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"2nd Workshop on Earthquake Engineering for Nuclear Facilities: Uncertainties in Seismic Hazard"

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Engineering quantities and secondary effects

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Engineering quantities and Secondary effects

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Outline

- Ground motion characteristics

- Engineering quantities

  - De-aggregation of hazard computation
  - horizontal response spectrum
  - vertical response spectrum
  - accelerograms

- Secondary effects (only a few remarks)

Ground motion characteristics

- Macroseismic intensity

advantages: direct measure of damage
available also for historical earthquakes

disadvantages: relatively subjective estimation,
a set of discrete values
vs. use as a continuous quantity

Ground motion characteristics

- time histories

seismograms, velocigrams, accelerograms

advantage: full description of ground motion at a site

disadvantage: hard to use it directly in PSHA

Ground motion characteristics

- characteristics derived from time histories

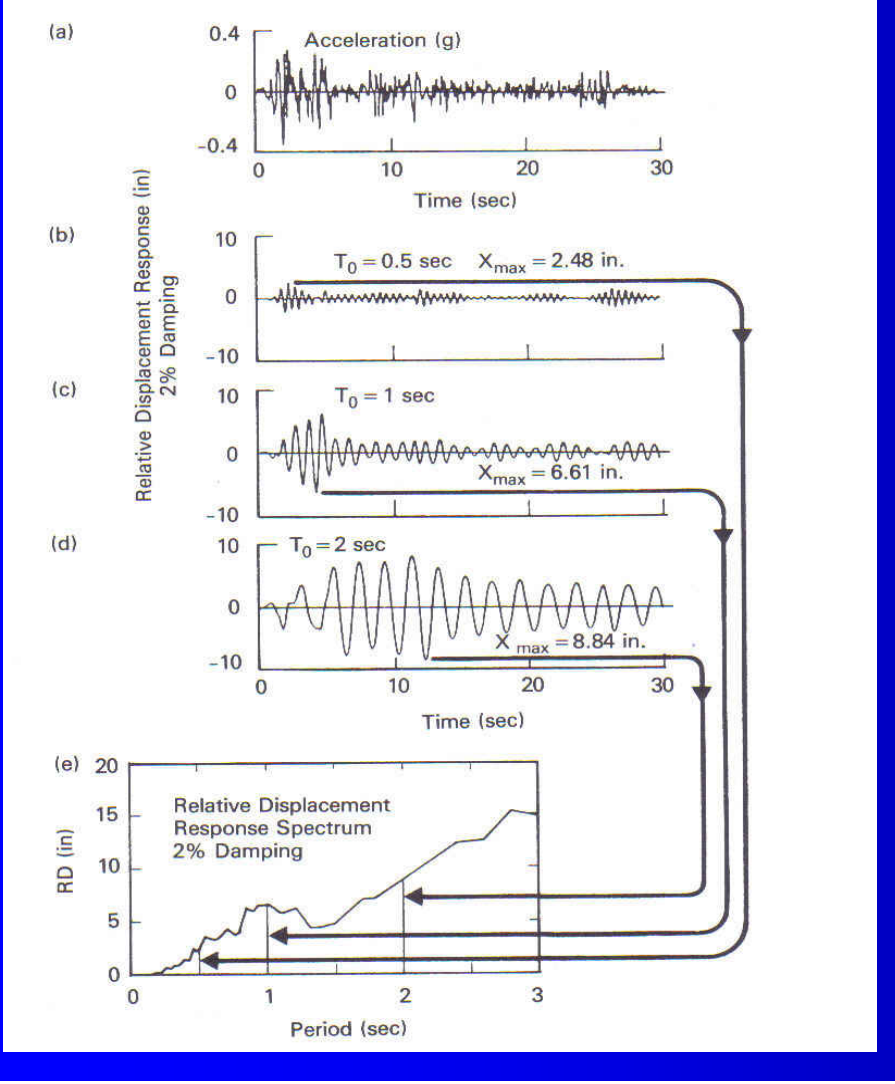
  - peak ground acceleration
  - strong motion duration
  - Arias intensity
  - root mean square acceleration
  - peak differential acceleration

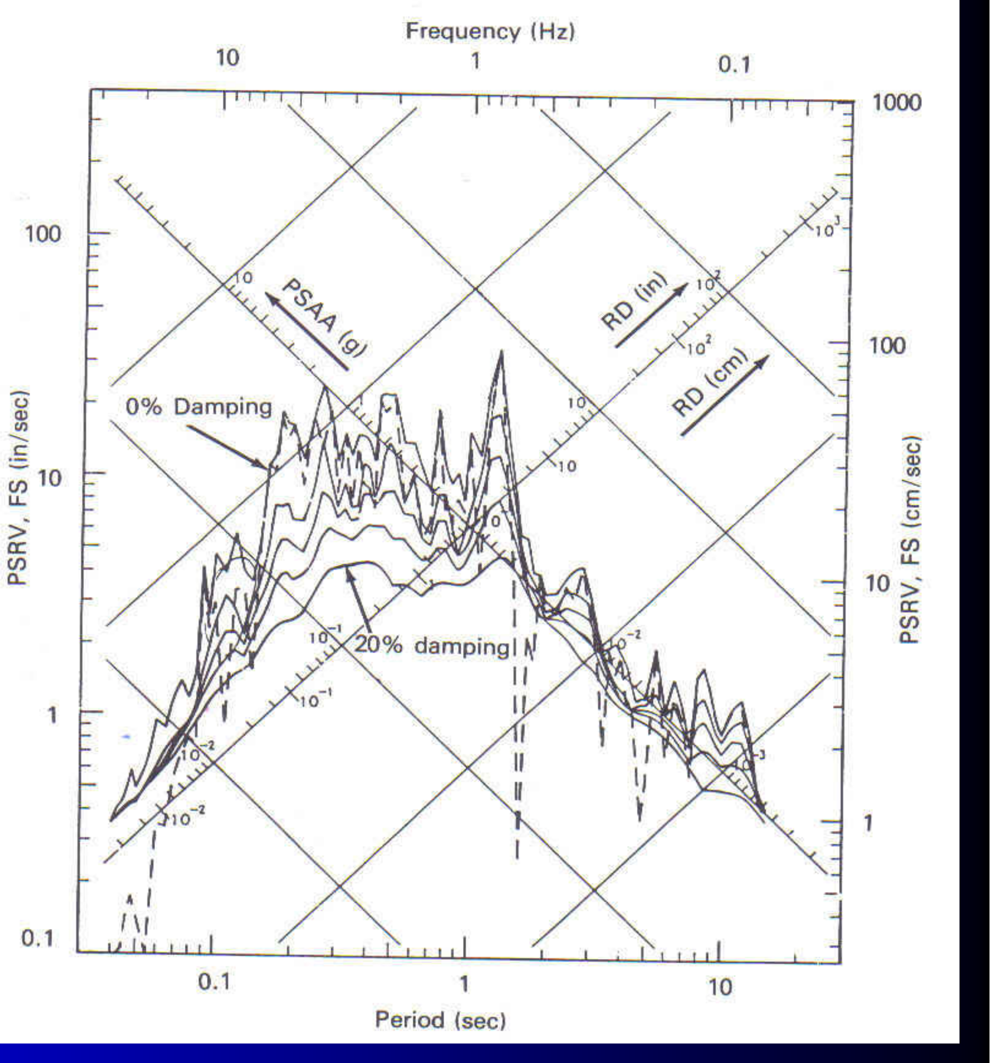
advantage: easier to use in PSHA

disadvantage: do not describe fully ground motion

Ground motion characteristics

- response spectra





Ground motion characteristics

- response spectra

advantage: easy to use in PSHA for selected periods

disadvantage: do not describe fully ground motion
(duration of motion is not described)

Engineering quantities

- ground motion characteristic(s)
for selected return period and confidence level

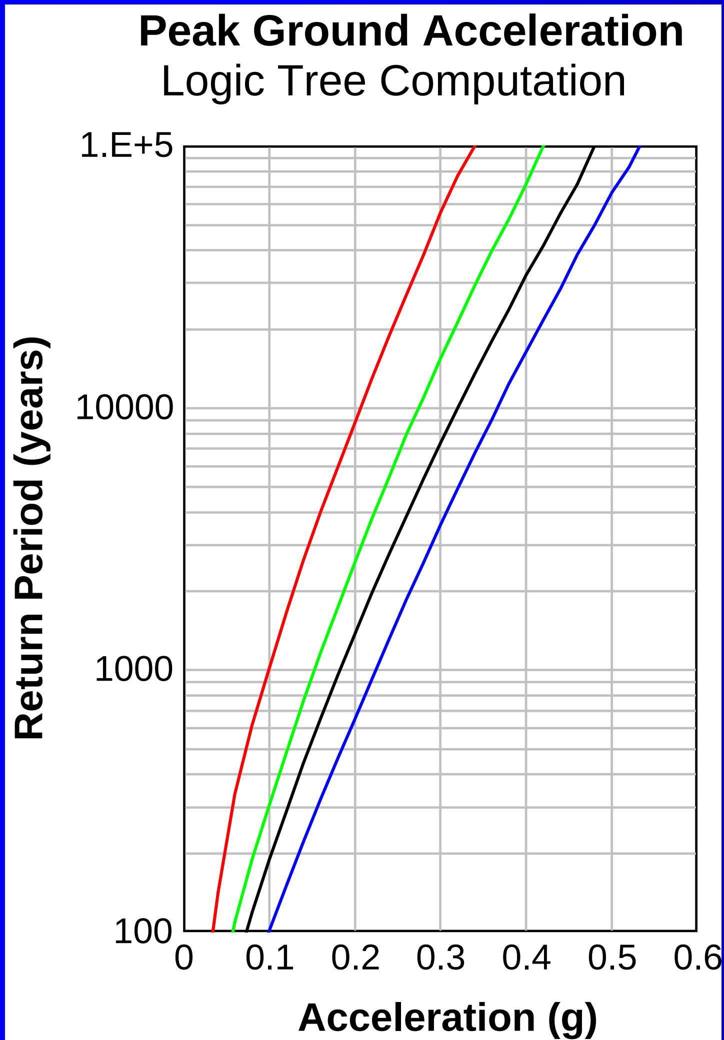
- for NPPs
  - time histories
  - response spectra

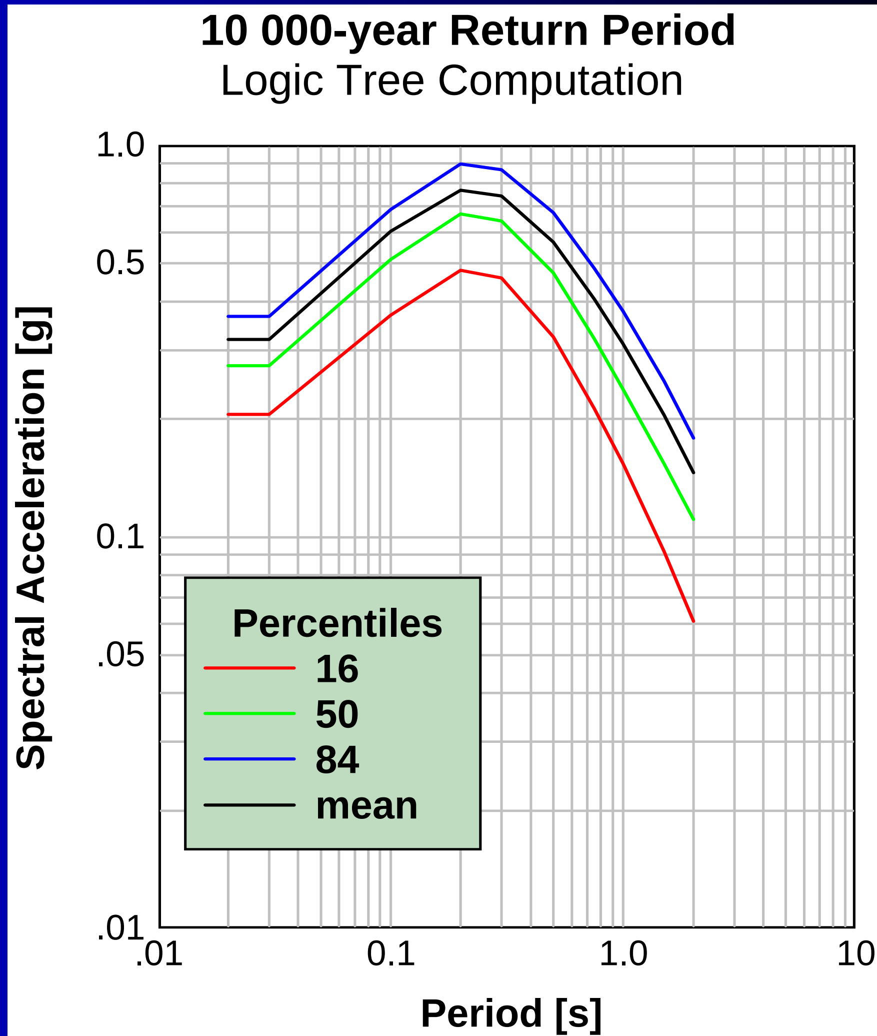
- in the case of SL-2, SSE
mean value for 10 000–year return period
median value for 100 000-year return period

However,

Probabilistic computations

Typical result





Engineering quantities

- how to obtain
site specific engineering quantities
(at free field or foundation level) ?

Example taken from Bohunice NPP (Slovakia) site

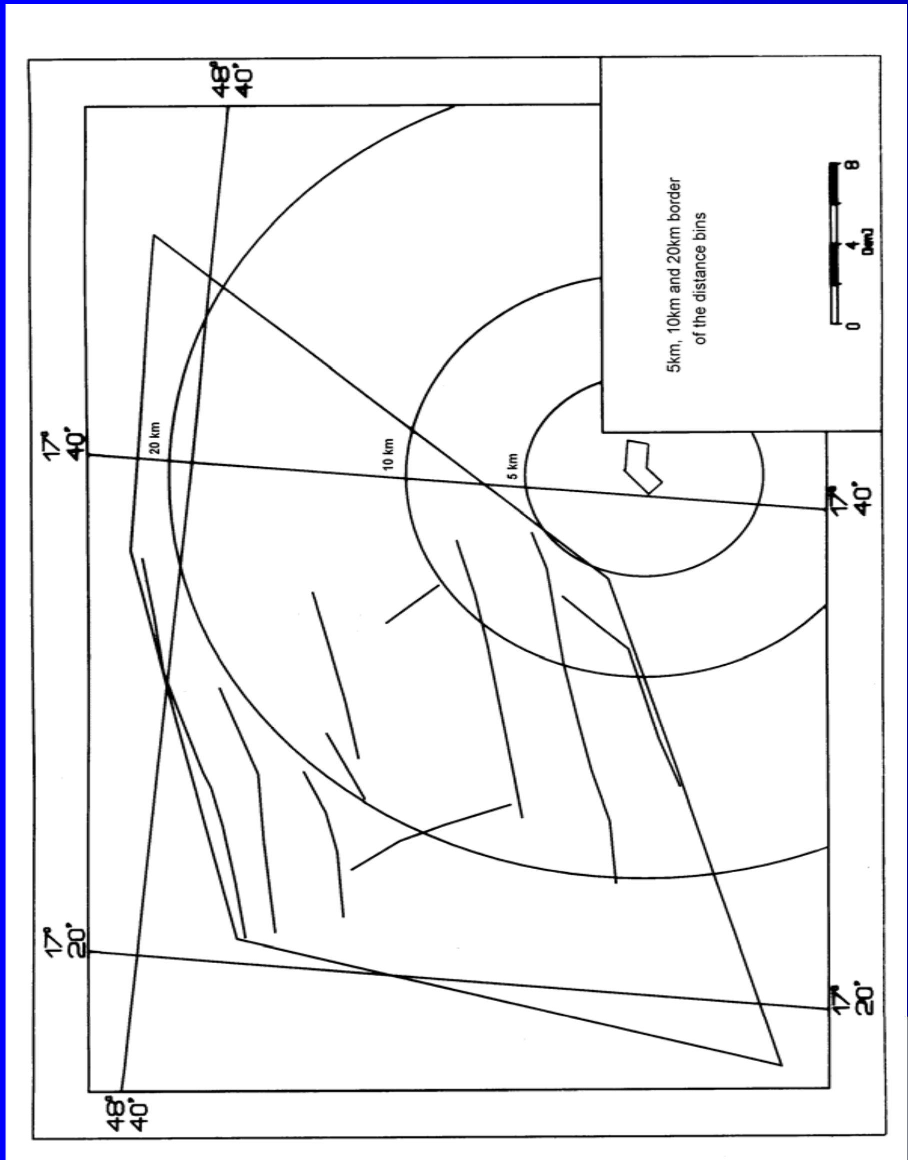
Engineering quantities

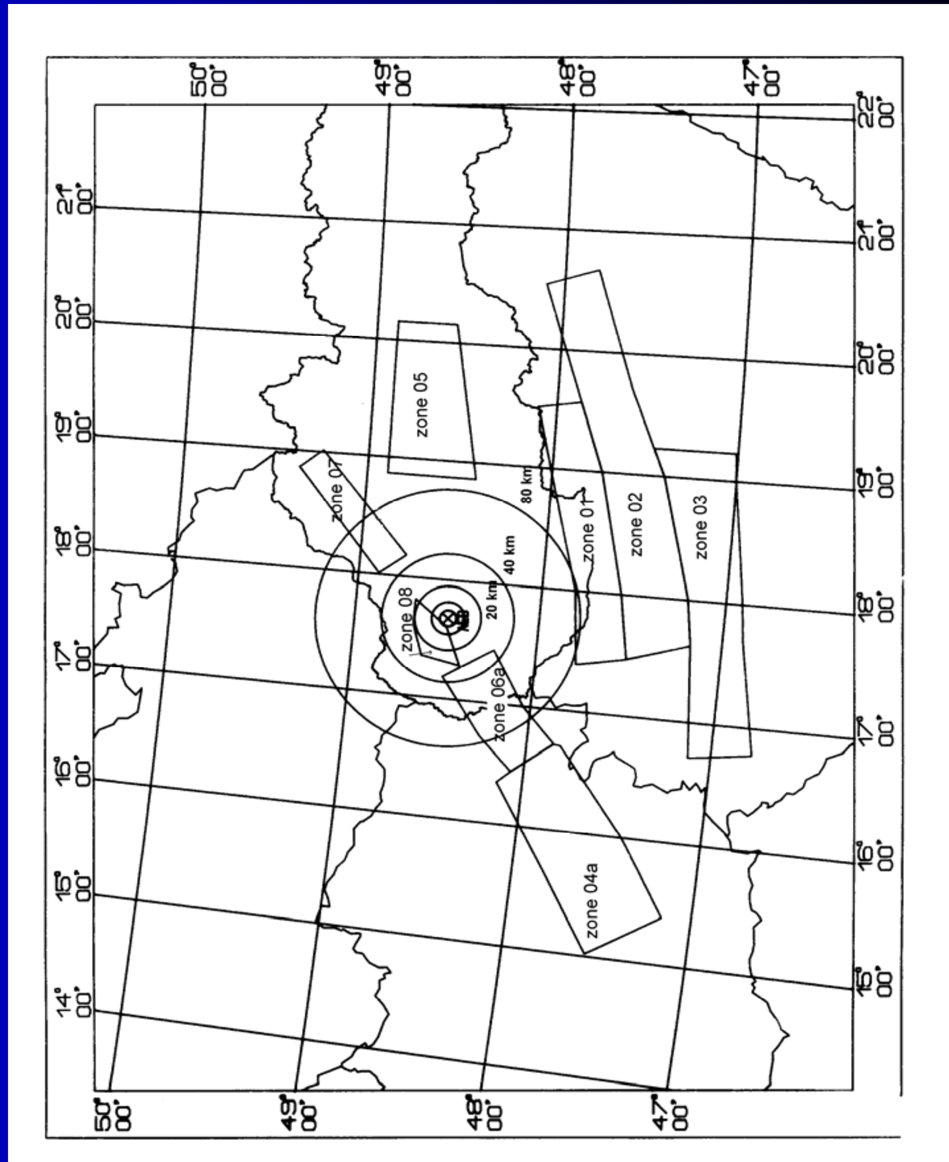
- de-aggregation of hazard computation
- horizontal response spectrum
- vertical response spectrum
- accelerograms

De-aggregation of hazard computation

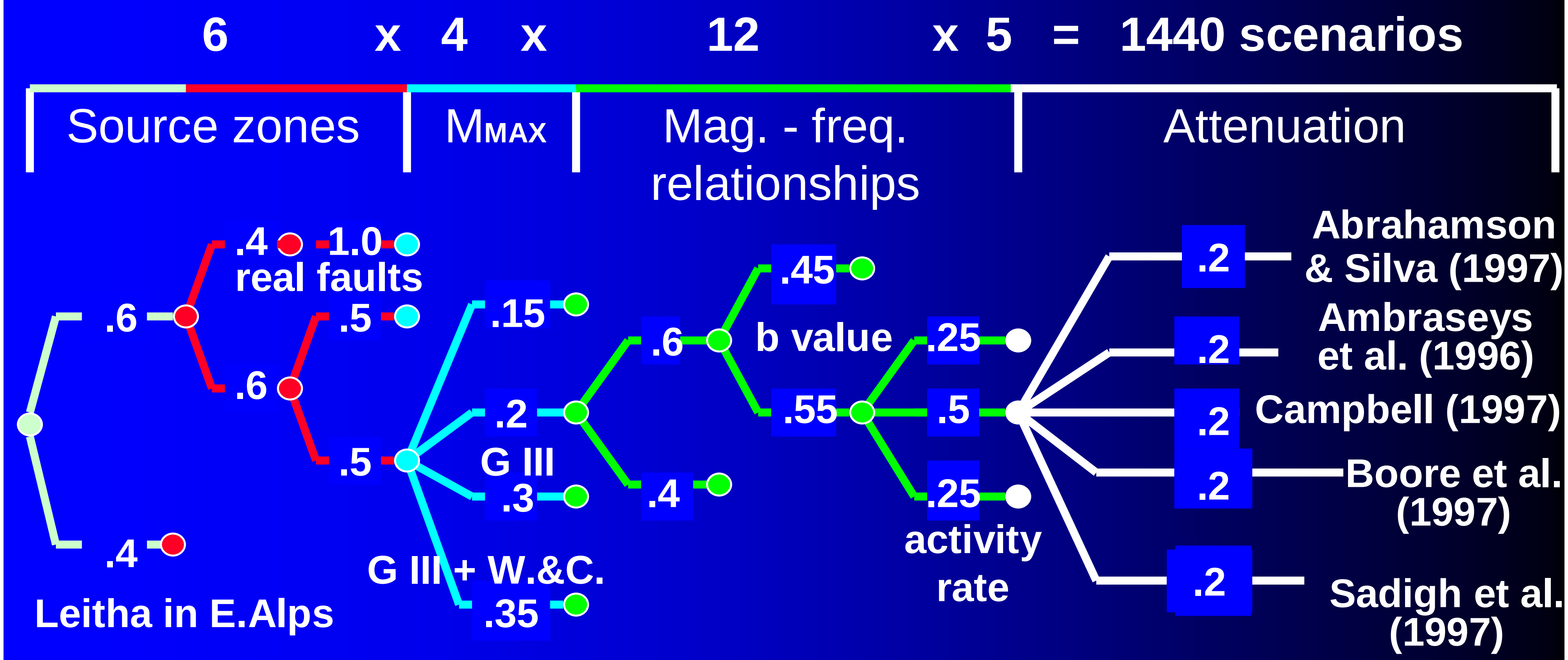
- The whole far region divided into distance bins
- The whole magnitude range between m_0 and M_{MAX} divided into the magnitude bins
- The whole LT computation performed for each magnitude-distance bin for a pre-selected period of response spectrum .
- Fractional relative contributions computed for each magnitude-distance bin
- Magnitude and distance of the controlling earthqauke computed fractional relative contributions

De-aggregation





De-aggregation



De-aggregation

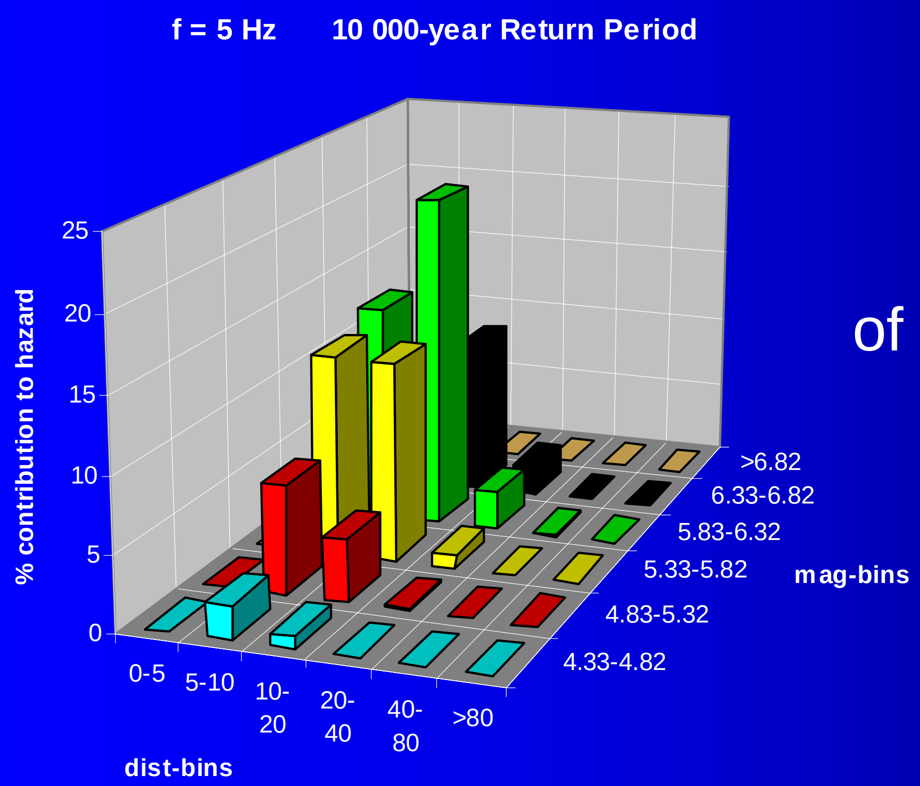
Result:

Magnitude(s)
of the controlling earthquake(s)

Distance(s) of the controlling earthquake

Interpretation of the result:
which source zone(s) and earthquake size
contribute mostly to your
seismic hazard
for specific period in response spectrum
and return period

De-aggregation



Example:
Bohunice NPP

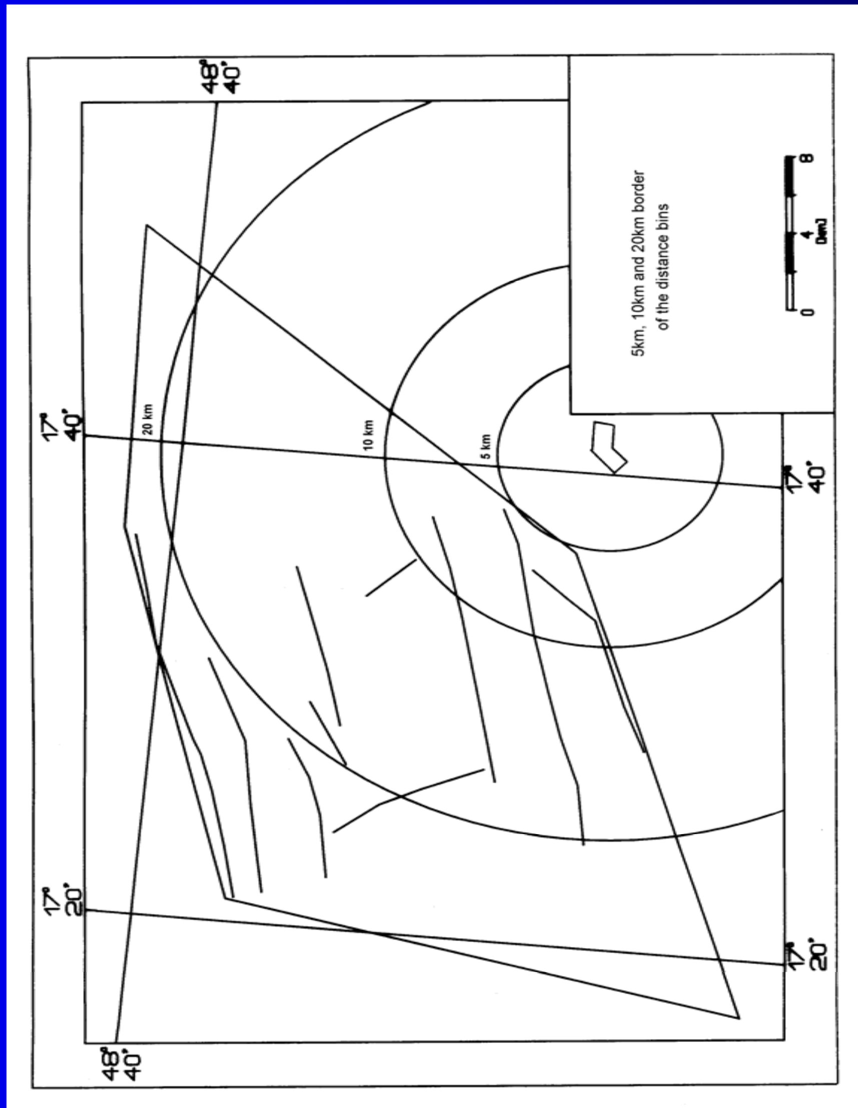
Magnitude
of the controlling earthquake M_S=5.9

Distance
of the controlling earthquake
r_{JB}=12.2 km

Interpretation:

Distance of the controlling earthquake is within one specific source zone

De-aggregation



Engineering quantities

Horizontal spectrum

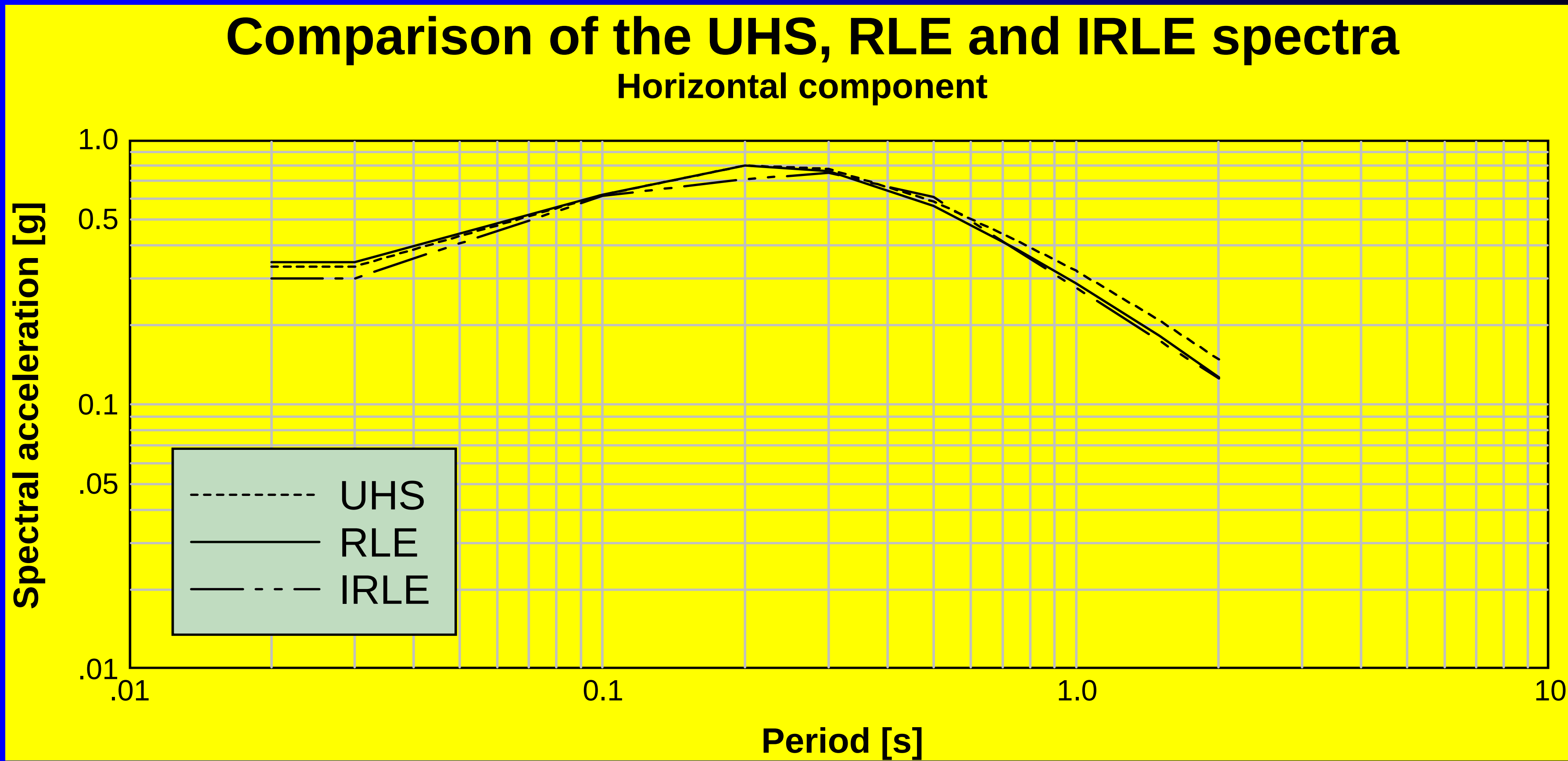
- attenuation relationships used in the hazard computation (in our case 5 different relationships)
- magnitude and distance of the controlling earthquake

mean spectrum

- mean spectrum scaled to the relevant UHS value (0.2 s in our case) = final horizontal spectrum

Engineering quantities

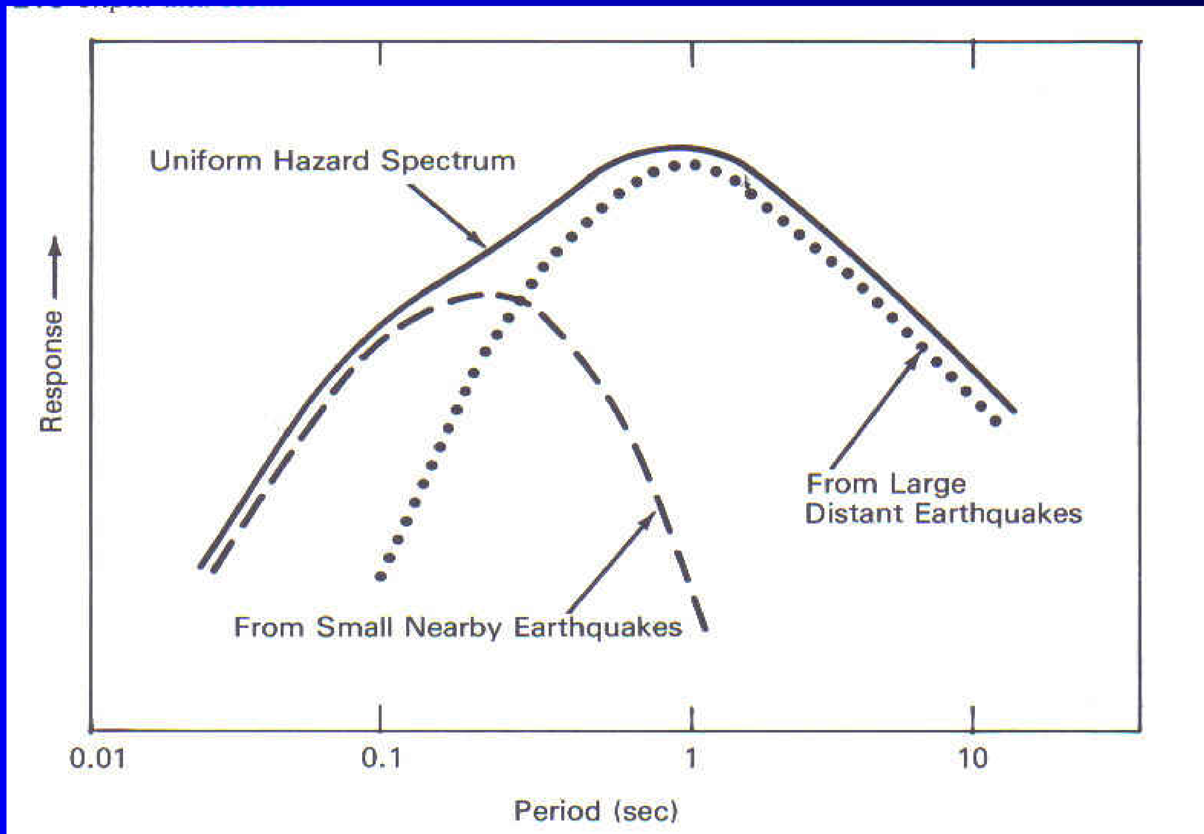
Horizontal spectrum



Engineering quantities

Horizontal spectrum

Other examples (Reiter, 1990)



Engineering quantities

Vertical spectrum

3 attenuation relationships -

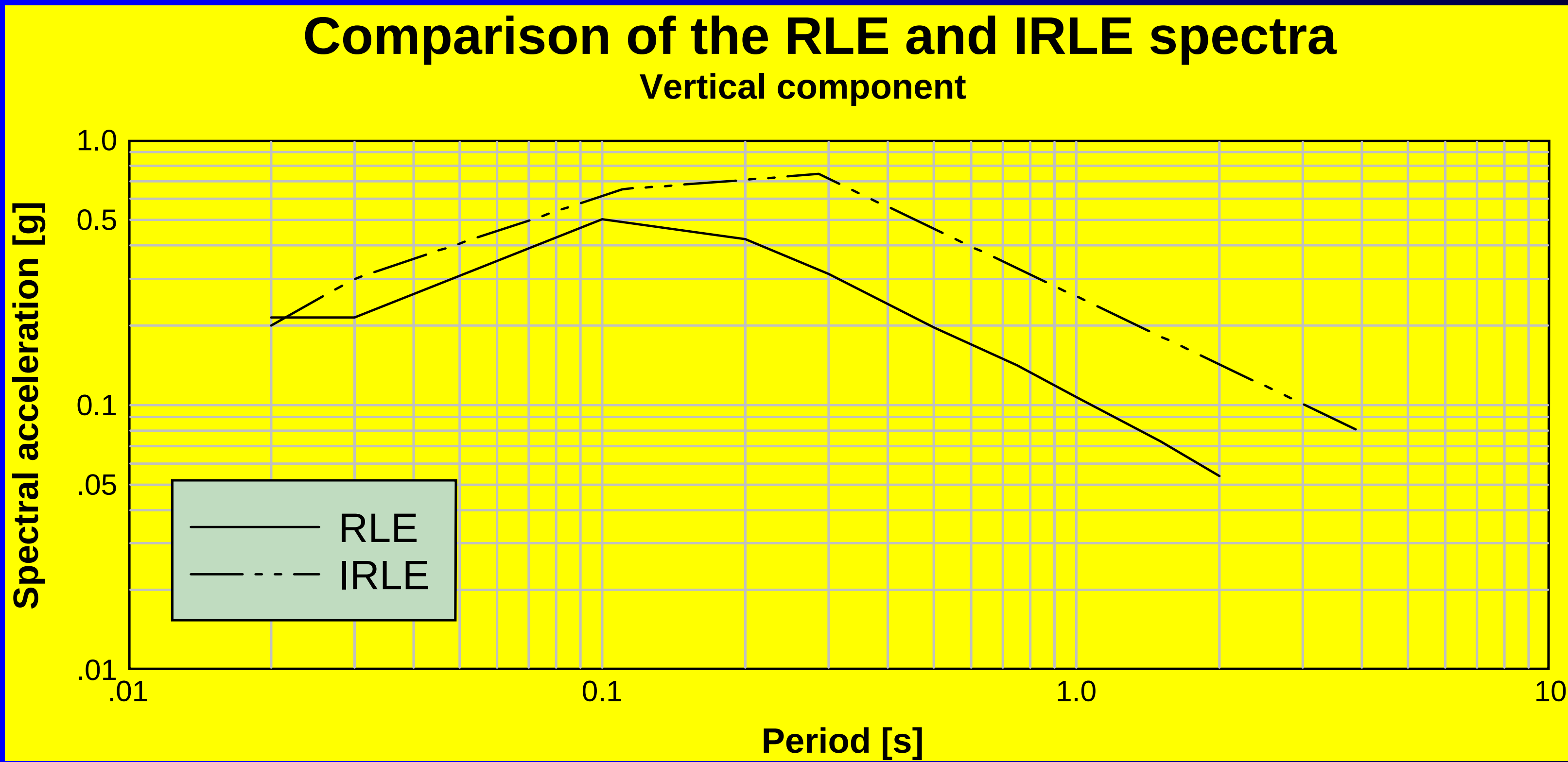
Ambraseys et al. (1996), Campbell (1997) and Sadigh et al. (1997) are available also for the vertical component (for all selected periods)

- for each attenuation relationship and each period - log(h/v)
- for each period - mean log(h/v)
- mean log(h/v) h/v
- for each period vertical RLE = horizontal RLE / (h/v)

Period [s]	h/v	Period [s]	h/v
PGA	1.61	0.75	2.74
0.1	1.23	1.0	2.67
0.2	1.89	1.5	2.47
0.3	2.44	2.0	2.35
0.5	2.87		

Engineering quantities

Vertical spectrum



Engineering quantities

Accelerograms

- from the region (if exist, and modified, if necessary)
- taken from analogous regions (modification required)
- artificial seismograms (numerically generated)

Engineering quantities

Accelerograms (example: from analogous region)

Criteria for selecting accelerograms

- the earthquake magnitude is in the interval <Mc-0.5, Mc+0.5>, where Mc is the controlling-earthquake magnitude

- the accelerometer that recorded the earthquake is located in the free field or in a one-story building at the most

- the geological basement is of similar type as at the NPP site (in our case S3 type (soil and glacial till) or S4 type (alluvium and unconsolidated deposits))

- the epicentral distance ranges from the minimum distance of the source zone up to the maximum distance (in our case from 5km to 30km from the Dobrá Voda source zone)

Engineering quantities

Accelerograms (example: from analogous region)

Criteria for selecting accelerograms

- the earthquake occurred in an analogous region (in our case to the Western Carpathians, i.e. in the Western USA or in the Balkans)
- the peak acceleration approximately corresponds to the computed PGA values

Engineering quantities

5 three-component accelerograms were selected in our case

local magnitude of the earthquakes were 5.9-6.2

the accelerographs were in one-story buildings

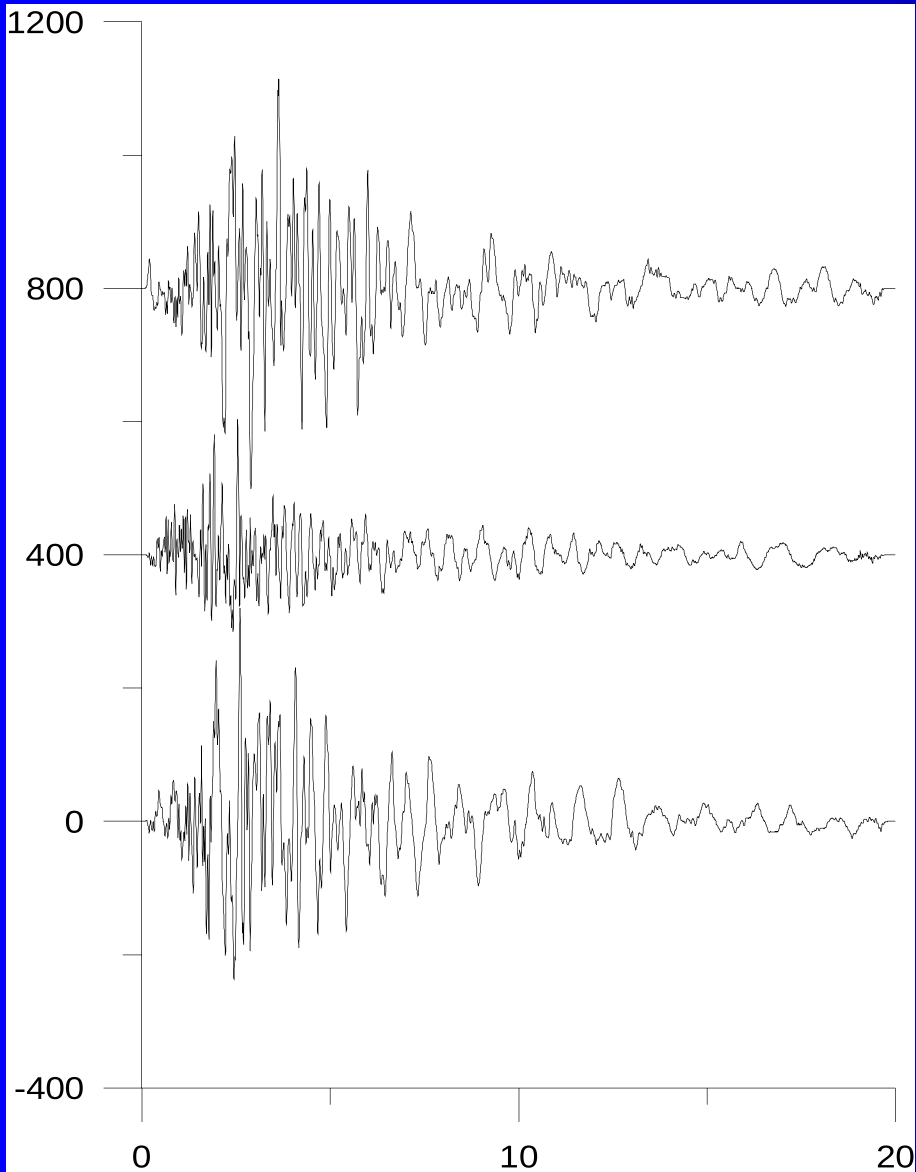
type of the basement was S4

the epicentral distances ranged from 9 to 13 km

accelerograms were from California

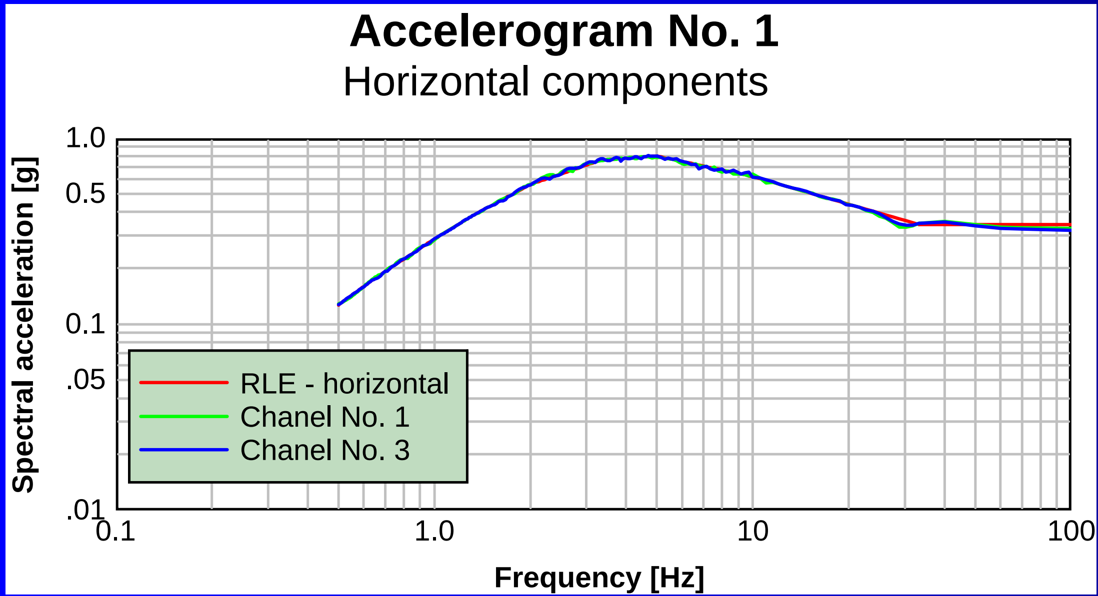
depths of the earthquake foci ranged from 9 to 16 km

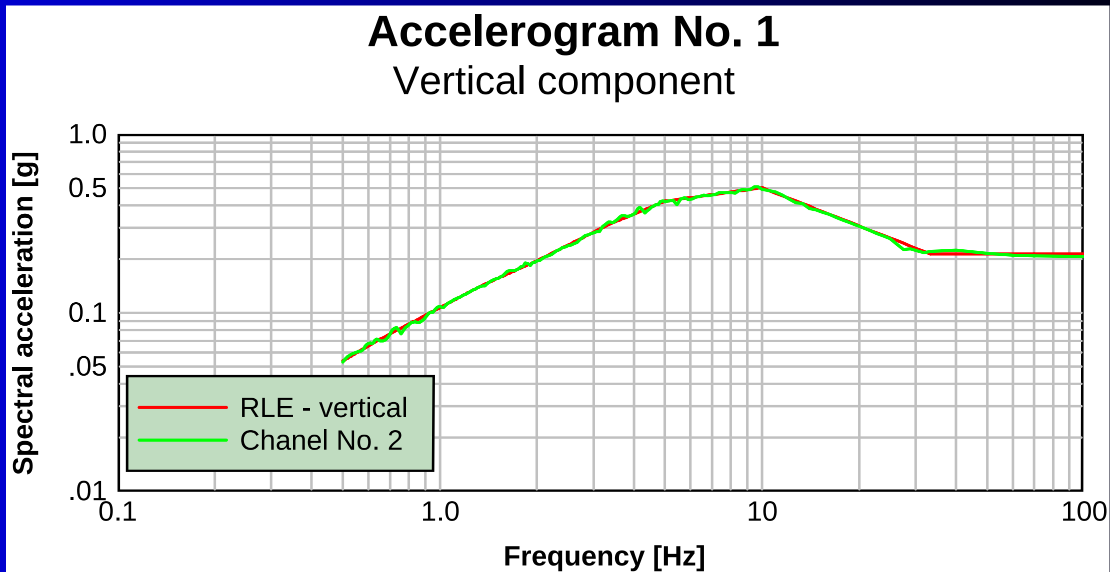
Engineering quantities



The accelerograms were modified using the non-stationary spectral matching method of Abrahamson (1998)

Engineering quantities





Engineering quantities

Source – identified from the de-aggregation

Path – described mainly by attenuation relationships

What else is needed to be known for a locality?

Site effects !

See the lecture
of P.-Y. Bard

Engineering quantities

Site effects – few remarks

Usual praxis includes only investigation of 1D effects
trough modification of response spectra
for a layered model(s)

This is, however, adequate only in the case
when dominant site effects are
really of 1D character

2D and 3D site effects may be in some cases
the dominant site effects
and can be significantly different from 1D effects
with respect
to the dominant frequencies, amplification and duration

Engineering quantities

Site effects – few remarks

Therefore, it is necessary to identify first,
which type of site effects (if any) influences
the NPP site

This can be done for example by experimental measurements
and/or numerical simulations

After that can be taken any decision on
how to take into account site effects in PSHA for a NPP

Secondary effects

Only very few remarks

Seismic PSA includes

- Development of a seismic hazard curve
- Structure and component seismic response determination
- Assigning of structure and component fragility
- Random failure data development
- Event/fault tree construction and solution
- Risk quantification incorporating results of first five steps

Secondary effects

Only those,
which are consequence of an earthquake

• Systems interactions (spatial or systematic)
- spatial: faling, hammering, spray and internal flooding
-systematic: failure of non-safety equipment

• Seismic fire interactions
(fire systems usually not designed for an earthquake)

• Other effects
- soil liquefaction, slope instability, subsidence,
ground collapse, surface faulting, aftershocks,
tsunami, seiche, dam failure, etc.

Secondary effects

Other effects

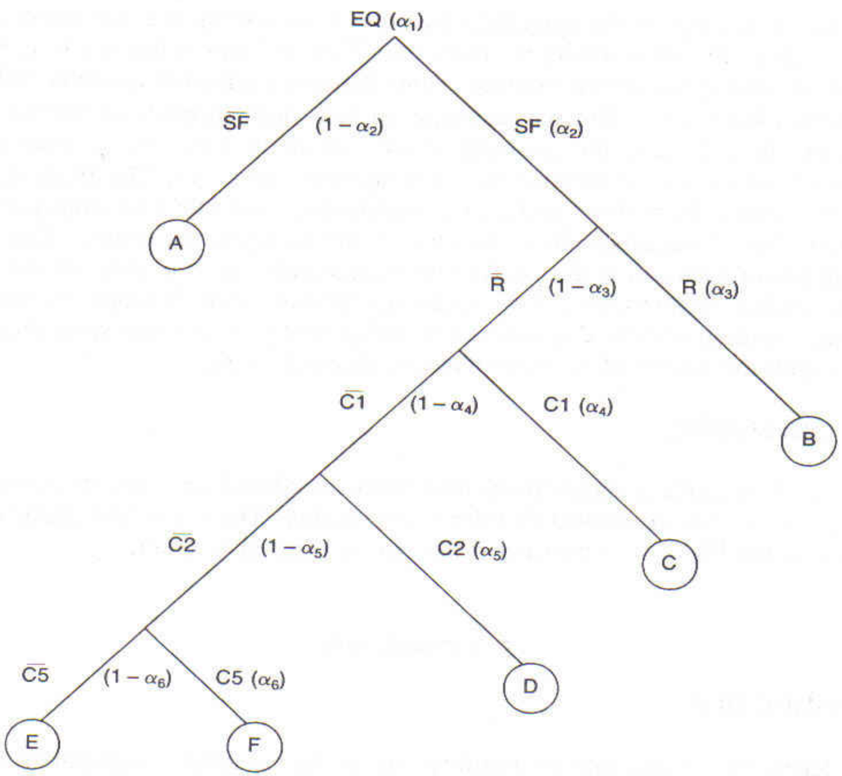
- to take into account only those relevant to the locality

Methods of analysis/incorporation

- event trees
- modifications of hazard curve

Secondary effects

Event tree - example



α_1: annual probability of an earthquake of $M \geq M^*$ in the site vicinity
α_2: probability of surface faulting SF
α_3: probability of SF intersecting the reactor building R
α_4: probability of SF intersecting other category 1 structures C1
α_5: probability of SF intersecting category 2 structures C2
α_6: probability of SF intersecting conventional structures C5

Summary

De-aggregation – technique for computing magnitude and distance of controling eearthquake

Horizontal and vertical response spectra – possible to compute using parameters of controling earthquake

Accelerograms – several approaches
- have to fit computed response spectra

Summary (cont.)

Site effects – needs careful investigation

Secondary effects – may influence shape of hazard curves