Impact of super extreme rainfall events on design criteria of the hydraulic infrastructures in Pohang region: a case study to typhoon Hinnamnor in 2022

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Abstract

The predominant cause of flooding is often attributed to extreme rainfall events. Historical records indicate that there have been instances of unprecedented extreme rainfall. Recent trends suggest an escalation in the occurrence of such record-breaking events. This increase in frequency might stem from a complex interplay of multiple factors. Numerous studies have delved into the reasons behind this rise in extreme events. Nonetheless, in practical scenarios, the focus is more urgently placed on responding to these events rather than exploring their underlying causes and mechanisms. The design criteria for hydraulic infrastructure are typically based on frequency analyses of annual maximum series, including metrics such as annual maximum precipitation, peak flow, and maximum inflow. However, when the dataset is too limited to provide reliable estimates for high return periods, the inclusion of these rare extreme events can spoil the frequency analysis results. Consequently, the design criteria for hydraulic infrastructure become susceptible to inaccuracies due to these anomalies. Constructing or renovating such infrastructure is not only costly but also challenging. Therefore, understanding how these extreme events might alter frequency analysis results is crucial. This study investigates the impact of exceptional rainfall events on the frequency analysis of annual maximum rainfall, using the 2022 Typhoon Hinnamnor as a case study, which resulted in significant economic damage due to flooding in industrial areas. Both at-site and regional frequency analyses were conducted, with and without the inclusion of the Hinnamnor event. The findings were then compared and scrutinized to assess the event's impact. It was observed that regional frequency analysis tends to yield more consistent results. However, the quantiles derived from regional frequency analysis were lower than those from at-site analysis. To enhance flood defense mechanisms, it is suggested that the estimated quantile values should be increased.

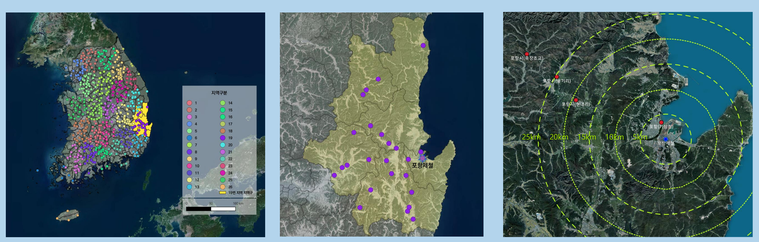
Introduction

- Typoon Hinnamnor gave Catastrophic damage onto Pohang area.
- This event will largely alter the design criteria of criteria for hydraulic infrastructure
- It is important to investigate the impact of super extreme event into the design criteria

- **Objective**

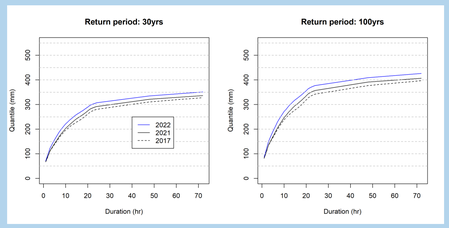
- Investigate impact of this event into estimation of design criteria for hydraulic infrastructure

Data and Materials



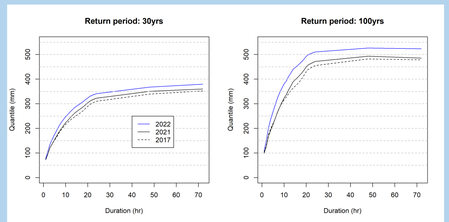
- Quantiles from rainfall frequency analysis is a design criteria of hydraulic infra structure in Republic of Korea
- At-site frequency analysis (AFA) and regional frequency analysis (RFA) were employed for rainfall frequency analysis.
- Index flood method was selected for RFA method
- Gumbel (GUM) and Generalized Extreme Value (GEV) distributions were employed for probability distribution models.
- Pohang rain gauge station is selected for analysis.
  - Record period: 1961-2022

Results



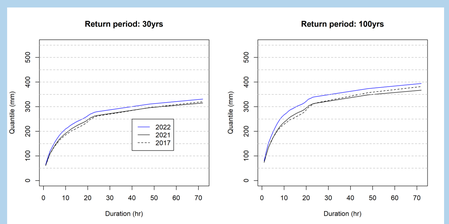
AT-SITE frequency analysis with GUM

- In the case of AFA using GUM, quantile estimates have increased.
- In 2022, magnitudes of increase were much larger than the increment from 2017 to 2021.



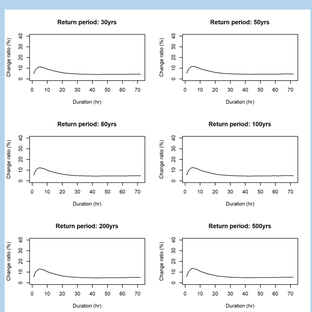
AT-SITE frequency analysis with GEV

- In the case of AFA using GEV, quantile estimates have increased.
- In 2022, magnitudes of increase were much larger than the increment from 2017 to 2021.

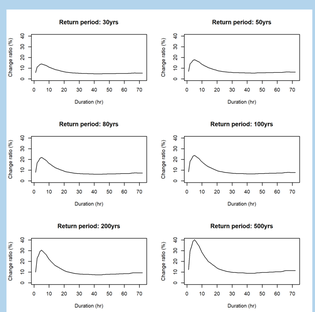


Regional frequency analysis with GEV

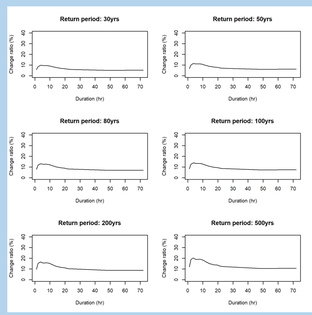
- In the case of RFA using GEV, there are no large changes from 2017 to 2021.
- However, Hinnamnor event drastically changed quantile estimates.



Change ratios with AFA using GUM



Change ratios with AFA using GEV



Change ratios with RFA using GEV

- Typhoon Hinnamnor gave the largest impact on rainfall depth for around 11 hour-duration.
- The results from the AFA have peak ratio change around 4-hour.
- Distribution of change ratios from RFA for rainfall duration has different of distributions from AFA, but their difference is small.
- Change ratios of AFA using GUM and RFA using GEV range from 5% to 20%.
- Change ratios of AFA using GUM have range from 5% to 40%.

Discussion

- The result shows that one single super extreme event change entire quantile estimate (design criteria). This means that our strategy to design hydraulic infrastructure is vulnerable to the super extreme event.
- RFA is considered as a more stable and reliable rather than AFA. Comparison between 2017 and 2021 support this fact.
- Even the RFA can lead to stable results, the Hinamnor event drastically increased a design criteria based on RFA using GEV.
- AFA using GEV was largely influenced by Hinarmnor event because GEV distribution has a shape parameter.
- Location parameters in GEV and GUM have changed very small in 2022 while scale parameter in GUM and scale and shape parameter in GEV have changed a lot.
- RFA method would be better than AFA because RFA is stable and considers a shape parameter. However, changes in RFA still seem large.
- It needs to study a new strategy to determine design criteria for considering such a super extreme event, e.g., Hinomnor, in the future.

Acknowledgement

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