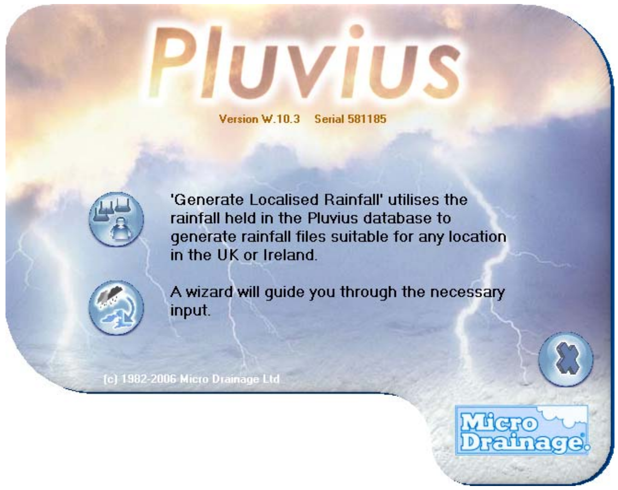
- Pluvius -

The complete drainage software system

RAINFALL – SHOULD WE USE CONTINUOUS ANALYSIS?

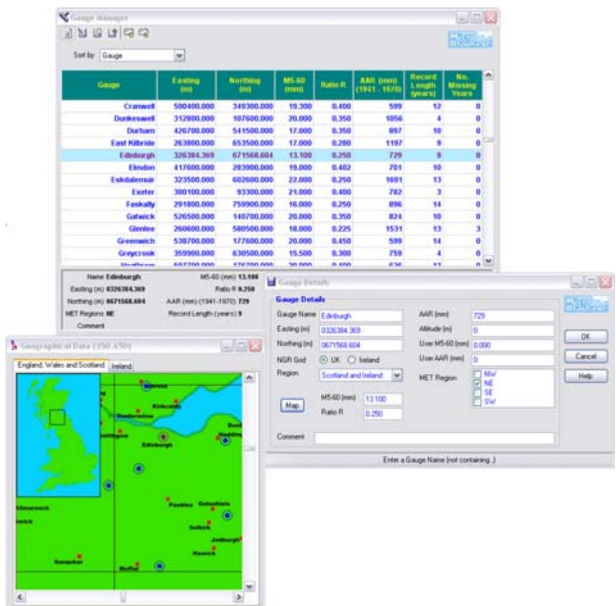
New software called Pluvius, developed by Micro Drainage in a joint project with the Meteorological Office, has made the use of true continuous rainfall analysis a practical reality for engineers. On the eve of the publication of PPS25, covering Development and Flood Risk, Micro Drainage Managing Director Aidan Millerick assesses where the use of continuous rainfall analysis may be appropriate.



Pluvius is a complete suite of rainfall data management and analysis resources, designed to overcome the difficulties previously associated with obtaining and using continuous rainfall analysis.

The first challenge is the question of access to good quality data. Hourly and sub-hourly records represent the most important data for pluvial flooding (flooding caused by rainfall) in urban areas.

Pluvius uses the Deluge database containing over 700 years' worth of rainfall data recorded at five-minute intervals on 73 sites across the UK. The data was from a single source, the Met Office, using tilting bucket rain gauges and quality controlled against nearby daily check gauges.



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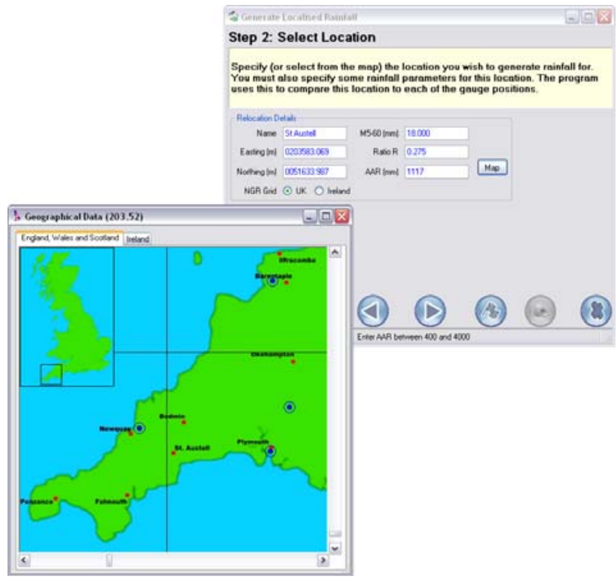
In addition to the Met Office’s quality controlled data, the Pluvius toolkit includes the facility for any user to augment this data with their own rain gauge records.

Secondly, there is the difficulty of data handling. Pluvius is a state of the art database capable of accessing and analysing huge records very quickly.

It can also be difficult to make sense of so much information and here Pluvius incorporates a wide range of analytical and sorting tools to help extract the important data and to validate it. Engineers can therefore generate long rainfall records spanning hundreds of years at any location in the UK. All the events from that record can be extracted, allowing the engineer to identify the most important of them from a drainage perspective and generate typical years or typical seasons from the record.



Pluvius can also be used to generate design storms from the data, or for the comparison of records with FEH and FSR analysis. Given the capabilities of this technology, engineers should now give serious consideration to where and how continuous rainfall analysis can be used.

Pollution

Design Storms are usually very effective at representing storms above a one-year return period. However, it is more usual to use continuous analysis when you need to know the performance of a system during the more common events. This becomes important when you wish to design a system for pollution performance. The calculation of the treatment volume for ponds can be verified by the continuous analysis of a typical year, or by determining its average performance over 10 to 20 years.

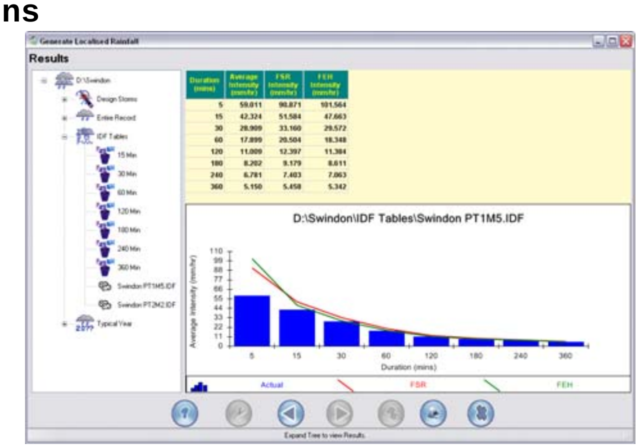
For pollution purposes we must treat the majority of the rainfall (90%) by ensuring the pond can retain it for several days. This majority will probably fall at rainfall rates less than 10mm/hour. Those designing drainage systems concentrate on heavy rainfall events that produce 25mm/hr and above, but these do not occur on most rainfall days. Also, low rainfall events can be the most polluted as they provide less dilution than the events that occur once every few years. While a method of approximating the treatment volume Vt from M5-60 (five year return period, 60 minute duration) is available, this method was itself derived from continuous analysis.

Continuous analysis is also applied to calculating the frequency of combined sewer overflow activations. Overflows can be limited to a set number per year, or even limited to a number per season. Pluvius can derive a design storm for these cases, known as a Super-Storm, but a continuous rainfall record is first required to construct the Super-Storm.

In short, continuous analysis is usually the preferred option for any problem that requires analysis of events that occur more frequently than once a year.

Continuous Analysis on New Designs

When sizing new drainage systems, it is common practice in the UK to use design storms derived from the Flood Estimation Handbook (or formally the Flood Studies Report) method. However, there are cases where these design storms may not cover all scenarios, or where their application may be unnecessarily conservative.



The 15-minute design storm will give the worst average intensity that you should expect in a 15 minute duration for a given return period. However, when this storm was sampled from real data it probably had some rainfall immediately before or after it. Also, the shape of the storm has been idealised to a typical summer or winter profile. If your catchment is made up of elements (streams, channels, pipe networks) with varying times of concentration, then this shape, or storm profile, may be important.

However, there are also advantages to design storms. If they are calculated using FEH or FSR methods, then they have been derived from the analysis of thousands of years of hourly and daily rainfall records across the country. They are also easy to use and enable alternative designs to be considered and compared quickly and efficiently.

But it is in the area known as *combined or joint probabilities* that the application of design storms alone may produce conservative and over-engineered solutions. With increased computing speed and the analytical power of Pluvius, there is little excuse not to use both Design Storms and Continuous Analysis to assess the performance of a design.

Combined/Joint Probabilities

Continuous analysis can give a realistic solution to the problem of combined probabilities. For example, what if we have a 30-year return period storm on very wet ground, or a water level at the outfall which occurs once in 30 years?

The return period of flooding does not only depend on the return period of the rainfall. It is a combination of rainfall and antecedent conditions that gives rise to ground wetness, the level of water in the outfall (river, ditch or downstream pipework) and the amount of water already in the network before the next rainfall occurs. When using design storms, it is necessary to make judgements about all of these factors.

When antecedent or downstream conditions are not considered it can result in significant error. For instance, the system may be assumed to have a freely discharging outfall, when in fact during most extreme events it may be surcharged.

Conversely, the engineer may assume that when the most critical 30-year design storm occurs on the development, the most critical 30-year design storm also occurs on the downstream system, causing peak 30-year water levels at the outfall. This is very unlikely, but it is also very difficult to determine the optimum combination without continuous analysis.

Let us consider two cases of combined probability.
What is the likelihood of the 30-year rainfall event happening on the same day, at the same hour, as the 30-year highest water level at the outfall? If the outfall water level was due to a tidal wave caused by an earthquake, then both instances would be independent of one another and the probability of their simultaneous occurrence would be measured in thousands of years.

However, if the outfall was a river and its high water was caused by the same weather front that produced the 30-year rainfall event on the site, then the events would be linked and they could occur on the same day. However, the critical durations of the drainage network and the river are likely to be very different.

The site drainage would respond to relatively short intense storms – the critical storm duration for the site may be only one hour. A river may be virtually unaffected by the short storm that is so critical for the drainage network. It would require a much longer storm (perhaps 12 hours) to produce its highest water level in 30 years. So what is the probability that both these short and long storms are contained in the one weather front, and that the highest water level in the river opposite the site occurs at the same time that the 30 year high intensity storm is over the site? It would be a very unusual coincidence for the one weather front to contain both the critical duration 30-year RP storm for the site, and the critical duration 30-year RP storm for the river, and for both these events to be synchronised so that the highest level in the river coincides with the highest flow from the site.

In both these cases the return period of the rainfall on the site is 30 years, but the return period of the event is much longer than 30 years because of the effect of combining the probabilities. However, an engineer using a design storm solution will often play it safe and combine these extremes, producing a conservative result.

Now let us consider how we might calculate the real return period of the event. It is easy to calculate the RP of two storms on the same day.

We may need to know this to determine the probability of a short duration event, which is critical for the developed site, occurring immediately after a long event that is critical for the river into which it outfalls, as in the above case.

Also, we may have two extreme events on the same day, and the drainage system and its storage structures may not be empty before the second event strikes.

From rainfall statistics, we can predict the combined probability of a 60-minute, 30-year RP storm, followed two hours later by a 120-minute, 30-year RP storm. The FSR model (M5-60 = 20, r = 0.4) for England predicts 30.8mm in the first storm and 37.2mm in the second. This equates to 68.0mm over a total of 5 hours which has an RP of 177 years. If the intention is to design for “no flooding” in a 30-year event, then this combination of storms is much too conservative.

In order to calculate the runoff from Design Storms, it is also necessary to assume a typical wetness for the ground before the rain starts to fall. In the Wallingford Procedure runoff equation, this wetness is related to the average annual rainfall for the site. A typical value of this Urban Catchment Wetness Index (UCWI) in the South East of England would be 80mm for summer rainfall.

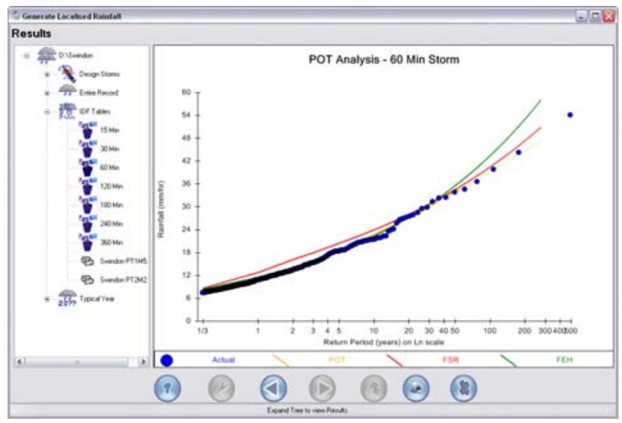
But what if this storm fell on wet ground with an UCWI of 150mm? Ground this wet will usually occur in winter, and extreme rainfall in the South East of England is most prevalent in August. Furthermore, each drainage network has unique characteristics and the above combination of events may not be the most critical for a specific network. So even if you could work out the probability of the runoff from this event, it may not be the critical event for your network.

Continuous analysis and combined probabilities

If you analyse 300 years of continuous real rainfall data, and you include the downstream network in the model, then you will produce a wide variety of storms, downstream water levels and partial drain down conditions based on real data. It is also possible to track the soil wetness based on the previous months’ rainfall. This provides the best current means of testing your system for a true 30-year event.

Examine the 300 years of data for the highest water levels (the Summary Wizard in the Win*Des* Simulation APT module will do this for you). The water level that is equalled or exceeded 10 times in 300 years will be the worst combination of all factors, producing a return period of once in 30 years (or 10 times in 300 years). Set the Simulation APT summary to give the 10th most critical event for the 300 year period and that will be the critical event for a 30-year RP. However, the critical event may vary from pipe to pipe in the network, and this will also be identified. Simulation APT with Pluvius can also identify the critical event by level, flow rate or flow volume. In most cases, if flooding is the criteria, the maximum level is required.

If you have a shorter record it is possible to determine a result. For example, the seventh most critical storm in a 210 year period will also equate to a 30-year RP, but the shorter the record, the less confidence you have in determining the return period.



It is important to emphasise that the first most critical result in a 300-year record should not be assumed to be the 300 year return period. There is a 63% probability that 300 years of record will contain a 300-year RP storm, but this implies that there is a 37% probability that it does not. It is also very likely that it might contain storms much greater than 300 years RP. It is more likely, however, that a 300-year record will have ten events equal to or greater than a 30-year RP, and this fact allows us to determine a return period with reasonable confidence from a long record. Since we are effectively trying to determine the return period from the combined effect of a number of factors, the more permutations we run, the more likely it is that the record will contain the critical event for the desired return period.

However, it should also be apparent from the above that effective continuous analysis for high return period verification requires a large amount of data. It is not practical to run a 300-year continuous analysis repeatedly when sizing a new network, or experimenting with different options. Design Storms still provide the most appropriate method for a design or optioneering task, followed by continuous analysis for final validation.

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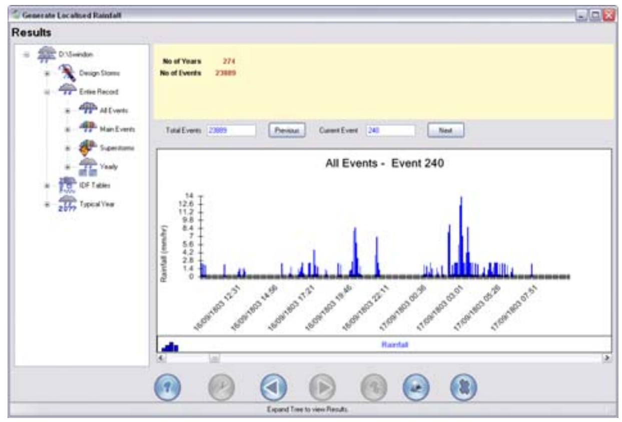
If there was one recommendation that we would make to all drainage engineers to improve the robustness of their designs, it would be to include the outfall system in their model, and run a complete family of summer and winter design storms, from 15 minutes to 24 hours – an easy task with Simulation APT. Assuming a free outfall can be a bad mistake.

Pluvius also makes it possible to test the system with a wide variety of real data that would give greater confidence to a design, and avoid the use of belt and braces when combined probabilities are involved.



The conditions that give rise to a particular water level in a river or drainage network are a combination of many factors. The analysis of real data, when it is available, provides the engineer with the means of validating the network more thoroughly than is possible with design storms alone.

The comprehensive rainfall management and analysis capabilities of Pluvius enable engineers to test drainage networks with real rainfall data, for use on flood, pollution and river modelling.

For further information about Pluvius and Micro Drainage training, visit www.microdrainage.co.uk, call 01635 582555, or email info@microdrainage.co.uk.
