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A Comprehensive and Systematic Design Approach

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There are a myriad of requirements with which designers of all drainage systems must comply and SUDS can provide many of the solutions. There are apparently so many requirements that they may appear both confusing and daunting.

This paper is not a substitute for a thorough knowledge of the contents of the references listed in the bibliography. However I hope that it will provide some milestones and help to make sense of the growing complexity of drainage design.

In the first part I have listed some of the essential elements for compliance and I have given the underlying philosophy behind them. An understanding of the objectives behind the requirements should foster support for what are difficult targets.

I have used an example to illustrate the steps in a systematic approach to design that will lead the engineer through this maize and produce a design that is fully compliant with the current Best Management Practices. In particular it will address the Environment Agency's and Water Company's requirements on levels of protection.

1. The Drivers

Protocol on Design, Construction & Adoption of Sewers in England and Wales
Water Framework Directive
PPG25

These three are part of the dissemination of high level political policy affecting drainage design. They provide a guide for engineers and planners on what is expected but they do not necessarily detail how to implement it.

Protocol on Design, Construction & Adoption of Sewers in England and Wales aims to produce a common approach for designing and constructing all sewers. In particular this has meant a harmonising of Part H of the Building Regulations with Sewers for Adoption 5th edition so that sewers that are not adopted are of adoptable standard. It should ensure that sewers cannot be precluded from adoption at a later date on the grounds of inadequate design.

The Water Framework Directive requires waters to attain "Good Ecological Status". In March, the European Environmental Bureau Policy Director Stefan Scheur said that of the 25 member states of the EU only 8 countries (Ireland, Finland, Romania, Estonia, Britain, France, Germany and Sweden) have implemented the WFD or are in the process of implementing it. We have until 2012 to do it and 2015 to demonstrate it – but what is it?

One of the most important aspects for the design of new drainage is its emphasis on diffuse pollution. This is everything that is not point source pollution e.g. CSOs and industrial outlets etc. Stormwater wash-off from car parks contains hydrocarbons and heavy metals with other pollutants in small quantities. Accumulativeley across a river catchment, this diffuse pollution is a problem that under the WFD must be addressed. The only proposed practical way of dealing with the problem is at source through SUDS. The implementation of SUDS therefore forms part of high level policy unless another method of dealing with diffuse pollution from new developments is proposed and accepted by the Environment Agency.

It is one of the Environment Agency's roles to promote sustainable development and its position on new developments is to promote and establish SUDS as normal practice (Phil Chatfield, EA Policy Advisor Pollution Prevention).

PPG25 continues the theme of improving the environment but it was also the first publication of policy guidance that suggested climate change had to be accounted for through the Precautionary Principle. At the time this was first mentioned in the late 90's no one knew what action designers needed to take but there is now an accepted approach using sensitivity analysis which is detailed later in this paper.

2. What the Papers Say

2.1 Part H of the Building Regulations

This gives priority to infiltration where possible for the disposal of surface water. This requirement is compatible with the volume balance requirements set out in the Interim Code of Practice for SUDS which is discussed below.

2.2 Sewers for Adoption 5th Edition, July 2001.

This publication in common with PPG 25 was greatly influenced by the flooding in 1998 which has been repeated biannually since then. SFA5 differs from the previous edition (SFA4, May 1995) in an important aspect. We have moved away from merely a design specification to a performance specification. It does not matter to the public, whom we serve, whether a pipe surcharges or a manhole floods. It matters when water is in their living rooms.

SFA5 specified for the first time that flood flow paths must be examined as part of the design of sewers to be adopted. It stated that this was to be done for storms above a 30 year return period but it gave no clue as to how far above a 30 year return period should be checked.

2.3 Draft framework for SUDS May 2003

The EA consulted widely during the drafting of this document and it brought together much of the current best practice and published it as a guide. It also drew heavily on CIRIA C609 prior to its publication which also sought to define best practice in the design of SUDS. These documents provided the first foundation for a consistent interpretation of high level policy and a national approach to the design of sustainable drainage.

2.4 Interim Code of Practice for SUDS July 2004

This superseded the draft framework document last summer. It built on the previous work but introduced an important new requirement. For more than 30 years in the UK new developments have had to limit their peak discharge to that of the original green-field runoff. However it was still possible within this requirement to radically change the volume of runoff and increase flooding in the larger river catchment downstream.

A site must usually discharge its runoff through a pond or other storage device designed not to overload the capacity of downstream sewers. This may involve delaying the discharge over two to three hours but it is not totally effective in protecting the main river system further downstream. If the overall volume of water is increased in this short period then the flows in the river will also increase as a river catchment usually has a much longer response time. Either the flow must be delayed further or the volume of runoff must be reduced. This became a new requirement in 2004.

2.5 CIRIA RP 697 :Updated SUDS guidance and CIRIA RP 699:Designing for Exceedance in Urban Drainage – good practice

These documents will be published within the next year. On SUDS, CIRIA RP 697 will expand on CIRIA 609, 2004 and will also contain more design examples. On exceedance Ciria RP 699 will emphasise the need for engineers to track overland flows.

Both publications will follow the service levels for flooding and exceedance which have been adopted as good practice in the UK already through the ICP for SUDS.

We are much closer to a national consensus on all the details of drainage design than at any time in the last 30 years. However there are engineers in various authorities who have their own ways and methods and may wish to stick with them. There is nothing wrong with some of these approaches but where there is agreement on a sensible method, I would argue that consistency is more important than individual preference. There will be a need for some variation in exceptional circumstances and the professional engineer in consultation with the statutory authorities will be responsible for the final choice of design criteria in each case. However, consideration should be given to at least each of the aspects presented in this paper.

3. Typical Design Criteria

The typical design criteria were originally detailed in CIRIA C609 and modified in the Interim Code of Practice for SUDS. Reference is also made to the Sewers for Adoption 5th Edition.

3.1 Treat 90% of average annual rainfall

90% of all rain that may fall on a site in a Typical Year should be treated before it leaves the source. This may be achieved by providing the treatment volume Vt as permanent storage in a pond. The requirements of Ciria 521 and Ciria 522 to provide 4Vt (retention pond) are now regarded as being too onerous for residential developments and storage over and above Vt will only be required where a high risk of pollution may exist e.g. a lorry park. The international review of best practice conducted for Ciria 609 found that typically the treatment volume used was about 15mm of runoff from the site. 4Vt could exceed 40mm and there did not seem to be any basis in international practice for this uniquely onerous specification.

3.2 Check for 1, 30 and 100 year runoff.

The capacity of a natural river is equivalent to about the mean annual runoff (RP 2.33 years). It had been common practice on new developments to allow the mean annual discharge based on the runoff from the undeveloped site. In the 1970's ponds were sized to accommodate the 5 or 10 year return period storm. This requirement was inflated over the years to typically a 100 year return period without ever allowing any increase in discharge. So the allowable discharge from a site was based on a return period of 2.33 years during the occurrence of a 100 year storm. If peak discharge was the only conveyance measurement of a river catchment regime it could be argued that this specification was inequitable.

The new guidance addresses this issue. A discharge equivalent to a 100 year RP runoff from the natural catchment will be allowable from developed sites during a 100 year storm. Checks also have to be made for the 1 and 30 year cases to ensure equivalence with the natural catchment for a range of return periods.

The peak volume criteria detailed below must also be met, see 3.5.

3.3 No on-site flooding for the 30 year event

It had been assumed that drainage systems designed using the Rational Method for no surcharging in the 1 & 2 year return periods would probably offer a protection against flooding of about a 20 year RP. This is not always the case and it became common practice after 1985 to check this assumption using simulation. In 1995 Sewers for Adoption 4th edition formalised the requirement for adoptable sewers. Proof, usually through simulation analysis, had to be furnished that no flooding would occur for a 30 year RP – an increase over the traditional 20 year RP which is still used in the European Standard BS EN 752.

Note: Engineers often assume that to comply with the requirement to limit discharge under 3.2 above that they must now design the drainage network for no flooding in the 100 year storm (and include climate change). As I will detail later, it is necessary to demonstrate that the flood flows for the 100 year RP storm are contained on-site and routed through storage, but it is not necessary to convey these exceedance flows in the drainage network.

3.4 Protect Floor slabs to a 100 year RP, up to a 200 year RP

The insurance industry has often set requirements at these levels for major industrial developments. The cut off for insuring new housing is currently a 75 year protection against flooding so it would be unwise not to comply. Also these requirements are interrelated with the new requirement to detail flood flow paths (SFA5) and also the need to account for climate change (PPG25, ICP SUDS & CIRIA 609) which is detailed later in this paper.

3.5 Peak Volume.

The volume of runoff from a site must be limited to the volume of runoff from the natural catchment. If this requirement cannot be met then the peak discharge will be based on the older requirement of the green-field mean annual discharge from the site during a 100 year event. In other words parity on the 100 year pre- and post-development discharge will not be granted unless it can be demonstrated that there is parity on volume.

The volume of discharge from the natural (i.e. undeveloped) site must be determined for the 100 year event. This poses an additional problem – what storm duration should be chosen? As it is usually the intention to protect the downstream river the critical duration for the river catchment should be determined. This is an additional complication which has been simplified by the choice of a 6 hour duration which is regarded as significant for river catchments. If the post development discharge volume is less than the original natural catchment run-off volume then the on-site storage will be allowed a discharge rate equivalent to that of 100 year RP event on the natural catchment.

It is difficult to meet this condition unless infiltration is incorporated into the design. On clay sites, or where infiltration is not permitted, an alternative is proposed. The maximum 100 year runoff may still be permitted if the excess volume is stored in long term storage and released slowly – below 2 l/s/ha. This has a similar effect on protecting the river catchment. Technically infiltration provides retention storage while the latter is a detention storage solution.

3.6 Climate Change

The best way of catering for climate change in a new development is through sensitivity analysis. Rainfall is typically increased by 10% or, in the case of rivers, flows are typically increased by 20% (CIRIA C609). However at this time the degree of climate change is not known and it may not be reasonable to increase the size of pipes and conduits to take this additional flow.
Nevertheless it is necessary to demonstrate that exceedance flows above ground do not cause buildings to flood for the 100 year return period. The additional effect of climate change can be taken into account here.
The 100 year RP + 10% to +20% is roughly equivalent to a 30 year return period +50%. This analysis of flood flow paths caused by climate change also yields compliance with the SFA5 requirement to track flood flow paths above the 30 year return period events.

4. The Calculation / Design Procedure

An example based on a 51 hectare site, analysed by Micro Drainage's Win*Des*, is used to illustrate the solution. Note that the method can and should be applied to all sizes of new developments – there is no lower limit.

4.1 Allowable discharge.

Development size	Method
<50 ha	IH 124 and use pro rata to 50ha result.
50-200 ha	Use IH 124 normally
>200 ha	Use FEH, Unit Hydrographs or IH 124,

Based on ICP SUDS, Table 6.1.

The calculation of allowable discharge is based on IH 124 as modified by the ICP SUDS. The ADAS method is still specified by The Highways Agency HA 106/04 and is available in the software. IH 124 is applicable to catchments up to 2000 ha but additional analysis may be justified on developments larger than 200ha. The Unit Hydrograph method is not difficult to apply using Win*Des* and unlike IH 124 it is sensitive to site slope.

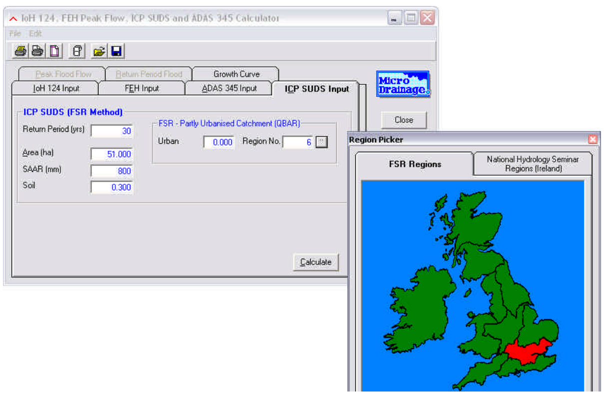

Figure 4.1 - ICP SUDS Input in the Win*Des* Source Control Module.

The 1, 30 & 100 year RP and mean annual events must be calculated to demonstrate compliance with ICP SUDS. A separate ICP SUDS tab is provided in the Source Control module of Win*Des*, version W.10, to automatically account for the modified use of IH 124.

4.2 Treatment Volume

There are two methods detailed in CIRIA C521 for the calculation of Vt. One is based on M5-60 and the other on continuous analysis. Both are supported in Source Control version W10.

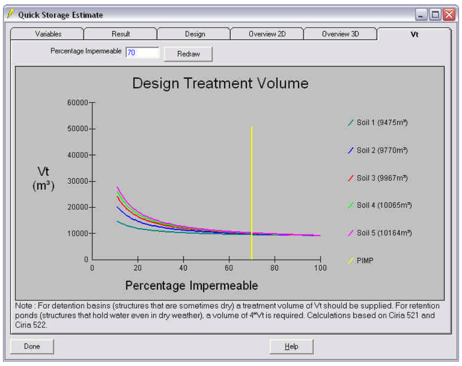

Figure 4.2 - Results Page from Vt calculation based on M5-60.

4.3 Storage Volume

A quick storage estimate is provided (with or without infiltration) as an initial guide.
Detailed storage design is then carried out of each element of the drainage system. The elements are analysed in sequence and combined with the full network ready for simulation.

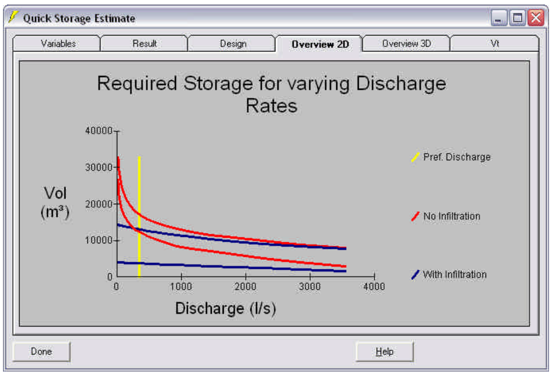

Figure 4.3 - Graphical Results of a Quick Storage Estimate

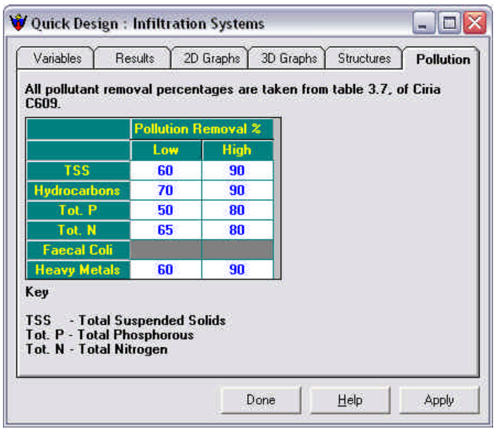

Figure 4.4 - Example of pollutant removal percentages for a SUDS structure.

4.4 Diffuse Pollution

Version W10 of Win*Des* also provides a comparative analysis of the pollution removal of a SUDS train. The designer may alter the layout of the SUDS elements to maximise treatment.

4.5 Network Build / Design

A tabular or graphical interface is provided for model build. The Drawnet graphical input is shown in figure 4.5. Modified Rational Method analysis for conduit sizing is integrated into the module and is automated through an optimisation procedure.

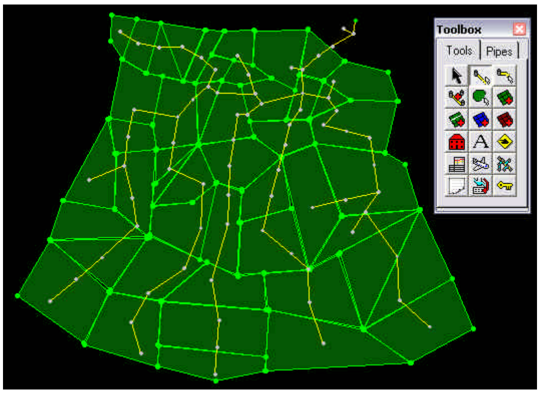

Figure 4.5 - Graphical input in the DrawNet module.

4.6 Greenfield Runoff Volume

The unit hydrograph method (both FSR and FEH supported in SimAPT) may be used to determine the runoff volume for the 6 hour 100 year RP storm. If the new design for the development does not produce more runoff for the same event then the 100 year greenfield runoff will be permitted as the maximum discharge from the site. Otherwise long term storage will need to be used for the excess volume or, failing that, the mean annual discharge should be adopted as the maximum allowable.

4.7 Developed Peak Discharge

Storage and infiltration structures, designed and tested in Source Control to comply with the allowable discharges calculated above, are integrated into the full simulation model. This model may also include any rural catchment or undeveloped areas that link into the drainage network to yield a holistic analysis.

A range of wizards are provided in SimAPT to confirm the maximum discharge for a series of summer and winter events. The 1, 30 and 100 year RP results must be produced.

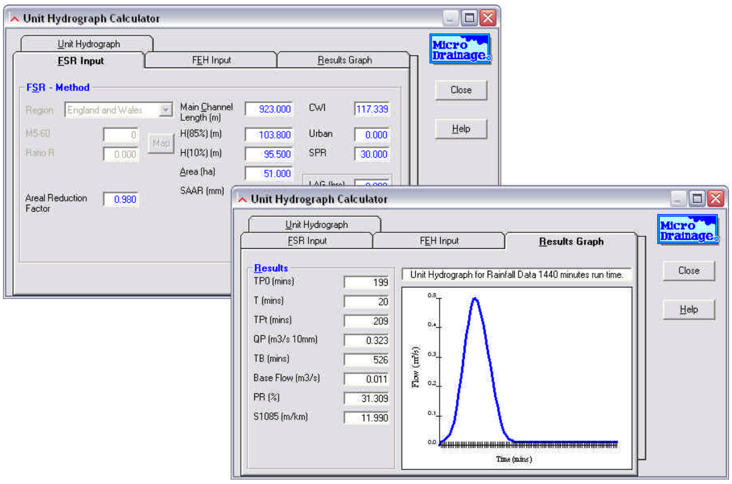

Figure 4.6 - Unit Hydrograph input and results screens.

4.8 Developed Volume Peak: Option 1, Storage only.

The maximum volume discharge for the 100 year 6 hour event is calculated and compared with the green-field runoff.

In this example a pond with a dual control has been used successfully to limit the peak rate of discharge (1 yr RP, 92l/s. 30 yr RP, 243 l/s. 100 yr RP, 346 l/s).

However the volume discharge for a 100 year RP, 6 hour event has increased from approximately 10700m^3 to 18700m^3. This developed catchment will increase the runoff volume by 80% while not exceeding the undeveloped peak discharge.

Figure 4.7 - Caption from the hydrograph tables in the Simulation module showing the pre-development runoff volume.

Figure 4.8 - Caption from the hydrograph tables in the Simulation module showing the post-development runoff volume.

This illustrates that peak discharge is not the only important parameter. 8000 m3 must be put into long term storage or infiltrated. If neither of these options is possible the discharge from this site must be reduced to the mean annual level, a reduction from 346 l/s to 108 l/s. The storage pond will have to be increased in size from 15,000 m3 to 20,000 m3. Therefore the long term storage option may be less economical than simply increasing the main on-site storage (5000 m3 extra in "normal" storage or 8000 m3 extra for long term storage).

Figure 4.9 - Caption from the hydrograph tables in the Simulation module showing the post-development runoff volume when infiltration is utilised.

4.9 Developed Volume Peak: Option 2, Storage with Infiltration

Again Source Control is used to design the required storage but this time infiltration structures are included in the design. The overall storage requirement reduces from 15,000 m3 to 12,500 m3. The 100 yr, 6 hour runoff volume is also reduced to 8100 m3 which is a 25% improvement from the undeveloped case.

If infiltration is possible on a site it really should be considered. In this case it is by far the best option. Only 30% of the storage structures on this site used infiltration. This also illustrates how beneficial it can be to route roof drainage to soakaways even if it is not possible to infiltrate any other part of the network.

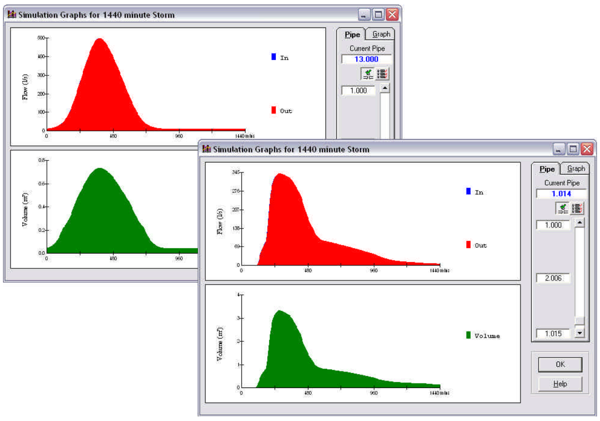

Figure 4.10 - Flows and volumes from the undeveloped catchment (top left) and the developed catchment using infiltration (bottom right).

5 Final Checks:

5.1 Design Audit to Sewers for Adoption 5th Edition

SFA 5 has several key requirements in addition to the 30 year RP service level on site flooding. These include minimum self cleansing velocity, maximum distance between manholes, manhole sizing etc. Win*Des* SimAPT provides an audit wizard that checks the design against a wide range of parameters including self-cleansing velocities in tank sewers for low flows.

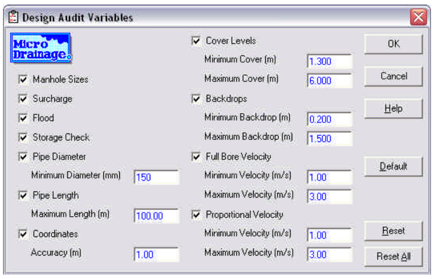

Figure 4.11 - Variables that SimAPT uses to audit a design.

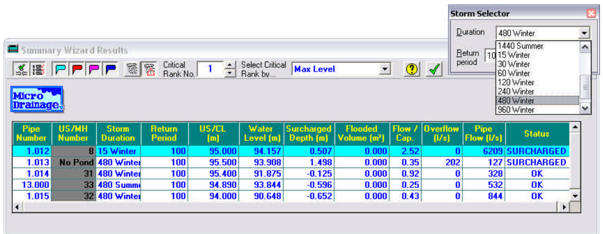

Figure 4.12 - Results from a Seasonal Return Period Wizard showing maximum discharge rates for the 100 year Return Period.

5.2 Run-Off parity to ICP SUDS

Use the seasonal return period wizards to audit run-off parity. If it has not been done by now then the before and after development run-off volume for the 100 year 6 hour storm must be calculated.

5.3 Climate Change and Exceedance

The "Sensitivity Wizard" is set to a 100 year return period, +10% and +20%. Use the 3d imaging available in SimAPT to inspect flood flow paths. If flood flow paths threaten building locations then landscape features may be designed into the 3d model to divert flows. Road layout and detailing can also be inspected – DTM and road design data may be downloaded into the model.

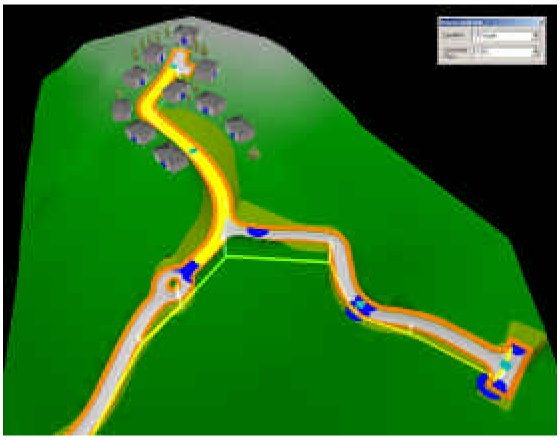

Figure 4.13 - Exceedance flows generated on a DTM. Yellow shows flow route and dark blue shows ponding areas.

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