WAPUG SPRING MEETING 1989

TOWARDS AN IMPROVED SURFACE RUNOFF MODEL

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Why do we need a new model?

When the original WASSP surface runoff model was developed, it was not (fully) envisaged that it would be applied to city-scale catchments, or storms lasting several hours. The model was intended only for above ground flow, and all pipe-lengths were expected to be individually modelled (unacceptable?). It does not allow percentage runoff to increase during storms, and is (deliberately?) inflexible over allowing the user to specify runoff rates for the various surface types (including non-contributing). As incorporated within WASSP it cannot handle storms of longer than 8 hours (or time series/real time). Initial (depression) losses are not handled consistently. Percentage runoff estimation uses the Met.Office's ESMD which is now being replaced by MORECS.

Many of these problems have arisen from the separate databases used to define the surface volume and routing models. The volume model (PR lumped in space and time) was based on data from 17 catchments, of which only 3 were greater than 1 km^2, but 10 were less than 0.1 km^2. The PR equation is often criticised, but it is the way the PR information is 'disaggregated' that is the main problem. Few of these 17 catchments were used for routing studies; the routing model was based on data from short, sharp storms (≃15min) at gulley inlets (areas ≃ 200m^2). Longer storms were often divided, effectively masking variation in PR during storms. The routing model relates discharge to instantaneous flow depth in an iterative procedure, and for computational efficiency, subareas are restricted to one of 10 standard discharge-depth equations on the basis of surface type, size and slope.

None of the data analysed included the effects of storage tanks, overflows, pumping stations, sea outfalls, or large undeveloped areas. No data permit direct estimation of flows above about a 5-year return period. Much of the data pre-date MORECS. A database more representative of the problems is desperately needed. Any new model must be fully calibrated against observed data.

What form should a new model take?

The requirements of a new model are to:

(i) model above-ground response, but also (optionally) pipe flow (with surcharging), thereby allowing lumped areas (≃10ha) to be input to trunk sewers.

(ii) allow greater flexibility in runoff generation by different surface types, and also allow for inlet restrictions and bypassing. Overall PR should be matched.

(iii) allow time-series application, with rainfall losses varying in time, depending on some measure of catchment soil wetness.

What is being done?

W.Osborne discussed proposals for a new runoff model in WaPUG's spring 1988 meetings. This paper is an update. Sewerage accounts for 30% of Water Authority capital expenditure, but only the North-West WA combined with WRc and HR to fund these model developments. The original WASSP database has been re-constituted and extended to include daily rainfall series (for soil moisture accounting in time-series applications). However, no new catchment data has yet been included. Modelling analysis is now beginning.

The proposed model is based on a module comprising:

(i) a loss model - an infiltration/contributing area model (with parameters related to the status of a continuously updated soil-moisture store) feeding via depression storage to

(ii) a surface routing model - a non/quasi-linear reservoir, feeding

(iii) a storage-diversion model which splits the runoff between (a) the current sewer inlet, (b) local storage, and (c) enhanced rainfall or runoff on an adjacent surface/subarea.

Currently, each subarea is made up of three such modules in parallel, feeding (optionally) a secondary routing model to account for pipe routing and surcharge within the subarea.

The problem is to maintain user flexibility within a parsimonious parameter set. For example, the loss model will need at least three parameters, the routing model maybe two, while the suggested storage-diversion model involves up to nine parameters, coupled with several possible destinations for the diverted water. With three such modules, feeding a pipe model of say 3 parameters, a total of up to 45 parameters may be needed for each subarea. It would be impossible to calibrate such a model, and the effect of each parameter on the overall response would be largely unpredictable.

In practice, several parameters could be combined (eg. using the same soil-moisture store for each module, and perhaps each subarea), while many of the storage-diversion parameters might be physically defined (much as pipe lengths, slopes, diameters and roughnesses are).

Current interest is focussed on:

(i) Using a soil moisture model to control infiltration, and
(ii) Using a quasi-linear reservoir model for surface routing.

The original WASSP model uses the Met.Offices ESMD estimate as a state variable in the PR model. ESMD is evaluated daily (but a month or more in arrears) from extensive climatological data at a number of sites around the country. The nearest site may be some way from the WASSP catchment. The Met.Office also estimate SMD weekly (in near real-time) via the MORECS programme, which uses climatological, soil, and land-use data averaged over a 40km grid. Studies at IH have shown that local rainfall is vital to accurate SMD modelling, and suggest using a simpler sine-wave-evaporation with daily rainfall as input to a soil store model. Using such a model in WALLRUS would require daily rainfall from the start of the year, but a hybrid approach using perhaps a months rainfall to update from a MORECS starting value is being investigated. As part of this work, MORECS and ESMD values have been compared, showing a strong dependence on local SAAR, but with considerable scatter.

The non-linear routing model in WASSP is iterative, and takes perhaps twice as long to solve as a linearised version. To speed up the model, the non-linear reservoir was solved for just 10 standard size/slope combinations. This variation is not sufficient to cover current WASSP applications. A quasi-linear reservoir model is currently being investigated, with a depth-discharge ratio defined independently for each subarea. This ratio is allowed to vary globally depending on a moving-average rainfall intensity. The model will be calibrated on the enhanced WASSP data set, and compared with the existing model.

Runoff routing note

All runoff modelling is based on the continuity equation

Change in storage = difference between inflow and outflow

or (i) $\Delta S = (i - q)\Delta t$

or (ii) $dy/dt = -dq/dx$, upstream boundary condition=i

This is one equation in two unknowns (q and S-or-y). To solve we need another equation. The kinematic wave model uses (ii) with (eg) a Chezy equation, $q = Cy^{3/2}$, where C depends on surface slope (a more exact approach would use water surface slope). A simpler lumped approximation uses equation (i) with the reservoir equation $q = CS^n$. The non-linear reservoir links to the chezy equation by using $n=3/2$, but needs iteration for solution. The linear reservoir avoids iteration by (in effect) using a representative depth to define a fixed flow velocity. The proposed quasi-linear reservoir allows velocity to vary, but with the preceding rainfall intensity, which built up the current flow depth. The time-of-entry model also assumes a constant flow velocity, with storage given as a moving average of previous inflows.

WaPUG Forum

The Chairman asked the floor for suitable topics for the Autumn meeting.

The following were suggested :

Quality Assurance for model building, verification, flow-surveys

Methods of data collection.

Progress with WALLRUS and MOSQITO, and early experiences.

Post-construction monitoring.

Pollution Studies.

Review of European practice.

Flow-monitoring outside the flow and monitors for large-diameter sewers.

Case Studies of hydrobrakes and similar devices.

The Workshops at the Bournemouth meeting were popular, but some delegates said they would like to have been able to attend three out of five instead of two.

There was support for the idea of retaining the popular topics and possibly sub-dividing these further.

A discussion regarding WALLRUS took place, and following N Orman's paper there was considerable concern regarding the apparent failings of the new software. There was general agreement with a statement that WALLRUS must be acceptable before MOSQITO et al is introduced.