# The Current Status of Input Data for PSHA in South Korea

**Hoseon Choi[1], Seon Jeong Park[1] and Myunghyun Noh[1]**

[1] Korea Institute of Nuclear Safety, Daejeon, South Korea

Hoseon Choi

Korea Institute of Nuclear Safety
Department of Structural Systems & Site Safety Evaluation
62 Gwahak-ro, Yuseong-gu, Daejeon 34142, Republic of Korea
e-mail: hoseon@kins.re.kr

## Abstract

In South Korea, probabilistic seismic hazard analysis (PSHA) of nuclear power plant (NPP) site has been conducted since 1990s, and national seismic hazard map has been published twice since 1997. Although experts' understanding of PSHA has been improved continuously through such a process, reliable input data for PSHA have not been sufficiently established yet.

In past years, geologic characteristics have been mainly considered when setting seismic source model in South Korea. One of the most important factor to be considered when setting seismic source model is seismological characteristic such as seismicity, and geophysical characteristic that can affect that is also important factor. In order to derive seismological characteristics for seismic source model, earthquake catalogues with spatial-temporal completeness and unified magnitude scale should be presented, but not fully prepared yet. It is necessary to consider all the seismic sources affecting a site within a certain radius of that site. However many experts have been still only considering seismic sources within near to national border when setting seismic source model.

Only several ground motion prediction equations (GMPEs) have been developed over 1990s and early-mid 2000s due to the lack of earthquakes with moderate or above magnitude in South Korea. Most of them were derived by the regression analysis of simulated ground motions using stochastic methods. In recent years, some GMPEs using earthquakes with less than moderate magnitude have been presented. Therefore it is not easy to select independent multiple GMPEs for reflecting epistemic uncertainty in PSHA, and most of GMPEs do not provide their standard deviations, that requires continuous research. On the other hand, NPPs in South Korea use standard design response spectra for seismic design, but the global trend is changing to develop site-specific response spectra to take account of site characteristics sufficiently. In particular, GMPEs used in such PSHA should be expressed for entire frequency range required by engineering analysis.

Earthquake activities in South Korea have been reported over about 2000 years in historical documents. But experts have interpreted variously for those records, causing confusions in PSHA. Since intensity and damage by ground motions recorded in historical documents originated at plain, basin or soil foundation where people lived in the past, it can be said that those records include site effects. In this case, site effect may be included in PSHA in the form of overestimation of historical earthquake magnitude. Therefore it is probable that PSHA can be overestimated because PSHA is applied to rock outcrop again and not to plain, basin or soil foundation.

In South Korea, PSHA is generally carried out for major national projects. Well defined and calibrated input data for PSHA should be established that can reduce uncertainty and increase reliability of seismic hazard, which begins from a good understanding of input data for PSHA.

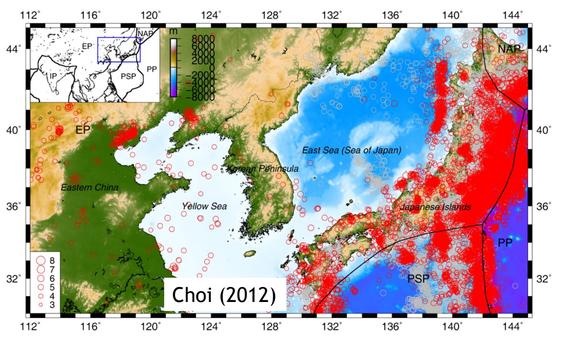
## Seismicity in and around the Korean Peninsula

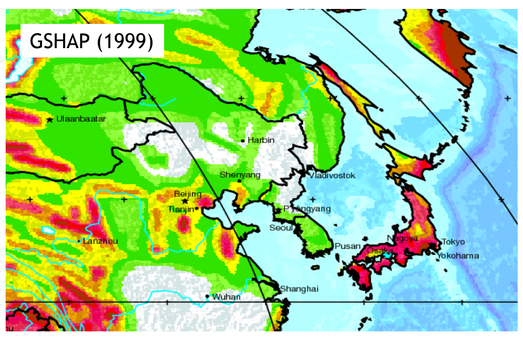
Plate Boundaries

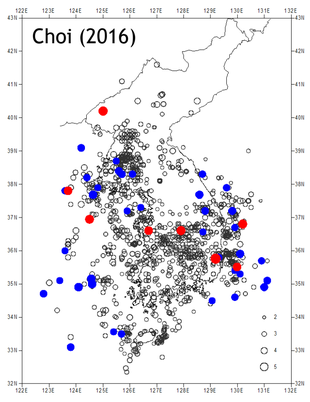
- The Korean Peninsula is located at the far eastern part of Eurasian Plate and within the intra-plate region several hundred km away from the nearest plate boundary.

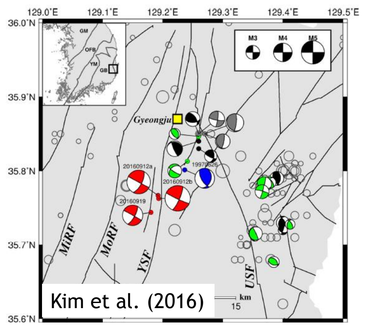
Seismicity

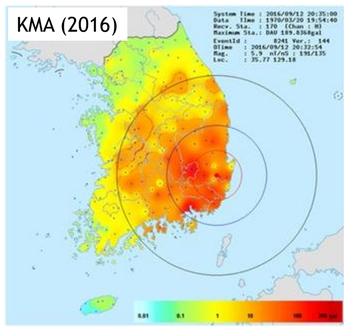
- The earthquakes in and around the Korean Peninsula show typical characteristics of intraplate earthquakes, those are low seismicity, relatively smaller magnitude than that of interplate earthquakes, spatially irregular epicenters.
- The Korean Peninsula is known to be relatively low in seismic activity and classified as a stable continental region. However it is recorded that earthquakes caused damage to people or property in historical documents.
- On 12 September 2016 event with magnitude $M_L$ 5.8 ($M_W$ 5.5) was occurred nearby Gyeongju area. This event is the largest instrumental one in South Korea after 1978.



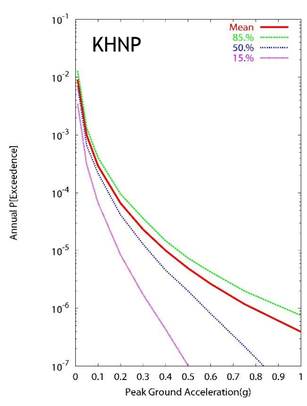

## Probabilistic Seismic Hazard Analysis (PSHA) in South Korea

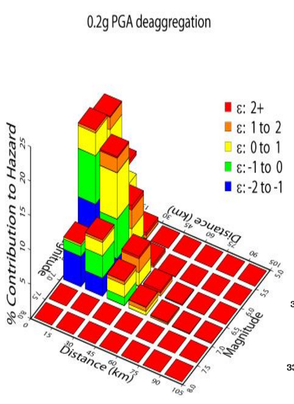
PSHA of Nuclear Power Plant (NPP) site

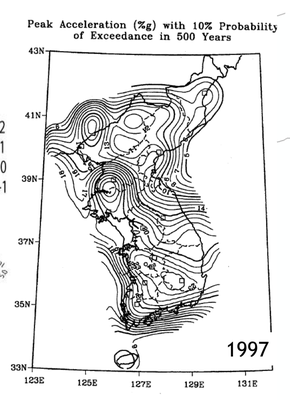
- Since 1990s, PSHA has been carried out mainly at NPP site in South Korea.
- PSHA of NPP site can be conducted separately from national seismic hazard map through consultation with the head of relevant governmental administration.

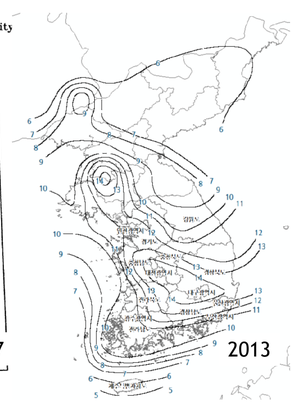
National Seismic Hazard Map

- The map has been published twice (1997, 2013).
- From 2009, the validity of the map shall be reviewed every five years from the date of publication, and it can be changed if necessary.




## Seismic Source

Seismogenic Source

- A seismotectonic province (or zone of diffuse seismicity) is usually treated as seismogenic source. It should be based on seismological characteristic preferentially, but geologic characteristics have been mainly considered when setting such seismic source model.
- It has not been directly used as an areal source of PSHA in South Korea.

Capable Tectonic Source

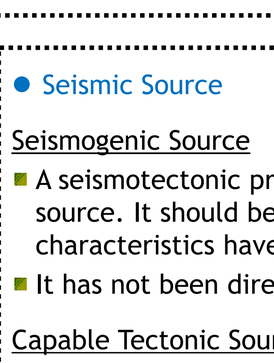
- A capable fault is usually treated as capable tectonic source in South Korea.
- It has been directly used as a linear source in PSHA. Whether including active fault, quaternary fault and etc. as linear sources of PSHA or not is under debate, especially PSHA of NPP site.

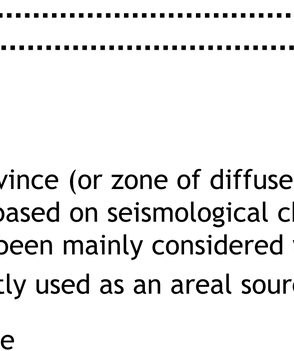
Earthquake Catalogue

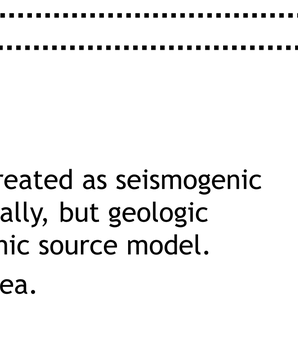
- Korea has several historical earthquake catalogues over about 2000 years, but many events have large discrepancies in location and magnitude with each other.
- South Korea has established compact and dense seismological stations since late 1990s. But there is no overall accepted instrumental earthquake catalogue yet with unified scale and location.

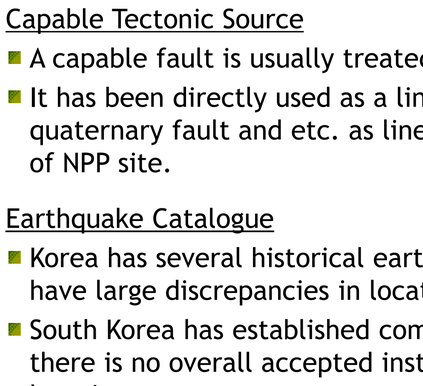
Range of Seismic Source to be Considered

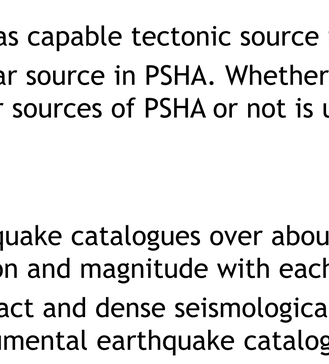
- It is necessary to consider all the seismic sources affecting a site within a certain radius (320 km for NPP site and can be extended depending on their significance) of that site.
- However, many experts have been still only considering seismic sources within near to national border when setting seismic source model.

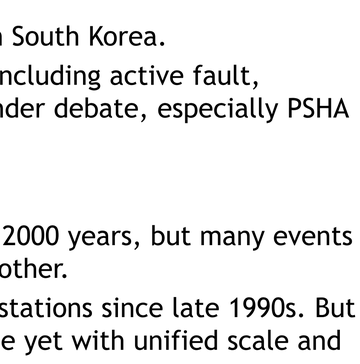


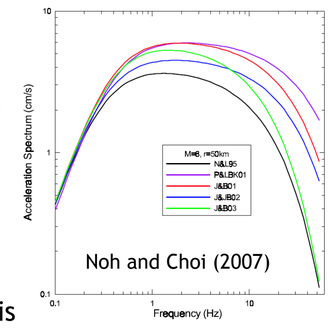



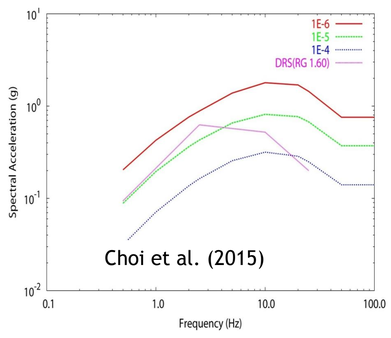




## Ground Motion Prediction Equation

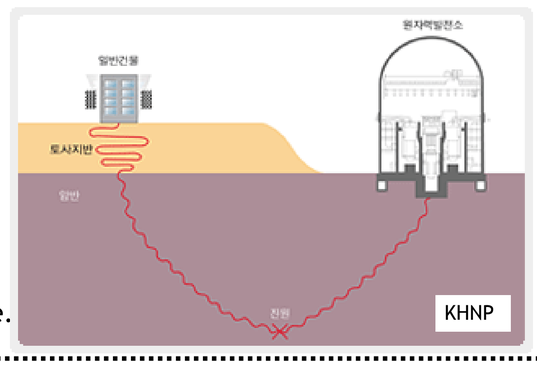
- Because of past poor seismic stations, low seismicity and absence of strong ground motion data in South Korea, most of GMPEs were derived by the regression analysis of simulated ground motions using stochastic methods. In recent years, some GMPEs using earthquakes with less than moderate magnitude have been presented Therefore, it is not easy to select independent domestic GMPEs that reflect epistemic uncertainties for PSHA.
- Foreign GMPEs developed in regions where seismic characteristic is considered to be similar to that of South Korea have been applied. However, there are no substantial studies showing that such regions (especially central and eastern United States) and the Korean Peninsular are similar seismological characteristics with each other.
- When a large fault and a site are close to each other, it is necessary to develop GMPEs with such near fault effect.
- GMPEs used in PSHA of NPP site should be expressed for entire frequency range (up to 100 Hz) required by engineering analysis for site-specific response spectra.




## Site Effect

- Compared to Japan, the depth of bedrock in South Korea is known to be very shallow. The information of $V_{S30}$ may not be meaningful, and another criteria may be developed.
- Many seismic stations in South Korea do not have (or do not share) the information (e.g. shear wave velocity profile) to know site effect in detail.
- Since intensity and damage by ground motions recorded in historical documents originated at plain, basin or soil foundation where people lived in the past, it can be said that those records include site effects. In this case, site effect may be included in PSHA in the form of overestimation of historical earthquake magnitude. Therefore it is probable that PSHA can be overestimated because PSHA in South Korea is applied to rock outcrop again and not to plain, basin or soil foundation.
- The site of NPP in South Korea is mostly composed of solid bedrocks, and the amplification of seismic waves is not expected. It is reasonable to apply GMPEs irrespective of seismic wave transmission characteristics.
- The development of GMPEs with site effect seems to be necessary in South Korea, if possible.




## Future Plan for PSHA in South Korea

- The government shall review the validity of national seismic hazard map every five years from the date (2013) of publication and can change if necessary. Since Gyeongju earthquake occurred in 2016, the map is likely to be revised in 2018.
- Geological survey of a fault (including Yangsan fault, Ulsan fault) nearby NPP site and reevaluation of PHSA by utility will be carried out by the end of 2019.
- In response to 2016 Gyeongju earthquake, governmental level geological survey (earthquake and fault survey, and research) will be carried out by the end of 2021. The quality of input data for PSHA is expected to be improved, which can reduce uncertainty and increase reliability of PSHA in South Korea.