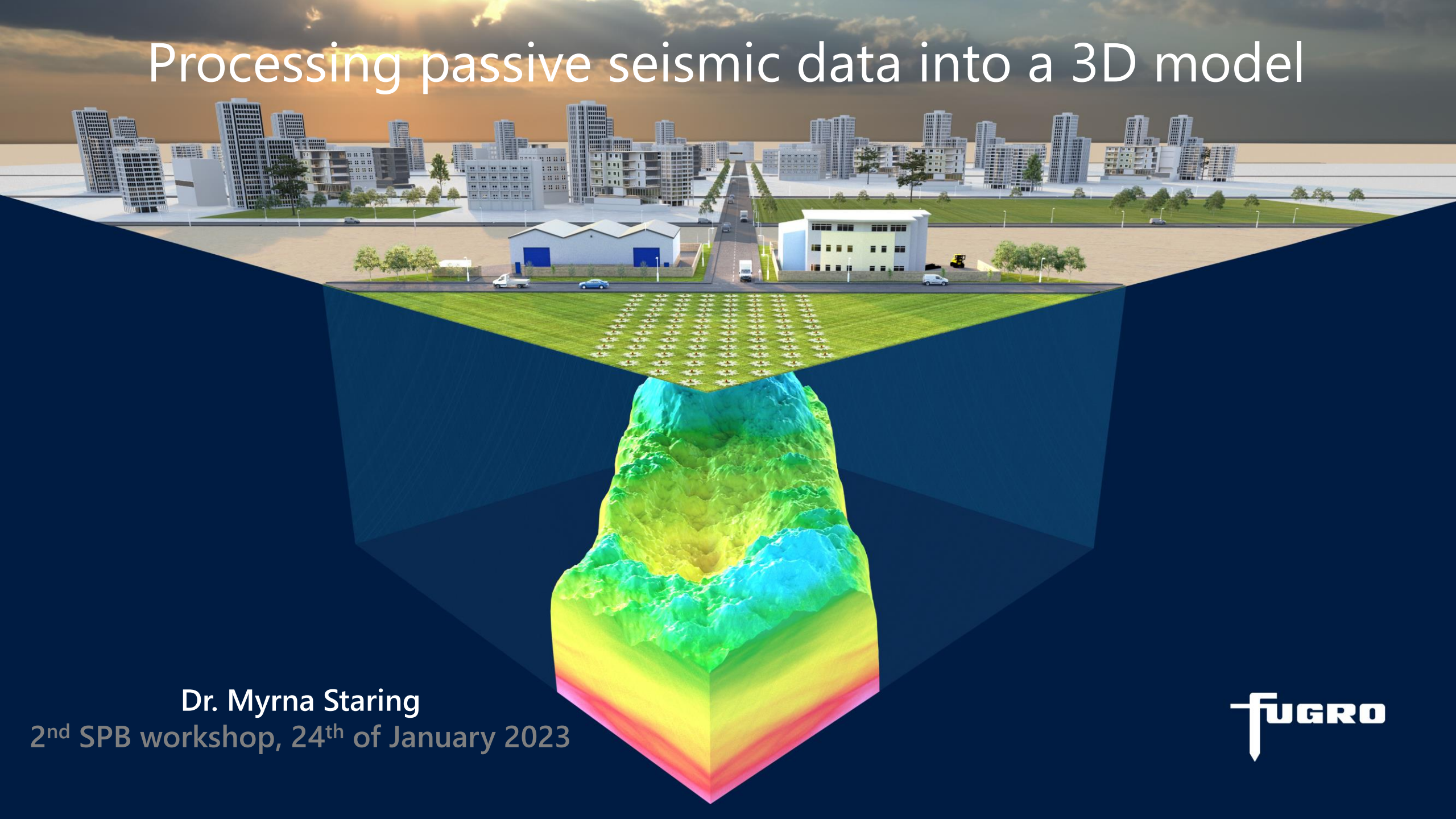
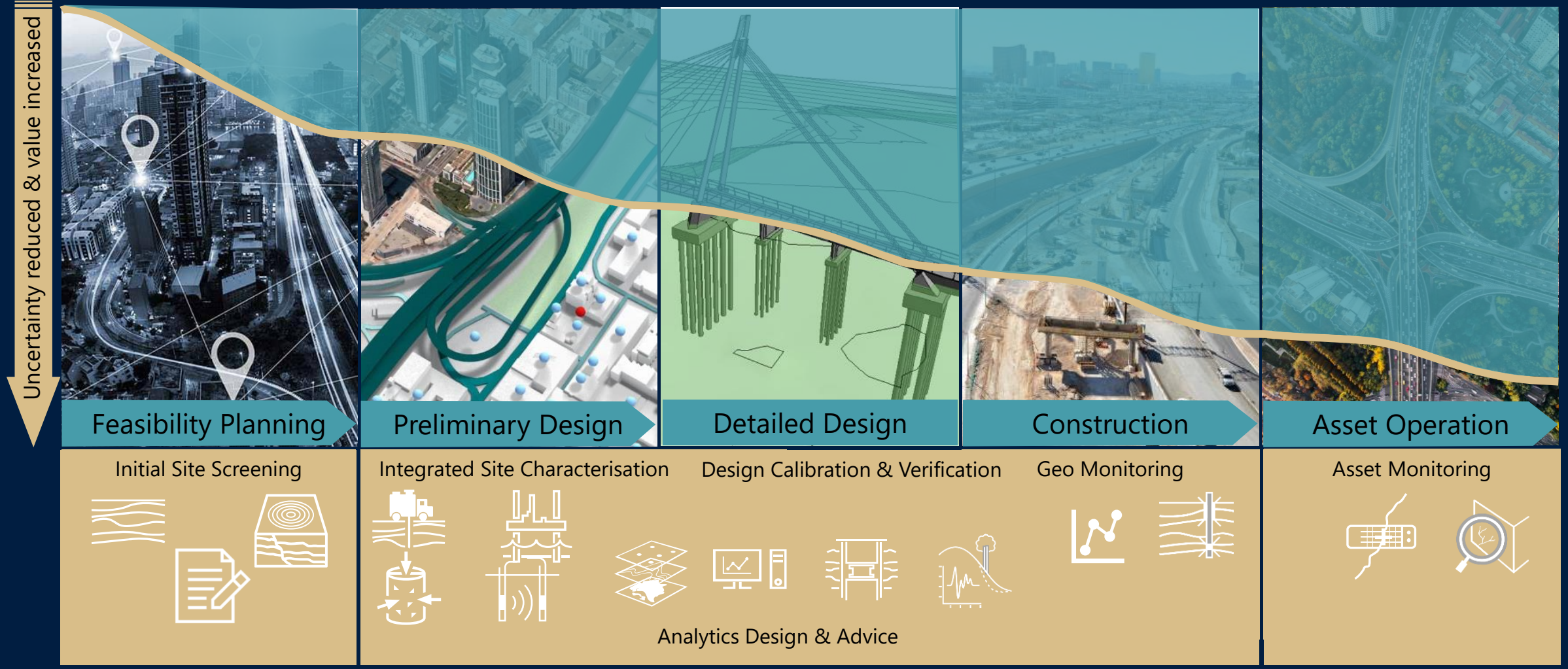
Processing passive seismic data into a 3D model



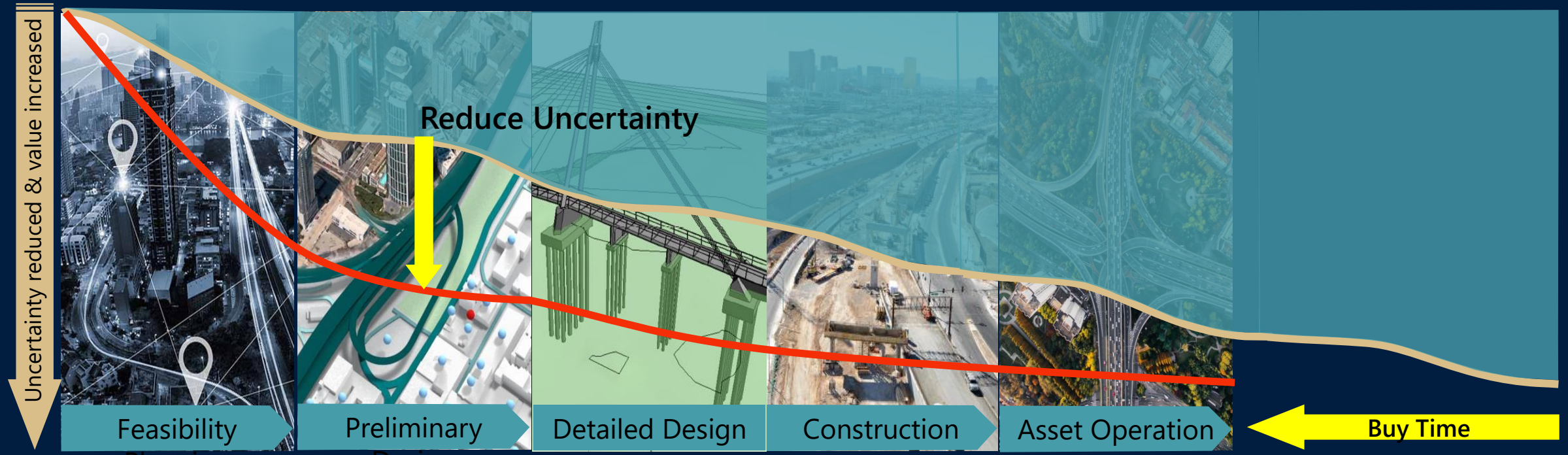
Dr. Myrna Staring

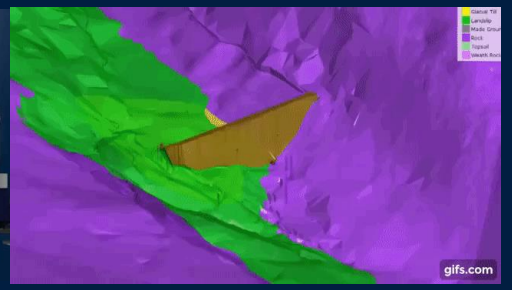
2nd SPB workshop, 24th of January 2023

Geo-Risk Management Framework



Geo-Risk Management Framework

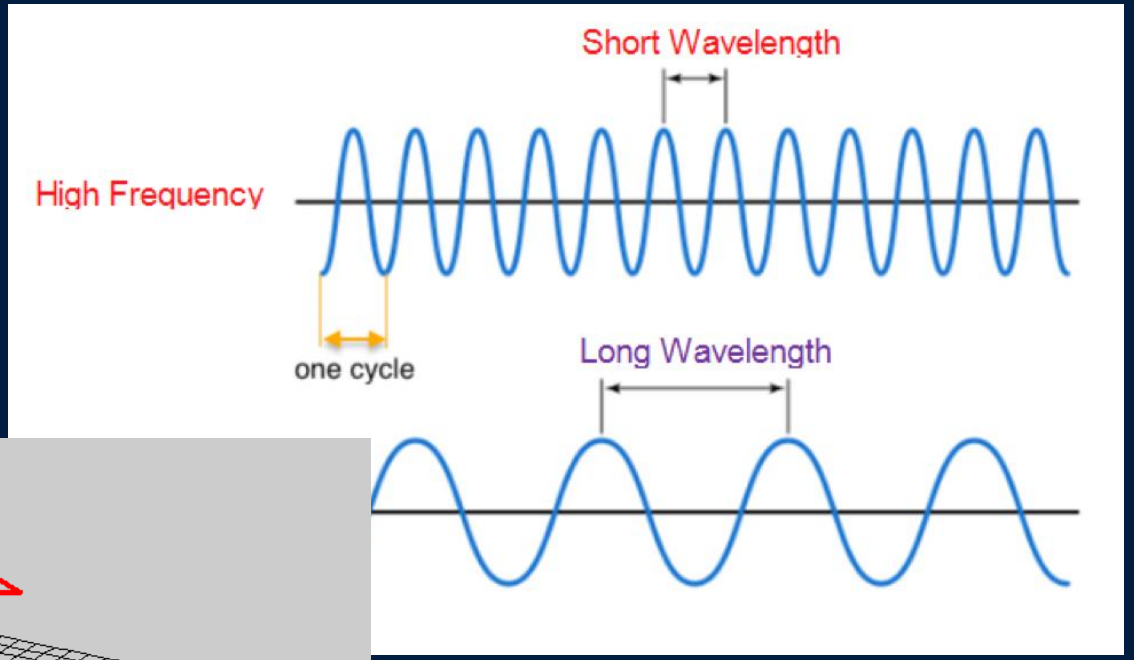


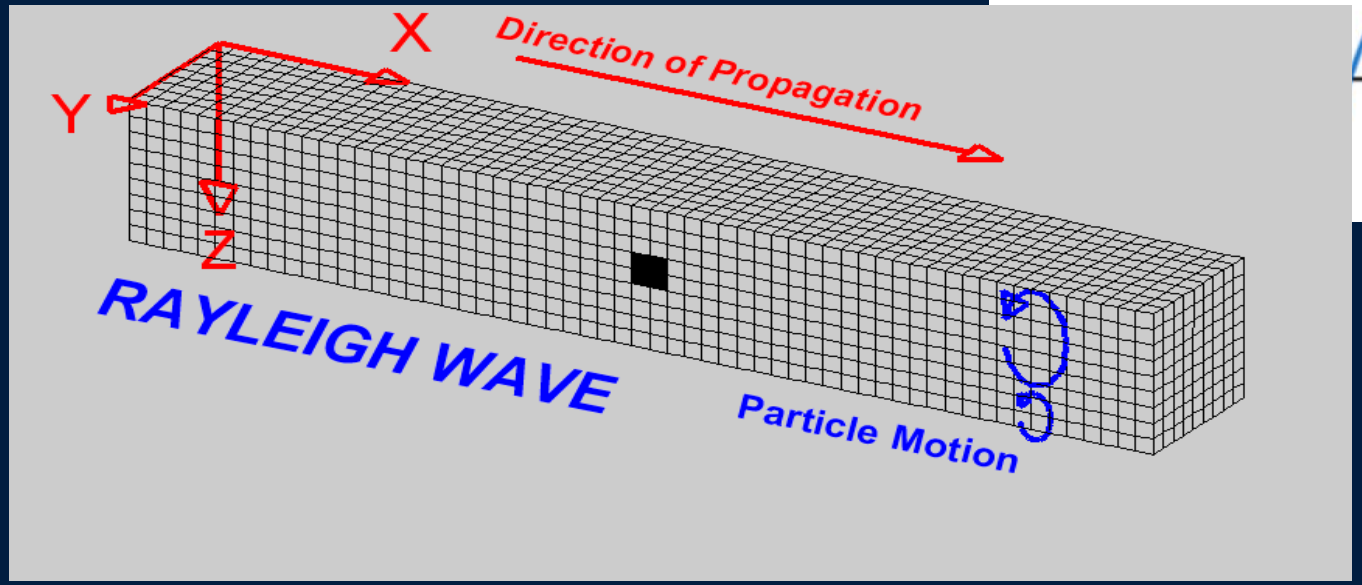


Using surface waves to characterize the subsurface

Global seismology to Exploration Geophysics to Engineering Geophysics

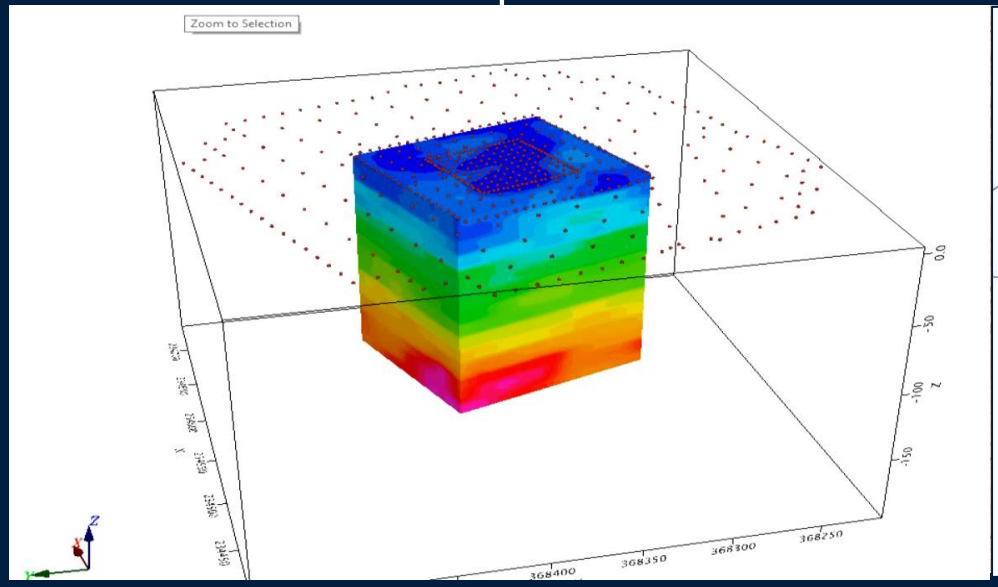
- Surface waves travel along the free surface
- Dispersion: different wavelengths travel at different velocities
- Tailor your frequency bandwidth to your application

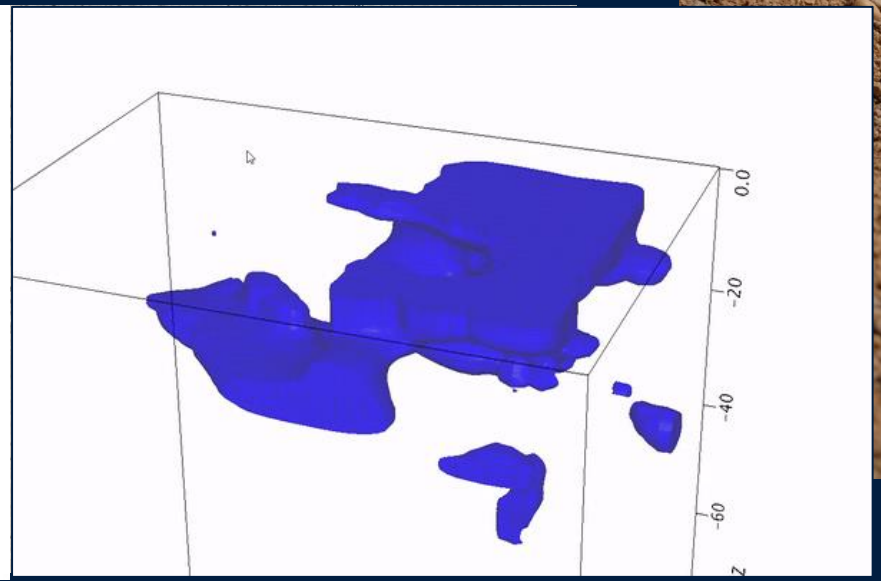




How does SWANS® work?

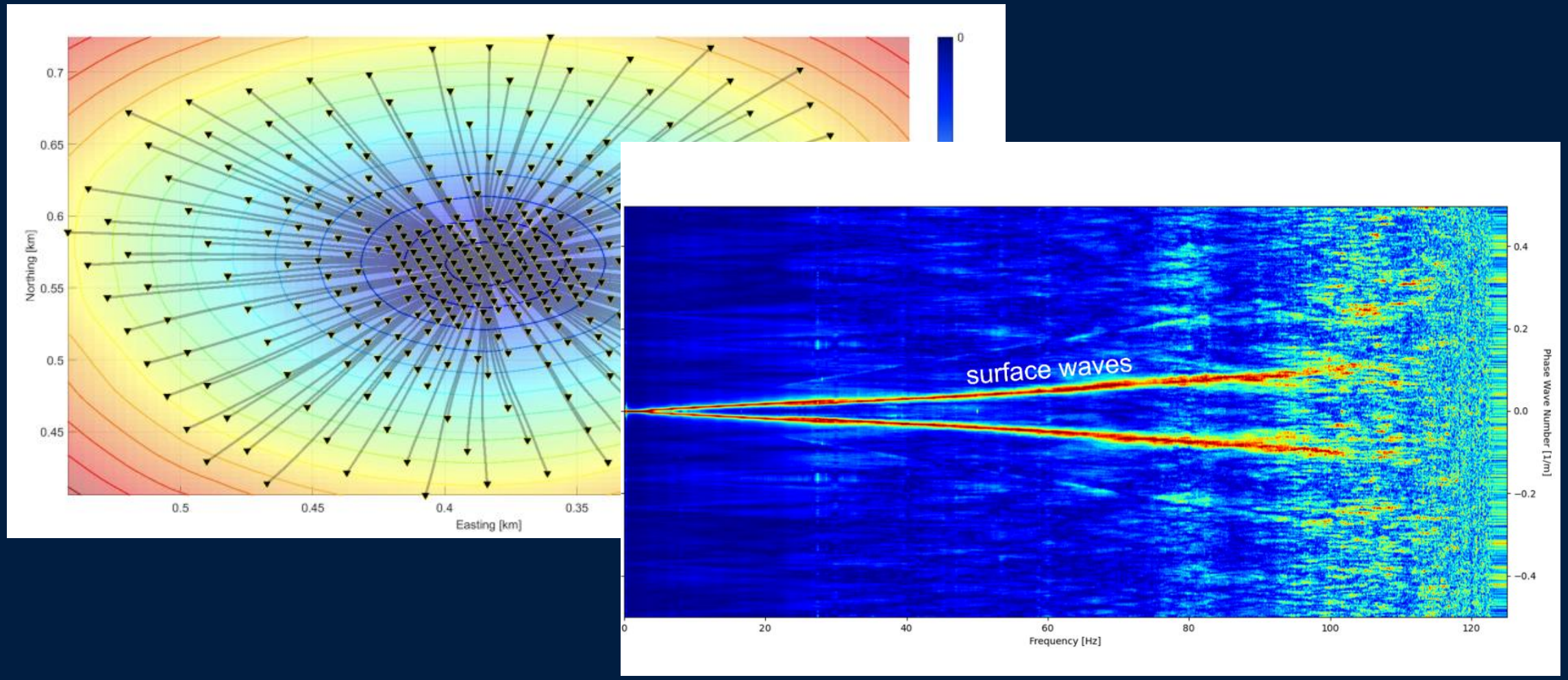
- place a georeferenced mesh of sensors on the site
- grid spacing & size are customized to the objective
- autonomous sensors acquire ambient noise 24/7
- data acquisition – days to weeks
- use a tried-and-tested method from seismology to turn the ambient noise into coherent signal
- use proprietary software to obtain a 3D model of geotechnical parameters from ~10 m depth down to > 100 m depth





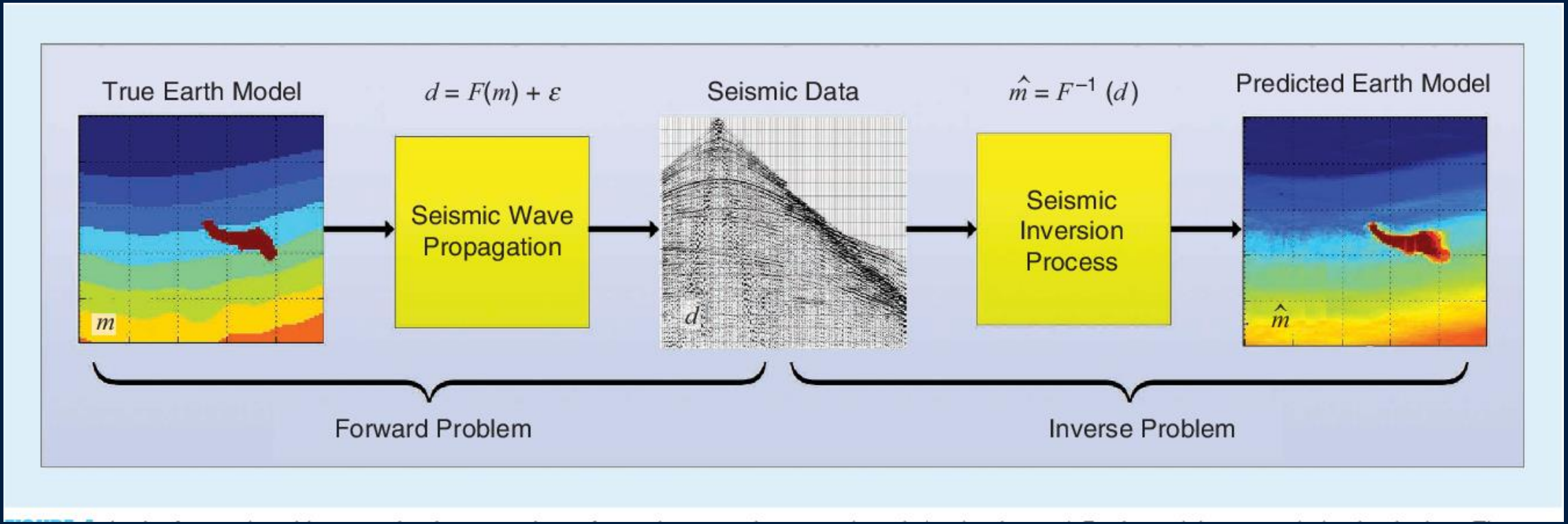
Create virtual sources

Using the ambient seismic noise recorded by all receivers



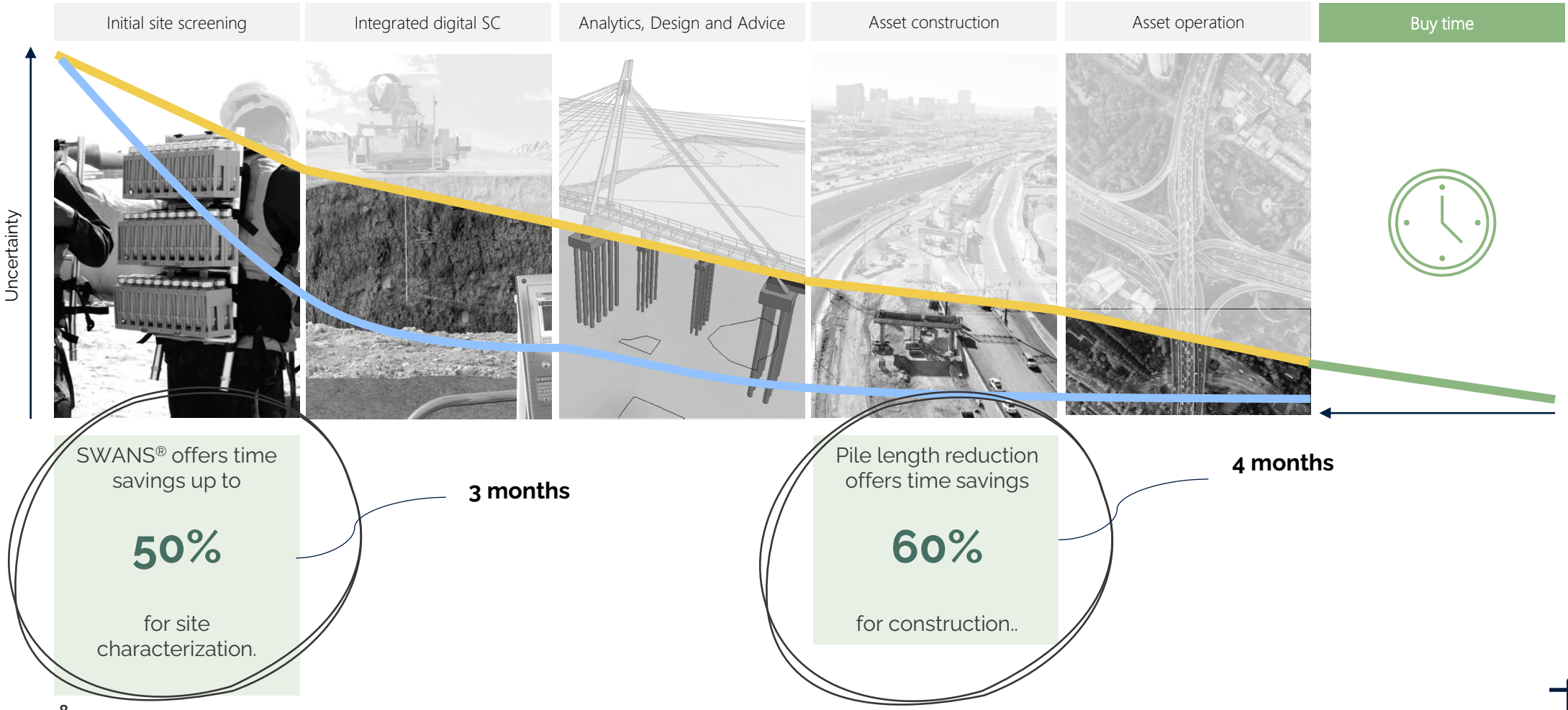
Tomography and inversion

Using the retrieved surface waves



How we reduce uncertainty and accelerate our client's schedules

Using site screening at an early stage



How do we contribute to our client's **sustainability goals**?

SWANS® on this project saved:

- ✓ **450-thousand m of pile**.
- ✓ **3.15 million m^3 of concrete** (of which 20K m3 of steel)

Total value for client:

- **XX Million EUR on CO_2 tax** (Future scenario?)
- Lower risk of incidents on site.

☑ **2 Megatonnes of CO_2** (concrete + steel)

Equivalent to **16K** transatlantic return flights (200 passengers)

☑ **9 million GJ of energy** (heat from cement)

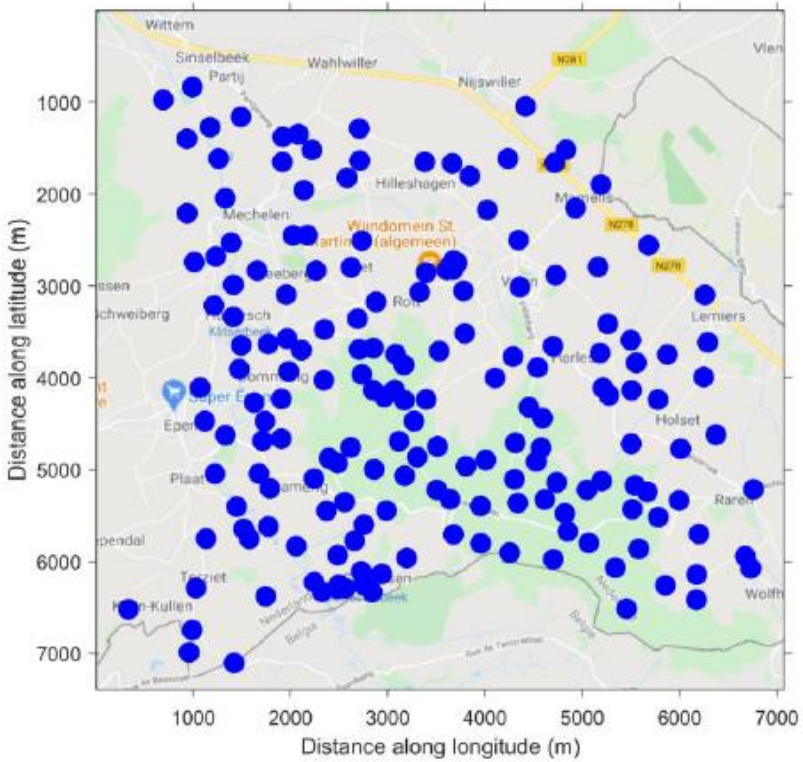
Equivalent to boiling **11K** Olympic pools

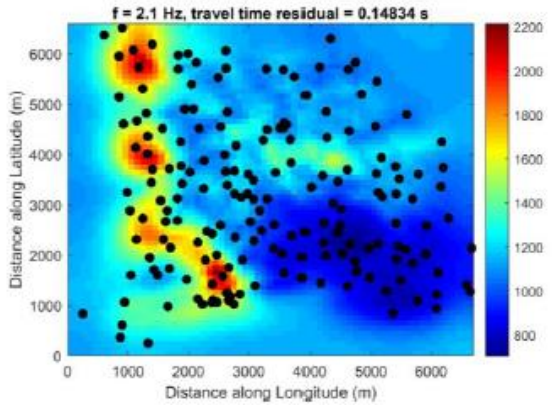
☑ **385 million liters of water**

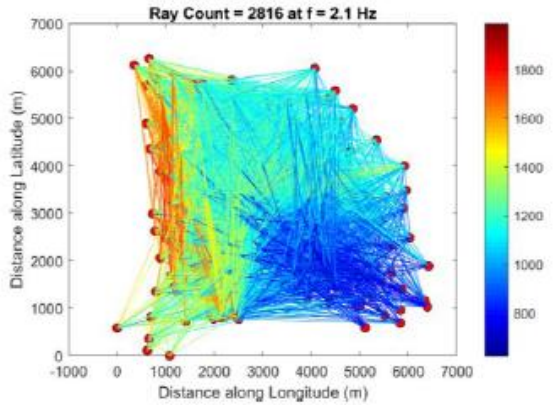
Enough to grow **150 Tonnes** of rice.

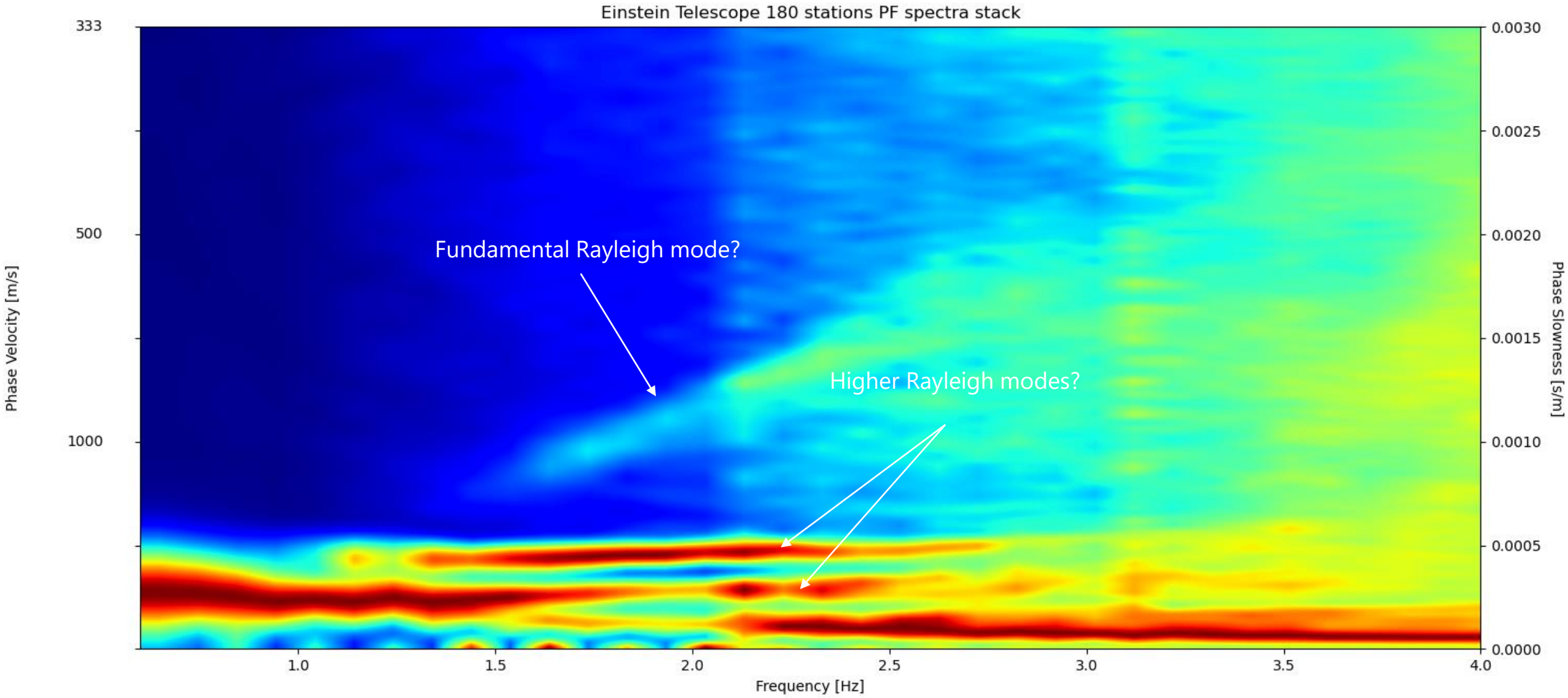
Passive seismic dataset

- 183 nodes on 7x7 sq. km
- 300-400 m station separation
- Previous work by Soumen:
  - Analysis of noise characteristics
  - Array processing
  - Seismic interferometry
  - Beamforming to obtain phase and group velocities
  - Frequency-time analysis
  - Straight ray tomography







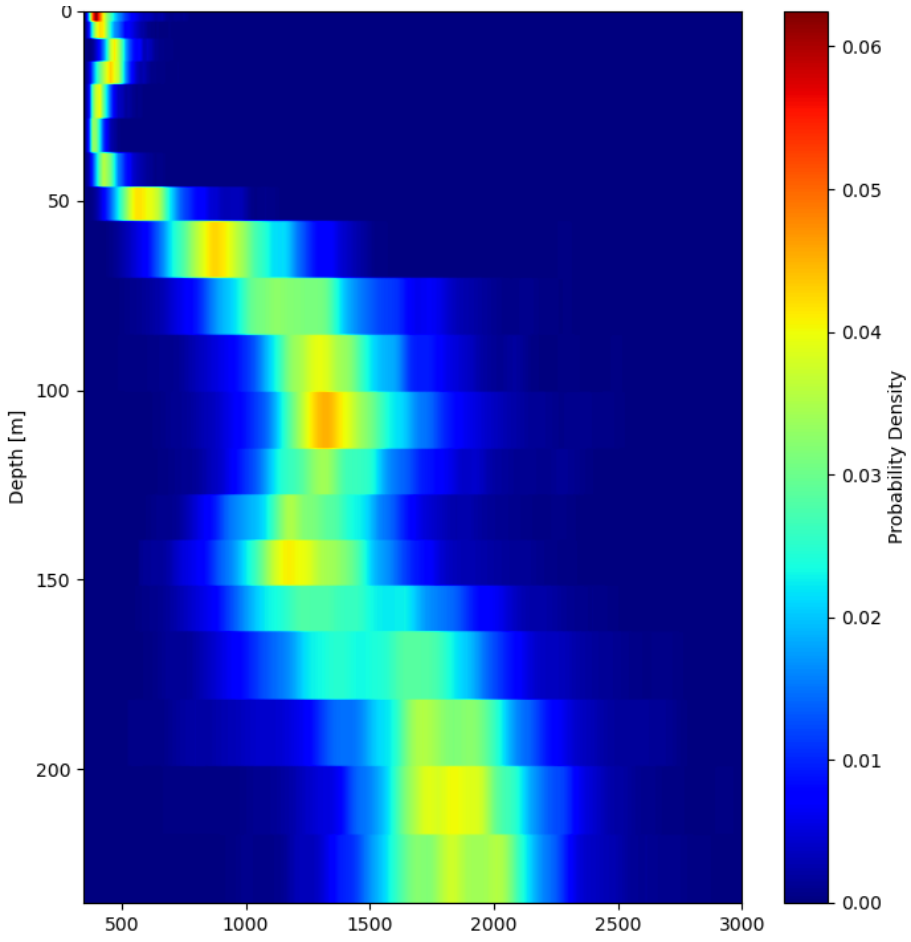

Einstein Telescope 180 stations PF spectra stack
Fundamental Rayleigh mode?
Higher Rayleigh modes?
Phase Velocity [m/s]
Phase Slowness [s/m]
Frequency [Hz]
333
500
1000
0.0030
0.0025
0.0020
0.0015
0.0010
0.0005
0.0000
1.0
1.5
2.0
2.5
3.0
3.5
4.0

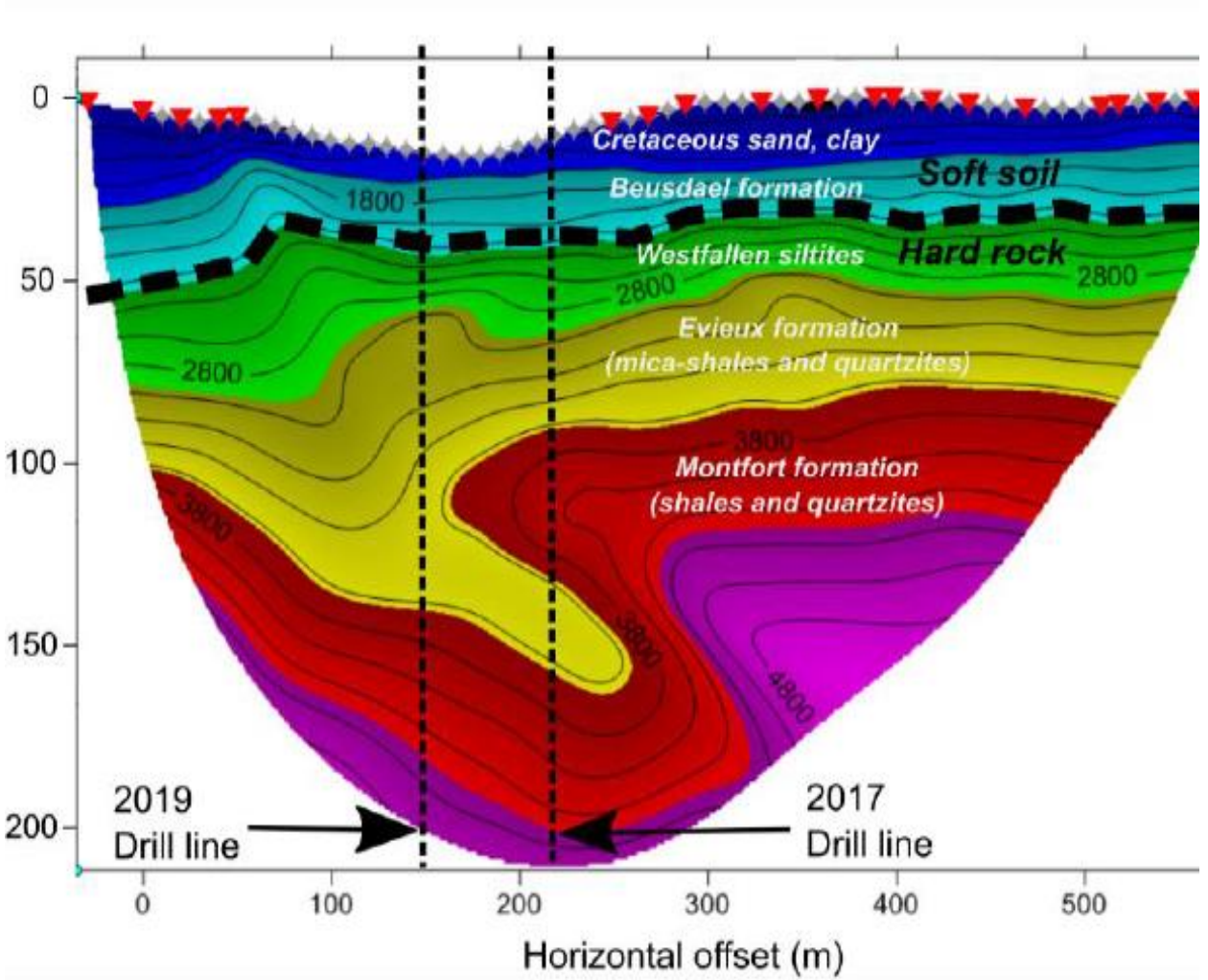
Checking our observations

South Limburg features a unique geology where relatively old hard rock (about 360 million years) is covered by layers of soft soil. This allows the infrastructure to be realized in a cost effective manner in hard rock. Simulations show that the impedance contrast between the soft soil layers on top and the hard rock below effectively shields the sensitive equipment from anthropogenic (human induced) seismic noise generated at the surface as illustrated in Figure 5. Once confirmed (see below) this will be an important characteristic since it not only attenuates the present anthropogenic seismic noise generated at the surface, but it also safeguards Einstein Telescope against possible future unknown anthropogenic noise sources in the region.

- Soft soil over hard rock
- The strong impedance contrast keeps the ambient seismic noise from penetrating the hard rock layer
- Instead, the seismic noise gets trapped in the soft soil layer and generates strong higher harmonics
- Most of the seismic energy that we retrieve is in these higher harmonics

Markov Chain Monte Carlo inversion





SWANS® result: 3D ground model