Korean Journal of Hydrosciences Vol 1. pp. 39 ~ 48 1990.

Rainfall Frequency Atlas of Korea

Kim, Kyu Ho* · Kim, Yang Su* · Lee, Jin Won* · Kim, Sung** · Seoh, Byung Ha***

ABSTRACT/The objective of this study is to develop "Rainfall Frequency Atlas of Korea" which can be used to determine hydrologic design criteria for minor hydraulic structures. Rainfall data used in frequency analysis are obtained from the recording charts for each duration. For accurate estimation of frequency rainfalls, several relationships are established for rainfall data between different observational times, between fixed- and true-intervals, and between annual maximum and exceedance series. Five types of continuous probability distributions are applied to each of the annual maximum and exceedance series. To determine a representative distribution among these five types for each rainfall series, the goodness of fit of each probability distribution is tested by the X^2-test and Kolmogorov–Smirnov test. As a result, the extreme value type I distribution is selected for the annual maximum series. Using frequency factors with the selected distribution (so called the Gumbel–Chow method), Rainfall Intensity–Duration–Frequency(IDF) curves for 24 recording rain gage stations are derived. In addition, 49 rainfall–frequency maps are drawn for durations from 30 minutes to 24 hours and return periods from 2 to 200 years. Area reduction curves are developed to provide the average depth of rainfall over an area rather than at a particular point for area size up to 1,000 km² and durations from 1 to 24 hours. To develop these curves, the geographically fixed–area relation method is used with telemetry rainfall data of the Han River basin.

1. Introduction

This study is intended to provide "Rainfall Frequency Atlas of Korea" for use in designing minor hydraulic structures.

* Researcher ** Research Fellow ***Senior Research Fellow,

Water Resources Engineering Division,

Korea Institute of Construction Technology

It is desirable to use the rainfall frequency atlas which is drawn by consistent and simplified relations for estimating rainfall intensity duration-frequency relationships (Aron et al., 1987 ; Miller et al., 1973).

In Korea, efforts to develop the rainfall frequency atlas have been made by Lee(1968, 1977, 1980), and the results of point and selected area rainfall frequency values have been used mainly to design the hydraulic structures in field works.

2. Analysis

2.1 Basic Data

Frequency analysis of rainfall data requires relatively long and stable station records. However, no technique for evaluation and modification of a seies of extreme rainfall values has been developed in this country. Therefore, it was necessary to ensure that the data used in this atlas represented.

Investigations reported herein were made using currently available records, periods longer than 10 years, and the maximum number of stations in Korea.

2.1.1 Types of data

The data used in this study are divided into two categories. First, there are the recording-gage data which have recording charts from the standard and the auxiliary Korea Meteorological Service (KMS) stations. There are 29 standard stations with records long enough to provide adequate results within the range of return periods of this paper and 37 auxiliary stations with 16 recording years. Second, there are very large amounts of non-recording-gage data from the 188 Ministry of Construction(MOC) stations with observations made by daily.

2.1.2 Two types of series

One requirement in the preparation of this atlas is that the results be expressed in terms of annual series frequencies. From KMS stations both the partial-duration series and the annual series data were collected and extracted, and from MOC stations the annual series data for the daily maximum series were collected.

Maximum values for each year of record from these stations have been tabulated for the various durations to the nearest minute. The maximum 1-hour value for each year is the amount recorded for a period of 60 consecutive minutes, regardless of the time beginning (Weiss, 1964).

2.2 Characteristics of Maximum Rainfall Series

Determination of rainfall-frequency values is usually based upon the longest record available. Published and unpublished data from the 254 stations were used in this study. The data from the 23 KMS standard stations with long-records were used to develop the most of relationships which described below.

First, relationships between two daily rainfall series with two different observational times, 24 o'clock at the KMS stations and 10 o'clock at the MOC stations, were examined using the annual maximum and annual exceedance series. The results indicate that there is no difference between these two daily rainfall series.

Secondly, the continuous clock–hour and observation–day data from most stations are available for intervals fixed by arbitrary clock intervals. In order to exploit conversion factors between fixed– and true–interval maximum rainfall values, it was necessary to determine their relationship to the 60–minutes and 1440–minutes periods containing the maximum rainfalls. These empirical values are established by graphical plots and shown in Table 1.

Last, conversion factors between annual and partial–duration series were investigated. It is based on a sample of the 23 widely scattered KMS standard stations. Table 2 gives the empirical

Table 1. Empirical factors for converting fixed–interval to true–interval maximum rainfalls

Fixed–interval duration	True–interval duration	Conversion factor
1 hour	60 minutes	1.129(1.13)*
3 hour	180 minutes	1.033
6 hour	360 minutes	1.013(1.02)
24 hour	1440 minutes	1.005(1.01)
1 day	1440 minutes	1.161(1.13)

* The results of U. S. Weather Bureau(1958) is in parenthesis.

Table 2. Empirical factors for converting annual series to partial-duration series.

Return period (years)		2	5	10
Duration	60 minutes	1.157 (1.136)*	1.033 (1.042)	1.008 (1.01)
	24 hour (1440 minutes)	1.107 (1.136)	1.029 (1.042)	1.012 (1.01)

*The parenthesis is the conversion factors of Langbein(1949).

factors that can be used to obtain the partial–duration series analysis values by multiplying the annual series analysis values.

2.3 Estimation of the Frequency Rainfall

2.3.1 Determination of the representative distribution type

This study has conducted goodness of fit tests for various continuous probability distributions with the partial–duration series and the annual series of the rainfall data.

The selected distribution types are the 2–parameter Lognormal, the 3–parameter Lognormal, the type– I extremal, Pearson type– Ⅲ, and the Log–Pearson type– Ⅲ, and are tested for goodness of fit by the χ^2–test method and the Kolmogorov–Smirnov test method using a 5% of significance level.

The representative distribution type was determined by selecting the distribution chosen as the best fit among the five distributions most frequently. The representative distribution type selected are the type– I extremal distribution for the annual series and the Pearson type– Ⅲ distribution for the partial–duration series.

2.3.2 Estimation of the frequency rainfall

Having the selected representative distribution function, parameters were estimated using the annual series of each duration rainfall data recorded at the KMS stations and the annual series of daily rainfall data recorded at the MOC stations. With these function and parameters rainfall values were calculated for return periods ranging from 2 to 200 years by the frequency factor method.

Since only daily records were originally obtained for estimating the frequency rainfalls at the MOC stations, 6 – and 12 – hour duration rainfalls were artificially derived. For deriving the shorter–duration rainfalls from the daily rainfall proportions of the shorter–duration rainfalls to the daily rainfall were computed for the KMS stations. Hereafter, maps showing isolines of these proportions were drawn for 6 – and 12 – hour durations and each return periods. Subsequently, the coefficient obtained from the map was applied to derive the shorter–duration rainfall from the daily rainfall.

2.3.3 Rainfall Intensity–Duration–Frequency Curves

IDF curves are sometimes used to estimate design rainfall at a given location. In this study, rainfall data, their durations ranging from 10 minutes to 24hrs, are analyzed to estimate rainfall intensities for the given frequencies. Henceforth, the results for each return period were fitted to a line to form one of the Rainfall Intensity–Duration–Frequency(IDF) curves for each of the 24 key stations of KMS.

2.3.4 Interpolation for the rainfall of required the duration and return period

A common approach to develop a precipitation frequency atlas is to draw key maps for frequently used durations and return periods and to estimate the required value from the values obtainable from the key maps by interpolation(Corn, 1956 ; Hershfield, 1962).

(1) Duration interpolation diagram

To estimate rainfall depth for a particular duration, which cannot be obtained from the key maps, a generalized diagram relating rainfall depth to rainfall duration has been developed(Fig. 1).

To use this diagram, a straightedge is laid across the values given for 1 – and 24–hour duration, and the value for the concerned duration is read at the proper intersections.

(2) Rainfall depth–return period diagram

When the maps for the required return period are not included in the atlas, the developed

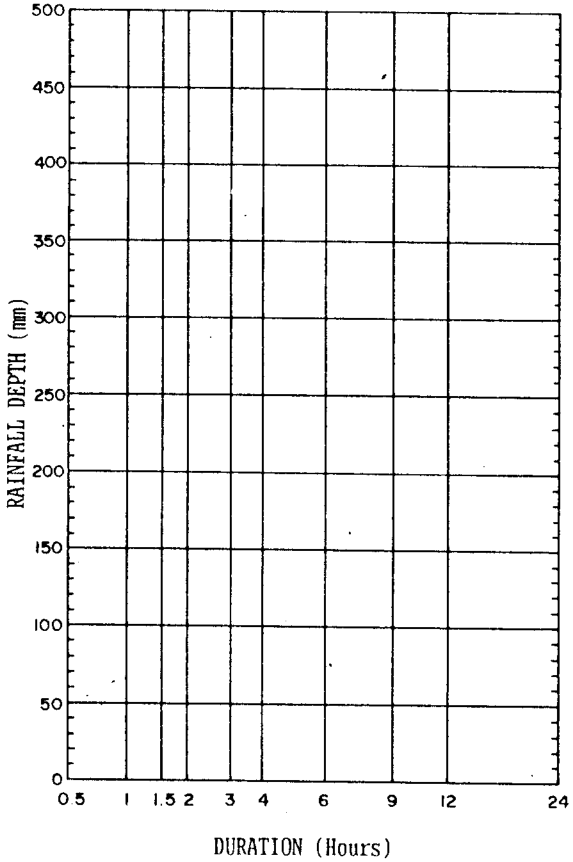

Fig. 1 Rainfall Depth–Duration Diagram

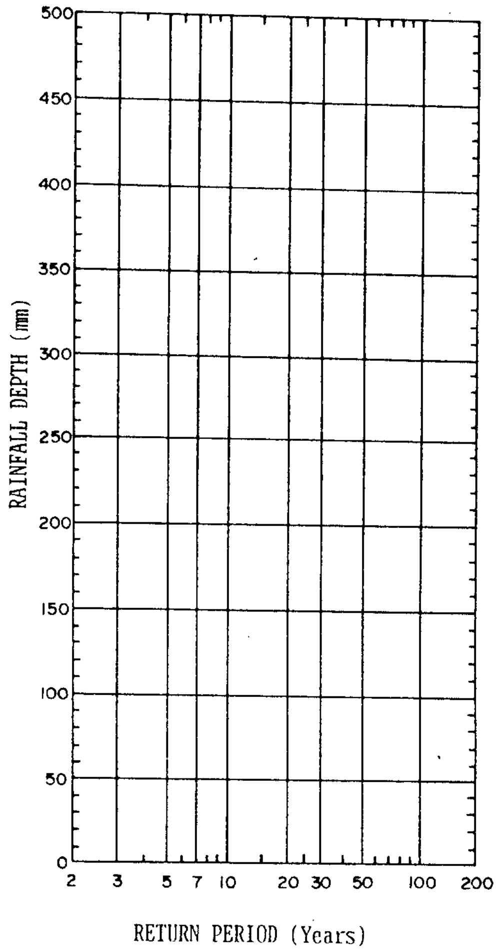

Fig. 2 Rainfall Depth–Return Period

return period diagram can be used in estimating the rainfall values for the required return period.

The return period diagram of Fig. 2 is based on the Gumbel procedure for fitting annual series data to the type– I extremal distribution.

The method to use this return period diagram is similar to the method for the duration interpolation diagram. For the interpolation, two rainfall depths, 2–year and 100–year values obtained from the key maps, are used.

2.4 Isopluvial Maps

The project objective is to define precipitation depths for durations ranging from 30 minutes to 24 hours and return periods ranging from 2 to 200 years. In this study, 49 isopluvial maps for seven return periods(2, 5, 10, 20, 100 and 200 years) and seven durations(30 minutes, 1, 2, 3, 6, 12, and 24 hours) were drawn with the scale of 1:1,000,000 by using the computerized space–averaging techniques (Frederick et al., 1976).

Isopluvial maps for return periods of 2 and 100 years and durations of 24 hours are shown in Fig. 3 and Fig. 4, respectively.

2.5 Area Reduction Curve

A value read from an isopluvial map in this atlas is the value for that location and for that

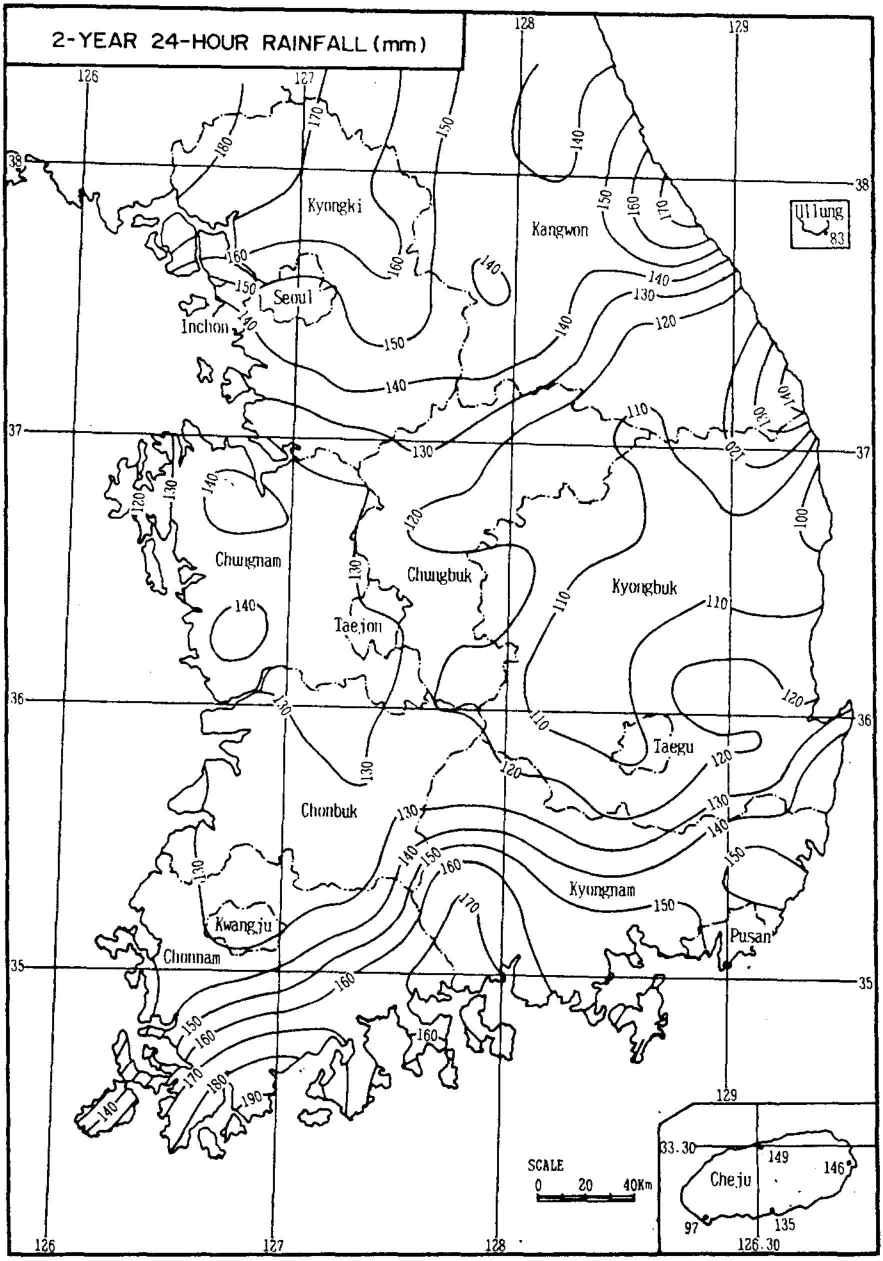

Fig. 3 Isopluvials of 2–YR 24–HR Rainfall (mm)

particular duration which is supposed to be equalled or exceeded, on the average, once during the period indicated on the individual map. In hydrologic design, engineers are more concerned with the average depth of rainfall over an area than with the depth at a particular point. The depth-area curve is an attempt to relate the average of all point values for a given duration and frequency within a basin to the average depth over the basin for the same duration and frequency (Bell, 1976 ; Miller et al., 1973).

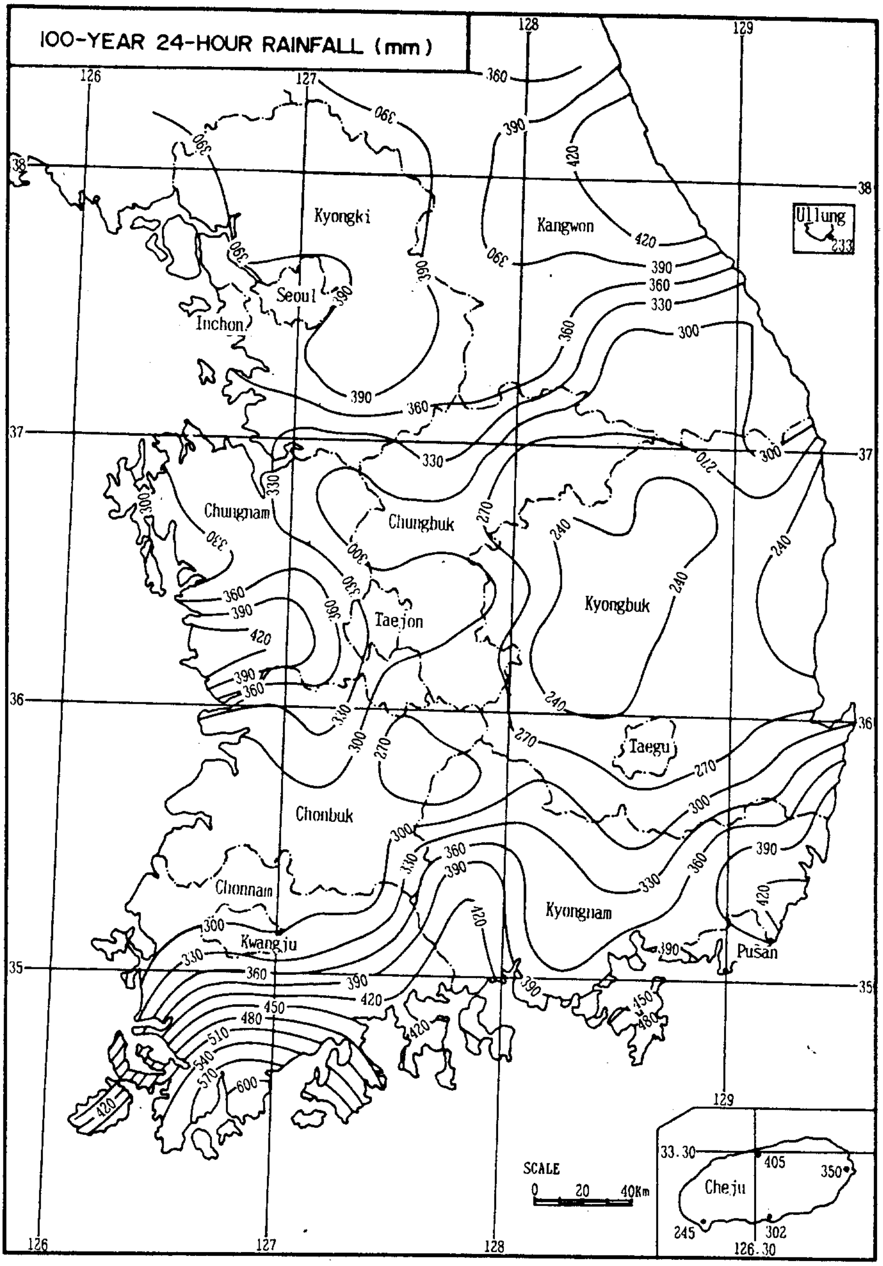

Fig. 4 Isopluvials of 100-YR 24-HR Rainfall (mm)

Generally, there are two types of depth–area relations. The first is the storm–centered relation ; that is, the maximum rainfall occurring when the storm is centered on the area affected. The second type is the geographically fixed–area relation where the area is fixed and the strom is either centered over it or is displaced so only a portion of the storm affects the area.

In this study, the second type was used to develop the average depth–area curves. In addition, it was assumed that the annual maximum area and point values are independent of return periods. The data used were from areas with dense networks, the Han River basin with 37 telemetry rainfall stations, for period from 1975 to 1987 recorded by clock–hour. The curves were developed for area size up to 1,000 ㎢ and durations ranging from 1 to 24 hours.

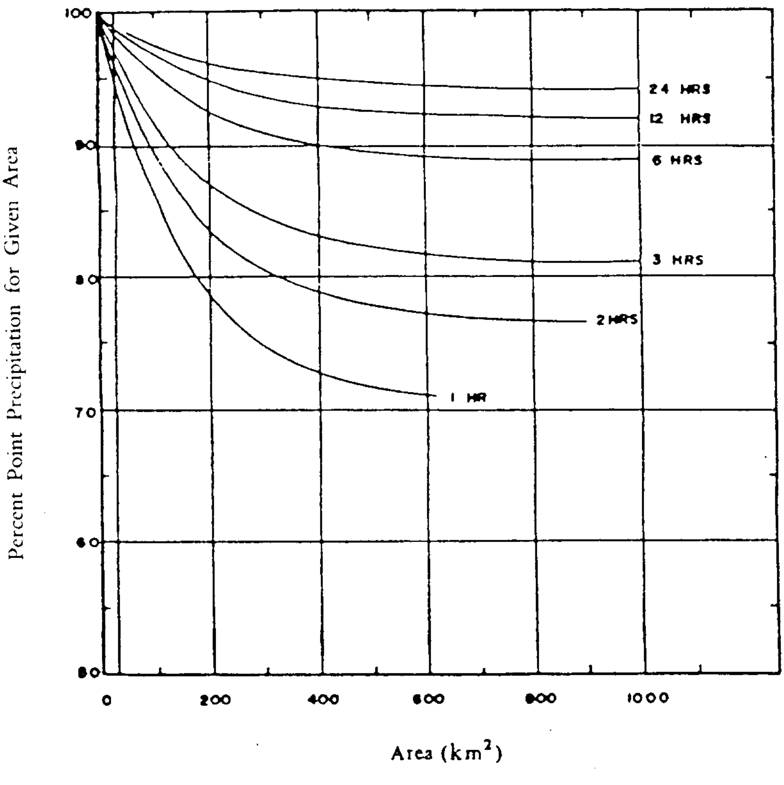

Fig. 5 Area Reduction Curves

3. Conclusion

The objective of this study is to develop "Rainfall Frequency Atlas of Korea" which can be used to determine hydrologic design criteria for minor hydraulic structures.

The generalized duration and the return period relationships were developed with which the rainfall depth for each selected durations and return periods can be determined for durations and return periods not shown on the maps.

And area reduction curves were developed to provide the average depth of rainfall over an area rather than with the depth at a particular point for area size up to 1,000 ㎢ and durations from 1 to 24 hours. To develop these curves, the geographically fixed-area method is used with telemetry rainfall data of the Han River basin.

This developed atlas can be used to estimate design rainfall depths for desired durations and return periods for the entire Korea.

Acknowledgements

Financial support for this project has been provided by the Ministry of Construction during the 1987 and 1988 fiscal years. The authors are grateful for data supprot to the personnel in the Ministry of Construction and the Korea Meteorological Service.

References

1. Aron, G., D. J. Wall, E. L. White, and C. N. Dunn. (1987) Regional Rainfall Intensity-Duration-Frequency Curves for Pennsylvania, Water Resources Bulletin, Vol. 23, No. 3, pp.479-485.
2. Bell, F. C. (1976) The Areal Reduction Factor in Rainfall Frequency Estimation, Institute of Hydrolgy, Report No. 35, Natural Environment Research Council, Wallingford, Oxon, U. K., 58pp.
3. Corn, H. M. (1956) Rainfall Depth-Duration Relationships, Journal of Hydraulics Division, Proc. ASCE, Vol. 81, pp. 840-1 ~ 840-14.
4. Frederick, R. H., V. A. Myers, and E. P. Auciello. (1976) Five to 60-minute Precipitation Frequency for the Eastern and Central United States, NOAA Technical Memorandum NWS HYDRO-35, National Weather Service, Silver Spring, Maryland, U. S. A.
5. Hershfield, D. M. (1961) Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years, Tech. Paper 40, U.S. Dept. of Commerce, Weather Bureau, Washington, D.C., U.S. A.
6. Hershfield, D. M. (1962) Extreme Rainfall Relationships, Journal of Hydraulics Division, Proc. ASCE, Vol. 88, No. HY6, pp. 73-92.
7. Langbein, W. B. (1949) Annual Floods and the Partial Duration Flood Series, Trans. Amer. Geophys. Union, Vol. 30, No. 6, pp. 879-881.
8. Lee, W. H. (1968) Study of the Rainfall Intensity Probability Formula Required for Designing City Sewerage and River Plans, Engineering Research Center, Yonsei University, Seoul, Korea, 77pp.
9. Lee, W. H. (1977) A Hydrological Study on Rainfall Frequency Atlas in Korea, Journal of the Korean Association of Hydrological Sciences, Vo. 10, No. 1, pp. 39-51. (In Korean)

10. Lee, W. H. (1980) A Stochastic Analysis on Determination of Design Precipitation for Planning of Urbanized Stream and Sewerage, Journal of the Korean Society of Civil Engineers, Vol. 28, No. 4, pp. 81–94. (In Korean)
11. Miller, J. F., R. H. Frederick, and R. J. Tracy (1973) Precipitation Frequency Atlas of the Western United States(by States), NOAA Atlas 2, 11 Vols., National Weather Service, Silver Spring, Maryland, U.S.A.
12. U. S. Weather Bureau (1958) Rainfall Intensity–Frequency Regime 2:Southern United States, Tech. Paper 29, U. S. Dept. of Commerce, Washington, D. C., U. S. A.
13. Weiss, L. L. (1964) Ratio of True to Fixed Interval Maximum Rainfall, Journal of Hydraulics Division, Proc. ASCE, Vol. 90, No. HY1, pp. 77–82.