The Development of an Integrated Catchment Management Plan for the City of Perth

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ABSTRACT

An integrated catchment management plan (ICMP) for the City of Perth is nearing completion. This plan has been developed utilising the Urban Pollution Management philosophy. This philosophy involves modelling each part of the drainage catchment using computer packages to represent sewer hydraulics, sewer flow quality, treatment plant performance and river quality. An explicit river model was not deemed necessary for the Perth study. The calibration and verification of each model in the system is discussed whilst detail is given regarding the associated problems encountered during construction of MOSQITO. The ultimate goal is to utilise the UPM philosophy as a backbone for research activities to achieve optimum solutions to sewerage system inadequacies.

KEYWORDS

Integrated catchment management plan, urban pollution management, computer modelling, holistic approaches, MOSQITO, infiltration, STOAT, optimum solutions.

INTRODUCTION

The UPM(1) approach is being applied to the drainage system of Perth in Tayside. A catchment management plan will be produced within the bounds of the study and a strategy will be proposed for evaluating the environmental benefits(2) from sewerage rehabilitation schemes. One of the main reasons for the building of a hydraulic computer model was the large scale of proposed developments, in and around Perth. Before any commitment to this development could be given, the hydraulic performance of the existing system had to be appraised using the best available techniques to achieve reliable answers on which to base decisions. It was thought prudent to adopt the UPM approach and construct a catchment management plan to look at all the aspects of the drainage network. The project commenced in the autumn of 1991(3).

OBJECTIVES

- To develop a catchment management plan for the City of Perth so that integrated analysis packages can be used to identify areas within the drainage system which are subject to pollution and hydraulic inadequacies.

- To develop an environmental and economic appraisal methodology to highlight the benefits of sewerage rehabilitation schemes from a holistic perspective.

- To develop optimum solutions to problems utilising the methodology.

TSS and Ammonia. A sediment depth survey was also carried out to determine the existing distribution and depth of sediment within the sewerage network. All sewer flow and sediment samples were analysed by the Waste Water Technology Centre (WWTC) at the University of Abertay Dundee.

The standard approach in **MOSQITO** is to identify each sub-catchment land use. This can vary between domestic to industrial depending on the sub-catchment under consideration. The approach adopted for the Perth model was to model each of the sub-catchments as an individual land use as it was believed that even domestic catchments would have varying flows and pollutant characteristics. This was essentially an improved approach but, unfortunately, left no available land uses to define the flow and quality associated with each sub-catchments' varying infiltration. It was estimated that the infiltration in the Perth system, under dry weather flow conditions, was in the order of 25% (60l/s) of the average peak **DWF** and thus contained a significant dilutant potential. Infiltration therefore posed a problem for the data averaging process. For the purpose of 'averaging', the infiltration flows were assumed to be 'clean' and an assumption made that all pollutants analysed in the laboratory were associated only with the foul part of the flow. This resulted in higher foul pollutant concentrations being calculated than was being observed in reality. However, by inputting 'clean' infiltration into the model via dummy pipes this effect was balanced. Averaging data in such a way, in effect, considers the actual pollution associated with the infiltration⁽⁵⁾. This solution was bound within the capabilities and limitations of the model.

Ideally the concentration of the infiltration should be subtracted from the total concentration and input into the model as a separate flow type, however, insufficient land uses are available to allow this to be done. As each sub-catchment can have different infiltration quality extra land-uses are required. Defining an average value of infiltration flow and quality is unsatisfactory. Consequently the method adopted was the only possible solution.

It should be noted, however that when the ratio of infiltration flow to foul flow is identical to that at the sampling point throughout a subcatchment infiltration does not constitute a problem. When the ratio differs however the approach developed for Perth will model the effect explicitly. The accuracy of this method is dependent upon the identification of infiltration quantity and its point of entry into the sewerage system.

Dry Weather Flow Verification

Utilising this strategy the modelled flows at all sampling points were observed to follow the logged values closely.

Dry Weather Pollutant Verification

The sediment transport model was first verified before attempting to verify pollutant concentrations. This required to be done as sediments convey a pollutant load, thus unrealistic amounts of modelled fine sediment would give rise to unrealistic amounts of pollutants. Verifying the sediment transport model involved examining the amount of suspended solids passing the sampling points at each sub-catchment and at the outfall. After comparing the measured and predicted sedographs it was apparent that too little sediment was being modelled as excessive settling was occurring in a number of the sub-catchments. This problem was remedied by decreasing the default density of the fine sediment fraction. Following this calibration a suitable fit was obtained at the sampling points and the outfall site.

The next stage in the verification process was the verification of chemical oxygen demand. Initial runs showed poor fits between measured and predicted data sets as **MOSQITO** was very much over predicting this determinand. After close analysis of the data it was observed that the predicted dissolved **CODs**, at the sampling points, at the top of the sub-catchments, were in fact, very close to the measured total **CODs**. However when **MOSQITO** added on the attached value, calculated from defined potency factors, final correlation was poor. It was therefore evident that **MOSQITO** was using the input value, as a filtered value and then adding on the sediment-attached **COD** to provide the total. Filtered values for **COD** were therefore input into the **DWP** files and acceptable fits were

Measured and Standard data values - weekdays only

	Moncrieffe observed data	*Rannoch observed data*	*Current default data MOSQITO*	*Revised default data MOSQITO*
TSS (mg/l)	168	229	240	250
F.BOD (mg/l)	57.2	91	160	210
BODPF	0.625	0.458	0.56	*0.03
F.COD (mg/l)	220	300.9	190	455
CODPF	1.208	1.14	0.68	*0.1
Ammn (mg/l)	33.8	45.7	20	30
Time	*Diurnal Factors*			
9	1.304	1.344	2.04	1.67
10	1.219	1.045	1.54	1.48
11	1.159	1.01	1.19	1.38
12	1.123	0.848	1.07	1.2
13	0.777	0.964	0.94	1.08
14	0.72	0.726	0.86	1.03
15	0.994	0.749	0.9	1.01
16	0.944	0.795	0.94	1.01
17	1.152	0.717	1	1.1
18	1.164	1.145	1.07	1.12
19	1.174	1.322	1.09	1.13
20	1.027	1.011	1.06	1.14
21	0.915	0.936	1.08	1.09
22	0.836	1.103	1.11	1.04
23	0.961	0.996	1.22	1.09
0	0.716	0.817	1.17	1.1
1	0.329	0.645	0.99	0.89
2	0.232	0.227	0.61	0.64
3	0.163	no sample	0.41	0.48
4	0.171	no sample	0.25	0.4
5	0.317	0.539	0.26	0.34
6	0.672	0.701	0.43	0.44
7	1.146	1.156	0.76	0.64
8	1.282	1.333	1.81	1.29

Table 1

* Where potency factors have been reduced, filtered values have been increased to compensate(7).

When multiplying the Event Mean Concentration (EMC) by the diurnal factors to obtain actual DWF pollutant concentrations it can be seen that significant differences still exist between the measured and standard input data values.

It may be concluded that whilst standard values are useful for design, more accurate data are required when attempting simulation. The main reason for this being that as **MOSQITO** is not a precision tool, the use of non site specific data may make it very difficult to decide whether or not a model is actually operating in a form which correctly represents the catchment under consideration.

A sampling programme is currently underway to provide further verification data for the Perth model under storm flow conditions.

STOAT

Sleepless Inch Wastewater Treatment Plant was built in 1971 to deal with the City of Perth's wastewater. Previous to the commissioning of this plant all sewage was discharged to the River Tay from various outfalls(8). The plant is located to the South East of the City.

Verification

Verification of the model was achieved by running storms through the model and comparing observed and predicted pollutographs for each process under consideration. This verification was attempted by running five days of data, including the storm collected on the 19th April, through the model. Results for ammonia were good but results for TSS and BOD were grossly over predicted. The cause of the mismatch is believed to be due to the build up of MLSS in the aeration tank, which ranged from 1000mg/l to 1800 mg/l over the two week survey period. As the model was calibrated using a value nearer the higher end of this scale, initial conditions on the 19th April within the reactor were misrepresented. It is therefore believed that manipulation of the MLSS set point to an average value will achieve more satisfactory outputs from the model. This is currently being investigated.

RIVER MODEL

An explicit river model was not deemed necessary for the Perth study. This was due to the large assimilative capacity of the River Tay. To produce a flow and quality model of the River Tay would not have been cost effective. Simpler techniques will be utilised to examine the impact of any pollutant discharges on receiving watercourses in the Perth catchment.

APPLICATIONS

The models discussed in this paper are being used in research programmes based at the University of Abertay Dundee (UAD) as the buildings blocks of criteria/ methodologies to

- Allow the identification of optimum solutions to drainage problems with respect to hydraulics, quality, treatment, economics and environmental impact.

- Ensure that WTPs are not adversely affected by any upgrading/ remedial measures taken in the sewerage system to alleviate hydraulic/ quality problems.

CONCLUSIONS

MOSQITO

- Infiltration quantity and quality must be identified and modelled to facilitate accurate DWF simulation.
- An extensive UK data base will not improve the applicability of average default values.
- Sub-catchments of similar land use should not be assumed to contain similar DWF and DWP characteristics.
- Site specific data should therefore be used for calibration purposes.
- Verification at the outfall of each sub-catchment is recommended to facilitate global modelling accuracy.

These conclusions are applicable to deterministic sewer flow quality models in general.

STOAT

- Data collection was essentially trouble free due to intensive prior planning. Such an approach is recommended when attempting work of this nature.

- The model is currently partially calibrated and work will be carried out in the early months of 1995 to finalise calibration and verification of the model.

- BOD is grossly over predicted from the ASP under low retention times. This is a possible limitation of the model.