NEW TOOLS FOR FLOOD LEVEL ESTIMATION - CONVEYANCE AND AFFLUX ESTIMATION SYSTEMS

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ABSTRACT
Accurate estimation of flood water level underpins almost all sectors of flood risk management. Two new support tools – the Conveyance Estimation System (CES) for river flow and the Afflux Estimation System (AES) for bridges and culverts – have been commissioned by UK flood management authorities to ensure that best available methods relevant to conditions in the UK are used for flood risk management. Commercial versions of river flow software incorporating the CES are being released in 2004. The AES will be available in 2005. Open code versions of the estimation systems will be made available to researchers and software developers so that they can work with the system and feed back improvements to other users.

1. BACKGROUND

User needs / practice

Uncertainty and poor accuracy in flood water level estimation increases the cost and risks in flood management. Water level estimation feeds into most sectors of flood risk management – strategic planning; flood forecasting and warning; design of improvement works and new schemes; operations and maintenance; planning and control of development. In its report on *Learning to live with rivers* (ICE, 2001) after the Autumn 2000 Floods, the Institution of Civil Engineers' Presidential Commission on technical issues of flood risk management drew attention to the importance of improving both the application of hydraulics to flood level estimation and the quality of the supporting models.

One of the main reasons for uncertainty and/or poor accuracy in flood level estimation is that there is a tendency among planners and designers to use their favoured river flow model as a "black box" which provides a definitive flood water level for a given flow. Obviously there are exceptions to this, and there are many good flood hydraulicians (if that's what they're called!) in the UK. However scoping work on current design and operational practice in 2001 showed that advances in understanding of flood hydraulics have not fed through into the design/planning process and that there is an undue dependency on outdated methods (e.g. Ven Te Chow, 1959 descriptions of hydraulic roughness).

Two further developments have influenced the call by leading planners and designers for new "decision support tools" for flood level estimation. First, vastly improved computing and data management systems are now available to support flow modelling. Second, flood management itself is moving to a risk-based as distinct from a deterministic approach. A risk-based approach must consider the performance of the flood management system under a range of flow conditions - for example flows in excess of the design standard; conditions when culvert or bridge openings are partially blocked; channel roughness at different states of vegetation growth / management etc. etc.

The Joint Defra / Environment Agency (EA) R&D Programme has therefore promoted a UK initiative, that involves researchers, software developers and end users, to develop improved decision-support systems for

(a) **conveyance estimation** to calculate the flow / depth / slope relationship in river channel and flood plain systems. *Conveyance* (K) is a function of flow cross-section, flow depth, and hydraulic roughness (e.g. Manning "n"). It enables flood level and/or flow depth to be calculated for given flood discharge in the river channel and flood plain.
(b) **afflux estimation** to calculate the difference in water levels upstream and downstream of a bridge or culvert . (*Afflux* can be defined as the maximum difference in water level caused by a structure at a location upstream in relation to the "without structure" flow condition).

Taken together, the conveyance and afflux estimation systems enable the water surface profile to be estimated along the flood route. While conveyance determines the general flow capacity of the river system, the local afflux at constrictions is often the trigger for localised flooding (e.g. upstream of a bridge in a town centre).

2. DEVELOPMENT PROGRAMMES

Two R&D projects, focusing respectively on estimation of conveyance and afflux, have been carried out under the Engineering Theme of the Defra / EA R&D Programme. The Scottish Executive and Rivers Agency, Northern Ireland have supported these projects so as to secure the UK ownership and relevance. The R&D Projects are:

(a) **Reducing uncertainty in river flood conveyance –** lead contractor HR Wallingford, two phased project running from early 2001 to mid 2004 to produce the new Conveyance Estimation System (CES). Project web site at www.river-conveyance.net.

(b) **Hydraulic performance of bridges and culverts at high flows** – lead contractor JBA Consulting, two phased project running from mid 2001 to mid 2005 to produce the new Afflux Estimation System (AES).

Attendees at the York Conference can find further details of these two projects and the relevant estimation systems at the contractors' stands in the Exhibition Area.

Each project has followed the same basic programme, namely to

- establish a network or contacts with researchers, practitioners and software companies;
- review current scientific knowledge, recent research findings, available data, and practice;
- synthesise this to produce overviews of best available guidance to practitioners;
- identify a focused (second phase) programme of research and development to produce a measured improvement in current practice, including new decision-support tools;
- carry out the Phase 2 programme to produce computer-based and paper outputs. This involves program development and testing to produce the new CES or AES, as well as development and user testing of commercial software.

Conveyance Estimation System (CES)

The approach taken in developing the CES was described in the paper on *A new conveyance estimation system* presented at the 2002 Keele Conference (Samuels et al, 2002). Key details are given below. The new CES will be available to users in mid 2004.

The project has been helped considerably by the EPSRC-funded Network on Conveyance in River and Flood Plain Systems through which large amounts of laboratory and field data, as well as scientific papers have been drawn together. This important activity – particularly the objective scrutiny of scientific advances by an independent group of users and scientists – has underpinned the major rationalisation that the project has produced in roughness and conveyance representation. Upward of 15 different approaches existed in the recent literature – quite an impossible range for the practitioner to cope with him or herself. Details of the reviews carried out can be seen on the project website.

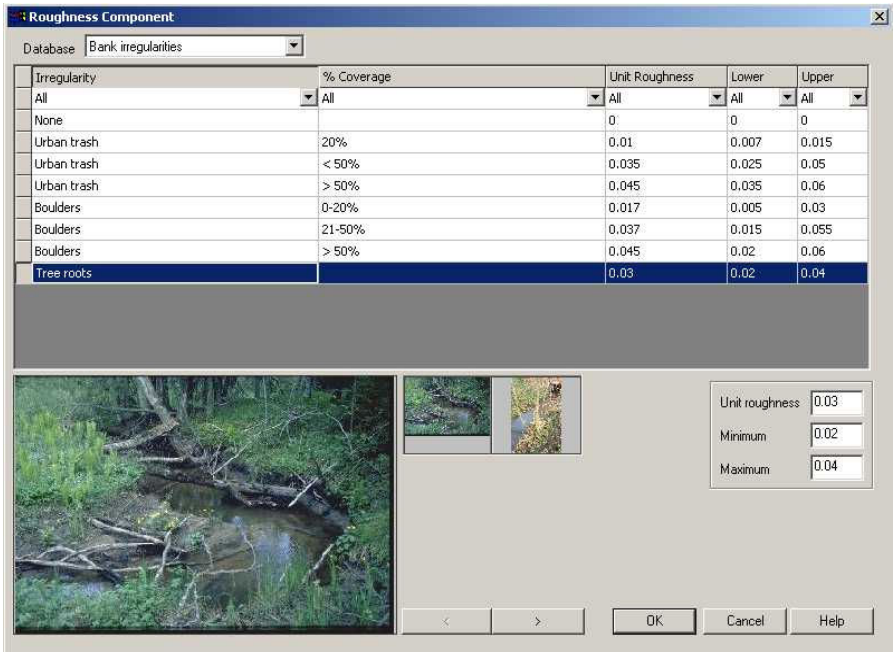
A key objective of the new approach to conveyance estimation has been to make the task of assembling information and of estimating hydraulic roughness and conveyance as logical and practical as possible for the user. The way that conveyance estimation is configured therefore had to be considered from a number of different viewpoints, and these are reflected in the outputs (see Section 3).

- **For scheme or channel design**, the new system had to able to be embedded into currently used commercial 1-D hydrodynamic modelling software such as iSIS flow, MIKE11 or HECRAS.
- **For channel maintenance**, the operations engineer wanted a simple stand-alone tool that was able to indicate the effects of reprofiling the channel (for example by dredging and/or cutting vegetation) on either the channel rating curve (i.e. the depth / flow relationship) or a simple backwater curve for given channel cross section and slope.
- **For bespoke application**, such as use in a flood warning system, the basic conveyance estimation tool had to be available for incorporation into the products of other software engineers and system designers.

The CES itself has three main components:

1. The **Roughness Advisor** for estimation of local hydraulic roughness due to surface material, vegetation or irregularities. This includes a major database of vegetation roughness compiled by the Centre for Ecology and Hydrology and not previously made available for flood management. The database also links into the UK River Habitat Survey (Raven et al, 1998) and will help to link flood risk management with river ecosystem management under the Water Framework Directive

2. The **Conveyance Generator** for improved calculation of flow conveyance. This makes significant advances in taking account of the complexities of real rivers – for example, shape and sinuosity, and dealing with the separate flood plain and main channel components of flow. The new approach is well suited for modern data management and computing systems.
3. An **Uncertainty Advisor** which provides a measure of confidence in the estimation.



Screen shot of Roughness Advisor, including (a) roughness range and (b) supporting photographs.

Afflux Estimation System (AES)
The Phase 2 project to produce the AES is currently in its early stages. The review of current knowledge, available data and practice showed that different methods are appropriate for estimating afflux in different situations (JBA Consulting, 2004). This is because bridges and culverts come in a multitude of shapes and sizes, and their geometry can interact with the flow and channel geometry in distinctly different ways. It will not be possible to derive a universal approach that fits all situations.

The approach taken by the Phase 2 project is:
- to synthesise and/or develop procedures that will adequately estimate afflux for the most common structure types and flood flow scenarios;
- to develop an advisor that indicates which method is best used in which circumstances;
- to produce a planning tool that will allow rapid comparison of the potential methods, and provides a clear visualisation of the parameters and steps involved in the afflux estimation;
- to produce a computer-based afflux estimation system that is compatible with the CES; and
- to identify the "special" circumstances in which afflux will need to be determined by a physical model or by complex 2-D or 3-D computer modelling.

A further issue that became clear in the review was that the potential effects of blockage constitute a major source of uncertainty in afflux estimation. This is mainly because insufficient data exists to predict the extent of trash movement in most catchments during floods. It is however essential to address the issue of blockage as an integral part of afflux estimation at any bridge or culvert. This in itself is a key reason why it is necessary to take a risk-based approach to afflux management.

Generic features
- Uncertainty
How best to address and indicate the various sources of uncertainty has been a common issue across both development programmes. (*Uncertainty* is quite distinct from either *Accuracy* or *Errors*). Uncertainty arises principally from lack of knowledge about some potentially relevant issue or from the inability to measure or calculate some relevant parameter (e.g. blockage of a culvert). A full framework for the combination of all the sources of uncertainty has yet to be established.

The approach adopted with the CES and AES is to represent uncertainty as upper and lower bands about the estimated mean water level. The paper on *A practical approach to uncertainty in conveyance estimation* (McGahey and Samuels, 2004) presented at the York Conference explains the issues addressed by the CES in detail.

- Advisory information
Both the CES and AES will incorporate a large amount of guidance that can be accessed either as hypertext files with the commercial software or as a separate paper or web documents. The front end of each system has to be relatively easy to use, with appropriate default settings. However, the systems will support more detailed analysis and provide extensive advisory information on request.

- Source code availability and future development
The funders have adopted an "open source code" policy with the CES and AES. The algorithms will be available as open code under licence either to bona fide researchers for further development or to software developers for incorporation into commercial river modelling software. In this way, it is hoped to involve a broad community of researchers and software developers in the ongoing development and improvement of these decision support tools.

3. NEW USER PRODUCTS

Related to conveyance
The principal user products from the project on "Reducing uncertainty in river flood conveyance" are:
- **CES** as a stand-alone software package through Wallingford Software to solve simple types of conveyance assessment (e.g. for maintenance operations, including backwater calculation module) and to support parameter selection in hydraulic models;
- **CES** currently implemented within iSIS flow 1-D hydrodynamic river modelling software
- **Conveyance manual** available either as a paper report or for web reference or downloading as a pdf file. The manual will also be available as hypertext in the software packages.
- **Training material** in the use of the software.

Related to afflux
The main user product from the Phase 1 project on "Hydraulic performance of bridges and culverts at high flows" is:
- **Review of current knowledge and practice** (JBA Consulting, 2004). Available either as a paper report or for web reference or downloading as a pdf file.

The Phase 2 project will produce through JBA Consulting in 2005:
- **Afflux advisor** as a stand-alone tool for rapid initial assessment of afflux.
- **AES** as a module, compatible with the CES, made available through (a) the stand-alone software package, and (b) implementation in iSIS flow and other commercial river modelling software.

All documents are available for reference or downloading over the Defra / Environment Agency web pages on outputs from the Joint R&D Programme (www.environment-agency.gov.uk/floodresearch).
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