PART II: CUSTOMIZED INFORMATICS TOOLS FOR THE HYDROPOWER RESERVOIR MANAGEMENT OPTIMIZATION, CONCERNING SEDIMENT MANAGEMENT AND HYDRAULIC MODELLING

WORK PACKAGE 3 – Methodologies and tools for better water & hydropower

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Preface

The present work is an outcome of the project “SEE HYDROPOWER, targeted to improve water resource management for a growing renewable energy production”, in the frame of the South-East-Europe Transnational Cooperation Programme, co-funded by the European Regional Development Fund (www.seehydropower.eu).

The project is based on the European Directive on the promotion of Electricity from Renewable Energy Sources with respect to the Kyoto protocol targets, that aims to establish an overall binding target of 20% share of renewable energy sources in energy consumption to be achieved by each Member State, as well as binding national targets by 2020 in line with the overall EU target of 20%. Objectives of the SEE HYDROPOWER deal with the promotion of hydro energy production in SEE countries, by the optimization of water resource exploitation, in a compatible way with other water users following environmental friendly approaches. Therefore, it gives a strong contribution to the integration between the Water Frame and the RES-e Directives.

Main activities of the project concerns the definition of policies, methodologies and tools for a better water & hydropower planning and management; the establishment of common criteria for preserving water bodies; to assess strategies to improve hydropower implementation, such as small hydropower; testing studies in pilot catchments of partner countries; promotion and dissemination of project outcomes among target groups all over the SEE Region countries.

In particular, the present report D3.4 (“Part II: Customized informatics tools for the hydropower reservoir management optimization, concerning sediment management and hydraulic modelling”), which is part of the Work Package 3 (Methodologies and tools for better water & hydropower planning and management).
Introduction

Many problems in the field of water management, the simulation of water flow, sediment transport are a matter of considerable interest in river engineering and water management. During the last decades the computational capabilities have increased and several simulation programmes and informatics tools have been developed.

Most of the modern numerical models and informatics tools have sophisticated user interfaces and create impressive colour graphics. But as described in Olsen (2007) this can people easily led to an understanding that the computer solves all the problems with a minimum knowledge of the user. Present computer programs can compute a huge variety of problems, but the absolute accuracy of the results is in many case unknown. Therefore it is important that the user of the numerical models and informatics tools has sufficient knowledge of both the numerical methods and their limitation as well as the physical processes modelled (Olsen, 2007).

In this report an overview about the numeric models for river hydraulics in computational fluid dynamics (CFD) and informatics tools used in the field of water management is given. Due to the fact that the number of numerical models and informatics tools is very large and still increasing, the given list is of course not complete.

Classification of numerical models and informatic tools

As mentioned above there exists a large number of computer programs for modelling hydraulics and environmental problems. All programs have varying degree of sophistication and reliability. In General the programs can be classified according to (Olsen, 2007):

- what is computed
- how many dimensions are used
- particulars of the numerical methods
- open source software; free software

A lot of programs are made for one specific application for example:

- Habitat modelling (Casimir)
- Decision support systems (Sesamo)
- Flood waves (DAMBRK)
- Rainfall-Runoff models
- Hydraulic Models

This was also the case for the first computational fluid dynamic (CFD) models, developed several years ago, when the computational power was limited. There are now modern CFD models including modules for computing several different problems.
Hydraulic computational fluid dynamics models

Computational fluid dynamic models for water flow simulation can be classified by the calculated flow dimensions and the application range. There are a large number of one-dimensional, two-dimensional and three-dimensional numerical models available. Some models also include the simulation of sediment transport.

One-dimensional (1D) models are well documented but limited to one-dimensional flow at uniform river sections. An alternative are two-dimensional numerical models, which are able to take floodplains or more complex river geometries into account. Two-dimensional models can be used if the 3D nature of the flow processes is of minor importance, like in straight river reaches with a large width-to-depth ratio. Three-dimensional numerical models are able to model many processes in complex river geometries, like curved channels. The correct modelling of the secondary currents is of major importance there, due to the fact that the secondary currents play an important role in the evolution of the channel topography.

One-dimensional numerical models

**HEC-RAS**

Description based on BMLFUW (2010), modified

HEC-RAS is a one-dimensional numerical model with modules for steady and unsteady flow, including mixed flow regime between subcritical and supercritical flow. It also has a dam break analysis tool. HEC-RAS has a connection to GIS programs, interactive data input masks and visualization of results. HEC-RAS uses an implicit finite difference scheme to solve the Saint-Venant equations.

**Developed by:** Hydrologic Engineering Centre (part of US Army Corps of Engineers), USA  
**Licence:** free ware  
**Operating Platform:** Microsoft Windows  
**Output format:** longitudinal section, river profile

**Sediment transport module:** only bed load  
**Formulas suspended load:** not implemented yet  
**Formulas bed load:**
- Ackers & White (1973)
- Engelund & Hansen (1967)
- Laursen (Copeland) (1968)
- Meyer Peter Müller (1948)
- Toffaleti (1968)
- Yang (1973)
- Wilcock (2001)

**Discretisation method:**
- Finite differences method  
- Tacit method 1st order
References: Brandmayr (2009)

**FLORIS**
Description based on BMLFUW (2010), modified

FLORIS\textsuperscript{2000} is a non-stationary, 1D simulation program for modelling flow processes in bodies of water. FLORIS was created in the 1990's by the VAW/ETH and since then, it has undergone on-going development in a joint effort by VAW/ETH, SCIETEC and TK Consult, Zurich.

FLORIS\textsuperscript{2000} is modular in design and consists of four modules:
- Hydraulics: 1D non-stationary, branch & node concept, finite differences and finite volume scheme
- Control: Direct image of power plants and operating regulations, integrated PID-control, interface for optional external control modules
- Sediment transport: 1.5D stream tube approach, multiple grain model, separate treatment of bed load and suspended sediment
- Inverse modelling: automatic estimation of hydraulic and hydrological model parameters

**Developed by:** VAW/ETH, SCIETEC and TK Consult, Zurich, Switzerland  
**Licence:** commercial (see homepage)  
**Homepage:** [www.scietec.at/navigation/powerslave,id,17,nodeid,17,_language,en.html](http://www.scietec.at/navigation/powerslave,id,17,nodeid,17,_language,en.html)  
**Operating Platform:** Microsoft Windows  
**Output format:** fully integrated in FLUX

**Sediment transport module:** yes; suspended load, bed load and bank erosion  
**Formulas suspended load:**
- Suspended load transport, longitudinal diffusion, transversal mixing with depth-averaged advection/diffusion equations (details see Fäh, 1997)
- Quantitative distribution between transport as bed load and transport as suspended load
- Van Rijn (1993)
- Deposition/precipitation of suspended particle: Lin (1984)
- Sorting/clogging: for single grain model: Günther (1971) otherwise automatically
- Consideration of consolidation, Van Rijn (1993)
- Determination of density, Allersma (1988)

**Formulas bed load:**
- Meyer-Peter/Müller (1948)
- VAW-Formel (Fäh 1997)
- Vetter-Formel (1992)

**Discretisation method:** Finite volume method, tacit method  
**References:** Reichel et al. (2000)

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**WASPI**
Description based on BMLFUW (2010), modified

The WASPI software is based on the program HEC2 of the US Army Corps of Engineers / Hydrologic Engineering Centre. The program has been enhanced based on the requirements of users in the German
speaking countries of Europe. WASPI uses the steady water level calculation routines of HEC2. The programme has a pre- and a post processing interface for Windows.

**Developed by:** Hydroconsult, Austria  
**Licence:** commercial (see homepage)  
**Homepage:** [www.hydroconsult.net/software_de.htm](http://www.hydroconsult.net/software_de.htm)  
**Operating Platform:** Windows XP  
**Output format:** cross profiles and longitudinal sections for each time step

**Sediment transport module:** suspended load, bed load and cohesive material  
**Formulas suspended load:**  
- Partheniades (1965)  
- Krone (1962)  
- Ariathurai (1976)

**Formulas bed load:** Eleven fixed bed load formulas, as well as one to be specified by the user  
- Tofaleti (1966)  
- Madden (1963)  
- Yang (1973)  
- DuBoys - Vanoni (1975)  
- Ackers-White (1973)  
- Colby (1964),  
- Tofaleti-Schoklitsch combination  
- Meyer Peter Müller (1948)  
- Tofaleti-MPM combination  
- Madden (1985)  
- Copeland (1990)

**Discretisation method:** Finite difference scheme  
**References:** [www.hydroconsult.net](http://www.hydroconsult.net)

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**MIKE 11**  
Description based on BMLFUW (2010), modified

MIKE 11 is a one-dimensional programme with both steady state water surface profile computation and solution of the Saint-Venant equations. The program has a graphical user interface and connections to GIS programs. MIKE11 has a number of different add-on modules computing for example flood analysis and flood alleviation design studies, real time flood forecasting, dam break analysis, optimisation of reservoir and canal gate / structure operations, ecological and water quality assessments in rivers and wetlands, sediment transport and river morphology studies, salinity intrusion in rivers and estuaries and wetland restoration studies.

**Developed by:** Danish Hydraulic Institute (DHI), Denmark  
**Licence:** commercial (see homepage)  
**Homepage:** [http://www.mikebydhi.com/Products/WaterResources/MIKE11.aspx](http://www.mikebydhi.com/Products/WaterResources/MIKE11.aspx)  
**Operating Platform:** Microsoft Windows  
**Output format:** Text editor, GIS, Excel
**Sediment transport module**: bed load and suspended load

**Formulas suspended load**:
- Engelund & Fredsoe
- Van Rijn
- Lane-Kalinske
- Ashida & Michiue

**Formulas bed load**:
- Van Rijn
- Engelund & Fredsoe
- Meyer-Peter & Müller
- Sato,
- Kikkawa & Ashida
- Ashida & Michiue
- Ashia
- Takahashi & Mizuyama

**Discretisation method**: Implicit finite difference scheme; river profiles are a sum of parallel, rectangular format single channels

**References**: see homepage

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**CCHE1D**

Description based on BMLFUW (2010), modified

CCHE1D is a software package for the simulation of one-dimensional unsteady flows and sediment transport in dendritic channel networks. The software package has been designed to facilitate the combined modelling of watershed and channel processes.

CCHE1D’s hydrodynamic model includes special procedures for the computation of flow across hydraulic structures like culverts, low and high-drop structures, bridge crossings, and measuring flumes.

The sediment transport module computes non-equilibrium transport of non-uniform sediment mixtures. It has been designed for long-term predictions of channel morphological changes, and it can be used to evaluate the effectiveness of in-channel remedial and control structures on the sediment yield.

The CCHE1D water quality module simulates the transport and fate of nutrients and other pollutants in channel networks, including the biogeochemical reactions that take place in the streams.

An ArcView GIS graphical interface facilitates the data management and the integration of the channel model with watershed models and other tools. It also includes a landscape analysis module that delineates the drainage network and corresponding sub catchments based on digital elevation data (NCCH, 2011).

**Developed by**: NCCHE

**Licence**: free ware

**Homepage**: [http://www.ncche.olemiss.edu/software/cche2d](http://www.ncche.olemiss.edu/software/cche2d)

**Operating Platform**: Windows; ArcView GIS v3.x

**Output format**: GIS based with rainfall-runoff models

**Sediment transport module**: yes, sediment transport with bank slide algorithm, uncoupled sediment transport

**Formulas suspended load**:
- Ackers–White (1973, modified by Proffit und Sutherland, 1983)
- SEDTRA (Garbrecht et al., 1995)
Wu, Wang und Jia (2000),
Engelund–Hansen (1967, modified)

Formulas bed load:
- Ackers–White (1973, modified by Proffit und Sutherland, 1993),
- SEDTRA (Garbrecht et al., 1995)
- Wu, Wang und Jia (2000),
- Engelund–Hansen (1967, modified)

Discretisation method: Multi-layer-model, unlimited quantity of layers, exposure/hiding processes considered

References: Vieira & Wu, 2002b

BASEMENT
Description based on BMLFUW (2010), modified

Basement is a numerical simulation software developed at the Laboratory of Hydraulics, Hydrology and Glaciology (VAW) of the Swiss Federal Institute of Technology (ETH) at Zurich, Switzerland. The purpose of the software is to provide a software tool for numerical modelling of environmental flow and natural hazard events.

Developed by: Versuchsanstalt für Wasserbau, Hydrologie und Glaziologie (VAW) der ETH Zürich
Licence: free ware
Homepage: http://www.basement.ethz.ch/
Operating Platform: Windows, Linux
Output format: ASCII, Tecplot, Matlab

Sediment transport module: yes, bed load and suspended load, uncoupled sediment transport

Formulas suspended load: Advection-diffusion according to Van Rijn

Formulas bed load:
- Meyer-Peter, Müller Formula and addition Hunziker
- Parker
- Rickenmann

Discretisation method:
- Finite volume method
- Explicit method 1st order

References:
Fäh (1997), Fäh et al. (2007), Fäh et al. (2008a), Fäh et al. (2008b), Farshi et al. (2005), Schleiss et al. (2008), Vetsch et al. (2005)
Two-dimensional numerical models

MIKE21C
Description based on BMLFUW (2010), modified

MIKE 21C is one of the best known tools for simulating river hydraulics. The simulated processes include bank erosion, scouring and shoaling brought about by activities such as construction and dredging or seasonal fluctuations in flows.

Typical MIKE 21C applications are:

- Design protection schemes against bank erosion
- Evaluate measures to reduce or manage shoaling
- Analyse alignments and dimensions of navigation channels for minimising maintenance dredging
- Predict sedimentation of water intakes, outlets, locks, harbours and reservoirs
- Forecast the impact of bridge, tunnel and pipeline crossings on river channel hydraulics and morphology
- Optimise restoration plans for habitat environment in channel floodplain systems

**Developed by:** Danish Hydraulic Institute (DHI), Denmark
**Sediment transport module:** yes
**Licence:** commercial (see homepage)
**Homepage:** [www.mikebydhi.com/Products/CoastAndSea/MIKE21/Hydrodynamics.aspx](http://www.mikebydhi.com/Products/CoastAndSea/MIKE21/Hydrodynamics.aspx)
**Operating Platform:** Microsoft Windows
**Output format:** Text editor, GIS, Excel

**Sediment transport module:** yes, bed load and suspended load
**Formulas suspended load:**
- Engelund & Hansen
- Van Rijn
- Engelund & Fredsoe
- Meyer-Peter & Müller
- Yang (sand)
- Yang (gravel)
- Smart und Jaeggi
- User defined formula

**Formulas bed load:**
- Engelund & Hansen
- Van Rijn
- Engelund & Fredsoe
- Meyer-Peter & Müller

- Yang (sand)
- Yang (gravel)
- Smart und Jaeggi
- User defined formula

**Discretisation method:** Implicit finite difference method

**References:** see homepage

**TELEMAC-2D**

Description based on BMLFUW (2010), modified

TELEMAC-2D is used to simulate free-surface flows in two dimensions of horizontal space. At each point of the mesh, the programme calculates the depth of water and the two velocity components.

TELEMAC-2D solves the Saint-Venant equations using the finite-element or finite-volume method and a computation mesh of triangular elements. It can perform simulations in transient and permanent conditions.

TELEMAC-2D can take into account the following phenomena:
- Propagation of long waves, taking into account non-linear effects
- Bed friction
- Influence of Coriolis force
- Influence of meteorological factors: atmospheric pressure and wind
- Turbulence
- Torrent and river flows
- Influence of horizontal temperature or salinity gradients on density
- Cartesian or spherical coordinates for large domains
- Dry areas in the computational domain: intertidal flats and flood plains
- Current entrainment and diffusion of a tracer, with source and sink terms
- Monitoring of floats and Lagrange drifts
- Treatment of singular points: sills, dikes, pipes.

**Developed by:** Laboratoire National d'Hydraulique, a department of Electricité de France's Research and Development Division, France

**Sediment transport module:** yes

**Licence:** open source

**Homepage:**


**Operating Platform:** UNIX, Windows

**Output format:** Layout, cross profile and longitudinal section

**Sediment transport module:** total transport approach
Formulas suspended load:
- Engelund-Hansen (1967)
- Bijker (1971)

Formulas bed load:
- Engelund-Hansen (1967)
- Bijker (1971)

Discretisation method:
- Streamline upwind Petrov-Galerkin (space)
- Fractional-Step (time)


**CCHE2D**
Description based on BMLFUW (2010), modified

The CCHE2D model is a two-dimensional depth-averaged, unsteady, flow and sediment transport model. The flow model is based on depth-averaged Navier-Stokes equations. The turbulent shear stresses are modelled using Boussinesq's approximation, and three different turbulence closure schemes are available for the calculation of the turbulent eddy viscosity. The resulting set of equations is solved implicitly using the control volume approach and efficient element method. The numerical technique employed ensures oscillation free and stable solution.

The sediment transport module is used to simulate non-uniform sediment (both non-cohesive and cohesive) using non-equilibrium transport models. Three different non-equilibrium transport approaches are proposed to handle the cases where the sediment transport occurs mainly as bed load, mainly as suspended load, or total load. The equations for this module include transport equations for bed load and suspended load, the bed change equation, and the bed sorting equation. These equations are discretized using efficient element method or exponential difference scheme.

Currently limited to Windows XP, not supporting Windows 7

**Developed by:** NCCHE
**Sediment transport module:** yes
**Licence:** free ware
**Homepage:** [http://www.ncche.olemiss.edu/software/cche2d](http://www.ncche.olemiss.edu/software/cche2d)
**Operating Platform:** Windows 2000/XP
**Output format:** Visualizations 2D and 3D, cross profiles and longitudinal sections

**Sediment transport module:** suspended loads and bed loads, Formulas suspended load:
- Ackers–White (1973, modified by Proffit und Sutherland, 1993),
- SEDTRA (Garbrecht et al., 1995)
- Engelund–Hansen (1967, modified)

**Formulas bed load:**
- Ackers–White (1973, modified by Proffit und Sutherland, 1993)
- SEDTRA (Garbrecht et al., 1995)
Engelund–Hansen (1967, modified)

**Discretisation method:**
- Efficient Element Method (Wang and Hu, 1992)
- Implicit method

Three-dimensional models

**ANSYS-Fluent**
Description based on BMLFUW (2010), modified

ANSYS FLUENT software contains the physical modelling capabilities needed to model flow, turbulence, heat transfer, and reactions for industrial applications ranging from air flow over an aircraft wing to combustion in a furnace, from bubble columns to oil platforms, from blood flow to semiconductor manufacturing, and from clean room design to wastewater treatment plants. Special models that give the software the ability to model in-cylinder combustion, aero acoustics, turbo machinery, and multiphase systems have served to broaden its reach.

**Developed by:** ANSYS, USA  
**Sediment transport module:** yes  
**Licence:** commercial (see homepage)  
**Homepage:** [www.ansys.com/products/fluid-dynamics/fluent/](http://www.ansys.com/products/fluid-dynamics/fluent/)  
**Operating Platform:** Linux, Windows  
**Output format:** Tecplot, Abacus, …

**Sediment transport module:** suspended load  
**Formulas suspended load:** UDF (User defined function)  
**Formulas bed load:** none  
**Discretisation method:**  
- Finite volume method of structured, blockstructuredem or unstructured Rechennetz (space)  
- Explicit, Implicit (time)  

**References:** [www.fluent.com](http://www.fluent.com)

**ANSYS-CFX**
Description based on BMLFUW (2010), modified

ANSYS CFX software is a high-performance, general purpose fluid dynamics program. It is a commercial program with bi-directional connections to all major CAD systems, geometry modification and creation tools with ANSYS Design Modeller, meshing technologies in ANSYS Meshing, and drag-and-drop transfer of data and results to share between applications.

**Developed by:** ANSYS, USA  
**Sediment transport module:** yes  
**Licence:** commercial (see homepage)  
**Homepage:** [www.ansys.com/Products/Simulation+Technology/Fluid+Dynamics/ANSYS+CFX](http://www.ansys.com/Products/Simulation+Technology/Fluid+Dynamics/ANSYS+CFX)  
**Operating Platform:** UNIX, Linux, Windows  
**Output format:** Tecplot, Abaqus, …

**Sediment transport module:** suspended load  
**Formulas suspended load:** UDF (User defined function)  
**Formulas bed load:** none  
**Discretisation method:**  
- Finite volume method (space)  
- Upwind approach 1st order (space)  
- Numerical advection corrected scheme (space)  
- Eulerian Back-difference approach 1st order (time)
SSIIM

Description based on BMLFUW (2010), modified

The SSIIM program solves the Navier-Stokes equations with the k-ε model on a three-dimensional mostly non-orthogonal grid. A control volume method is used for the discretization, together with the power-law scheme or the second order upwind scheme. For the pressure coupling the SIMPLE method is used. An implicit solver produces the velocity field in the geometry.

There are two version of SSIIM: SSIM1 uses a structured grid and SSIIM2 uses an unstructured grid. The program is made for research and teaching purposes (Olsen, 2009).

Developed by: Olsen, NTNU
Sediment transport module: yes
Licence: free ware
Homepage: [http://folk.ntnu.no/nilsol/ssiim/](http://folk.ntnu.no/nilsol/ssiim/)
Operating Platform: Linux, OS/2, Windows
Output format: Layout, cross profile and longitudinal section, no GIS or CAD interfaces

Sediment transport module: suspended load, bed load

Formulas suspended load: Convection-diffusion equation for noncohesive sediments with boundary conditions by van Rijn (1987)
Formulas bed load: Van Rijn (1987)

Discretisation method:
- Finite volume method (space)
- Upwind approach 2nd order (space)
- Implicit approach 1st order (Olsen et al., 1999b) (time)

References: Olsen (1999a), Olsen (2000a)

CCHE3D

CCHE 3D is a three-dimensional computational simulation model developed at the National Centre for Computational Hydrosience and Engineering, The University of Mississippi. It is for simulating unsteady, free surface turbulent flows and associated sediment transport, pollutant transport and water quality problems.

This model is based on Efficient Element Method, a collocation approach of the Weighted Residual Method. The computational domain is discretized into a collection of hexahedrons with quadrilateral elements in horizontal space connected with vertical mesh lines. Free surface is solved with the kinematic equation; the discretization of 3D elements varies with the motion of the surface.

A variety of turbulence closure schemes, including parabolic, mixing length, k-ε, RNG k-ε, k-ω, and non-linear k-ε mode, are available. For most applications in hydraulic engineering study, the hydrostatic pressure assumption is valid; however, one often needs dynamic pressure solution for near field problems around hydraulic structures. CCHE3D provides both options. This model has been verified using analytic approach, physical model data and field data; it has been applied to many problems of river flow, sedimentation, coastal processes, thermal stratification, and wind driving flow, pollutant transport, and water quality analyses.

Developed by: NCCHE

References: Ribeiro et al. (2005), Oehi & Schleiss (2007)


Sediment transport module: yes
Licence: NOT free ware
Homepage: http://www.ncche.olemiss.edu/software/cche3d

Rainfall-runoff models

GSFLOW (PRMS w/MODFLOW)
Description based on (Tullos & Copeland, 2009b)

Resolution of Model Calculations
Semi-distributed model calculates on hydrologic response units, a scale delineated by the user

Watershed size limitations
Can model both small and large watersheds

Data Input Requirements
Climate date of air temperature and precipitation, solar radiation is optional. Delineation of hydrologic response units. Information on other portions of hydrologic cycle can be used to improve model use.

Sub-surface water algorithm
PRMS soil water modelling is coupled with MODFLOW for an integrated routing of sub-surface and groundwater.

Soil/Geology consideration
This can handled in the delineation of the hydrologic response units. Varying soil and geology conditions can be differentiated by the unit then adjust model parameters for that unit accordingly.

Vegetation consideration
This can handled in the delineation of the hydrologic response units. The “average” potential evaporation across each unit is specified. Also interception of precipitation by vegetation considered across each unit by average plant cover density.

Snow Algorithm
Initiation, accumulation, and depletion of a snowpack on each hydrologic response unit

Operating Platform
Windows or Unix

Computing Needs
Model can run on a powerful PC. However, the model will run on UNIX, which would enable use of a cluster of computers and likely handle the computing needs.

Model structure modifications
Parameters used in the various algorithms can be modified by user in the input files.

Developed by: USGS
Licence: free ware

HBV
There are many different versions of the HBV Model software besides the original SMHI version developed by S. Bergström and others since 1976.

Further description based on (Tullos & Copeland, 2009b):

Resolution of Model Calculations
Semi-distributed model which runs on sub-watershed scales delineated by the user

Watershed size limitations
Has been applied to plot scale up to very large river basins

Related applications
The model has been applied in some 40 countries, in all parts of the world. Has been used in climate change impact on water discharge
**Data Input Requirements**
Sub basin delineation and altitude and land cover distribution needed. Time-series of precipitation and temperature (time series of observed water discharge within watershed)

**Sub-surface water algorithm**
HBV works at the sub-basin scale. Uses a statistical distribution soil water response, user can alter this distribution.

**Soil/Geology consideration**
This can be handled in the delineation of the sub basins. Average soil and geology conditions that affect the hydrology can be adjusted for each sub basin.

**Vegetation consideration**
General land cover considered by sub-basin delineated.

**Snow Algorithm**
Uses a degree day approach from air temperature and water holding capacity of snow for melt. Examples in the literature of modifications of snow melt algorithm in HBV for improved results.

**Operating Platform**
Windows

**Computing Needs**
Model can be run on a powerful PC.

**Model structure modifications**
Parameters used in the various algorithms can be modified by user. In fact this is the intent of HBV. It provides a conceptual platform for modification as needed by the user.

developed by: Bergström and others, many improved version available

Licence: free ware

Homepage:
- The HBV model at the Swedish Department of Climate (SMHI) [http://www.smhi.se/sgn0106/if/hydrologi/hbv.htm](http://www.smhi.se/sgn0106/if/hydrologi/hbv.htm)
- HBV Matlab Code (lumped version) [http://www.aghakouchak.com/resources/hm/hbv.edu](http://www.aghakouchak.com/resources/hm/hbv.edu)

**MIKE SHE**
Description based on (Tullos & Copeland, 2009b)

**Resolution of Model Calculations**
Daily or sub-daily time steps. MIKE SHE is a distributed model but the grid scale is delineated by user.

**Watershed size limitations**
Can model both small and large watersheds

**Related applications**
MIKE SHE has been used in consultancy and research applications around the world.

**Data Input Requirements**
MIKE SHE model can include any or all of the processes in the land-phase of the hydrologic cycle. Interacts with GIS files for simplicity in use.

**Sub-surface water algorithm**
Sub-surface calculation and routing done at user specified time steps and scales.

**Soil/Geology consideration**
Soil and geology conditions that affect the hydrology can be adjusted for any use specified scale.

**Snow Algorithm**
MIKE SHE manages snow pack accumulation and melting using an advanced degree-day method
Operating Platform
Windows
Computing Needs
Model can run on a powerful PC.
Model structure modifications
Lots of flexibility in use of parameters and methods depending on amount of input data or computing needs

developed by: Danish Hydraulic Institute (DHI), Denmark
Licence: commercial (see homepage)
Homepage: http://www.mikebydhi.com/Products/WaterResources/MIKESHE.aspx

HEC-HMS
The Hydrologic Modelling System (HEC-HMS) is designed to simulate the precipitation-runoff processes of
dendritic watershed systems. It is designed to be applicable in a wide range of geographic areas for solving
the widest possible range of problems. This includes large river basin water supply and flood hydrology, and
small urban or natural watershed runoff. Hydrographs produced by the program are used directly or in
conjunction with other software for studies of water availability, urban drainage, flow forecasting, future
urbanization impact, reservoir spillway design, flood damage reduction, floodplain regulation, and systems
operation.

Resolution of Model Calculations
HEC-HMS can handle minute time steps.

Data Input Requirements
Large input requirements/possibilities: DEM of watershed, soils layer, vegetation layer, meteorological inputs
of: solar radiation, wind, air temp, at the time scale of modelling
Sub-surface water algorithm
Sub-surface calculation and routing done at custom time steps
Soil/Geology consideration
Required input to model.
Vegetation consideration
Required input to model.
Snow Algorithm
Only one snowmelt method
Operating Platform
Windows and Unix

Developed by: Hydrologic Engineering Centre (part of US Army Corps of Engineers), USA
Licence: free ware

DHSVM
Description based on (Tullos & Copeland, 2009b)

Resolution of Model Calculations
Distributive model working at a DEM grid scale (common applications range from 10m to 150m) DHSVM is
designed for sub daily time steps.
Watershed size limitations
100 m² to 100,000 km²
Related applications
DSHVM has been linked with climate models to determine climate change effects.
Data Input Requirements
Large input requirements: DEM of watershed, Soils layer, Vegetation layer, Meteorological inputs of: solar
radiation, wind, air temp, rel. humidity at the time scale of modelling
Sub-surface water algorithm
Sub-surface calculation and routing done at sub-daily time steps.

**Soil/Geology consideration**
Required input to model.

**Vegetation consideration**
Required input to model.

**Snow Algorithm**
Models snow melt and accumulation very well.

**Operating Platform**
Unix

**Computing Needs**
Data intensive model with many calculations. Would require model runs to be done on a cluster of Unix computers or large mainframe computer.

**Model structure modifications**
This is a research model you have full access to the code and control of the inputs.

**Negative Attributes for hydrologic modelling:**
Does not model lake or reservoir effects

**Developed by:** University of Washington
**Licence:** free ware
**Homepage:** [http://www.hydro.washington.edu/Lettenmaier/Models/DHSVM/contact.shtml](http://www.hydro.washington.edu/Lettenmaier/Models/DHSVM/contact.shtml)

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**VIC**

Description based on (Tullos & Copeland, 2009b)

**Resolution of Model Calculations**
Calculates from a large grid of land surfaces (>1 km2 per grid surface) at daily time steps or larger.

**Watershed size limitations**
Large scale, river basin size (e.g. Columbia or Colorado Rivers)

**Data Input Requirements**
Inputs are time series of daily or sub-daily meteorological drivers (e.g. precipitation, air temperature, wind speed). Large scale land cover information is needed.

**Sub-surface water algorithm**
No consideration of sub-surface water, water is only routed based on surface water inputs, good for large scale applications i.e. entire U.S., but not for smaller watersheds.

**Soil/Geology consideration**
Deals with soil effects based on changes made to the infiltration capacity algorithm of the model.

**Vegetation consideration**
Vegetation is considered by land cover type for modelled tiles or grid cells (>1 km2). Land cover is gross; forest, lake, grass, wetland, urban.

**Snow Algorithm**
VIC considers snow in several forms: ground snow pack, snow in the vegetation canopy, and snow on top of lake ice. Main features: Ground snow pack is quasi 2-layer; the topmost portion of the pack is considered separately for solving energy balance at pack surface, can consider spatially-distributed (laterally) snow coverage, can consider blowing snow sublimation

**Operating Platform**
Unix

**Computing Needs**
Large scale model probably would require working on a cluster of Unix computers.

**Model structure modifications**
Model parameters are modifiable. The model calculations are not. The assumptions must be accepted.

**Developed by:** Xu Liang at the University of Washington
**Licence:** free ware
**Homepage:** [http://www.hydro.washington.edu/Lettenmaier/Models/VIC/](http://www.hydro.washington.edu/Lettenmaier/Models/VIC/)
Habitat models

Habitat models can be an appropriate instrument for studying and investigating the ecological functions of these systems. They allow for the qualitative assessment of habitat conditions for the species under consideration, most commonly for indicator species such as fish.

**PHABSIM**

The purpose of the Physical Habitat Simulation System (PHABSIM) is to simulate a relationship between stream flow and physical habitat for various life stages of a species of fish or a recreational activity. The basic objective of physical habitat simulation is to obtain a representation of the physical stream so that the stream may be linked, through biological considerations, to the social, political, and economic world (USGS, 2011).

Description based on (Tullos & Copeland, 2009a)

**Spatial scale**

Mesohabitat

**Integration with hydrodynamic model**

PHABSIM WSP uses step-backwater method to obtain 1D representation of flow. STGQ and MANQ models use empirical means to obtain transect based representations of flow. Assume fixed bed profile

**Approach to solving governing equation**

- IFIM Instream Flow Incremental Methodology
  1. that water depth, water velocity, and substrate size are the only physical habitat variables determining position choice by fish;
  2. Manning’s n remains constant with changes in streamflow;
  3. mean water velocities in individual cells change in the same way as the mean velocity for a cross-section with changes in streamflow;
  4. water velocities at 6/10 of the depth affect fish preference;
  5. habitat preference curves can be treated as probability functions;
  6. habitat variables are independent in their influence on position choice;
  7. large areas of less than optimum habitat have the same productive capacity as small areas of optimum habitat; and
  8. that areas of stream not occupied by fish are useless.

**Data needs**

- cross-sections, discharges, coordinate data, suitability curves

**Model output**

- Water surface level (WSL) & velocity calibrated & then simulated
- habitat time series (mesohabitat)

**Developed by:** USGS
**Licence:** free ware

**RHABSIM**

RHABSIM (Riverine HABitat SI Mutation) is a fully integrated program for river hydraulics and aquatic habitat modeling using the Instream Flow Incremental Methodology (IFIM). Running in Microsoft Windows and DOS, it is an extensive conversion of the PHABSIM hydraulic and habitat simulation system developed by the U. S. Fish and Wildlife Service.
Further description based on (Tullos & Copeland, 2009a)

**Spatial scale**
Up to 100 cross-sections per data file, 300 data points per cross-section, five stage/discharge calibration sets, 30 Calibration Flows (HYDSIM) and Simulation Flows (HABSIM).

**Time step**
Stream flow data matrix can be set up as days by months, months by years, weeks by years or hours by days. Up to 600 columns of data (50 years as daily)

**Integration with hydrodynamic model**
High

**Data needs**
- Import and export PHABSIM data files (IFG4, MSQ and WSP).
- Import standard ASCII files with X, Y, Velocity and Attribute data.
- Import acoustic Doppler files. Automatic generation of average cell velocities. Option to calculate cross-section bearing. Graphic interface allows easy adjustment velocities to cross-section, shows boat-track, calculated cross-section, bad points. Correctly finds negative velocities. Report shows ADCP reported flow compared with RHABSIM calculated flow.
- Convert files between metric and U.S. units.

**Model output**
- Reach plan view (water depths, flow velocity, substrate, refuge, habitat suitability)
- Cross sections
- Profile views
- 3D view
- Fish maps
- Wetted area
- Frequency distributions for water d, v, substrate
- Habitat distribution
- WUA

Developed by: Thomas R. Payne & Associates

**Licence**: free ware

**Homepage**: [http://www.trpafishbiologists.com/rindex.html#specifics](http://www.trpafishbiologists.com/rindex.html#specifics)

**CASIMIR-Fish module**

CASIM is unique in that it makes use of physical and biological parameters through the application of expert knowledge using a fuzzy logic based rule system (JORDE et al. 2000, SCHNEIDER 2001), but can also use the standard preference function method as well.
The main advantages of using habitat simulation models are that:

- The ecological condition of an aquatic ecosystem is directly coupled with the living conditions of the typical resident species.
- The use of habitat models allows for the effects of changing flow rates and structural characteristics to be account for, and to some extent, can be used to predict their impacts.
- Changes to the flow rate result primarily in impacting the water depth, flow velocity, and substrate conditions, all of which are major factors in determining the habitat suitability and can be directly evaluated with numerical models.
- Due to the direct relationship between habitat conditions and flow rate, a quantitative basis can be established whereby an overall ecological assessment of the habitat requirements can be performed.

**Data needs**

Required input data for the basis version are measured or calculated water surface elevations. An expanded version of CASiMiR allows for the use of 2D hydraulic calculations (eg. from HYDRO_AS-2D) to be included as well. Currently under development is a GIS-based Meso CASiMiR model which allows for an unlimited number of user-defined input parameters.

**Model output**

- reach plan view (water depths, flow velocity, substrate, refuge, habitat suitability)
- cross sections
- profile views
- 3D view
- fish maps
- wetted area
- frequency distributions for water d, v, substrate
- habitat distribution
- composite habitat suitability WUA HHS

**Developed by:** University Stuttgart, Jorge & Schneider

**Licence:** free ware for research, commercial see homepage

**Homepage:** [http://www.casimir-software.de/aufbau_eng.html](http://www.casimir-software.de/aufbau_eng.html)
Conclusion

In this report a short overview about the numeric models for river hydraulics in computational fluid dynamics (CFD) and about informatics tools used in the field of water management is given. Due to the fact that the number of numerical models and informatics tools is very large and still increasing, the given list is not complete. All these programs have varying degree of sophistication and reliability.

Depending on the problem and on the special configurations which depend on the specific case the user has to choose the right informatics tool.
References


Harb, G., St. Haun, S. Ortner, C. Dorfmann and J. Schneider (2010), The influence of secondary currents on reservoir sedimentation – experimental and numerical studies. IAHR Conference 2011, Brisbane, Australia, in print


NCCHE (2011), Homepage of the National Centre for Computational Hydrosience and Engineering: http://www.ncche.olemiss.edu/software; visited on the 29th of March 2011

Nester, T., U. Drabek, D. Gutknecht, R. Kirnbauer (2010), Real Time Flood Forecasts For The Danube Tributaries In Austria. BALWOIS 2010 - Ohrid, Republic of Macedonia - 25, 29 May 2010


University Stuttgart (2011), CASIMIR Homepage; http://www.casimir-software.de/aufbau_eng.html; visited on the 29th of March 2011


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