SIMULATING HIGH RETURN PERIOD STORMS

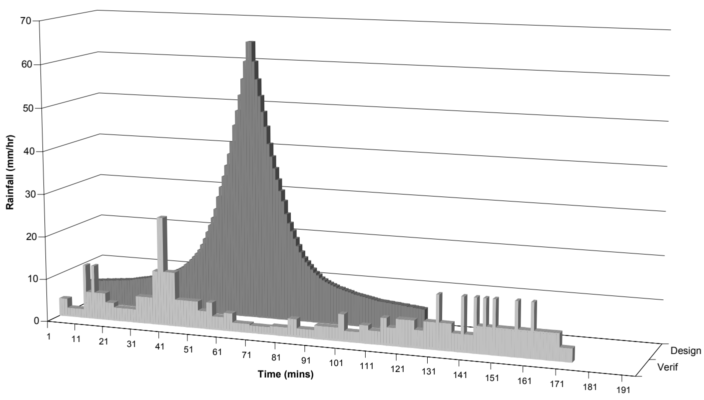
**Presented at WaPUG Spring Meeting**
**19 May 1998**

**Author:** **Richard Allitt**
**Richard Allitt Associates Ltd**
111 Beech Hill,
Haywards Heath,
West Sussex
RH16 3TS
Tel & Fax (01444) 451552

## 1. INTRODUCTION

As the UK Water Industry has gained more experience in the use of hydraulic models of sewerage systems there has also come a tendency to expect more and better performance from these models with a general expectation by non practitioners that the models will always give the correct results no matter what is asked of them.

The modelling practitioners in the UK have met the challenges of these greater expectations with models being built to far higher standards than was generally the case even a few years ago. It is extremely reassuring that non practitioners in the industry are now basing a significant part of their company's forward planning on a modelling strategy.




However, these greater expectations have also meant that certain aspects of the model building process now need to be given far more attention than was previously necessary. Models are generally verified against low return period storms with the norm being that 3 such storms would occur during a typical 5 week short term flow survey. Whilst this verification is a vital step in the process it is also vital to test the model with higher return period storms and to compare the predicted flooding with historical flooding records. The graph on the left illustrates the differences between a typical (good) verification storm and a 1 in 10 year 120 minute storm – the difference in peak rainfall is readily apparent.

It is also interesting to compare the recommended minimum criteria for verification storms with a synthetic design storms with a 10 year return period.

| ***Minimum Criteria for Verification Storm*** | | ***Synthetic M10-60 Design Storm*** |
|---|---|---|
| *5 mm* | Total Rainfall | *21.8 mm* |
| *4 minutes* | Duration with Intensity greater than 6 mm/hr | *60 minutes* |
| *No requirement* | Peak Intensity | *82.8 mm/hr* |

If models are used for assessment or design purposes with standard synthetic design storms of return periods of 10, 20, 30 or even 50 years then various aspects of the model will become significant which will not have been tested at verification stage. This paper discusses some of these aspects with a general regard to simulations with relatively high return period storms.

This paper has been written from the viewpoint of a Hydroworks practitioner but the points raised are equally applicable to other modelling programs though with slight variations in the exact method to be employed.

The aspects to be considered (in order of priority) are:-

- Choice of Flood Types;
- Storage Compensation;
- Overland Flow Routing;
- Increased Runoff.
- Un-verified Ancillaries

## 2. CHOICE OF FLOOD TYPE

In Hydroworks there is the ability to set different flood types at each node in the dsd file as follows:-

- Type 0 – *this is for sealed nodes where no flooding can occur (eg junctions with no manholes or manholes with sealed covers);*
- Type 1 – *this is for when flood water is temporarily stored above ground on the surface and then returns to the system once surcharge levels have subsided;*
- Type 2 – *this is for when any flooding at the node is then lost from the system (eg it spills into a watercourse).*

The default setting in WALLRUS was 2 but in Hydroworks the default setting is now 1 and this has brought several problems when old WALLRUS models are converted into Hydroworks.

The use of Types 0 & 2 are straightforward with no real difficulties encountered. However the use of Flood Type 1 appears to have problems with frequent errors occurring which can have a pronounced effect on the simulation results.

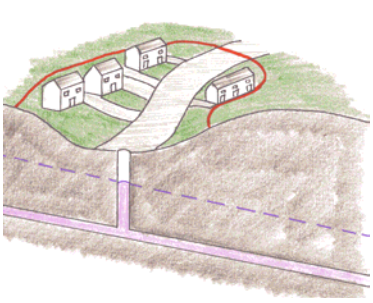


Fig 2 (a)
With surcharge level below
Ground Level but rising

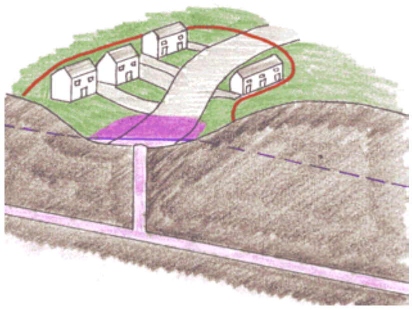


Fig 2 (b)
With surcharge risen above
Ground Level and with 10%
of Contributing Area flooded

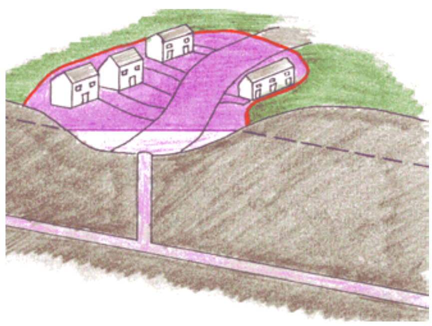


Fig 2 (c)
With surcharge level risen further
to give flood depth greater than 0.5m
and with 100% of Contributing
Area flooded

The sequence of sketches above show the use of Flood Type 1. As the sewer system surcharges during storm conditions the surcharge level rises until it reaches ground level. At that point the water surface spreads over 10% of the contributing area (default values which are adjustable). As the surcharge level increases and the storage volume in 10% of the area is used up with the water depth greater than 0.5m the water surface then spreads over 100% of the contributing area. As the surcharge level subsides the water stored above ground is then returned to the node.

The diagram overleaf illustrates the effect of using a Flood Type 1 with zero contributing area. In these cases there is effectively no above ground storage as there is zero plan area over which the water can spread and the surcharge can rise to 99.5m above ground level without any flooding occurring. Therefore it is advisable to never use Flood Type 1 with Zero contributing area. A forthcoming release of Hydroworks will have an addition validation routine to flag up a warning if a node with zero contributing area has Flood Type 1.

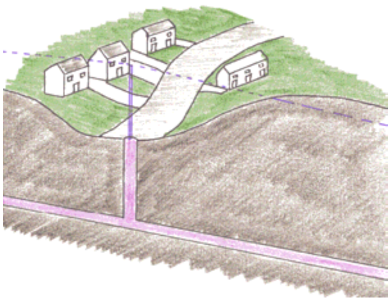


Fig 3
Effects of high surcharge with Flood Type 1 and zero Contributing Area. This gives no flooding but very high surcharge.

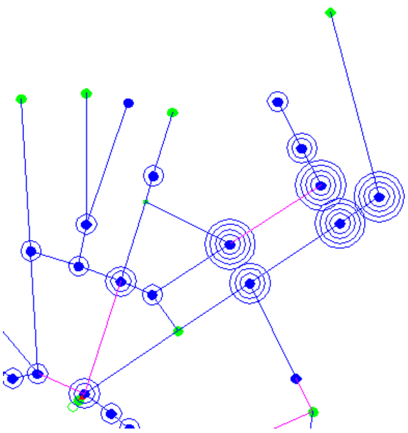
It is possible within Hydroworks to have "Contributing Areas" which do not actually contribute as one can add zero areas to the 3 standard surface types. Because of this facility it is possible to add a sensible "Contributing Area" to a node to enable the flood hydraulics to work as intended with no increase in flow due to any added areas.

The default values in Hydroworks for the depths of flooding with Flood Type 1 (0.5m for stage 1 – 10% of area & 99m for stage 2 – 100% of area) are questionable. In terms of sewage flooding it is very unusual for any flooding to be more than about ½ m deep as it tends to flow away somewhere at depths beyond this and spread around the catchment. It maybe more appropriate to consider a depth for stage 1 of 0.2m.

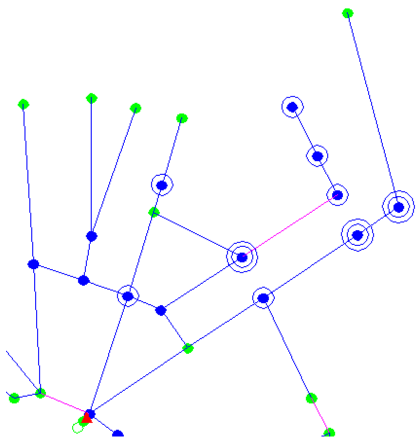
A simple criteria for whether flooding is significant or not based on a flood volume (eg 25$m^3$) can lead a modeller to thinking that some flooding is not significant whereas it is but the quoted volume is distorted by having too small a "Contributing Area" which allows the surcharge to rise far higher than it would have done with a larger area when possibly a larger volume would have flooded. It is therefore important that care is taken in selecting a suitable value for the "Contributing Area".

## 3 STORAGE COMPENSATION

WaPUG User Note 15 discussed in detail the matter of storage compensation. Whilst this was written for use with WASSP and WALLRUS the principles and the methodology documented are equally valid with Hydroworks. However a simple program like MADD is not currently available and therefore the matter of storage compensation is glossed over by many less experienced modellers. Some organisations have developed their own programs but all are based on the original work carried out by Ron Chapman.



The diagram on the left shows the flooding in a typical system where no compensation has been made for loss of storage. The diagram on the right, by contrast, shows the flooding for the same system and the same storm but with compensation made for loss of storage following the methodology in WaPUG User Note 15.



In almost any model which simply uses the manholes from Sewer Records as nodes there is inadequate allowance made for storage because the storage available in laterals, road gullies, inspection chambers, pruned sewers and manholes is not allowed for. As a result of this the model will over-predict flooding as illustrated above.

In Hydroworks the loss of storage is compensated for by increasing the plan areas of the nodes. The lower part of the manhole (from invert level to soffit level) is referred to in Hydroworks as “Manhole Area 2” and as this is generally contained within the benching there is very little storage available and therefore this value will usually be quite small. The upper part of the manhole (from soffit level to ground level) provides most of the storage and is referred to in Hydroworks as “Manhole Area 1”. The storage in this upper part of the manhole is not mobilised until the system surcharges and this is why the correct allocation of storage volume is so important when modelling higher return period storms. Some model building programs give a large plan area to both the upper and the lower parts of the manhole but this will tend to flatten the flow hydrographs artificially in non surcharge conditions especially when the plan areas are large. It is important that the modeller has the correct amount of storage compensation and modellers are recommended to study WaPUG User Note No 15.

The original algorithms developed by Ron Chapman required an assessment to be made of the housing density within a catchment or sub-area. In MADD this requirement was worked around by working out a housing density based on dry weather flows but this was clearly erroneous when infiltration flows etc were also added in as dry weather flows. The advances in computing systems and mapping techniques now allow housing densities to be calculated quickly and accurately from seed point data.

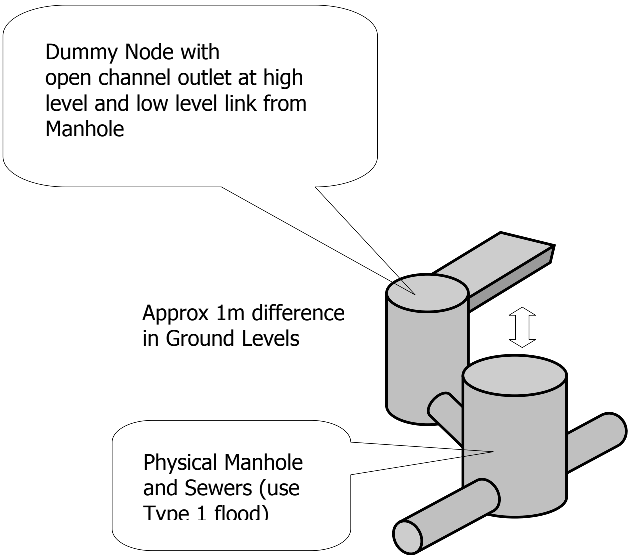
It many situations the volume of the “Priestman Slot” can be a significant proportion of the storage available within a pipeline and clearly the volume already allowed for in this should be subtracted from the additional storage added at manholes to compensate for losses as described above. Some modellers reduce the pipe diameter to compensate for the Priestman Slot but it is preferable to subtract some volume from the manholes as this gives a more realistic representation and allows the full capacity of the pipeline to be maintained.

Unfortunately there is currently no simple to use program available for storage compensation in Hydroworks models but it is time that such a program was written either separately or incorporated as a function within Hydroworks.

## 4 OVERLAND FLOW ROUTING

The conditions that can prevail at ground level during severe storm events can be substantially different from those encountered during dry periods or small storms (eg typical verification storms). In some cases the effects of these conditions can be quite dramatic with flows from overloaded watercourses or flooding from the sewer system travelling significant distances and entering the sewer system at unexpected places. It is very difficult to estimate these effects and there is no substitute for the modeller having a good local knowledge of the catchment and listening to anecdotal evidence from householders and Operations staff.

In some cases there will be reports of historical flooding which at first assessment do not appear to have any logical explanation and which are not predicted in the model. In these cases it is usually worthwhile spending some time walking around the catchment to see whether any obvious overland flow routes can be seen. Obviously video or photographic evidence of any overland flows during storm conditions are especially useful.

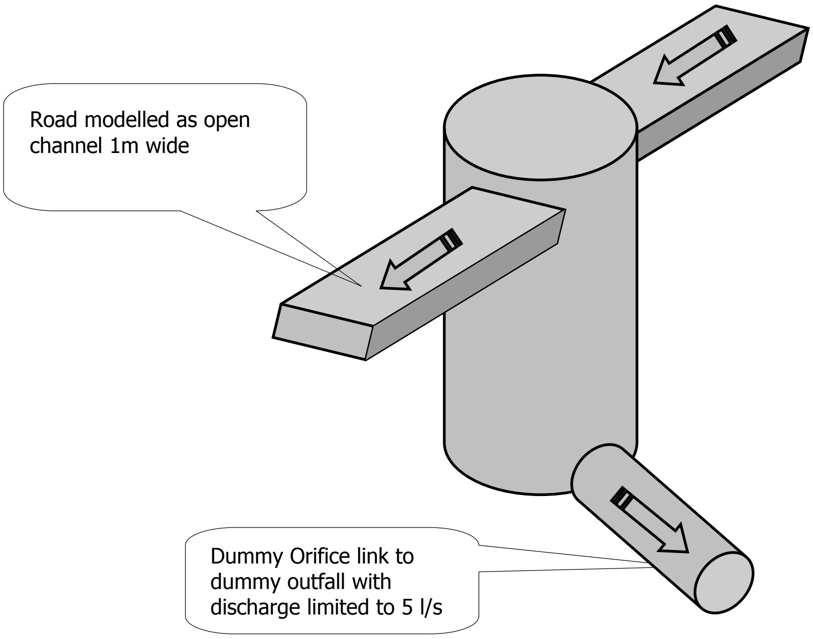



Once an overland route has been identified it is necessary to determine whether this will be of importance when trying to simulate high return period storms. If they are likely to be important then a modeller will need to consider whether such overland flow routes should be modelled. With a little ingenuity it is possible to model most things and the diagram to the left illustrates how overland flow from flooding at a manhole can be modelled with an open channel from a dummy node representing overland flow along a road channel, this can then be routed into another node in the network.

In the situation illustrated it is important that the open channel at high level is kept relatively narrow (0.5m to 1.0m) otherwise a ridiculous minimum depth will automatically be applied by Hydroworks in order to keep the model stable. It is therefore unwise to model the channel as the same width as a 7.3m wide road. Where the minimum depth in a channel becomes problematical it is worth considering whether a weir would be preferable as this can also be routed directly to the inflow point.

## 5 INCREASED FLOWS

It is a well appreciated fact that during severe storm conditions there are frequently inflows into a sewer system that do not occur in lesser storms or are insignificant in lesser storms. The most obvious cases are where large grassed or permeable areas become saturated and start to contribute runoff – this example has been documented previously by others and it is far easier to model such phenomena with Hydroworks that it was previously with WASSP and WALLRUS by use of the New Runoff Model which is available in Hydroworks.




Another example of increased runoff is very common in the southern part of the UK where catchments are drained on a separate basis but with substantial areas draining to soakaways. Where soakaways are used for highway drainage (as in many areas of the South Downs which are predominantly chalk) and especially when road gradients are steep, the soakaways frequently have a limited capacity or soakage rate. The soakage rate in many cases is now only a few litres per second as little or no maintenance has been carried out in the past decade. In these cases it is possible that with storms with a return period of 1 or 2 years substantial areas of highway cannot be adequately drained by the gullies draining to soakaways and these areas suddenly contribute flow to the sewer system by means of overland flow along the roads. This example of increased runoff can be modelled with a little ingenuity, as illustrated on the right, with each of the soakaways modelled as a node with a dummy outfall link set with a limit of a few litres per second and with the road modelled as an open channel. As sensitivity analysis is usually required with this approach to set the discharge limits so that simulated flooding or overland flow corresponds with historical information.

## 6 UN-VERIFIED ANCILLARIES

With the relatively modest criteria for a verification storm it is inevitable that many hydraulic ancillaries in a sewer system will not have operated during these storms. The most common ancillary which does not operate in a verification storm is a Combined Sewage Overflow (CSO). Obviously for a model to provide a realistic prediction with higher return period storms it is vital that such ancillaries are correctly modelled. The fact that they have not operated during a verification event does not meant that they should be left out of the model.

In these circumstances the testing or verification of the model against historical data gains far more importance but also consideration should be given to longer term flow and rainfall monitoring.