# Designing attenuation storage for redeveloped sites

This factsheet is intended for designers, Local Authorities (incl. LLFA), Water Authorities, Environment Agency and Planners; essentially anyone who is involved in process of conditioning or designing of redevelopment sites or who has a vested interest in urban flooding or the impacts of Combined Sewer Overflow spills.

This factsheet establishes that whilst the current approach of incorporating betterment attenuation storage is effective to an extent; using an identical volume of storage (that is currently calculated for Betterment flow reduction) greater benefits could be delivered in the drainage network through a change in design approach.

## The authors

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## Background

Not all new sites have the luxury of being built in green field (GF) areas; many sites are the redevelopment of existing sites, commonly referred to as previously developed land (PDL). On PDL natural runoff characteristics have already been significantly altered and flows have been collected, diverted and historically allowed to discharge uncontrolled into the sewer or river system. More recently development sites have been required to attenuate and control the rate of runoff, for both GF sites and redevelopment of PDL.

The current aspiration for redevelopment sites is that runoff rates are reduced to natural Greenfield status. This is not often the case as there is no mandatory requirement for the reduction in runoff. Requirements are stated in both LA policy and Guidance with some examples below;

The London Sustainable Design and Construction SPG states that:
"*Most developments referred to the Mayor have been able to achieve at least 50% attenuation of the site's (prior to re-development) surface water runoff at peak times. This is the minimum expectation from development proposals.*"

The SuDS design Guide for Islington and the Essex SuDS Design Guide both recommend a 50% reduction in rate from the peak pre-redevelopment rate [with no stated return period].

This reduction in flow rate is termed by the industry as 'Betterment'.

## Introduction

It is important to appreciate that many of the issues which affect our urbanised catchments occur during much smaller rainfall events, generally ranging between the 1 in 1 year and 1 in 10 year likelihood of occurrence. The redevelopment of sites provides an ideal opportunity to integrate SuDS, which if designed properly will reduce frequency, rate and volumes of surface runoff both for day-to-day rainfall as well as for the more extreme events.

This fact sheet considers the SuDS approach and in particular the impact of attenuation storage for redeveloped sites. The following areas will be explored by this fact sheet;

- Drivers for reducing flows within a drainage catchment.
- Methods for controlling flow from a redevelopment sites
- Analysis outcomes (from comparing the outputs from the 2 Methods)

This fact sheet focuses on the control of flow rates over a range of return periods and the time of retention. Consideration is not given to the integration of interception losses or long term storage which contributes to provide volume control (i.e. the actual volume of runoff that leaves the site). The additional benefits of volume control are outlined by the SuDS Manual can be delivered through well considered SuDS design.

## Drivers for reducing flows within a drainage catchment

A large proportion of the drainage infrastructure in urbanised areas is provided by piped networks which can either be separate (storm and foul flows in separate pipes) or combined (foul and storm flows combined in one pipe). Piped networks are generally good at dealing with long duration low intensity rainfall events. However, parts of the system can be susceptible to flooding from relatively short duration high intensity rainfall, even for rainfall which is statistically likely to occur on a regular basis.

### Combined Sewer Overflows (CSOs)

CSOs located on combined sewer networks act as a release valve whenever moderate to high rainfall is experienced, allowing combined foul flow mixed with storm water runoff to spill to a local watercourse rather than occurring as surface flooding. CSOs are required to meet industry requirements of spilling no more than 10 times per year or three times per bathing season.

CSO discharges have become more frequent and greater in volume as the sewerage system in the UK has aged. This has been caused by increasing population and a greater area of paved surfaces introducing flows to the system which have exceeded the original design parameters. Various reports which are publically available suggest that some CSOs in London now discharge at least once a week on average and/or after very light rain (2mm).

Making better use of betterment storage would assist in relieving the pressure on the combined sewer system.

### Flooding

Flooding can be a serious issue on any type of drainage system. Anecdotally, in urbanised areas, which are predominately served by piped sewers, the return period which causes the most inconvenience is considered as being the 1 in 10 year rainfall event. When compared with the 1 in 100 year rainfall, rainfall depths for the 1 in 10 will not be as severe. However, flooding for the 1 in 10 still causes duress to home owners, business owners (with internal flooding, sometimes with sewage) and road users, and inevitably flooding for this lower return period occurs with much greater frequency compared with the 1 in 100 year.

**Sewerage undertakers'**
DG5 Register records properties which have experienced internal flooding at least twice in a 10 year period.

Figure 1 indicates predicted rainfall depths over a range of return periods (60 minutes rainfall duration only is considered here). It is noted that the 1 in 10 year rainfall event is predicted to produce half the depth of rainfall when compared against the 1 in 100 year rainfall event of the same duration.

**Future development and urban creep**

Many of our existing combined and separate sewer systems are at or beyond their originally intended capacity. Capacity issues are compounded by the effects of urban creep where permitted development such as driveways and patios add runoff to the drainage system. Redevelopment of sites provides an ideal opportunity to integrate a new drainage regime to reduce runoff rates from a site. This could potentially free up capacity within the storm (or combined sewer) to facilitate additional development elsewhere in the catchment and (or) offset the impact of urban creep.

## Controlling the rate of runoff from redevelopment sites

The objectives of controlling flows from redevelopment sites have been explored by the previous section on identifying catchment drivers.

Two methods for controlling flow have been considered for the purposes of this factsheet. Method 1 adopts the traditional approach to delivering Betterment discharge flow rates. Method 2 adopts an approach whereby an identical volume of storage is used to that calculated for Method 1, however, flows are restricted to GF runoff rates. Runoff in excess of the storage volume is allowed to overflow uncontrolled into the drainage system.

Figure 2 outlines the two methods for controlling flows from a site.

**Method 1. Reduction in peak runoff by 50% (Betterment)**

Guidance on establishing predevelopment rates is set out in BS8582. To establish the existing

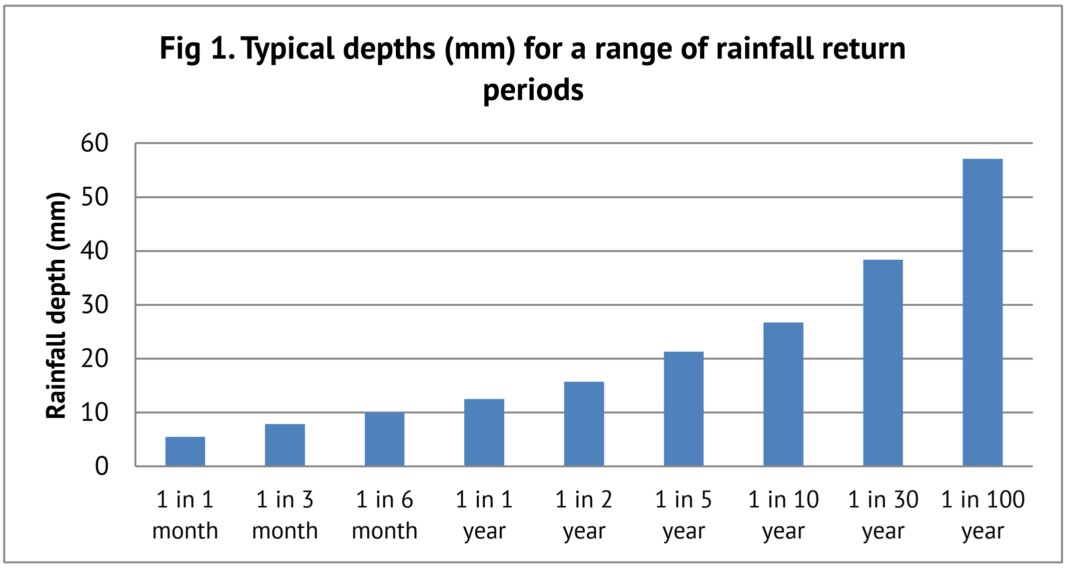


*Figure 1: Typical depth (mm) for a range of rainfall return periods*

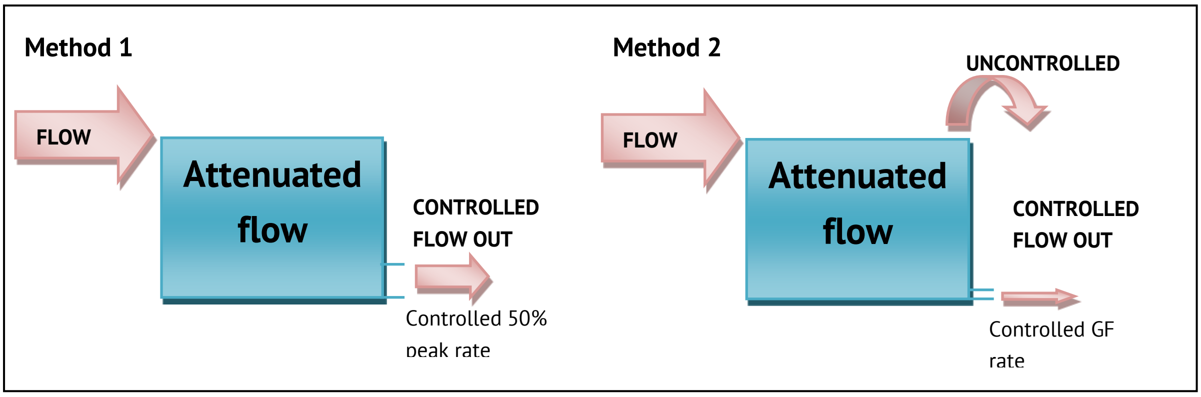


*Figure 2: Methods for controlling runoff*

peak rate of runoff there is generally a requirement to undertake hydraulic assessment of the existing drainage network. Where limited information on the existing network is available, the Modified Rational Method has been used to define peak runoff rates. It is noted that each approach will result in a different output.

Once existing development peak rate of runoff has been derived (and agreed with the LA);

- Peak Rates are divided by two (50%). A range of return periods should be considered and this will act as the flow control setting for the proposed drainage system.
- Calculations / hydraulic simulations are undertaken to estimate storage requirements.

A simple analysis has been undertaken to estimate the likely storage volumes required to facilitate a 50% reduction in offsite flow rates. The results are indicated by Table 1.

**Method 2. Controlling outflow to GF Runoff rate**

Method 1 (sized for 50% Betterment for the 1 in 100yr return period) requires 290m$^3$ of attenuation storage volume. An identical storage volume is used for Method 2. Using hydraulic modelling, a 60 minute summer rainfall event (which is the critical duration for the 50% betterment scenario) has been simulated for both methods. This rainfall duration is also considered for the purposes of this factsheet to broadly represent an intense short duration storm, which typifies the trigger for many urban flooding scenarios.

Over a range of return periods (1 in 1 up to 1 in 100 year) this would result in attenuating runoff larger volume of runoff and (or) attenuation runoff for a longer period. What this means can be best demonstrated by comparing hydraulic modelling results for the two methods.

Figures for flows and volumes quoted within this factsheet are based on specific catchment and rainfall parameters. They provide a guide but should not be used arbitrarily for all sites.

| Return period | 1 year | 30 year | 100 year |
|---|---|---|---|
| **Peak runoff rate (l/s/ha)** | 40 | 115 | 140 |
| **Flow control rate (l/s/ha) (50% reduction in peak rate)** | 20 | 57 | 70 |
| **Attenuation volume required - m$^3$ per ha of developed area** | 83 | 180 | 290 |
| **mm per m$^2$ of developed area** | 8.3 | 18 | 29 |

*Table 1: Storage requirements to facilitate 50% reduction in peak off site runoff*

Figures 3-6 illustrate the process of filling and drawdown of the storage volume for the two methods over a range of return periods.

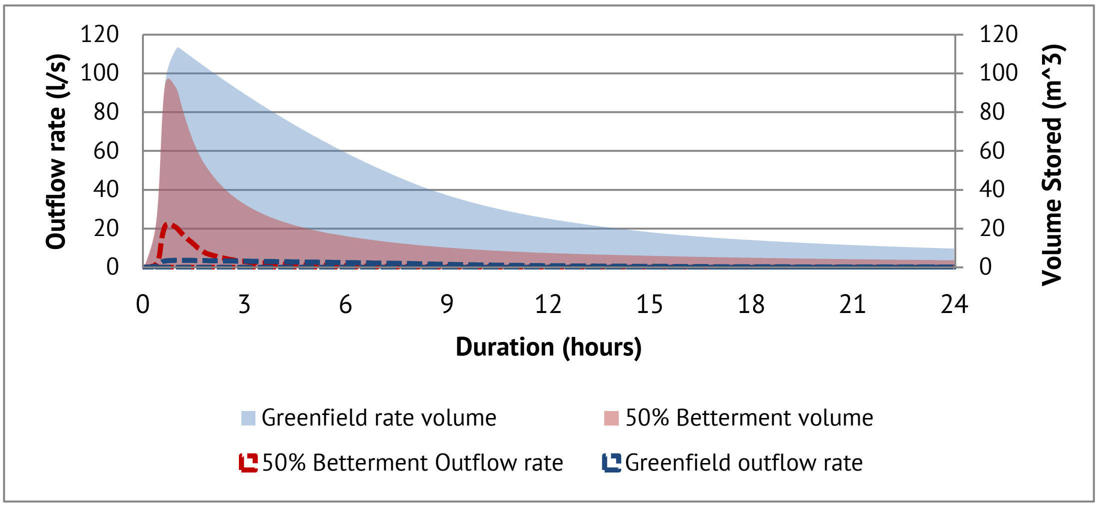


*Figure 3: 1 in 1 year rainfall return period*

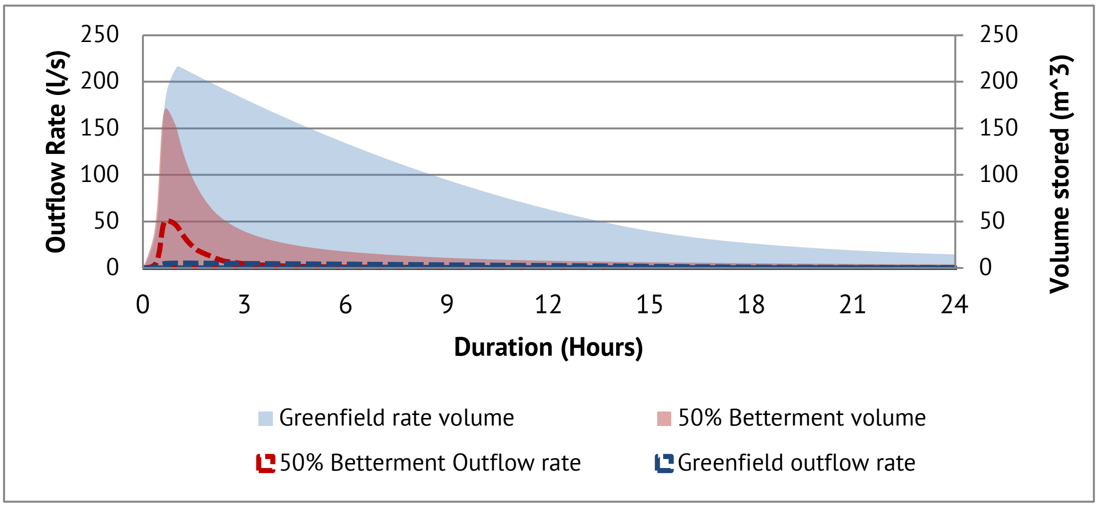


*Figure 4: 1 in 10 year rainfall return period*

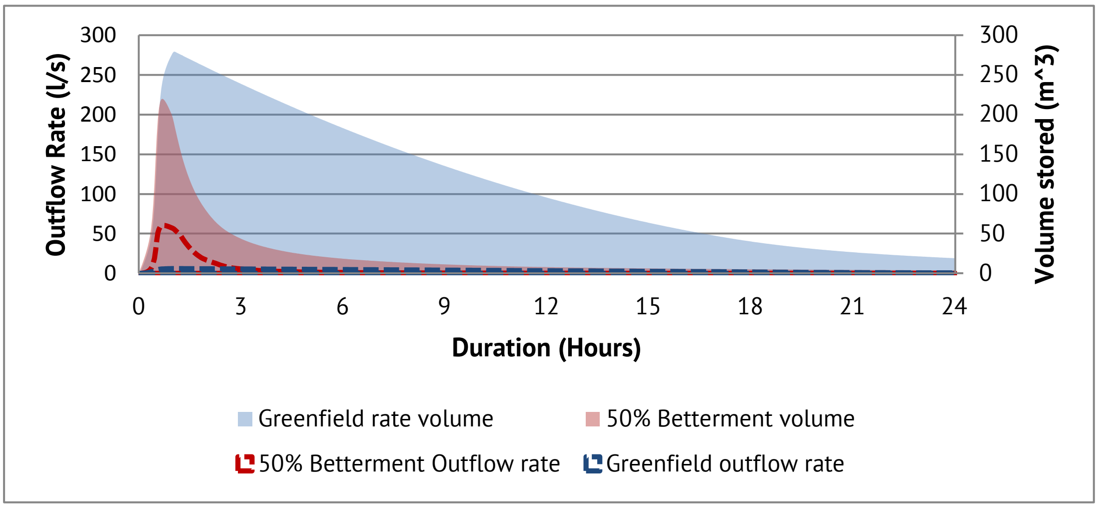


*Figure 5: 1 in 30 year rainfall return period*

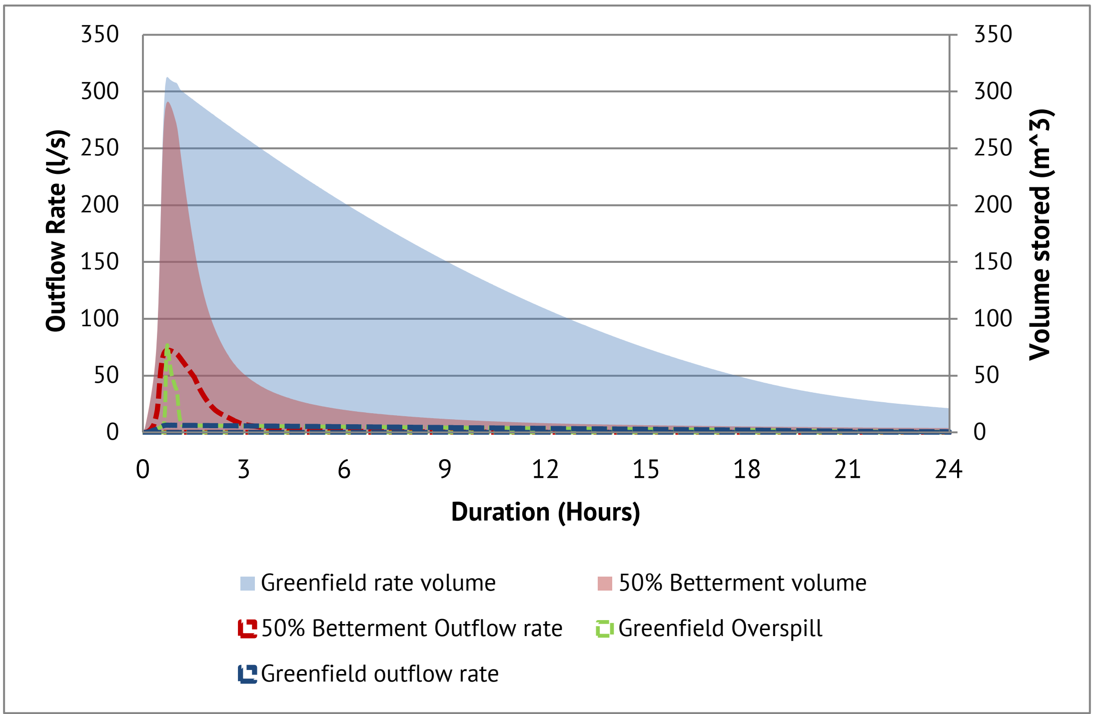


*Figure 6: 1 in 100 year rainfall return period*

## Analysis Outcomes

It is important to consider the duration of storage as well as the volume of storage. If flows are returned to the drainage system after a very short detention time, the receiving sewer is likely to still be under stress due to flooding, or may be continuing to spill untreated flows to the watercourse at CSO locations. The following points are drawn from the analysis.

**Method 1**

- Most of the volume attenuated is released back to the drainage system within 2 hours post rainfall ending. This flow may be entering the drainage system when it is still susceptible to flooding or CSO spill. 50% of the flow is release back to the system within 40 minutes.
- Less storage is utilised for all rainfall events less than the 1 in 100 year rainfall event, when compared with Method 2. It is noted that Method 1 is designed specifically to handle the 1 in 100 year rainfall, whereas for Method 2 the return period is arbitrary.
- The critical duration for storage is defined by a short 60 minute duration storm.

**Method 2**

- Method 2 contains runoff for up to the 1 in 30 year rainfall event at GF runoff rates.
- Method 2 does not fully contain runoff from the 1 in 100 year rainfall event. The additional flows will flow to the sewer at an uncontrolled rate. However the combined peak outflow rate is approximate to the outflow rate for Method 1.
- It takes approximately 8 hours (post rainfall) to drain 50% of the storage volume back to the drainage system. At this point in time the risk of flooding and CSO spill will have significantly reduced.
- A larger volume of storage is utilised using GF runoff control over a wider range of return periods.
- The volume of flow which is retained will contain first flush runoff, extending residence time allowing more effective water quality treatment, where the SuDS / drainage system is designed to provide treatment.
- The critical duration is defined by a prolonged storm (analysis not shown within fact sheet). Unsurprising, controlling to Greenfield runoff rates means that the system operates more like a normal catchment (rural catchment are prone to

flooding during much more prolonged storms during wetter winter periods).

- The retention of flow for longer periods will allow for greater potential interception losses (where design facilitates) within the system.

## Summary

There are a number of important aspects to consider whenever designing or setting the requirements for attenuating runoff on redevelopment sites. In relation to how flows are controlled on site;

1. Controlling flows to 50% of the pre-redevelopment rate will reduce the flow to the sewer. However, the high rate of discharge means that flows are held for a relatively short period. The duration over which runoff is stored may be as important a consideration as the volume of storage provided. Assessment of critical durations on the receiving sewer system will better inform how flows should be controlled. The sewerage undertaker is generally best placed to provide this advice.
2. When undertaking critical duration analysis for brownfield sites it is important to remember that the critical duration of the drainage catchment may be more important than the critical duration for the drainage system. Runoff which is attenuated needs to be retained on site until the main risks to the receiving sewer (flooding and CSO spill) have significantly reduced.
3. Retention of flows within the system, will allow for greater interception losses and more effective treatment (but only where it is design facilitates this). A storm sewer should be given the same level of importance as the watercourse that it discharges to.
4. Careful consideration need to be given to the design of controls, particularly whenever the opening size will be small to allow for control of flows to GF runoff rates. This is achievable where the control is protected.
5. Significant benefits can be achieved by holding runoff on site until the main risks within the catchment have passed. Conversely there may be certain situations where a quicker release of flows is beneficial. Careful consideration is required on how flows are controlled to fully realise these benefits, particularly at the lower range of return periods where CSO are likely to spill and flooding is experienced during low return period rainfall. Ideally SuDS for redevelopment sites can be designed to cater for full attenuation to GF runoff rates for the 1 in 100 year event. Good design can help achieve this.

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