STORAGE COMPENSATION

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1. INTRODUCTION

When simulating the behaviour of drainage networks using hydraulic modelling software, the system is normally to a greater to lesser extent represented in a simplified form. This is necessary in order to reduce the data collection that would be involved if all pipes from the main sewer to the buildings were included and to reduce computer run times. This means that not all of the storage available in the drainage system under surcharged conditions are included in the model. This unmodelled storage includes connections, gulley pots and unmodelled pipes and manholes. If this storage is not added to the model, it will over-predict the flooding that occurs during storm events.

Accurate measurement of the unmodelled storage is extremely difficult. The information on sewer records normally show the location of the sewers in the roads but not the building drainage. If the missing pipes are on the sewer records the volume of these could be measured although this is a time consuming business. Normally, manholes will also be marked and the volume of these can be estimated by assuming a standard diameter. The volumes associated with gulley pots and pipes connecting gulley pots and properties to the sewer cannot be measured from the records. The lengths of the connecting pipes can be measured but determining the numbers of the gulley pots and the size of the connecting pipes can only be ascertained by fieldwork. Carrying out such fieldwork would require an enormous amount of effort.

The problem is further complicated by the fact that not all of this measured volume is available as storage since some of it will be taken up by flows in the pipes. The volume available will therefore be different for every storm event. Another complication is that not all of the system connected to a surcharged pipe will fill to ground level and so some storage will not be utilised.

As no realistic user of a sewer hydraulic model would expect the program to predict volumes of flooding to the nearest cubic metre, it is not worth attempting to define accurately the additional storage available. What is needed is a method which provides a realistic estimate of the available additional storage without requiring any information other than the pipe data.

2. DEVELOPMENT OF METHOD

To be widely applicable any method developed needs to be able to deal with drainage networks ranging from fully combined to fully separate. To facilitate this, the method was developed in three parts; one to account for paved area drainage, one for roof drainage, and one for foul drainage.

For each pipe in a model the upstream ground level, pipe depth, pipe slope, pipe shape and pipe size are all known. The total contributing area, the percentage of the area which is roof or paved area and the foul flows are also known.

The first assumption made in developing the model is that the contributing area in linearly distributed along the pipe length (see Figure 1). It is further assumed that paved and roof areas would be associated together, that is that the roads serve the properties and that the properties are randomly distributed. This gives an average connection length to a property as below:

$$X -A/ 4L \tag{1}$$

where: X - connection length (m)

A - catchment area (m^2)

L - pipe length (m)

The amount of storage that can be mobilised will be controlled by the ground topography. To account for this the distance of the average connection in limited to:

$$X < 0.5\ x \tag{2}$$

where: x - depth to soffit/ pipe slope

This assumes that the model pipe slope is typical of the local ground slope and that the area is surcharged to the ground level above the model pipe.

A minimum length of 5 m is assigned to X to prevent it becoming unrealistically short:

$$X > 5 \tag{3}$$

The basis of the method is that, whatever the actual system of connection, it is equivalent to each property being connected individually to the model pipe directly by a 100 mm pipe running half full.

For connected paved area the number of connections is calculated by assuming one connection per 300 m^2 of connected paved area which corresponds to a typical gulley spacing.

For connected roof area the number of connections is calculated by assuming one connection per 80 m^2 of roof area which is the typical area of roof over one dwelling.

For foul only connections, which are represented by a base flow in the model, the number of connected properties is calculated by assuming that 0.01 litres/ second comes from each dwelling. This is based on 4 persons per dwelling and 200 litres/ head/ day. The number of connections calculated for the roof area is deducted from the foul connections to avoid double accounting.

The remaining foul only connections are translated into an equivalent connected area by assuming a housing density of 35 properties per hectare. A connection length can then be calculated from Equation (1) as before.

The total number of connections and appropriate lengths are multiplied and then summed for the three types. This total length is then multiplied by half the area of a 100 mm pipe to give the total unmodelled storage:

$$\text{unmodelled storage} = L * PA/ 2 \qquad (4)$$

where:

L = length of paved + roof + foul connections

PA = area of 100 mm pipe

This algorithm (MADD) can be used to calculate the volume of additional storage which can be added into the model for example by increasing the manhole sizes.

3. CALIBRATION AND COMPARISONS

Since the model for predicting unmodelled storage is developed in such an ad hoc manner it needs to be verified by reference to measured data. This has been done as follows:

The only physical method of measuring the available storage in a drainage system is to block the outfall pipe and check how long it takes to surcharge to ground level. However, this would need to be done during a rainstorm to get a realistic answer and so the problems of measuring the inflow to the system would need to be tackled. This seemed to be an unnecessarily complicated exercise so another approach was taken.

1:1250 scale plans of drainage networks were used to measure the unmodelled storage. The pipes in the road and the manholes were marked and it was assumed a road gully and connection was provided for every 300 m2 of road area. The actual system of foul and roof connection was traced and measured. This gave a figure for the maximum possible unmodelled storage. An estimate of the storage available during storm events was made by assuming that the combined pipes and paved connections would be flowing half full, roof connections quarter full and in foal only connections the flow area was ignored. The topography was taken into account and connections were assumed to be 1 m deep.

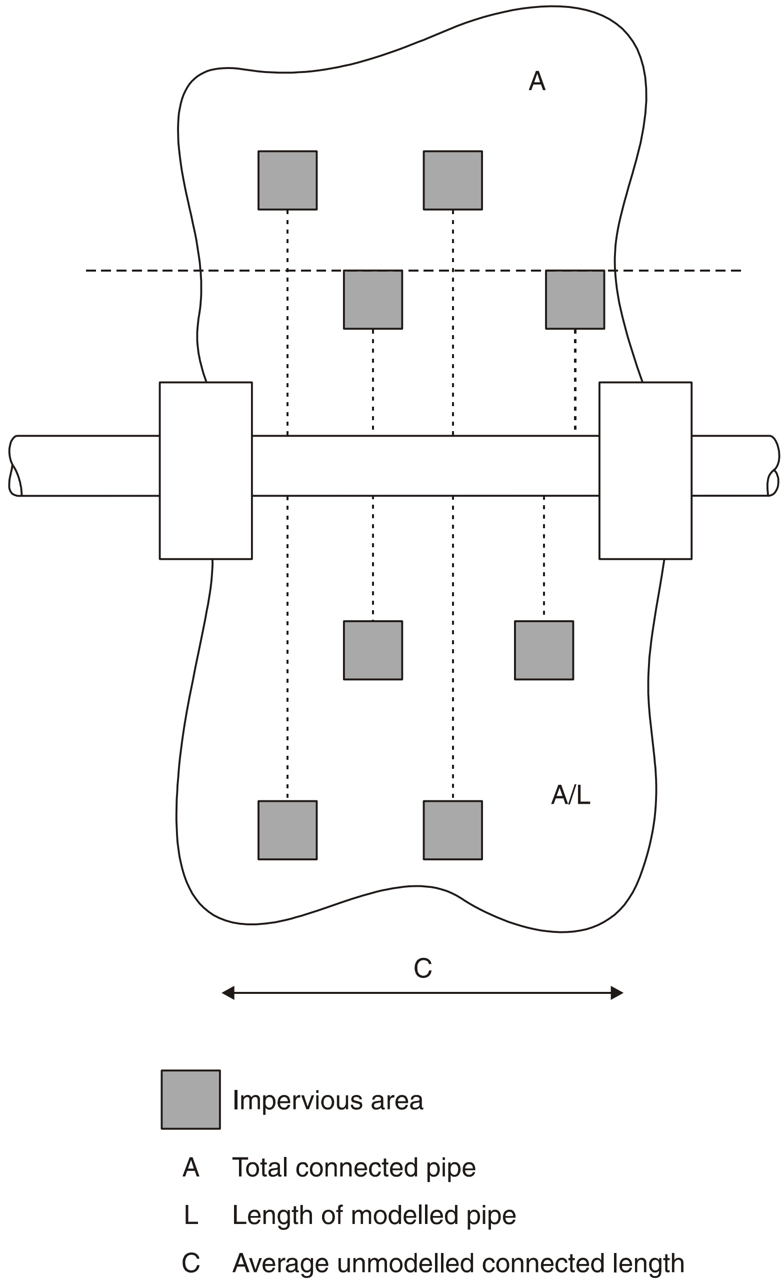

Figure 1 Conceptual layout of unmodelled Storage

Measurements were carried out on pipes with contributing areas ranging from 0.5 ha to 20 ha which covers the range of values normally found in models. Four different types of drainage network were analysed ranging from fully combined, through semi-separate to fully separate systems. The results are shown in Figure 2. The storage model's predictions match the measured estimates well and never exceed the maximum measured storage.

The storage model (MADD) was then used to add storage to three existing major models. These models were built by three modellers who each estimated the additional storage required by a different method. All three models were consequently verified by reference to a flow survey and gave good correlation between predicted and observed flooding. Table 1 shows the volume of storage predicted by MADD and the volume originally added. Winton is a model covering 500 ha of Bournemouth and includes a combined system and two stormwater systems. Weston-super-Mare models 1,000 ha of the Weston-super-Mare combined system and includes significant inflows from foul only networks. Clifton covers the 72 ha Clifton area of York and is a fully combined system. The Clifton model included an allowance for unmodelled pipes only and did not include connections. Finally, the Bedford model covers 12 km^2 of Bedford and is a mainly combined system with large foul only catchments connecting. The match between the MADD predictions and the original volumes added is, in all cases, very good.

Model	**Original Storage Volume**	**MADD Volume**
Winton	3,500	3,511
Weston-super-Mare	15,000	16,503
Clifton	624	738
Bedford	5,861	5,598

Table 1: Comparison of MADD with Estimates in Large Models

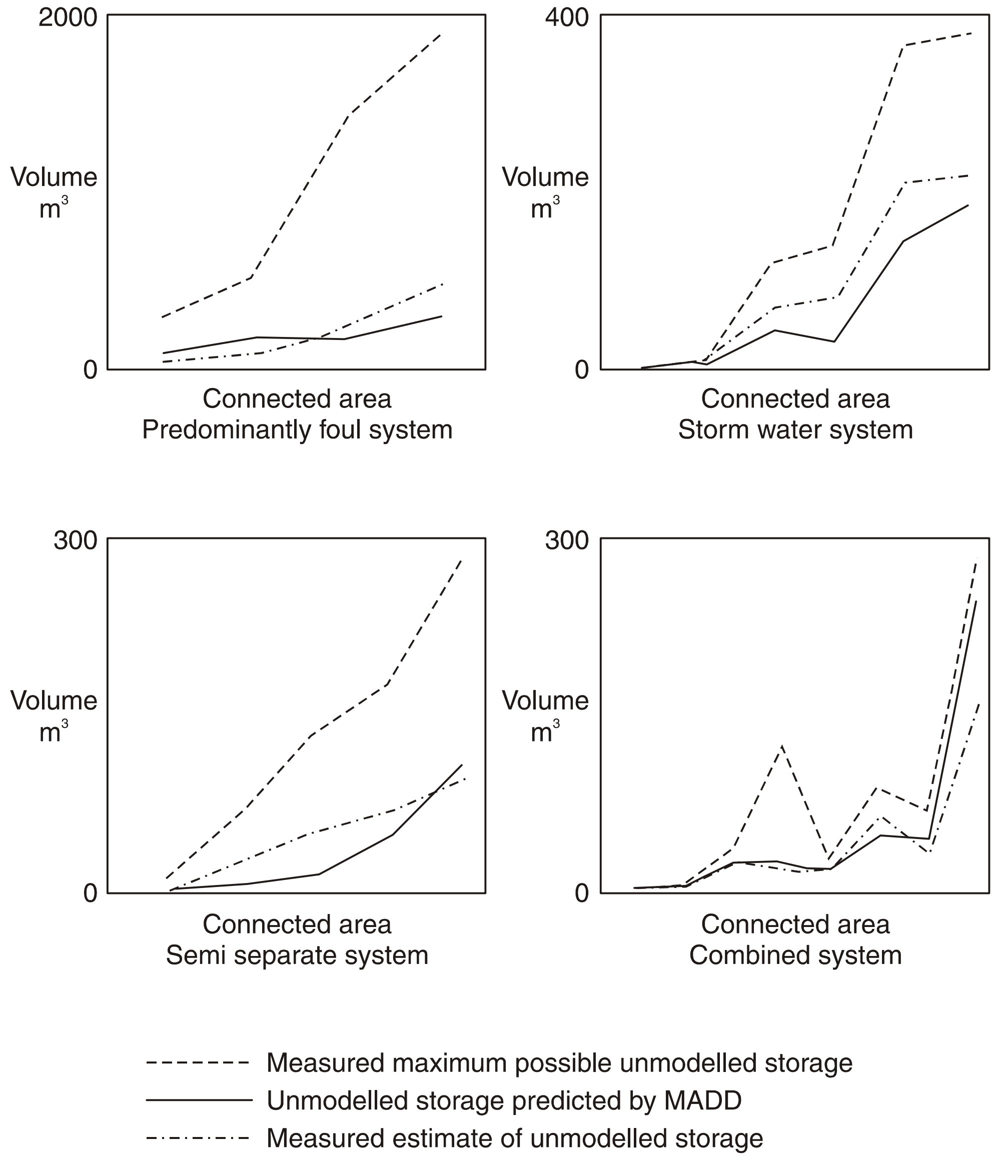

Figure 2: Unmodelled Storage in Drainage Networks

4. CONCLUSIONS

Simulation models for sewerage need to have the storage volume represented by the unmodelled parts of the system added to them or they will over-predict flooding.

This volume of storage will vary with the state of flow in the system, and is very difficult and time consuming to measure accurately.

A method of obtaining a reasonable estimate of this storage without carrying out any extra data collection is required.

The predictions from MADD correlate well with measured data for single pipe lengths for a wide range of conditions and also with estimates made for large models by a variety of methods.

5. RECOMMENDATIONS

All hydraulic models should include an allowance for unmodelled storage.

The predictive model encoded in MADD should be used to estimate the allowance required for unmodelled storage.

The predictive model should only be used by modellers who are aware of its implicit assumptions and those made about the modelling software.

AMENDMENTS

Ver	Description	Date
1.	First Published	May 1988
2.	Updated	October 1996
3.	Updated	March 2009