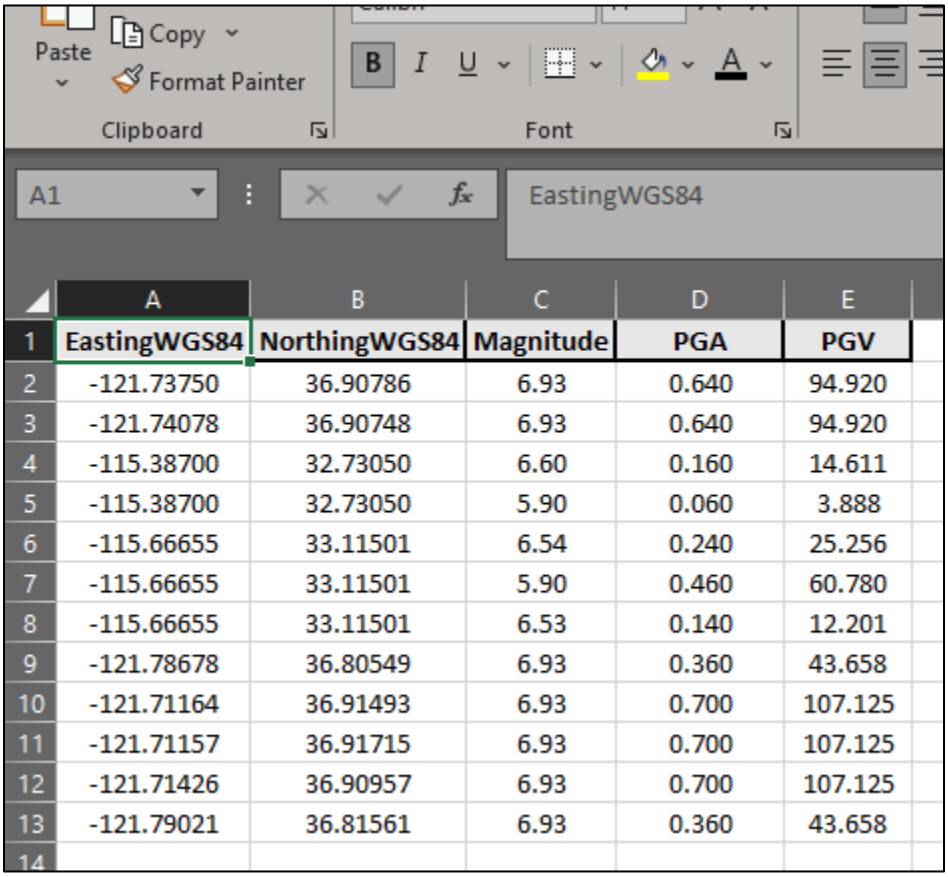


Figure 7. Exploring *RapidLiq* predictions with the http://app.geotiff.io/) web explorer.

Example 2. Input type: Tabular

The software also allows for tabular input, should a user wish to enter specific sites of interest and ground-motion parameters at those sites, rather than study the regional effects of an earthquake. To use this option, select the "Tabular" tab from the user interface and create a .xlsx file with columnar data in the order of: (1) Latitude (WGS84); (2) Longitude (WGS84); (3) Moment Magnitude (*Mw*); (4) Peak Ground Acceleration, *PGA*, in g; and (5) Peak Ground Velocity, *PGV*, in cm/sec. An example input file is shown below in Figure 8. Import this table to *RapidLiq* by selecting the "Input Table" button. *RapidLiq* will inform the user whether the import is successful and display the tabular data on the upper right side of the user interface. Next, select the "Extract Model Parameters" button to compile necessary model inputs. This may take several seconds depending on the size of the dataset. After extraction is complete, parameters at each site of interest are displayed on the lower right side of the user interface. Press "Run *RapidLiq*" to compute

the predictions using each of the four models. A Table of results will appear and a new timestamped .xlsx file will be created in the directory where the input file is located.



	A	B	C	D	E
1	EastingWGS84	NorthingWGS84	Magnitude	PGA	PGV
2	-121.73750	36.90786	6.93	0.640	94.920
3	-121.74078	36.90748	6.93	0.640	94.920
4	-115.38700	32.73050	6.60	0.160	14.611
5	-115.38700	32.73050	5.90	0.060	3.888
6	-115.66655	33.11501	6.54	0.240	25.256
7	-115.66655	33.11501	5.90	0.460	60.780
8	-115.66655	33.11501	6.53	0.140	12.201
9	-121.78678	36.80549	6.93	0.360	43.658
10	-121.71164	36.91493	6.93	0.700	107.125
11	-121.71157	36.91715	6.93	0.700	107.125
12	-121.71426	36.90957	6.93	0.700	107.125
13	-121.79021	36.81561	6.93	0.360	43.658
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Figure 8. Example input table for *RapidLiq* tabular analyses.

Acknowledgements

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References

Geyin, M., Maurer, B.W., and Christofferson, K. (2021). An AI driven, mechanistically grounded geospatial liquefaction model for rapid response and scenario planning. *Soil Dynamics and Earthquake Engineering, In Review.*

Rashidian V and Baise LG (2020) Regional efficacy of a global geospatial liquefaction model. *Engineering Geology*, 105644.