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Probable Maximum Precipitation for Hong Kong

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ABSTRACT**:** Results of 24-hour and 4-hour Probable Maximum Precipitation updating studies are presented. The updated PMPs are found to be smaller than those derived in earlier work which made use of a seasonal adjustment factor. Both the 24-hour and 4-hour point PMPs exceed the corresponding maximum point rainfalls recorded at Tai Mo Shan, the station with the highest climatological rainfall in Hong Kong.

1 INTRODUCTION

Probable Maximum Precipitation (PMP) is widely taken to mean the theoretical upper limit of the depth of precipitation that is possible for a given duration and a particular basin (WMO 1994).

PMP is traditionally used for designing large dams, reservoirs, spillways and for the derivation of probable maximum floods. Many countries have conducted PMP studies to meet these needs. Examples are the US Weather Bureau (1966), Clark (1997) and Wang (1999a).

For Hong Kong, PMP was first derived by Bell and Chin (1968) using data from 21 major storms recorded between 1955 and 1965 to meet the planning and design requirements of the Waterworks Office of the Public Works Department.

This paper presents some of the results of a 24-hour PMP updating study undertaken in 1999 by the Hong Kong Observatory. The objective was to provide the Geotechnical Engineering Office (GEO) with a fresh reference for developing possible extreme event scenarios for designing landslide emergency preparedness measures. A full report of the study can be found in Hong Kong Observatory (1999).

Some results of a 4-hour PMP updating study for the Drainage Services Department for flood risk assessment are also presented. Details are given in Hong Kong Observatory (2000).

2 DATA

The storms documented in GEO (1984-1997), for which 24-hour isohyetal maps are readily available, formed the primary data set for this updating study.

In addition, major storms occurring between 1966 and 1983 and between 1998 and 1999, especially those which induced major landslides, are also taken into account.

In all, for the 24-hour PMP updating study, 53 storms spanning a period of 34 years from 1966 to 1999 inclusive and covering all synoptic patterns yielding extreme rainfall in Hong Kong were used.

20 major storms occurring between July 1985 and April 2000 were selected for the 4-hour PMP updating study.

3 ESTIMATING PMP

3.1 *General steps*

The estimation of PMP, whether of 24-hour or other duration, normally involves storm selection, storm transposition (i.e. the transfer of storms from where they have occurred to where they could occur), adjustment for orographic effects, depth-area-duration (DAD) analysis which yields a set of curves relating depth of rainfall to area for a given duration, and rainfall enhancement through moisture maximization. The envelope of the maximized rainfall gives the PMP. Details can be found in Bell and Chin (1968) and WMO (1986).

3.2 *Moisture maximization*

Because of its central importance in the estimation of PMP and in the present study, moisture maximization is given particular mention here.

Moisture maximization is the enhancement of observed storm rainfall by a numerical factor known as the moisture maximization ratio, R_m. R_m is calculated as the ratio of the climatological maximum precipitable water (W_m) to the precipitable water estimated for the storm concerned (W_s). Mathematically,

$$R_m = W_m/W_s, \quad (1)$$

so that the maximized rainfall is given by the product of R_m and the observed rainfall.

W_m and W_s can be obtained from the highest persisting 12-hour dew points near ground level. The definition and derivation of 12-hour persistent dew point can be found in WMO (1986). In practice, given a highest 12-hour persisting dew point, W_m or W_s is read off from tables such as those given in Eihle et. al. (1968).

Bell and Chin (1968) calculated W_m from monthly highest 12-hour persisting dew-points. Wang (1999b) suggested calculating W_m from the 50-year or 100-year return period highest persisting 12-hour dew points. The 100-year values are used in this updating study.

3.3 *Seasonal adjustment*

Bell and Chin (1968) further enhanced their PMP estimates through the introduction of a seasonal adjustment factor. Wang (1999b) suggested that this adjustment factor might lead to overly conservative estimates. No seasonal adjustment was made in the updating study.

3.4 *Transposition and orographic adjustment*

Transposition and orographic adjustment are not taken into account in the updating study so as to facilitate a direct comparison with PMP estimates of Bell and Chin (1968) which did not include these considerations.

3.5 *Procedures used in the updating studies*

A schematic of the steps involved in the 24-hour and 4-hour PMP updating studies is shown in Figure 1.

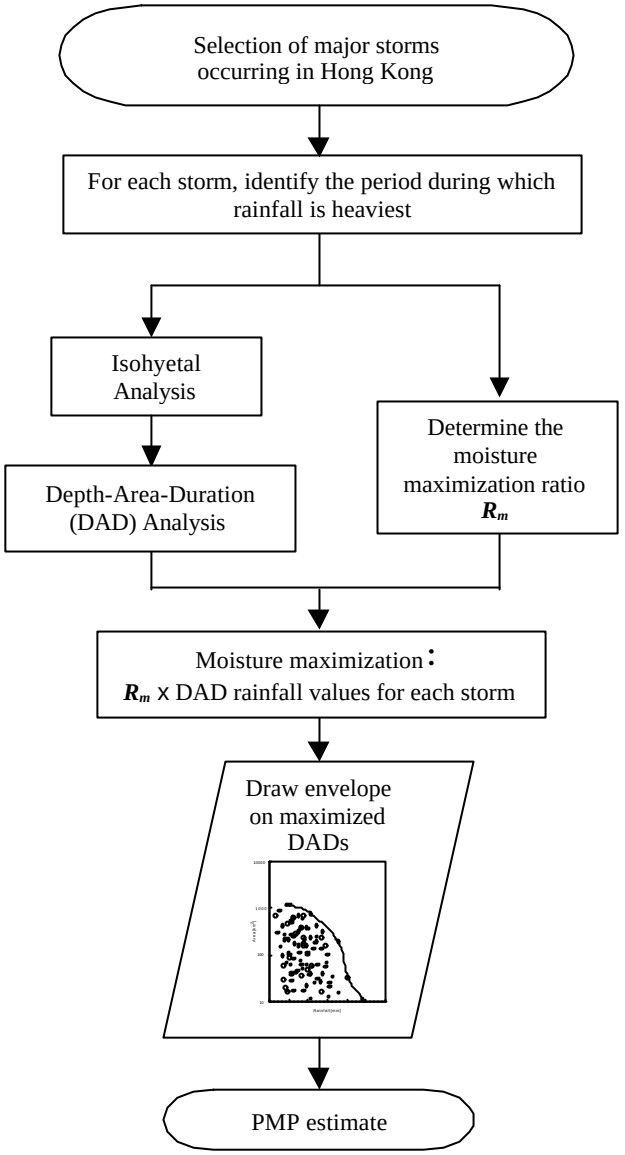

Figure 1. Steps used in the 24-hour and 4-hour PMP updating studies.

4 THE UPDATED 24-HOUR PMP

The updated 24-hour PMP, as obtained from 53 storms occurring between 1966 and 1999, is shown in Figure 2 (open circles). Updates are given for areas between 10 km^2 and 1000 km^2. 10 km^2 is roughly the area for which point rainfall is applicable in the case of Hong Kong (Wang, 1998). 1000 km^2 is the approximate geographical size of the Hong Kong.

Readers interested in the details of the DAD analysis for each storm, the moisture maximization ratio etc. can refer to Hong Kong Observatory (1999).

The 24-hour PMP given by Bell and Chin (1968) was also re-estimated by using W_m calculated from 100-year highest persistent dew points and removing seasonal adjustment. The revised values are shown in Figure 2 (solid circles).

The envelope of the updated 24-hour PMP for 1966-1999 and the revised 24-hour PMP for 1955-

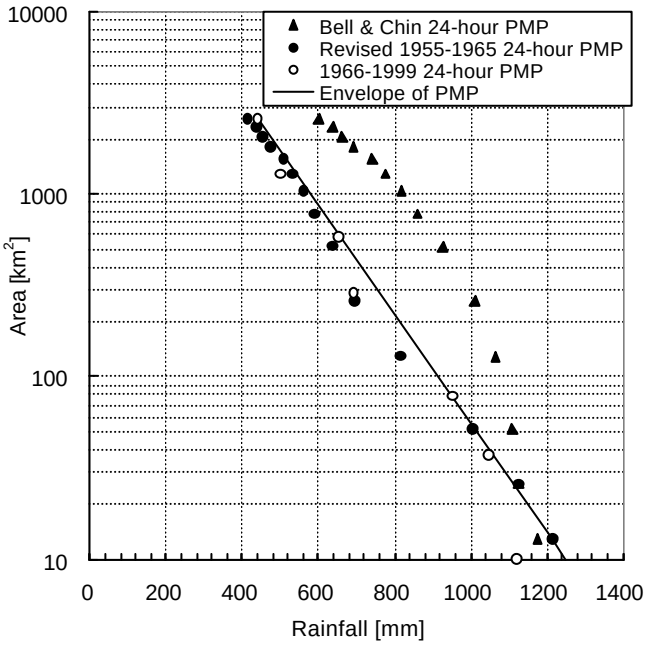

Figure 2. 24-hour PMP.

1965 (solid line in Figure 2) can be regarded as giving the combined 24-hour PMP for the period 1955 to 1999 as a whole.

Figure 2 also shows that the combined 24-hour PMP is generally smaller than the original 24-hour PMP given by Bell and Chin (1968). This is due to the omission of seasonal adjustment in the combined 24-hour PMP.

5 COMPARISON OF 24-HOUR PMPS

Table 1 compares the combined 24-hour PMP for Hong Kong with the 24-hour PMP of Hainan coast and Hawaii (Wang 1998).

Table 1. Comparison of the 24-hour PMPs.

Area [km2]	Combined PMP for Hong Kong [mm]	PMP for Hainan Coast [mm]	PMP for Hawaii [mm]
10	1250	-	980
100	930	1129	925
500	690	1060	770
1000	580	1026	-

It appears that, for large areas, the combined PMP for Hong Kong is biased towards the low side.

The combined 10 km^2 or point PMP for Hong Kong is also on the low side when compared with the world's greatest observed 24-hour point rainfalls as given in WMO (1986). However, it is substantially greater than the highest rolling 24-hour point rainfalls of 697.1 mm recorded at the Hong Kong Observatory and 954.0 mm recorded at Tai Mo Shan, the station with the highest rainfall climatologically (Hong Kong Observatory, 1999).

One possible explanation for the relatively low values of PMP for Hong Kong is that transposition has not been included.

6 THE UPDATED 4-HOUR PMP

The updated 4-hour PMP as obtained from 20 major storms occurring between 1985 and 2000 is shown in Figure 3 (open circles). The 4-hour PMP of Bell and Chin (1968), revised by maximizing with W_m calculated from 100-year highest persistent dew points and removing seasonal adjustment, is shown in Figure 3 (solid circles).

Again, the envelope of the updated 4-hour PMP for 1985-2000 and the revised 4-hour for 1955-1965 (solid line, Figure 3) can be viewed as a combined 4-hour PMP for these two periods.

Figure 3 shows that the combined 4-hour PMP is generally smaller than the original 4-hour PMP of Bell and Chin (1968). The difference is approximately 100 mm. This is once more due to the omission of seasonal adjustment in the combined 4-hour PMP.

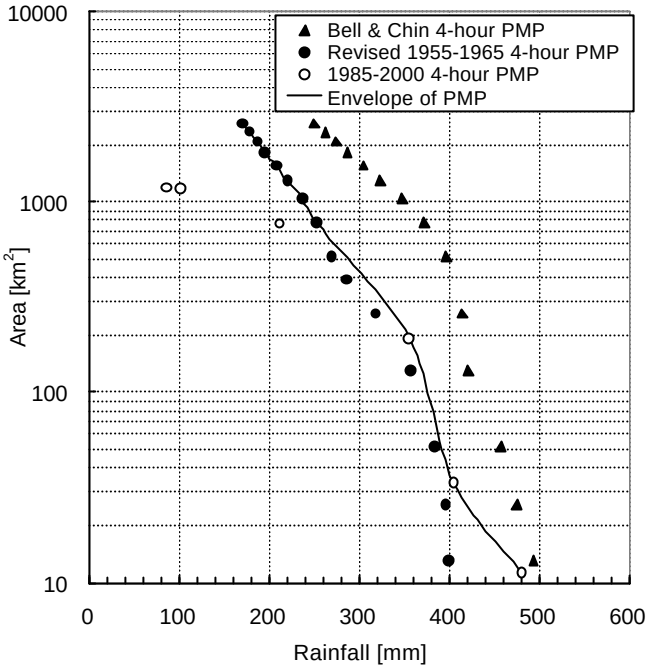

Figure 3. 4-hour PMP.

Unfortunately, 4-hour PMPs from Hainan and Hawaii listed in Table 1 are not available for comparison.

The 10 km^2 or point 4-hour combined PMP of about 490 mm exceeds both the maximum running 4-hour rainfall of 302.3 mm recorded at the Hong Kong Observatory, and that of 349.0 mm recorded at Tai Mo Shan.

7 CONCLUSIONS

For both the 24-hour and the 4-hour PMPs, the updated estimates are generally smaller than those previously obtained. This is because seasonal adjustment was not used in the updating studies.

Both the 24-hour and 4-hour point PMPs exceed the corresponding maximum point rainfalls recorded at Tai Mo Shan.

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