WALLRUS URBAN RIVER MODEL

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ABSTRACT

This paper illustrates a computer modelling case study of an urban river system in North London for National Rivers Authority, Thames Region. The study area of the Edgware Brook at Stanmore, North London has a long history of primary and secondary flooding. The paper describes the key elements of the study that investigated the causes of flooding through the construction and simulation of FRQSIM hydrological and WALLRUS hydraulic models. These models were used to represent the geographic, topographic and geological catchment parameters. Scheme designs were evolved to offer cost-effective solutions based on a clear understanding of the hydraulic systems.

INTRODUCTION

Bingham Cotterell was invited to investigate the causes of flooding, level of existing flood protection and to identify cost-effective improvement options. The flood events of May 1988, September 1992 and at least eight similar flood events since 1966 resulted in significant flooding of residential properties. The investigation identified the need for an accurate model of the hydrological and hydraulic systems to consider the existing system performance and to derive effective improvement options.

CATCHMENT DESCRIPTION

The Edgware Brook is a tributary of the River Brent that flows through Stanmore before joining Deans Brook to form the Silk Stream. The Brook rises in the grounds of Bentley Priory and flows in a south-easterly direction through open channels, culverts and Ponds before entering Wolverton Road Culvert and Wemborough Road Culvert. The Brook falls steeply from the upper reaches and flattens through the culverted sections of Wolverton and Wemborough Road.

Natural on-line attenuation is provided by undersized upstream culverts, natural ponds and local flooding. Off-line attenuation has been introduced in recent years by developers and the local authority as tank sewers and throttled outfalls

from public surface water sewers. Both On-line and Off-stream ponds also feature on the Edgware Brook system.

The 5.7km2 catchment area to the Wemborough Road culvert, is a mixture of rural grassland and developed areas. Rural areas include Bentley Priory, Grove Field and Cloister Wood in the north and a Golf Course and municipal sports ground in the south.

MODELLING

Accurate modelling of the hydrological and hydraulic systems was considered essential given the complex nature of catchment characteristics. Accurate predictions of peak flow and hydrograph shapes were considered important to model both replacement culverts and possible flood storage areas.

Site measurements and inspections were carried out on the existing culverts, channels and flood plain arrangements. River flows, soil moisture deficit and rainfall were monitored for model verification.

Hydrological Modelling

The FRQSIM hydrological model was used for this study. This model was developed by the Greater London Council and later enhanced by Thames Water Authority. The model is now used by National Rivers Authority, Thames Region and provides best estimate flood flow predictions for the Thames catchment area.

Several sub-catchments were identified based on the existing land drainage. These were grouped into seven sub-catchments providing seven representative input hydrographs to the hydraulic model.

FRQSIM uses a synthetic unit hydrograph approach based on time-area data. It uses three unit hydrographs to generate the total outflow hydrograph from a sub-catchment, these being:

- Paved areas
- Open Spaces - including riparian open spaces
- Other open spaces - Typically back gardens within the urbanised part of the catchment

Flow from each of the seven sub-catchments entered the hydraulic model at Node Points as input hydrographs representing the sub-catchment characteristics and a range of design storm events.

FRQSIM has a set of 250 rainfall profiles representing 100 years of flood producing rainfall. These were derived from an analysis of 30 years of autographic raingauge records from the London area. Ten basic profile shapes with durations ranging from four to over 30 hours were derived, and rainfall totals were selected so that the overall depth-duration-frequency statistics of the profile

set matched published figures from recorded data. The profile shapes included single, multi-peaked, symmetrical and skewed combinations.

Hydraulic Modelling

Various hydraulic models were considered to route the simulated flows. These included both river models and urban sewerage models. The steep upper catchment slopes, supercritical flows and many small conduits could not be modelled effectively by traditional river modelling packages.

WALLRUS was therefore chosen in the study to :

- o model the urban culverts
- o route the seven input hydrograph flows
- o route relatively long design events
- o predict surcharge levels and flooding in the study area.
- o route flows through the existing ponds.

This innovative approach allowed the benefits of the FRQSIM model to be combined with the accuracy of the WALLRUS package for this study.

WOLVERTON AND WEMBOROUGH ROAD CULVERTS

Wolverton Road culvert has been extended several times over many years. Presently, it is a Main River culvert of composite sections differing in both size and construction material. The smallest brick conduit measures 900mm diameter, while the largest concrete box culvert measures 1.8 metres by 2.25 metres. The culvert extends over 500 metres with a minimum cover of less than 300mm and maximum cover of 1.0 metre. This relatively shallow culvert surcharges and causes surface flooding when the conduit capacity is exceeded by flood flows.

Many service pipe crossings pass through the culvert and debris was also found in the invert of the culvert. These obstructions further reduced the capacity of the existing conduit.

Wemborough Road culvert is situated downstream of Wolverton Road Culvert. It has greater diameter, capacity and cover than the Wolverton Road Culvert.

A large municipal Sports Ground, Wemborough Road Playing Fields, is located between Wolverton and Wemborough Road Culvert, through which passes the Edgware Brook open channel.

RESULTS

The sub-catchment flood hydrographs were routed through the hydraulic model to first verify the models then simulate flood events for the existing and proposed improvements. Wolverton Road culvert was confirmed to be a significant hydraulic restriction. The maximum hydraulic capacity of the conduit was found

to be unacceptable with an estimated level of service of approximately three year flood return period. Flood flows more than the existing culvert capacity were conveyed overland by alternative routes to the Wolverton Road Culvert outlet.

Wemborough Road culvert was found to convey the flood flows satisfactorily although storm flows from sub-catchment No 7 were very responsive to intense short duration events due to the high level of urbanisation within this sub-catchment.

IMPROVEMENT OPTIONS

As the Wolverton Road culvert had insufficient capacity, a number of attenuation and culvert improvement options were considered. Both upstream and downstream flood storage options were considered as possible solutions in addition to increasing the existing culvert capacity.

Upstream Storage

Upstream flood storage in the existing Ponds was investigated. Insufficient flood storage volume could be provided in Bentley, Boot and Temple Ponds to reduce flood flows to the existing capacity of Wolverton Road Culvert even with regrading and altered outlet controls.

Increased Capacity of Wolverton Road Culvert and Downstream Storage

The optimum improvement option was found to be the provision of a parallel, larger culvert to Wolverton Road Culvert by an alternative off-line route. The optimum improvements were established through detailed Benefit/Cost analyses of a number of flood events through the existing arrangements and improvement options. The recommended solution conveyed flood flows and volumes downstream of the flood prone area. Unfortunately, the downstream river system could not accommodate the increased flows.

On-line flood storage was therefore introduced into the proposed system at Wemborough Road Playing Fields to attenuate the flood flows to existing flood flow rates. The proposed flood storage volume was to be contained by raising existing flood protection bunding at the downstream boundaries to the Playing Fields.

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WALLRUS Urban River Model
Alan McNaughton **Bingham Cotterell**

Question Dennis Dring Yorkshire Water Services

I am not sure about the adjustment of the values in the Middlesex Polytechnic cost model to get a more accurate Cost Benefit ratio. Was this because there was a problem with the property values?

Answer

Yes, the properties and building contents in the North London catchment had a much higher value then the HAZARD values, particularly the detached properties.

Question

Did you have problems justifying this?

Answer

The Client was aware of the possible discrepancy from other work and he commissioned an independent surveyor to assess actual damage values.

Question Roger Brown South Somerset District Council

Did you ask the Statutory Undertakers to remove the services in the culvert?

Answer

Our Client was informed. I am not aware if the services have yet been removed.

Question Jess Mann Thames Water Utilities Ltd

Were they any overflows discharging into the river system?

Answer

There were no known overflows, the sewers were separate.

Written Question John Packman Institute of Hydrology

Did you have any problems modelling the on and off stream ponds with WALLRUS? These ponds presumably had variable area-stage relationships (i.e. not fixed plan tanks),and different outfall controls (not drowned orifices). In particular was their performance tested at long return periods when they might overtop?

Answer

Ponds upstream from Wolverton Road Culvert were modelled as rectangular tanks as they have long weirs outlets. This simplication was found to give little loss of accuracy through the selection of representative pond areas.
The Wemborough Pond Playing Field Storage pond was modelled by an alternative software package which took account of stage-area and stage-discharge parameters.
A wide variety of events were considered. The containment bunding was designed with an emergency spillway arrangement.