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

JUNE 18, 1999

Name of Model:
MIKE SHE

Model Type:
Physically Based, distributed and integrated hydrologic modeling system

Model Objective(s):
The purpose of MIKE SHE is the simulation of coupled hydrologic processes with emphasis on surface water - groundwater interactions, channel flow, unsaturated zone flow and groundwater flow.

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Model Structure or Mathematical Basis:

1. Basin Types

MIKE SHE is applicable for a wide range of different basin types. Typically the model is however used to model rural, urban or agricultural areas. Mountainous regions may be considered in the model either using a physically based or a lumped conceptual rainfall-runoff type model that provides inflow to the physically based model. Thus you may adopt simple models for the border regions and more complex physically based models for the main areas of interest.

2. Size of the basin

MIKE SHE has been applied to detailed studies ranging from detailed flow and transport investigations, to wetland studies and basin studies. Thus the model has been applied on scales from about 1 km2 to 100.000 km2. Typical basin sizes are small to medium (100 – 5000 km2).

3. Simulation type

The model is designed for continues simulations ranging typically from 1-100 years.

4. Components included
The model includes modules that describe the entire land-phase of the hydrologic cycle:
- Precipitation and evapotranspiration
- Interception
- infiltration (unsaturated zone flow)
- Overland flow
- Channel flow
- groundwater flow

The above processes are dynamically coupled.

5. Underlying hypotheses (equations adopted)
- Actual evapotranspiration is calculated using the Kristensen&Jensen model. This model calculated actual evapotranspiration as the sum of evaporation from interception storage, ponded water, soil evaporation and transpiration.
- The interception is calculated as a function of the vegetation coverage described in terms of Leaf-Area-Index.
- Infiltration is calculated using an unsaturated zone flow model. In its most comprehensive mode Richard's equation is adopted. A simplified Richards equation that ignores the tension forces is also included and finally a very simple model using constant infiltration capacity/mass-balance approach is included.
- Overland flow is described in a 2-dimensional implicit finite difference model based on the Kinematic wave theory.
- Channel flow is described using DHI's MIKE11 river modeling system which solves the full Saint-Venant equations (dynamic wave). The channel flow model supports a suite of hydraulic control structures. Simplified approaches (kinematic and diffusion wave) is also supported by the model.
- Groundwater flow is described using either a 3-dimensional Boussinesq finite-difference model or a lumped (semi-distributed) linear-reservoir flow model. Both approaches may be linked to an of the surface water and infiltration models available in MIKE SHE.

6. Mathematical Formulation.
- The core of MIKE SHE is a distributed, physically based model. The model adopts finite-difference techniques and uses implicit solvers for the various model components. As described above the physically based formulations may optionally be replaced by more simple formulations (for instance linear reservoir flow for the groundwater and the simple infiltration module for the unsaturated zone).

7. Additional Modules
- The model include modules for water quality (advection-dispersion,biology, chemistry, particle tracking) and agriculture (crop and nutrient dynamics, irrigation)

Model Parameters:

The model parameters depend to some extent of the selected technical approach. In its most comprehensive mode (integrated, physically based) the most important input parameters are:

- Evapotranspiration Module (Kristensen&Jensen)

daily rainfall, potential evapotranspiration (daily, weekly, monthly), leaf-area-index, root depth and 4 empirical parameters.

- Snow melt

Temperature, temperature treshold for snowfall, degree-day factor for snow-melt calculation.

- Infiltration

Saturated hydraulic conductivity and soil-moisture retention curves for all soiltypes, exponent for calculated the unsaturated hydraulic conductivity as a function of moisture content (using a power function).

- Overland Flow

Surface topography, Mannings M.

- Channel Flow

River Cross-sections, Mannings M/n.

- Groundwater Flow

Geological layers, hydraulic conductivity and storage coefficients, boundary conditions (heads, gradients, fluxes), groundwater extractions

- calibration data

surface water stages and discharges, groundwater stages, pumping test data, (soil moisture contents typically for detailed studies focusing on infiltration and recharge processes)

Spatial Scale Employed in the Model:

The model is fully distributed. Thus all input data may be distributed in space and specified in maps (GIS maps etc). The number of computational cells in the groundwater model typically varies between 20.000 – 250.000.

Temporal Scale Employed in the Model:

MIKE SHE is designed for long-term, continuos simulations. The length of a simulation period varies depending on the dynamics of the hydrological system and the purpose of the model. Typical simulation periods are 1-25 years.
The different components in MIKE SHE adopts different (and dynamically varying) simulation time-steps. Typical time-steps are:

- Overland flow (½-3 hours)
- channel flow (5 min – 1 hour)
- unsaturated zone flow (½ hour – 24 hours)
- saturated zone flow (6 hours – 48 hours)

Input Data Requirements:

- Watershed characteristics (topographic maps, geological stratification and hydraulic aquifer properties, channel cross-sections (and lengths),
- Climate data (daily precipitation, daily mean temperature, potential evapotranspiration)
- Stream flow data (water stages and flows)
- Ground water data (groundwater stages, groundwater extractions)
- Soils data (saturated hydraulic conductivity, soil-moisture retention curves)
- Land use data (Land use and cropping pattern, leaf-area-index and root depth)

Computer Requirements:

MIKE SHE runs on PENTIUM PC's under Windows NT, 95 and 98.

Model Output:

MIKE SHE produces a vast amount of data that describes the hydrological system in details. The most important output data are:

- actual evapotranspiration
- stages and flows in the river system
- recharge to the saturated zone and moisture contents in the unsaturated zone
- stages and flows in the saturated zone (groundwater model)
- exchange flows between rivers and aquifers, rivers and drained areas, rivers and overland flow.

Parameter Estimation / Model Calibration:

Being physically based MIKE SHE adopts input data that are measured in field. Some model calibration is however always required. The most important calibration parameters are hydraulic conductivity of the aquifer, manning number in rivers, saturated/unsaturated hydraulic conductivity for the unsaturated zone model.

Model Testing and Verification:

MIKE SHE has been extensively used and tested on many different hydrologic systems and for many different purposes. Most MIKE SHE model applications include split-sample tests for model calibration and validation. Test data sets are available for user training and model performance testing.

Model Sensitivity:

As for pure groundwater models MIKE SHE are highly sensitive to the hydraulic properties of the aquifer system. In surface water dominated regimes it may however be the surface water features (Mannings M, cross-sectional geometry) that becomes the most important for the model calibration (Mannings M, channel geometry). Sensitivity analysis is often carried out in connection with a model application.

Model Reliability:

A highly professional team develops MIKE SHE and a number of quality assurance procedures are implemented to ensure high software reliability standards. For instance source-code control systems are used and automatic code building and performance tests are done on a daily basis. Finally, a software service center provides support to MIKE SHE users. Reliability of model results depends obviously on the quality of a site-specific MIKE SHE model. The reliability (or precision) of model results can be assessed through sensitivity analysis.

Model Application / Case Studies:

MIKE SHE has been applied in many different countries typically for studies where surface-water/groundwater interactions are important. Examples are general river basin water management studies, wetland protection and river restoration studies, well field protection studies, non-point pollution studies, landfill pollution studies.

Documentation:

MIKE SHE USER MANUALS are available that contains both user's guide and technical reference manuals.

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:

MIKE SHE has been employed in most countries in Europe and in many Asian countries. In the US MIKE SHE is currently used by South Florida Water Management District as part of the Everglades Restoration Project.

REFERENCES

Singh, V. P. (Ed.), 1995
Computer Models of Watershed Hydrology, Water Resources Publications, P.O.Box 260026, HIghlands Ranch, Colorado 80126-0026 USA