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External Flood Hazard Assessment of NPP Sites under RCP and SSP Climate Change Scenarios

Beom-jin Kim[1*], Minkyu Kim[1], Daegi Hahm[1]
[1]*Strctural and Seismic Safety Research Division, Korea Atomic Energy Research Institute*
[*]*Corresponding author: beomjin88@kaeri.re.kr*

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1. Introduction

Due to the influence of recent climate change, typhoon invasions of the Korean Peninsula with extreme rainfall frequently occur. Between August and September 2020, three typhoons, Bavi, Maysak, and Haishen, attack the Korean Peninsula, and the resulting heavy rains that fell caused flood damage. As typhoons Maysak and Haishen passed east of Korea, the local nuclear power plants were automatically shut down.

In this study, referring to the IPCC report, probability precipitation was estimated using the Representative Concentration Pathways (RCP) and Shared Socioeconomic Pathways (SSP) scenarios. Second, the nuclear power plant basin was divided into sub-basins according to drainage flow. After that, rainfall-runoff analysis was performed for each climate change scenario. Consequently, rainfall runoff from nuclear power plants was evaluated and presented according to changes in climate change scenarios. Finally, based on the previous results, a flood analysis was conducted considering climate change scenarios. Then, the flood depth results according to climate change scenarios were compared.

2. Methods and Results

This study's rainfall-runoff analysis was performed according to climate change scenarios RCP and SSP. The local frequency analysis method was applied to estimate the probabilistic precipitation. And the worst scenarios, RCP8.5 and SSP5-8.5, were applied to the climate change scenario. In the rainfall-runoff analysis, runoff analysis by sub-basin was performed using HEC-HMS. After that, a nuclear power plant site model was constructed using ArcGIS for flood analysis. Then, 2 m × 2 m created a mesh for flood analysis. Finally, flood analysis was performed for each climate scenario using FLO2D.

2.1 Probabilistic precipitation estimation

The R13 region containing the Ulsan precipitation point closest to the target area was selected to estimate the probabilistic precipitation. Afterward, the regional frequency analysis technique was applied. Climate change RCP8.5 and SSP5-8.5 scenarios were applied to the regional frequency analysis results to estimate the probabilistic precipitation for a 10,000-year return period. The GEV probability distribution suggested for use in the domestic 'Standard Guidelines for Flood Estimation (2019)' was applied to estimate probabilistic precipitation. Finally, the probabilistic precipitation according to the climate change scenario was estimated as follows.

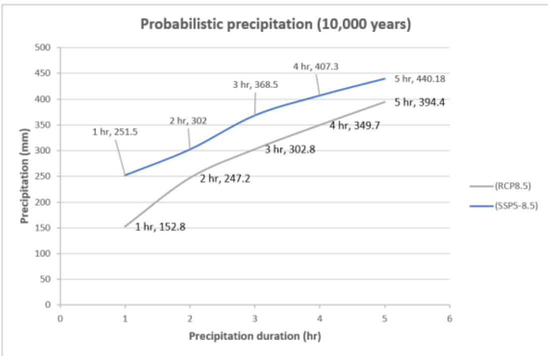

Fig. 1. Estimation of probabilistic precipitation

Table 1. Comparison of probabilistic precipitation

Probabilistic precipitation (10,000 years)					
Duration (hr)	1	2	3	4	5
Precipitation (RCP8.5)(mm)	152.8	247.2	302.8	349.7	394.4
Precipitation (SSP5-8.5)(mm)	251.5	302.0	368.5	407.3	440.18
Increase (mm)	98.7	54.8	65.7	57.6	45.78

2.2 Sub-basin classification

The Gori site was divided into three basins for rainfall-runoff analysis, and the Shin-Gori site was divided into four basins. Basins were classified based on drainage flow through digital maps, satellites, and workdown to classify sub-basins.

Fig. 2. Sub-basin of Gori site

Fig. 3. Sub-basin of Shin Gori site

2.3 Rainfall-runoff analysis

HEC-HMS, provided free of charge by the U.S. Corps of Engineers, was used for rainfall-runoff analysis. The Huff methodology was applied to derive the temporal distribution of probabilistic precipitation. Rainfall-runoff analysis for rainfall durations from 1 to 5 hours at the site revealed that the peak flow was highest at 2 hours for the RCP scenario and 1 hour for the SSP scenario. Also, the Clark unit method presented in the 'Standard Guidelines for Flood Estimation (2019)' was applied to estimate floods.

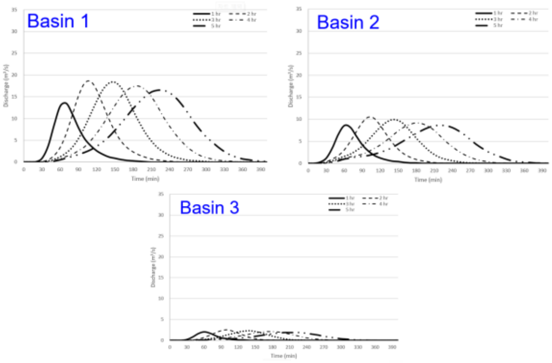

Fig. 4. Rainfall-runoff analysis result for RCP8.5

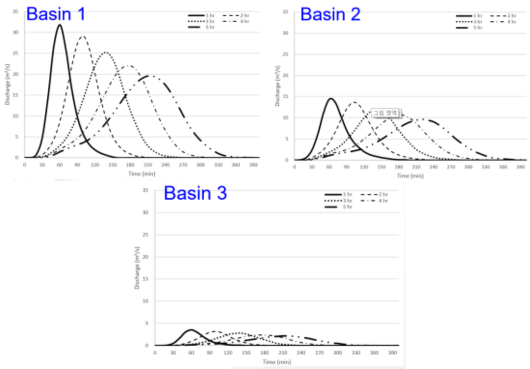

Fig. 5. Rainfall-runoff analysis result for SSP5-8.5

2.4 Result of rainfall-runoff analysis

According to climate change scenarios, rainfall-runoff analysis estimated that the runoff outflow by basin was more significant in the SSP scenario than in the RCP scenario.

Table 2. Result of rainfall-runoff

	Point	Rainfall-runoff analysis (1hr) [m^3/s]		Increase/decrease compared to RCP	
		SSP5-8.5	RCP8.5	Increase/ decrease	Rate (%)
Gori	Basin 1	31.8	13.5	-18.3	135.56
	Basin 2	14.4	8.6	-5.8	67.44
	Basin 3	3.5	2	-1.5	75
Shin Gori	Basin 1	8	4	-4	100
	Basin 2	8.9	4.6	-4.3	93.48
	Basin 3	22.5	11.9	-10.6	89.08
	Basin 4	23.7	13	-10.7	82.31

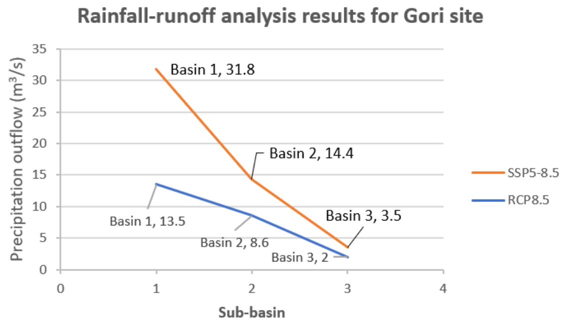

Fig. 6. Comparison of climate change scenarios for Gori site

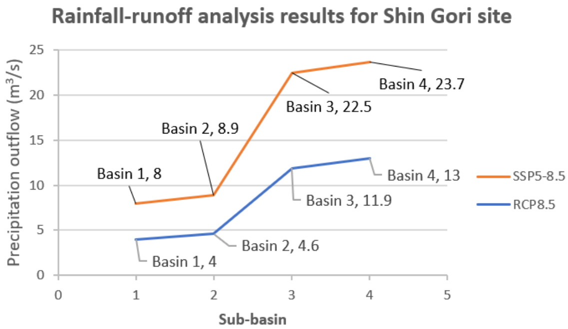

Fig. 7. Comparison of climate change scenarios for Shin Gori site

2.4 Flooding analysis

An integrated flood analysis model was developed to analyze floods under climate change scenarios.

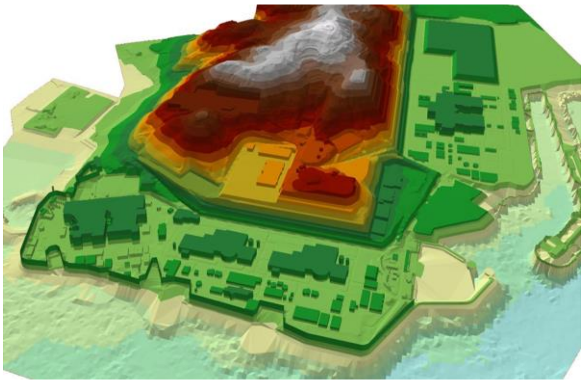

Fig. 8. Flood analysis model

Using the climate change scenario, a 2 m × 2 m mesh was created for flood analysis. Then, the results of rainfall-runoff analysis were considered input data for flood analysis, and flood analysis was performed according to the climate change scenario.

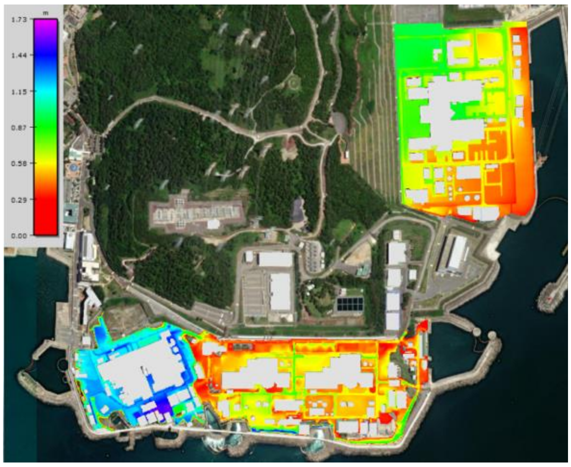

Fig. 9. Flood analysis result for RCP8.5

Fig. 10. Flood analysis result for SSP5-8.5

3. Conclusions

This study assessed the impact of flooding at a nuclear power plant site under a climate change scenario. As a result, it was confirmed that the SSP scenario presented in the IPCC 6th report had more runoff outflows and flood depth than the existing RCP scenario.

This study's results are expected to provide initial input data for external flooding PSA for nuclear power plant sites in the future.

Acknowledgments

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