The application of MIKE SHE to floodplain inundation and urban drainage assessment in South East Asia

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Abstract MIKE SHE is a powerful modelling tool that can simulate the entire land phase of the hydrological cycle, including hydraulics. A high degree of flexibility enables the model to be tailored to suit the specific needs of an application. This broad capability and flexibility is demonstrated, with examples of applications to broad river flooding, catchment hydrology and urban drainage within the South East Asia region.

Introduction

Assessment of overland flooding, establishing the performance of drainage infrastructure and quantifying effects of growth is effectively accomplished using computer-based modelling tools. These tools simulate hydrologic and hydraulic processes, so as to establish discharges and flood levels. Integrated with GIS, calibrated to available measurements and observations, they enable the performance of the existing drainage system, sizing of drainage system improvements and flood hazard maps to be quantified.

Populated areas of South East Asia are often characterised by major rivers draining into low lying coastal plains. This creates an often complex situation where flooding occurs through a combination of:

- Broad river flooding and overtopping of levee banks
- Tidal inundation from high tides and storm surge effects
- Local ponding and urban flooding due to intense, localised storm events

To accurately assess these effects in combination, a modelling system is required that can simulate all the relevant phases of the hydrologic cycle. MIKE SHE (DHI, 2006), simulates the entire land phase of the hydrologic cycle (including hydraulics); a conceptual diagram is shown in Figure??. Each component of the cycle can be modelled in various ways, with differing levels of detail. This flexibility enables the model to be tailored to suit the specific requirements of each application. MIKE SHE is generally more physically based than other models, which reduces the interpretations and assumptions required during model establishment and, with a basis primarily on spatial data (which is extracted directly from the GIS), makes changes and updates easier.

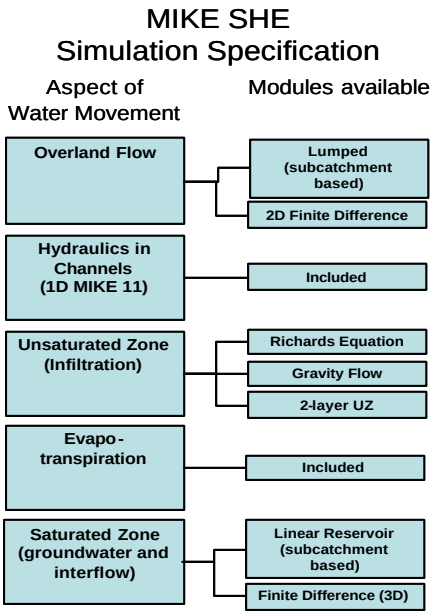

Figure 1 Overview of MIKE SHE components and modules

This paper demonstrates the flexibility of MIKE SHE in various applications, ranging from catchment hydrology to broad floodplain inundation to small scale urban drainage design.

Catchment Hydrology

The following example demonstrates the application of MIKE SHE as a lumped hydrologic model; its requirement is to accurately generate catchment runoff from subcatchments on a nationwide scale. Rainfall is applied from point rainfall stations, spatially distributed using Thiessen polygons. Evapotranspiration (of less importance in the context of intense rainfall that causes flooding) is applied using reference evaporation data and default model parameters. Overland flow is described using a simplified kinematic wave approach, with each subcatchment defining a lumped overland flow zones with values of slope, slope length, friction, detention storage and initial depth. A two layer unsaturated zone flow description is applied, with parameters defined initially using a soil map. Subject to calibration and land use maps, infiltration rates in urban areas were modified to account for impervious ground cover. Larger river systems were found to be sensitive to subsurface response; interflow and groundwater flow was represented using linear reservoirs, the characteristics derived through model calibration. The dominant parameter is the interflow time constant, which determines the response time of subsurface flow a particular subcatchment. This was defined using a loose relationship between calibrated values and subcatchment characteristics (area, slope and hydraulic length).

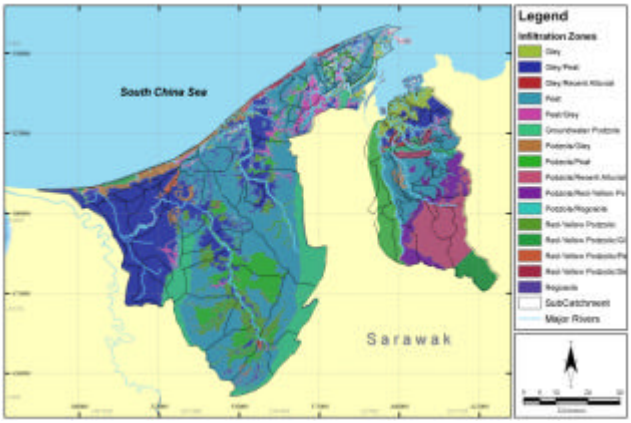

Figure 2 **Regional hydrologic model, showing subcatchment definitions overlaid with infiltration zones defined from soil mapping**

Inundation of Coastal Zones

Outputs from the hydrologic model described above were subsequently applied to a local model of a low lying coastal zone subject to local ponding and inundation and backwater effects from tides. Using the hydrologic model as a basis, key enhancements were the inclusion of a two-dimensional finite difference overland flow (2DOL) module (instead of a lumped approach) and a channel hydraulics module (linkage to MIKE 11, DHI, 2006) to simulate flows overland, through rivers, drains and waterways, including the interchange between ocean and channel and overland and channel.

The 2DOL module is a two-dimensional diffusive wave model; this formulation can accurately simulate friction dominated flow, which is the controlling process of overland flow. Model geometry is input via a terrain raster; water is then free to flow according to the features of the terrain, without any of the inferences or definitions of flow paths that are required in a one-dimensional (1D) model. Assuming that the DEM representing terrain is at least as accurate as a corresponding 1D geometry layout, this approach is less conceptual, more accurate and can generate flood maps automatically. A limitation of the 2DOL approach is grid size; for example a 50 m grid is not suitable for simulating flow through a 2 m drain. This is overcome by incorporating 1D MIKE 11 channels. MIKE 11 uses a system of interconnected branches to represent flow. Each branch represents a separate flowpath, be it a main river channel, an open drain, a closed conduit or floodplain. By producing an interconnected mesh a “quasi-two-dimensional” model is created, where the flow of water in various directions along different flowpaths is simulated. The MIKE 11 network is fully embedded into MIKE SHE, which allows subsurface and surface interchange in both directions; this permits simulation of tidal variations and its consequences on flooding.

In urban catchments there are areas with secondary drainage; the interconnected system of smaller drains and storages that manage stormwater on a local scale within a development. Explicitly defining such drainage networks is beyond the scope of the modelling exercise. Instead, secondary drainage networks are implicitly defined by increasing infiltration rates to divert flow away from the overland component and into the channel networks via the saturated zone. Pumps, which convey ponded water away from bunded areas, are represented in

the same manner. MIKE 11 can simulate structures such as pumps more precisely; however this would require the full description of the secondary drainage network within MIKE 11.

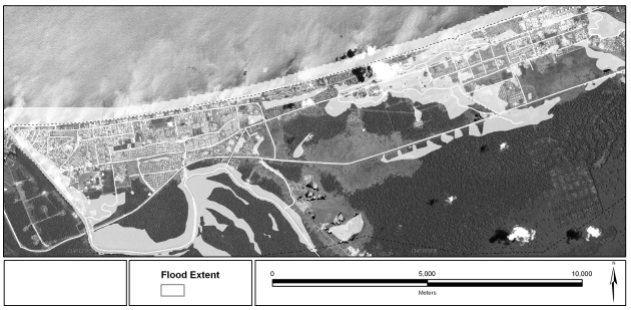

Figure 3 **Coastal inundation model, showing flooding from combined influences of elevated ocean water levels and ponding from intense local rainfall**

Broad Floodplain Inundation

As spatial terrain data becomes more readily available, application of the overland (FDOL) module in combination with MIKE 11 river links to generate flood maps is made easier. Use of MIKE SHE in this manner is now considered to be a good option as opposed to flood mapping from one-dimensional modelling. The following example demonstrates this, showing broad scale floodplain inundation from overtopping of the main river channels.

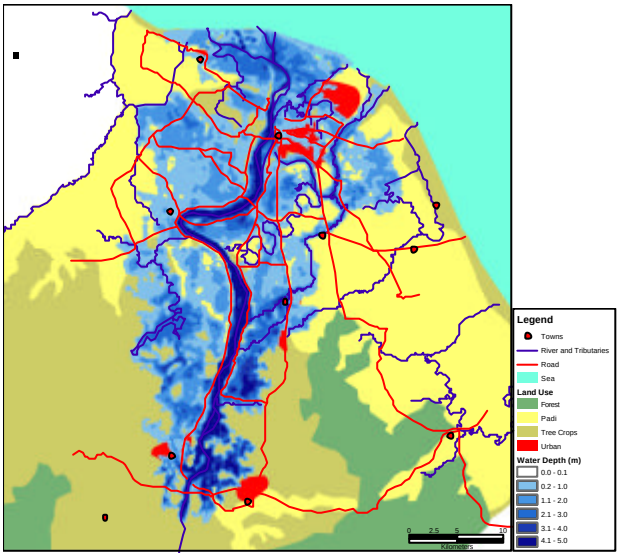

Figure 4 **Flood mapping using MIKE SHE 2D Overland Module**

Urban Drainage

The figure shows an example of an urban application of MIKE SHE. A 1D model network of the broad river and drainage system was developed with a detailed focus area, which consists of a detailed local drainage network with overland inundation. The model is capable of simulating overland inundation due to the combined effects local rainfall and backwater effects from river flooding and/or storm surge and tide.

Unless modelling to a very fine scale, urban drainage applications require consideration of secondary drainage; the interconnected system of small drains and storages that manage stormwater on a local scale. This can be achieved using MIKE SHE by either increasing infiltration rates (to increase conveyance from overland runoff into the 1D drainage channel network) or setting paved areas (which allows a given fraction of overland volume to divert directly to the saturated zone).

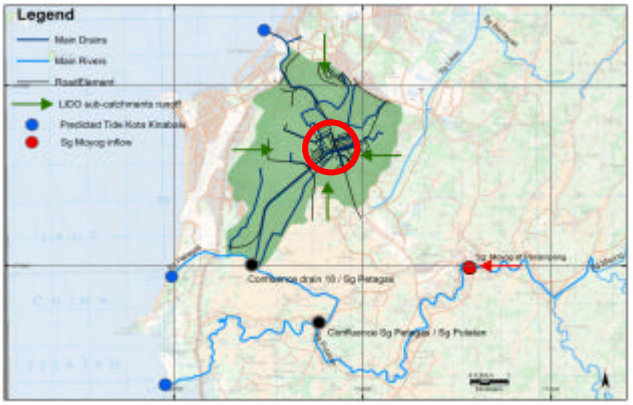

Figure 5 **Overview of urban drainage model, showing broad 1D network combined with local catchments and detailed 1D/2D focus area (red circle)**

Figure 6 **Local inundation of urban area due to combined influences of local rainfall and backwater effects from river flooding and/or storm surge and tide.**

Conclusions

MIKE SHE simulates the entire land phase of the hydrologic cycle (including hydraulics), and each component can be modelled to differing levels of detail (or switched off). This flexibility enables the model to be tailored to suit the specific requirements of each application. MIKE SHE is generally more physically based than other models, which reduces the interpretations and assumptions required during model establishment and, with a basis primarily on spatial data (which is extracted directly from the GIS), makes changes and updates easier.

The examples above demonstrate a broad range of application of MIKE SHE to flood and drainage modelling; this is in some respects contrary to the traditional fields of application of MIKE SHE, which is more towards groundwater and water management.

REFERENCES

- DHI Water and Environment, “MIKE SHE Users Manual, Release 2006”, DHI, (2006).
- DHI Water and Environment, “MIKE 11 Users Manual, Release 2006”, DHI, (2006).