Modelling And Verifying A Small Urban Catchment Using WASSP

T.Cootes, D.J.Balmforth
School of Construction, Sheffield City Polytechnic, Pond St.
Sheffield S1 1WB

Introduction

As part of a project to monitor the performance of a Vortex Storm Sewage Overflow(1) in Sheffield, it was decided to make a model of the catchment upstream of the structure.

The area is about 55 hectares, with a 120m drop over the 2km length of the catchment (Fig.1). The higher areas encompass housing estates, the lower areas light industry and waste-land. Permitted industrial discharges into the sewers are from an abbatoir, an alloy casting firm, a tooling firm and a concrete company. However duing our work we have observed, and had equipment coated in, discharges of large volumes of thick oil, the source of which has yet to be tracked down.

The area is predominantly drained with combined sewers, but there are some small separate systems.

Building the WASSP Model

The approximate boundaries of the catchment were found from maps in the Main Drainage Department of Sheffield City Council. Some time ago a TRRL model had been made of the area, and the data used was obtained. By comparing the old map from the TRRL model with current sewer maps , the catchment boundary was more clearly defined. All the sewers in the area were traced from seven 1:1250 maps onto one large sheet. Manhole cover and invert levels were copied across, or obtained from the card index in the Main Drainage office. Most manholes on each map were numbered, and there should have been a card including details for every one. Of course, there were some that had either gone missing, or the manhole hadn't been surveyed, so educated guesses were made as to levels.

The system contained some 250 pipes, and was ripe for simplification. Consecutive pipes were grouped together, with nodes chosen

i) at end points,

ii) at branches,

iii) at large changes of gradient (where known),

iv) at manholes whose levels were known.

The last proved useful where levels were known for only a few manholes in a long series of pipes.

Driving round the system it was discovered that an area marked as terraced housing on the maps had been demolished and landscaped. Appropriate changes were made to the catchment map.

Using notes from the TRRL model, the latest sewer maps and visual examination of the catchment, runoff areas were ascribed to each defined pipe length. Areas were measured with a planimeter. The percentage impermeable and roofed areas were estimated from the maps and from site visits where appropriate.

The data on levels and areas was written onto standard WASSP data entry sheets, and a SSD file made up from this.

The area contained two storm sewer overflows, which had to be included. The details concerning these in the card index were limited to sketches of their layout, one without any dimensions at all. It was necessary to visit these structures.

With the assistance of our in-house sewer entry team the undimensioned overflow was surveyed. This turned out to be an oddly shaped stucture perhaps best described as a low side weir (Fig.2). It was found to contain a 2 meter steel bar and a crumpled up 'Keep Left' sign, which cannot have helped it's hydraulic characteristics. Measurements were made, and used to estimate parameters for the overflow ancillary data in the SSD file.

Both overflows seemed to spill into a surface water system, which is assumed to drain into either a canal or the nearby River Don.

When all the data was entered, the SSD file was run through WASSP-CHK and inconsistancies identified.

Verification of the Model

The model was run with a number of design storms to look for obvious problems, such as excessive flooding.

A pipe running from an industrial area seemed to be spilling large volumes. The area it drained was entirely impermeable macadam and roofs. Closer inspection of the site suggested that the macadam drained into neighbouring low lying wasteland. Adjustments were made to the impermeable areas used in the model.

It was decided to conduct a flow survey to compare the model predictions with measured flows during storm events.

Five monitor sites were chosen. These were selected so as to measure the flows coming from the 3 major sections of the catchment and to allow deduction of the flows into and out of the storm overflows (Fig.1).

The sites were

1) At the downstream end of the catchment,
2) Just upstream of where the Eastern area sewer joins the main trunk,
3) Just upstream of Storm Overflow (A)
4) On the downstream end of the pipe joining the SE area to the main trunk,
5) On the pipe joining the SW area to the main trunk, upstream of Storm Overflow (B).

Four Detectronics Flow Survey Units (FSUs) (Fig.4) and a Golden River 'Water Rat' flow monitor were used for the survey. Both types of device require a small sensor head to be fixed to the invert of the sewer, connected to solid state logging equipment hung in the manhole, as far from the sewage as possible. The sensor measures the depth with a pressure transducer, and the velocity is deduced from the doppler shift of ultrasonic pulses reflected from particles in the flow.

To get the best results the FSUs should be placed at the downstream of staight sections with subcritical flow, minimum turbulence and little silting[(2)]. In practise installation is often limited to those sewers which are accessable. A number of possible manholes were selected in the region of the desired sites, using the maps of the sewer network. Each of these were visited to choose the most appropriate. In some cases manholes marked on the map were inspection covers, too small for access to the sewer. Some covers hadn't been lifted for a long time and required gentle persuasion with a sledge hammer and crowbar to get them up. In one case the cover had become inextricably linked to the frame, and our efforts nearly lifted the latter out of the road. The Drainage Department came and replaced the cover when it was mentioned to them.

Site 3 proved to have a manhole ideal except that the sewer was more than 7m below the surface. As such it is defined as a deep sewer and required a 'Permit to Work' to enter. At that time we had only two technicians fully trained to work in sewers, which was too few to enter such a potentially dangerous sewer. To install and remove the sensor at this site we were joined by the Main Drainage Sewer Team.

The monitors were visited once a week to replace batteries, collect data and clean the sensor heads, which in some cases were prone to become 'ragged up'. Fortunately the sensor in the deep sewer remained faily clean, so we didn't have to call out the Main Drainage Team too often - we were able to maintain the logging unit which was hung at the top of the ladder, easily accessable from the surface.

Data was collected using an Epson HX20 Portable Computer, and transferred to an IBM PC in the office (Fig.3). Rainfall data was collected by two tipping bucket rainguages placed on flat-roofed buildings in the catchment. These were connected to Technolog 'Newlog' data recorders, the information from which was again transferred to the IBM via the Epson Portable Computer.

This data was processed using WRc's Sewer Survey Analysis Software (SSAS). This package allows data to be transferred from a variety of computers and data collection devices. The size and shape of each pipe with a sensor in it is entered into the program, and any calibration data required for the FSU's. The program then calculates the flows and depths from the raw depth and velocity readings. It converts rainfall data into rainfall hyetographs, and allows the display and output of rainfall, flows, depths and so on for events which can be defined.

The most suitable storms for verification can be chosen by inspecting the graphs.

A program was written to convert the output from the SSAS package into control files. These were transferred to the Polytechnic's IBM mainframe and run on WASSP. The results were plotted against the measured results using a Calcomp plotter.

Results

The initial flow survey lasted three months from mid-September to mid-December 1988. The FSUs at sites 1,2 and 3 had few problems during this time. However the units at sites 4 and 5 regularly broke down due to battery failures and water seeping inside the logger casing. In the few occasions the rainfall coincided with an operational logger the flow was rarely sufficient to give one any confidence in the readings. (A depth of greater than 150mm is recommended for good velocity readings)

Further attempts were made to get data from sites 4 and 5 at the beginning of 1989, but again were hampered by problems with loggers and the dry weather. Only one notable storm was recorded, at site 5. The predicted flows during this event were in good agreement with those measured.

The flows measured at sites 1-3 generally compared well with the WASSP predictions (Fig. 5-7), and the model was considered acceptable.

Since samples have been taken at the downstream end of the system, it is hoped to use the existing model as a basis for a MOSQITO model, to investigate how well that program can predict pollution loads.

Time spent on each stage of work

The work was carried out in parallel with setting up and beginning to monitor the vortex overflow at the bottom of the system. Estimates of the time spent on the WASSP modelling and verification are as follows :

Model Building :

Aquiring sewer maps and drawing one large map of the network	- 1.5 days
Tracking down manhole data and putting on map	- 3 days
Choosing pipe-lengths for WASSP network	- a few hours.
Driving round catchment	- 1 day
Defining and measuring areas contributing to each (WASSP) pipe	- 2 days
Measuring SSO	- 1/2 day
Putting data into a WASSP SSD file	- 1 day

Model Verification :

Selecting manholes for Flow Survey Units	- 2 days
Surveying manhole cover levels	- 1/2 day
Check calibration of FSU's	- 1 day
Installing FSU's and rainguages	- 1 day
Maintaining loggers & collecting data	- 1/2 day per week
Time spent removing, arranging for repair & replacing FSUs	- 1 day/month
Analysis of data & comparison with WASSP	- A few hours per event.

Note : We were fortunate in that good correlations occurred first time, so no major adjustments were needed.

Conclusions

A small catchment has been modeled using WASSP, and the model verified with a flow survey.

It took about 10 days of work to build the model (although these were spread over several months due to other activities), and about five days of work to set up the flow survey. Running the flow survey took around one to two days a week, depending upon weather and the state of the flow loggers.

A considerable amount of time was spent becoming aquainted with the equipment and techniques to be used early on in the project, but this would not have to be repeated should another model be built.

It is hoped to extend the current model to use the MOSQITO package.

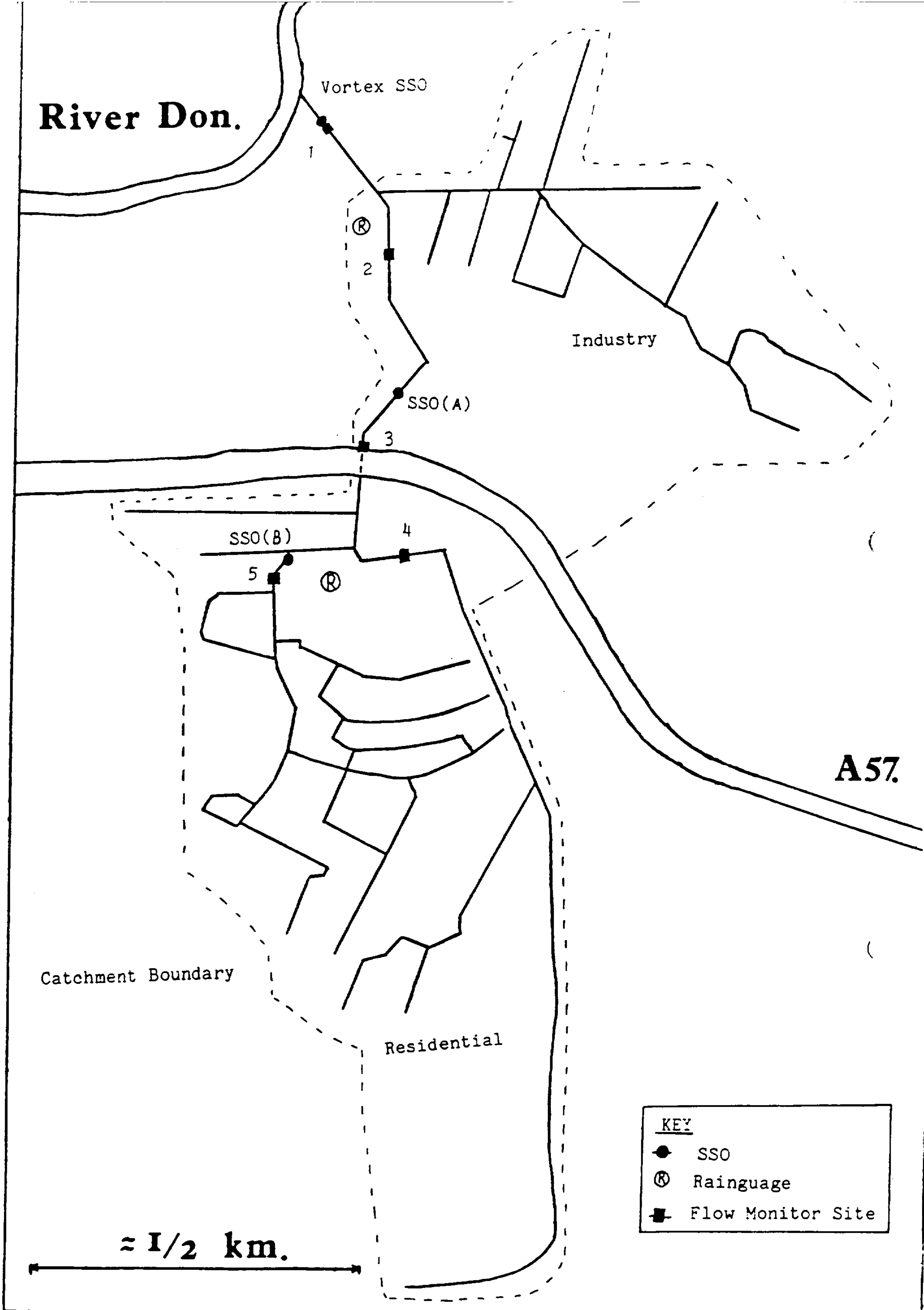
Acknowledgements

The authors would like to thank Sheffield Main Drainage Dept., WRc Engineering and Thames Water for their assistance in this project.

References

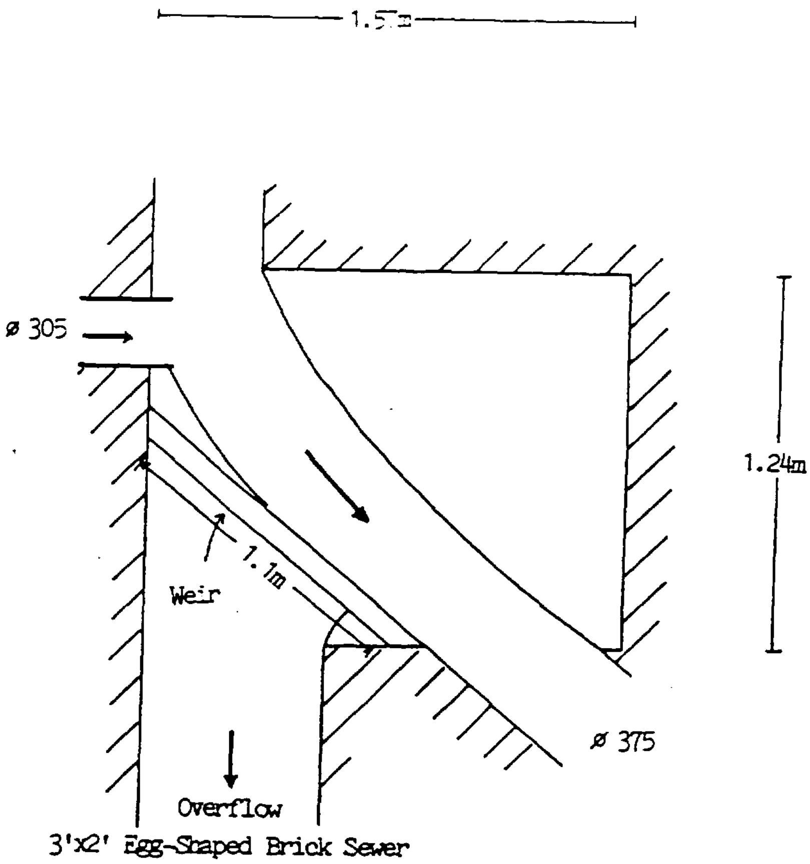
1) 'Monitoring a Vortex Storm Sewage Overflow With Peripheral Spill', Cootes et al., 2nd Conf. on Urban Storm Water Quality and the Ecological Effects upon Recieving Waters, Wageningen '89.

2) 'A Guide to Sewer Flow Surveys', Water Research Centre, Swindon.



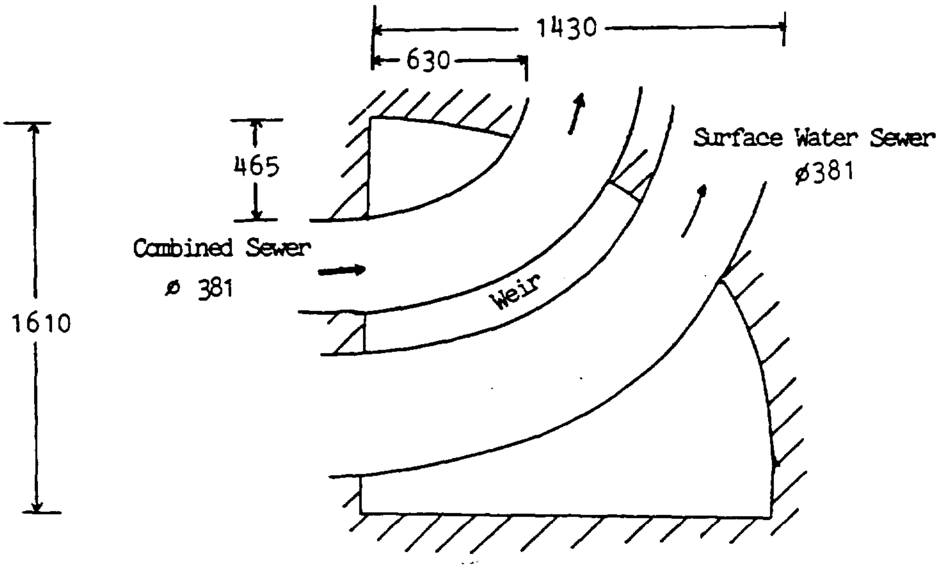
Bacon Lane Catchment - Sheffield.
Pipe Network Schematic.
FIG. 1

Based on a figure by
S.P. Gibson.



A) Woodburn Road Bifurcation

(Dimensions from data card)



B) Cricket Inn Crescent SSO

(Dimensions measured on site)

Figure 2 Storm Sewage Overflows in Bacon Lane Catchment

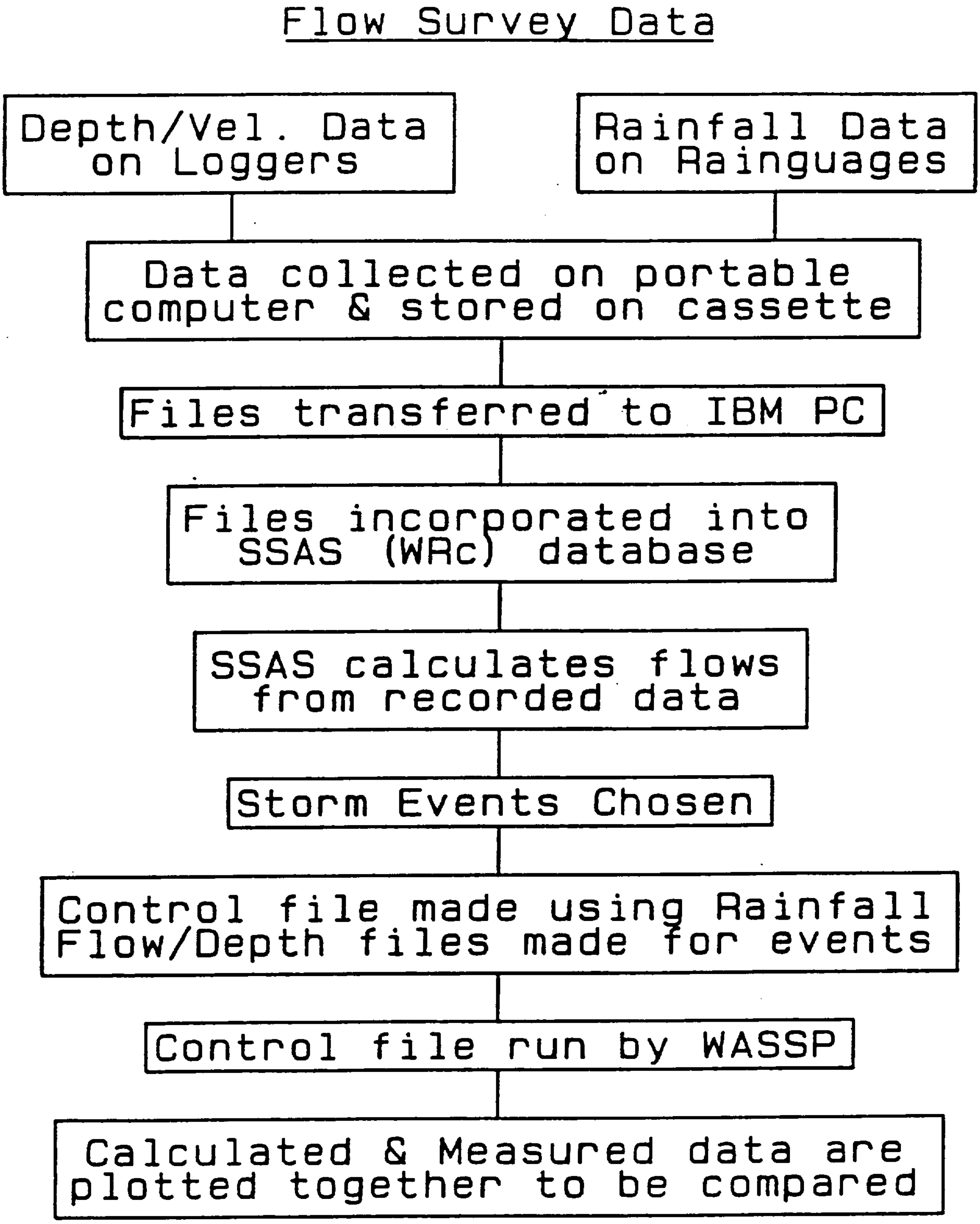


Figure 3 Path of data gathered for Flow Survey.

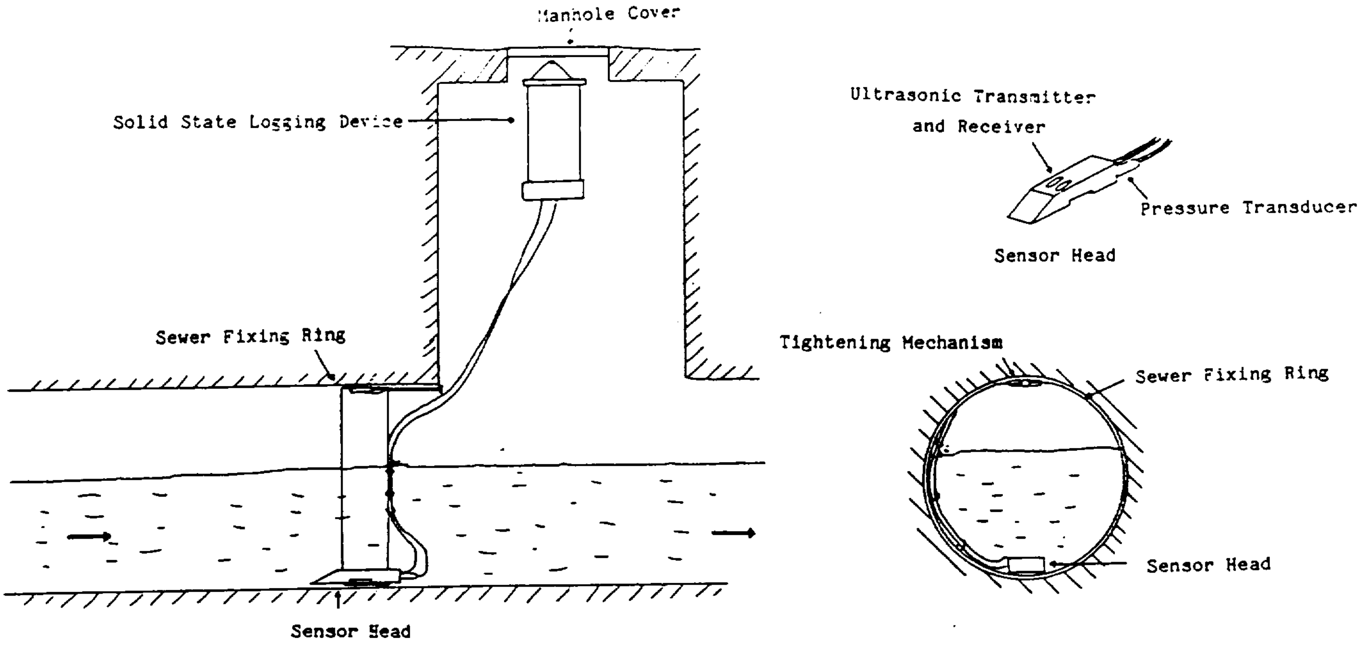


Figure 4 Typical Flow Survey Equipment Installation

DISCHARGE AND RAINFALL   BACON LANE CATCHMENT MODEL

MONITOR : 1   MEASURED PEAK= .260   MEASURED VOLM cu.m.= 1154.3

DATE : 11.10.88   WASSP PEAK = .199   WASSP VOLM cu.m. = 1040.6

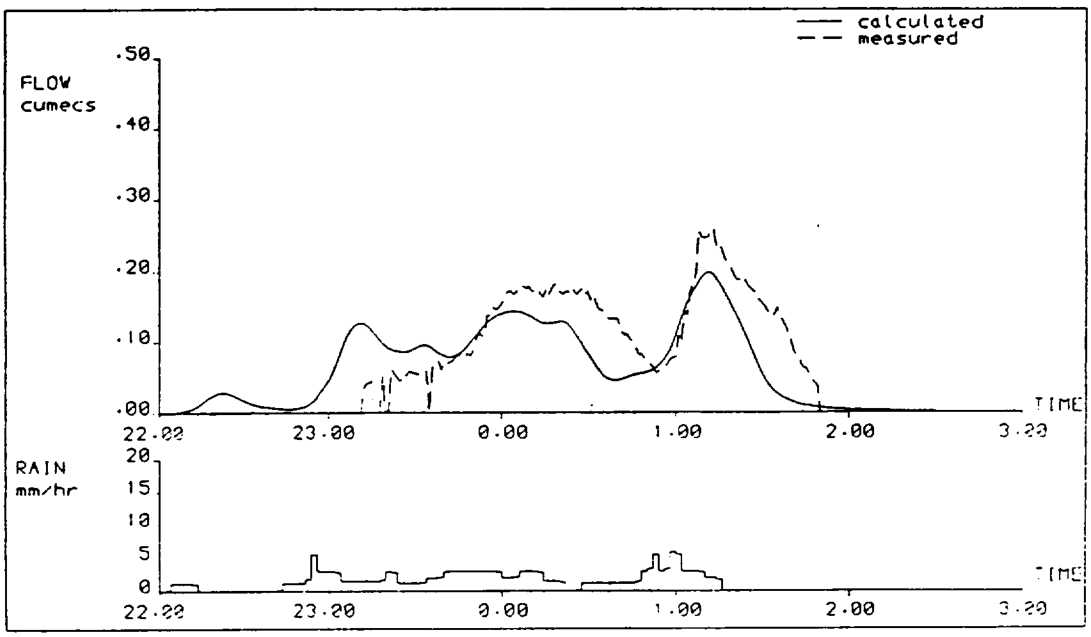


Figure 5 Comparison of WASSP prediction with measured flow at monitor site 1 (Bacon Lane Overflow).

DISCHARGE AND RAINFALL — BACON LANE CATCHMENT MODEL

MONITOR	: 2	MEASURED PEAK=	.118	MEASURED VOLM cu.m.=	52[illegible].0
DATE	: 11.10.88	WASSP PEAK =	.128	WASSP VOLM cu.m. =	54[illegible].2

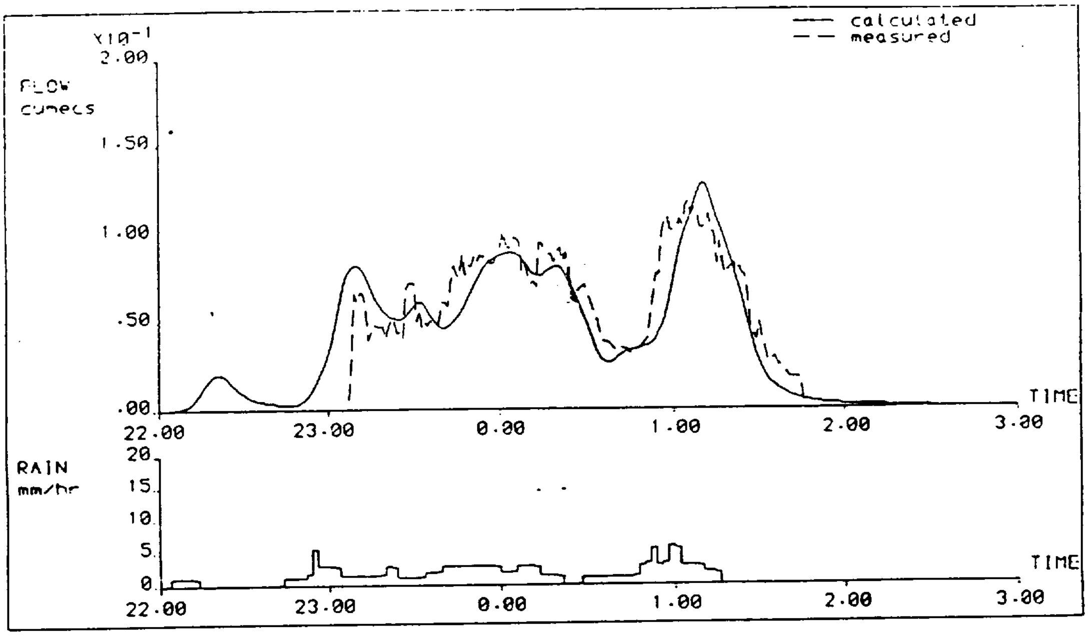


Figure 6 Comparison of WASSP prediction with measured flow at monitor site 2.

DISCHARGE AND RAINFALL — BACON LANE CATCHMENT MODEL

MONITOR	: 3	MEASURED PEAK=	.158	MEASURED VOLM cu.m.=	579.9
DATE	: 11.10.88	WASSP PEAK =	.124	WASSP VOLM cu.m. =	606.8

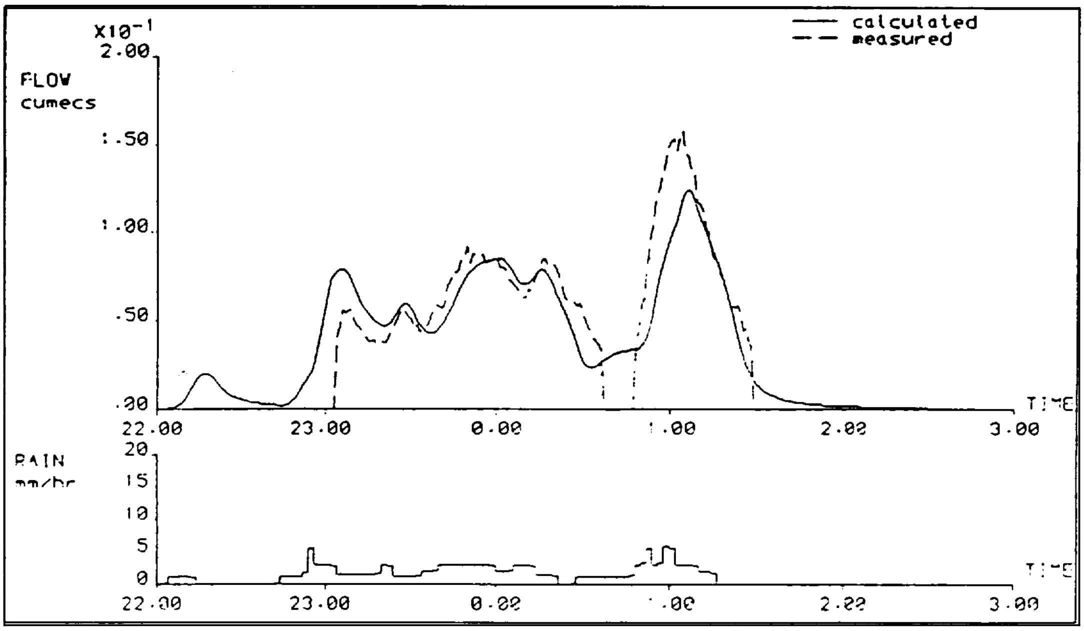


Figure 7 Comparison of WASSP prediction with measured flow at monitor site 3.

3.1 Modelling a small urban catchment
T. Cootes, Sheffield City Polytechnic

Don Prebble - Shepway D.C.

Was it absolutely impossible to survey the second manhole chamber, or would it have been useful to have done this?

Ans: It was difficult, and as the model showed good agreement with the assumed details, it was not carried out.

Richard Marshall - Sheffield C.C.

The overflow has since been checked by the City Council and is as shown on the drawings.

A Delegate

How were the loggers calibrated?

Ans: The water level was measured manually each week and the offset between this and the recorded value entered into the SSAS package which was used for the data analysis.

Lawrence Bailey - Severn Trent Water

What safety precautions were taken for the sewer work?

The Authors

The Polytechnic has a sewer entry team who have been on a training course and who have all of the required safety equipment including a winch. Theu follow a code of practice which is a very similar to the local authority one. The manhole would be coned off, a gas monitor used to check the atmosphere. For manholes deeper than 7m the local authority provided an extra back up team to assist. This was needed for one manhole in the study.