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SUPPLEMENTARY TESTING OF MIKE 11 SOFTWARE - VERSION 3.0

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SUMMARY

I BENEFITS

The supplementary testing of MIKE 11 (Version 3.0) will give users greater confidence in the new version and its improved capabilities.

II OBJECTIVE

To retest the upgraded MIKE 11 (Version 3.0) program against the original UPM requirement specification.

III REASON

The original testing programme (FR 0242) reported on Version 2.1 of the program. Since then Version 3.0 of MIKE 11 has been released. Significant alterations have been made to the way in which BOD and sediments are represented, in order to model their interactions more realistically. Therefore, a limited retesting programme has been conducted to ensure that this version fully complies with the UPM specification.

IV CONCLUSIONS

MIKE 11 Version 3.0 generally works as required, and the aspects relating to the UPM specification are working as specified.

However, care should be taken when using the MOSQITO interface for the input of polluting flows. Currently, it is recommended that wherever possible, polluting inputs should be introduced as lateral inflows within MIKE 11, until an updated MOSQITO interface is available. This is now available in a subsequent version 3.01.

Additionally, using the new version of MIKE 11 for complex simulations involving sediment / pollutant modelling can result in excessively long 'run times' (approximately half real time).

Within these constraints, the model produces accurate results for a wide range of modelling scenarios.

V RECOMMENDATIONS

MIKE 11 Version 3.0, or subsequent minor upgrades, should become the UPM standard river impact model. Any previous versions of the software should be upgraded to Version 3.0 as soon as possible.

A conversion program is required to enable the TSF and MIF datafiles produced by previous versions of MIKE 11 to be compatible with Version 3.0.

More detailed guidance and documentation should be made available to support the modelling of BOD and sediments, and the other UPM aspects of the model.

1. INTRODUCTION

1.1 Background

The history and development of the UPM version of MIKE 11 has been described in the introduction to the original testing report, 'Testing of MIKE 11 software' (FR0242)[1].

Subsequently, Version 3.0 has been released. It was designed to overcome shortcomings in the way in which BOD and sediments are modelled.

In this new version an improved sediment / BOD formulation allows for a more accurate description of the exchange of BOD between the bed and suspended sediments. Also the erosion and deposition formula for non-cohesive sediments has been updated, which results in a better description of the exchange of BOD between the non-cohesive bed and suspended sediments.

These alterations were also made to remedy the problems of instabilities with the suspended BOD noted in the original testing programme[1].

The result of this is that the manner in which the BOD and sediments are modelled in Version 3.0 is significantly different to the way they are modelled in Version 2.1. Therefore, a new testing programme was required to confirm not only that Version 3.0 works as specified, but also **how** each component in a BOD-sediment simulation is modelled.

This report takes a format similar to the original testing report for ease of reference. Since only a limited retest of changes to the program were undertaken the original report should also be referred to where appropriate.

1.2 Objectives and benefits

The objectives were to retest Version 3.0 of the program, to ensure that the model fully complied with the UPM specification, (see Appendix A) and to identify how each component in a BOD / sediment model is now specified.

The supplementary testing will give users greater confidence in the new version and its improved capabilities.

2. QUALITY OF SOFTWARE ENGINEERING

2.1 Introduction

Version 3.0 of the model remains as UNIX based software, and is largely the same as in Version 2.1. Any alterations, improvements or errors apparent in the software are identified here.

2.2 Data storage and retrieval

The database management system has been improved by organising the database boundary conditions in alphabetical order, for both the cross sectional and boundary condition data. Additionally, the manipulation of cross sectional database information has been improved, thereby making it easier to alter database information quickly.

2.3 Error handling

Error handling is now better than in Version 2.0, although some error messages still remain vague. The run time indicators have also been improved and now give an indication of the model run time and simulation run time.

Overall the program appears less likely to crash without producing error messages.

2.4 Help text

General improvements have been made in both the quality and range of availability of help options.

2.5 Presentation of results

The results, and the range of results available, remain as reported previously[1].

An error, noted in Version 2.1, occurred when producing a disc file from a timeseries result selection. The disc file (option 3) is now produced without an additional extension (.TXT.TXT) as occurred in Version 2.1. An additional problem with Version 2.1 was that part of the header information occasionally appeared at the end of the file. This has also been rectified with Version 3.0.

2.6 Graphics

The graphics were not thoroughly tested but seem to be working adequately although a few minor improvements have been made. Some of the problems noted in the original testing[1] remain, they are:

1. explanatory text for profiles is omitted from the screen.

2. animation from the long section can "wipe off" the cross-section markers if overwritten by the moving boundary.

A new problem was discovered with the presentation of profiles. When accessing profile plots, selection of a dissolved oxygen profile **after** viewing any other profile plot, will caused exit from the program. Therefore, to view the dissolved oxygen profile plot, it is necessary to either select the dissolved oxygen results first or 'back out' of the menu and re-enter the profile plot (Menu J.6).

3. HYDRODYNAMIC MODULE

3.1 Stability

Tests were conducted on the hydrodynamic module's stability. Both steady and rapidly varying flows were routed down a range of channel architectures, including looped and divergent channels.

The results were similar to those reported previously[1]. No major instabilities were encountered, Any minor instabilities could be alleviated by adjustments to the time step and DX-MAX (number of calculation points).

3.2 Structures

Several of the in-river structures capable of being modelled in MIKE 11 were also re-tested. Many of the structures modelled were found to be very sensitive to the physical definition of the river and volume of flow routed down it. Care should, therefore, be taken in choosing the upper and lower levels for the calculation of stage discharge relationships over weirs, whilst also ensuring that the maximum and minimum flows likely to be encountered are within this range.

Additionally in rivers where there is a large change in conveyance between the upstream and downstream cross-sections (i.e. rapidly varying cross sectional profiles) either side of a structure, the iterative calculation can not always be closed (i.e. the model cannot resolve the Q-h calculations between the cross sections). This results in the program crashing. This problem is particularly acute on steep streams. However, these problems can be overcome by inserting composite cross sections to reduce the large change in conveyance and thus assist with the calculation. Otherwise the results were generally as reported previously.

4. ADVECTION/DISPERSION MODEL

Version 2.1 referred to this module as the Transport/Dispersion module. It is based on the one dimensional equation of conservation of mass of dissolved or suspended material. As with Version 2.1, it requires the results from a relevant hydrodynamic simulation.

4.1 Mass balance

The mass balance (using the program MASSB) of a conservative pollutant was tested with both a steady and a rapidly varying flow, to check on the conservation of mass. The results indicate that no significant mass was lost during any of the simulations (<0.05%).

4.2 Dispersion

Dispersion coefficients and factors were altered from the default values and a mass balance check was also carried out. No significant loss was found in any of the simulations.

4.3 Decay

The decay coefficients were set at a range of values to test the effectiveness of this aspect of the model. As would be anticipated an exponential loss of mass was experienced in simulations where decay was specified.

5. WATER QUALITY MODEL

The emphasis of this supplementary testing programme was to demonstrate the effect of the alterations to the way in which BOD and sediments are modelled in Version 3.0. Therefore, the water quality algorithms were not within the scope of this testing programme.

A limited test of the water quality module was conducted to ensure that this module was working effectively, as this will have a strong influence on the pollutant / sediment modelling.

It is important to realise that, although the hydrodynamic model can accurately simulate low flows, modelling water quality interactions in streams with a small volume of water (and especially where the water depth is less than 6cm), can give erroneous results. It is advisable to either maintain the required depth of water by either altering the cross sections or by introducing a larger flow. It is generally not recommended to use MIKE 11 to model very small streams with very low flow volumes, and/or steep channel profiles.

5.1 Default values for process rates

Default values for water quality process representations within MIKE 11 are give automatically. These values were found to be representative of values given in the literature[2]. Additional information on these values are given in an updated MIKE 11 Technical Reference[3,4].

5.2 Model sophistication

The level of water quality sophistication is dependent upon the type of simulation, and guidance is given in the Users Guide and the 'Help' text within the program. However one alteration noticed was that component 5 represents **total** BOD in levels 1, 2, 3 and 4 of a water quality simulation.

5.3 Water quality parameters

A brief test of the water quality parameters suggested that they are operating in a manner identical to that in Version 2.1.

6. COMBINED POLLUTANT/SEDIMENT MODELLING

As stated previously, the main alterations to Version 3.0 are associated with in the way in which BOD and sediment interactions are modelled.

The new formulation allows a more accurate description of the exchange of BOD between the bed and suspended sediments. Also, the erosion and deposition formula for non-cohesive sediments has been improved. This results in a better description of the exchange of BOD between the non-cohesive bed and suspended sediments. These alterations were made to remedy the problems of instabilities with suspended BOD noted during testing of the previous version.

The pollutant sediment modelling was tested in some detail in order to:

(a) test the model's capabilities and to check that they conform to the original UPM specifications,

and:

(b) to determine the correct procedure for the accurate definition of user specified input sediment volumes and pollutant/sediment concentrations in MIKE 11, and to understand how they are calculated.

6.3 Specification of pollutants and sediments

A major aspect of the testing of Version 3.0 was to investigate the manner in which pollutants and sediments are specified within the model.

Previously, each sediment type was specified by a single suspended sediment concentration. Version 3.0 requires each sediment type to have both its concentration and attached BOD to be specified. Thus, a simulation modelling two sediments (one cohesive and one non cohesive) will be specified as shown below (in the TSF file);

Parameter	Component	Comment
BOD (sus)	5	Total suspended BOD (mg/l).
BOD (diss)	6	Dissolved BOD (mg/l).
BOD (sed)	7	Total BOD at bed (mg/l).
Cohesive sed.	8	Suspended sediment concentration attached to the cohesive sediment (mg/l).
Cohesive BOD	9	BOD attached to cohesive sediment (mg/l).
Non coh. sed.	10	Suspended sediment concentration attached to the non-cohesive sediment (mg/l).
Non coh. BOD	11	BOD attached to non-cohesive sediment (mg/l).

When specifying the components in a TSF file, the user will now automatically be asked if the simulation is for a water quality model and if the model will include the

suspension/resuspension of sediments. If the answer is "yes" to both questions then the above components will automatically be specified in the TSF file.

If required, more than one sediment type can be modelled. These can be modelled as either cohesive or non-cohesive sediments.

In specifying the boundary and initial conditions for each of the cohesive and non cohesive sediments, it is necessary to understand the relationships between each of the components. The relationships for the above scenario are as follows;

Component 5 = Component 9 + Component 11

Component 7 = (Sed 8 x PF8 + Sed 10 x PF10) / Stored Volume of Water at grid point

where:

PF = Potency Factor (kg BOD per kg Sediment) specified in TSF file.
Sed * = Initial volume of sediment specified in TSF file

Boundary condition concentrations for components 5 (BOD suspended) and 7 (BOD sediment) need to be set at zero if modelling either one or more sediments. Initial concentrations for component 5 will be defined in boundaries 9 and 11 and then summed to give the total suspended BOD.

In a similar manner, boundary conditions for component 7 need not be specified (i.e. set at zero), as this is defined in the TSF file. The total bed BOD will be given by the results of erosion and deposition of the sediments.

Practically, this means that it is difficult to specify exactly what the initial BOD bed sediment concentrations are, as it is necessary to know the exact volume of water at that grid point in order to calculate the BOD of the sediment.

It is also worth bearing in mind that when simulating pollutant / sediment interactions the run times will be long (up to about half 'real time' for many simulations). The model is also very sensitive to the amount of bed sediment specified in the TSF file.

6.4 Pollutant/sediment relationships

The pollutant/sediment relationships are unchanged and are as specified in Section 6.2 of the original testing report[1].

6.5 Sediment results output

The output of sediment and sediment / pollutant results are as in Section 6.3 of the original testing report[1].

7. MOSQITO INTERFACE AND EVENT SUMMARY STATISTICS

7.1 MOSQITO interface

A check was made on the MOSQITO interface within MIKE 11 Version 3.0, to ensure that the interface is still able to directly input MOSQITO output files into MIKE 11 as lateral inflows.

The results of this phase of testing were that the MOSQITO interface generally works as reported in the original testing programme.

However a flaw in the manner in which pollutants are introduced was highlighted in this testing programme.

Any parameter not directly specified within the MOSQITO interface (i.e. dissolved oxygen, nitrate and temperature) is introduced, by default, into the model with a concentration (or value) of zero. This could obviously produce erroneous results, especially if the flow associated with the input is large in comparison to the flow in the river. Currently DHI are investigating the problem and will be producing an updated interface where dissolved oxygen, temperature and nitrate can be specified by the user in the interface, without the need for additional pollutographs.

It should also be noted that any sediment or pollutants attached to sediments will automatically be assigned to the non-cohesive sediments in MIKE 11 by default, as it assumes the sediments leaving the CSO are largely non-cohesive.

The further significant difference for the user is that the MOSQITO source files should now be specified in lower case format only.

7.2 Event summary statistics

The event summary statistics have been retested in a similar manner to that undertaken with Version 2.1. The module has been shown to work in accordance with the requirements of the specification.

8. USER GUIDANCE AND SUPPORTING DOCUMENTATION

A significant constraint on the effective use of MIKE 11 is the lack of a comprehensive User Guide that has clear and extensive worked examples of modelling situations. This is particularly apparent with the UPM specification, especially with regard to BOD/sediment modelling, where there is no guidance presently available to the user of how to model BOD associated with sediments. The Users Guide issued with Version 3.0 has not been updated from Version 2.1, and makes no reference to the modifications highlighted in this report and elsewhere[1]

The new Technical Reference, issued with Version 3.0 has been significantly improved and now incorporates useful background information relating to physical and biochemical processes, as well as the mathematical solutions to these processes within the diagram. However, its value is limited by poor layout and missing sections.

Overall, a need remains for greater user support and documentation, as a matter of some urgency.

9. CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

MIKE 11 Version 3.0 generally works as required, and the aspects relating to UPM specification are working as specified.

However, care should be taken when using the MOSQITO interface for the input of polluting flows, as described in Section 7.0. Currently it is recommended that wherever possible, polluting inputs should be introduced as lateral inflows within MIKE 11, until an updated MOSQITO interface is available.

It was found that the modelling of streams with low flow volumes and steep channels is not always possible with the water quality module.

Additionally it should be appreciated that using MIKE 11 (Version 3.0) for complex simulation involving sediment pollutant modelling can result in excessively long "run times" (approximately half real time).

Within these constraints the model produces accurate results for a wide range of modelling scenarios.

9.2 Recommendations

It is recommended that MIKE 11 Version 3.0 should become the standard UPM river impact model. However, the following improvements should be actioned:

1. An amended MOSQITO interface should be made available as soon as possible.

2. A conversion program is required to enable the TSF and MIF datafiles produced by previous versions to be compatible with Version 3.0.

3. Both the Technical Reference and User Guide, for the UPM Version 3.0 specification of MIKE 11, need to be updated, to enable the first time user to gain a more rapid understanding of how the model works.

4. Improved user support documentation is required to assist in the modelling of BOD and sediments.

9.3 Addendum

Version 3.01 of the program has been released by DHI. At present it is the general release version of the upgraded software, Version 3.01 has not been tested. However the amendments made to this newer Version, in comparison to Version 3.0 (tested here), appear to be relatively minor. A cursory examination of the software indicates that the main improvements to the program are to the file conversion and export facilities.

A more significant alteration, however, would appear to the the correction of the error noted in this testing report about the introduction of MOSQITO inputs (Section 7.1) as lateral inflows. This amendment is found on all Version 3.01 releases after December 1992.

It is now possible to specify default values for dissolved oxygen, nitrate and temperature for MOSQITO inflows in Menu F.5.1. This new interface was briefly tested and was found to be working adequately.

The use of the interface with user defined default values is now considered acceptable to use for all polluting inflows to a model.

REFERENCES

1. BECKER M, HUTCHINGS C. Testing of MIKE 11 Software. FWR Report No. FR0242, March 1992.

2. U.S. Environmental Protection Agency, Rates, Constants and Kinetics (Second Edition), June 1985.

3. MIKE 11 Users Guide, Danish Hydraulic Institute, Horsholm, Denmark.

4. MIKE 11 Technical Reference, Danish Hydraulic Institute, Horsholm, Denmark

APPENDIX A

UPM REQUIREMENT SPECIFICATION FOR A DYNAMIC RIVER FLOW QUALITY MODEL FOR INTERMITTENT DISCHARGES

APPENDIX A - UPM REQUIREMENT SPECIFICATION FOR A DYNAMIC RIVER FLOW QUALITY MODEL FOR INTERMITTENT DISCHARGES

Introduction

The proposed dynamic river flow quality model is required to model the processes causing changes in receiving water quality arising from sewerage discharges (CSOs, SWOs and STW storm tanks) during, before and after storm events.

Specification

1. Purpose

   The dynamic river flow quality model should be capable of simulating the changes in receiving river water quality caused by single or multiple intermittent storm sewage discharges. The model should be capable of use in conjunction with proposed environmental standards for transient pollution to assess the significance of the simulated changes in river water quality. Environmentally-based standards will be in the form of a concentration and a duration with a given return period. The receiving water may be assumed to be dendritic, unidirectional, i.e. looped and tidal effects will not be considered. While the model is primarily directed at the simulation of acute pollution effects during storm events, the inter-storm dry weather periods may also be important in terms of the chronic effects on receiving water quality exercised by benthic sediments. The model should therefore be capable of simulating the various processes, as outlined below, during both baseflow and storm conditions.

2. Inputs

   The model should be capable of using the predicted hydrographs and pollutographs from CSOs, SWOs and storm tank discharges, including the output of MOSQITO.

   The model must be able to read upstream flow and quality data and other inflows provided by the user. Alternatively the model may incorporate a simple method to generate these inputs.

3. Determinands

   The dynamic river flow quality model should be capable of modelling the following determinands:

   - dissolved oxygen;
   - COD and/or BOD;
   - ammonia (NH_4-N);
   - suspended solids;

- a number of user-defined dissolved determinands which may be conservative or have the capability of first order decay.

4. Hydraulics

The model must comprise both hydraulic and quality sub-models, which can be run conveniently together as a package.

The option must be provided to run the quality sub-model separately with the hydraulic model of the user's choice (which may require modification to provide standard output file format).

The hydraulic sub-model provided with the package should be as simple as possible and of the kinematic wave type.

5. Quality model processes and mechanisms

The dynamic river flow quality model must simulate all the significant processes impacting upon river quality. Three major processes modelling components have been identified these are:

- *Pollutant routing:* the advection, dispersion and mixing of pollutants within the modelled river system.

- *Biochemical processes:* the significant biochemical degradation processes affecting simulated determinands within the modelled river system. The model is required to simulate re-aeration but not to take account of photosynthesis.

- *Sediment interactions:* the settlement, resuspension and transport of river and sewer-derived sediments, plus the storage and release of associated pollutant loads.

6. Computational techniques

A balance needs to be made between the speed and accuracy of the chosen solution techniques. The numerical errors should be relatively small in comparison to other potential error sources within the modelling exercise (e.g. data collection). The model needs to operate with time steps of between 1 and 60 minutes and spatial steps of between 30 and 1000 metres.

7. Data requirements

- *Hydraulic*

  Input data requirements relate to channel cross-sections, channel gradients and instream structure configurations. These data are required at salient points in the river channel. Recorded hydrographs for historic events and/or time of travel data are required to calibrate and verify the model.

- *Quality*

  Input data for the quality model may be derived from the implied distribution from the river quality classification. At appropriate sites, improved data derived from routine sampling programmes may be available. In rare circumstances it may be appropriate to derive data from specially mounted local intensive surveys.

  There is a minimum requirement for field data from one storm event for calibration of the model.

8. Computing requirements

The software should be written in a modular form. The program should be developed to run on hardware that is widely available in the Water Industry, in particular IBM PCs and UNIX workstations.

9. Outputs

The following requirements relate to the outputs of the model:

- Instantaneous concentrations of the specified determinands at time steps and locations specified by the user.
- Event summary statistics compatible with the environmental standards at locations specified by the user.
- Format easily accessible by other computer software.
- Graphical and tabular forms.