Defra/Environment Agency
Flood and Coastal Defence R&D Programme

Benchmarking of hydraulic river modelling software packages

Project Overview

R&D Technical Report: W5-105/TR0

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Department for Environment
Food and Rural Affairs

ENVIRONMENT
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Defra/Environment Agency
Flood and Coastal Defence R&D Programme

BENCHMARKING OF HYDRAULIC RIVER MODELLING SOFTWARE PACKAGES

Project overview

R&D Technical Report: W5-105/TR0

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Statement of use
This document provides an overview of the Environment Agency's Benchmarking for hydraulic river modelling software packages. The test specifications and findings are intended to be a supplementary resource for Defra and Agency staff, research contractors and consultants, academics and students for assessing the applicability of any one of the tested software packages (ISIS, MIKE 11 and HEC-RAS) for their own modelling requirements.

It is intended that by the publication of the test specifications and datasets others will be able to carry out these tests, for one or more of the following purposes: by novice modellers as a training exercise; by vendors with updates of the packages tested; and by other software houses to test their products against those already tested. This report should not be considered in isolation and should be read in conjunction with the other tests reports produced as part of this R&D project.

Keywords
Hydraulic modelling, river modelling, software, benchmarking, test specifications

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EXECUTIVE SUMMARY

In 1997 the Environment Agency published its 'Benchmarking and Scoping Study of Hydraulic River Models'. Applying this benchmarking process enabled the Environment Agency to identify and apply best practice in the use and application of hydraulic modelling for flood level estimation.

Since 1997 the software versions previously tested (version date of 1995) have undergone significant upgrades, the most important being that HEC-RAS now includes an unsteady state module. During the same period the Agency has rationalised the software provided to its staff, leaving just three river modelling packages currently supported namely ISIS, MIKE 11 and HEC-RAS. Consequently and as a result of the ever-increasing demands for hydraulic river modelling by the Agency and its consultants and the increased number of flood risk assessments being carried out by smaller consultants, the Agency has undertaken this new benchmarking study. HEC-RAS is particularly attractive for the smaller consultants, being available to download free of charge from the internet, yet its capabilities were unknown.

A new generic test dataset and specification, which has built upon the strengths of the previous work (Harpin et al, 1995 and Crowder et al, 1997) has been devised to enable river modelling software packages to be benchmarked. The specifications provide a range of different tests that cover a broad range of modelling scenarios. A total of twelve test specifications are published specifically to provide methods of assessing a) numerical accuracy, b) model capability, and c) reproducibility.

Datasets for each test and for each of the three software packages covered by the project are also available on request from: FCERMscience@environment-agency.gov.uk These offer material for training exercises; allow software updates to be readily tested by using identical data to that used in the original tests; and give other software houses raw data to convert for use by their own packages.

The test specifications only assess a limited range of model capabilities and should be reviewed, updated and added to as new datasets become available and as software capabilities and needs develop. The publication of the test specifications and datasets will enable others to carry out these tests, for one or more of the following purposes:

- by novice modellers as a training exercise;
- by vendors with updates of the packages tested; and
- by other software houses to test their products against those already tested.
-

The results of the testing have identified the capabilities of the three software packages for a given set of prescribed modelling scenarios. In addition the project has identified where the software packages have very similar or diverse performances, and in some instances where their application should be considered with caution.

The specific test reports, which provide a succinct account of the test findings, should be reviewed/referenced when individuals wish to assess the applicability of any one of the tested software packages (ISIS, MIKE 11 and HEC-RAS) for their own modelling requirements.

The undertaking of the benchmarking study has led to a number of notable recommendations for further study and software improvements.

CONTENTS

1 BACKGROUND

1.1 Background to R&D project

The National Rivers Authority (NRA) initiated a 'Benchmarking Study' of hydraulic river models in 1993, with Stage 1 defining a series of tests for both steady-state and unsteady-state applications.

In 1995 Stage 2 of this project was initiated, which involved all river modelling packages then in use by the NRA being subjected to the tests defined by Stage 1 of the project. The versions current at the start of this stage of the project (September 1995) were used throughout the project, and comprised six steady-state models and five unsteady-state modelling packages. The project was completed under the Environment Agency in 1997, and the title amended to 'Benchmarking and Scoping Study of Hydraulic River Models' so as to reflect the overall substance of the study. Applying the benchmarking process has enabled the Environment Agency to identify and apply best practice in the use and application of hydraulic modelling.

1.2 River modelling packages currently used by the Environment Agency

Many of the eleven packages in the original test are no longer supported, and the others have undergone significant upgrades since the 1995 versions previously tested. In addition, the Environment Agency has since rationalised the software provided to its staff, leaving just three river modelling packages currently supported:

- ISIS
- MIKE 11
- HEC-RAS

Both ISIS and MIKE 11 are unsteady-state packages, which have been upgraded since 1995. A major change to HEC-RAS is that it is now has an unsteady-state module, so a direct comparison of its capabilities with those of ISIS and MIKE 11 is now possible.

1.3 The need for river modelling

There are ever-increasing demands for hydraulic river modelling in support of flood risk management by the Agency and other Flood Defence Operating Authorities together with the consultants working for them and other organisations involved in flood risk assessment. These needs cover a wide range of flood risk management activities - plans, strategies, flood risk mapping and assessment, flood alleviation scheme option appraisal and design, and operation and maintenance of rivers and channnels. The requirements of PPG 25 – Development and Flood Risk – mean that flood risk assessments have to be carried out for any development within the floodplain, and in many cases this requires modelling of a river reach.

Many such flood risk assessments will be carried out by smaller consultants, for whom HEC-RAS is particularly attractive, being available to download free of charge from the internet.

1.4 Need for updated testing

With the widespread use of HEC-RAS, and its recent ability to model unsteady-state flows, the Agency became concerned that the capabilities of this new package had not been tested, as apart from its use by the Agency's own staff, it was anticipated that large numbers of sites may be modelled using this package for flood risk assessments associated with planning applications. However, it was realised that the testing should not be of HEC-RAS alone, as the other two packages supported within the Agency had also undergone significant changes since the previous series of tests.

1.5 Principal funding

The project was funded and managed through the Engineering Theme of the joint Defra / Environment Agency Flood and Coastal Defence R&D Programme on behalf of the range of users described in Section 1.3.

1.6 Team members

The study was delivered through the following team:

Dr Chris Tomlin, Hydraulic Modeller, Environment Agency, Warrington
Dr Richard Crowder, Associate Director, Water Management and Planning, Halcrow
Dr Chris Whitlow, Director, EdenVale Modelling Services
Dr Andrew Sleigh, Lecturer in Civil Engineering, University of Leeds
Dr Nigel Wright, Senior Lecturer in Civil Engineering, University of Nottingham
Mr Andrew Pepper, External Advisor to Defra / Environment Agency Engineering Theme – Project Manager

2 TESTING PHILOSOPHY

2.1 Introduction

Software versions current at the start of the project (March 2002) were adopted for the new series of tests. These included the beta version of HEC-RAS Ver 3.1, from which there were no significant changes in the final version, released during the project period. At the start of the project it was ascertained that no significant upgrades to ISIS or MIKE 11 were imminent. The actual versions tested were thus:

Software	**Version**		**Developer**
ISIS	User Interface:	2.0 (13/01/01)	Halcrow /
	Flow Engine:	5.0.1 (27/06/01)	Wallingford Software
MIKE11	User Interface:	Build 5-052 (2001b)	DHI Water and
	Flow Engine:	5.0.5.5	Environment
HEC-RAS	User Interface:	3.1.0 (Beta) (03/02)	US Corps of Engineers
	Pre-processor:	3.1.0 (Beta) (03/02)	
	Steady Flow Engine:	3.1.0 (Beta) (03/02)	
	Unsteady Flow Engine:	3.1.0 (Beta) (03/02)	
	Post-processor:	3.1.0 (Beta) (03/02)	

One of the key reasons for undertaking the project was to assess the capability of the new unsteady-state mode of HEC-RAS. As indicated above, this package utilises separate engines for steady-state and unsteady-state flow computations. For those tests which specified steady-state conditions the models were used in quasi-steady state – i.e. using the unsteady-state mode with boundary conditions that were unvarying with time - as well as steady-state mode.

A reporting proforma was prepared as a number of different testers took part in the series of tests. The testers included postgraduates, who initially had training in the three different packages and were subsequently able to carry out testing work under the supervision of a team member. Adoption of this procedure avoided the risk that experienced modellers would automatically include their own ‘fixes’ for non-standard situations, and it was thus possible to highlight areas where the packages were lacking either a feature or an explanation.

Support from the testers came either from team members or the vendors’ helplines (albeit this was not available with HEC-RAS).

3 STUDY OUTPUTS

3.1 Introduction

Benchmarking can be undertaken in many different guises; however, the project considered that benchmarking of software should ideally embrace methods of assessing the following criteria:

- Numerical accuracy
- Capability
- Reproducibility
- Adaptability
- Form and function

A total of twelve test specifications were prepared as part of this study. These aimed at covering as many of the above criteria as possible.

3.2 Numerical accuracy

The numerical accuracy of a software package can only be assessed if an analytical solution exists for the physical situation/configuration that is being modelled, which for real world modelling probably never exists. However, for a number of contrived situations/ configurations there are known analytical solutions. The following four tests, which all have analytical solutions, were developed and undertaken:

Test A: Subcritical and Supercritical Flows – An assessment of the ability of the software package to calculate subcritical, supercritical and transitional flows and assess the numerical accuracy of the software packages with reference to analytical results.

Test C: Triangular Channel – An assessment of the capability of the software package to calculate the normal subcritical flow depth and the normal supercritical flow depth in a triangular channel.

Test E: Ippen Wave – A comparison of results generated by the software package with an analytical solution based on the hydrodynamic theory of tidal wave propagation in a horizontal channel of uniform cross-section and finite length.

Test F: Monoclinal Wave – An assessment of the ability of the software package to recreate the special case of unsteady flow, known as the monoclinal rising wave, as a typical case of uniformly progressive flow.

3.3 Software capability

The capability of a software package can be assessed objectively by testing the most commonly required features of a software package. For this project, the capability of the

software was been tested by the following "can do" tests, which were defined and undertaken specifically to assess capability:

Test B: Looped System – An assessment of the capability of the software package to calculate a diverging and converging flow scenario, i.e. a looped system.

Test D: Weirs – An assessment of the capability of the software package to model a Crump weir and broad crested weir.

Test H: Rules (Pumps and Gates) – An assessment of the capability of the software package to implement a rule based methodology to simulate the operation of hydraulic structures.

Test I: Side Spill – An assessment of the capability of the software package to model flow over an embankment (side spill).

Test K: Culverts – An assessment of the capability of the software package to model unsteady fluid flow in a circular culvert and the changes from free surface open channel flow to fully pressurised pipe flow.

Test O: Outfalls – An assessment of the capability of the software package to model flapped outfalls that are influenced by both tidal and fluvial boundary conditions.

3.4 Reproducibility

Reproducibility has been tested by a series of comparison tests i.e. numerical results have been compared with experimental or real world datasets, as follows:

Test J: Bridges – An assessment of the ability of each software package to model an Arch Bridge (Part A) and a US BPR Bridge (Part B) under steady boundary conditions and reproduce the flows as observed in experimental work.

Test L: Contractions and Expansions – An assessment of the ability of the software package to replicate the behaviour of a surge wave, caused by the sudden collapse of a large body of water, in a channel with a local constriction and expansion and compare the numerical results against laboratory results.

Note that three other tests, namely Tests G, M and N, were initially conceived as part of the project, but were omitted due to the need for further refinement and development.

3.5 Adaptability, form and function

A software package may excel at some or all of the above-mentioned tests, however without the ability to be adaptable or to have suitable form and function the user will potentially be hindered in its use. Any such assessment must, however, be subjective as users have different levels of experience and technical knowledge. Within this project only a limited assessment of on-line help and technical support, and error reporting and trapping has been

included. Other factors that affect usability, but which are beyond the scope of this project, include:

- Data management
- Data import and export
- Flexibility to incorporate user-defined controls/structures
- Integration with other modelling software/tools (including GIS)
- Principal outputs of the project

3.6 Test specifications

Specifications for all twelve tests of hydrodynamic river models were prepared as stand-alone documents for use by future testers, with the results reported separately. All these specifications have been placed on the webpages of the Engineering Theme of the Joint Defra / Environment Agency R&D Programme at www.environment-agency.gov.uk/floodresearch.

3.7 Datasets

Data files have been prepared for each test in an appropriate form for each of the three software packages (where possible). These files have also been placed on the Joint Defra / Environment Agency R&D Programme webpages at www.environment-agency.gov.uk/floodresearch.

3.8 Results of the R&D Project

The results of the testing have identified the capabilities of the three software packages for a given set of prescribed modelling scenarios. In addition the project has identified where the software packages have very similar or diverse performances, and in some instances where their application should be considered with caution.

However, most of the tests could be completed with reasonable satisfaction by all three model packages. The results of the testing were passed to the vendors for their comments, and in certain cases the report has been modified as a result of their comments. Detailed comments are written up in the test results.

A key finding, common across many tests, was the need to be aware of the potential problems in using default values of various coefficients and parameters in the model. In many cases it was found that the default parameters were inappropriate, although guidance on when to alter the default – and to what value - was often lacking.

3.9 Use of R&D outputs

It is intended that by providing the above information others will be able to carry out these tests, for one or more of the following purposes:

- By novice modellers as a training exercise
- By vendors with updates of the packages tested
- By other software houses to test their products against those already tested

The test specifications and test results are intended to be a supplementary resource for Defra and Agency staff, research contractors and consultants, academics and students for assessing the applicability and performance of river modelling software packages against defined best practice for their own modelling requirements.

If tests for upgraded or new packages are carried out appropriately, and have been independently verified, then the Agency will consider also placing those results on the website.

Since the commencement of this R&D study, the software packages that have been tested have had subsequent releases. The developers of the software packages have provided details of these releases and supporting information in Appendix A. The responses presented in Appendix A, are those received direct from the developers of the respective software packages with out any editorial change.

It is the opinion of the authors that some of the new updates stated by the developers are not new and that they were available in the test versions of the software. This is particularly the case for HEC-RAS. Furthermore, in the response for ISIS, statements are made about the InfoWorks RS user interface (UI). In the opinion of the authors this is an alternative UI to the ISIS numerical engine/software which was not available at the commencement of this study. If it had been available then it would not have been part of the testing as it is currently not supported by the Agency.

4 RECOMMENDATIONS FOR FUTURE R&D

Applying the benchmarking process enables the Environment Agency and others, particularly other Operating Authorities, to identify and apply best practice in the use and application of hydraulic modelling and as such should be considered as an ongoing and evolutionary process.

The specifications need to be enhanced and expanded in order to enable benchmarking of software as improvements and capabilities are made, and so as to consider more complex hydraulic issues and real-life modelling problems that are relevant to river management. This typically includes the following:

- hydraulic issues associated with planform (i.e. confluences, split flows and bends);
- use of hybrid 1D/2D, quasi-2D or 2D models (i.e. higher dimension models) for enhanced floodplain modelling (inundation modelling / flood spreading);
- logical rules (i.e. structure operation);
- hydrological boundaries (i.e. groundwater flow, evapotranspiration, evaporation, FEH inputs etc.);
- use of XML as a language for common data format; and
- effectiveness of water quality and sediment transport modules in hydrodynamic models.

In order to achieve the above, suitable field data will be needed so as to enable qualitative and quantitative benchmarking.

From undertaking the benchmarking study, a number of issues arose which were outside the scope of the project, but which the project team felt worthy further of investigation, in order to improve the accuracy of the hydrodynamic river modelling. These include the following:

- how packages handle interpolation – when it is needed, and what intervention by the modeller is required;
- whether the default weighting factors are acceptable, and under what circumstances they should be altered;
- use and relevance of the Courant number and appropriate time-step intervals;
- modelling of junctions - two methods can be used (water level or energy level balance), but it is not clear which is the more appropriate in different junction configurations. It may be necessary to carry out model or field tests to provide clear guidance;
- incorporation of new conveyance formulations, such as the new Conveyance Estimation System (CES) produced through the associated R&D Project ‘Reducing uncertainty in river flood conveyance’. This may also involve guidance on preparing and using conveyance tables; and
- incorporation of new afflux formulations, such as the forthcoming Afflux Estimation System (AES) being produced through the associated R&D Project ‘Hydraulic performance of river bridges and other structures at high flows’

The respective technical reports (W5-105/TR2 A to O) on each of the tests undertaken as part of this study provides an expanded comment on recommendations for future R&D and improvements to the modelling software tested.

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Harpin, R., Webb D. R., Whitlow, C.D., Samuels P., and Wark, J.B., (May 1995) Benchmarking of Hydraulic Models Stage One, Environment Agency Research and Technical Report, PR 508/ST/2

APPENDIX A SOFTWARE UPDATES

The responses presented in this Appendix are those received direct from the developers of the respective software packages without any editorial change. They record updates to the following versions that were used for testing.

Software	Version		Developer
ISIS	User Interface:	2.0 (13/01/01)	Halcrow /
	Flow Engine:	5.0.1 (27/06/01)	Wallingford Software
MIKE11	User Interface:	Build 5-052 (2001b)	DHI Water and
	Flow Engine:	5.0.5.5	Environment
HEC-RAS	User Interface:	3.1.0 (Beta) (03/02)	US Corps of Engineers
	Pre-processor:	3.1.0 (Beta) (03/02)	
	Steady Flow Engine:	3.1.0 (Beta) (03/02)	
	Unsteady Flow Engine:	3.1.0 (Beta) (03/02)	
	Post-processor:	3.1.0 (Beta) (03/02)	

It is the opinion of the authors that some of the new updates stated by the developers are not new and that they were available in the test versions of the software. This is particularly the case for HEC-RAS. Furthermore, in the response for ISIS, statements are made about the InfoWorks RS user interface (UI). In the opinion of the authors this is an alternative UI to the ISIS numerical engine/software which was not available at the commencement of this study. If it had been available then it would not have been part of the testing as it is currently not supported by the Agency.

Summary of Latest Revisions and Improvements to the River Modelling Software Packages used for Testing and Analysis within the Benchmarking Study

Section 1

Please complete Sections 3 through to 7 of this form according to the guidance notes provided. Do not change page margins, increase the size of the boxes or the overall length of the form. Only use Times New Roman font with font size 12.

Section 2

Version of the developers software used during the Benchmarking Study.

Developer	Software Package	Version	Release Date
Halcrow / Wallingford Software	ISIS (user interface) (flow engine)	 2.0 5.0.1	 13/01/2001 27/06/2001

Section 3

Please highlight all subsequent releases of any part of the software package and the corresponding release dates in the boxes below, starting with the most recent.

Software Package Element (i.e. user interface, flow engine)	Version Number	Release Date
InfoWorks RS User Interface Flow Engine	5.0 5.2	July 2003
ISIS User Interface Flow Engine	2.2 5.2	April 2003
InfoWorks RS User Interface Flow Engine	4.5 5.1	October 2002
ISIS User Interface (UI) Flow Engine	2.1 5.1	April 2002

Section 4

Using the space provided below and NO MORE please summarise the most significant revisions and improvements that have been made/included in the software releases named in Section 2. Do not include changes / revisions / improvements which are to be included in subsequent releases (including beta) of the software as section 6 provides you with the opportunity to mention these.

Changes, revisions and improvements may relate to any part of the software such as the graphical user interface (GUI), the numerical flow engines, software functionality (i.e. new structures, procedures etc.) and the data pre and post processors.

Your response MUST be limited to the space provided on pages 2 to 5 of this form. Please include any screen dumps, schematics or illustrations as appropriate, to support your text.

Summary of revisions and improvements:

The major revisions since ISIS version 2.0 (UI v version 2.0, Flow Engine version 5.0) are summarised by release version as follows.

InfoWorks RS version 5.0 (Flow Engine version 5.2)

Improved Network Object Creation - InfoWorks includes facilities for rapidly adding nodes and links to the GeoPlan View without having to name each object or view the object property sheet.

Editable GIS Layer Information - You can now edit data in external GIS layers that you have loaded onto the GeoPlan View.

Adjusting Replay Speed - You can adjust the time delay between timesteps when replaying simulations. The time delay is applied before redrawing the open network views for the next timestep.

Improved Hyperlinks - *Hyperlinks on Master Database Tree Objects.* You can now use hyperlinks on master database tree objects in the same way as you can on objects in your networks. This means that you can link to external files or internet addresses directly from any item in the database.

ESRI ArcMap Support - InfoWorks now includes support for ESRI ArcMap, which forms part of the new ArcView v8. You can launch ArcMap from within InfoWorks and carry out all the operations you can with ArcView v3.

HTML Format Log Files - Many of the log files produced by @@@APPPNAME@@@ are now displayed in HTML format. HTML provides far more scope for displaying the data in a structured way.

Validation - Network validation has been improved to include link and node overlay checking. If a link or node is effectively hidden on the GeoPlan View because it is completely overlayed by another link or node, then network validation will now warn you that this situation exists. *User Defined Validation using SQL. Comparison Based on Selection* The entire mechanism of comparing version controlled items has been improved. A new feature introduced in this version is the ability to compare just a selection of objects in a network.

Master Database Tree Improvements – *Sorting* You can sort items in the master database tree in a number of ways to make it easier to find the data you want. The sort options are ID, Name, Date and User. *Find Checked Out Objects* You can automatically open up all branches of your master database tree to show all version controlled items that are checked out.

Improved Polygon and Polyline Editing - You can now choose whether you want editing points in polygons or polylines to snap together when placed at the same

point. Snapped editing points can then be moved as if they are one point. Previously, snapping was always enabled. This made it difficult sometimes, to move or delete points independently if they were snapped to another point.

3D Terrain View - The 3D Terrain View allows you to view the ground surface of a network that has a ground model loaded on its GeoPlan View.

New Groundmodel functionality, including the ability to create a TIN Ground Model from a number of different data sources. *Converting Grid to TIN Format*: *Converting Raw Data to TIN Format.* You can create a new TIN ground model from a variety of data sources, including: network data from cross sections and spills another TIN ground model; a Grid ground model; MapInfo MIF files containing point data; ESRI Shape files; Text files. *Thinning TIN Data* You can reduce the size of a TIN Ground Model by removing a percentage of the points that it contains. *Hill Shading* You can use hill shading to emphasise the contours of a ground model displayed on the GeoPlan View. Hill shading simulates a light source (the sun) which you can point towards your model: *Grid Performance Improvement* The data for a Grid ground model is now stored in files instead of inside the master database.

New Network Object Types - InfoWorks RS includes two new boundary object types. *Rainfall Evaporation Boundary* & *Normal/Critical Depth Boundary* (see ISIS v2.2 for description)

Engineering Validation - InfoWorks now implements an additional level of validation for network data called Engineering Validation. Standard network validation mainly checks for data that will cause the calculation engine to fail. Engineering Validation allows you to check for data that falls outside sensible bounds, or simply makes no sense from an engineering point of view.
The available checks are fixed. You can set your own limits for these checks, assign them a priority level, or decide to ignore them completely.

Cross Sections - There are several improvements when working with cross sections. *Displaying Cross Section Direction* You can add arrows to each cross section on the GeoPlan View to show the effective direction of the cross section. *Showing Level from the Ground Model* You can display ground model levels at a cross section on the object property sheet as long as a ground model is loaded on the GeoPlan View. Missing values, or values that are significantly different from the model, are shown on the grid with a coloured border. *Rotating Sections.* InfoWorks now provides a tool to help you do this. *Cross Section Interpolation* InfoWorks includes tools for creating new cross sections by interpolation between existing cross sections. You can: create a single interpolated section at a specific point between two existing sections; create a series of interpolated sections at intervals along an existing sub-reach. The tools create a new section by generating x,y points to allow interpolation between the x,y points on the existing sections. *Highlight Currently Viewed Cross Section* When viewing cross sections, you now have the option to highlight the currently viewed cross section on the GeoPlan View. This means that when you step through adjacent cross sections, you can easily see which cross section you are currently viewing. *Improved Cross Section Comparison* You can compare cross sections with one or more adjacent sections, or with another section anywhere in the model.

Generating Flood Depth Grids - You can now generate grids of flood depth data at any point in the flood mapping model. This feature is in addition to the existing graphing functionality

Improved Simulation Comparison - You can now compare simulations that use networks that have changed. In the past you couldn't compare simulations if any network objects had been added or deleted, or had their names changed. Now, simulation comparison will continue to work normally. Any objects that exist in one network but not the other are simply ignored for the comparison.

Colour Coding of Simulation Results - The simulation icons are colour coded to provide information on the outcome of the simulation. Colour coding has been extended and there are now six colours used to help you see the status of each simulation.
Volume Balance Report - InfoWorks allows you to generate a volume balance report detailing the approximate volume of water in a sub-reach. The report also includes **Cumulative Inflow** and **Cumulative Outflow** data so you can make volume balance comparisons. By default, InfoWorks generates volume balance information for the start and end times of the simulation. However, you can choose to generate volume balance data at intervals during the simulation if you want.
PDM Hydrograph on Property Sheet - You can now view the PDM Hydrograph in both grid and graphical form on the PDM Boundary property sheet.
Velocity Profile Reports - The Velocity Profile Report provides a detailed breakdown of Section Flow and Section Bulk Velocity for one or more selected cross sections. These values are provided at each timestep for the section as a whole, and for each individual panel that makes up the section.

ISIS v2.2 (UI version 2.2, Flow Engine version 5.2):

New lateral inflow unit introduced so that an inflow boundary hydrograph, hydrological boundary unit or a rainfall boundary can be applied to any number of receiving river or reservoir units. The method allows for variable weighting of inflow hydrographs, or distribution proportional to reach length, or by surface area in the case of a rainfall boundary.
New rainfall/evaporation boundary by which the modeller can specify a time series of rainfall and/or evaporation and/or infiltration to apply across the surface (or specified area) of a reservoir or river unit.
New Normal/Critical downstream boundary unit where the modeller can apply normal depth or critical depth at a downstream boundary, removing the need to explicitly calculate a finite rating relationship.
New breach unit introduced, which allows for a time-varying breach to be applied to an existing spill unit.
Easy conversion from an eight-character node label model to a twelve-character node label model. Although each has been independently compatible with each version of ISIS since the 12-character node labels were introduced, the two could not be easily merged. This conversion utility facilitates this.
Flow engine is now compiled in a FORTRAN 95 compiler which has resulted in speed improvements and a new, improved design of the run-time graphics.
Low-flow wavespeed smoothing available with Muskingum routing units.
Loss calculations can now apply to either total head or static head in the culvert inlet/outlet loss units (previously used static head only).
Multiple simulations using the same data file are now allowed.
Path names of ISIS files are no longer restricted to 120 characters.
Event data files (*.ied) can be edited from the UI.
Section data can now be inserted on pasting (as opposed to overwritten, as previously) in the UI.
MrSID layer files now supported in the GIS Visualiser.
Search path for layer files not found by the GIS Visualiser introduced.
MUSK-RSEC routing unit now generates a correct Q-H relationship.
Reservoir units no longer add volume during pseudo-timesteps at the beginning of an unsteady run.
Modular limit field reinstated on spill property form.
Warning messaging on closing the form if the form has changed now fully

implemented.
Importing a unit with a duplicate node label no longer necessary renames it.

ISIS version 2.1 (UI version 2.1, Flow Engine version 5.1):

New visualiser introduced with the ability to display background layers, improved pan and zoom functionality, directly editable coordinate display window.
New run forms interface introduced, including saveable run parameters, batch run facility, "plug-in" boundary and moveable structure units, snapshot output files, user-definable results and initial conditions file names, run history log file and time/date facility.
Probable maximum flood capability introduced into the FEH hydrological boundary unit.
Channel and reservoir volumes calculated.
Number of data pairs in boundary units and length of logical rule strings increased.
Coordinate extraction facility from section data into visualiser introduced.
Tabular postprocessor parameter file now saveable.
Utility to convert Microdrainage hydrograph output files into ISIS hydrograph input unit.
Option to remove superfluous data from river and spill sections improved.
Division by zero (area) check introduced so that zero wetted area now implies zero velocity.
Bug fix for rectangular or sprung-arch conduits followed by a replicate unit.
Direct (steady) method now applies flow values in the interior sections of Muskingum routing reaches.

Section 5

Using the space provided below please make reference to any websites, published material or other sources of information (i.e. a point of contact) which can be accessed to obtain more detailed information on the changes highlighted in Sections 3 and 4.

Contact Details
Website:
www.isis-software.co.uk
Email:
sales@wallingfordsoftware.com
support@wallingfordsoftware.com
ISIS@halcrow.com

Section 6

Using the space provided below please list any improvements to the software that you are currently working on or have future plans for and give timescales for their release.

The following are all planned for implementation in the next release of ISIS (v2.3) scheduled for April 2004:

Measures taken to improve the resolution of bridge section data as highlighted by the Benchmarking study.
Implementation of the new Conveyance Estimation System for estimating conveyance in natural channels.
Wind shear stress term added to the St Venant equations.
Optimal Storm Duration tool for FEH hydrology introduced.
Increased number of output variables available to the modeller, such as wetted perimeter, area, volume, structure velocity.
Further user-selectable options to improve robustness, such as simplifying terms in the St Venant equations at low depth and performing enforced matrix refactorisation at regular intervals.
Most array variables within the ISIS Flow engine now stored as FORTRAN 95 dynamic arrays, therefore removing many of the constraints regarding data size, and also making the engine run more efficiently.
"Warm-up" start option available.
Rainfall boundaries may apply directly to rivers or reservoirs, without the need to be connected via a lateral inflow unit.

Within the ensuing year, an updating/forecasting mechanism based on aligning simulated and measured data will be introduced for real-time forecasting purposes.

In addition to the above enahncements new tools for automated model building, import and export from/to AutoCAD and statistical analysis of results will be come available in InfoWorks RS v5.5, scheduled for release during July 2004.

Section 7

Please add any further comments with regard to the software package and the changes highlighted which you feel have not been addressed in this form.

Form completed by : Tyrone Parkinson & Konrad Adams……..……...
On behalf of : Halcrow & Wallingford Software..……..…(Company)
Date 9th March 2004……..……

Summary of Latest Revisions and Improvements to the River Modelling Software Packages used for Testing and Analysis within the Benchmarking Study

Section 1

Please complete Sections 3 through to 7 of this form according to the guidance notes provided. Do not change page margins, increase the size of the boxes or the overall length of the form. Only use Times New Roman font with font size 12.

Section 2

Version of the developers software used during the Benchmarking Study.

Developer	Software Package	Version	Release Date
DHI Water and Environment	MIKE11 (user interface) (flow engine)	 Build 5-052 5.0.5.5	2001b

Section 3

Please highlight all subsequent releases of any part of the software package and the corresponding release dates in the boxes below, starting with the most recent.

Software Package Element (i.e. user interface, flow engine)	Version Number	Release Date
User interface and flow engine	2003b	Oct 2003
User interface and flow engine	2003	May 2003
User interface and flow engine	2002b	Nov 2002
User interface and flow engine	2002	Aug 2002

Section 4

Using the space provided below and NO MORE please summarise the most significant revisions and improvements that have been made/included in the software releases named in Section 2. Do not include changes / revisions / improvements which are to be included in subsequent releases (including beta) of the software as section 6 provides you with the opportunity to mention these.

Changes, revisions and improvements may relate to any part of the software such as the graphical user interface (GUI), the numerical flow engines, software functionality (i.e. new structures, procedures etc.) and the data pre and post processors.

Your response MUST be limited to the space provided on pages 2 to 5 of this form. Please include any screen dumps, schematics or illustrations as appropriate, to support your text.

Summary of revisions and improvements:

VERSION 2003/2003B

Boundary Editor
A new and completely re-designed boundary editor has replaced the previous version. The boundary editor is no longer divided into HD/AD/ST tab pages, but all are integrated into an intelligent single page editor, which provides efficient data entry features and a number of useful new boundary types. The new boundary editor allows any timeseries to be scaled and distributed along a river reach, which is useful for catchment inflows. Q-h boundaries can also be automatically generated based on a Manning formulation (using cross section data) or assuming critical flow conditions.

Cross Section Editor
The editor now allows the user to tag a cross section, and subsequently to perform actions on all or selected cross sections, including plotting, deleting, copying, processing, exporting etc. A new feature allowing for plotting multiple cross sections on screen, printer or metafiles is available.

Network Editor
- A new feature for automatic re-calculation of Q/h relations in all weirs, culverts and links channels has been added.
- Background images now include JPEG and ArcView Shape files. The feature for loading and managing background images is now similar that used elsewhere in MIKE Zero.
- Once loaded as a background, the information in a Shape file can be used to auto-generate points and MIKE 11 river branches.

HD Editor/Engine
The energy equation is now available as an option for steady state calculations. This makes it possible to carry out steady state calculations compatible with the HEC-RAS steady state analysis.

Water Quality using ECOLab
The previous water quality modules (WQ/EU/HM) have been replaced by a modelling tool called ECO Lab. This is a generic tool working with MIKE 11,

MIKE 21 and MIKE 3. ECO Lab allows the user to define their own water models (components, processes, etc) or to use one of the pre-defined water quality models provided by DHI. There are a range of pre-defined models (or templates) available corresponding to the WQ/EU/HM modules previously available.

Simulation Editor/Engine
An adaptive timestep has been introduced, which will automatically adjust to a number of user defined conditions, such as the rate of change of boundary conditions and/or simulated water levels and discharges as well as the Courant number. The timetep can also be pre-specified by the user in tabular format.

Flow Engine
An alternative option for the suppression of the convective acceleration term in the momentum equation has been added. However, the old option is used as default. To activate the alternative option use the switch called ALTERNATIVE_CONV_SUPPR_FOR_FULLY_DYNAMIC in the MIKE11.INI file. The alternative option improves stability in particular at transitions from steep to flat slopes and vice versa. However, the simulated water levels and discharges do change and care should be taken when applying this option on a model which is already calibrated.

VERSION 2002/2002B

MIKE Flood.
This is a unique modelling system that couples the MIKE 11 and MIKE 21, for flooding and storm surge analysis. MIKE FLOOD makes it feasible to model flood plains and coastal zones in 2D, while at the same time modelling the river system in 1D. This also makes it possible to put computational effort into modelling areas of special interest in greater detail with 2D while using the less computationally heavy 1D model in other areas.
The coupling to MIKE 21 adds to the existing possibilities for coupling. This also includes MOUSE and MIKE SHE which are DHI's modelling systems for piped networks and sub-surface flows (unsaturated flow and ground water).

Pumps
Through the structure operation module simulation of pumps has been available since version 2000. However, to facilitate simulation of pumps in the standard HD module and to allow for quick and easy specification of pumps, a new feature dedicated to modeling pumps has been developed. With this feature you can model pumps in different levels of detail. The approaches range from specifying just a start level, a stop level and a pump rate to more complex levels including specification of the pump acceleration and deceleration times, a pump head-discharge curve and an outlet level. The latter is used to automatically switch between drowned and free flow at the outlet.

User Written Code Module
With this module a user can program his own flow calculation routines if the structure types available in MIKE 11 do not cover the present needs. This could be for example the release from a reservoir being regulated according to a set of very specific and local operation rules. With the UWC module a user can write his own source code and compile it into a DLL which MIKE 11 calls initially and at each time step for each UWC structure. The information passed from MIKE 11 to the

user written code allows for accessing a large range of MIKE 11 state variables such as water level, discharge, volume, area, velocity etc in any grid point. DHI has developed UWC for a number of unusual structure types, including flap gates where the mass, rest angle and buoyancy of the gate is taken into account.

MIKE 12
Using a two-layer approach MIKE 12 simulates density stratification as a result of a significant vertical variation in temperature or salinity. This module was previously available in the former generation of MIKE 11 and thus the computational procedure is well proven and has been applied on a number of reservoirs and estuaries. MIKE 12 provides a valuable alternative to the full 2D vertical solution technique applied in the MIKE Reservoir module.

Flood Estimation Handbook
The Flood Estimation Handbook was introduced in the UK in 1999 by Centre of Environment and Hydrology (CEH) to replace the previous Flood Studies Report (FSR) methods for flood estimation in the UK. The MIKE 11 FEH module is an implementation of the rainfall-runoff procedures defined within Vol. 4 of FEH. The FEH module reads catchment descriptor data from the FEH CD-ROM, and allows the user to compute T-year, PMF and observed events for any number of catchments simultaneously. The results are generated as MIKE Zero result files which can be applied as point inflows to MIKE 11 or scaled and distributed along a river reach using the new boundary editor.

Section 5

Using the space provided below please make reference to any websites, published material or other sources of information (i.e. a point of contact) which can be accessed to obtain more detailed information on the changes highlighted in Sections 3 and 4.

Web site for DHI Software Product: http://www.dhisoftware.com

Point of contact: software@dhi.dk

Section 6

Using the space provided below please list any improvements to the software that you are currently working on or have future plans for and give timescales for their release.

ArcGIS Integration
The add-on GIS tools which MIKE 11 offers as ArcView 3.X Extensions are being re-designed and re-developed within ArcGIS 8/9. This includes 1) MIKE 11 GIS for cross section extraction and flood map generation (to be released later in 2004) 2) MIKE Flood Watch for real-time flood forecasting (already released)

Usability
A significant portion of the development effort to be spent in 2004 will go towards improving the usability of the software. Newcomers will get started quicker and experienced users will carry out their modelling projects more efficiently.

Coupling to other DHI models
The ability to dynamically couple MIKE 11 to other DHI software products has been a priority at DHI for some years. In 2004 MIKE Flood (which is the combination of MIKE 11 and MIKE 21) will be further developed to provide additional options for the coupling and to improve the graphical user interface.

Section 7

Please add any further comments with regard to the software package and the changes highlighted which you feel have not been addressed in this form.

None

Form completed by: Morten Rungø.....
On behalf of: DHI Water & Environment.....(Company)
Date: 4th March 2004.....

Summary of Latest Revisions and Improvements to the River Modelling Software Packages used for Testing and Analysis within the Benchmarking Study

Section 1

Please complete Sections 3 through to 7 of this form according to the guidance notes provided. Do not change page margins, increase the size of the boxes or the overall length of the form. Only use Times New Roman font with font size 12.

Section 2

Version of the developers software used during the Benchmarking Study.

Developer	Software Package	Version	Release Date
US Corps of Engineers	HEC-RAS		
	(User Interface)	3.1.0 (Beta)	(03/02)
	(Pre-processor)	3.1.0 (Beta)	(03/02)
	(Steady Flow Engine)	3.1.0 (Beta)	(03/02)
	(Unsteady Flow Engine)	3.1.0 (Beta)	(03/02)
	(Post-processor)	3.1.0 (Beta)	(03/02)

Section 3

Please highlight all subsequent releases of any part of the software package and the corresponding release dates in the boxes below, starting with the most recent.

Software Package Element (i.e. user interface, flow engine)	Version Number	Release Date
HEC-RAS	3.1.1	(05/03)
(User Interface)	3.1.1	(05/03)
(Pre-processor)	3.1.1	(05/03)
(Steady Flow Engine)	3.1.1	(05/03)
(Unsteady Flow Engine)	3.1.1	(05/03)
(Post-processor)	3.1.1	(05/03)
HEC-RAS	3.1.0	(11/02)
(User Interface)	3.1.0	(11/02)
(Pre-processor)	3.1.0	(11/02)
(Steady Flow Engine)	3.1.0	(11/02)
(Unsteady Flow Engine)	3.1.0	(11/02)
(Post-processor)	3.1.0	(11/02)

Section 4

Using the space provided below and NO MORE please summarise the most significant revisions and improvements that have been made/included in the software releases named in Section 2. Do not include changes / revisions / improvements which are to be included in subsequent releases (including beta) of the software as section 6 provides you with the opportunity to mention these.

Changes, revisions and improvements may relate to any part of the software such as the graphical user interface (GUI), the numerical flow engines, software functionality (i.e. new structures, procedures etc.) and the data pre and post processors.

Your response MUST be limited to the space provided on pages 2 to 5 of this form. Please include any screen dumps, schematics or illustrations as appropriate, to support your text.

Summary of revisions and improvements:

New Unsteady Flow Routing Features

1. **Dam Break Analysis** – HEC-RAS can now perform a Dam Breaching analysis. The user enters information about the size and dimensions of the breach, as well as how long it will take to form. The software will then perform unsteady flow routing of the flood wave through the breach and on down stream.
2. **Levee Breaching** –The user models a levee as a lateral structure in HEC-RAS. They can then define the location, size, shape, and time for the breach. The breached flow can go into a storage area, or it can be connected to another river reach.
3. **Mixed Flow Regime For Unsteady Flow** – HEC-RAS can now perform mixed flow regime (subcritical to supercritical, as well as hydraulic jumps) calculations during an unsteady flow run.
4. **Pump Stations** – HEC-RAS now has the capability to model pump stations. The user can attach a pump station to a storage area or a river reach. Each pump station can have up to 10 non- identical pump groups, for which a different pump efficiency curve (head versus flow) can be entered. Each pump group can have up to ten identical pumps (same pump efficiency curve). However, every pump can have a different on and off trigger elevation.
5. **Navigation Dams** – This feature will optimize gate settings for a navigation dam in order to maintain an upstream water surface within a specified range.
6. **Culvert Flap Gates** – This feature allows the user to put a flap gate on a culvert that is defined as part of a lateral structure. The flap gate can be set to allow water to only flow in one direction through the culvert.
7. **Floodway Encroachments** – Floodway encroachments can now be analyzed during an unsteady flow simulation.
8. **New Flow Data and Boundary Conditions Features** – Several new features have been added to the Unsteady Flow Data editor. The following is a list of those features:

   - Additional rules for controlling gates. New features were added to the current "elevation controlled gate" option.
   - Internal River Station Initial Stages: allows the user to set a water surface at any river station for the initial conditions.
   - Minimum Flow and Flow Ratio Table: This option allows the user to specify a minimum flow for any of the flow hydrograph boundary conditions being used in the simulation. Additionally, there is an option to enter a ratio that will be multiplied by every ordinate in a flow hydrograph boundary condition.

- Observed (Measured) Data: Two new options have been added, High Water Marks and measure Rating Curves (mean curve and measured points can be entered). When high water marks are entered, they will show up on the profile plots as well as the cross section plots. When entering measured rating curves, the user-entered mean curve and measured points will show up on the rating curve plots, along with the computed values.

9. **Initial Conditions Flow Optimization –** This option allows the user to direct the program to try to optimize the flow at junctions and lateral structures for the calculation of the initial conditions

10. **Log File Output –** The Log File Output for Unsteady flow calculations has been dramatically improved.

New Geometric Data Features

1. **Improved Background Map Viewing for River System Schematic –** We have changed the background mapping and imaging capability within the geometric editor to allow for a wider range of image types.

2. **New Terminology for Inline and Lateral Structures**, as well as Storage Area Connections **–** Previously in version 3.0, we used the terms "Inline Weir/Spillway", "Lateral Weir/Spillway", and "Hydraulic Connections". These terms have been changed to more generic names in order to account for the fact that we now allow for a wider range of hydraulic features to be combined at each of these structure types. The new names, and their use are described below:

-Inline Structure: Can be used to model a hydraulic structure that crosses the main stream. This structure can have gated spillways, as well as a free flowing overflow weirs/spillways.

-Lateral Structure: Can be used to model a hydraulic structure that is lateral (parallel) to the main river. This type of structure can remove flow from the river, or bring flow into the river. A lateral structure can be connected to a Storage Area or to another river reach. Lateral structures can contain gated spillways, culverts, free flowing overflow weirs/ spillways, and user-defined diversion rating curves.

-Storage Area Connections: Storage area connections allow the user to model the transition of flow from one storage area to another. This option allows the user to define a hydraulic structure using a free flowing weir, weir and gated spillways, weir and culverts, or a simple linear routing option.

3. **Improved Interface to GIS (GeoRAS) –** The interface for reading and writing information from and to a GIS using GeoRAS has been improved.

4. **Flow and Seasonal Roughness Factors Stored in Geometry –** Previously, when a user defined a flow versus roughness or seasonal roughness change, the information was stored as part of the Plan file. This capability allowed a modeller to make changes to the roughness without re-running the geometric pre-processor (this is a common need in real-time forecasting). However, it is recognized that these changes may also be appropriate as permanent values that should always be applied to the geometry data. Therefore, we have added the same features directly into the geometric data editor.

5. **Improved Display of Information on The River System Schematic –** We have added the ability to highlight in red the current active node (cross section, bridge, culvert, hydraulic structure, etc.). Additionally, a red circle is drawn around it in order to make it easy to find on the schematic.

6. **New Data Editing Tables For Geometric Editor –** The following data editor tables have been added to the geometric editor (under the Tables menu bar), to allow easier editing of multiple locations and global information: Levee Elevations; Node Descriptions; Picture File Associations; Weir and Gate Coefficients; and HTAB Internal Boundaries (Geometric Pre-processor).

7. **New Data Manipulation Tools For Geometric Editor –** The following is a list of the new geometric editor tools that have been added: View reach connectivity; Datum adjustment; Fix overlapping ineffective areas; GIS coordinates manipulation; Reach order for computations; and Find loops in river system schematic.

New Hydraulic Design Functions

1. **Uniform Flow Computations –** For a selected cross section, any of the parameters of Manning's equation can be computed, when the other parameters are input by the user. For example, if the user wishes to know the discharge, the slope and water surface elevation must be entered along with the existing cross section, and the discharge will be solved. A number of different roughness analysis techniques can be used, including Manning, Strickler, Keulegan, Limerinos, Brownlie, and the SCS Grass Curves.
2. **Stable Channel Design–** This function can be used to determine the channel geometry and characteristics needed to achieve channel stability at a given cross section. The user has the choice of using Copeland's method, Regime method, or Tractive Force method.
3. **Sediment Transport Capacity–** The sediment transport capacity at any existing cross section can be determined using this feature. Six transport methods are available, which include Ackers-White, Engelund-Hansen, Laursen, Meyer-Peter Müller, Toffaleti, and Yang.

Help System and Manuals

1. **New Help System –** The HEC-RAS help system has been updated to reflect the new documentation and features added to the software. User's can activate the help system from any of the HEC-RAS windows.
2. **New Manuals Online** - All three HEC-RAS manuals (User's, Hydraulic Reference, and Applications Guide), have been updated and put into PDF format. These manuals can now be viewed from within the HEC-RAS software by selecting one of the three manuals from the Help menu on the main HEC-RAS window.
3. **Custom Help Files** - Users can add a file link to the main RAS help menu bar by adding a file to the \Program Files\HEC\RAS directory that starts with "RasHelp_". For example, a help file in Spanish can be added with a file labeled: "RasHelp_Spanish Glossary.hlp" (it is up to the user to create this help file). Other file types can also be added, for example: ".txt", ".doc", ".xls", etc.

Graphical and Tabular Output

1. **Cross-Section Plots –** New animate, record, and picture buttons have been added to the cross-section plot.
2. **Profile Plot –** New buttons have been added to this plot to make it more convenient to select river reaches and which profiles to plot. Additionally, buttons for animating the plot, recording an AVI movie of the animation, and reloading the data from a new run have been added.
3. **Rating Curve Plot –** The animate, record AVI, and picture buttons have been added to this plot as described above.
4. **Hydrograph Plots –** The following new features have been added to the hydrograph plotting capability:

-Hydrograph Statistics – A window has been added to the upper right hand corner of the plot window to display statistics about the computed flow and stage hydrographs, as well as any observed data at this location.

-Calibration Aids – Tabs have been added for a rating curve plot, computed minus observed stage versus flow, and computed minus observed stage versus season.

-Selecting Variables To Plot – New check boxes have been added directly above the tabs to allow the user to quickly turn variables on or off. This includes stage, flow, observed stage, observed flow, and whether or not to use a reference

elevation for scaling the plot (invert of the cross section is used as minimum elevation for stage scale).

5. **3-D Graphic** – Users can now display the river stations on this plot.
6. **Hydraulic Tables Plot** (HTAB) – A new button has been added to this plot in order to more conveniently turn the plot variables on and off.
7. **Detailed Output Tables** – Some new table types have been added to the detailed output table window, these include: multiple openings, storage areas, storage area connections, and pump stations. Additionally, a Plan selection button has been added to the window in order to view detailed output from other plans without opening the entire plan data.
8. **Summary Output Tables** – A new summary table type has been added for pump stations.
9. **DSS Viewer** – The HEC-DSS viewer has been updated to handle larger DSS files.
10. **Cross-Section Editor** – The graphic of the cross section is more closely tied to the cross section data editor. Data in the plot changes when the Apply Data button is pressed on the editor. The plot also changes to a new cross section when a new cross section is selected from the editor.

New HEC-GeoRAS Features

The new version of the HEC-GeoRAS software (version 3.1) includes the following new features:

1. **XS Plot Tool**. Cross sections may be previewed in ArcView using the GeoRAS XS Plot tool. The selected cross section is plotted in an ArcView Chart. The user may interactively select points in the Cross Section Plot using the Point Locator Tool. The point selected is drawn on the plan View.
2. **Ineffective Flow Areas Theme**. GeoRAS 3.1 allows the user to define ineffective flow areas at locations on the cross section that are not actively conveying flow. This is done in the Ineffective Flow Areas Theme. GeoRAS will extract the beginning and ending location of the ineffective flow area along the cross section in the Cross-Sectional Cut Line theme.
3. **Levee Alignment Theme**. GeoRAS 3.1 allows the user to incorporate existing or proposed levee features (or land forms that act similarly to levees) in the geometric data.
4. **Storage Areas Theme**. Users can now define storage area locations. Elevation-Volume data is extracted for each storage area.

Section 5

Using the space provided below please make reference to any websites, published material or other sources of information (i.e. a point of contact) which can be accessed to obtain more detailed information on the changes highlighted in Sections 3 and 4.

The HEC web site can be used to get the latest software, documentation, and general information concerning HEC-RAS. The following is the web address:

www.hec.usace.army.mil

Section 6

Using the space provided below please list any improvements to the software that you are currently working on or have future plans for and give timescales for their release.

The following are major new features we are working on:

1. Sediment Transport (i.e. erosion and deposition) - we plan to have a beta version with this capability by September of 2005, and a release version by September 2006.

2. Water quality (water temperature, constituent transport, and chemical interactions). We currently have a working version with water temperature modelling. This will be released for testing by September 2004, released by September 2005. We are currently working on constituent transport\diffusion. This will be available for testing by September 2005, and released by September 2006. We plan to work on chemical interactions, but not sure when this would be released.

In addition to these two major focus areas, we will be adding many new improvements to the user interface, general hydraulics capabilities, and GIS linkages and features. Updates will continue to come out at a rate of about one new version per year.

Section 7

Please add any further comments with regard to the software package and the changes highlighted which you feel have not been addressed in this form.

Form completed by: Gary W. Brunner.....
On behalf of: The Hydrologic Engineering Center, U.S. Army Corps of Engineers.....
Date: March 9, 2004.....