REPORT BY THE FOUNDATION FOR WATER RESEARCH
WASTEWATER RESEARCH & INDUSTRY SUPPORT FORUM

ACTION WORKSHOP ON URBAN RUNOFF MODELLING WHY NOT DO IT PROPERLY?

A Workshop Held
Wednesday 18th April 2007

at
Cropston Visitor Centre

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SPONSORED BY SEVERN TRENT WATER, FWR AND WAPUG

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FWR (Foundation for Water Research) is an independent charity dedicated to education and information exchange. Its subjects are the science, engineering and management of water resources, water supply, wastewater disposal and the water environment in general. FWR brings together and disseminates knowledge and makes this available widely.

WaPUG (Wastewater Planning Users Group) is a not-for-profit organisation established over fifteen years ago to promote best practice in the wastewater industry. Its terms of reference are to:

- Provide a forum for discussion between users
- Facilitate the exchange of information between relevant organisations
- Identify areas for improvement or modifications to and associated research and development of wastewater planning modules
- Identify education and training needs and encourage the necessary education and training.

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1 Executive summary

This was the third FWR/WaPUG workshop to consider how runoff modelling can be improved[1]. The first reviewed the subject of runoff. The second identified strategies for improving modelling. WaPUG reviewed the outcome of the second workshop and concluded that progress will be made by dividing the subject into three task-areas. The purpose of this, the third workshop, was to work on the task-areas. It was a productive meeting that resulted in useful consensus conclusions.

Runoff modelling is arguably the weakest part of sewer modelling; it is certainly the most contentious. The runoff models in use today were based on field measurements made 30 years ago, albeit 100 field measurement sites were used. The data are not invalid because of their age, but a) experience of working with the models has identified knowledge gaps and b) the precise detail of the field work is difficult to access. Unavoidably, field measurements of runoff are limited because, practicably, there is only a limit to number of surfaces and precipitation events that can be measured. The workshop agreed that it is time to revisit this fieldwork; indeed, it is overdue. It is also time to look at how models are built and verified.

The photographs (right) show examples of hard surfaces in urban areas and experimental work undertaken by Severn Trent Water in 2004 looking at runoff.

The first rain to fall on a surface might remain trapped in the surface and might not runoff. Whilst the water is on or in the surface, it is subject to evaporation. Eventually the depressions and roughness fill up, water overflows to the next depression and runoff progresses down the gradients and may eventually find its way into the drainage system. Runoff can continue for an extended period after the end of precipitation as the depression storage drains until each store [puddle] is once again isolated. Runoff is seldom, if ever, 100% of precipitation.

Even at the time of the first workshop, computing power was considered to be inadequate to go beyond 1-dimensional modelling, but now 2D is practicable. Available software has progressed significantly in the last few years to allow 2D overland flow routing. Current runoff models do not represent the detailed flow paths on the surface. Volume and routing are represented by relatively simplistic empirical models. In contrast, 2D enables models to compute flow that travels across surfaces and open channels to reach formal drainage systems.

Workshop 2 identified that because of a lack of standardisation; archived models currently have limited life and limited transferability. This is a very significant inefficiency. WaPUG resolved to reduce the costs of model building and to increase the longevity of models and of the calibration data by introducing more standardisation to the categorisation of connected surfaces.

Also, because the current run-off model is fixed and pre-calibrated, flow surveys are used specifically to check input surface areas. This is wasteful where the fault is with the process rather than the surface areas and leads to model 'fixes' which have no scientific basis. Now that these areas can be checked more effectively by digital maps and satellite imagery, flow surveys could be used to verify or indeed calibrate new run-off processes in an entirely new approach.

The intelligence within digital maps increased enormously when Ordnance Survey released MasterMap. Prior to MasterMap there was no intelligence in the definition of polygons and zones, but now the mapping software knows which features are roads and which are roofs, for example.

[1] The workshop reports are available at www.fwr.org publications

Satellite imagery is now easily available (GoogleEarth, etc.) and enables discrimination between different types of surface – possibly with some ground-truth referencing. However, satellite imagery cannot differentiate whether a surface connects to a combined sewer, a surface water drain or a soakaway. Therefore, a thorough knowledge of the system is essential and this needs to be supplemented by survey.

The workshop agreed that we need to understand the entry of surface water into the drainage network better [whether from roofs or highways, etc.]. For example, a significant amount of runoff can flow over or around gullies during high surface flow velocities: i.e. some is admitted and some is passed forward – the proportions depend on the designs of the inlets. We do not model the inlets currently and we need to do some fieldwork to quantify this important aspect.

The terms of reference were agreed for each of the groups together with a planned way forward and a list of immediate actions. Some more general outcomes are outlined below.

Standard Surfaces Group

- Review the ability of MasterMap to assess the areas of the different standard surface. This has the potential for major savings in terms of time and cost, but the Standard Surfaces Group must also assess the limitations. How much can they be overcome by using satellite imagery? How much ground-truthing is necessary? What is cost/benefit balance in reducing residual error at the expense of ground-truthing?
- We need fieldwork to understand typical surface parameters such as depression storage, slope, roughness and the effects of cracks, puddles, etc so that different surface types can be identified and grouped.
- It is necessary to review the number of surfaces used by modellers (including 'grey surface') and to recommend the optimum number for future development within modelling approaches. Currently the number ranges from three, which is simple, to twelve, which is complex. The number is further compounded by condition.
- Recommend standard approaches to quantifying surface types and to surveying surface types

Runoff Processes Group

- We need better understanding of roof drainage and how the runoff water enters the drainage system, especially gutter and down-pipe capacity, which is not understood adequately at present and the findings need to be included in models. The relationship between precipitation volume and the volume intercepted by roofs and the consequent runoff volume and routing also need more work.
- We also need better understanding of gully restrictions and highway surface-flows so that they can be factored into models better; this area is not adequate at present, and improved methods are needed. A formal guidance note is needed on current best practice.
- We know that a single all-embracing run-off model is too insensitive to the many variables that operate in urban areas and it is therefore likely that several sub-processes will be needed. A new approach using targeted flow surveys will provide useful verification of these processes.
- We need to investigate further the benefits of detailed runoff modelling, including 2D approaches. It is believed that many of the verification "fixes" that modellers find necessary when using the traditional empirical volume models could be addressed with more deterministic approaches. Today's computing power enables us to consider these more complex approaches, and we should be attempting to include these within models where necessary. Current 2D overland flow models could be scaled down to 2D runoff models.

Design Parameter Group

- The group will produce a list of standard growth factors and idealized or average conditions that are projected for design in order to give an adequate life for proposed sewer improvements.
- Antecedent conditions (e.g., whether soil is parched, moist, frozen or saturated when precipitation starts) are critical to the fate of precipitation and rate of runoff. Currently there are many conflicting approaches and often modellers do not understand this subject fully. By means of a

questionnaire, literature review and assessing the sensitivity of parameters, it will be important to establish industry best practice for antecedent conditions. There is an urgent need for a user guide on this aspect.

- We need more investigation of 'urban creep' and how it should be applied to design models; for example, what is the annual percentage increase in patios and paving that contributes to sewers and drains.

WaPUG considers that it is important to continue with runoff modelling research but it needs to be tuned to the new approach to modelling outlined here.

We may also need to establish best practice for modelling overland flow of flood flows where it is needed to understand events where sewers cannot carry all the flows. This is being developed and used gradually but with little coordination and consequently there is a divergence of practices. Establishing best practice for overland flows will allow knowledge transfer and scaling of approaches to more complex runoff routing models, for example 2D runoff routing.

We probably need to work on getting river, sewer and STW models talking to each other.

It is essential that the degree of integration between catchment modelling and planning is improved. Flood risk assessment is certainly becoming more and more integrated. Through this, the capability to model overland flow has improved. It is not too unrealistic to expect that runoff modelling and routing can follow similar lines, given that overland flow and runoff routing are similar mechanisms but on different scales. Whilst the local sewerage undertaker is just one of many members of the integrated urban drainage community and its delivery programme is probably more integrated than most, there is merit in continuing to work to create river, sewer, surface water, overland flow, runoff and sewage treatment works models that can interact and thus test and model integrated solutions. Defra's sixteen pilot projects[2] examining integrated catchment modelling and planning should yield useful inputs for improved overland flow and runoff modelling.

An Open Forum at the November 2007 WaPUG meeting, members confirmed that more research is needed on 2D overland flow, and on how this can be scaled down to runoff modelling. Members also highlighted rainfall modelling and representation as a key issue.

[2] http://www.defra.gov.uk/environ/fcd/policy/strategy/ha2.htm

CONTENTS

2 Runoff Workshop Introduction

Andy Eadon and Jamie Margetts (see also Appendix 2)

The runoff process used in models is basically more than 30 years old; even then, it was known to be less than perfect, but it has been the best we have until now. Experiences show improvements are overdue. Despite the best endeavours to allocate the areas of different types of surface accurately within models during their construction, “fixes” are often required to align model predictions with the observed runoff and flow responses, this is because of limitations and generalisations within these original models.

In the last ten years, the issue of slow-response runoff has become increasingly problematic, particularly due to the large number of storage solutions developed during AMP3. This has been linked historically to permeable runoff, which may be significantly delayed during the routing process. The current empirical models all have known limitations when calibrated to represent this slow response runoff phenomenon.

The 2nd Runoff Workshop demonstrated that slow-response runoff may in fact be partly due to urban impermeable runoff that is greatly attenuated and delayed during the routing process, in a manner that is not adequately replicated with the current volume and routing models. Figure 1 shows the runoff into a gulley versus time from a car park predicted by five different models for a 1 mm rainfall event. The traditional Wallingford and fixed models show the most rapid response, but when attempts are made to represent the routing over the car park surface through a detailed grid model that enables better consideration of variable depression storage, a much more realistic delayed response is predicted. The volume of runoff is the same in these two extremes (10 m^3) but the maximum flow rate was 0.004 and 0.002 m^3/s respectively, which obviously makes a huge difference in the prediction of the size of pipe required. These tests undertaken by Severn Trent indicated one of the potential benefits of moving away from lumped large area subcatchment volume and linear routing models to more detailed 2D runoff routing models.

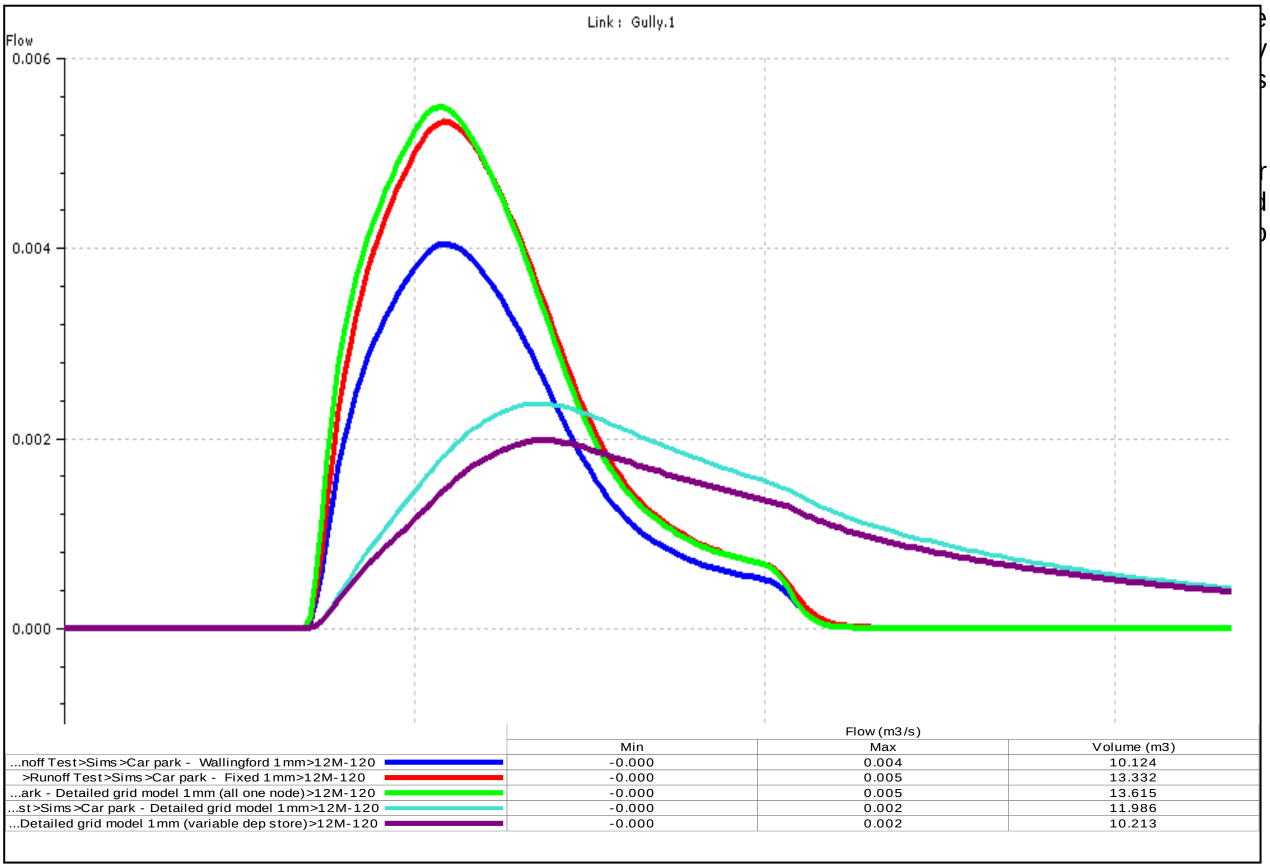

Figure 1 Predictions of runoff following 1 mm rainfall on a carpark according to five different models

In addition to the development of improved runoff models, data input requires expert handling. By ensuring measurable parameters (such as impermeable and permeable area, allocation to system type and rainfall) are accurately measured and represented within the models, discrepancies during the verification process can be more readily attributed to variations in runoff and flow processes. Better use could be made of flow survey results, they are expensive to undertake and the results often indicate issues with the model build. An expedient that modellers employ frequently is to insert additional "dummy" surfaces to force a fit (despite having measured the "real" surfaces accurately); clearly this is not satisfactory. The use of dummy surfaces is an expedient to make model and real flow data fit, but they have no reality on the ground and a successor modeller might not know about them, which compromises the life of the [expensively built] model. This has produced a multitude of calibrated models containing unconfirmed areas and calibrated "black box" runoff coefficients. The latter often leads to the question - What characteristics should be used in design? Answering this has been particularly difficult in terms of runoff as the extrapolation of some of these parameters from low return period verification conditions to extreme events has often led to erroneous, or even nonsensical, model results.

Some Water Companies are re-examining how surface characteristics affect runoff processes. Traditional approaches are very standardised and historically little consideration has been given to measuring the different runoff characteristics of (for example) a newly laid highway and an old worn paved area. Both have significantly different volume contributions and routing characteristics. The concepts of micro, meso and macro topography have been introduced in recent publications (references?) and these all impact on the volume of runoff produced for any particular return period of event and how this ultimately is routed to the sewer during that event. Different surfaces (or scaleable topographies) are activated for different return periods of event. This issue has never really been tackled, and only with more detailed modelling of runoff and overland flow in tandem can this be addressed.

Gullies and Inlets are important parts of a sewer system; they facilitate rapid disposal of surface water from connected surfaces (and may limit flows to sewers if their intake capacity is restricted). Many models represent Gullies and Inlets poorly at present, but they have a profound impact on the entry of runoff into the sewer system under a wide range of events.

Flow survey results could be used to verify the runoff process as well as surface data. It must be possible to 'dumb down' surface data capture [perhaps by remote sensing and better use of MasterMap – Figure 2]

Figure 2 An example of Mastermap and the intelligence in the categorisation of surfaces

so that sampling [and ground truth reconciliation] can be used for checking accuracy. Model building is very expensive and it must therefore be an objective to reduce the overall cost, perhaps by extending the useful life of models. Urban runoff models can sit within more general integrated catchment models.

Proposals agreed during WaPUG discussions are to:

- Standardise surface-data capture so that it is transferable for one model [and modeller] to another and so that there is a common and shared understanding.
- Improve the runoff processes from standardised areas and incorporate verification from flow surveys into the selection of process or sub-process parameters.
- Develop more detailed runoff models to better utilise this improved data capture and representation. Integration with overland surface flow mechanisms should be a long term objective.
- Develop a guide for extrapolating data for the design event so as to accommodate reasonably expected developments in the area
- The work falls conveniently into three working groups (see Figure 3)

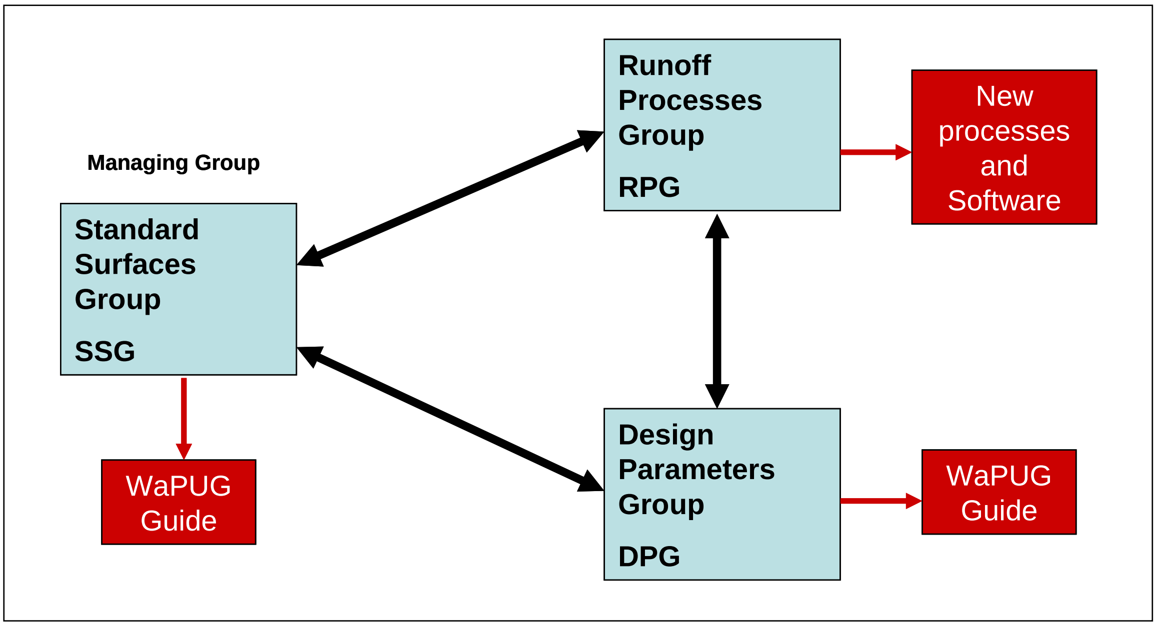

Figure 3 Proposed working groups and outputs

The intention of this Workshop was to discuss further some of the key issues identified in previous Workshops (see section 2.2) and relate these to the individual workgroups so that focus and considered actions could be agreed, with the intention of highlighting the main research needs, data deficiencies, and areas of uncertainty requiring immediate or long-term investigation. The workgroups' terms of reference are developed in sections 3 to 5.

2.1 Discussion

Richard Allitt: We use four types of impermeable surface [compared with the more usual two, which are 'paved' and 'roof']. These four are road, roof, driveways and 'fudge' [grey]. The last is used to achieve verification; it might really exist but was not measurable, e.g. patios.

Graham Squibbs: In my experience the difficulty is not so much identifying the fast response runoff surfaces, it is identifying whether they are connected to combined, surface water or soakaway drainage.

John Packman: Runoff from roofs has always been a problem, even knowing how much rain falls upon them because of wind, additionally the material from which they are constructed and the slope are complicating factors. By 2009, all clients will have Mastermap, which has about 10 classes of surface that can be backed up by satellite imagery; they can be classified man-made or not. An added complication that the severity of the event can affect the drain to which a surface connects.

Andy Eadon: It might be a bit of a distraction to spend too much time on extreme events. Can we work/cope with satisfying the Water Framework Directive? When an Impermeability Area Survey is undertaken, it could also assess the gullies, for instance. This would improve the value for money of surveys.

2.2 Background – established likes and dislikes relevant to runoff modelling

The following "likes and dislikes" about current runoff modeling are derived from the second workshop on this topic following intensive discussion and debate (Evans and Eadon, 2006). The topics with the highest scores are listed.

2.2.1 Standard Surfaces Likes

	TOPIC	Value to Industry	Potential for Error Reduction	Group
26	Distinction between expert modeller and data technician	Med	High	SS/RP/DP
30	Direct link to the WaPUG competency framework	High	Med	SS/RP/DP
32	Integration	High	Med	SS/RP
35	Post Project Analysis	-	-	SS/RP
4	Measure evaporation during verification	Med	Low	SS/RP
16	Account for the differences between surfaces with direct connections to sewers and those without.	High	Med	SS/RP
17	Use modelling to forecast possible future changes to surfaces (more info on urban creep)	High	-	SS/RP
18	Use larger sub catchments in modelling	High	-	SS/RP
21	Database of models and FSR data	High	Low	SS/RP
36	More advice on characteristics of permeable surfaces	High	Med	SS/RP
10	Better decision prompts in models	High	High	SS
14	Better training for all modellers	High	High	SS
19	Standard approach to infiltration	High	High	SS
22	Standard guidance on evaporation	High	Med	SS
23	More understandable approach to runoff	High	High	SS
25	Reduce risks in model from too much flexibility	High	High	SS
27	Better defined catchment topography.	High	Med	SS
28	Trust in data collected	High	Med	SS
29	Guidance on data capture, reporting and archiving.	Med	High	SS
33	Detailed runoff and routing model using only measurable physical data.	High	Med	SS

2.2.2 Runoff Process Likes

	TOPIC	Value to Industry	Potential for Error Reduction	Group
26	Distinction between expert modeller and data technician	Med	High	SS/RP/DP
30	Direct link to the WaPUG competency framework	High	Med	SS/RP/DP
32	Integration	High	Med	SS/RP
35	Post Project Analysis	-	-	SS/RP
4	Measure evaporation during verification	Med	Low	SS/RP
16	Account for the differences between surfaces with direct connections to sewers and those without.	High	Med	SS/RP
17	Use modelling to forecast possible future changes to surfaces (more info on urban creep)	High	-	SS/RP
18	Use larger sub catchments in modelling	High	-	SS/RP
21	Database of models and FSR data	High	Low	SS/RP
36	More advice on characteristics of permeable surfaces	High	Med	SS/RP
3	Database for extreme events	High	-	RP
7	Real time modelling and forecasting.	Med	-	RP
9	Better understanding of rainfall	High	Low	RP
11	Modelling of real extreme events	High	Med	RP
20	Better assessment of antecedent conditions	High	Med	RP
24	2D modelling of overland flow	High	Med	RP
31	Better representation of green field hydrology	High	High	RP
34	More use of historic verification and large events	High	Low	RP
37	Better understanding of how run off from pervious surfaces enters drainage systems	High	Low	RP
38	Long term monitoring of permeable pavement performance.	High	Low	RP
1	Fixed equation fixed runoff volume for pervious surfaces	High	Med	RP
5	Better understanding of interface of above and below ground flows	High	Med	RP
8	Make previous monitoring data available before new surveys are undertaken	High	-	RP
12	Extend number of soil types (low impact on urban surfaces)	Low	Low	RP
13	More guidance on when soakaways are overwhelmed.	Med	High	RP

2.2.3 Design Parameters Likes

	TOPIC	Value to Industry	Potential for Error Reduction	Group
26	Distinction between expert modeller and data technician	Med	High	SS/RP/DP
30	Direct link to the WaPUG competency framework	High	Med	SS/RP/DP
2	Better understanding of extrapolation to design events	High	High	DP
6	Better understanding of risk when extrapolating to design events. (Support for long term monitoring)	High	High	DP

2.2.4 Dislikes

	Topic	Value to Industry	Potential for Error Reduction	Group
13	Over-enthusiastic belief in models	Med	Med	DP
6	The black and white distinction between pervious and impervious surfaces	Med	Med	RP
7	The use of PIMP where impervious areas are the dominant contributor to run off	Med	High	RP
1	Use of dummy areas	Med	High	RP
2	Current definitions of land use	Med	Med	RP
5	Dependence on Minor Events	-	High	RP
9	Dumbing down	High	High	RP
10	Don't like the way slow response to rainfall is currently handled/perceived	Med	Med	RP
14	Inclusion of surfaces that won't or are very unlikely to drain to a sewer system.	Low	Med	RP
15	Use of Sub catchments	High	Med	RP
4	Voids in understanding	-	High	SS
3	Students don't like the data we use	Med	High	SS/RP
12	Model fixes which are not explained	Low	High	SS/RP
8	Level of current misunderstanding	-	High	SS/RP/DP
11	Current Perceptions about modellers' value	High	Med	SS/RP/DP

3 Standard Surface Group

3.1 Draft Terms of Reference

1. Select, modify or introduce standardised surfaces that collect runoff in urban areas.

2. Include separately areas that could deliver runoff in extreme events.

3. Take due account of watersheds and formal inlets and gullies to sewer systems.

4. Make sure that both uniform and composite surfaces can be assigned to more than one drainage system where required (i.e. combined, separate, partially separate, soakaways and other SUDS).

5. Ensure that all areas are readily determined by topographical survey alone and can take advantage of satellite imaging.

6. Take the view that standard surfaces can be measured independently of system modelling.

7. Take the view that standard surfaces can be used for a variety of runoff models.

8. Take advantage of current definitions and practices.

9. Develop a data checking and audit process that does not rely on flow survey results.

10. Liaise and cooperate with the Runoff Processes Group and the Design Parameters Group.

11. Respect the need to reduce the costs of modelling drainage systems in overall terms.

12. Produce and present progress reports to WaPUG.

13. Produce a draft code of practice suitable for publication by WaPUG

3.2 Notes of Group Session – Standard Surfaces Group.

Group members present –

Dave Terry	Severn Trent Water (Chair)
Bob Draper	R & K Contractors and Consultants (Notes)
Tony Bamford	MWH
Tim Evans	FWR
Dave Farrer	Yorkshire Water
James Hale	MP Ewan
Graham Squibbs	United Utilities
Neil Swindale	Atkins
Mike Wood	Hyder Consulting

The terms of reference for the group were discussed and agreed with slight modifications as follows –

1. Select, modify or introduce standardised surfaces that collect runoff in urban areas.

2. Include separately areas that could deliver runoff in extreme events.

3. Take due account of watersheds and formal inlets and gullies to sewer systems.

4. Make sure that both uniform and composite surfaces can be assigned to more than one drainage system where required (i.e. combined, separate, partially separate, soakaways and other SUDS).

5. Ensure that all areas are readily determined by topographical survey alone and can take advantage of satellite imaging.

6. Take the view that standard surfaces can be measured independently of the type of runoff model ~~system modelling~~.

7. Take the view that standard surfaces can be used for a variety of runoff models.

8. Take advantage of current definitions and practices.

9. Develop a data checking and audit process that does not rely on flow survey results.

10. Liaise and cooperate with the Runoff Processes Group and the Design Parameters Group.

11. Respect the need to improve the cost effectiveness ~~reduce the costs~~ of modelling drainage systems in overall terms.

12. Produce and present progress reports to WaPUG.

13. Produce a draft code of practice suitable for publication by WaPUG

It was agreed that the consideration of routing across and from the surfaces was not part of Standard Surfaces' ToR and should be considered by the Runoff Processes Group although it is difficult to consider surfaces without reference to how the water runs across and off them. Hence the interactive arrows in Figure 3.

It was generally agreed that we should consider the methods by which surfaces are applied within all software used to model sewerage systems including InfoWorks, Mouse, MicroDrainage, etc.

The means of identification of the standard surfaces was discussed, the alternatives being characters (names) or integers (numbers) and it was thought numbers would have to be used to maintain software compatibility.

It was understood from previous discussions during the day that various methodologies are currently applied to assigning surfaces within contributing areas in models.

Severn Trent Water currently has a model building specification that requires the use of all 12 categories of surface (where appropriate to the area) with roads being assigned to areas 1 to 3, paved areas being assigned to areas 4 to 6, and roof areas being assigned to areas 7 to 9. Areas 10 to 12 are used for areas of variable runoff and the adjusted permeabilities are identified during verification.

United Utilities does not have a standard methodology at present but is about to introduce one

Yorkshire Water also does not have a standard methodology

It is understood that in the main, modelling consultants employ their own methods that they are comfortable with and that to aid the verification process, they generally use 4 surfaces; paved, roof, permeable and an additional area that they can 'borrow' area from to aid verification.

In the main therefore, the majority of models built outside specially defined specifications use the current standard of three surfaces as a base. The new WaPUG guide should be flexible enough to include all current working practices.

The Group discussed the methods by which surfaces could be measured easily. This is crucial to maintaining least cost of model builds. It was agreed that the use of the new OS Mastermap plans with stored layers identifying roads, buildings, etc. would be the most appropriate together with support from satellite imagery or aerial photography and selective ground truth verification. It was understood that most Water Companies are now moving towards the purchase of OS Mastermap licenses.

Consideration of the surfaces that exist and are currently, or could be input, into a sewer model's contributing areas resulted in the findings summarised in Table 1. It was suggested that pitched roofs should be defined as any roof that has a pitch greater than 11.25 degrees. It was recognised that current measurement of roof areas from plans does not take into account the full surface area of a pitched roof.

It was also agreed that depression storage (loss) occurs on all flat roofs and this is why the Wallingford Procedure recommended that large flat roofs are modelled as paved areas due to the amount of depression storage (loss). Whilst the group agreed that greater losses occur on flat roofs, the group should review the practice of calling them paved, as this is a confusing terminology. Roughness and surface evaporation were considered to be part of the Runoff Process and therefore not within Standard Surfaces ToR but we should liaise with them.

Table 1 Summary of categories of surfaces and their conditions

Surface	***Type***	***Surface Material or Condition***
1. Roofs	1.1 Pitched	1.1.1 Tiled
		1.1.2 Thatched
		1.1.3 Felt
		1.1.4 Lead, Zinc etc
	1.2 Flat	1.2.1 Felt
		1.2.2 Green Roof
		1.2.3 Storage
2. Paved	2.1 Roads (Major, Minor or Track)	2.1.1 Non porous (HRA, dense bitumen, concrete etc)
		2.2.2 Porous or semi porous (SMA, block paving etc)
		2.2.3 Kerbed or non-kerbed
		2.2.4 Good condition or poor condition
		2.2.5 Steep Gradient or shallow gradient
	2.2 Private Driveways	As above, 5 sub-categories
	2.3 Pedestrian Areas/squares etc	As above + slabs
	2.4 Car Parks	As above
	2.5 Playgrounds/Parks etc	As above + slabs
3. Permeable	3.1 Urban Parkland	3.1.1 Grass
		3.1.2 Bark chippings
		3.1.3 Other man made material (geotextiles etc)
	3.2 Agricultural	3.2.1 Grass, crops etc
		3.2.2 Furrowed etc

The use of rainwater harvesting systems was also mentioned but perhaps these should be considered as part of the runoff process together with other similar SUDS techniques

The properties of porous and semi-porous surfacing were discussed and it was considered that further information is required to aid the understanding of different runoff characteristics of the different types of surfacing materials. A literature search would be a good starting point for this.

The performance of permeable surfaces during rainfall events (extreme or otherwise) was discussed and it was recognised that permeable surfaces can contribute runoff either directly via land drainage systems (if connected) or indirectly across other adjoining impermeable surfaces and careful consideration of this was required. Sub-surface inflows should be considered as part of the Infiltration Model where available.

It was considered that a system of specifying different numbers of surfacing that could be applied to the model dependent upon the complexity or detail of the model being constructed. This could be built into Table 3.1 of the WaPUG Code of Practice. For example, for a type 1 model we could require the use of the 3 standard surfaces but for a type 3 this could be broken down further to require seven or eight standard surfaces. Perhaps we need to be careful of the data being 'backward compatible'.

The term of reference No 6 was clarified with the author, Andy Eadon, and essentially the reference required that the proposed standard surfaces should be measured independently of the sewer system type being modelled. This would mean that the standard surface would have to be attached with an identifier that would enable the software to assign the correct runoff equation to the correct system.

It was also suggested that it might be worthwhile to investigate the merits of calculating the runoff from each sub-catchment prior to running main simulations of the model.

It was agreed that the introduction of standard surfaces and measurement systems would enable an audit process to be developed.

The requirement to consider increased value for money of the model building process was discussed and it was agreed that provided the introduction of standard surfaces reduced the requirement for detailed impermeable area surveys (IAS) an increase in the value would almost be automatic. It was agreed that it might not be possible to eliminate the need for IAS. Measurement of areas by using OS Mastermap would also realise some costs savings. Verification of models would possibly be a shorter process if confidence in the measured contributing area were increased.

A programme of future actions was discussed, the following goals were agreed:

a) SHORT TERM

   i) Carry out a literature review considering the requirements/abilities of the available software to handle multiple surfaces and information on runoff characteristics of surface treatments (material spec sheets)

   ii) Review the ability of OS Mastermap to produce the different surface measurements

   iii) Review the available satellite imagery and its possible use in the process; Google Earth has become quite useful and the higher resolution area is spreading progressively

   iv) Collect data on current methodologies employed by model builders – number of surfaces used and measurement techniques.

   v) A decision is needed on “grey” surfaces [fudge factors] which are useful for reconciling models with verification data, but it needs to be auditable

   vi) Review current IAS methodology

b) MEDIUM TERM

   i) Investigate (in association with the Runoff Process Group) the surface parameters including roughness and effect of slope etc. with a view to defining a practicable list of surfaces; for example, evaporation might be in the surfaces file as well as, or instead of, being in the rainfall file.

c) LONG TERM

   i) Consider numbers of individual or groups of standard surfaces

   ii) Research how water runs off surfaces – consider non-linear – consult hydrologist

   iii) Consider how to quantify depression storage

   iv) Consider standard approach to assigning surfaces and possible audit routine for checking.

   v) Consider standard approach to IAS

Note: there has been experience that Mastermap area take-off does not feed into Infoworks very well.

4 Runoff Processes Group

4.1 Draft Terms of Reference for Runoff Processes Group

1. Develop, using standardised surfaces, a runoff model specifically for sewered systems in urban areas.

2. Take realistic, logical and proper account of formal inlets and gullies to underground drainage systems.

3. Allow for runoff contributions from remote and unconnected surfaces in extreme conditions or events.

4. Take advantage of current recommended processes and associated research.

5. Ensure that the process is as logical and understandable as possible.

6. Consider the use of flow survey results to verify runoff process coefficients.

7. Make recommendations for overland flow processes to be dealt with separately.

8. Liaise and cooperate with the Standard Surfaces Group and the Design Parameters Group.

9. Respect the need to reduce the costs of modelling drainage systems in overall terms.

10. Produce a draft process with definitions and illustrated examples suitable for implementation.

11. Produce and present progress reports to WaPUG.

12. Contact appropriate software developers and encourage availability of the recommended process for the Industry.

4.2 Members

Richard Long	(RJL)	(Richard Long Associates) (Chair)
Richard Allitt	(RA)	(Richard Allitt Associates)
Mark Booker	(MB)	(Ayris Ward)
Vicky Harty	(VH)	(HartFair Ltd)
John Malone	(JSM)	(Clear)
Jamie Margetts	(JRM)	(Clear)
John Packman	(JP)	(CEH)
Mark Priestley	(MP)	(Montgomery Watson Harza)
Richard Seabert	(RS)	(Faber Maunsell)
Andy Sharpe	(AS)	(Black and Veatch)
Rob Whittaker	(RW)	(Environment Agency)

The terms of reference for the group were discussed and agreed with slight modifications as follows –

1. Develop, using standardised surfaces, a runoff model specifically for sewered systems in urban areas.

2. Take realistic, logical and proper account of formal inlets and gullies to underground drainage systems.

3. Allow for runoff contributions from remote and unconnected surfaces in extreme conditions or events.

4. Take advantage of current recommended processes and associated research.

5. Ensure that the process is as logical and understandable as possible.

6. Consider the use of flow survey results to ~~verify~~ calibrate runoff process coefficients [it could be that several are needed].

7. Make recommendations for overland flow processes to be dealt with separately.

8. Liaise and cooperate with the Standard Surfaces Group and the Design Parameters Group.

9. Respect the need to reduce the costs of modelling drainage systems in overall terms.

10. Produce a draft process with definitions and illustrated examples suitable for implementation.

11. Produce and present progress reports to WaPUG.

12. Contact appropriate software developers and encourage availability of the recommended process for the Industry.

    Note: The Runoff Processes Group needs to consider the volume of runoff as well as the route; the two are related.

Task	Subject	ToR items	Short term (Nov 2007)	Medium term (<2 years)	Longer term (>2 years)
1	Roof drainage and entry (JRM leads)	2	Literature search (JRM) Gap analysis (JRM)	Research gaps if required and develop new roof routing and volume model (JRM)	
2	Ground level entry (RA leads)	2	Literature search re other inlets – strip drains, kerb inlets etc. (JSM) Detailed modelling of highway gullies currently in progress by RA	Write formal guidance on detailed modelling (Guide or User Note) (RA) Develop methods for detailed modelling of other inlets (RA).	
3	New Runoff Volume model (JRM leads) – Incorporate results of WaND project (due Sept 07) for new pervious surfaces runoff model and develop a new variable PR model for impervious surfaces (both paved and roof). Infiltration accounted for but not modelled in detail.	1, 3, 4	Literature search (JP)	Scope project and seek funding (JRM)	Develop and implement through an appropriate route (JRM)
4	New runoff routing model (RJL leads) – vision is dynamic simulation of runoff and loss processes in a grid of cells spanning the drainage area, including large pervious surfaces where required. 2D hydraulic simulation of surface flows. Improved inlet modelling based on results from Tasks 1 and 2 above.	1, 3, 7	Scope project and seek funding (RJL)	Develop and implement through an appropriate route (RJL).	
5	Flow Surveys (MB leads)	6	Identify existing data sources (MB IETG, RS Onsite, VH Environmental & Titan, AS RPS. Encourage water companies to consider siting long-term flow monitors in positions useful for present purposes (MB to co-ordinate).		

5 Design Parameters Group

5.1 Draft Terms of Reference for Design Parameters Group

1. Fully consider which surface and base data need modifying in the sewer design and rehabilitation processes to give an economic design life for investments.

2. Take account of the stages for option development and final design of proposals as outlined in "Designing Hydraulic Improvements for Sewer Systems" (copy attached).

3. Canvas the Industry and produce a list of parameters and range of allowances for growth/demand currently in use.

4. Liaise and cooperate with the Standard Surfaces Group and the Runoff Processes Group.

5. Respect the need to reduce the costs of modelling drainage systems in overall terms.

6. Produce a draft list of parameters and recommended allowances with definitions and illustrated examples, suitable for use in modelling.

7. Produce and present progress reports to WaPUG.

8. Produce a draft code of practice suitable for publication by WaPUG

Present

Mark Russell	(MR)	Grontmij Group (Chair)
Tom Boichot	(TB)	Atkins
Jonathan Cutting	(JC)	Mouchel Parkman Ewan
Tim Dawe	(TD)	Mouchel Parkman
Mark Howard	(MH)	Grontmij Group
Alexander Sneath	(AS	Pick Everard
Rob Woodall	(RW)	Anglian Water

The Design Parameters Group agreed the ToR unchanged from 5.1 above.

Action

1 General

The group agreed that the way forward was to canvass the industry to determine what are the current design standards being used. It was agreed that a questionnaire would be the best vehicle. This would also aid in the production of a WaPUG User Note for Design NAPI values, which was raised as a requirement from the workshop. It was agreed that the WaPUG mailing list would be used as a list of contacts to which the questionnaire will be sent. It was also agreed that the questionnaire should be sent out to interested parties outside of the UK, although they would probably not be able to contribute to the design NAPI values.

2 Define Design Parameters to form the Basis of a Questionnaire

The group brainstormed the following areas to be included in the questionnaire.

NAPI Values – Antecedent Conditions – Evaporation

What are modellers changing in these areas to represent design conditions for these parameters?

There may be a need to obtain more *historic rainfall* data through the water catchments to expand upon Jamie Margetts' WaPUG paper.

MR to contact Nick Martin regarding a previous survey that may have been carried out. **MR**

Urban Creep – How do we define this? Do we need to do more research into this? The data needs to be based on numerous cases. A local university could be approached on this. JC to look into this to expand upon original WaPUG paper. Looking at old OS maps and aerial photographs may be a viable option. **JC**

Development / design horizon for future development – how are people dealing with this - Adding a max flow as a base flow – shape of profile? Should highway improvements be taken into account on how a change in surface impacts upon the speed of runoff and the potential reduction in depression storage?

Rainfall Induced Infiltration – How are people dealing with this? Produce a guide in the medium term, due to concerns of its potential over prediction during longer duration events.

Base Flow – Infiltration (varying with system deterioration). How is this applied / calculated?

Soil Type - Are modellers using the New UK runoff model for soil type 5?

Foul flow – DWF multiplier – l/h/d. Trade – what do people do with this?

What version of the software are modellers using? If not InfoWorks then what?

Seasonality in general is an issue.

Seasonal population – Holiday resorts etc.

Gullies / Inlet Capacities – Do we really understand this? How sensitive are results to the parameters used in InfoWorks?

Sewer Physicality / Siltation – do we take this out in design – Do modellers base the removal of silt on dwf velocities or just assume that the sewer system is maintained? Are modellers degrading the performance of assets over time and under what basis?

NewUK Depth – greater than 2 mm? Are modellers amending this during verification / calibration? If so, is this parameter re-visited as part of the design process?

Routing Values – What values of routing factors are modellers using? What do users consider to be realistic values? Are modellers adjusting the values / changing runoff models during design events.

Surface Activation – Do we need to consider this in extreme events? Is this a process problem? What is an extreme event (in this instance we are taking it to mean greater than the storms generally captured during the short-term flow survey period for verification? Canvass people to provide models and verification data for events greater than 1in 5 years

Designing for exceedence? Methods applied? Are modellers currently doing this in their current scopes of work?

Coverage – modelling moving storms. Areal reduction factor. What are modellers currently doing?

Climate Change – FEH or FSR? What methodology is being adopted?

CSOs – Are we modelling back-to-back storms?

Pump rates? – Are modellers adjusting these for any possible design scenarios?

Risk – What allowance for risk are modellers adopting in designs?

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3 Other discussion points

Sensitivity – Does NAPI really make a difference?

Note of caution: We do not want to specify what to do in guidance – WaPUG are not taking the risk. It needs to be a guide highlighting the risks; it is up to the end users to decide the level of risk they adopt.

NAPI was a bit of a fudge in the existing models. The new approach will have a proper soil moisture accounting model, which will not give more than 100% runoff. It will generate Soil Moisture Deficit (SMD) without having to get it from the Met Office.
“Impermeable” surfaces are often less than 100% impermeable, if there is some infiltration through the surface, it will pick up the soil model.

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4 Actions

Short term:

MR to put together questionnaire by the end of May. **MR**

Questionnaire to be issued to those on the WaPUG mailing list and other known interested parties.	**MR**
The questionnaire needs to be issued to the group for comment.	**MR**
AS to publicise the questionnaire at the next WaPUG conference.	**AS**
TD to process questionnaire results.	**TD**
MH to review existing WaPUG papers on design parameters and the issues covered.	**MH**

Long Term:

User guide to be drafted by September and issued at Autumn WaPUG.

Feedback from the other groups is required.

Speak to Mike Reeves re: sensitivity of various design parameters – see early Wallingford Procedure documents.

Guidance needs to give ranges to parameters and explain limitations.

Can we have a "future design" button in InfoWorks?!

5 Possible Areas for Future Research

Antecedent conditions across the UK.

Urban Creep.

Rainfall Induced Infiltration.

Modelling Sensitivity to various parameters.

6 Linkages to other groups

Awaiting the outcome of the other groups' deliverables to progress specifics on associated design parameters.

6 Contributions from invitees unable to attend

6.1 Mike Reeves

The recent severe flooding at various locations throughout the UK was caused by a variety of complex mechanisms involving urban drainage, river catchments and groundwater. We currently struggle to represent all these mechanisms within a single hydraulic model. To improve our understanding of flooding, CSO spills etc. we need to address the issue of whole catchment modelling. One potential way forward is a 2-dimensional runoff routing model.

Whichever approach is decided upon, removing the current limitations of runoff modelling will require a significant, structured programme of academic research backed up with measured data and detailed analysis of real catchments. This is a major task requiring significant funding and support from a wide variety of stakeholders.

6.2 Richard Kellagher

1. A radically New Modelling Approach, which needs to be put into the context of future capital spend for flooding, CSO, WQ and future SWS WQ schemes ….
2. We need to saturate one or more catchments with long term flow monitors
3. Accurate and detailed definition of areas
4. New runoff parameters to determine variability in catchment wetness function across surfaces
5. Calibrate wetness parameters based on flow monitors
6. We need totally different modelling procedures

7 Conclusions and recommendations

The conclusions of the workshop were an agreed consensus. Modelling runoff in urban areas is very important for directing investment to protect quality of life, preserve assets and protect the environment. Models are expensive to build and to validate, albeit a small fraction of the cost of investments in drainage works. Their cost effectiveness could be improved by improving our understanding of the fundamentals and by standardising methods of working. Currently, models have a limited life because modellers have individual approaches to their work, this means that data are not necessarily transferable. In order to standardise on optimum practice, we need to understand why the different practices have been adopted and their pros and cons. It is acknowledged that practitioners will have to compromise in order to standardise. Thirty years' experience of modelling has shown that we need to invest in additional fieldwork to improve our understanding of the fundamentals on which modelling is built.

Standard Surfaces Outcomes

- Review the ability of MasterMap, combined with satellite imagery if necessary, to assess the areas of the different standard surface. This has the potential for major savings in terms of time and cost, but it is also essential to understand the limitations and how much ground-truthing is necessary.
- We need fieldwork to investigate, research and measure typical surface parameters such as depression storage, slope, roughness and the effects of cracks, puddles, etc.
- It is necessary to review the number of surfaces used by modellers (including 'grey surface') and to recommend the optimum number for future development. Currently the number ranges from three, which is simple, to twelve, which is complex. The number is further compounded by condition.
- Recommend standard approaches to quantifying surface types and to surveying surface types

Runoff Processes Outcomes

- We need better understanding of roof drainage and how the runoff water enters the drainage system, especially drain pipe capacity, which is not understood adequately at present and the findings need to be included in models. The relationship between precipitation volume and the volume intercepted by roofs and the consequent runoff volume and routing also needs more work.
- We also need better understanding of gully restrictions and highway overland flows so that they can be factored into models better; this area is not adequate at present, and improved methods are needed. A formal guidance note is needed on current best practice.

Design Parameter Outcomes

- Antecedent conditions (e.g., whether soil is parched, moist, frozen or saturated when precipitation starts) are critical to the fate of precipitation, currently there are many conflicting approaches and often modellers do not understand this subject fully. By means of a questionnaire, literature review and assessing the sensitivity of parameters, it will be important to establish industry best practice for antecedent conditions.
- Produce user guide as soon as possible
- We need more investigation of 'urban creep' and how it should be applied to design models; for example, what is the annual percentage increase in patios and paving that contributes to sewers and drains.

WaPUG considers that it is important to continue with runoff modelling research. We need to establish best practice for overland flow modelling of flood flows; this is being developed and used gradually but with little guidance and consequently there is a divergence of practices.

It is essential that catchment modelling and Planning become integrated better. Flood risk assessment is becoming more and more integrated. The capability to model overland flow has improved. We probably need to work on getting river, sewer and STW models talking to each other. Defra's sixteen Pilot Projects[3] examining integrated catchment planning should yield useful inputs for improving modelling. There will be an Open Forum at November WaPUG for Members to identify next few years' research needs.

[3] http://www.defra.gov.uk/environ/fcd/policy/strategy/ha2.htm

8 References

Ashley, R.M.; Bertrand-Krajewski, J.-L.; Hvitved-Jacobsen, T. and Verbanck, M (2004) *Solids in sewers: characteristics, effects and control of sewer solids and associated pollutants.* IWA Publishing, London.

Evans, T.D. (editor) (2004) *Urban Rainfall & Run-Off* report of FWR WaPUG workshop, 30th April 2004, Coleshill. FWR, Marlow, England

Evans, T.D. and Eadon, A.R. (editors) (2006) *Workshop On Urban Run-Off Modelling -Why Not Do It Properly?* report of FWR WaPUG workshop, 8th March 2006, Coleshill. FWR, Marlow, England

Appendix 1. Abbreviations and acronyms

AMP	Asset Management Plan
CSO	combined sewer overflow
DAP	drainage area plan
DAS	drainage area study
DP	Design Process
DWF	dry weather flow
FEH	flood estimation handbook
FMEA	Failure Mode and Effect Analysis
FSR	Flood Studies Report (NERC, 1975)
FTE	Full time equivalent [employee]
GIM	Ground Infiltration Module
HRA	hot rolled asphalt
IAS	Impermeable Area Survey
NAPI	Net Antecedent Precipitation Index
OFWAT	Office of Water Services
OS	Ordnance Survey
PR	Percentage Runoff
PIMP	Percentage IMPervious
RP	Runoff Process
SCS	Soil Conservation Service [USA]
SMA	stone mastic asphalt
SMD	Soil moisture deficit
SOIL	Soil Index Value obtained from the WRAP [soil classification] map
SS	Standard Surfaces Input
SUDS	sustainable urban drainage systems
SWS	surface water sewer
ToR	terms of reference
UCWI	Urban Catchment Wetness Index
WaND	Water Cycle Management for New Developments
WASSP	suite of software for sewer system design and analysis
WQ	water quality
WRAP	Winter Rain Acceptance Potential

Appendix 2. Background - Designing Hydraulic Improvements for Sewer Systems

Andy Eadon

The introduction of hydraulic simulation tools for sewer systems in the early 1980s created a breakthrough for the design of sewer improvements. Previously, the available techniques were direct design methods more appropriate for small systems serving new building development and the approach amounted to a comparison of pipe sizes between the existing and a brand new system. The calculations did not take full account of system storage and invariably resulted in grandiose schemes, which were not affordable. It was essentially an empirical approach which, when applied to existing systems of city proportions, generated unrealistic needs at a time when awareness of National deficiencies was at its height.

The introduction of computer simulation tools, starting with WASSP, paved the way for a different approach. Computer simulation provided analysis of the points of failure of a sewer system normally demonstrated by the on-set of surface flooding. This is a recognised performance measure. It can be directly aligned with properties that suffer regular flooding from sewers. To have this capability, the required model includes hydrological as well as hydraulic processes so that runoff is accurately generated from a supplied storm profile, which is then routed to and through the sewer system. It is therefore possible to complete a series of desktop analyses for different storm loadings in order to assess the performance of a sewer system reliably. It is further possible to repeat the exercise on a modified system to complete a 'before and after' desktop exercise. These tools are detailed and sophisticated but readily available in a number of software packages.

The established design method outlined below has been variously developed and used by individual organisations but has not been formally documented as an industry reference. The main purpose of this Note therefore, is to address that issue so that any dependent research and development can move forward.

A2.1 Design Procedure

The established design procedure for improving the hydraulic performance of urban drainage systems is illustrated below. Unlike many other civil engineering processes, it is not a direct design procedure but rather an analysis process, which captures the detailed performance of urban sewerage systems and relies on being able to simulate both recorded and design events realistically. The principal is to identify pinch points in the system of underground pipes and chambers that lead to premature surface flooding. The analysis also identifies elements with under-utilised reserve capacity. The system can then be modified by intuitive 'try and test' and the effectiveness of proposed improvements assessed by 'before and after' simulations. The process has been proven to make best use of the existing infrastructure and limit the extent and cost of improvements.

The process begins with a robust model of the existing system under the current connected area and base flow loading, which has been verified against historic records and a recent flow survey. This is referred to as the **base model** and should be carefully referenced and archived. A range of suitable design storms are run through the model to create a current performance profile for each element. This is usually depicted in the form (1-5); i.e. surcharges in a one-year return frequency storm and floods in a five-year return frequency storm. This highlights the 'pinch points' in the system.

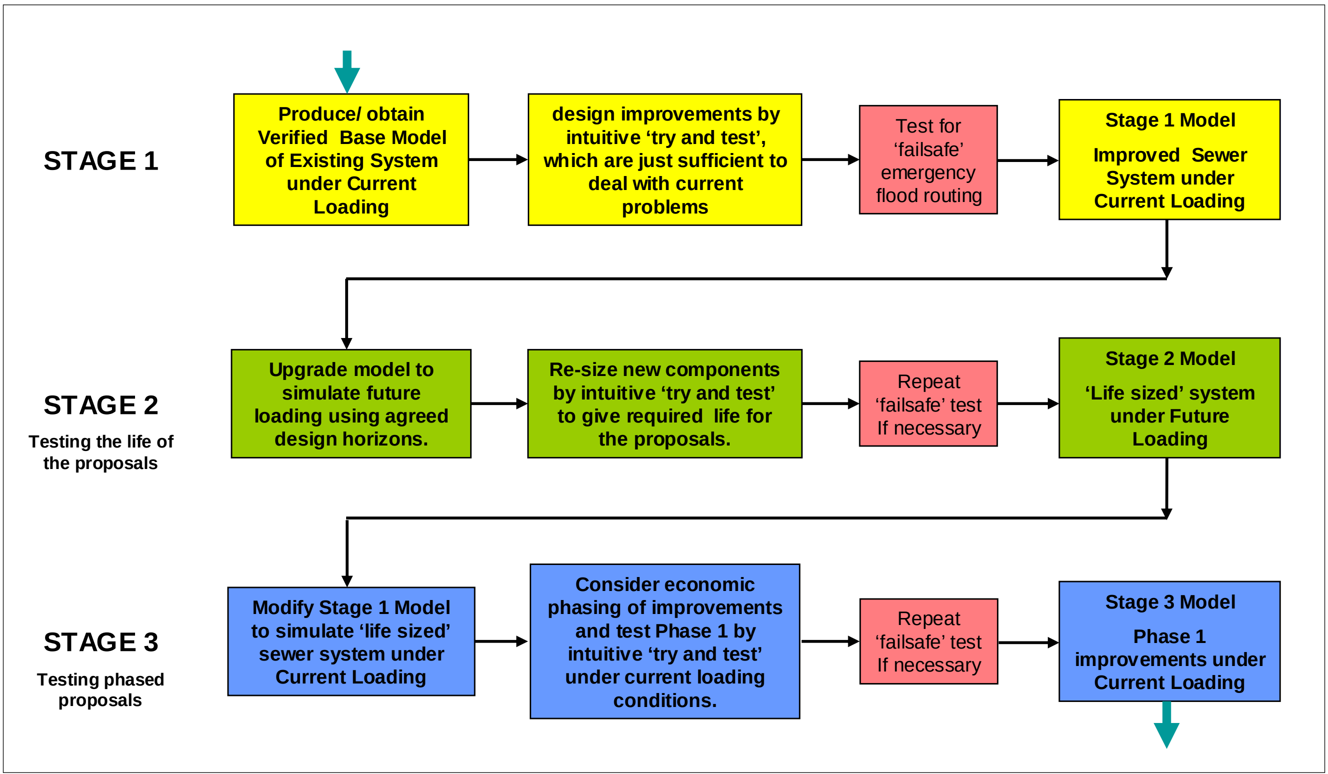

Figure 4 Design process for upgrading the hydraulic performance of existing sewer systems

STAGE 1

Design in Stage 1 is done by working on the base model and introducing new elements into the system by intuitive 'try and test'. The extent and size of proposals is tuned successively to just eliminate areas of poor performance. The usual accepted performance criterion is 'no indicated flooding' for the adopted standard. Standards set by organisations vary between about 1 in 10 to 1 in 40 years and may take further account of types of flood risk.

It is common for proposed new elements to fall into the following types:

- increased transmission (enlarged or additional sewers)
- increased storage (on or off-line tanks)
- catchment transfer (diverting flows to another system)
- isolation or 'cut and pump' (protecting local areas whilst permitting main sewer surcharging)

The analysis may well indicate deficiencies that have not been triggered by recorded flooding events. Any proposals should therefore either avoid overstressing those elements or address these as well in a more comprehensive improvement strategy.

The most likely solutions are thus incorporated into the model and the same range of design storms run to produce a 'before and after' analysis. This procedure is repeated successively for a selected critical design storm and a satisfactory proposal arrived at.

It is then prudent to examine various failure modes including power and mechanical failure of pumping stations, blockage of control devices and overloading in extreme events and to determine where flooding will be routed (Failure Mode and Effect Analysis, FMEA). If vulnerable areas can be avoided or protected locally, this will enhance the robustness of the proposals.

A number of options may be identified and after suitable checks have been made on buildability and costing, the preferred option is arrived at, which is just sufficient to eliminate current pinch points and should therefore be the lowest cost option. This modified model is the **Stage 1 model**.

STAGE 2
It is recognised that sewerage systems serve communities that change over time and consequently vary the future loading on the drainage infrastructure. The solutions developed in Stage 1 could therefore have a limited life if the design process does not take predictable changes into account. In Stage 2 therefore, the model is upgraded to account for future demand by incorporating; predicted growth in base flows, connected areas from planned new development and perhaps increased runoff from urban creep. Allowances and planning horizons are normally specified by the responsible organisation. A repeat analysis on this model will therefore indicate future loading on the components proposed in Stage 1 that can be resized as necessary to give the required life. The analysis is then repeated to show compliance with design criteria and the **Stage 2 model** produced. The Stage 2 model may also indicate entirely new pinch points that will have to be addressed in at some time in the future. However, unless there are special circumstances or considerations, these [future pinch points] are not addressed in the proposals although any interactions should be taken into account in sizing the Stage 1 components. [It is argued that increasing a pipe size is a worthwhile extra marginal cost to avoid replacing the Stage 1 components after a relatively short time, but increasing the length of pipe for future loading should not be undertaken until the need is more clearly demonstrated.]

STAGE 3
The final part of the design process is a step to check that components, which are re-sized to accommodate growth, do not themselves create new problems under current loading. It is probable for instance, that flow control devices or pumping rates will need to be tuned down for current operation and sensibly adjusted when required in the future. The Stage 3 model can therefore be produced from the stage 1 model with all major components sized for future loading but with controls and equipment tuned for current loading. This is checked with a further design storm analysis and the **Stage 3 model** completed. The Stage 3 model will therefore incorporate the detailed components of the final scheme with the proposed ‘Phase 1’ operating regime.

LIMITED FUTURE DEMAND
It should be noted that Stages 2 and 3 together can be optional and would not be required if future loading on the system is negligible. However, where stage 2 generates different sizes, even if there is no possibility of phasing the works, it is recommended that Stage 3 be undertaken to check that resizing will not in itself create problems.

A2.2 Using Design Rainfall

The design approach implies the assumption that the return period of the storm is at least a first order indication of the return period of any flooding that is generated in simulations. Other variables are peaked or averaged for ease of application. Catchments and sewer systems vary in size and, in order to fill the system, the storm duration is critical. Too short and the system does not fill at the outfall and too long and the peak storm intensity will be too low. Therefore, short duration storms are critical for local sewers and longer duration storms are critical for main and trunk sewers. It has therefore become common practice to select the required return frequency, run a series of different durations and to take the worst case for each sewer in the system. In this way, all sewers are tested under the appropriate loading. A typical range of durations is 15 minutes, 30 minutes and 60 minutes.

Models of urban drainage systems are very detailed and now tend to cover large areas. However, the extent to which a single stationary design storm can be used to predict performance is more questionable as the plan area, or the catchment length or width increases. It is generally known that convective storms (which are regarded as the most critical for urban drainage) rarely cover more that 2 to 3 km^2. Perception also questions the validity of stationary design storms of long return periods, which also persist for a long duration. Such events are known to be beyond the acknowledged research base and should only be used with care. There are also significant concerns about using existing models to represent extreme events because additional processes such as overland flow are activated. One important aspect is that the areal reduction factor for point rainfall for a large model, will reduce design rainfall intensities and this could result in under-design of local sewers in sub-catchments and side branches. It may therefore be more appropriate to run sub-catchment models only and to use the resulting hydrographs as inputs to test independent trunk sewer models.

A2.3 Failsafe Analysis

It is recognised that whatever the design frequency used, sewer systems can be overwhelmed in extreme events. There may also be some points in the system where operational performance is critical and the failure of a pumping station or control device can cause surface flooding. It is therefore recommended that an examination be undertaken to determine the consequences of such an occurrence.

The examination can take the form of a modelled event to indicate the escape points followed by a simple site inspection or a more intricate flood routing exercise using digital terrain modelling. Criteria for assessing a satisfactory situation are clearly not available and judgement of acceptable risk is needed. Therefore, where the risk is thought to be acceptable no further action will be required. Otherwise, it may be necessary to review the proposals and move the failure point to a more suitable location, to undertake surface profiling to divert flows to a safer route or to take special measures to protect vulnerable properties on the indicated flood route.

"*Creativity is merely a plus name for regular activity.*
Any activity becomes creative when the doer cares about doing it right, or better."

John Updike - American novelist, poet, critic, and short story writer (born 18 March 1932)

Appendix 3. Workshop programme

Objective - to launch Working Groups

Chairman Jamie Margetts, Clear Environmental Ltd

Presenters

Andy Eadon

PROGRAMME FOR THE DAY

09.00 – 09.30	*Arrival and Coffee*
09.30 – 09.45	Welcome and Objectives - Jamie Margetts
09.45 – 10.00	Background – Andy Eadon
10.00 – 10.45	Discussion – ToR for Standard Surfaces Group
10.45 – 11.00	*Tea/Coffee*
11.00 - 11.45	Discussion – ToR for Runoff Processes Group
11.45 – 12.30	Discussion – ToR for Design Parameters Group
12.30 – 13.30	*Lunch*
13.30 – 14.00	Groups Resourcing – volunteers and representation
14.00 – 15.30	Group Sessions – agree first steps and programme
15.30 – 15.45	*Tea/coffee*
15.45 – 16.30	Summaries of group sessions - Group Chairmen
16.30 – 16.45	Overall Programme and Summary– Jamie Margetts

Appendix 4. List of Invited Delegates

	Name	Affiliation
	Members	
1	Andy Eadon	WaPUG
2	Bob Draper	R&K
3	Dave Terry	Severn Trent
4	George Hare	MWH
5	James Hale	MP/Ewan
6	John Malone	MP/Ewan
7	Jonathan Cutting	MP/Ewan
8	John Packman	CEH
9	Mark Russell	CarlBro
10	Martin Osborne	Ewan Associates
11	Mike Reeves	Wallingford Software
12	Mike Wood	Hyder
13	Phil Dyke	Severn Trent
14	Richard Allitt	RAA
15	Rob Whittaker	EA
16	Tim Evans	FWR
17	Tim Dawe	MP
18	Dave Farrer	Yorkshire Water
19	Tony Bamford	MWH
20	Mark Priestley	MWH
21	Alex Sneath	Pick Everard
	Committee	
22	Jamie Margetts	Clear Environmental
23	Adrian Saul	Sheffield University
24	Graham Squibbs	United Utilities
25	Nick Orman	WRc
26	Nick Martin	Thames Water
27	Richard Long	Ewan
28	Vicky Harty	Hartfair