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The Nile Basin Decision Support System

Hydrolink

THE NILE BASIN DECISION SUP

BY HENRIK REFSTRUP SØRENSEN, MEKURIA BEYENE AND HANS CHRISTIAN AMMENTORP

The Nile Basin Initiative (NBI) managed to successfully develop a shared and accepted set of water management tools to be used by 10 Nile Basin countries – the Nile Basin Decision Support System (NB DSS). The NB DSS was developed by DHI in close cooperation with the NBI, and it was funded a World Bank grant. The NB DSS also became the starting point for a generalized DSS, which was later commercialised by DHI and which is now used to improve water management in many other countries in Africa and elsewhere in the world.

Figure 1 - The Nile River is a vital water source for the Nile Riparians not least Egypt which rely almost entirely on the Nile River Water. The image shows city lights along the Nile River in Egypt (NASA)

The Nile basin with an area of 3 million km^2 covers about 10% of the area of Africa. More than 190 million people live in the basin itself and the population in the 11 basin countries exceeds 400 million. The average annual flow of the Nile is approximately 85 billion m^3, which makes the Nile basin, compared to many big rivers, a water stressed region. Livelihoods and ecosystems as well as economic activities in the region depend significantly on the Nile water. Most of the water comes from the Lake Victoria region and the Ethiopian highlands. Water supply in most downstream countries in the basin, not least Egypt, relies almost entirely on the Nile water. It is expected that the growing population and climate change will further strain the available water resources in the region.

The main challenges in the basin include droughts, environmental degradation, floods, poor coverage of water supply, food insecurity and power shortages. On the other hand, the region offers opportunities because of the still untapped potential for energy and food production. In appreciation of this, the Nile riparian countries have expressed their political will for cooperation and there has been international readiness for support.

In the last decades, the Nile riparians have been in the process of working towards cooperatively developing and managing their shared water resources. This required identifying mutually beneficial development and management options as this is the key to sustainable use of the shared water resources. Consequently, the Nile riparians have recognized that accurate information and shared water management tools would provide a sound technical basis for joint decision-making.

This was the rationale behind the NBI's decision to develop the NB DSS – a common, computer-based platform for communication, information management, and analysis of Nile basin water resources.

Coupled with human resources development and institutional strengthening, the NB DSS would provide a framework for sharing knowledge, understanding river system behaviour, evaluating alternative development and management schemes. It will also support informed decision-making from a regional perspective with the shared objective of developing the water resources in a cooperative manner, sharing socio-economic benefits, and promoting regional peace and stability.

The NB-DSS was developed between 2006 and 2012. The needs assessment was based on a comprehensive consultative processes with relevant stakeholders and led to the conceptual design of the system and the identification of the functionality required to address the key areas of concerns. This process resulted in a number of requirements related to the software development process (process requirements), the functionality of the system (functional requirements), the software architecture and deployment options (non-functional requirements).

The functional requirements were derived based on additional stakeholder consultations focused on identifying the key challenges in the Nile Basin. These were identified as the water resources development (infrastructure, e.g. new dams), optimal utilization of the water resources (e.g. reservoir operation rules), energy (hydropower) development, irrigated and rain fed agriculture, coping with droughts, coping with floods, navigation, and watershed management (soil erosion and sediment loads). In addition and across the eight areas of concern come climate change and water quality.

The non-functional requirements were related to ease of use, expandability options, openness and transparency and included a long-term commitment for maintenance and support. Hence, largely the non-functional requirements focused on ensuring long-term sustainability of the system, for instance, by requiring a software architecture that allows developers other than DHI's to extend the system with new functionality.

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With these prerequisites, it was apparent that developing a generalized DSS rather than a very specific Nile Basin system would be the most efficient option. Such a system would fulfil the requirements for the NB DSS and it would be an opportunity to adapt and customize the system easily to other river basins in Africa and elsewhere. Both parties recognized a mutual interest in DHI's commercialization of the system. For DHI, the commercial scalability was the driver while for NBI the driver was sustainability of the product, as DHI would commit to maintain and further develop the system.

The NB DSS is an integrated solution with four main components:

1) An information management system that comprises (a) a relational database management system to store all information in one repository
2) A geographic information system (GIS) to process all geo-referenced information
3) A time series management toolkit to process and analyse time-series data
4) A set of analytical and modelling tools including:
   - a water resources modelling platform that allows plugging-in and linking of water balance and allocation, rainfall-runoff and hydrodynamic models (an open modelling framework)
   - scenario management including key performance indicator (KPI) calculations for scenario comparison
   - ensemble generator for probabilistic analyses
   - climate downscaling tools based on global circulation models
   - multi-objective optimization and trade-off analysis
   - economic cost-benefit-analyses, and multi-criteria-analysis to support a structured stakeholder involvement and decision-making process

Today, the commercialized products are marketed under names MIKE INFO, MIKE PLANNING and MIKE OPERATIONS (http://www.mikepoweredbydhi.com/areas-of-application/data-management-decision-support-and-operational-forecasting). The NB DSS was the predecessor of MIKE INFO and MIKE PLANNING, while MIKE OPERATIONS has added capabilities to work with online data, forecasting and operational control. These products are integrated with DHI's MIKE modelling systems, but they are also open to non-DHI models, which was one of the key features of the NB DSS. During the past few years, they have been applied to a large number of projects both in Africa and elsewhere. The two applications presented next demonstrate the use of MIKE INFO for data management in the Lake Victoria basin and MIKE OPERATIONS for forecasting floods and droughts in the Shire river basin in Malawi.

Figure 3 - The Functionality of the Nile Basin DSS is now embedded in MIKE INFO, MIKE PLANNING and MIKE OPERATIONS

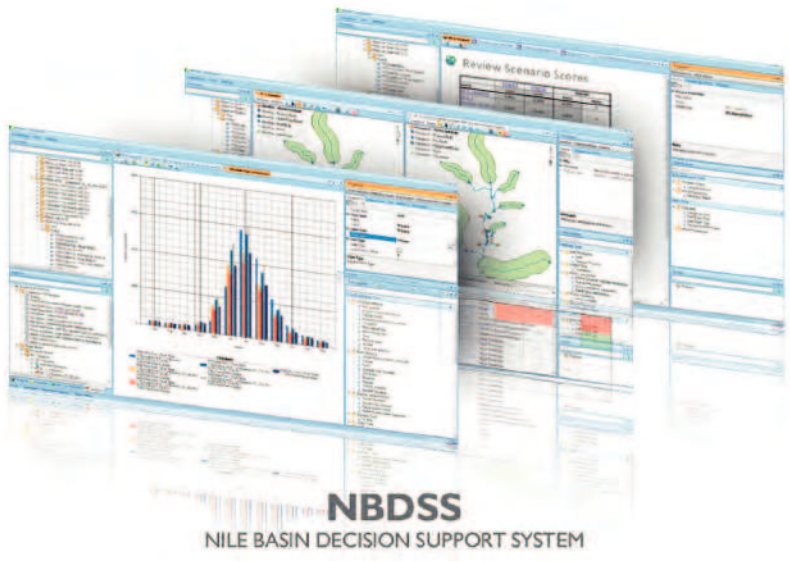

Figure 2 - The NB DSS provides a suite of tools for time-series analysis, scenario management and Multi-Criteria-Analysis

Henrik Refstrup Sørensen **is Sales Director in DHI's MIKE software organisation. He has more than 25 years of professional experience and has worked on numerous water resources projects all over the world. From 2010-2013 Henrik was DHI's Team Leader on the project "Development and Deployment of the Nile Basin DSS" where he worked closely with the Nile Basin Initiative in developing the Nile Basin DSS. Henrik holds a M.Sc. from University of Aalborg, Denmark.**

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Hans Christian Ammentorp **is a senior hydrologist at DHI with more than 30 years of professional experience. He has held several Team Leader positions and has been in charge of establishing multiple forecasting- and decision support systems addressing issues of drought and floods in many different pats of the world. He has worked Head of the Water Resources Department of DHI Malaysia during 2013 and 2014. Hans Christian holds a M.Sc. from the Danish Technical University.**

Application 1: Lake Victoria Water Resources Information System (WRIS)

Several East African countries depend on Lake Victoria – the world's second largest freshwater body – for transportation, hydropower generation, food, and water. Environmental changes in recent years have highlighted the need to coordinate various water resources and environmental initiatives in the basin. Working with the Lake Victoria Basin Commission (LVBC), DHI developed a Water Resources Information System (WRIS) based on MIKE INFO.

The 68 800 km^2 Lake Victoria is the second largest freshwater body in the world. The lake's basin is a vital trans-boundary resource shared by the East African Community (EAC) – Kenya, Tanzania, Uganda, Rwanda, and Burundi. Part of the upper Nile River Basin system, the Lake Victoria Basin (LVB) and the lake itself support a wide diversity of habitats, flora and fauna, making it ecologically significant. It is also economically important for the EAC, as the basin:

- supports a large fishing industry – both for export and local consumption
- is an important source of water
- provides a means of transportation
- is vital for hydropower generation

In 2001, the EAC established the Lake Victoria Basin Commission (LVBC) to serve as a mechanism for coordinating various water resources and environmental initiatives in the basin. Today, it is a centre for the promotion of studies, investments, and information sharing among the various stakeholders.

Well-documented environmental changes have occurred in Lake Victoria's and the basin's ecosystems over the past several decades. Increased strain on the basin's water resources has led to water quantity and quality issues. This could potentially affect the natural flora and fauna habitats in Lake Victoria and its basin.

Concerns about these changes led to the creation of the large-scale Lake Victoria Environmental Management Project (LVEMP), supported by the Global Environment Facility (GEF) and the Government of Sweden. With the goal of improving the livelihood of the communities that depend on the natural resources of the Lake Victoria Basin, the long-term, trans-boundary LVEMP is designed to:

- improve the collaborative management of natural resources
- identify and reduce environmental stress in hotspots and selected degraded sub-catchments
- better utilise water resources

LVEMP is now focused on developing a Water Resources Information System (WRIS) to monitor surface water, groundwater and water quality, and making this key information available. It includes a GIS-based database for land-use, hydrology, and biodiversity in the Lake Victoria Basin.

As part of the LVEMP, DHI has developed and operationalized the WRIS for use by multiple stakeholders, including technical and managerial personnel and selected information is available to the public. The project will also

Figure 4 - Local Fishermen on Lake Victoria (photo by Jens Kristian Loerup, DHI)

Figure 5 - The WRIS gives easy access to data for water managers within the Lake Victoria Basin (graphics by DHI)

contribute to the development of guidelines and methods for data exchange between stakeholders.

Application 2: Operational Decision Support System, Malawi

The Shire River is the largest river in Malawi and is the only outlet of Lake Malawi. From the lake, it flows around 400 kilometres before entering the Zambezi River in Mozambique. The river is an important water source for local water supply, irrigation and hydropower. Malawi relies almost entirely relies almost entirely on hydropower on the Shire Riverf or its power production, which depends primarily on a stable and sufficient outflow from Lake Malawi. Consequently sustainable use of water in the Lake Malawi basin is essential. The sustainable use of the water resources is a key element of the Shire River Basin Management Program (SRBMP, World Bank) which is currently being implemented in Malawi to increase social, economic and environmental benefits by effectively and collaboratively planning, developing and managing the Shire River Basin's natural resources.

Another central component of the SRBMP is the development of an Operational Decision Support System (ODSS) to provide short- and long-term forecasts of river flow and water levels along with a range of drought indicators to support operational decisions in the Shire River basin. The ODSS builds on MIKE INFO for data management, MIKE PLANNING for scenario analysis and MIKE OPERATIONS for long- and short-term forecasting.

The ODSS implementation is carried out in close cooperation with the Malawian authorities, particularly the Department for Climate Change and Meteorological Services and the Department of Water Resources, to ensure its applicability in reducing the adverse impacts of future climate extremes.

Figure 7 - The recent floods caused severe damage to important infrastructure in Malawi

The ODSS automatically imports the latest spatial and temporal data, performs the required analyses and forecast calculations, and extracts key results and information for dissemination to stakeholders. It also includes a range of tools for the operators to monitor, process, and analyse the imported data and results of the ODSS.

Using satellite information as a data source is an important element of the project. Figure 7 shows the soil water index from 17th November 2014 through 1st January 2015 a period during which a drought was developing.

Shortly after 1st January 2015 (the last satellite image in Figure 7) the country was hit by heavy rainfall – more than 400 mm/day - causing severe floods, loss of life and damage to property, crops and infrastructure (see Figure 7). Thus, within few days the country went from dealing with drought to dealing with severe floods. This illustrates the relevance of the ODSS in helping water managers understanding, forecasting and managing these extremes and reducing their impacts.

Key results are kept up-to-date on a web site accessible by all stakeholders in the river basin as well as by the general public. Personnel with responsibilities for emergency actions automatically receive notifications (SMS or email messages) whenever the risk of flooding increases in their area. Figure 8 shows MIKE OPERATIONS giving water managers quick and simple access to key information during extreme events such as floods.

Conclusions

The Nile Basin DSS was the starting point for the development of a generalised software platform for data management, water resources planning and forecasting. The NB DSS is today a shared and accepted water management tool used by the Nile Basin countries. Today NB DSS is driven by the commercialised version of the software platform - MIKE PLANNING - which is used by many other countries in Africa. The system has further developed into a data and information management system and for operational forecasting, as exemplified by the Lake Victoria Water Resources Information System (WRIS) and the Operational Decision Support System (ODSS) in Malawi. MIKE INFO, MIKE PLANNING and MIKE OPERATIONS are today used globally and are continuously being further developed by DHI. Many of these new developments are made available to the NBI as part of their long-term service and maintenance agreement. What started with the NB DSS in 2009 has proven its usefulness at a global scale and is now moving into other water domains. For instance, MIKE OPERATIONS now helps cities reducing combined sewer overflows by controlling and optimising their collection systems in real-time and soon MIKE OPERATIONS will provide marine water forecast services – for instance during oil spill accidents or dredging activities. ■

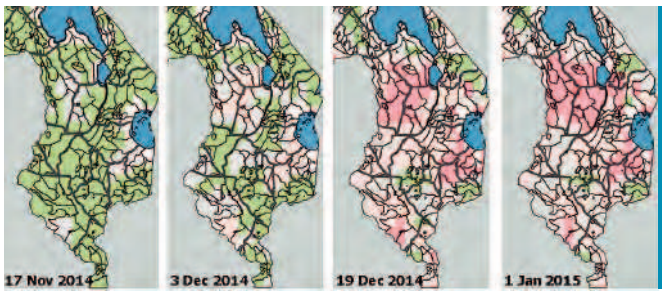

Figure 6 - Satellite-based soil water index illustrating the unusually dry conditions prevailing in December 2014 and early January 2015. These very dry conditions were followed by floods in January and February (graphics by DHI)

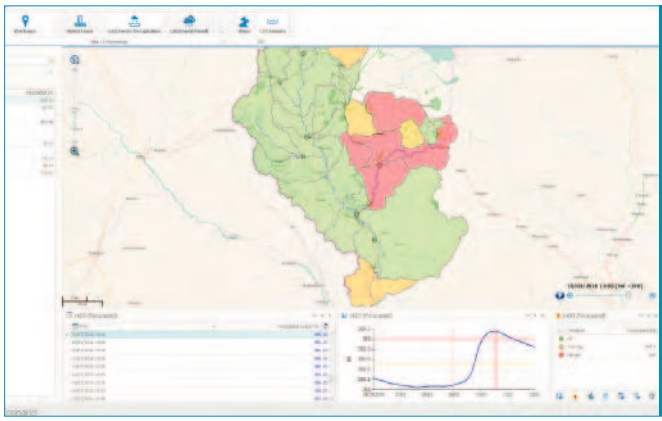

Figure 8 - A Real-Time Flood Forecasting System is being established with MIKE OPERATIONS, which gives water managers access to rainfall forecasts from meteorological models and forecasted flows and water levels at key locations along the rivers (graphics by DHI)