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LONG RAINFALL RECORDS - DESIGNING FOR DETENTION STORAGE

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Introduction

Detention storage is added to a sewerage system to improve its performance in terms of flooding and/or pollution. Performance criteria can be set to cover a range of operating characteristics, such as:

Volume of spill per year
Maximum rate of spill
Number of spills per year
Frequency of flooding
Annual pollutant load

Different techniques are used to evaluate the different criteria and one of the key issues is what rainfall and antecedent conditions to use. Typical options for rainfall are:

Annual Time-Series rainfall
Wallingford rainfall generator
Real rainfall records

The subject of this paper is the design of a large detention facility which is to eliminate flooding and CSO spill in all storms of up to 50 years return period.

Given a performance criterion in excess of one year, the Annual Time Series rainfall finds no application. The Wallrus rainfall generator will synthesize standardised summer and winter rainfall profiles for return periods of one year and upwards and any duration from five minutes. It was developed primarily by selection of peakedness to yield a good match with observed peak discharges rather than flow volumes. Selection of suitable antecedent conditions is of critical importance. These uncertainties can be reduced by using long-term real rainfall records but this introduces other problems. A record at least twice as long as the design parameter is required (ie at least 100 years of data in the present case). This will be difficult to find, expensive and the oldest data will be only daily totals. Hourly data values can be disaggregated to yield input suitable for Wallrus.

Another major difficulty with long records of real rainfall data is the length of time needed to run simulations through a Wallrus model. WRc© have sought to overcome this problem through the use of a much simplified calibrated catchment model. In the present study however there were clear advantages to retaining the detailed and verified Wallrus model of the sewer system as a base on which to build the improvements and therefore a method using the Wallrus rainfall generator together with limited amounts of real rainfall data in combination was proposed. This method involved extracting the most significant events from twenty years of local hourly rainfall in order to calibrate the Wallingford rainfall generator and derive local antecedent conditions applicable to long return period events. The analysis began by identifying the critical storm duration yielding the largest storage requirement using standard design rainfall and antecedent conditions. The critical duration depends on the flow control regime to be applied and it is therefore necessary to have this developed in outline detail before beginning the rainfall analysis.

Antecedent conditions

The wetness of a catchment onto which a rain storm falls can have a significant effect on the amount of runoff which is produced, particularly on catchments with a large amount of permeable surface. The equation for the percentage runoff which is normally used in the Wallingford Procedure is:

$$PR = 0.829PIMP + 25SOIL + 0.078UCWI - 20.7$$

Taking typical catchment characteristics of 50% PIMP and 0.35 SOIL we can calculate PR for typical low and high values of UCWI.

	UCWI	PR
Low	65	34.5
High	140	40.4

The proportional increase in runoff would be 17%. The cost and performance implications of these differences are very significant in the design of a large detention storage scheme where once the continuation flow limit is reached all extra runoff requires additional storage.

Earlier work carried out to analyse timeseries (ii) had already shown that many summer storms had values of UCWI much higher than the average summer values. We were therefore concerned that this might be generally true, and that high values of UCWI should be used for the design. The rainfall analysis therefore covered two stages. The first was to consider the depth of rain in the storms in the long rainfall record to see if they showed that the standard synthetic storms were incorrect. The second was to look at the antecedent conditions for each of the large storms in the record.

Rainfall analysis

The rainfall record which was available was for just less than 20 years at a 1 hour timestep. This was analysed for storm durations of 1,2,4,8,16 and 32 hours. For each of these durations the total depth of rain was calculated starting at every clock hour of the record. Local maxima (ie values greater than those on either side) were identified. Where there were multiple maxima within one duration period of each other, only the largest one was chosen.

These selected maxima were then sorted into order of size, and the largest hundred were printed out together with the start time of the storm period.

This analysis differs from the traditional Met Office analysis in that it is a peaks over threshold analysis rather than an annual maximum analysis. It may therefore include storms which would not be included in the Met Office analysis.

The initial data was hourly "clock hour" data. It therefore underestimates the maximum depth in one hour storms, as there may be a significant storm which is split between two clock hours. This will also have a small effect on two hour storms as these may be split over three clock hours. The correction factors to allow for this are given in the Flood Studies Reports. The depths should be increased by:

1 hour storm	+15.0%
2 hour storm	+ 6.0%
4 hour storm	+ 1.5%

Return period analysis

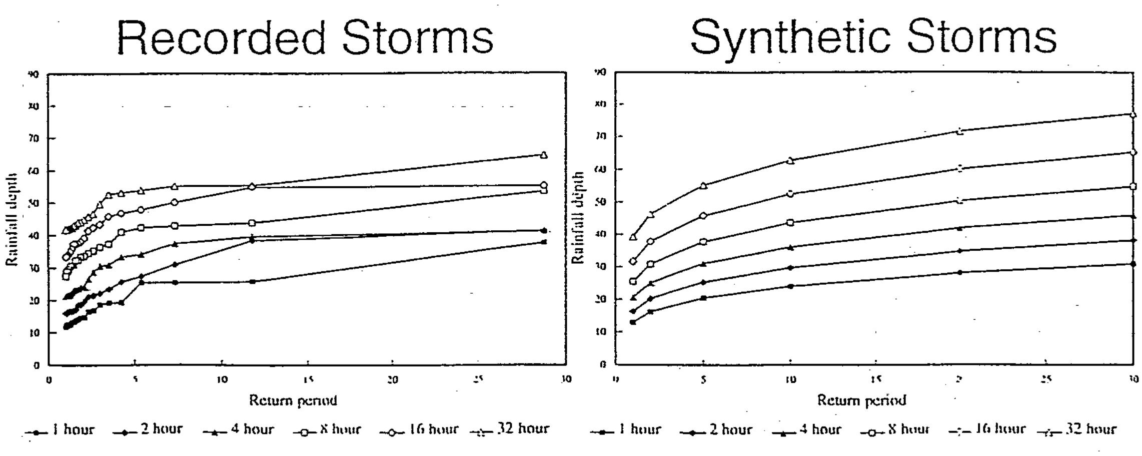
The Flood Studies Reports provide an equation for calculating the return period of storms from a ranked list (strictly an annual maximum series). This is given by:

$$R = (N + 0.38)/(m - 0.31)$$

where R — estimated return period
N — number of events in the annual maximum series here taken as the number of years (19.45)
m — ranked position of the event.

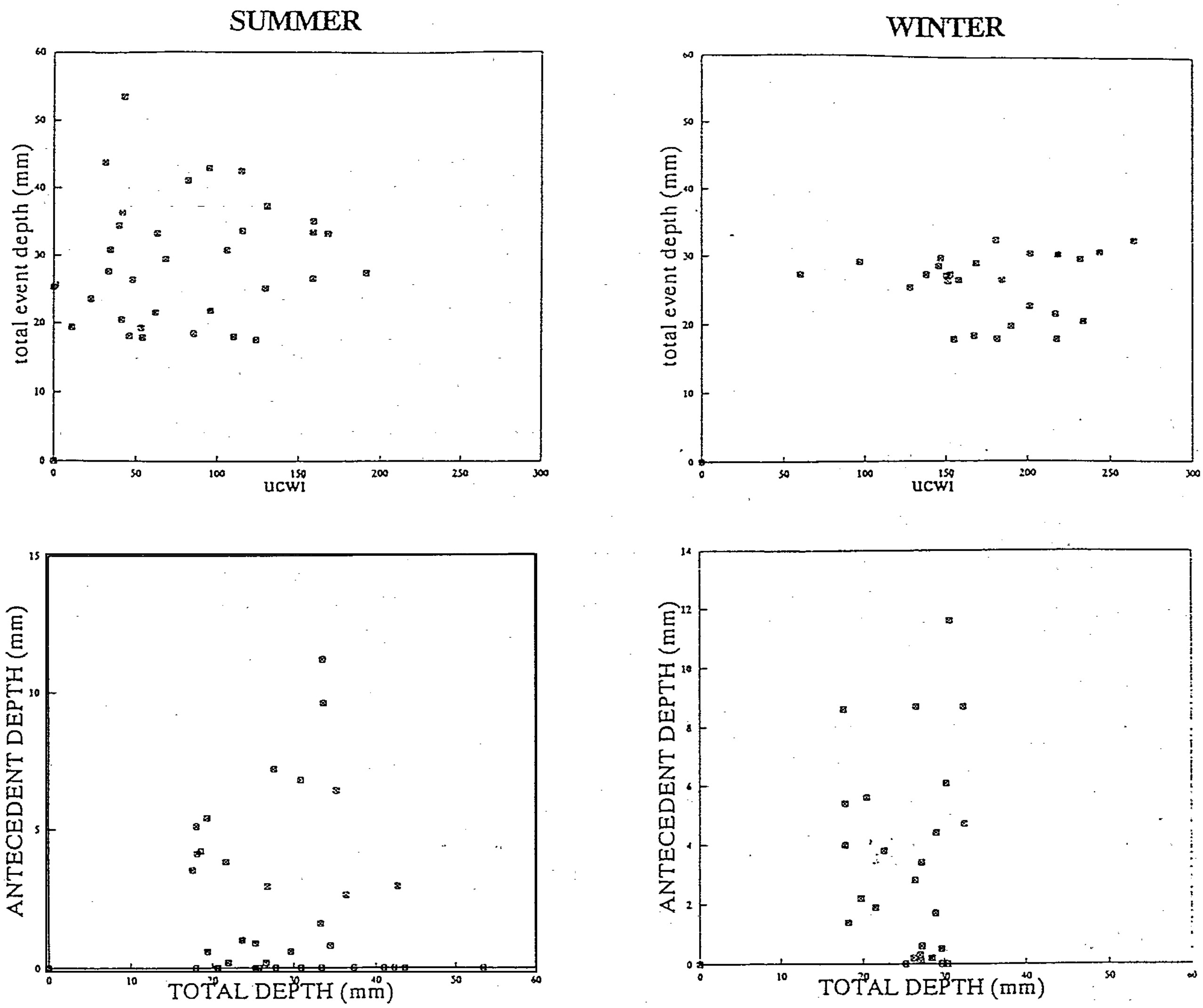
Synthetic storms of comparable return period and duration to the recorded events were generated using the Wallingford rainfall generator and the depths were compared. The comparison shows a reasonable agreement for short durations and return periods (allowing for the clock hour correction for the observed data). However for return periods greater than 5 years, and for durations of 16 hours or more the data shows significantly smaller values than the standard storms.

These differences should be put into context. The addition of one large duration storm to the observed data would probably be sufficient to remove the difference. Statisticians would be quick to point out that this difference was insufficient to prove that the standard storms were incorrect. The standard storm depths were therefore used without any adjustment for return periods up to 50 years. Had adjustment been found necessary it would have been applied by altering the return period of the generated storms up or down to match the observed depths.



Antecedent conditions

For the top 20 of the observed storms of critical duration and for the top 20 storms of the next higher and lower durations, the antecedent conditions were calculated. This procedure allowed analysis of the 60 heaviest storms (all 1 year return period or greater) closest to the critical duration, whereas if only the critical duration had been considered, many of the events would have been of much less than 1 year return period. The values of UCWI and antecedent depth were then plotted against various parameters of the ranked observed events. This showed considerable scatter, but no trend of values. There was no tendency for larger storms to have drier or wetter antecedent conditions. The data was also analysed for seasonal variations in antecedent conditions. The results are summarised in the scattergraphs given below.



Storage evaluation

Having established the critical storm duration and antecedent conditions and having made any necessary calibration of the Wallingford rainfall generator it then becomes a simple matter to carry out a simulation of the appropriate design event. A single simulation is all that is needed and this is a great advantage when developing a design or testing various options.

Summary

A technique to apply corrections to the Wallingford rainfall generator based on limited amounts of local data has been developed for the design of detention storage under long return period performance parameters. The technique permits the use of detailed Wallrus or SPIDA models and avoids extensive simulation times.

References

(i) P C Head et al; Bathing in the rain... IAWPRC 1992

(ii) C M L Rainey & M P Osborne; Design for storage using synthetic rainfall. WaPUG Nov 1992

Long Rainfall Record-Design for Detention Storage
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Question Nigel Simmonds Consultant

Did you take into account flooding as well as rainfall and try to relate the two?

Answer

No we were provided with a verified model and used that.

Question John Packman Institute of Hydrology

I am not sure the Met office would be impressed with calibration against a single raingauge, as this may not be typical, ut it does show that the Met Office rainfall model is good.
I was pleased to see that the UCWI holds up reasonably well, although it is important to realise that it is an average value for all days rather than an average value for the start of storms.
However is it really valid to modify the values from the standard ones without more evidence?

Answer

We did not want to re-calibrate the depth of rainfall in the storms, and would only have done so if we had got an extremely bad correlation of results. In those circumstances we would have gone to the Met Office for advice before re-calibration.
For UCWI there does seem to be evidence that the values at the start of storms are higher than the average values, although the picture is not consistent. Sometimes it is the summer values which are higher, in this case the winter values. There is a need for more work on the subject, but we think that it was valid to adjust the values.