Texas A & M University and U.S. Bureau of Reclamation
Hydrologic Modeling Inventory
Model Description Form

JUNE, 1999

Name of Model: Two-Dimensional Alluvial River and Floodplain Model (MIKE21 CHD & CST)

Model Type:

MIKE 21 CHD and CST is a comprehensive modeling system for two-dimensional free surface flood flows in alluvial rivers.

Model Objective(s):

MIKE21 CHD simulates spatial variations in flood water levels, depths, flows and velocities in two dimensions. MIKE21 CHD can be used for the prediction of flood inundation areas, depth maps, velocity maps, flood hazard maps and flood flow distributions. MIKE21 CST is an add-on module for advanced river morphological modeling for prediction of stream bank erosion, bed scour and fill, floodplain sedimentation.

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Model Structure or Mathematical Basis:

MIKE21 CHD is a special version of the MIKE21 HD particular suited for flow simulations of alluvial rivers. It simulates water level and flow variations in river

channels, on river floodplains (both urban and rural) and in lakes and estuaries in response to various forcing functions. The water levels and flows are resolved on a curvilinear grid covering the area of interest using the river channel and floodplain topography, bed resistance coefficients and hydrographic boundary conditions.

MIKE21 CHD solves the vertically integrated, fully dynamic equations of continuity and conservation of momentum in two horizontal directions using implicit finite difference methods. The following effects are included in the equations:

- Convective and cross momentum
- Momentum dispersion
- Floodplain flooding and drying
- Evaporation

MIKE21 CHD forms the basis for calculations in additional MIKE21 CST module describing advection dispersion and sediment transport. The following processes are simulated:

- Helical flow (secondary currents)
- Sediment transport, based on different optional formulas. Separate bed load and suspended load models
- Alluvial resistance due to varying bed material and bed forms
- Scour and fill by solving sediment continuity equation, feedback via updated bed elevations
- Bank erosion and plan form changes, feedback via updated bank lines

Model Parameters:

MIKE21 CHD solves the vertically integrated, fully dynamic equations of continuity and conservation of momentum in two horizontal directions. Model parameters for MIKE21 CHD are:

- Bed resistance
- Momentum dispersion (eddy) coefficient

Model parameters for MIKE 21 CST are

- Sediment transport formula for bed load and suspended load (or total load)
- Bank erosion coefficients
- Bed slope coefficients (default values available)
- Helical flow coefficient (default values available)
- Dispersion coefficient for suspended and dissolved matters

Spatial Scale Employed in the Model:

In MIKE21 CHD, the floodplain and channel topography is described in a curvilinear grid. The grid is designed by the user by means of a separate grid generator programme. MIKE21 CHD and CST are particularly designed to simulate two dimensional

hydrodynamic and morphological conditions in natural rivers and channels over a wide spatial range from small channels only few metres wide to broad scale river floodplains of several kilometres width. The length of modelling areas ranges correspondingly from few hundred meters to more than 100 km.

Temporal Scale Employed in the Model:

The temporal scale of MIKE21 CHD is characterized by its flexibility and is based on the boundary time series defined by the user. MIKE21 CHD has the flexibility to run short scale, event based time series or time series covering months or years of flow simulation. The user enters boundary time series into a database and defines in that connection the length and time step of the series. In addition, the MIKE21 CHD and CST can run in a quasi-steady state mode where the only limitation of the selected timestep is the sediment transport Courant number (migration of bedforms) and resolution of boundary conditions. Timescales for morphological modelling range from few days to several years (decades).

Input Data Requirements:

MIKE21 CHD requires the following data:

- Basic Model Parameters
  - Model grid size and extent defined in a curvilinear grid generated with the MIKE 21C pre and postprocessor
  - Times step and length of simulation
  - Type of output required and its frequency
- River channel and floodplain topography
- Calibration factors
  - Bed resistance coefficients
  - Momentum Dispersion coefficients
- Boundary Conditions
  - Water levels or flow magnitudes
  - Q-h discharge rating curve relation (optional)
  - Flow direction

In addition, MIKE21 CST requires the following data:

- Sediment properties in the entire modeling area
  - Grain size distribution
  - Porosity
  - Density
- Calibration factors
  - Sediment transport formula for bed load and suspended load
  - Bank erosion coefficients

- Bed slope coefficients
- Helical flow coefficient
- Dispersion coefficient for suspended and dissolved matters

- Boundary Conditions
  - Sediment transport, bed levels or rate of bed level changes

Computer Requirements:

MIKE21 CHD and CST is available in the Microsoft Windows (Win95, Win98, WinNT) environment as well as Unix environment. Minimum computer requirements are Pentium processor, 16MB RAM, 100MB hard disk space.

Model Output:

MIKE21 CHD provides output as time varying maps of water surface level and water flux in two dimensions with values defined on the model grid specified by the user. MIKE21 CST provides output as time varying maps of sediment transport, concentration of suspended sediment, updated bed levels and bank lines, scour and fill rate, bank erosion rates, net sedimentation, dune dimensions, updated bed resistance in two dimensions. The graphical interpretation of the model results includes:

- Color presentation of plans of water surface, water depth, flow distribution, flow speed, suspended sediment concentration, bed levels, scour and fill rate, net sedimentation, bed resistance
- Vector representation of flow velocity, sediment transport
- Plots of time series of water surface, water depth, flow flux, flow velocity, sediment transport, scour, fill, bank erosion at any point on the model grid
- Plots of the variation in space along any line of the water surface, water depth, flow flux, flow velocity, sediment transport, scour, fill, bank erosion etc.
- Discharge calculations, accumulated volume calculations across any line
- Sediment transport calculations, accumulated volume calculations across any line
- Statistical calculations on model output
- Digital video animation of model outputs

Parameter Estimation / Model Calibration:

MIKE21 CHD has two calibration parameters, namely bed resistance factor and momentum dispersion (eddy) coefficient. Calibration of the model can be achieved easily by adjustment of these factors. In practice, the calibration of a model depends more on the accuracy of the available data e.g. topography and boundary time series definition than the model parameters. Model calibration parameters are chosen by the user. Instruction and guidelines for parameter selection are provided in the model documentation. Further information on parameter selection is available from a wide selection of published references and case studies.

MIKE21 CST has five calibration parameters, which are sediment transport formula, bank erosion coefficients, bed slope coefficients, helical flow coefficients, dispersion coefficients. Key data for establishment of a reliable sediment transport model is the sediment properties (grain size) as well as the sediment transport formula, where the user can choose between a number of different formulas described in the literature (Van Rijn, Engelund-Hansen, Engelund-Fredsøe, Meyer-Peter and Müller, Smart-Jaeggi etc.). For morphological modeling, the feedback between hydrodynamics and sediment transport (through updated 1. Bank lines, 2. Bed levels, 3. Bed resistance) means that also the hydrodynamic model calibration parameters should be further tuned. This is done in an iterative calibration process involving both the sediment transport model and the hydrodynamic model.

Model Testing and Verification:

MIKE21 CHD and CST have been extensively tested on a wide range of morphological projects worldwide since 1995. Especially for simulation of sandy braided rivers, the model is forming state-of-the-art within mathematical modeling of detailed river morphology. A list of applications and case studies in available on the DHI website or by contacting DHI direct.

Model Sensitivity:

The sensitivity of MIKE21 CHD to calibration parameters is largely case dependent e.g. in areas where the floodplain topography is uniform and the flood slope gentle, little sensitivity to parameters is observed. However, on floodplains with rapidly varying topographies or steep floodwater slopes model outputs may be more sensitive to the parameter values chosen. For morphological modeling (MIKE 21CST), there is traditionally a much bigger sensitivity to changes in the calibration parameters. The sensitivity of the morphological model parameters depends on the extent of the simulation period.

Model Reliability:

MIKE21 CHD has a reliability proven over many years on numerous projects worldwide. When properly calibrated, MIKE21 CHD can predict flood levels to within 0.1m and flood flows and velocities to within 10% of observed data. MIKE 21CST for morphological modeling has a smaller reliability for predicted bed levels and bank line movements compared to the hydrodynamic model. The reliability depends on the extent of the simulation period. The accuracy of simulated bed level changes and bank line changes may range from decimeters to meters depending also on the flow conditions.

Model Application / Case Studies:

MIKE21 CHD and CST has been utilized in especially river morphology related studies worldwide including:

- Morphology forecast studies in connection with bridge construction over highly active alluvial river
- Bank erosion studies
- Sedimentation and scour at off-take channels (in connection with restoration of the off-take)
- Detailed impact studies in terms of flooding and erosion
- Navigation studies, i.e. prediction of depths and velocities in rivers and channels
- Estuary studies including tidal wave excursion, mud simulation, salinity intrusion
- Detailed flow and local scour studies of groynes

A list of specific case studies is available on the DHI website or directly from DHI on request

Documentation:

MIKE21 CHD and CST are supported by a user manual and technical reference documentation.

In addition, DHI offers a comprehensive system of technical support through its dedicated Software Support Centre. 24 hour assistance from DHI's highly trained technical staff can be obtained through our Software Support Centre via telephone hotline, fax or the Internet (software@dhigroup.com). As a part of License Service Agreements DHI software users are updated regularly with software developments via newsletters and Internet broadcasts.

Other Comments:

Since its establishment in 1964, DHI has a provided a continuing, long-term commitment to the research and development of reliable and useable modeling software. DHI offers a broad range of software tools and services, which support investigation, design, operation and maintenance tasks ranging from urban drainage hydraulics, to broad scale flood studies to offshore and coastal hydraulics.

As an independent research and consulting organisation, DHI supplies knowledge, technology and advisory services for the provision of safe and reliable infrastructure with sustainable and environmentally sound development.