



liquefACT

NORSAR

Exploring the Earth



# A Software to Assess Liquefaction-induced Damage to Critical Infrastructures

## Main Outcomes from LIQUEFACT Project

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Senior Research Engineer

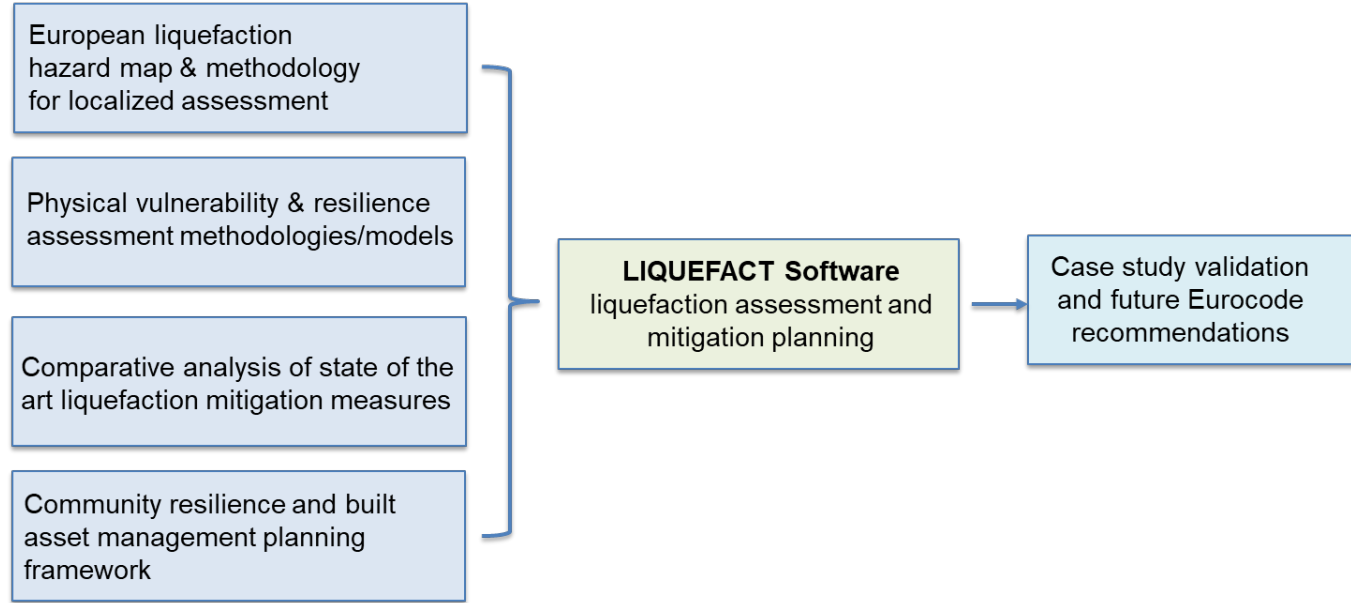
NORSAR, Norway

LIQUEFACT Project Workshops, EUCENTER, October 8th, 2019

# LIQUEFACT Software

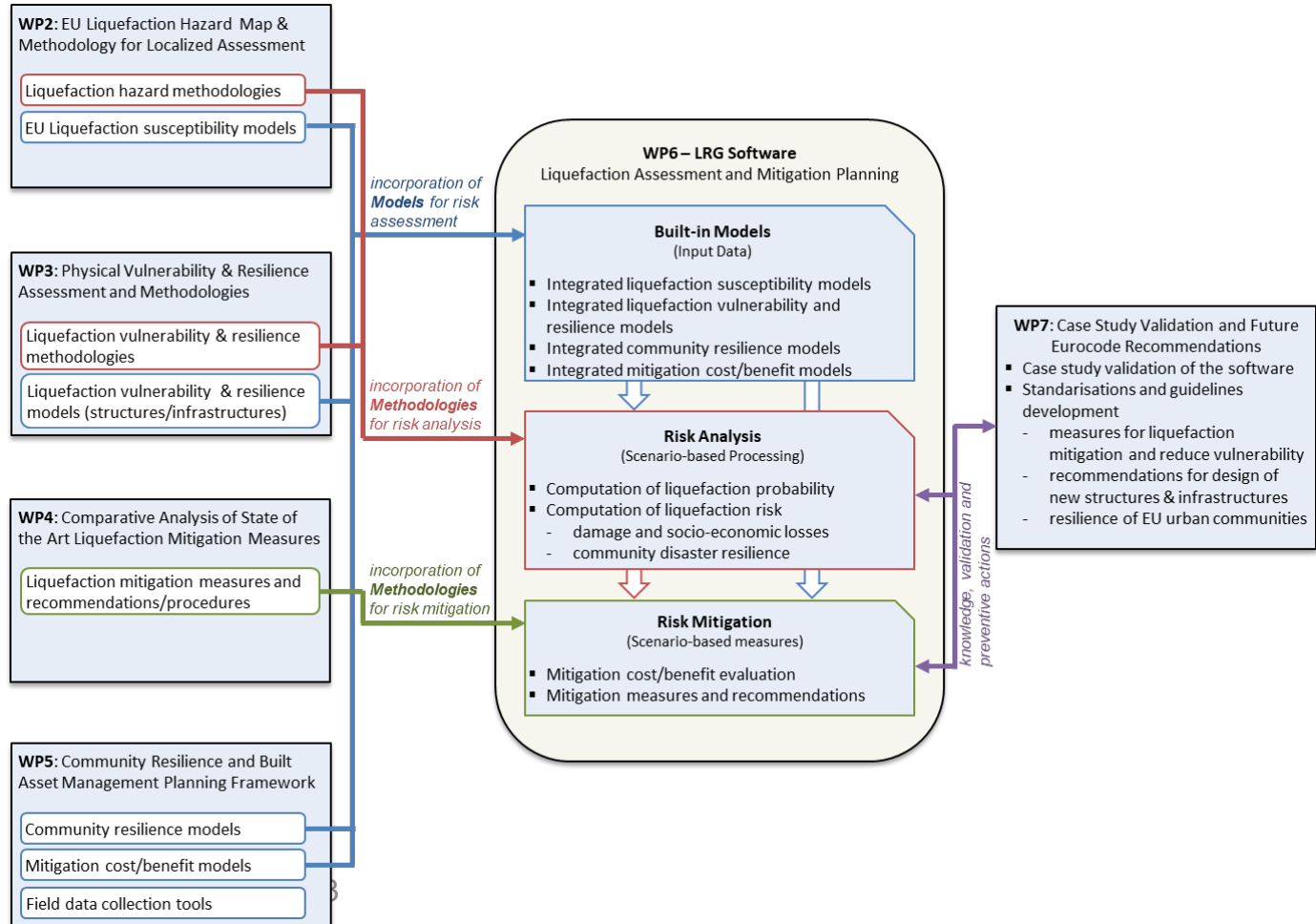
One of the key outputs from the project is the LIQUEFACT software, under development at NORSAR

The basic for the development of the LIQUEFACT software consists in integrating the knowledge (methodologies, procedures and models) from WP2, WP3, WP4 and WP5



By using LIQUEFACT software, civil engineers and relevant stakeholders involved in the design and implementation can be guided to assess the feasibility and cost-benefit of certain liquefaction mitigation techniques or compute the socio-economic impacts of risk reduction and resilience improvement strategies.

# LIQUEFACT Software



# LIQUEFACT Software

LIQUEFACT software is a user-friendly toolbox for liquefaction mitigation planning and decision support, able to estimate and predict the likely consequences of an earthquake-induced liquefaction damage at individual structure /infrastructure, at regional or city level

The screenshot displays the LIQUEFACT software interface, which is divided into several panels. The main panel on the left is titled "Liquefaction Reference Guide" and contains a "Hazard Data Input" tab. This tab includes sections for "Type of Analysis and Geographical Region", "Geographical region", and "Location of interest".

The "Type of Analysis and Geographical Region" section includes dropdown menus for "Assessment analysis" (set to "Hazard, Risk & Mitigation"), "Risk assessment" (set to "Physical Impact & Economic"), and "Mitigation analysis" (set to "Existing Structures").

The "Geographical region" section includes a "Select region..." button and a "Set region" button. Below these are input fields for "North" (44.8049), "West" (11.4088), "East" (11.4119), and "South" (44.8032).

The "Location of interest" section includes a "SHAPE or CSV file with building locations. Only locations within the selected region are imported." and an "Import locations..." button.

On the right side of the interface, there is a "Location View" panel displaying a table of location data. The table has columns for "Risk Identification", "Latitude", "Longitude", "Street", "District", "Municipal", "City", "Region", "Postal Code", "Geo-code", and "Shape".

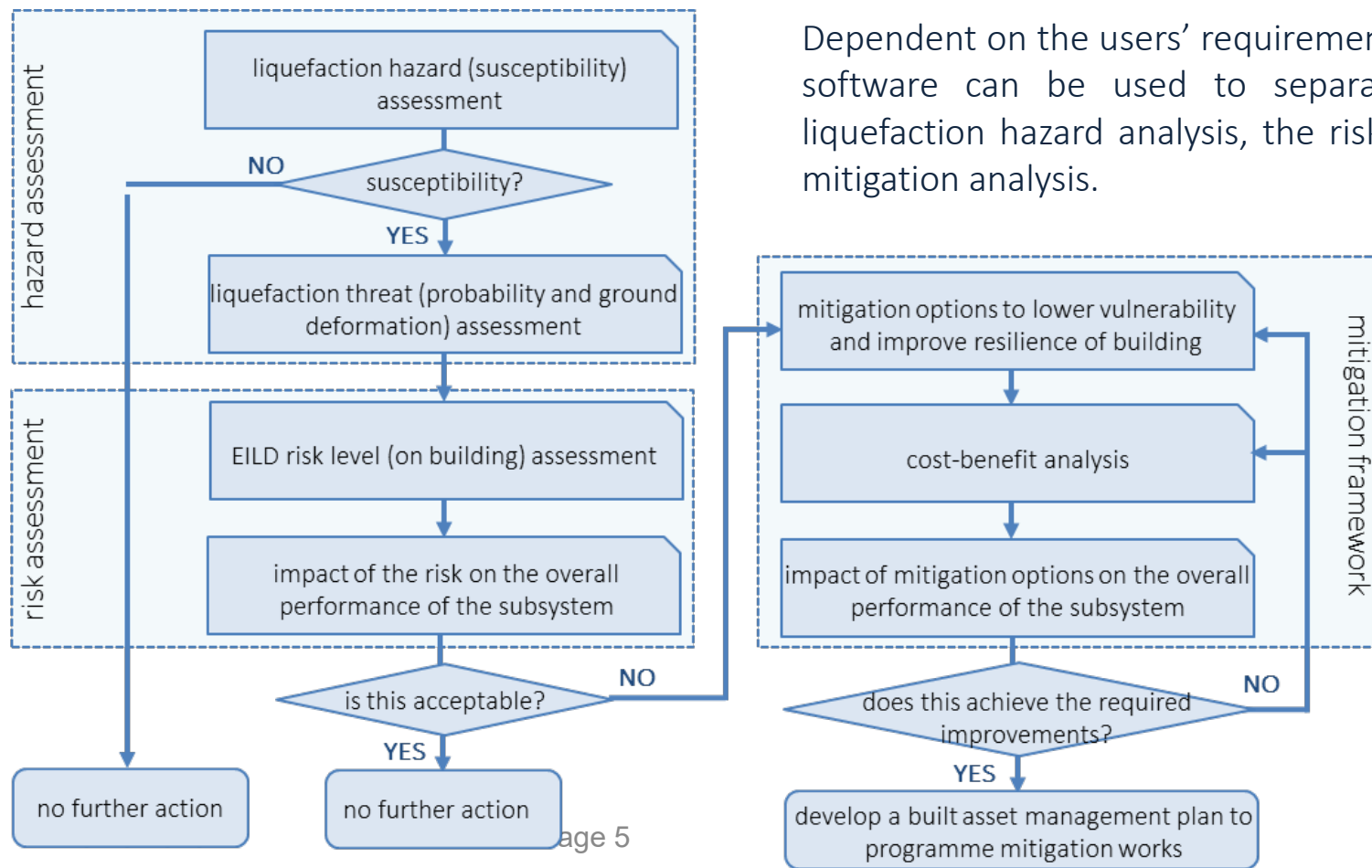
| Risk Identification | Latitude | Longitude | Street    | District | Municipal | City    | Region         | Postal Code | Geo-code | Shape |
|---------------------|----------|-----------|-----------|----------|-----------|---------|----------------|-------------|----------|-------|
| 1                   | B019     | 44.803789 | 11.410564 |          |           | Bologna | Emilia-Romagna | 40100       | 1        | ✓     |
| 2                   | B020     | 44.804494 | 11.410094 |          |           | Bologna | Emilia-Romagna | 40100       | 1        | ✓     |
| 3                   | B021     | 44.804180 | 11.410419 |          |           | Bologna | Emilia-Romagna | 40100       | 1        | ✓     |
| 4                   | B022     | 44.804892 | 11.411208 |          |           | Bologna | Emilia-Romagna | 40100       | 1        | ✓     |
| 5                   | B023     | 44.804677 | 11.411108 |          |           | Bologna | Emilia-Romagna | 40100       | 1        | ✓     |
| 6                   | B024     | 44.804846 | 11.410874 |          |           | Bologna | Emilia-Romagna | 40100       | 1        | ✓     |
| 7                   | B025     | 44.804519 | 11.411434 |          |           | Bologna | Emilia-Romagna | 40100       | 1        | ✓     |
| 8                   | B026     | 44.804201 | 11.411934 |          |           | Bologna | Emilia-Romagna | 40100       | 1        | ✓     |

Below the table is an "Export..." button.

At the bottom right, there is a "Map View" panel showing a map of the area. The map includes labels for "San Carlo Centro", "Via Goethe-Rossini", "Via Carlo Marzotto", "Via Alfonso-Lar", "Via Carlo Evangelisti", and "Via Carlo Marzotto". A red pin is located on the map.

On the far right, there is a "Map overlays" panel with checkboxes for "Shapes" (Region), "Markers" (Locations), and "Hazard maps" (PGA, LSN, LPT, ESP, LSN Risk Level, LPT Risk Level, GD). The "Locations" checkbox is checked.

# Processing and Analysis Concept



Dependent on the users' requirements, the LIQUEFACT software can be used to separately conduct the liquefaction hazard analysis, the risk analysis, and the mitigation analysis.

# Processing and Analysis Concept

Type of Analysis and Geographical Region    Hazard Data Input    Risk Data Input

Type of analysis

Assessment analysis    Hazard, Risk & Mitigation ▼

Risk assessment    Hazard ▼

Mitigation analysis    Hazard, Risk & Mitigation  
Existing Structures ▼

Type of Analysis and Geographical Region    Hazard Data Input    Risk Data Input

Type of analysis

Assessment analysis    Hazard, Risk & Mitigation ▼

Risk assessment    Physical Impact & Economic ▼

Mitigation analysis    Physical Impact  
Physical Impact & Economic

Type of Analysis and Geographical Region    Hazard Data Input    Risk Data Input

Type of analysis

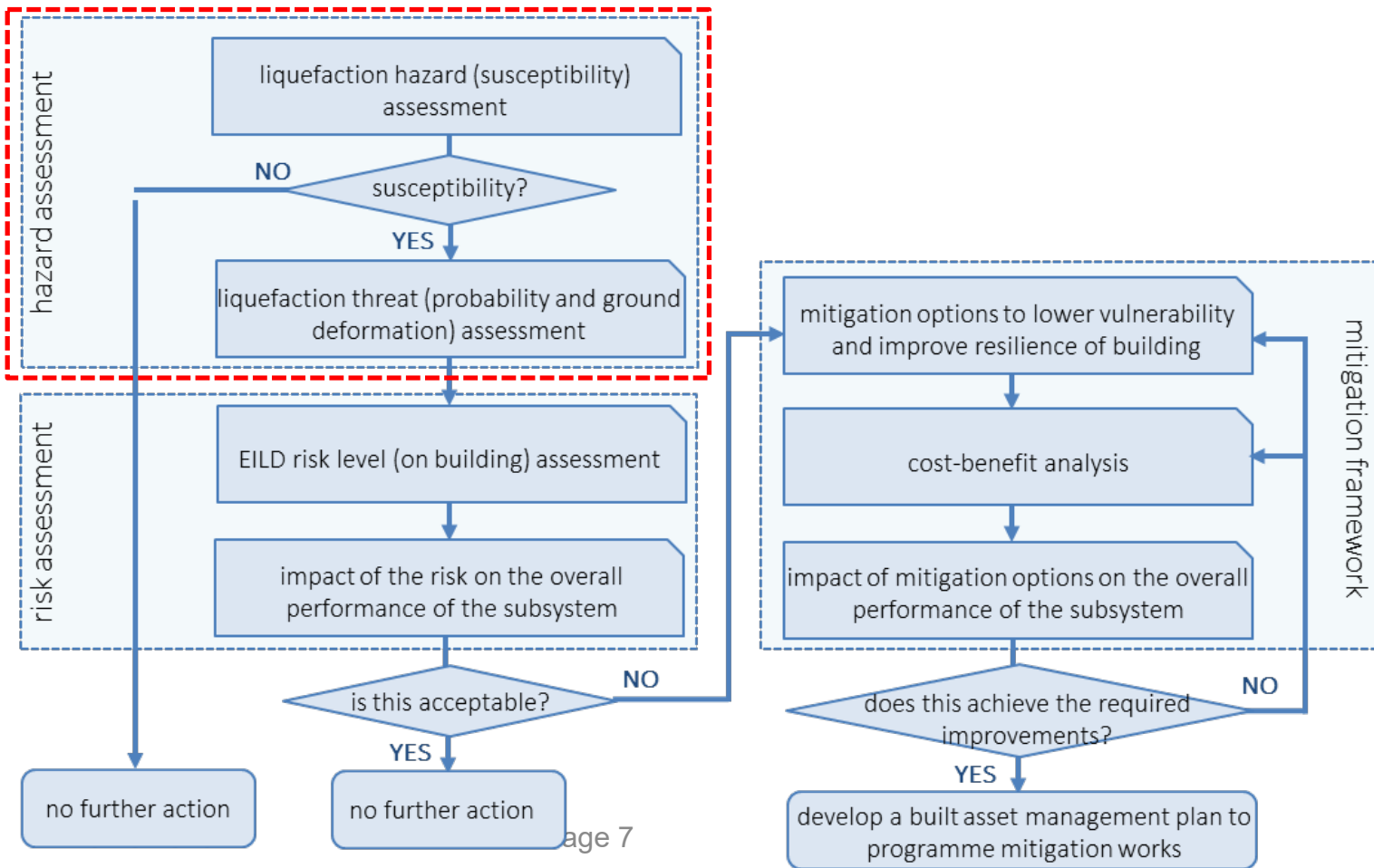
Assessment analysis    Hazard, Risk & Mitigation ▼

Risk assessment    Physical Impact & Economic ▼

Mitigation analysis    Existing Structures ▼

Geographical region    Existing Structures  
New Construction

# Liquefaction Hazard Assessment



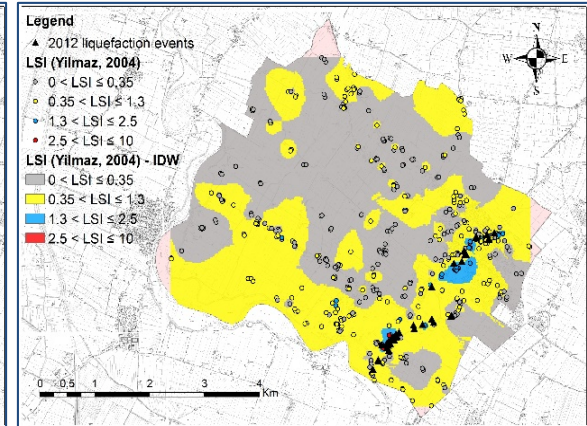
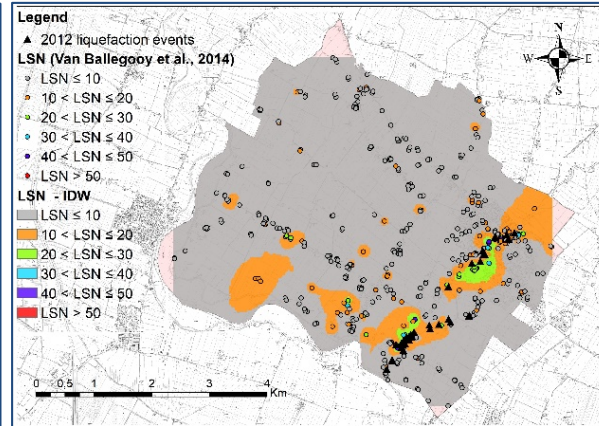
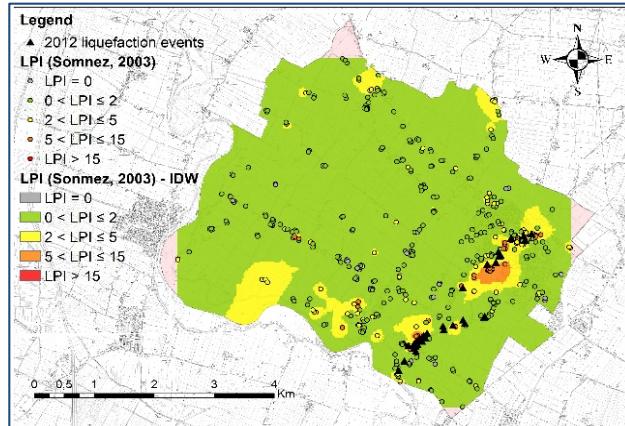


# Liquefaction Hazard Assessment - Susceptibility

## ○ User-Defined and Pre-Defined Model

Evaluation of liquefaction susceptibility of the soil at a specific location: qualitative analysis allowing end-users to identify how likely an asset (e.g. individual building/CI asset, portfolio of buildings/distributed infrastructure assets, etc.) is susceptible to liquefaction;

## User-Defined: Microzonation maps



Ref: DELIVERABLE D2.7: Methodology for assessment of earthquake-induced risk of soil liquefaction at the four European testing sites (microzonation) (<http://www.liquifact.eu>)

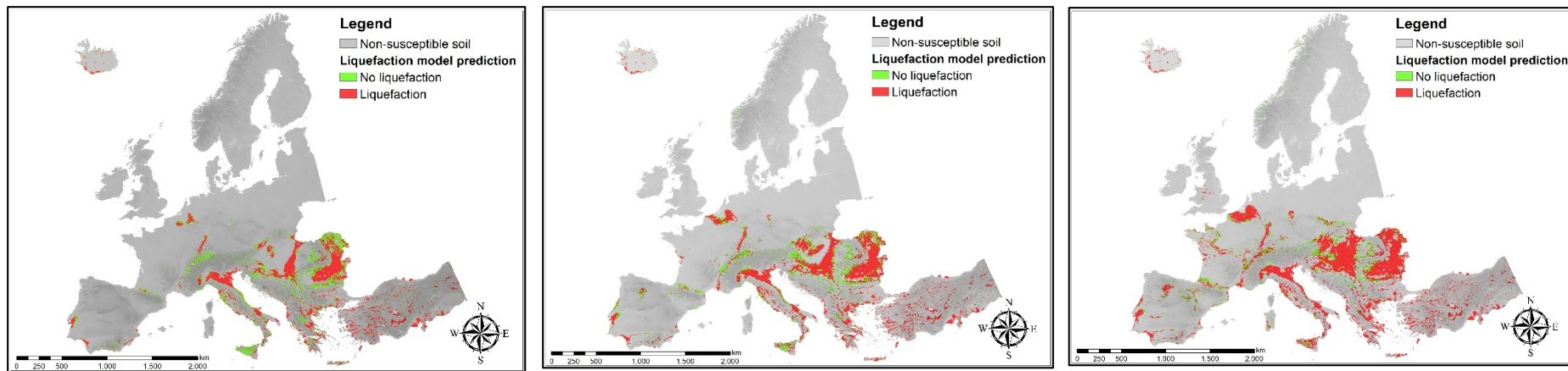


# Liquefaction Hazard Assessment - Susceptibility

## ○ User-Defined and Pre-Defined Model

Evaluation of liquefaction susceptibility of the soil at a specific location: qualitative analysis allowing end-users to identify how likely an asset (e.g. individual building/CI asset, portfolio of buildings/distributed infrastructure assets, etc.) is susceptible to liquefaction;

## Pre-Defined: Macrozonation maps



European liquefaction binary model (ADASYN) prediction maps for 475 years, 975 years and 2475 years return period.

# Liquefaction Hazard Assessment - Susceptibility

- User-Defined and Pre-Defined Model

User-Defined: upload liquefaction hazard maps in terms of LPI, LSN, LSI, LDI, Settlement

Pre-Defined: used embedded European Liquefaction Hazard map

The screenshot displays the 'Liquefaction Reference Guide' software interface. The 'Pre-Processing' tab is active, showing options for 'Type of Analysis and Geographical Region', 'Hazard Data Input', and 'Risk Data Input'. Under 'Hazard Data Input', the 'Liquefaction Hazard Model' is selected. A file selection dialog is open, prompting the user to 'Please select the file' with a 'Browse...' button.

The 'Location View' table lists 8 locations with the following data:

|   | Risk Identification | Latitude  | Longitude | Street | District | Municipal | City    | Region         | Postal Code | Geo-code | Shape |
|---|---------------------|-----------|-----------|--------|----------|-----------|---------|----------------|-------------|----------|-------|
| 1 | B019                | 44.803789 | 11.410564 |        |          |           | Bologna | Emilia-Romagna | 40100       | 1        | ✓     |
| 2 | B020                | 44.804494 | 11.410094 |        |          |           | Bologna | Emilia-Romagna | 40100       | 1        | ✓     |
| 3 | B021                | 44.804180 | 11.410419 |        |          |           | Bologna | Emilia-Romagna | 40100       | 1        | ✓     |
| 4 | B022                | 44.804892 | 11.411208 |        |          |           | Bologna | Emilia-Romagna | 40100       | 1        | ✓     |
| 5 | B023                | 44.804677 | 11.411108 |        |          |           | Bologna | Emilia-Romagna | 40100       | 1        | ✓     |
| 6 | B024                | 44.804846 | 11.410874 |        |          |           | Bologna | Emilia-Romagna | 40100       | 1        | ✓     |
| 7 | B025                | 44.804519 | 11.411434 |        |          |           | Bologna | Emilia-Romagna | 40100       | 1        | ✓     |
| 8 | B026                | 44.804201 | 11.411934 |        |          |           | Bologna | Emilia-Romagna | 40100       | 1        | ✓     |

The 'Map View' shows a street map of Bologna with a red location pin. The 'Map overlays' panel on the right includes options for 'Shapes' (Region), 'Markers' (Locations, Ground amplification profiles, Liquefaction profiles, Marker labels), and 'Hazard maps' (PGA, LSN, LPI, ESP, LSN Risk Level, LPI Risk Level, GD).

# Liquefaction Hazard Assessment - Susceptibility

```
LiquefactionHazard_475YRP.txt - Notepad
File Edit Format View Help
#Liquefaction Hazard in Europe for 475 Years Return Period
# In 3rd Column: 0: Non-susceptible / 1: No Liquefaction / 2: Liquefaction
#Longitude      Latitude      Liquefaction Hazard
24.024000 71.028000 0
24.047000 71.027000 0
24.654000 70.988000 0
24.677000 70.986000 0
24.747000 70.982000 0
-----
Ln 1, Col 1 100%
```

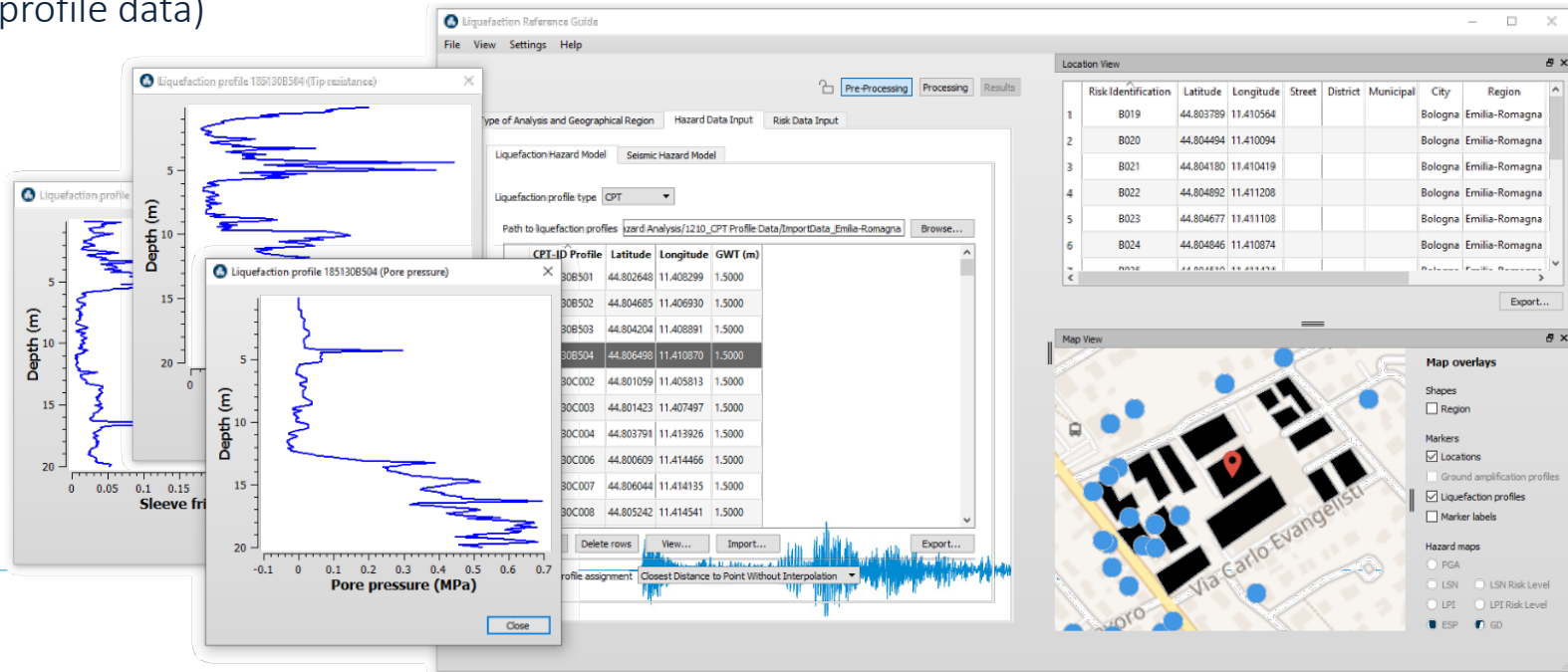
```
LiquefactionHazard_975YRP.txt - Notepad
File Edit Format View Help
#Liquefaction Hazard in Europe for 975 Years Return Period
# In 3rd Column: 0: Non-susceptible / 1: No Liquefaction / 2: Liquefaction
#Longitude      Latitude      Liquefaction Hazard
24.024000 71.028000 0
24.047000 71.027000 0
24.654000 70.988000 0
24.677000 70.986000 0
24.747000 70.982000 0
24.980000 70.966000 0
-----
Ln 25, Col 22 100%
```

```
LiquefactionHazard_2475YRP.txt - Notepad
File Edit Format View Help
#Liquefaction Hazard in Europe for 2475 Years Return Period
# In 3rd Column: 0: Non-susceptible / 1: No Liquefaction / 2: Liquefaction
#Longitude      Latitude      Liquefaction Hazard
24.024000 71.028000 0
24.047000 71.027000 0
24.654000 70.988000 0
24.677000 70.986000 0
24.747000 70.982000 0
24.980000 70.966000 0
25.003000 70.965000 0
-----
Ln 10, Col 22 100%
```

# Liquefaction Hazard Assessment – Quantitative Analysis

- CPT, SPT, Vs profile

evaluation of liquefaction probability for a given level of amplitude and duration of ground shaking: quantitative analysis for liquefaction potential allowing end-users to evaluate quantitatively the level of the threat. End-users will be able to provide different type of inputs data for liquefaction assessment (CPT, SPT, Vs30 profile data)



# Liquefaction Hazard Assessment – Seismic Input at bedrock

- Scenario Earthquake
- Predefined Uniform Hazard
- User-defined seismic hazard

Type of Analysis and Geographical Region    Hazard Data Input    Risk Data Input

Liquefaction Hazard Model    Seismic Hazard Model

Hazard Analysis: Scenario Earthquake

Please input:

|                  |       |           |       |
|------------------|-------|-----------|-------|
| Latitude         | 44.89 | Longitude | 11.23 |
| Focal Depth (km) | 10    | Magnitude | 5.9   |
| Strike*          | 270   | Dip*      | 83    |
| A                | 5     | B         | 1.1   |

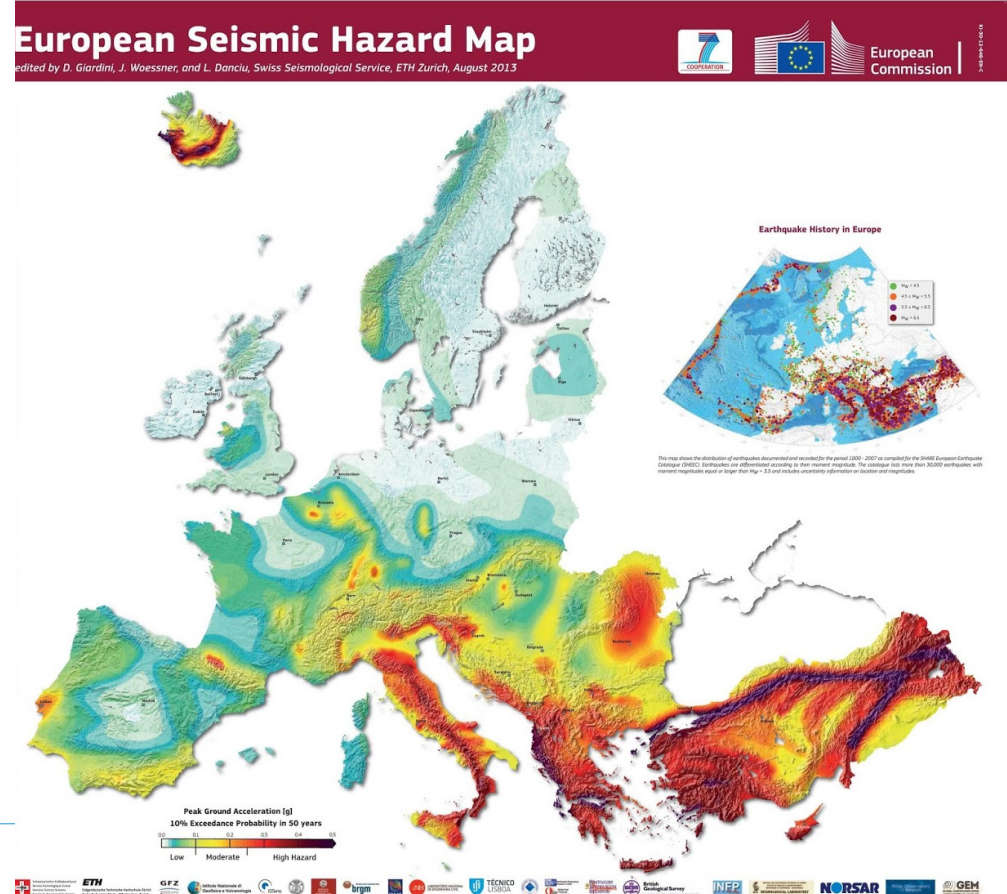
Fault Mechanism: Strike-Slip

Attenuation Table: Boore and Atkinson (2008) NGA    View...

**\*Positive clockwise.**

# Liquefaction Hazard Assessment – Seismic Input at bedrock

- Scenario Earthquake
- Predefined Uniform Hazard
- User-defined seismic hazard



# Liquefaction Hazard Assessment – Seismic action at ground surface

## Response spectrum

- Code-design (Eurocode-8)
- Site-specific (Vs30 profiles)

Liquefaction Reference Guide

File View Settings Help

Pre-Processing Processing Results

Type of Analysis and Geographical Region Hazard Data Input Risk Data Input

Liquefaction Hazard Model Seismic Hazard Model

Hazard Analysis Scenario Earthquake

Please input the Earthquake Parameters

Latitude 44.89 Longitude 11.23

Focal Depth (km) 10 Magnitude 5.9

Strike\* 270 Dip\* 83

Fault Mechanism Strike-Slip

Attenuation Table Boore and Atkinson (2008) NGA View...

\*Positive clockwise.

Response Spectrum Code-Design

|   | Ground Amp Profile | Latitude  | Longitude | Soil Type    |
|---|--------------------|-----------|-----------|--------------|
| 1 | 185130B002         | 44.830508 | 11.357707 | EC8-Type-1-B |
| 2 | 185130B003         | 44.830548 | 11.367877 | EC8-Type-1-B |
| 3 | 185130B004         | 44.825187 | 11.362831 | EC8-Type-1-B |
| 4 | 185130B005         | 44.825345 | 11.374342 | EC8-Type-1-B |
| 5 | 185130C034         | 44.830627 | 11.379545 | EC8-Type-1-B |

Add row Delete rows View... Import...

Export...

185130B003 - Code Design Response Spectrum of type 1

Normalized spectral acceleration

Period T (s)

Soil Type EC8-Type-1-B

Close



# Liquefaction Hazard Assessment – Interpolation

Liquefaction Hazard Model    Seismic Hazard Model

Liquefaction profile type: CPT


Path to liquefaction profiles: D:\FTWARE\1200\_IRG\_Liquefaction Hazard Analysis\1210\_C

|    | CPT-ID Profile | Latitude  | Longitude | GWT (m) |
|----|----------------|-----------|-----------|---------|
| 1  | 185130B501     | 44.802648 | 11.408299 | 1.5000  |
| 2  | 185130B502     | 44.804685 | 11.406930 | 1.5000  |
| 3  | 185130B503     | 44.804204 | 11.408891 | 1.5000  |
| 4  | 185130B504     | 44.806498 | 11.410870 | 1.5000  |
| 5  | 185130C002     | 44.801059 | 11.405813 | 1.5000  |
| 6  | 185130C003     | 44.801423 | 11.407497 | 1.5000  |
| 7  | 185130C004     | 44.803791 | 11.413926 | 1.5000  |
| 8  | 185130C006     | 44.800609 | 11.414466 | 1.5000  |
| 9  | 185130C007     | 44.806044 | 11.414135 | 1.5000  |
| 10 | 185130C008     | 44.805242 | 11.414541 | 1.5000  |
| 11 | 185130C009     | 44.805236 | 11.411079 | 1.5000  |
| 12 | 185130C010     | 44.803746 | 11.409698 | 1.5000  |
| 13 | 185130C011     | 44.803025 | 11.410717 | 1.5000  |
| 14 | 185130C012     | 44.806553 | 11.400562 | 1.5000  |
| 15 | 185130C013     | 44.806897 | 11.401372 | 1.5000  |

Add row Delete rows View... Import...

Ground amp profile assignment: Closest Distance to Point Without Interpolation

Ground amp profile assignment: Closest Distance to Point Without Interpolation

 Interpolation Settings ✕

Interpolation method

☒ Kriging (using weighted average if Kriging fails)

Variogram model: Stable Manual Kriging

Filters

☐ Neighborhood ☐ Variance filter ☐ Median filtering

☐ Shepard's Weighted Average

☒ Distance damping

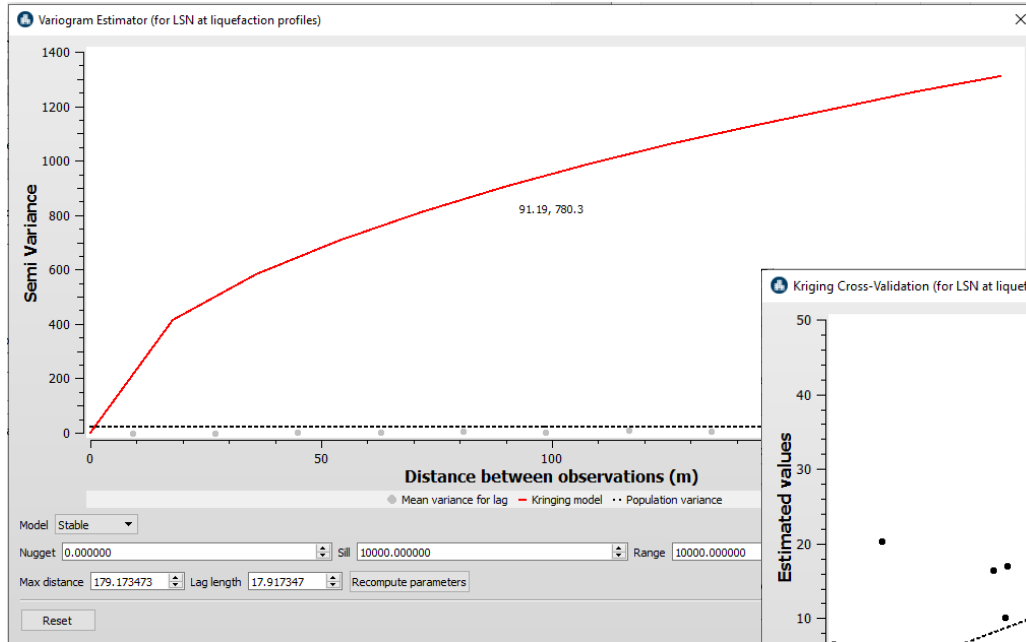
Interpolation neighborhood

☒ Average minimum distance between profiles

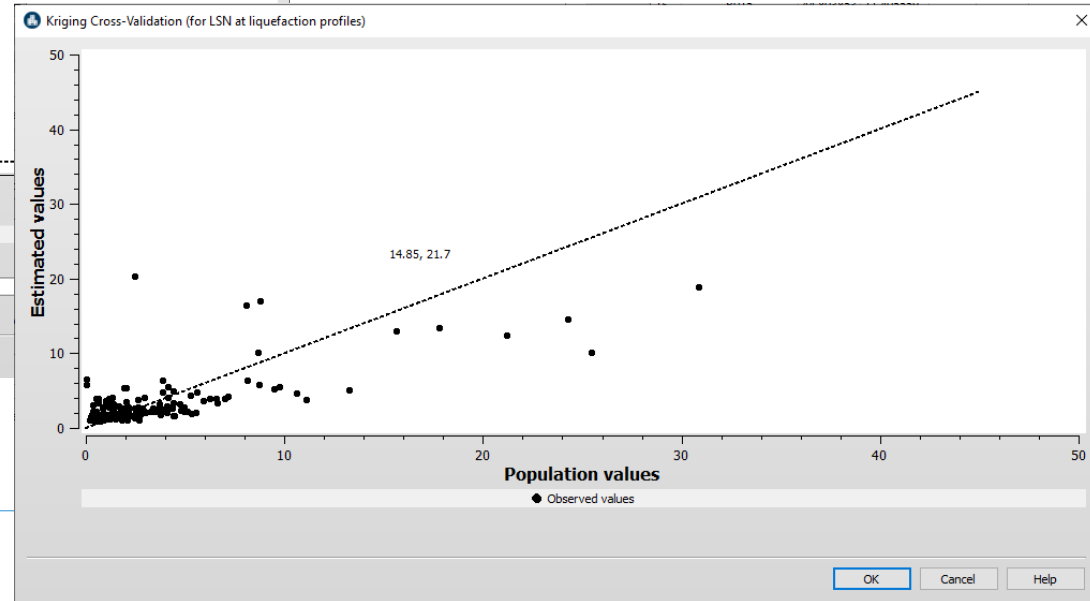
☐ Radius (m) 600

Reset OK Cancel Help

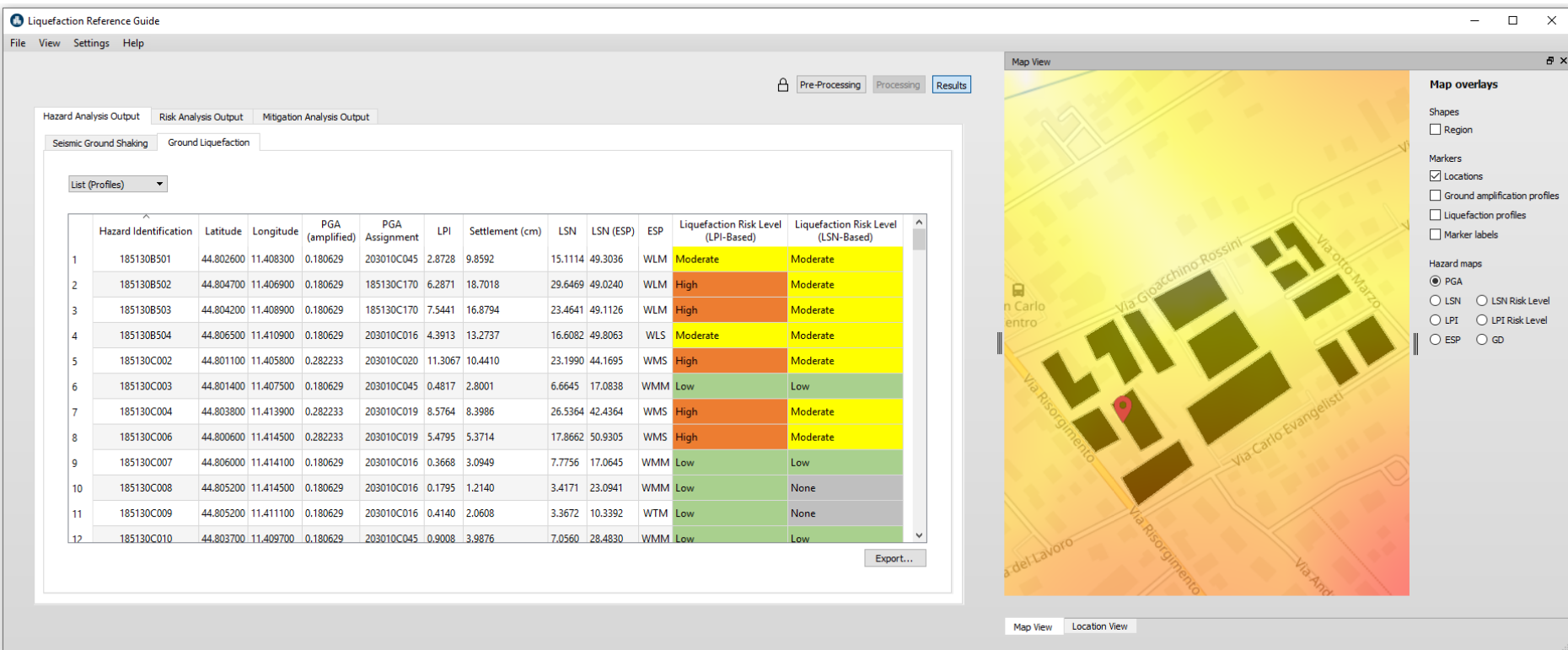
# Liquefaction Hazard Assessment – Seismic action at ground surface



- Variogram estimator
- Kriging cross-validation



# Liquefaction Hazard Assessment – Quantitative Analysis

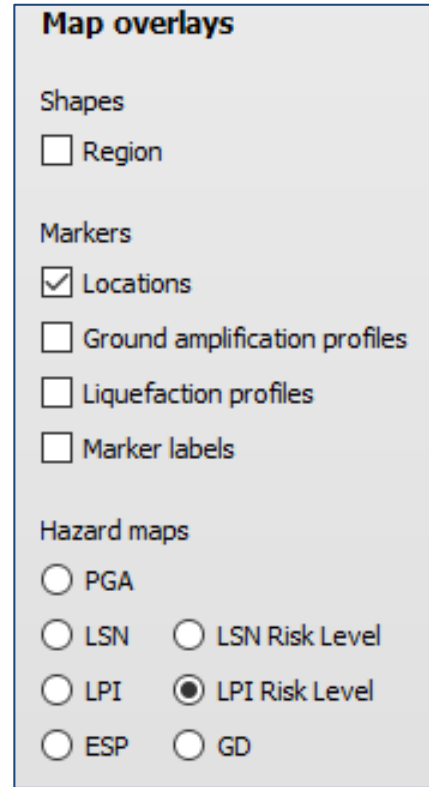
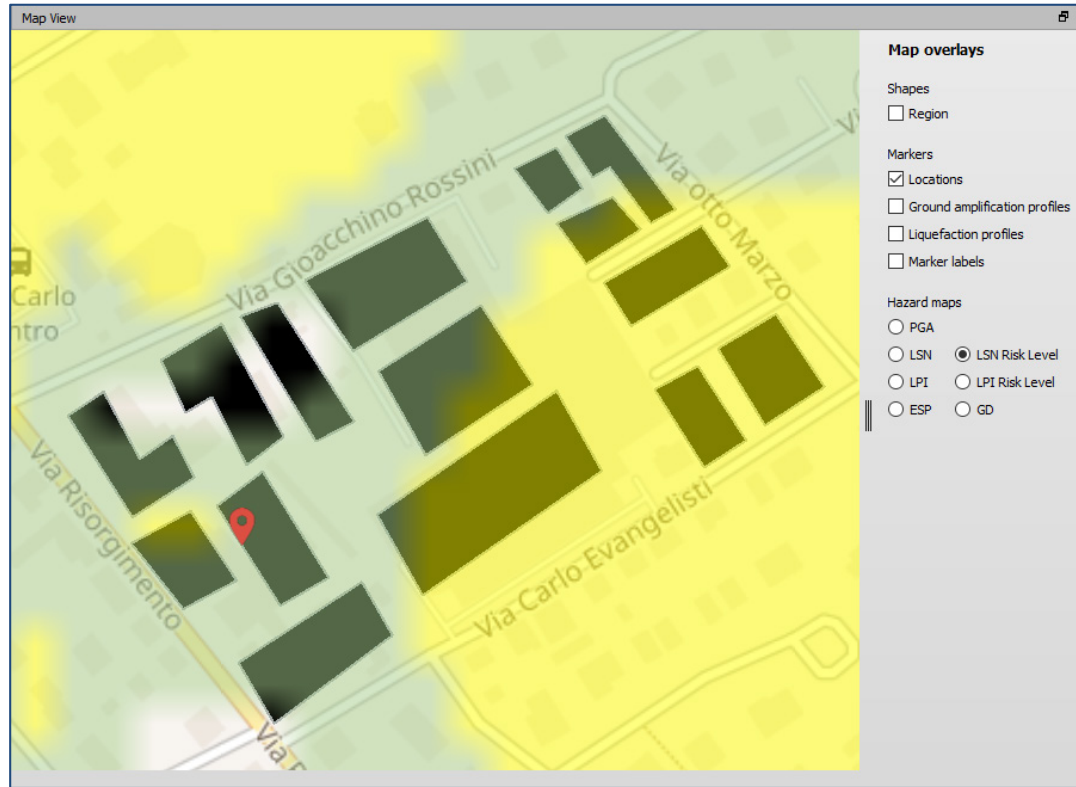


# Liquefaction Hazard Assessment – Quantitative Analysis

|    | Hazard Identification | Latitude  | Longitude | PGA (amplified) | PGA Assignment | LPI     | Settlement (cm) | LSN     | LSN (ESP) | ESP | Liquefaction Risk Level (LPI-Based) | Liquefaction Risk Level (LSN-Based) |
|----|-----------------------|-----------|-----------|-----------------|----------------|---------|-----------------|---------|-----------|-----|-------------------------------------|-------------------------------------|
| 1  | 185130B501            | 44.802600 | 11.408300 | 0.180629        | 203010C045     | 2.8728  | 9.8592          | 15.1114 | 49.3036   | WLM | Moderate                            | Moderate                            |
| 2  | 185130B502            | 44.804700 | 11.406900 | 0.180629        | 185130C170     | 6.2871  | 18.7018         | 29.6469 | 49.0240   | WLM | High                                | Moderate                            |
| 3  | 185130B503            | 44.804200 | 11.408900 | 0.180629        | 185130C170     | 7.5441  | 16.8794         | 23.4641 | 49.1126   | WLM | High                                | Moderate                            |
| 4  | 185130B504            | 44.806500 | 11.410900 | 0.180629        | 203010C016     | 4.3913  | 13.2737         | 16.6082 | 49.8063   | WLS | Moderate                            | Moderate                            |
| 5  | 185130C002            | 44.801100 | 11.405800 | 0.282233        | 203010C020     | 11.3067 | 10.4410         | 23.1990 | 44.1695   | WMS | High                                | Moderate                            |
| 6  | 185130C003            | 44.801400 | 11.407500 | 0.180629        | 203010C045     | 0.4817  | 2.8001          | 6.6645  | 17.0838   | WMM | Low                                 | Low                                 |
| 7  | 185130C004            | 44.803800 | 11.413900 | 0.282233        | 203010C019     | 8.5764  | 8.3986          | 26.5364 | 42.4364   | WMS | High                                | Moderate                            |
| 8  | 185130C006            | 44.800600 | 11.414500 | 0.282233        | 203010C019     | 5.4795  | 5.3714          | 17.8662 | 50.9305   | WMS | High                                | Moderate                            |
| 9  | 185130C007            | 44.806000 | 11.414100 | 0.180629        | 203010C016     | 0.3668  | 3.0949          | 7.7756  | 17.0645   | WMM | Low                                 | Low                                 |
| 10 | 185130C008            | 44.805200 | 11.414500 | 0.180629        | 203010C016     | 0.1795  | 1.2140          | 3.4171  | 23.0941   | WMM | Low                                 | None                                |
| 11 | 185130C009            | 44.805200 | 11.411100 | 0.180629        | 203010C016     | 0.4140  | 2.0608          | 3.3672  | 10.3392   | WTM | Low                                 | None                                |
| 12 | 185130C010            | 44.803700 | 11.409700 | 0.180629        | 203010C045     | 0.9008  | 3.9876          | 7.0560  | 28.4830   | WMM | Low                                 | Low                                 |



# Liquefaction Hazard Assessment – Quantitative Analysis

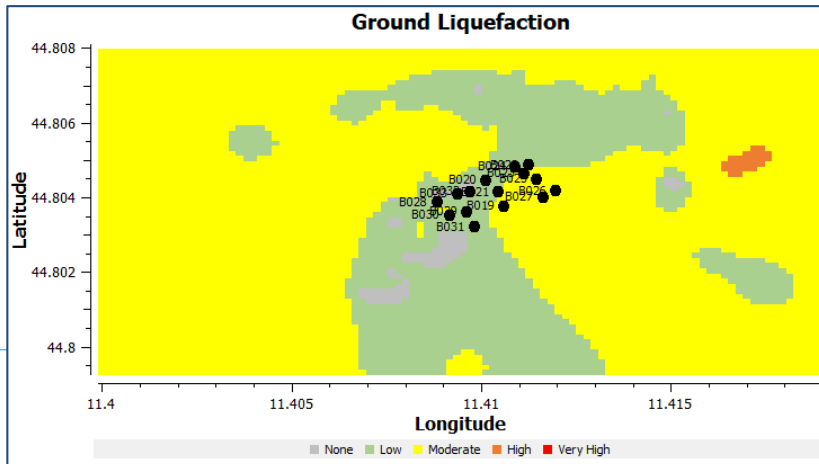
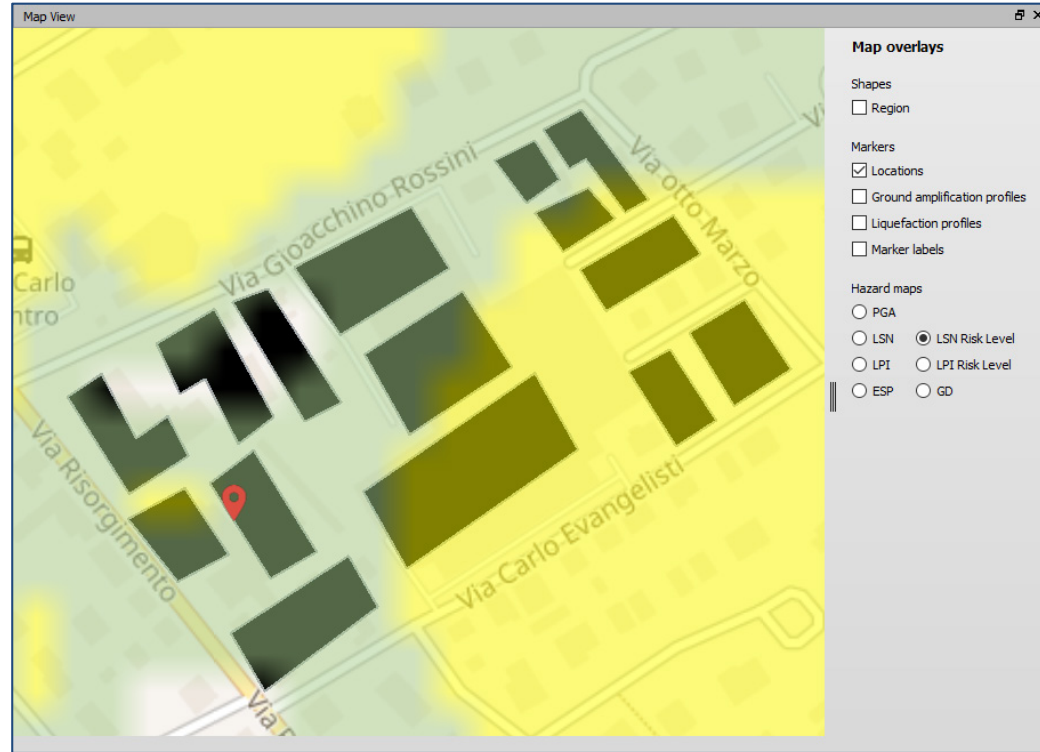


# Liquefaction Hazard Assessment – Quantitative Analysis

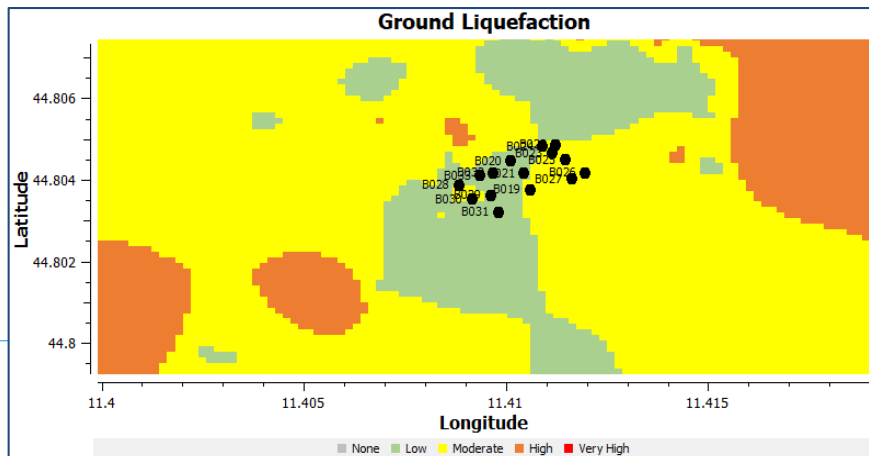
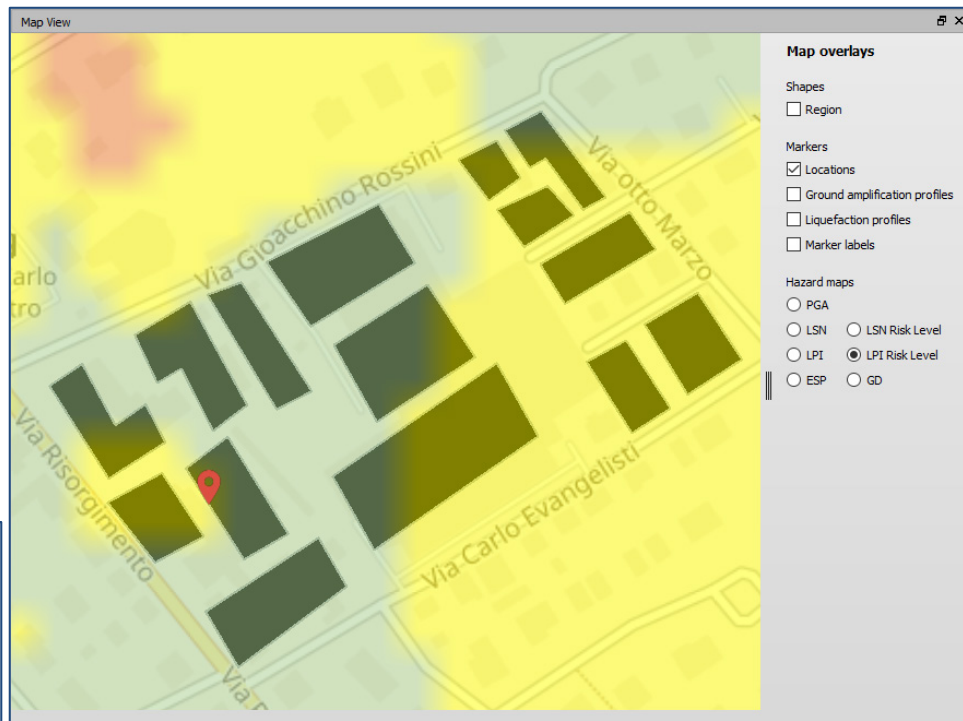
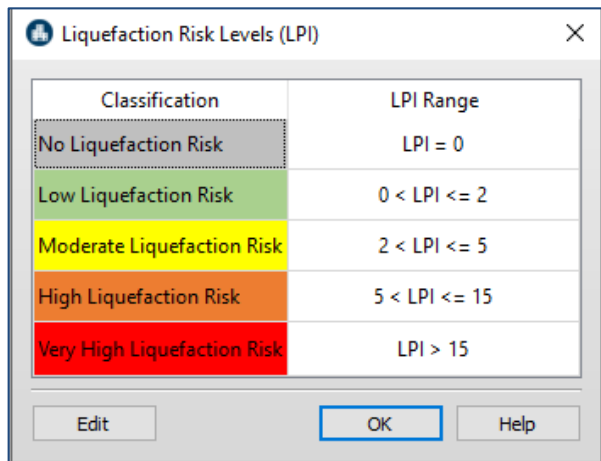
Liquefaction Risk Levels (LSN)

| Classification              | LSN Range          |
|-----------------------------|--------------------|
| No Liquefaction Risk        | $LSN < 5$          |
| Low Liquefaction Risk       | $5 < LSN \leq 10$  |
| Moderate Liquefaction Risk  | $10 < LSN \leq 30$ |
| High Liquefaction Risk      | $30 < LSN \leq 50$ |
| Very High Liquefaction Risk | $LSN > 50$         |

Edit OK Help

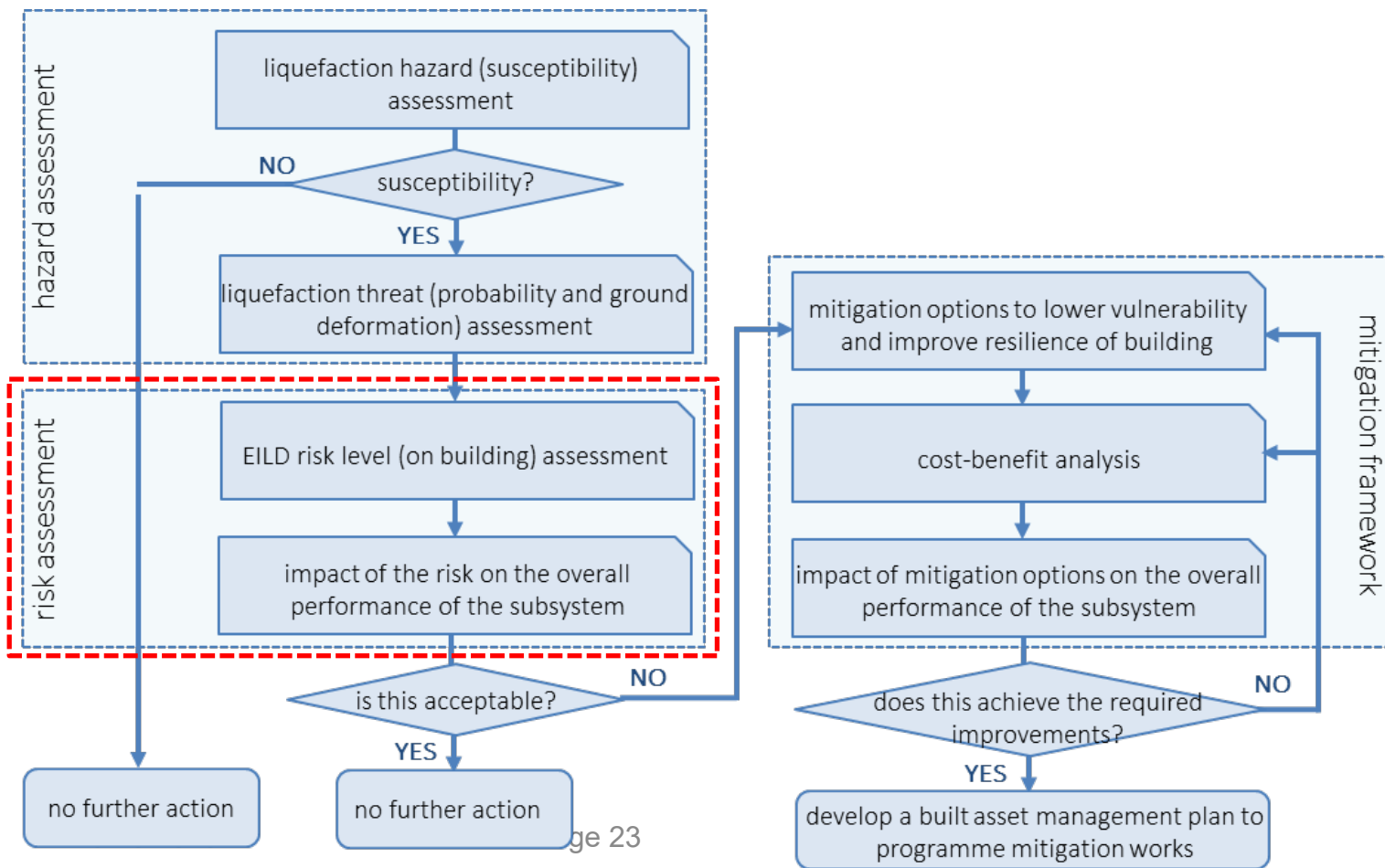


# Liquefaction Hazard Assessment – Quantitative Analysis





# Risk Assessment



# Risk Assessment

## ① Physical Impact

- Computation of Damage Probability and Loss Ratio
  - ESP-based Procedure
  - Conventional Procedure

## ② Economic Loss

- Owner Loss (Building, Contents, Business Interruption)
- Insurance Loss (Building, Contents, Business Interruption)

## ① Hazard for Risk Assessment

- Liquefaction
- Liquefaction + Ground Shaking (without liquefaction)

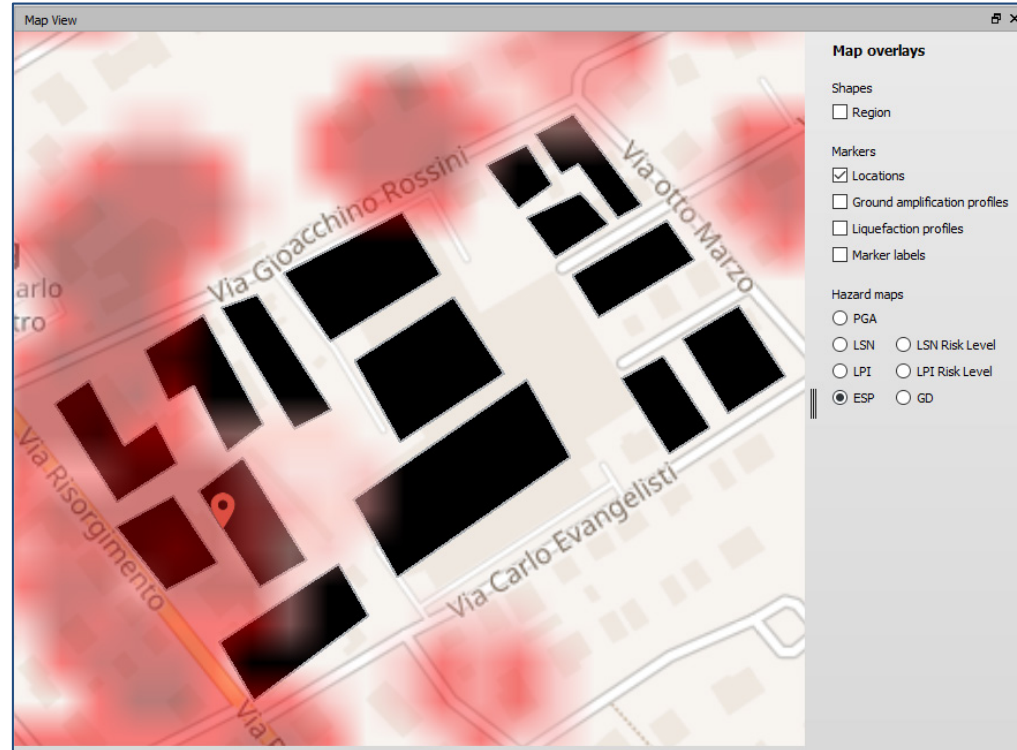


# Physical Impact - Equivalent Soil Profile (ESP) method

Strength - Size - Position

|         |         | Weak | Mid. | Strong | Resist |
|---------|---------|------|------|--------|--------|
| Large   | Shallow | WLS  | MLS  | SLX    | RXX    |
|         | Mid.    | WLM  | MLM  |        |        |
|         | Deep    | WLD  | MLD  |        |        |
| Midsize | Shallow | WMS  | MMS  | SMX    |        |
|         | Mid.    | WMM  | MMM  |        |        |
|         | Deep    | WMD  | MMD  |        |        |
| Thin    | Shallow | WTS  | MTS  | STX    |        |
|         | Mid.    | WTM  | MTM  |        |        |
|         | Deep    | WTD  | MTD  |        |        |

■ WLS ■ WLM ■ WLD ■ WMS ■ WMM ■ WMD ■ WTS ■ WTM ■ WTD  
■ MLS ■ MLM ■ MLD ■ MMS ■ MMM ■ MMD ■ MTS ■ MTM ■ MTD  
■ SLX ■ SMX ■ STX ■ RXX

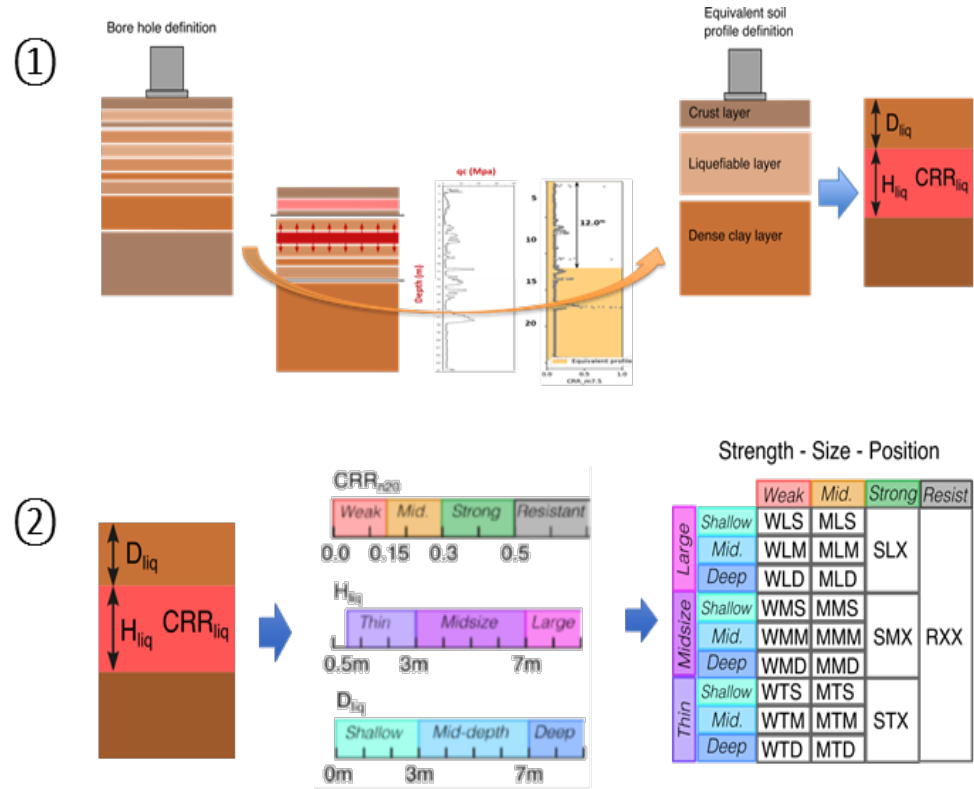


# Physical Impact - Equivalent Soil Profile (ESP) method

**Step 1:** is about generating an equivalent soil profile that will be used for the evaluation of liquefaction risk;

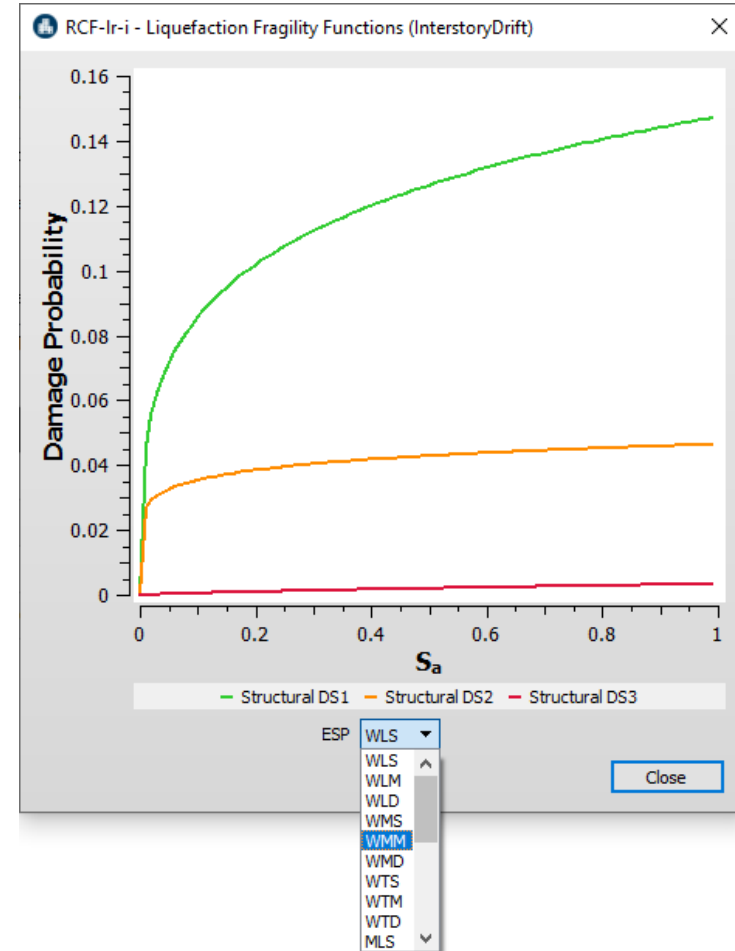
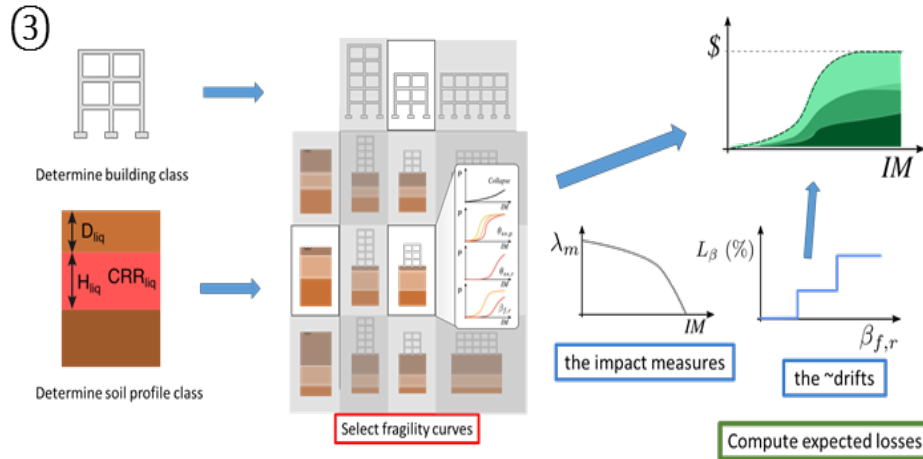
**Step 2** uses of liquefaction soil profile criteria to identify the characteristics of the equivalent soil profile considering parameters of soil strength, thickness of liquefiable layer, depth of the liquefiable layer from the surface.

Ref: DELIVERABLE D3.3: Design guidelines for the application of soil characterisation and liquefaction risk assessment protocols (<http://www.liquefact.eu>)

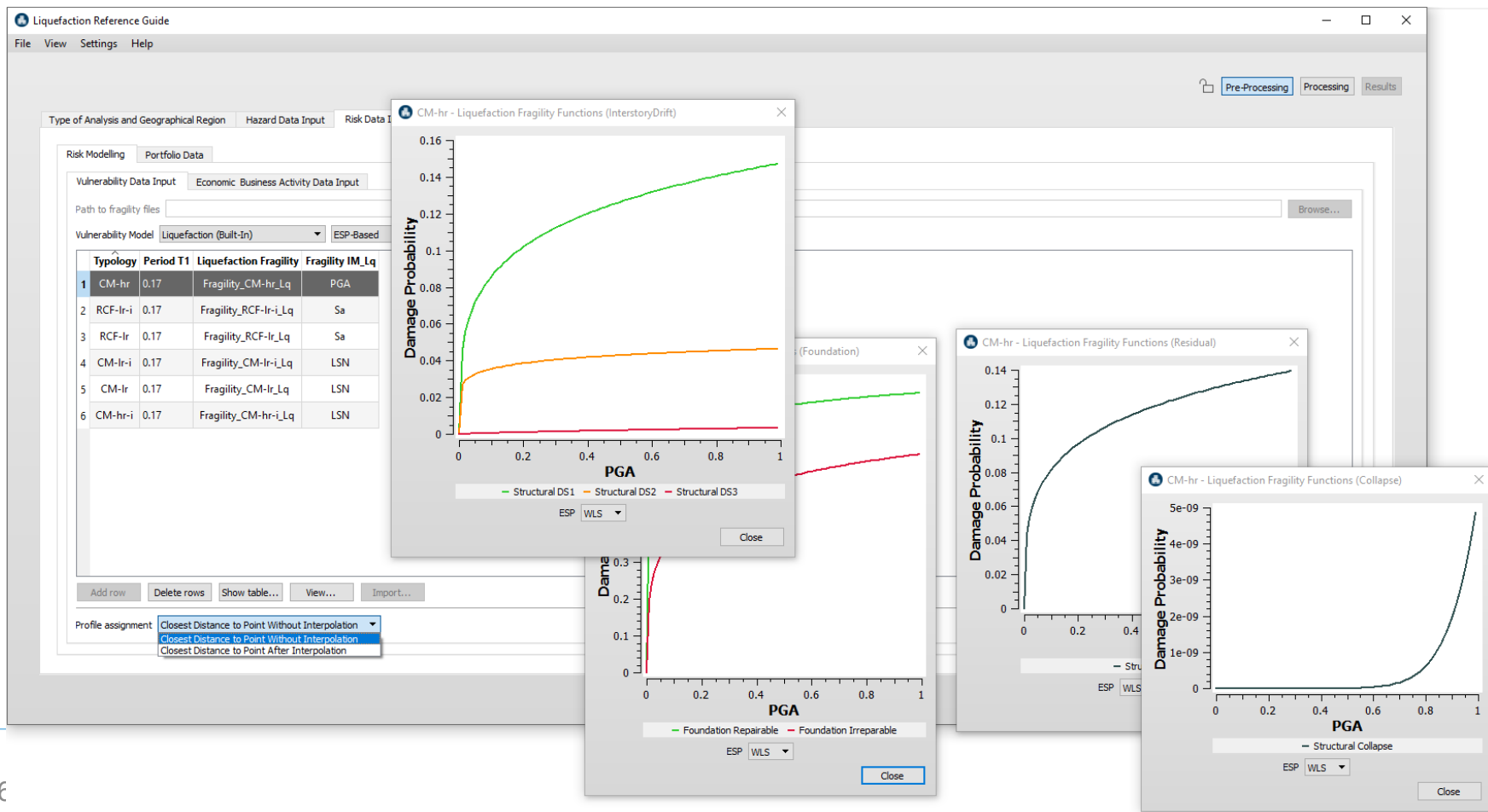


# Physical Impact - Equivalent Soil Profile (ESP) method

Combines the selected building or infrastructure in terms of its typology/class with the determined equivalent soil profile class to select the associated fragility curves for the computation of physical impact and the expected losses.



# Physical Impact - Equivalent Soil Profile (ESP) method



# Physical Impact - Equivalent Soil Profile (ESP) method

Liquefaction Reference Guide

File View Settings Help

Type of Analysis and Geographical Region Hazard Data Input Risk Data CM-hr - Liquefaction Fragility Functions (InterstoryDrift)

Pre-Processing Processing Results

## Loss Factors (ESP-Based)

|                       | Structural (DS1) | Structural (DS2) | Structural (DS3) | Foundation (Repairable) | Foundation (Irreparable) | Demolition and Replacement Cost | Replace Cost from Collapse |
|-----------------------|------------------|------------------|------------------|-------------------------|--------------------------|---------------------------------|----------------------------|
| Building              | 0.1              | 0.2              | 0.5              | 0.3                     | 1                        | 1                               | 1                          |
| Contents              | 0.2              | 0.5              | 0.7              | 0.4                     | 1                        | 1                               | 1                          |
| Business Interruption | 0                | 0.15             | 1                | 0.1                     | 1                        | 1                               | 1                          |

Reset OK Cancel Help

Profile assignment: Closest Distance to Point Without Interpolation  
Closest Distance to Point Without Interpolation  
Closest Distance to Point After Interpolation

PGA

Foundation Repairable Foundation Irreparable

ESP WLS

Damage

PGA

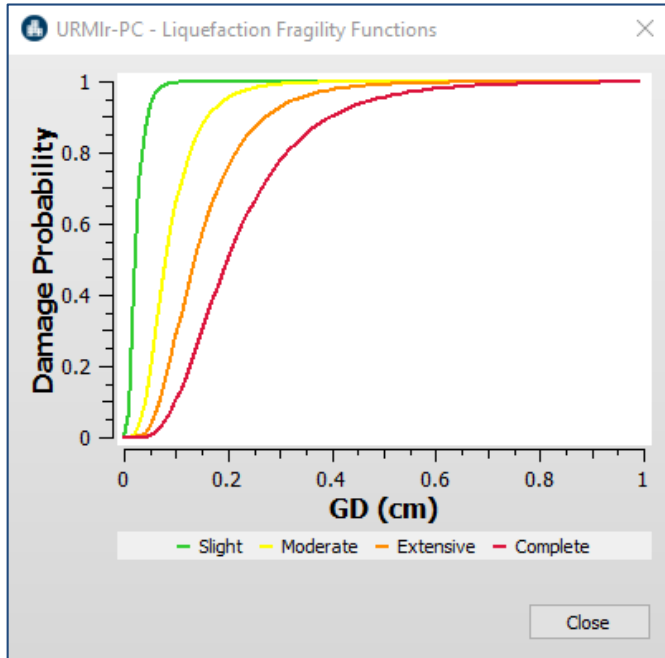
Structural Collapse

ESP WLS

Close



# Physical Impact - Conventional method



URMlr-PC - Liquefaction Fragility

| GD, Slight | beta Slight | GD, Moderate | beta Moderate | GD, Extensive | beta Extensive | GD, Complete | beta Complete |
|------------|-------------|--------------|---------------|---------------|----------------|--------------|---------------|
| 0.0221     | 0.54        | 0.0806       | 0.54          | 0.1365        | 0.54           | 0.1995       | 0.54          |

Close

# Physical Impact – Limit States

**Loss Factors (Conventional 2 State)**

|                       | Minor | Complete |
|-----------------------|-------|----------|
| Building              | 0.1   | 1        |
| Contents              | 0.2   | 1        |
| Business Interruption | 0     | 1        |

Reset OK Cancel Help

**Loss Factors (Conventional 3 State)**

|                       | Damage Limitation | Significant Damage | Near Collapse |
|-----------------------|-------------------|--------------------|---------------|
| Building              | 0.1               | 0.6                | 1             |
| Contents              | 0.2               | 0.7                | 1             |
| Business Interruption | 0                 | 0.5                | 1             |

Reset OK Cancel Help

**Loss Factors (Conventional 4 State)**

|                       | Slight | Moderate | Extensive | Complete |
|-----------------------|--------|----------|-----------|----------|
| Building              | 0.08   | 0.33     | 1         | 1        |
| Contents              | 0.2    | 0.5      | 0.85      | 1        |
| Business Interruption | 0      | 0.15     | 1         | 1        |

Reset OK Cancel Help



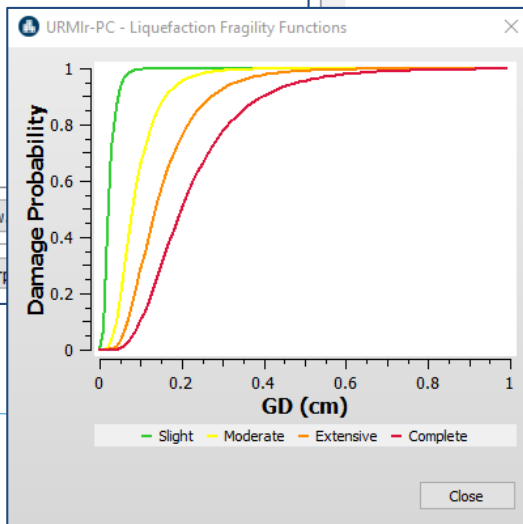
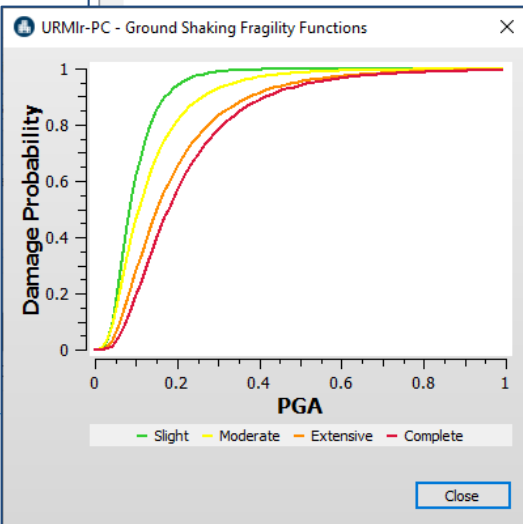
# Physical Impact – Liquefaction and Ground Shaking

Risk assessment due to liquefaction

Risk assessment due to liquefaction and ground shaking

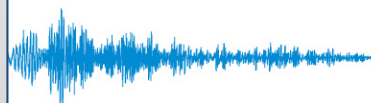
| Vulnerability Model <span>Liquefaction</span> <span>Conventional</span> |          |           |                        |                 |
|---|----------|-----------|------------------------|-----------------|
|   | Typology | Period T1 | Liquefaction Fragility | Fragility IM_Lq |
| 1   | RCFfr-LC | 0.16      | LQF_RCFfr-LC           | GD              |
| 2   | RCFmr-LC | 0.32      | LQF_RCFmr-LC           | GD              |
| 3   | RCFhr-LC | 0.46      | LQF_RCFhr-LC           | GD              |
| 4   | URMfr-PC | 0.10      | LQF_URMfr-PC           | GD              |
| 5   | URMmr-PC | 0.25      | LQF_URMmr-PC           | GD              |

| Vulnerability Model <span>Ground Shaking and Liquefaction</span> <span>Conventional</span> |          |           |                          |                 |                        |                 |
|--|----------|-----------|--------------------------|-----------------|------------------------|-----------------|
|  | Typology | Period T1 | Ground Shaking Fragility | Fragility IM_GS | Liquefaction Fragility | Fragility IM_Lq |
| 1  | RCFfr-LC | 0.16      | GSF_RCFfr-LC             | PGA             | LQF_RCFfr-LC           | GD              |
| 2  | RCFmr-LC | 0.32      | GSF_RCFmr-LC             | PGA             | LQF_RCFmr-LC           | GD              |
| 3  | RCFhr-LC | 0.46      | GSF_RCFhr-LC             | PGA             | LQF_RCFhr-LC           | GD              |
| 4  | URMfr-PC | 0.10      | GSF_URMfr-PC             | PGA             | LQF_URMfr-PC           | GD              |
| 5  | URMmr-PC | 0.25      | GSF_URMmr-PC             | PGA             | LQF_URMmr-PC           | GD              |



ws Show table... View... Import... Export...

Distance to Point Without Interpolation



# Physical Impact – Intensity Measures

## IM for Liquefaction Fragility Curves

- PGA
- LSN
- LPI
- GD -Settlement

## IM for Ground Shaking Fragility Curves

- PGA
- Sa
- Sd

Type of Analysis and Geographical Region    Hazard Data Input    Risk Data Input

Risk Modelling    Portfolio Data

Vulnerability Data Input    Economic Business Activity Data Input

Path to fragility files

Vulnerability Model

|    | Typology | Period T1 | Ground Shaking Fragility | Fragility IM_GS | Liquefaction Fragility | Fragility IM_Lq |
|----|----------|-----------|--------------------------|-----------------|------------------------|-----------------|
| 1  | RCF-Ir   | 0.07      | GS-Fragility_RCF-Ir      | Sa              | LF-Fragility_RCF-Ir    | LSN             |
| 2  | RCF-mr   | 0.13      | GS-Fragility_RCF-mr      | Sa              | LF-Fragility_RCF-mr    | LSN             |
| 3  | RCW-Ir   | 0.06      | GS-Fragility_RCW-Ir      | PGA             | LF-Fragility_RCW-Ir    | Sa              |
| 4  | RCW-mr   | 0.12      | GS-Fragility_RCW-mr      | PGA             | LF-Fragility_RCW-mr    | Sa              |
| 5  | URM-Ir   | 0.05      | GS-Fragility_URM-Ir      | Sa              | LF-Fragility_URM-Ir    | LSN             |
| 6  | URM-mr   | 0.10      | GS-Fragility_URM-mr      | Sa              | LF-Fragility_URM-mr    | LSN             |
| 7  | RM-Ir    | 0.05      | GS-Fragility_RM-Ir       | Sd              | LF-Fragility_RM-Ir     | GD              |
| 8  | RM-mr    | 0.10      | GS-Fragility_RM-mr       | Sd              | LF-Fragility_RM-mr     | GD              |
| 9  | STF-Ir   | 0.05      | GS-Fragility_STF-Ir      | PGA             | LF-Fragility_RM-Ir     | PGA             |
| 10 | STF-mr   | 0.10      | GS-Fragility_STF-mr      | PGA             | LF-Fragility_RM-mr     | PGA             |

Profile assignment

# Physical Impact – Portfolio

| Type of Analysis and Geographical Region |                     |           |           |        |          |           |         |                |             |          |          |               |           |            |            |                      |                      |       |
|--|---------------------|-----------|-----------|--------|----------|-----------|---------|----------------|-------------|----------|----------|---------------|-----------|------------|------------|----------------------|----------------------|-------|
| Hazard Data Input                        |                     |           |           |        |          |           |         |                |             |          |          |               |           |            |            |                      |                      |       |
| Risk Data Input                          |                     |           |           |        |          |           |         |                |             |          |          |               |           |            |            |                      |                      |       |
| Risk Modelling                           |                     |           |           |        |          |           |         |                |             |          |          |               |           |            |            |                      |                      |       |
| Portfolio Data                           |                     |           |           |        |          |           |         |                |             |          |          |               |           |            |            |                      |                      |       |
| ALL LOCATION STRUCTURE                   |                     |           |           |        |          |           |         |                |             |          |          |               |           |            |            |                      |                      |       |
|  | Risk Identification | Latitude  | Longitude | Street | District | Municipal | City    | Region         | Postal Code | Geo-code | Typology | Use           | Width (m) | Length (m) | Height (m) | Stories Above Ground | Stories Below Ground | Shape |
| 1  | B019                | 44.803789 | 11.410564 |        |          |           | Bologna | Emilia-Romagna | 40100       | 1        | URMlr-PC | Health System | 7.00      | 5.00       | 2.80       | 1                    | 0                    | ✓     |
| 2  | B020                | 44.804494 | 11.410094 |        |          |           | Bologna | Emilia-Romagna | 40100       | 1        | URMlr-PC | Health System | 9.00      | 12.00      | 5.60       | 2                    | 0                    | ✓     |
| 3  | B021                | 44.804180 | 11.410419 |        |          |           | Bologna | Emilia-Romagna | 40100       | 1        | RCFlr-LC | Health System | 8.00      | 10.00      | 2.80       | 1                    | 0                    | ✓     |
| 4  | B022                | 44.804892 | 11.411208 |        |          |           | Bologna | Emilia-Romagna | 40100       | 1        | RCFlr-LC | Health System | 20.00     | 10.00      | 8.40       | 3                    | 0                    | ✓     |
| 5  | B023                | 44.804677 | 11.411108 |        |          |           | Bologna | Emilia-Romagna | 40100       | 1        | RCFlr-LC | Health System | 15.00     | 20.00      | 8.40       | 3                    | 0                    | ✓     |
| 6  | B024                | 44.804846 | 11.410874 |        |          |           | Bologna | Emilia-Romagna | 40100       | 1        | RCFlr-LC | Health System | 18.00     | 10.00      | 5.60       | 2                    | 0                    | ✓     |
| 7  | B025                | 44.804519 | 11.411434 |        |          |           | Bologna | Emilia-Romagna | 40100       | 1        | RCFlr-LC | Health System | 8.00      | 15.00      | 8.40       | 3                    | 0                    | ✓     |
| 8  | B026                | 44.804201 | 11.411934 |        |          |           | Bologna | Emilia-Romagna | 40100       | 1        | URMlr-PC | Health System | 20.00     | 10.00      | 5.60       | 2                    | 0                    | ✓     |
| 9  | B027                | 44.804042 | 11.411598 |        |          |           | Bologna | Emilia-Romagna | 40100       | 1        | RCFlr-LC | Health System | 20.00     | 15.00      | 2.80       | 1                    | 0                    | ✓     |
| 10                                       | B028                | 44.803901 | 11.408807 |        |          |           | Bologna | Emilia-Romagna | 40100       | 1        | RCFlr-LC | Health System | 15.00     | 10.00      | 5.60       | 2                    | 0                    | ✓     |
| 11                                       | B029                | 44.803652 | 11.409595 |        |          |           | Bologna | Emilia-Romagna | 40100       | 1        | URMlr-PC | Health System | 5.00      | 8.00       | 2.80       | 1                    | 0                    | ✓     |
| 12                                       | B030                | 44.803551 | 11.409127 |        |          |           | Bologna | Emilia-Romagna | 40100       | 1        | RCFlr-LC | Health System | 7.00      | 4.00       | 8.40       | 3                    | 0                    | ✓     |
| 13                                       | B031                | 44.803232 | 11.409781 |        |          |           | Bologna | Emilia-Romagna | 40100       | 1        | RCFlr-LC | Health System | 20.00     | 10.00      | 8.40       | 3                    | 0                    | ✓     |

Add row

Delete rows

Import...

Export...

# Physical Impact – Portfolio in GIS platform

Liquefaction Reference Guide

File View Settings Help

Location View

Pre-Processing Processing Results

Risk Identification Latitude Longitude Street District Municipal City Region Postal Code Geo-code Shape

Bologna Emilia-Romagna 40100 1 ✓

Bologna Emilia-Romagna 40100 1

Export...

Type of Analysis and Geographical Region Hazard Data

Risk Modelling Portfolio Data

ALL LOCATION STRUCTURE

|    | Risk Identification | Latitude  | Longitude |
|----|---------------------|-----------|-----------|
| 1  | B019                | 44.803789 | 11.410564 |
| 2  | B020                | 44.804494 | 11.410094 |
| 3  | B021                | 44.804180 | 11.410419 |
| 4  | B022                | 44.804892 | 11.411208 |
| 5  | B023                | 44.804677 | 11.411108 |
| 6  | B024                | 44.804846 | 11.410874 |
| 7  | B025                | 44.804519 | 11.411434 |
| 8  | B026                | 44.804201 | 11.411934 |
| 9  | B027                | 44.804042 | 11.411598 |
| 10 | B028                | 44.803901 | 11.408807 |
| 11 | B029                | 44.803652 | 11.409595 |
| 12 | B030                | 44.803551 | 11.409127 |
| 13 | B031                | 44.803232 | 11.409781 |

Add row Delete rows Import...

Export...

Shape editor (Edit)

Via Gioacchino Rossini

New polygon Close polygon Undo Zoom In Zoom Out OK Discard Cancel Help

Map overlays

Shapes

☐ Region

Markers

☒ Locations

☐ Ground amplification profiles

☐ Liquefaction profiles

☐ Marker labels

Hazard maps

☐ PGA

☐ LSN ☐ LSN Risk Level

☐ LPI ☐ LPI Risk Level

☐ ESP ☐ GD

# Economic Model – Owner

| Vulnerability Data Input |                     | Economic Business Activity Data Input |                             |                           |              |
|--------------------------|---------------------|---------------------------------------|-----------------------------|---------------------------|--------------|
| ALL                      | ECONOMICAL MODEL    | POLICY                                | CONTENTS                    | BUSINESS INTERRUPTION     |              |
|                          | Risk Identification | Monetary Values of Building           | Monetary Values of Contents | Business Revenue Building | Time Horizon |
| 5                        | B023                | 109 240.00                            | 10 924.00                   | 109.24                    | 23           |
| 6                        | B024                | 162 900.00                            | 6 516.00                    | 162.90                    | 20           |
| 7                        | B025                | 428 100.00                            | 85 620.00                   | 428.10                    | 15           |
| 8                        | B026                | 160 750.00                            | 6 430.00                    | 160.75                    | 35           |
| 9                        | B027                | 271 050.00                            | 54 210.00                   | 271.05                    | 40           |
| 10                       | B028                | 327 100.00                            | 13 084.00                   | 327.10                    | 42           |
| 11                       | B029                | 132 700.00                            | 5 308.00                    | 132.70                    | 43           |
| 12                       | B030                | 506 250.00                            | 21 250.00                   | 106.25                    | 46           |
| 13                       | B031                | 162 800.00                            | 32 560.00                   | 162.80                    | 15           |
| 14                       | B032                | 107 700.00                            | 21 540.00                   | 107.70                    | 35           |
| 15                       | B033                | 327 100.00                            | 65 420.00                   | 327.10                    | 40           |



# Economic Model – Insurance data

| Vulnerability Data Input |                     | Economic Business Activity Data Input |                                       |                           |                                 |
|--------------------------|---------------------|---------------------------------------|---------------------------------------|---------------------------|---------------------------------|
| ALL                      | ECONOMICAL MODEL    | POLICY                                | CONTENTS                              | BUSINESS INTERRUPTION     |                                 |
|                          | Risk Identification | Insured Amount<br>(Building)          | Facultative Reinsurance<br>(Building) | Coinsurance<br>(Building) | CEDED Reinsurance<br>(Building) |
| 5                        | B023                | 5 462.00                              | 0.15                                  | 0.00                      | 0.98                            |
| 6                        | B024                | 3 258.00                              | 0.15                                  | 0.00                      | 0.98                            |
| 7                        | B025                | 8 562.00                              | 0.15                                  | 0.00                      | 0.98                            |
| 8                        | B026                | 3 215.00                              | 0.15                                  | 0.00                      | 0.98                            |
| 9                        | B027                | 5 421.00                              | 0.15                                  | 0.00                      | 0.98                            |
| 10                       | B028                | 6 542.00                              | 0.15                                  | 0.00                      | 0.98                            |
| 11                       | B029                | 2 654.00                              | 0.15                                  | 0.00                      | 0.98                            |
| 12                       | B030                | 2 125.00                              | 0.15                                  | 0.00                      | 0.98                            |
| 13                       | B031                | 3 256.00                              | 0.15                                  | 0.00                      | 0.98                            |
| 14                       | B032                | 2 154.00                              | 0.15                                  | 0.00                      | 0.98                            |
| 15                       | B033                | 6 542.00                              | 0.15                                  | 0.00                      | 0.98                            |

# Economic Model – Insurance data

Vulnerability Data Input

ALL

ECONOMICAL MODEL

5

B023

6

B024

7

B025

8

B026

9

B027

10

B028

11

B029

12

B030

13

B031

14

B032

15

B033

Economic Business Activity Data Input

Vulnerability Data Input

Economic Business Activity Data Input

ALL

ECONOMICAL MODEL

POLICY

CONTENTS

BUSINESS INTERRUPTION

5

B023

1 092.40

0.17

0.00

0.36

6

B024

651.60

0.17

0.00

0.32

7

B025

1 712.40

0.17

0.00

0.30

8

B026

643.00

0.17

0.00

0.30

9

B027

1 084.20

0.17

0.00

0.22

10

B028

1 308.40

0.17

0.00

0.20

11

B029

530.80

0.17

0.00

0.88

12

B030

425.00

0.17

0.00

0.68

13

B031

651.20

0.17

0.00

0.54

14

B032

430.80

0.17

0.00

0.50

15

B033

1 308.40

0.17

0.00

0.32



# Risk Analysis Output – Owner Loss at Individual Level

- Resulted from liquefaction
- Building Loss

| Hazard Analysis Output   Risk Analysis Output   Mitigation Analysis Output |                     |                     |                       |          |         |                 |         |           |     |                                     |                                     |                     |                        |                         |                        |                            |                            |                 |  |
|--|---------------------|---------------------|-----------------------|----------|---------|-----------------|---------|-----------|-----|-------------------------------------|-------------------------------------|---------------------|------------------------|-------------------------|------------------------|----------------------------|----------------------------|-----------------|--|
| Seismic Ground Shaking   Ground Liquefaction                               |                     |                     |                       |          |         |                 |         |           |     |                                     |                                     |                     |                        |                         |                        |                            |                            |                 |  |
| Owner Loss   |                     | Risk Identification |                       |          |         |                 |         |           |     |                                     |                                     |                     |                        |                         |                        |                            |                            |                 |  |
| ALL  | BUILDING            | CONTENTS            | BUSINESS INTERRUPTION |          |         |                 |         |           |     |                                     |                                     |                     |                        |                         |                        |                            |                            |                 |  |
|  | Risk Identification | Latitude            | Longitude             | Geo-code | LPI     | Settlement (cm) | LSN     | LSN (ESP) | ESP | Liquefaction Risk Level (LPI-Based) | Liquefaction Risk Level (LSN-Based) | Probability (Slite) | Probability (Moderate) | Probability (Extensive) | Probability (Complete) | Mean Loss Ratio (Building) | Monetary Values (Building) | Loss (Building) |  |
| 5  | B023                | 44.804700           | 11.411100             | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 109 240.00                 | 0.00            |  |
| 6  | B024                | 44.804800           | 11.410900             | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 162 900.00                 | 0.00            |  |
| 7  | B025                | 44.804500           | 11.411400             | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 428 100.00                 | 0.00            |  |
| 8  | B026                | 44.804200           | 11.411900             | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 160 750.00                 | 0.00            |  |
| 9  | B027                | 44.804000           | 11.411600             | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 271 050.00                 | 0.00            |  |
| 10   | B028                | 44.803900           | 11.408800             | 1        | 9.7548  | 3.7707          | 7.1690  | 60.4450   | WLS | High                                | Low                                 | 0.000000            | 0.000000               | 0.000002                | 0.999998               | 1.000000                   | 327 100.00                 | 327 099.99      |  |
| 11   | B029                | 44.803700           | 11.409600             | 1        | 13.4352 | 5.1838          | 11.1685 | 80.6003   | WMS | High                                | Moderate                            | 0.000000            | 0.000000               | 0.000000                | 1.000000               | 1.000000                   | 132 700.00                 | 132 700.00      |  |
| 12   | B030                | 44.803600           | 11.409100             | 1        | 8.6068  | 3.9682          | 4.0382  | 129.5341  | WLD | High                                | None                                | 0.000000            | 0.000000               | 0.000001                | 0.999999               | 1.000000                   | 506 250.00                 | 506 249.99      |  |
| 13   | B031                | 44.803200           | 11.409800             | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 162 800.00                 | 0.00            |  |
| 14   | B032                | 44.804200           | 11.409700             | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 107 700.00                 | 0.00            |  |
| 15   | B033                | 44.804100           | 11.409300             | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 327 100.00                 | 0.00            |  |

Export...

# Risk Analysis Output – Owner Loss at Individual Level

- Resulted from liquefaction
- Contents Loss

Hazard Analysis Output

Risk Analysis Output

Mitigation Analysis Output

Seismic Ground Shaking

Ground Liquefaction

Owner Loss

Risk Identification

ALL

BUILDING

CONTENTS

BUSINESS INTERRUPTION

|    | Risk Identification | Latitude  | Longitude | Geo-code | LPI     | Settlement (cm) | LSN     | LSN (ESP) | ESP | Liquefaction Risk Level (LPI-Based) | Liquefaction Risk Level (LSN-Based) | Probability (Slite) | Probability (Moderate) | Probability (Extensive) | Probability (Complete) | Mean Loss Ratio (Contents) | Monetary Values (Contents) | Loss (Contents) |
|----|---------------------|-----------|-----------|----------|---------|-----------------|---------|-----------|-----|-------------------------------------|-------------------------------------|---------------------|------------------------|-------------------------|------------------------|----------------------------|----------------------------|-----------------|
| 5  | B023                | 44.804700 | 11.411100 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 10 924.00                  | 0.00            |
| 6  | B024                | 44.804800 | 11.410900 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 6 516.00                   | 0.00            |
| 7  | B025                | 44.804500 | 11.411400 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 85 620.00                  | 0.00            |
| 8  | B026                | 44.804200 | 11.411900 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 6 430.00                   | 0.00            |
| 9  | B027                | 44.804000 | 11.411600 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 54 210.00                  | 0.00            |
| 10 | B028                | 44.803900 | 11.408800 | 1        | 9.7548  | 3.7707          | 7.1690  | 60.4450   | WLS | High                                | Low                                 | 0.000000            | 0.000000               | 0.000002                | 0.999998               | 1.000000                   | 13 084.00                  | 13 084.00       |
| 11 | B029                | 44.803700 | 11.409600 | 1        | 13.4352 | 5.1838          | 11.1685 | 80.6003   | WMS | High                                | Moderate                            | 0.000000            | 0.000000               | 0.000000                | 1.000000               | 1.000000                   | 5 308.00                   | 5 308.00        |
| 12 | B030                | 44.803600 | 11.409100 | 1        | 8.6068  | 3.9682          | 4.0382  | 129.5341  | WLD | High                                | None                                | 0.000000            | 0.000000               | 0.000001                | 0.999999               | 1.000000                   | 21 250.00                  | 21 250.00       |
| 13 | B031                | 44.803200 | 11.409800 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 32 560.00                  | 0.00            |
| 14 | B032                | 44.804200 | 11.409700 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 21 540.00                  | 0.00            |
| 15 | B033                | 44.804100 | 11.409300 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 65 420.00                  | 0.00            |

Export...

# Risk Analysis Output – Owner Loss at Individual Level

- Resulted from liquefaction
- Business Interruption

Hazard Analysis Output

Risk Analysis Output

Mitigation Analysis Output

Seismic Ground Shaking

Ground Liquefaction

Owner Loss

Risk Identification

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BUSINESS INTERRUPTION

|    | Risk Identification | Latitude  | Longitude | Geo-code | LPI     | Settlement (cm) | LSN     | LSN (ESP) | ESP | Liquefaction Risk Level (LPI-Based) | Liquefaction Risk Level (LSN-Based) | Probability (Slite) | Probability (Moderate) | Probability (Extensive) | Probability (Complete) | Mean Loss Ratio (Interruption) | Business Revenue | Loss (Interruption) |
|----|---------------------|-----------|-----------|----------|---------|-----------------|---------|-----------|-----|-------------------------------------|-------------------------------------|---------------------|------------------------|-------------------------|------------------------|--------------------------------|------------------|---------------------|
| 5  | B023                | 44.804700 | 11.411100 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                       | 109.24           | 0.00                |
| 6  | B024                | 44.804800 | 11.410900 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                       | 162.90           | 0.00                |
| 7  | B025                | 44.804500 | 11.411400 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                       | 428.10           | 0.00                |
| 8  | B026                | 44.804200 | 11.411900 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                       | 160.75           | 0.00                |
| 9  | B027                | 44.804000 | 11.411600 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                       | 271.05           | 0.00                |
| 10 | B028                | 44.803900 | 11.408800 | 1        | 9.7548  | 3.7707          | 7.1690  | 60.4450   | WLS | High                                | Low                                 | 0.000000            | 0.000000               | 0.000002                | 0.999998               | 1.000000                       | 327.10           | 327.10              |
| 11 | B029                | 44.803700 | 11.409600 | 1        | 13.4352 | 5.1838          | 11.1685 | 80.6003   | WMS | High                                | Moderate                            | 0.000000            | 0.000000               | 0.000000                | 1.000000               | 1.000000                       | 132.70           | 132.70              |
| 12 | B030                | 44.803600 | 11.409100 | 1        | 8.6068  | 3.9682          | 4.0382  | 129.5341  | WLD | High                                | None                                | 0.000000            | 0.000000               | 0.000001                | 0.999999               | 1.000000                       | 106.25           | 106.25              |
| 13 | B031                | 44.803200 | 11.409800 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                       | 162.80           | 0.00                |
| 14 | B032                | 44.804200 | 11.409700 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                       | 107.70           | 0.00                |
| 15 | B033                | 44.804100 | 11.409300 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                       | 327.10           | 0.00                |

Export...

# Risk Analysis Output – Owner Loss at Geo-code Level

- Resulted from liquefaction

| Hazard Analysis Output   Risk Analysis Output   Mitigation Analysis Output |          |           |           |                                |                                |                     |                               |                               |                    |                                 |                   |                      |              |
|--|----------|-----------|-----------|--------------------------------|--------------------------------|---------------------|-------------------------------|-------------------------------|--------------------|---------------------------------|-------------------|----------------------|--------------|
| Seismic Ground Shaking   Ground Liquefaction                               |          |           |           |                                |                                |                     |                               |                               |                    |                                 |                   |                      |              |
| Owner Loss   Geo-code  |          |           |           |                                |                                |                     |                               |                               |                    |                                 |                   |                      |              |
|  | Geo-code | Latitude  | Longitude | Mean Loss Ratio<br>(Buildings) | Monetary Values<br>(Buildings) | Loss<br>(Buildings) | Mean Loss Ratio<br>(Contents) | Monetary Values<br>(Contents) | Loss<br>(Contents) | Mean Loss Ratio<br>(Businesses) | Business Revenues | Loss<br>(Businesses) | Total Loss   |
| 1  | 1        | 44.804153 | 11.410370 | 0.200000                       | 4 259 630.00                   | 851 925.99          | 0.200000                      | 1 173 302.00                  | 234 660.37         | 0.200000                        | 3 859.63          | 771.93               | 1 087 358.28 |



# Risk Analysis Output – Insurance Loss at Individual Level

- Resulted from liquefaction
- Building Loss

Hazard Analysis Output

Risk Analysis Output

Mitigation Analysis Output

Seismic Ground Shaking

Ground Liquefaction

Insurance Loss

Risk Identification

ALL

BUILDING

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BUSINESS INTERRUPTION

|    | Risk Identification | Latitude  | Longitude | Geo-code | LPI     | Settlement (cm) | LSN     | LSN (ESP) | ESP | Liquefaction Risk Level (LPI-Based) | Liquefaction Risk Level (LSN-Based) | Probability (Site) | Probability (Moderate) | Probability (Extensive) | Probability (Complete) | Mean Loss Ratio (Building) | Insured Amount (Building) | Retained Loss (Building) | Facultative Loss (Building) | Coinsurance Loss (Building) | CEDED Loss (Building) |
|----|---------------------|-----------|-----------|----------|---------|-----------------|---------|-----------|-----|-------------------------------------|-------------------------------------|--------------------|------------------------|-------------------------|------------------------|----------------------------|---------------------------|--------------------------|-----------------------------|-----------------------------|-----------------------|
| 5  | B023                | 44.804700 | 11.411100 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000           | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 5 462.00                  | 0.00                     | 0.00                        | 0.00                        | 0.00                  |
| 6  | B024                | 44.804800 | 11.410900 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000           | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 3 258.00                  | 0.00                     | 0.00                        | 0.00                        | 0.00                  |
| 7  | B025                | 44.804500 | 11.411400 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000           | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 8 562.00                  | 0.00                     | 0.00                        | 0.00                        | 0.00                  |
| 8  | B026                | 44.804200 | 11.411900 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000           | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 3 215.00                  | 0.00                     | 0.00                        | 0.00                        | 0.00                  |
| 9  | B027                | 44.804000 | 11.411600 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000           | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 5 421.00                  | 0.00                     | 0.00                        | 0.00                        | 0.00                  |
| 10 | B028                | 44.803900 | 11.408800 | 1        | 9.7548  | 3.7707          | 7.1690  | 60.4450   | WLS | High                                | Low                                 | 0.000000           | 0.000000               | 0.000002                | 0.999998               | 1.000000                   | 6 542.00                  | 0.00                     | 145.23                      | 0.00                        | 6 396.77              |
| 11 | B029                | 44.803700 | 11.409600 | 1        | 13.4352 | 5.1838          | 11.1685 | 80.6003   | WMS | High                                | Moderate                            | 0.000000           | 0.000000               | 0.000000                | 1.000000               | 1.000000                   | 2 654.00                  | 0.00                     | 58.92                       | 0.00                        | 2 595.08              |
| 12 | B030                | 44.803600 | 11.409100 | 1        | 8.6068  | 3.9682          | 4.0382  | 129.5341  | WLD | High                                | None                                | 0.000000           | 0.000000               | 0.000001                | 0.999999               | 1.000000                   | 2 125.00                  | 0.00                     | 47.17                       | 0.00                        | 2 077.82              |
| 13 | B031                | 44.803200 | 11.409800 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000           | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 3 256.00                  | 0.00                     | 0.00                        | 0.00                        | 0.00                  |
| 14 | B032                | 44.804200 | 11.409700 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000           | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 2 154.00                  | 0.00                     | 0.00                        | 0.00                        | 0.00                  |
| 15 | B033                | 44.804100 | 11.409300 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000           | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 6 542.00                  | 0.00                     | 0.00                        | 0.00                        | 0.00                  |

Export...

Export...





# Risk Analysis Output – Insurance Loss at Individual Level

- Resulted from liquefaction
- Contents Loss

| Hazard Analysis Output   Risk Analysis Output   Mitigation Analysis Output |                     |           |           |          |         |                 |         |           |     |                                     |                                     |                     |                        |                         |                        |                            |                           |                          |                             |                             |                       |
|--|---------------------|-----------|-----------|----------|---------|-----------------|---------|-----------|-----|-------------------------------------|-------------------------------------|---------------------|------------------------|-------------------------|------------------------|----------------------------|---------------------------|--------------------------|-----------------------------|-----------------------------|-----------------------|
| Seismic Ground Shaking   Ground Liquefaction                               |                     |           |           |          |         |                 |         |           |     |                                     |                                     |                     |                        |                         |                        |                            |                           |                          |                             |                             |                       |
| Insurance Loss   Risk Identification                                       |                     |           |           |          |         |                 |         |           |     |                                     |                                     |                     |                        |                         |                        |                            |                           |                          |                             |                             |                       |
| ALL   BUILDING   CONTENTS   BUSINESS INTERRUPTION                          |                     |           |           |          |         |                 |         |           |     |                                     |                                     |                     |                        |                         |                        |                            |                           |                          |                             |                             |                       |
|  | Risk Identification | Latitude  | Longitude | Geo-code | LPI     | Settlement (cm) | LSN     | LSN (ESP) | ESP | Liquefaction Risk Level (LPI-Based) | Liquefaction Risk Level (LSN-Based) | Probability (Slite) | Probability (Moderate) | Probability (Extensive) | Probability (Complete) | Mean Loss Ratio (Contents) | Insured Amount (Contents) | Retained Loss (Contents) | Facultative Loss (Contents) | Coinsurance Loss (Contents) | CEDED Loss (Contents) |
| 5  | B023                | 44.804700 | 11.411100 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 1 092.40                  | 0.00                     | 0.00                        | 0.00                        | 0.00                  |
| 6  | B024                | 44.804800 | 11.410900 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 651.60                    | 0.00                     | 0.00                        | 0.00                        | 0.00                  |
| 7  | B025                | 44.804500 | 11.411400 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 1 712.40                  | 0.00                     | 0.00                        | 0.00                        | 0.00                  |
| 8  | B026                | 44.804200 | 11.411900 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 643.00                    | 0.00                     | 0.00                        | 0.00                        | 0.00                  |
| 9  | B027                | 44.804000 | 11.411600 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 1 084.20                  | 0.00                     | 0.00                        | 0.00                        | 0.00                  |
| 10   | B028                | 44.803900 | 11.408800 | 1        | 9.7548  | 3.7707          | 7.1690  | 60.4450   | WLS | High                                | Low                                 | 0.000000            | 0.000000               | 0.000002                | 0.999998               | 1.000000                   | 1 308.40                  | 830.91                   | 220.20                      | 0.00                        | 257.28                |
| 11   | B029                | 44.803700 | 11.409600 | 1        | 13.4352 | 5.1838          | 11.1685 | 80.6003   | WMS | High                                | Moderate                            | 0.000000            | 0.000000               | 0.000000                | 1.000000               | 1.000000                   | 530.80                    | 0.00                     | 62.38                       | 0.00                        | 468.42                |
| 12   | B030                | 44.803600 | 11.409100 | 1        | 8.6068  | 3.9682          | 4.0382  | 129.5341  | WLD | High                                | None                                | 0.000000            | 0.000000               | 0.000001                | 0.999999               | 1.000000                   | 425.00                    | 65.82                    | 71.53                       | 0.00                        | 287.65                |
| 13   | B031                | 44.803200 | 11.409800 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 651.20                    | 0.00                     | 0.00                        | 0.00                        | 0.00                  |
| 14   | B032                | 44.804200 | 11.409700 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 430.80                    | 0.00                     | 0.00                        | 0.00                        | 0.00                  |
| 15   | B033                | 44.804100 | 11.409300 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 1 308.40                  | 0.00                     | 0.00                        | 0.00                        | 0.00                  |

Export...



# Risk Analysis Output – Insurance Loss at Individual Level

- Resulted from liquefaction
- Business Interruption

| Hazard Analysis Output   Risk Analysis Output   Mitigation Analysis Output |                     |           |           |          |         |                 |         |           |     |                                     |                                     |                     |                        |                         |                        |                                |                               |                              |                                 |                                 |                           |        |
|--|---------------------|-----------|-----------|----------|---------|-----------------|---------|-----------|-----|-------------------------------------|-------------------------------------|---------------------|------------------------|-------------------------|------------------------|--------------------------------|-------------------------------|------------------------------|---------------------------------|---------------------------------|---------------------------|--------|
| Seismic Ground Shaking   Ground Liquefaction                               |                     |           |           |          |         |                 |         |           |     |                                     |                                     |                     |                        |                         |                        |                                |                               |                              |                                 |                                 |                           |        |
| Insurance Loss   Risk Identification                                       |                     |           |           |          |         |                 |         |           |     |                                     |                                     |                     |                        |                         |                        |                                |                               |                              |                                 |                                 |                           |        |
| ALL   BUILDING   CONTENTS   BUSINESS INTERRUPTION                          |                     |           |           |          |         |                 |         |           |     |                                     |                                     |                     |                        |                         |                        |                                |                               |                              |                                 |                                 |                           |        |
|  | Risk Identification | Latitude  | Longitude | Geo-code | LPI     | Settlement (cm) | LSN     | LSN (ESP) | ESP | Liquefaction Risk Level (LPI-Based) | Liquefaction Risk Level (LSN-Based) | Probability (Slite) | Probability (Moderate) | Probability (Extensive) | Probability (Complete) | Mean Loss Ratio (Interruption) | Insured Amount (Interruption) | Retained Loss (Interruption) | Facultative Loss (Interruption) | Coinsurance Loss (Interruption) | CEDED Loss (Interruption) |        |
| 5  | B023                | 44.804700 | 11.411100 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                       | 273.10                        | 0.00                         | 0.00                            | 0.00                            | 0.00                      |        |
| 6  | B024                | 44.804800 | 11.410900 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                       | 162.90                        | 0.00                         | 0.00                            | 0.00                            | 0.00                      |        |
| 7  | B025                | 44.804500 | 11.411400 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                       | 428.10                        | 0.00                         | 0.00                            | 0.00                            | 0.00                      |        |
| 8  | B026                | 44.804200 | 11.411900 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                       | 160.75                        | 0.00                         | 0.00                            | 0.00                            | 0.00                      |        |
| 9  | B027                | 44.804000 | 11.411600 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                       | 271.05                        | 0.00                         | 0.00                            | 0.00                            | 0.00                      |        |
| 10   | B028                | 44.803900 | 11.408800 | 1        | 9.7548  | 3.7707          | 7.1690  | 60.4450   | WLS | High                                | Low                                 | 0.000000            | 0.000000               | 0.000002                | 0.999998               | 1.000000                       | 327.10                        | 48.28                        | 0.00                            | 0.00                            | 0.00                      | 278.82 |
| 11   | B029                | 44.803700 | 11.409600 | 1        | 13.4352 | 5.1838          | 11.1685 | 80.6003   | WMS | High                                | Moderate                            | 0.000000            | 0.000000               | 0.000000                | 1.000000               | 1.000000                       | 132.70                        | 19.49                        | 0.00                            | 0.00                            | 0.00                      | 113.21 |
| 12   | B030                | 44.803600 | 11.409100 | 1        | 8.6068  | 3.9682          | 4.0382  | 129.5341  | WLD | High                                | None                                | 0.000000            | 0.000000               | 0.000001                | 0.999999               | 1.000000                       | 106.25                        | 15.46                        | 0.00                            | 0.00                            | 0.00                      | 90.79  |
| 13   | B031                | 44.803200 | 11.409800 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                       | 162.80                        | 0.00                         | 0.00                            | 0.00                            | 0.00                      |        |
| 14   | B032                | 44.804200 | 11.409700 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                       | 107.70                        | 0.00                         | 0.00                            | 0.00                            | 0.00                      |        |
| 15   | B033                | 44.804100 | 11.409300 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                       | 327.10                        | 0.00                         | 0.00                            | 0.00                            | 0.00                      |        |



# Risk Analysis Output – Insurance Loss at Geo-code Level

- Resulted from liquefaction

Hazard Analysis Output

Risk Analysis Output

Mitigation Analysis Output

Seismic Ground Shaking

Ground Liquefaction

Insurance Loss

Geo-code

|   | Geo-code | Latitude  | Longitude | Mean Loss Ratio<br>(Buildings) | Insured Amount<br>(Buildings) | Retained Loss<br>(Buildings) | Facultative Loss<br>(Buildings) | Coinsurance Loss<br>(Buildings) | CEDED Loss<br>(Buildings) | Mean Loss Ratio<br>(Contents) | Insured Amount<br>(Contents) | Retained Loss<br>(Contents) |
|---|----------|-----------|-----------|--------------------------------|-------------------------------|------------------------------|---------------------------------|---------------------------------|---------------------------|-------------------------------|------------------------------|-----------------------------|
| 1 | 1        | 44.804153 | 11.410370 | 0.200000                       | 134 235.00                    | 0.00                         | 596.00                          | 0.00                            | 26 251.00                 | 0.200000                      | 6 711.75                     | 579.17                      |

|  | Facultative Loss<br>(Contents) | Coinsurance Loss<br>(Contents) | CEDED Loss<br>(Contents) | Mean Loss Ratio<br>(Businesses) | Insured Amount<br>(Interruption) | Retained Loss<br>(Interruption) | Facultative Loss<br>(Interruption) | Coinsurance Loss<br>(Interruption) | CEDED Loss<br>(Interruption) | Total Loss |
|--|--------------------------------|--------------------------------|--------------------------|---------------------------------|----------------------------------|---------------------------------|------------------------------------|------------------------------------|------------------------------|------------|
|  | 220.74                         | 0.00                           | 542.43                   | 0.200000                        | 6 711.75                         | 212.36                          | 0.00                               | 0.00                               | 1 129.99                     | 29 531.70  |



# Risk Analysis Output – Owner Loss at Individual Level

- Resulted from ground shaking (without liquefaction)
- Building Loss

Hazard Analysis Output

Risk Analysis Output

Mitigation Analysis Output

Seismic Ground Shaking

Ground Liquefaction

Owner Loss

Risk Identification

ALL

BUILDING

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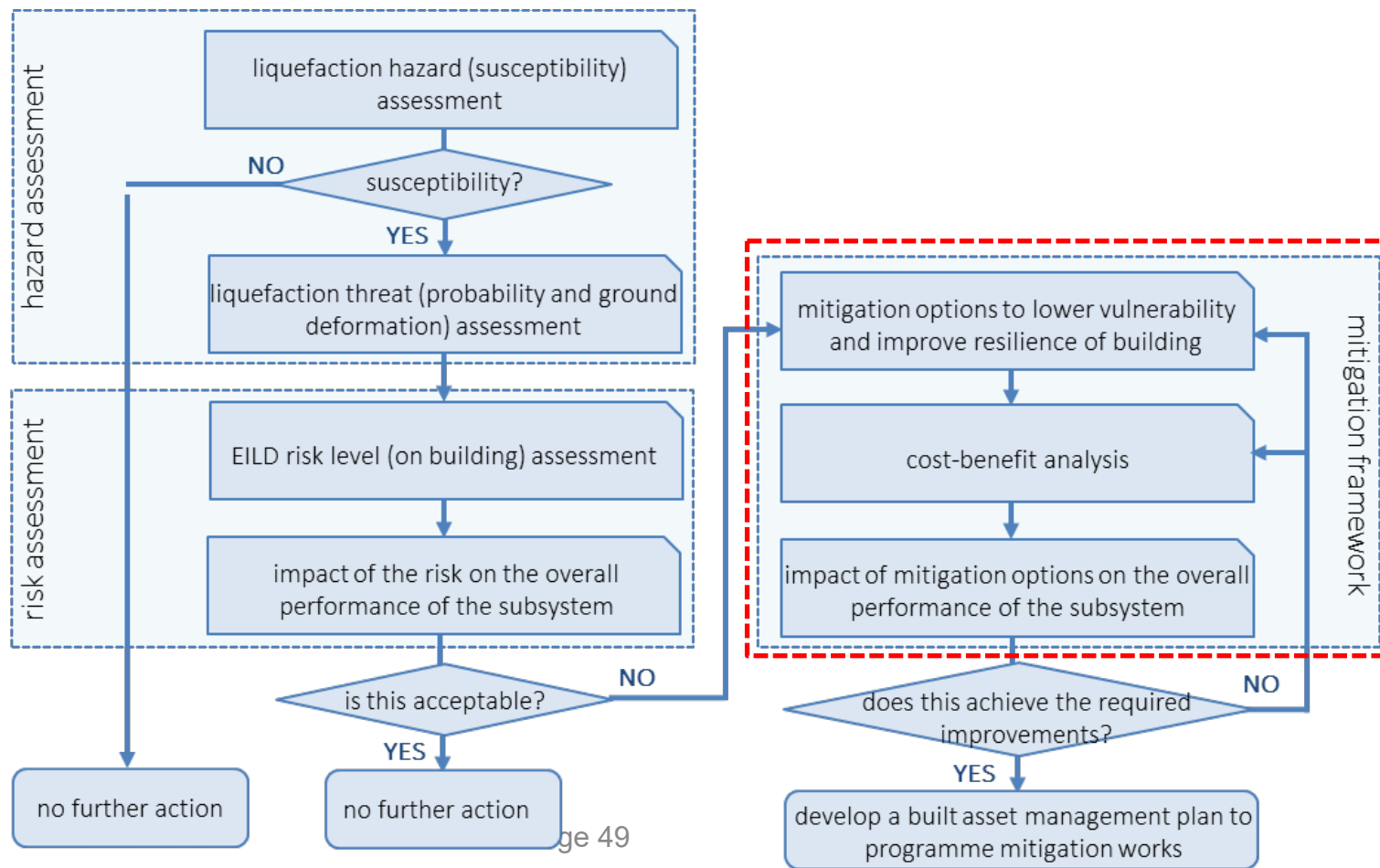
BUSINESS INTERRUPTION

|    | Risk Identification | Latitude  | Longitude | Geo-code | Probability (Slite) | Probability (Moderate) | Probability (Extensive) | Probability (Complete) | Mean Loss Ratio (Building) | Monetary Values (Building) | Loss (Building) | Mean Loss Ratio (Contents) | Monetary Values (Contents) | Loss (Contents) | Mean Loss Ratio (Interruption) | Business Revenue | Loss (Interruption) | Total Loss |
|----|---------------------|-----------|-----------|----------|---------------------|------------------------|-------------------------|------------------------|----------------------------|----------------------------|-----------------|----------------------------|----------------------------|-----------------|--------------------------------|------------------|---------------------|------------|
| 5  | B023                | 44.804700 | 11.411100 | 1        | 0.365638            | 0.194737               | 0.002946                | 0.204310               | 0.300770                   | 109 240.00                 | 32 856.15       | 0.377310                   | 10 924.00                  | 4 121.74        | 0.236467                       | 109.24           | 25.83               | 37 003.72  |
| 6  | B024                | 44.804800 | 11.410900 | 1        | 0.365638            | 0.194737               | 0.002946                | 0.204310               | 0.300770                   | 162 900.00                 | 48 995.48       | 0.377310                   | 6 516.00                   | 2 458.55        | 0.236467                       | 162.90           | 38.52               | 51 492.56  |
| 7  | B025                | 44.804500 | 11.411400 | 1        | 0.365638            | 0.194737               | 0.002946                | 0.204310               | 0.300770                   | 428 100.00                 | 128 759.77      | 0.377310                   | 85 620.00                  | 32 305.31       | 0.236467                       | 428.10           | 101.23              | 161 166.31 |
| 8  | B026                | 44.804200 | 11.411900 | 1        | 0.166542            | 0.192891               | 0.095171                | 0.242463               | 0.414611                   | 160 750.00                 | 66 648.76       | 0.453112                   | 6 430.00                   | 2 913.51        | 0.366568                       | 160.75           | 58.93               | 69 621.19  |
| 9  | B027                | 44.804000 | 11.411600 | 1        | 0.365638            | 0.194737               | 0.002946                | 0.204310               | 0.300770                   | 271 050.00                 | 81 523.79       | 0.377310                   | 54 210.00                  | 20 453.99       | 0.236467                       | 271.05           | 64.09               | 102 041.88 |
| 10 | B028                | 44.803900 | 11.408800 | 1        | 0.365638            | 0.194737               | 0.002946                | 0.204310               | 0.300770                   | 327 100.00                 | 98 381.97       | 0.377310                   | 13 084.00                  | 4 936.73        | 0.236467                       | 327.10           | 77.35               | 103 396.05 |
| 11 | B029                | 44.803700 | 11.409600 | 1        | 0.166542            | 0.192891               | 0.095171                | 0.242463               | 0.414611                   | 132 700.00                 | 55 018.91       | 0.453112                   | 5 308.00                   | 2 405.12        | 0.366568                       | 132.70           | 48.64               | 57 472.67  |
| 12 | B030                | 44.803600 | 11.409100 | 1        | 0.365638            | 0.194737               | 0.002946                | 0.204310               | 0.300770                   | 506 250.00                 | 152 264.97      | 0.377310                   | 21 250.00                  | 8 017.84        | 0.236467                       | 106.25           | 25.12               | 160 307.94 |
| 13 | B031                | 44.803200 | 11.409800 | 1        | 0.365638            | 0.194737               | 0.002946                | 0.204310               | 0.300770                   | 162 800.00                 | 48 965.41       | 0.377310                   | 32 560.00                  | 12 285.22       | 0.236467                       | 162.80           | 38.50               | 61 289.13  |
| 14 | B032                | 44.804200 | 11.409700 | 1        | 0.166542            | 0.192891               | 0.095171                | 0.242463               | 0.414611                   | 107 700.00                 | 44 653.63       | 0.453112                   | 21 540.00                  | 9 760.03        | 0.366568                       | 107.70           | 39.48               | 54 453.14  |
| 15 | B033                | 44.804100 | 11.409300 | 1        | 0.166542            | 0.192891               | 0.095171                | 0.242463               | 0.414611                   | 327 100.00                 | 135 619.34      | 0.453112                   | 65 420.00                  | 29 642.59       | 0.366568                       | 327.10           | 119.90              | 165 381.83 |

Export...

Export...

# Mitigation Framework



# Mitigation Framework

- Existing Structure or New Construction (Free Field)
- Mitigation Thresholds
- Mitigation Cost and Expected Benefit (in terms of reducing liquefaction risk)



# Mitigation Safety Thresholds / Mitigation Cost and Expected Mitigation Solution Level

**Mitigation Safety Thresholds**

Safety thresholds

☐ LPI

☐ LSN

☒ Loss ratio

Reset OK Cancel Help

**Mitigation Cost and Benefit**


| G.I. TECNOLOGY             | Mitigation cost / m <sup>3</sup> | Expected Mitigation Solution Level (%) |
|----------------------------|----------------------------------|--|
| EARTHQUAKE DRAINS          | 100                              | 80                                     |
| DEEP DYNAMIC COMPACTION    | 100                              | 60                                     |
| VIBRO COMPACTION           | 100                              | 40                                     |
| BLASTING COMPACTION        | 100                              | 50                                     |
| VIBRO REPLACEMENT          | 100                              | 55                                     |
| INDUCED PARTIAL SATURATION | 100                              | 45                                     |
| COMPACTION GROUTING        | 100                              | 70                                     |
| LOW PRESSURE GROUTING      | 100                              | 65                                     |
| JET GROUTING               | 100                              | 75                                     |
| DEEP SOIL MIXING           | 100                              | 60                                     |

Constant discount rate (%)

Reset OK Cancel Help

# Set Mitigation Parameters

Selected building for mitigation investigation based on pre-defined mitigation thresholds

 Set mitigation parameters ✕

**Applicationable to Existing Buildings/Infrastructure**

|   | Risk Identification | Soil Type    | Stratigraphy | Depth of treatment zone | Size of Area     | Foundation Type     | Project Constraints    | Subsurface Obstructions | Environmental Compatibility |
|---|---------------------|--------------|--------------|-------------------------|------------------|---------------------|------------------------|-------------------------|-----------------------------|
| 1 | B028                | Gravel soils | Soil crust   | <3 m                    | Small (<1000 m2) | Shallow foundations | Low overhead clearance | No                      | Yes                         |
| 2 | B029                | Gravel soils | Soil crust   | <3 m                    | Small (<1000 m2) | Shallow foundations | Low overhead clearance | No                      | Yes                         |
| 3 | B030                | Gravel soils | Soil crust   | <3 m                    | Small (<1000 m2) | Shallow foundations | Low overhead clearance | No                      | Yes                         |

OK

Cancel

Help





# Set Mitigation Parameters

Selected building for mitigation investigation based on pre-defined mitigation thresholds

Hazard Analysis Output

Risk Analysis Output

Mitigation Analysis Output

Seismic Ground Shaking

Ground Liquefaction

Owner Loss

Risk Identification

ALL

BUILDING

CONTENTS

BUSINESS INTERRUPTION

|    | Risk Identification | Latitude  | Longitude | Geo-code | LPI     | Settlement (cm) | LSN     | LSN (ESP) | ESP | Liquefaction Risk Level (LPI-Based) | Liquefaction Risk Level (LSN-Based) | Probability (Slite) | Probability (Moderate) | Probability (Extensive) | Probability (Complete) | Mean Loss Ratio (Building) | Monetary Values (Building) | Loss (Building) |  |
|----|---------------------|-----------|-----------|----------|---------|-----------------|---------|-----------|-----|-------------------------------------|-------------------------------------|---------------------|------------------------|-------------------------|------------------------|----------------------------|----------------------------|-----------------|--|
| 5  | B023                | 44.804700 | 11.411100 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 109 240.00                 | 0.00            |  |
| 6  | B024                | 44.804800 | 11.410900 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 162 900.00                 | 0.00            |  |
| 7  | B025                | 44.804500 | 11.411400 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 428 100.00                 | 0.00            |  |
| 8  | B026                | 44.804200 | 11.411900 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 160 750.00                 | 0.00            |  |
| 9  | B027                | 44.804000 | 11.411600 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 271 050.00                 | 0.00            |  |
| 10 | B028                | 44.803900 | 11.408800 | 1        | 9.7548  | 3.7707          | 7.1690  | 60.4450   | WLS | High                                | Low                                 | 0.000000            | 0.000000               | 0.000002                | 0.999998               | 1.000000                   | 327 100.00                 | 327 099.95      |  |
| 11 | B029                | 44.803700 | 11.409600 | 1        | 13.4352 | 5.1838          | 11.1685 | 80.6003   | WMS | High                                | Moderate                            | 0.000000            | 0.000000               | 0.000000                | 1.000000               | 1.000000                   | 132 700.00                 | 132 700.00      |  |
| 12 | B030                | 44.803600 | 11.409100 | 1        | 8.6068  | 3.9682          | 4.0382  | 129.5341  | WLD | High                                | None                                | 0.000000            | 0.000000               | 0.000001                | 0.999999               | 1.000000                   | 506 250.00                 | 506 249.99      |  |
| 13 | B031                | 44.803200 | 11.408600 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 162 800.00                 | 0.00            |  |
| 14 | B032                | 44.804200 | 11.409700 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 107 700.00                 | 0.00            |  |
| 15 | B033                | 44.804100 | 11.409300 | 1        | 0.0000  | 0.0000          | 0.0000  | 0.0000    | RXX | None                                | None                                | 0.000000            | 0.000000               | 0.000000                | 0.000000               | 0.000000                   | 327 100.00                 | 0.00            |  |

Export...

# Mitigation Framework

## Mitigation techniques applicability score

Hazard Analysis Output

Risk Analysis Output

Mitigation Analysis Output

Applicationable to Existing Buildings/Infrastructure

ALL

MITIGATION TECHNIQUES APPLICABILITY SCORE

MITIGATION COST

EXPECTED BENEFIT

COST BENEFIT RATIO (CBR)

|   | Risk Identification | Latitude  | Longitude | EARTHQUAKE DRAINS (Score) | DEEP DYNAMIC COMPACTION (Score) | VIBRO COMPACTION (Score) | BLASTING COMPACTION (Score) | VIBRO REPLACEMENT (Score) | INDUCED PARTIAL SATURATION (Score) | COMPACTION GROUTING (Score) | LOW PRESSURE GROUTING (Score) | JET GROUTING (Score) | DEEP SOIL MIXING (Score) | HIGHEST RANKED G. I. TECHNOLOGY |
|---|---------------------|-----------|-----------|---------------------------|---------------------------------|--------------------------|-----------------------------|---------------------------|------------------------------------|-----------------------------|-------------------------------|----------------------|--------------------------|---------------------------------|
| 1 | B028                | 44.803901 | 11.408807 | 173                       | 141                             | 192                      | 90                          | 128                       | 236                                | 227                         | 256                           | 209                  | 191                      | LOW PRESSURE GROUTING           |
| 2 | B029                | 44.803652 | 11.409595 | 173                       | 141                             | 192                      | 90                          | 128                       | 236                                | 227                         | 256                           | 209                  | 191                      | LOW PRESSURE GROUTING           |
| 3 | B030                | 44.803551 | 11.409127 | 173                       | 141                             | 192                      | 90                          | 128                       | 236                                | 227                         | 256                           | 209                  | 191                      | LOW PRESSURE GROUTING           |

# Mitigation Framework

## Mitigation Cost

Hazard Analysis Output Risk Analysis Output Mitigation Analysis Output

### Applicationable to Existing Buildings/Infrastructure

ALL MITIGATION TECHNIQUES APPLICABILITY SCORE MITIGATION COST EXPECTED BENEFIT COST BENEFIT RATIO (CBR)

|   | Risk Identification | Latitude  | Longitude | EARTHQUAKE DRAINS<br>(Mitigaton Cost) | DEEP DYNAMIC COMPACTION<br>(Mitigaton Cost) | VIBRO COMPACTION<br>(Mitigaton Cost) | BLASTING COMPACTION<br>(Mitigaton Cost) | VIBRO REPLACEMENT<br>(Mitigaton Cost) | INDUCED PARTIAL SATURATION<br>(Mitigaton Cost) | COMPACTION GROUTING<br>(Mitigaton Cost) | LOW PRESSURE GROUTING<br>(Mitigaton Cost) | JET GROUTING<br>(Mitigaton Cost) | DEEP SOIL MIXING<br>(Mitigaton Cost) |
|---|---------------------|-----------|-----------|---------------------------------------|---|--------------------------------------|---|---------------------------------------|--|---|---|----------------------------------|--------------------------------------|
| 1 | B028                | 44.803901 | 11.408807 | 11 567                                | 11 567                                      | 11 567                               | 11 567                                  | 11 567                                | 11 567   | 11 567                                  | 11 567                                    | 11 567                           | 11 567                               |
| 2 | B029                | 44.803652 | 11.409595 | 4 824                                 | 4 824                                       | 4 824                                | 4 824                                   | 4 824                                 | 4 824  | 4 824                                   | 4 824                                     | 4 824                            | 4 824                                |
| 3 | B030                | 44.803551 | 11.409127 | 19 639                                | 19 639                                      | 19 639                               | 19 639                                  | 19 639                                | 19 639   | 19 639                                  | 19 639                                    | 19 639                           | 19 639                               |



# Mitigation Framework

## Expected Benefit

Hazard Analysis Output Risk Analysis Output Mitigation Analysis Output

### Applicationable to Existing Buildings/Infrastructure

ALL MITIGATION TECHNIQUES APPLICABILITY SCORE MITIGATION COST EXPECTED BENEFIT COST BENEFIT RATIO (CBR)

|   | Risk Identification | Latitude  | Longitude | EARTHQUAKE DRAINS<br>(Expected Benefit) | DEEP DYNAMIC COMPACTION<br>(Expected Benefit) | VIBRO COMPACTION<br>(Expected Benefit) | BLASTING COMPACTION<br>(Expected Benefit) | VIBRO REPLACEMENT<br>(Expected Benefit) | INDUCED PARTIAL SATURATION<br>(Expected Benefit) | COMPACTION GROUTING<br>(Expected Benefit) | LOW PRESSURE GROUTING<br>(Expected Benefit) | JET GROUTING<br>(Expected Benefit) | DEEP SOIL MIXING<br>(Expected Benefit) | MAXIMUM BENEFIT   |
|---|---------------------|-----------|-----------|---|---|--|---|---|--|---|---|------------------------------------|--|-------------------|
| 1 | B028                | 44.803901 | 11.408807 | 16 604.50                               | 12 453.40                                     | 8 302.24                               | 10 377.80                                 | 11 415.60                               | 9 340.03   | 14 528.90                                 | 13 491.10                                   | 15 566.70                          | 12 453.40                              | EARTHQUAKE DRAINS |
| 2 | B029                | 44.803652 | 11.409595 | 7 255.38                                | 5 441.53                                      | 3 627.69                               | 4 534.61                                  | 4 988.07                                | 4 081.15   | 6 348.45                                  | 5 894.99                                    | 6 801.92                           | 5 441.53                               | EARTHQUAKE DRAINS |
| 3 | B030                | 44.803551 | 11.409127 | 30 268.90                               | 22 701.70                                     | 15 134.40                              | 18 918.10                                 | 20 809.90                               | 17 026.20  | 26 485.30                                 | 24 593.50                                   | 28 377.10                          | 22 701.70                              | EARTHQUAKE DRAINS |



# Mitigation Framework

## Cost Benefit Ratio (CBR)

Hazard Analysis Output Risk Analysis Output Mitigation Analysis Output

### Applicationable to Existing Buildings/Infrastructure

ALL MITIGATION TECHNIQUES APPLICABILITY SCORE MITIGATION COST EXPECTED BENEFIT COST BENEFIT RATIO (CBR)

|   | Risk Identification | Latitude  | Longitude | EARTHQUAKE DRAINS (CBR) | DEEP DYNAMIC COMPACTION (CBR) | VIBRO COMPACTION (CBR) | BLASTING COMPACTION (CBR) | VIBRO REPLACEMENT (CBR) | INDUCED PARTIAL SATURATION (CBR) | COMPACTION GROUTING (CBR) | LOW PRESSURE GROUTING (CBR) | JET GROUTING (CBR) | DEEP SOIL MIXING (CBR) | MINIMUM CBR       |
|---|---------------------|-----------|-----------|-------------------------|-------------------------------|------------------------|---------------------------|-------------------------|----------------------------------|---------------------------|-----------------------------|--------------------|------------------------|-------------------|
| 1 | B028                | 44.803901 | 11.408807 | 0.70                    | 0.93                          | 1.39                   | 1.11                      | 1.01                    | 1.24                             | 0.80                      | 0.86                        | 0.74               | 0.93                   | EARTHQUAKE DRAINS |
| 2 | B029                | 44.803652 | 11.409595 | 0.66                    | 0.89                          | 1.33                   | 1.06                      | 0.97                    | 1.18                             | 0.76                      | 0.82                        | 0.71               | 0.89                   | EARTHQUAKE DRAINS |
| 3 | B030                | 44.803551 | 11.409127 | 0.65                    | 0.87                          | 1.30                   | 1.04                      | 0.94                    | 1.15                             | 0.74                      | 0.80                        | 0.69               | 0.87                   | EARTHQUAKE DRAINS |



# Mitigation Framework

Overall result of mitigation and cost-benefit analysis for a selected building

Mitigation Result (B028)

| G.I. TECHNOLOGY            | Score | Mitigation cost | Annual Frequency of Damage (%) | Expected Annual Loss Before Mitigation (EAL) | Expected Annual Loss After Mitigation (EALM) | Expected Loss Avoided (EAL - EALM) | Expected Benefit | Cost-Benefit Ratio |
|----------------------------|-------|-----------------|--------------------------------|--|--|------------------------------------|------------------|--------------------|
| EARTHQUAKE DRAINS          | 173   | 11 567          | 0.072149                       | 245.68                                       | 49.14  | 196.54                             | 16 604.50        | 0.70               |
| DEEP DYNAMIC COMPACTION    | 141   | 11 567          | 0.072149                       | 245.68                                       | 98.27  | 147.41                             | 12 453.40        | 0.93               |
| VIBRO COMPACTION           | 192   | 11 567          | 0.072149                       | 245.68                                       | 147.41                                       | 98.27                              | 8 302.24         | 1.39               |
| BLASTING COMPACTION        | 90    | 11 567          | 0.072149                       | 245.68                                       | 122.84                                       | 122.84                             | 10 377.80        | 1.11               |
| VIBRO REPLACEMENT          | 128   | 11 567          | 0.072149                       | 245.68                                       | 110.55                                       | 135.12                             | 11 415.60        | 1.01               |
| INDUCED PARTIAL SATURATION | 236   | 11 567          | 0.072149                       | 245.68                                       | 135.12                                       | 110.55                             | 9 340.03         | 1.24               |
| COMPACTION GROUTING        | 227   | 11 567          | 0.072149                       | 245.68                                       | 73.70  | 171.97                             | 14 528.90        | 0.80               |
| LOW PRESSURE GROUTING      | 256   | 11 567          | 0.072149                       | 245.68                                       | 85.99  | 159.69                             | 13 491.10        | 0.86               |
| JET GROUTING               | 209   | 11 567          | 0.072149                       | 245.68                                       | 61.42  | 184.26                             | 15 566.70        | 0.74               |
| DEEP SOIL MIXING           | 191   | 11 567          | 0.072149                       | 245.68                                       | 98.27  | 147.41                             | 12 453.40        | 0.93               |

OK

Help

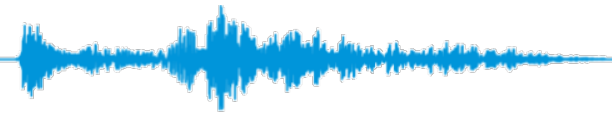
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