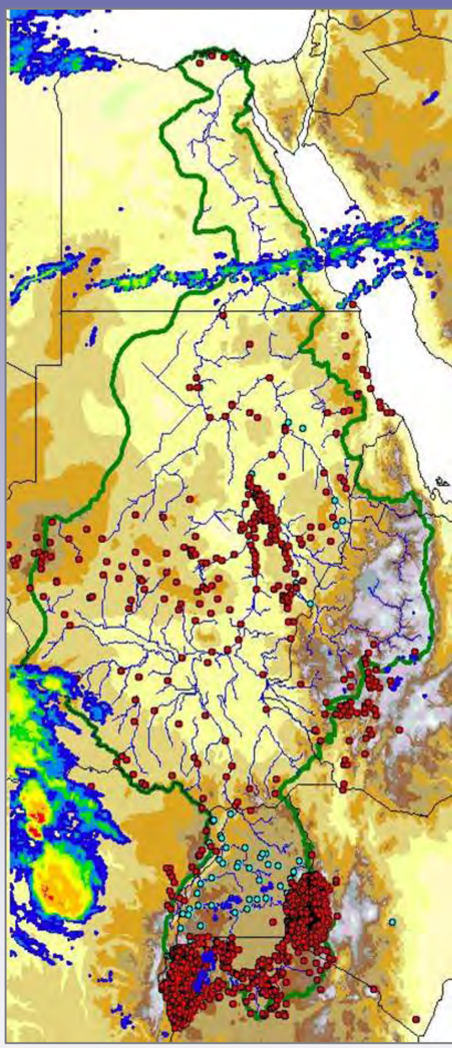
Consolidation of the Nile Decision Support Tool

Burundi
Congo
Egypt
Eritrea
Ethiopia
Kenya
Rwanda
Sudan
Tanzania
Uganda



Technical Completion Report

Developed collaboratively by

The Nile Basin Nations,

The Georgia Water Resources Institute at the Georgia Institute of Technology,

and

The Food and Agriculture Organization of the United Nations

July 2007

Consolidation of Nile Decision Support Tool (Nile DST)
Technical Completion Report

Report developed by

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In collaboration with

The Nile Basin Nations

and

The Food and Agriculture Organization (FAO)
of the United Nations

Nile Basin Water Resources Project
(TF/UGA/CPA 177517-2005/AGLW)

July 2007

Acknowledgements

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The GWRI Director and project staff are grateful to the Nile Basin nations (Burundi, Congo, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, Sudan, Tanzania, and Uganda), their focal point institutions, their Project Steering Committee (PSC) members, and their National Modelers for entrusting us to work with them in this important basin-wide project. The development of databases, models, technical reports, software, and user manuals are key but not the only project accomplishments. Even more important are the evolving contributions relating to people and the difference the project is poised to make in data and information sharing, developing a common knowledge base for policy debates, and long term capacity building.

GWRI is also grateful to the Government of Italy and to FAO and its Chief Technical Advisor, Mr. Bart Hilhorst, for sponsoring the project and for providing dependable logistical and technical support through the FAO office in Entebbe.

It is our hope that the Nile DST effort will contribute in some positive way to the historic process of the Nile Basin nations to create a sustainable and peaceful future.

Aris Georgakakos
GWRI Director
Atlanta, July 2007

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1. Introduction

This report documents the work carried out by Georgia Institute of Technology (GIT) for the Food and Agricultural Organization of the United Nations (FAO) under Contract No. TF/UGA/CPA 177517-2005/AGLW, as part of the Nile Basin Water Resources Project.

The Contract was a follow-up to earlier work done by GIT under the same project and was specifically aimed at updating and consolidating the River Simulation and Reservoir Operation module of the Nile DST and conducting additional training for Engineers and Scientists from the Nile Basin countries in the use of the updated tool.

Scope of Work

The work under this contract comprised of two main tasks summarized below:

TASK 1: Consolidate the River Simulation and Reservoir Operation (RSRO) module of the Nile DST

a) Prepare a detailed Technical Report and User Manual for the consolidated RSRO module;
b) Document a system structure and source code of the Nile DST;

TASK 2: Training of Engineers and Scientists from the Nile Basin Countries in the use of the updated Nile DST.

a) Develop Nile DST training program and prepare associated training materials;
b) Implement internet based pre-workshop training;
c) Implement 2-weeks regional training workshop on the revised Nile DST;
d) Implement internet based post-workshop training;
e) Prepare a report on the Nile DST training outlining the activities executed during the course, the results achieved, and recommended follow up activities.

Contract Outputs

TASK 1: Consolidate the River Simulation and Reservoir Operation (RSRO) module of the Nile DST

The River Simulation and Reservoir Operation (RSRO) module of the Nile DST was updated and the following additional facilities were incorporated in the tool:

(i) Six potential hydropower facilities in Uganda i.e. Bujagali, Karuma, Kalagala, South Ayago, North Ayago, and Murchison Falls.
(ii) Merowe Dam on the Main Nile in Sudan;
(iii) Roseires Dam on the Blue Nile in Sudan; and
(iv) Tana-Beles Hydropower Facility.

Most of the data and technical information on the above facilities was provided by the relevant government agencies. Additional data/information was extracted from other public sources. A detailed technical description of the specific updates made with respect to the above facilities is attached as **Annex A**.

A detailed User Manual for the updated RSRO module was prepared and incorporated into the general Nile DST User Manual which is an integral part of the Nile DST Software. The User Manual can be accessed on-line through the "**Help**" menu.

A detailed description of the updated Nile DST system structure is attached as **Annex B**.

TASK 2: Training of Engineers and Scientists from the Nile Basin Countries in the use of the updated Nile DST.

The following was accomplished under this task:

(i) Developed and implemented a comprehensive Nile DST training program;
(ii) Implemented internet based pre-workshop training;
(iii) Implemented a 2-weeks regional training workshop on the revised Nile DST;
(iv) Implemented internet based post-workshop training;

A detailed training report was prepared and is attached as **Annex C**.

ANNEX A –Technical description of the specific updates made to the River Simulation and Reservoir Operation Module

1. Addition of Merowe Dam

The Merowe Dam has been added to the simulation model. The project data was provided by Government agencies of Sudanese water department. The following data and assumptions are adopted in the system:

(i) Reservoir storage versus elevation curve: This curve describes the relationship between the Merowe reservoir elevation (m) and storage (bcm). Table 1 lists the data values, and Figure 1 shows the plot. This curve is also used to derive the area versus elevation relationship. The reservoir operation range is from 285 meter to 300 meters. The flood constrained elevation in the summer is 290 meter. The maximum elevation constraints are plotted in Figure 2.

(ii) Tail water curve. This curve describes the relationship between the tailrace and the discharge from the dam. It is used to compute the gross head for the hydro turbines in the power generation. Table 2 lists the data values, and Figure 3 shows the plot.

(iii) Reservoir Evaporation Rates. Monthly average values are used to compute the evaporation from the reservoir in the water balance. Table 3 lists these values.

(iv) Power Data. Total 10 generating units with 1250 MW capacity will be installed in the power house. No detailed turbine characteristics are available. An approximate power function is used: $P=9.81*e*Q*H$, where 0.9 is used for the efficiency e.

(v) River routing: Data are not available to establish the routing models from the upper stream river nodes to Merowe dam, and from Merowe dam to High Aswan dam. In this version, the simulation model assumes that the previous routine model to HAD is valid to Merowe Dam, and the release from Merowe flows into HAD with a user-specifiable loss coefficient.

2. Tana-Beles Hydropower Project

The information of Tana-Beles Hydropower project is obtained from the USBR report (1964, Land and Water Resources of the Blue Nile Basin). The planned installed power capacity is 200 MW, the hydraulic head is 245 meters, and the discharge capacity is 110 cms. The release from the project will re-enter the Blue Nile at upper stream of Border reservoir. Approximated power functions are used in the energy calculation. The total annual water amount passing through the power facility and the corresponding monthly distribution can be easily specified from the interface.

3. Toshka/New Valley Pumping Energy Calculation

The annual amount and the corresponding monthly distribution of the Toshka/New valley pumping can be specified from the interface. The pump characteristics were adopted from the HAD DSS report. The corresponding energy functions were derived and are accessible from the interface.

4. **Access to energy generation functions**

The energy functions for all hydropower plants can be plotted from the interface.

5. **Addition of six planned hydropower facilities in Uganda**

Six planned hydropower plants along the Victoria Nile, Bujagali, Kalagala, Karuma, South Ayago, North Ayago, and Murchison were added in the simulation model to assess the potential energy generation in that area. The project data were adopted from Lake Victoria DST 2004 by WREM International Inc.

6. **Updated user manual**

User manual has been updated and incorporated into the Nile DST software. A standalone Nile DST River Simulation Program is also generated.

Tables and Figures:

Table 1: Merowe Storage vs. Elevation Data:

Storage (bcm)	Elevation (m)
0.817	270
1.52	275
2.57	280
4.12	285
6.17	290
8.9	295
11.05	298
12.45	300
17	305

Table 2: Merowe Tailwater Curve

Discharge (cms)	Elevation (m)
0	243.5
500	246
1000	247
2000	248.8
3000	250
4000	251.1
5000	252
6000	252.8
7000	253.5
8000	254.1
9000	254.7
10000	255.2
15000	257.7

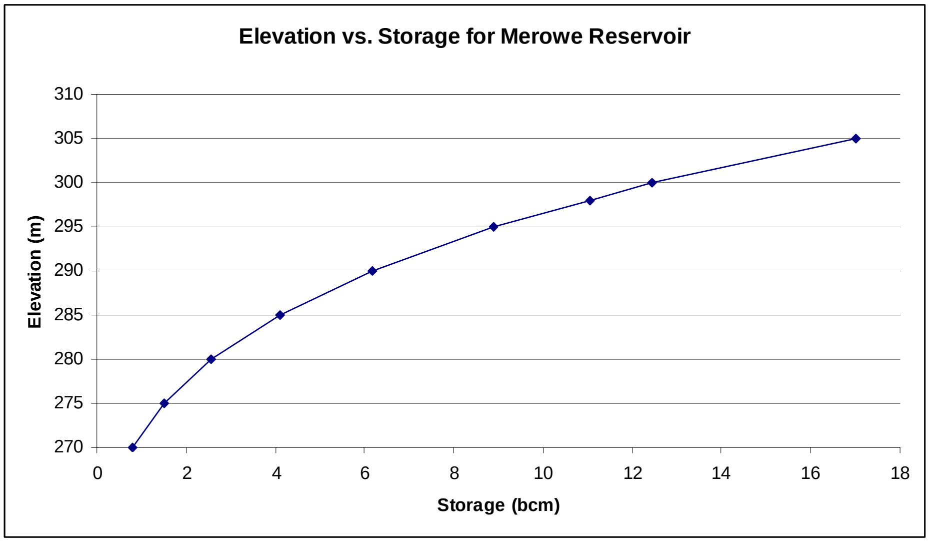


Figure 1: Merowe Storage vs. Elevation Curve

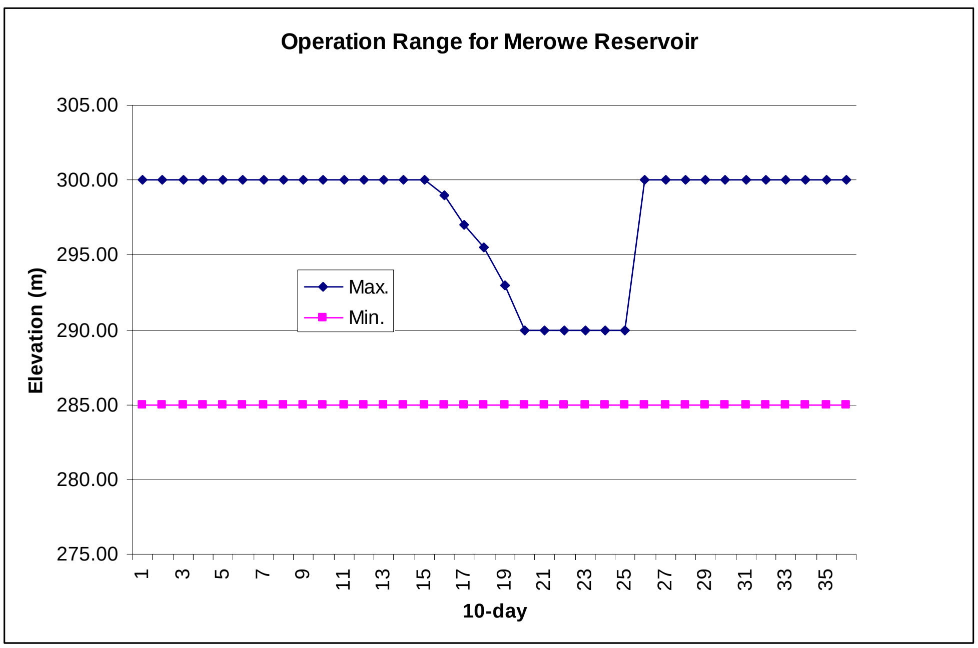


Figure 2: Reservoir Operation Range

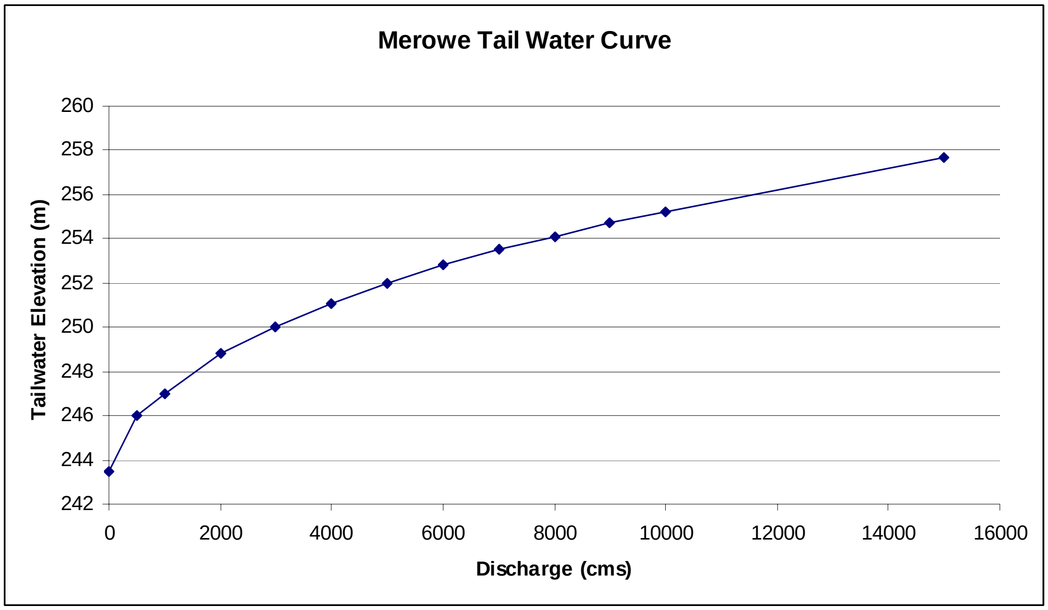


Figure 3: Merowe Tail Water Curve

Table 3: Monthly Evaporation Rates (mm/day)

Month	Evaporation Rate
1	5.6
2	6.4
3	7.5
4	8.5
5	9.5
6	9.7
7	9.3
8	9.2
9	9
10	8.1
11	6.6
12	5.4

Screen Shots from Nile DST Simulation Components:

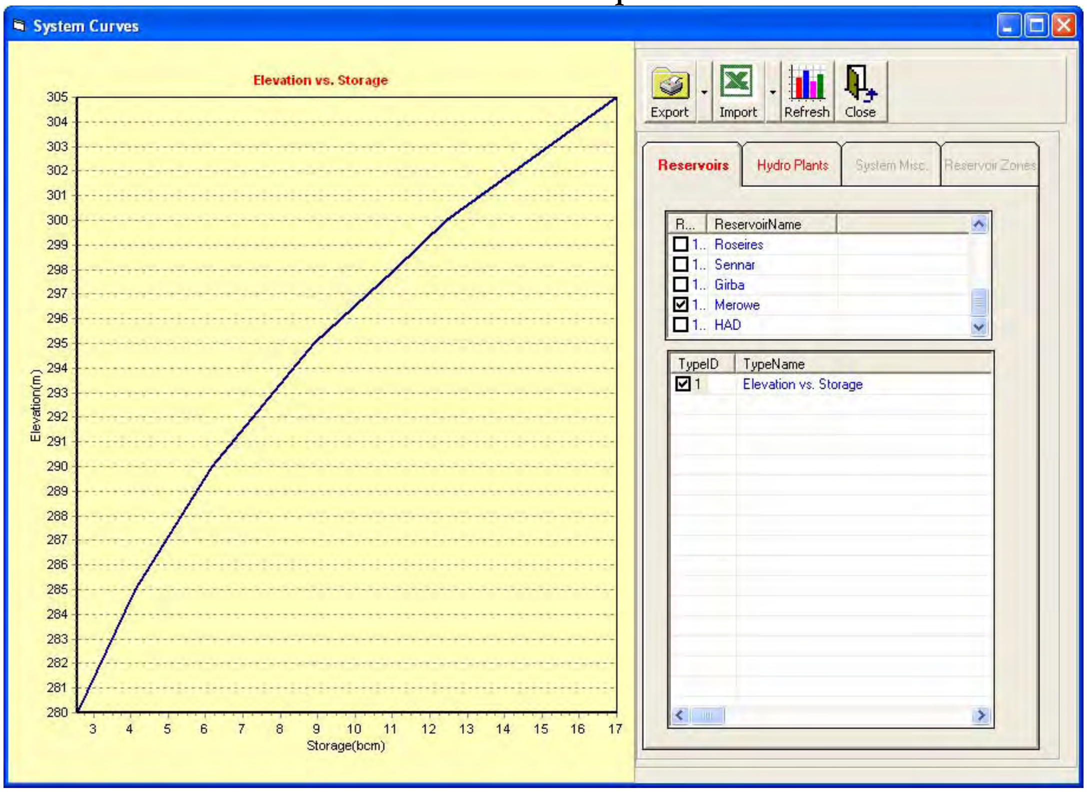


Figure 4: Storage vs. Elevation Curves for Merowe Dam

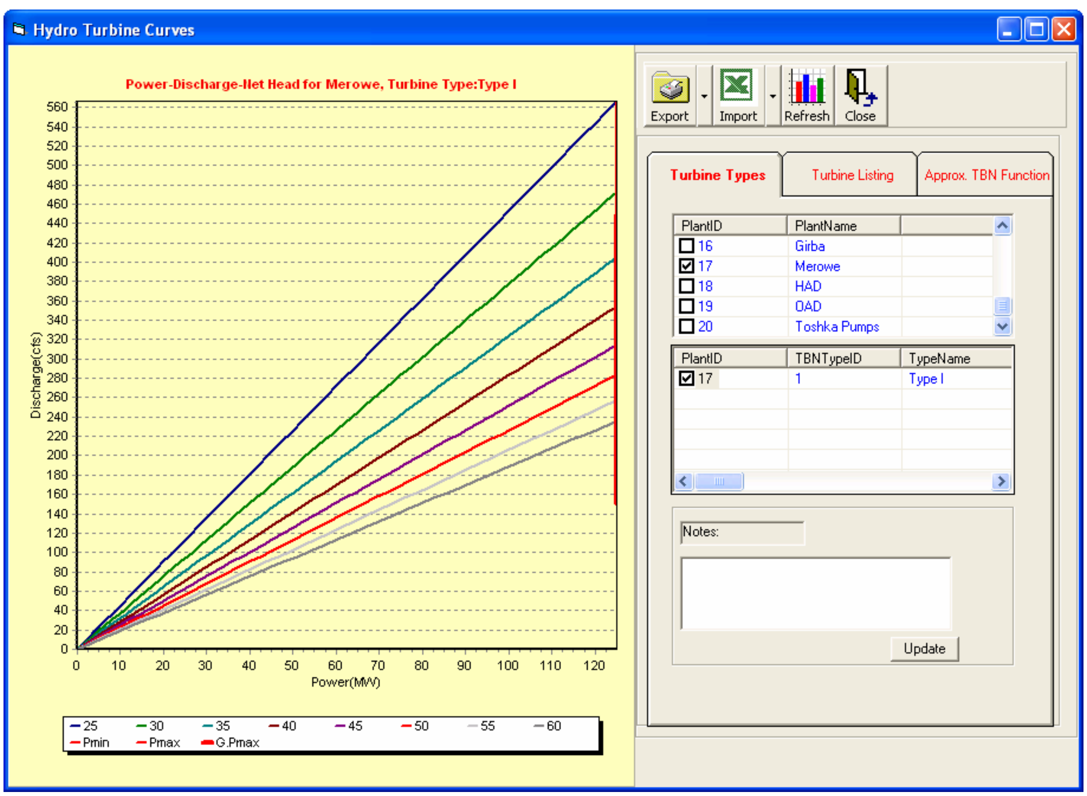


Figure 5: Approximated turbine characteristics for Merowe Dam

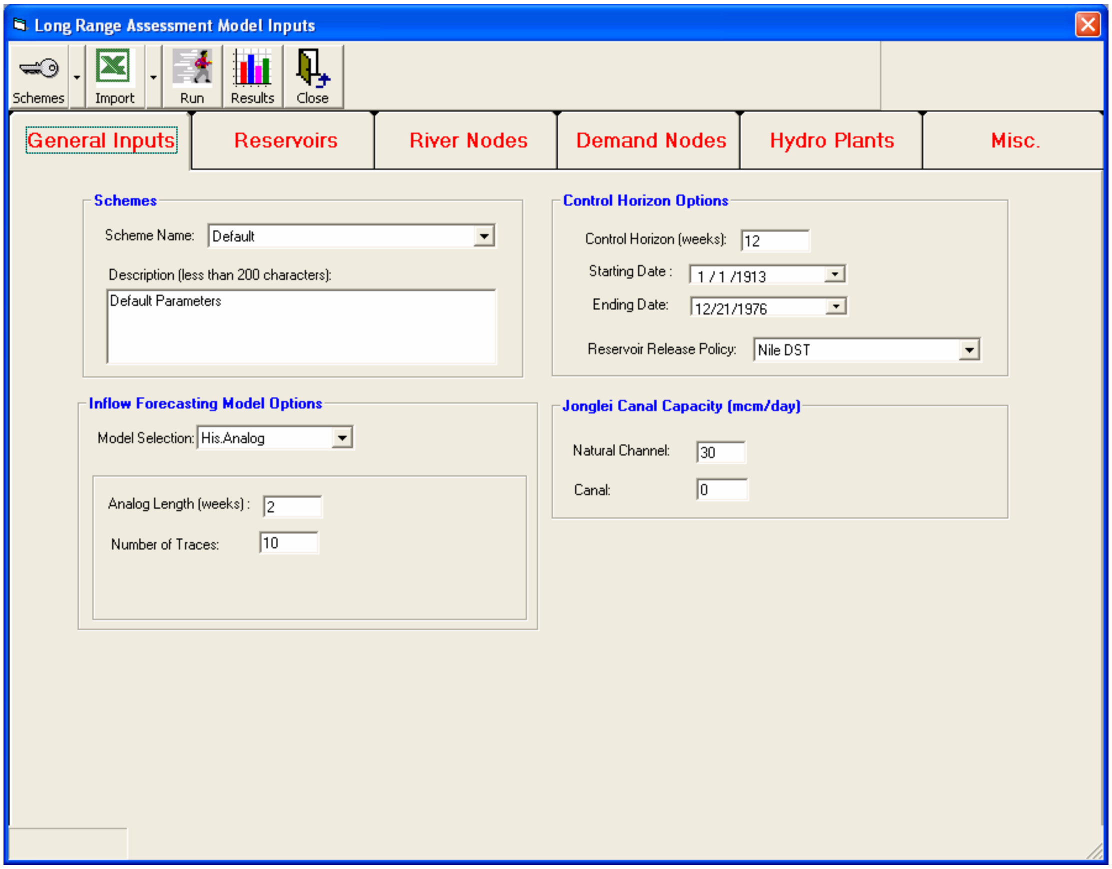


Figure 6: General Inputs for the assessment model

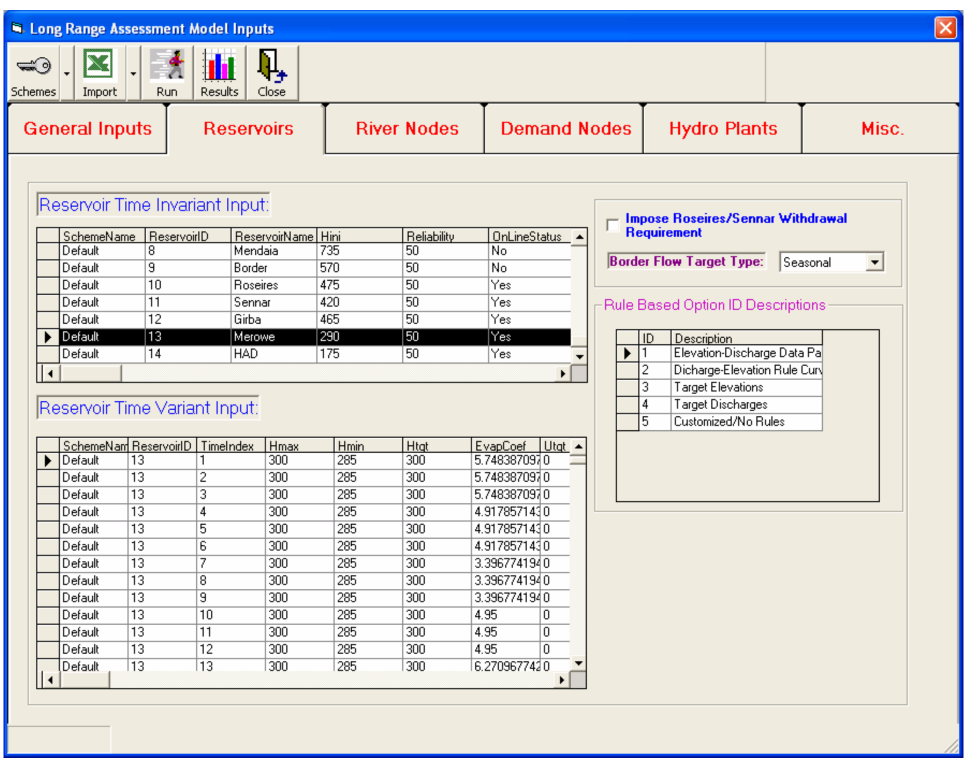


Figure 7: Reservoir Inputs

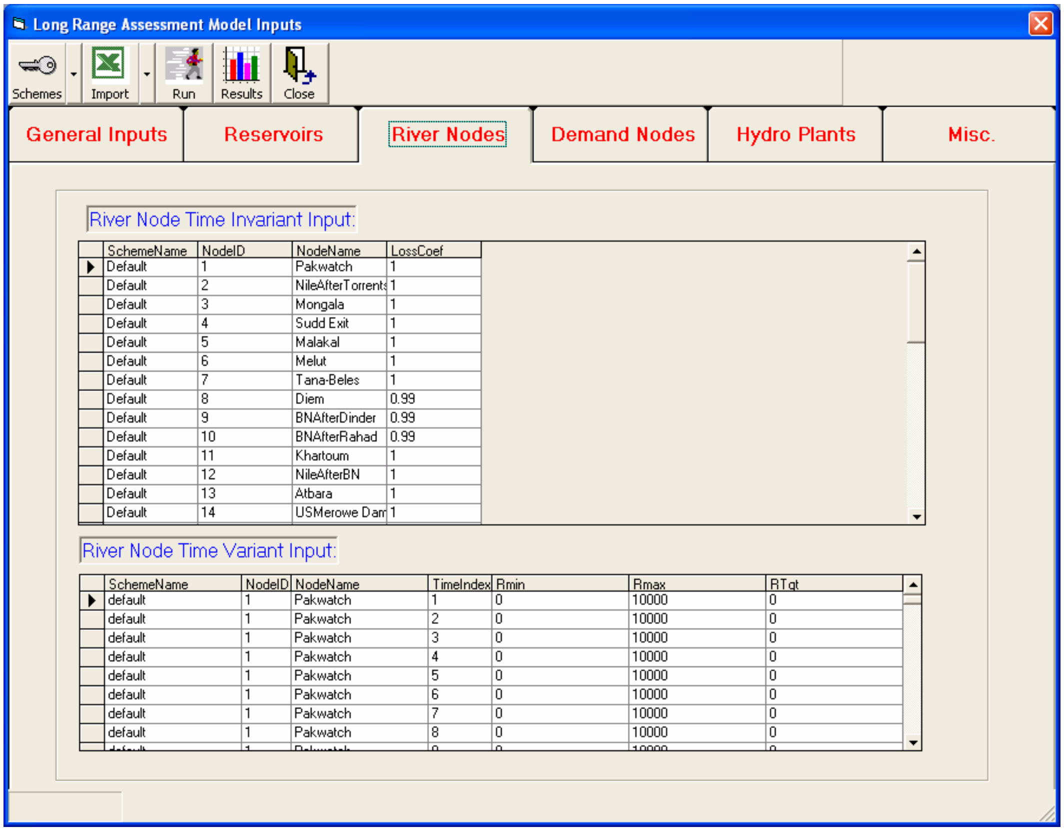


Figure 8: River Node Inputs

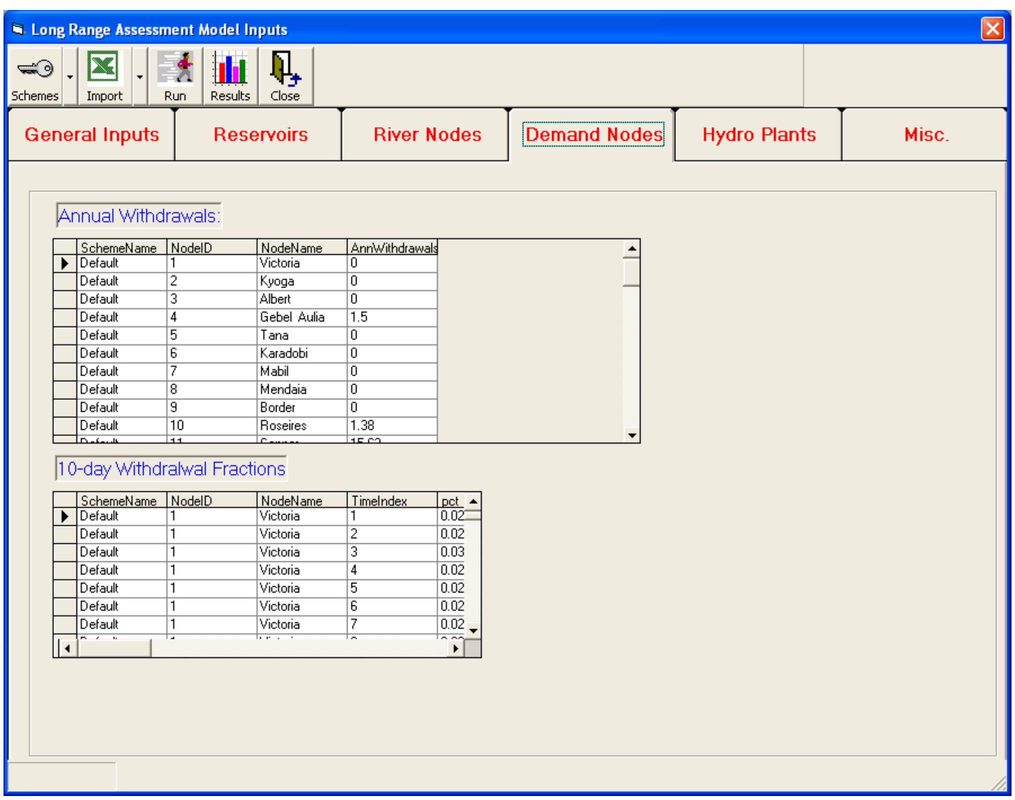


Figure 9: Demand Node Inputs

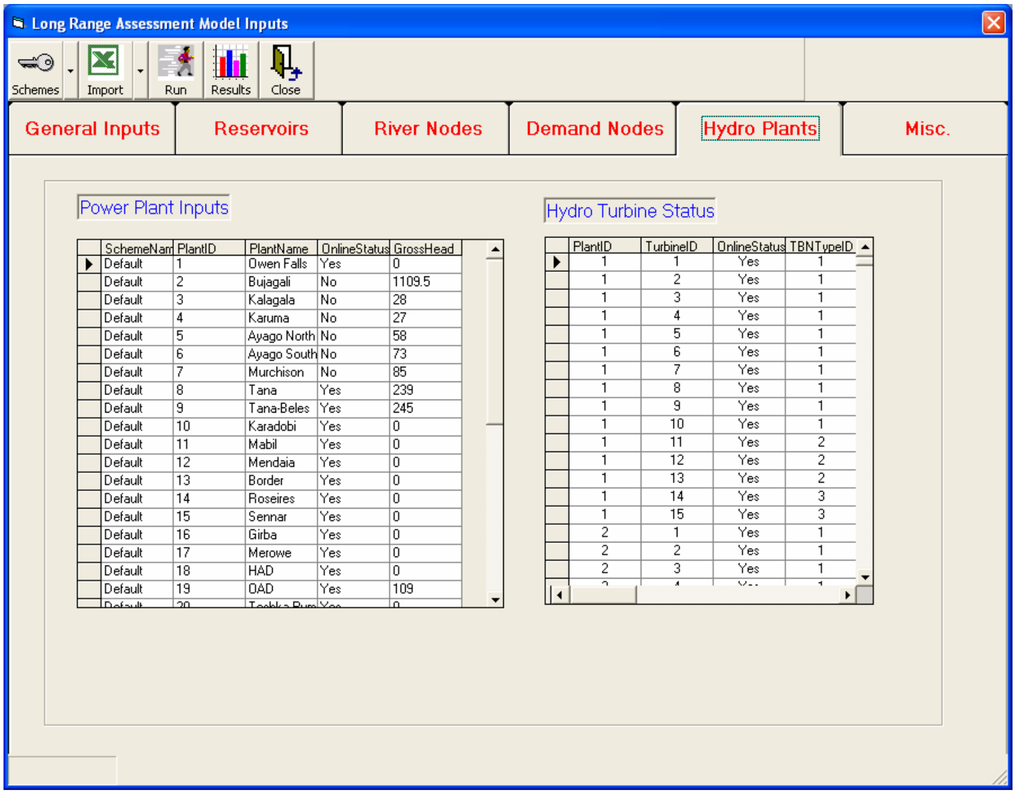


Figure 10: Hydro plant Inputs

Figure 11: Sample simulation sequences

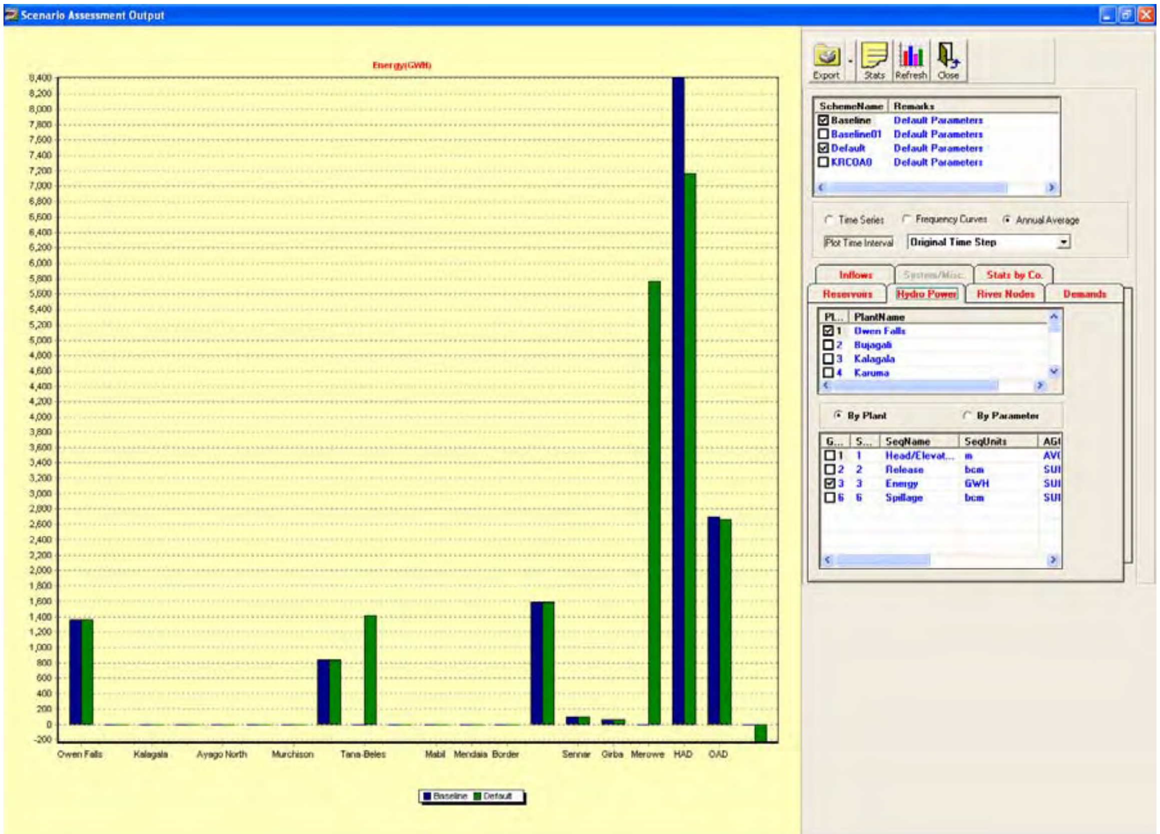


Figure 12: Sample simulation statistics.

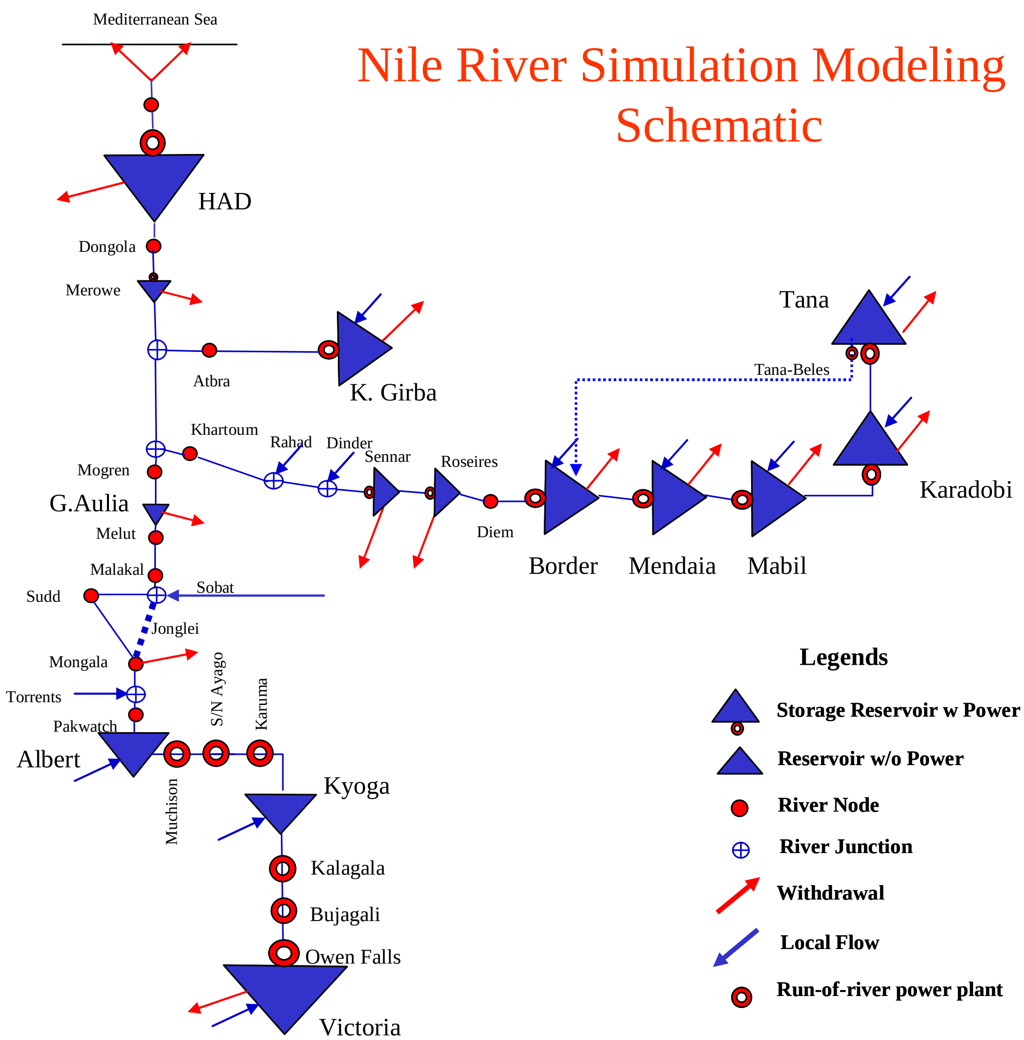


Figure 13: Updated System Schematic

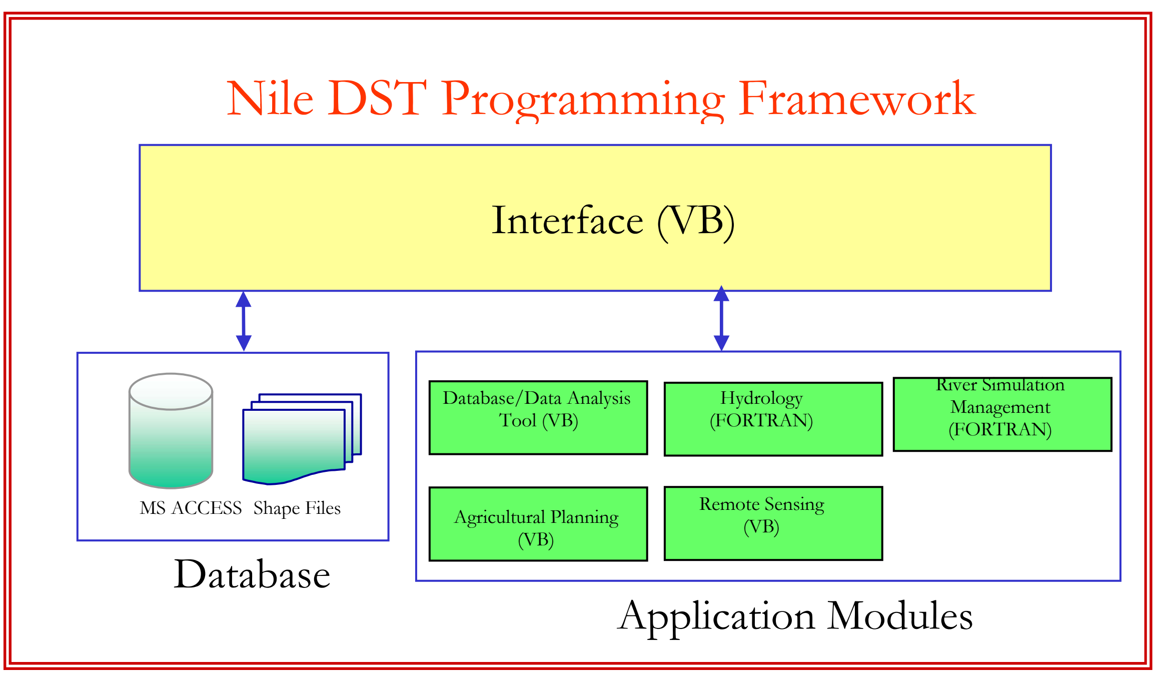
ANNEX B – Description of the updated Nile DST System Structure

1. Nile-DST Programming Framework

The Nile DST is a program running under MS windows XP operating system. It requires MS Office XP pre-installed in order to run properly. In addition, the Nile DST uses several third party active X controls to implement specific functionalities. The most important ones are MapObjects and Tee Charts. All active X controls are purchased by the developer and are free to re-distribute.

The Nile DST is an integrated software package of three major components: Database, Interface, and Application Modules. The Nile DST Database consists of many data files with various formats. It is used to store the system data and the inputs/outputs of applications. The Nile DST data can be divided into two categories: Geo-referenced and Non Geo-references data. The geo-referenced data contains geometric information of basin boundary, coordinates of ground monitoring stations, and river networks. These information are stored in ESRI's shape format. The remote sensing image files are also geo-referenced data. They are saved in binary files using Nile DST's special format. The non geo- referenced data in the Nile DST database are saved in MS ACCESS files. The Nile DST Interface provides tools to access and manage the database, prepare the inputs and display of outputs of various applications. The interface is written in Visual Basic 6 language.

The Nile DST Application Modules comprise applications for various purposes. They are Database, Data Analysis Tool, Hydrology, Agricultural Planning, River Simulation Management, and Remote Sensing. The applications are written with either VB 6 or FORTRAN language. The hydrology module and the river simulation module can be installed as a standalone application.



Nile DST Programming Framework

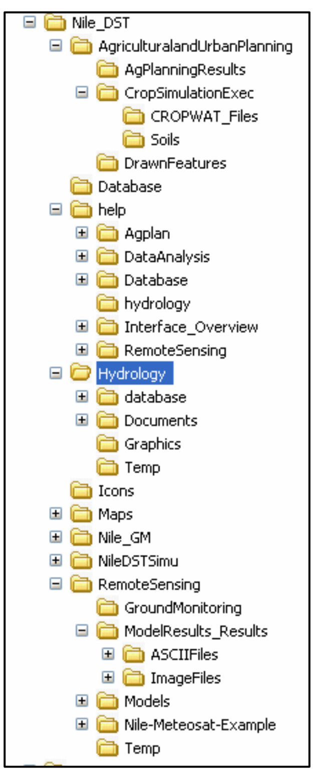
2. Nile-DST Installation and File Directory Structure

The installation is launched by running program Nile_DST_Install.exe. User only needs to specify the working directory name (default value is c:\NileDST) during the process. Once finished, the installation program creates several sub directories under the working directory. The sub directories are listed below:

- \AgriculturalandUrbanPlanning\ (Agricultural planning model related files)
- \Database\ (Central Database, interface preferences and file locations)
- \NileDSTSimu\ (River simulation module related files)
- \Icons\ (Interface icons)
- \RemoteSensing\ (Remote sensing module related files)
- \Hydrology\ (Hydrology module related files)
- \Nile_GM\ (Ground monitoring station data)
- \Maps\ (Geo reference data, GIS maps)
- \help\ (Part of help documents)

User should never change the file directory structure above.

In addition to the Nile DST internal files, the installation program copies and registers all required third part active X controls and DLLs to the system. The MapObjects by ESRI and the TeeCharts by Steema Software Inc are two most important ones. The former is used to display and operate on the GIS data, while the latter is used to display charts in the interface.



Directory Structure of Nile DST

3. **Nile-DST Database**

The Nile DST Database consists of many data files with various formats. The data can be divided into two categories: geo-referenced and non geo-referenced. The geo-referenced data contains geometric information of basin boundary, coordinates of ground monitory stations, river networks, and etc.

Most of geo-referenced data files are located in sub directory \maps\. The meta information such as file name, geometric type, and initial display color of a particular geo dataset is stored in two tables, DatabasePreferences and GeneralPreference, in MS ACCESS data file CentralDB.mdb under \database\. These two tables are accessible from the interface. In this way, the user can add new GIS data or delete the existing data from the Nile DST interface.

Historical data pertaining to the ground stations are stored in a set of MS ACCESS files under sub directory \Nile_GM\. The data for each country are stored in separated files under different sub directory identified by the country names. For example, the files under \Nile_GM\Uganda\ are for Uganda. There are five files under each directory. The files for Uganda are:

- Uganda Station Metabase.mdb
- Uganda StreamFlow Station Metabase.mdb
- UgandaDB.mdb
- UgandaStreamFlowDB.mdb
- UgandaSurrogateDB.mdb

Name	Index	Type	PathName
Niledem_shape	203	Elevation	..\Maps
watershed_dd	601	Watershed	..\Maps
waterbdy_dd	403	River	..\Maps
nilelkwt	405	River	..\Maps
simnodes	708	River Network Nodes	..\Maps
Extent	702	Extent	..\Maps
nileriv	406	River	..\Maps
continent	500	Political Boundaries	..\Maps
rivers_dd	404	River	..\Maps
countries_dd	703	Political Boundaries	..\Maps\GeoBase
nilecity	707	Land Use/ Land Cover	..\Maps\GeoBase
Soils_dd	300	Soil Types	..\Maps\GeoBase
Roads_dd	704	Transport	..\Maps\GeoBase
railways_dd	700	Transport	..\Maps\GeoBase
Urban_pt_dd	705	Land Use/ Land Cover	..\Maps\GeoBase
forests_dd	701	Land Use/ Land Cover	..\Maps\GeoBase
adm_pop_dd	501	Political Boundaries	..\Maps\GeoBase
riv5	401	River	..\Maps\GeoBase
Soils_Complete	306	Soil Types	..\Maps\GeoBase
sg_ethiopia	906	GMStations	..\Maps\GMData
sg_burundi	908	GMStations	..\Maps\GMData
sg_all	909	GMStations	..\Maps\GMData
sg_congo	907	GMStations	..\Maps\GMData
NileStreamFlow	900	Hydrologic	..\Maps\GMData
sg_tanzania	902	GMStations	..\Maps\GMData
Nile_Climate_Zones	200	GMStations	..\Maps\GMData
hmEthiopia	805	GMStations	..\Maps\GMData
sg_rwanda	904	GMStations	..\Maps\GMData
sg_kenya	905	GMStations	..\Maps\GMData
sg_uganda	901	GMStations	..\Maps\GMData
hmTanzania	801	GMStations	..\Maps\GMData
hmEgypt	806	GMStations	..\Maps\GMData
zonedemc	201	GMStations	..\Maps\GMData
hmSudan	802	GMStations	..\Maps\GMData
hmRwanda	803	GMStations	..\Maps\GMData
sg_sudan	903	GMStations	..\Maps\GMData
hmDrCongo	807	GMStations	..\Maps\GMData
hmKenya	804	GMStations	..\Maps\GMData
hmBurundi	808	GMStations	..\Maps\GMData
hmall	809	GMStations	..\Maps\GMData
hmUganda	800	GMStations	..\Maps\GMData
NileWatershedGrid	106	GRID	..\Maps\Grids
Nilegrid_5deg_full	107	GRID	..\Maps\Grids
Nilegrid_1deg_full	109	GRID	..\Maps\Grids
MeteosatGrid	108	GRID	..\Maps\Grids
CDAS1grid	105	GRID	..\Maps\Grids

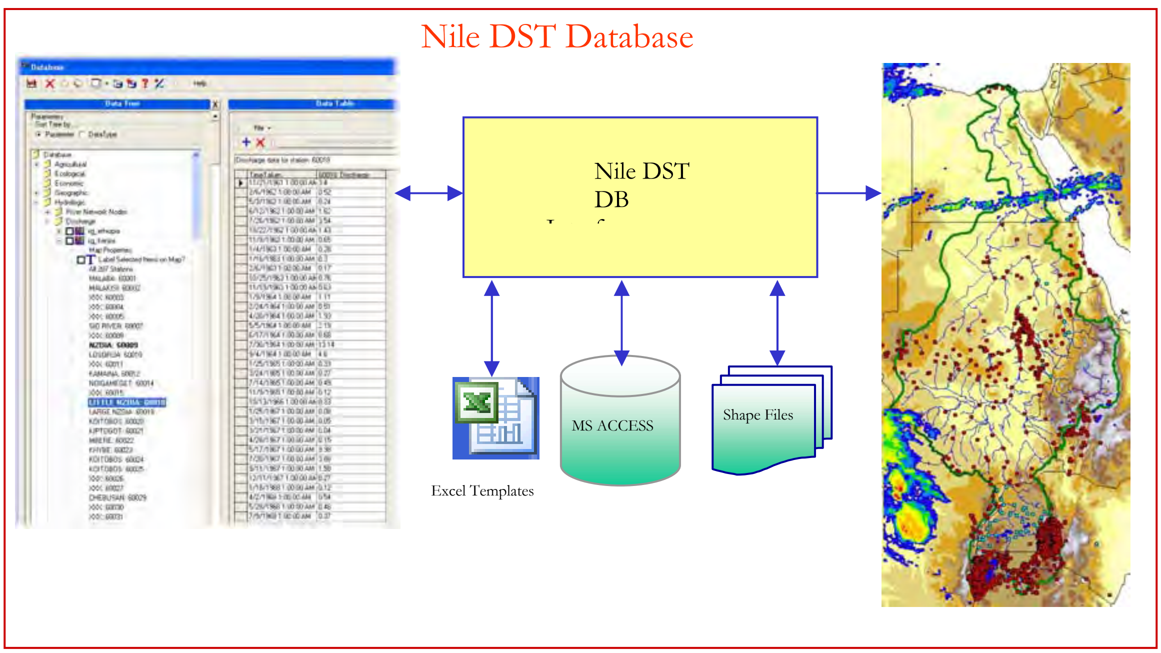
In the above list, Uganda Station Metabase contains the basic information of climatic stations. The actual historical data are stored in file UgandaDB. Each data table in UgandaDB stores the records of one climate parameter. The table structure uses the station ID as the column name which does not follow the convention of relational database design philosophy. This design creates burden for the data management. However, this design is resulted from many bench mark tests. It is found that this is the only way to make MS ACCESS workable to host a dataset with such a huge record sets like in Nile DST. The overhead of the data management is taken care of by the interface. The limitations of MS ACCESS can be overcome by using more powerful database engines such as MS SQL Server or MySQL Server. This option will be available in the future version of Nile DST. The StreamFlow Station Metabase and StreamFlowDB are used to stored the stream flow station IDs and actual data. They have the similar structure to the climatic files.

Nile-DST Database Application

The Nile DST Database application is designed to visualize and analyze a large and dynamic database. This database holds data recorded at stations throughout the Nile basin. It also holds basin-wide remotely sensed data recorded by the MeteoSat satellite and used for inferring rainfall occurrence and quantity. The database is designed to be easily expandable both in terms of adding new data for existing stations, adding new stations to existing databases, and adding entirely new databases. The database interface is designed to allow for quick and complex analysis of the data in the database.

The Database application uses data tree, map window, chart window, and menus jointly to accomplish various tasks. The data tree lists the data in a well organized way, and lets user navigate through different data types easily. The map window is used to display the geo referenced data selected from the data tree. The Chart window is used to plot the historical time series for the selected stations.

Adding a new station to the database is done by typing the required information directly from the interface. Adding new data for an existing station to the system is implemented using a predefined Excel template file.



Nile DST Database Application

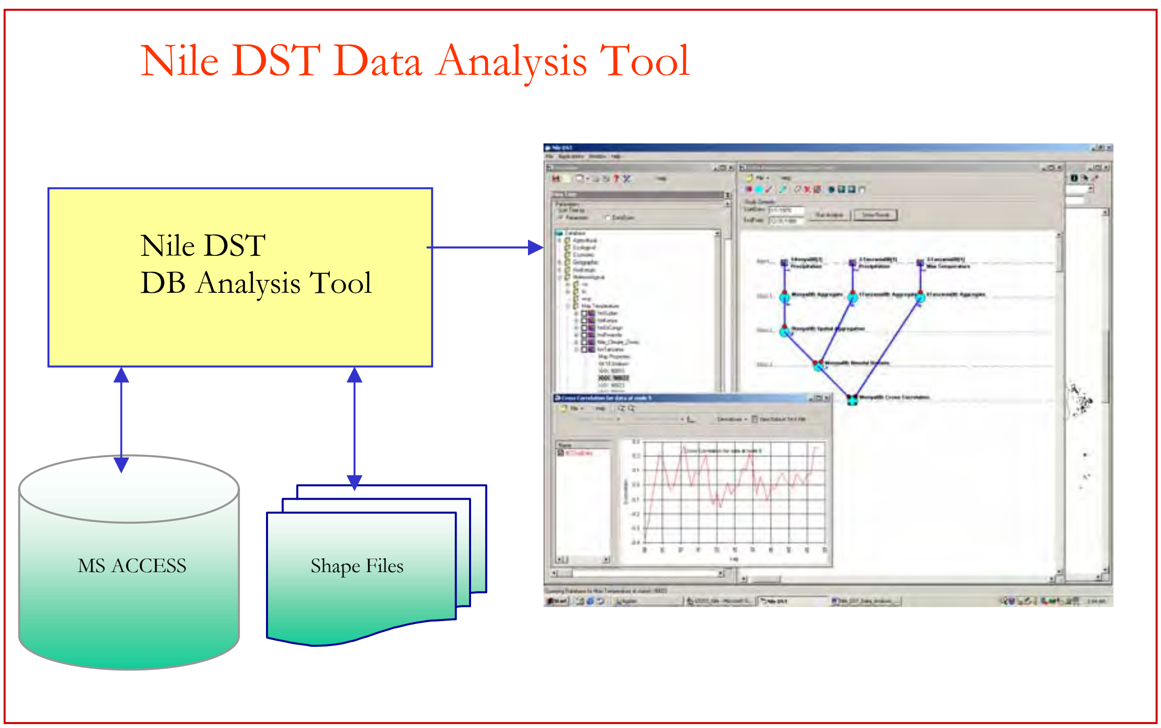
4. Nile-DST Data Analysis Tool

The Nile DST data analysis tool allows the user to build a map of the algorithm they propose. The map is composed with nodes, and links. A node can either represent data retrieved from the database or an operator, which operates on the data passed to the node. When the proposed analysis is built, it can be run and the user can view both the final result of the analysis and the results at the intermediate steps in chart and textual form.

By creating a graphical map of the analysis, the user can:

- Get a clear view of the algorithm.
- Keep track of what the analysis is doing.
- Observe the data as it is operated on in the course of the algorithm
- Repeat the analysis at any time.
- Modify the analysis.
- Save and Open the analysis.

The results of data analysis tool can be saved and used later as the inputs for other application modules. For example, the mean area precipitation, potential evapotranspiration, and inflow sequences of a particular subbasin all can be derived using the data analysis tool. They are the required inputs for the hydrology module.



Nile DST Data Analysis Tool

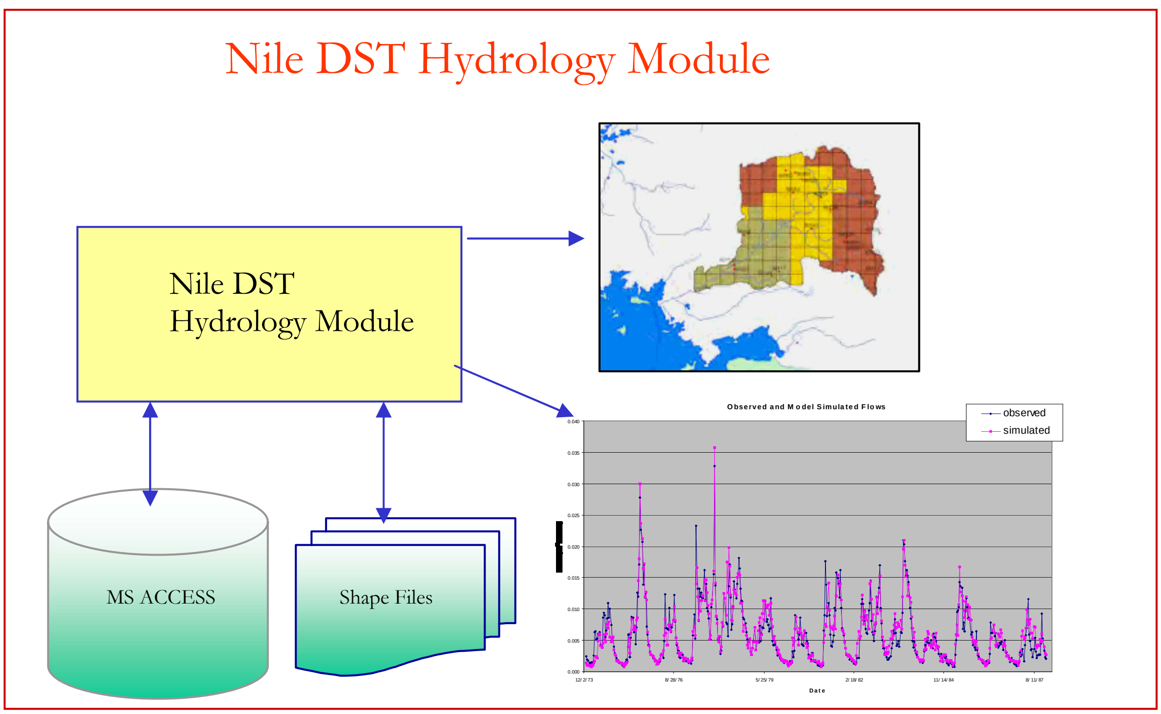
5. **Nile-DST Hydrology Module**

The hydrology module in the Nile DST uses the rainfall and evapotranspiration as inputs to estimate the basin soil moisture index and generates the inflow forecasts. The soil moisture index is a good indicator for identifying the long term drought condition. The forecasted inflows are used as an input in the planning and operational modules. The hydrological models are calibrated for each sub-basin in the Nile DST.

The data analysis tools are used first to prepare the required inputs for this module, then, the hydrology module is used to calibrate the model for selected sub basins. The required inputs of this module are:

- Sub basin watershed delineation;
- Mean Area Precipitation;
- Average Potential evapotranspiration (PET);
- Streamflow.

The inputs/outputs of the hydrology module are stored in database file under directory \hydrology\database\. The interface provides tools to prepare the inputs and display the results.

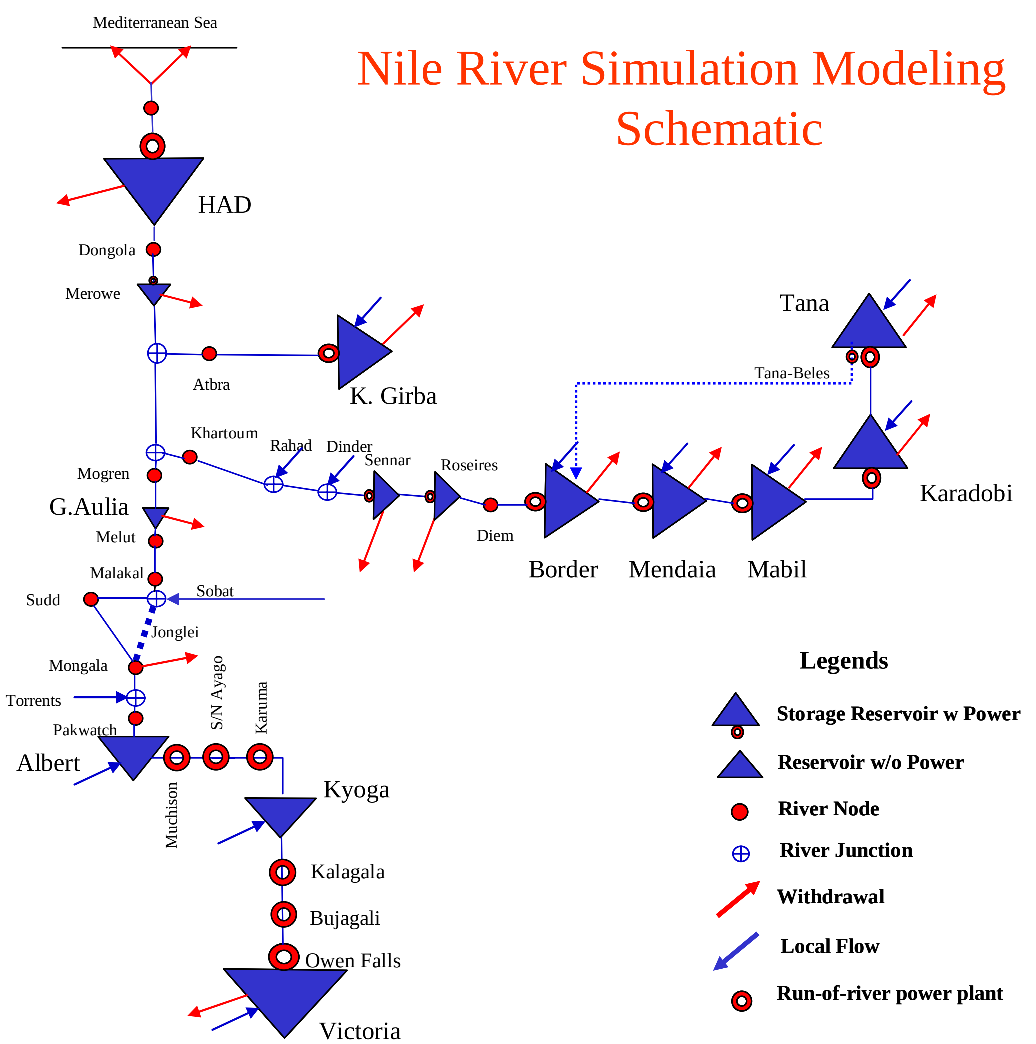


Nile DST Hydrology Module

6. Nile-DST River Simulation Module

The River Simulation Module is a planning tool for water resource management. It simulates the system responses under different development configurations and regulation policies. This module includes a long term inflow forecasting model for major tributaries, river routing models, and reservoir operation models. It is designed for quick impact assessment of various factors such as different water allocation plans, reservoir regulation policies, physical constraints, climate changes, and etc.

The Nile DST system includes 14 existing and planning reservoirs (Victoria, Kyoga, Albert, Gebel Aulia, Tana, Karadobi, Mabil, Mendaia, Border, Roserires, Sennar, Girba, Merwe, HAD), 20 existing and planning hydro power plants (Owen Falls, Bujagali, Kalagala, Karuma, Ayogo North, Ayago South, Murchison, Tana, Tana-Beles, Karadobi, Mabil, Mendaia, Border, Roseires, Sennar, Girba, Merowe, HAD, OAD, and Toshka Pump Station), 13 inflow nodes, 16 river nodes, and 15 demand nodes.

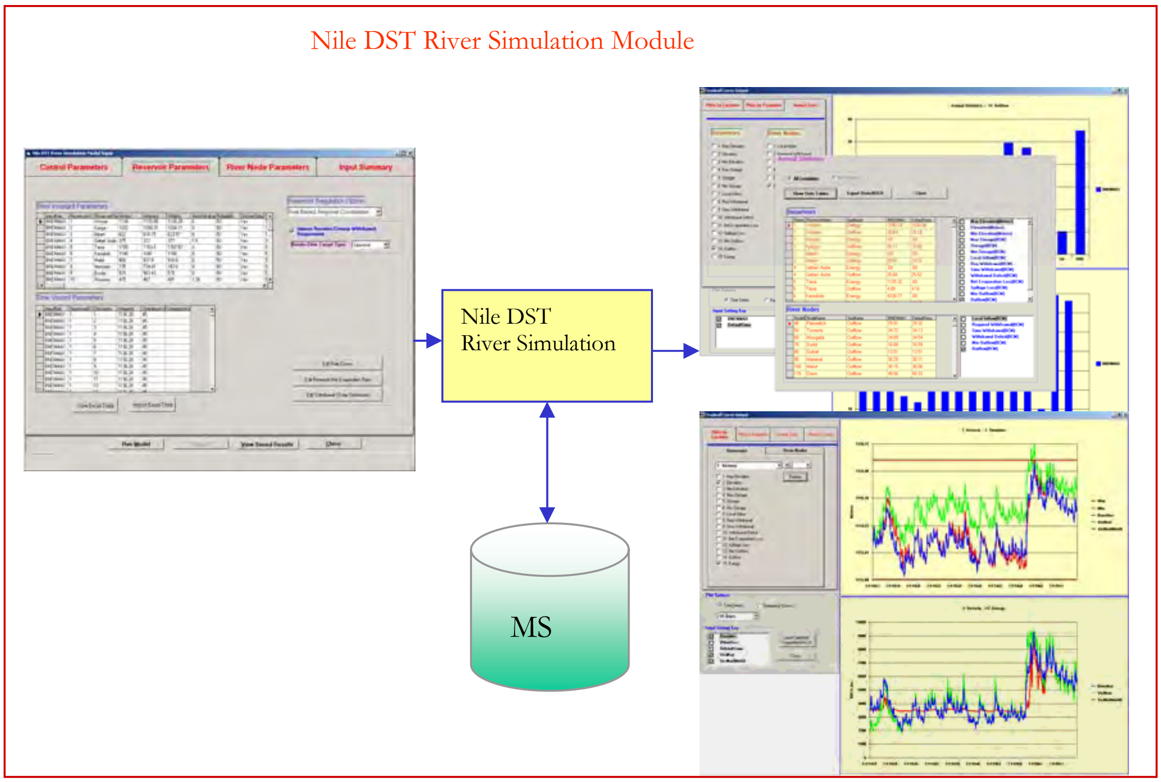


Nile DST River Simulation System Configuration

The inputs/outputs of the river simulation module are stored in a database file under directory \NileDSTSimu\database\. The interface provides easy tools to prepare the inputs and to display the results.

The river simulation model can be used to address the following issues easily:

- Impact of different hydrology
- Impact of Jonglei Canal project
- Reservoir storage sensitivity (change the reservoir upper bounds)
- Reservoir downstream minimum constraints
- Water withdrawal sensitivity (can specify water withdrawal at any reservoir or river segment)
- System configuration sensitivity (potential projects on Blue Nile On/Off)
- Reservoir release rule sensitivity
- Impact of different release rules

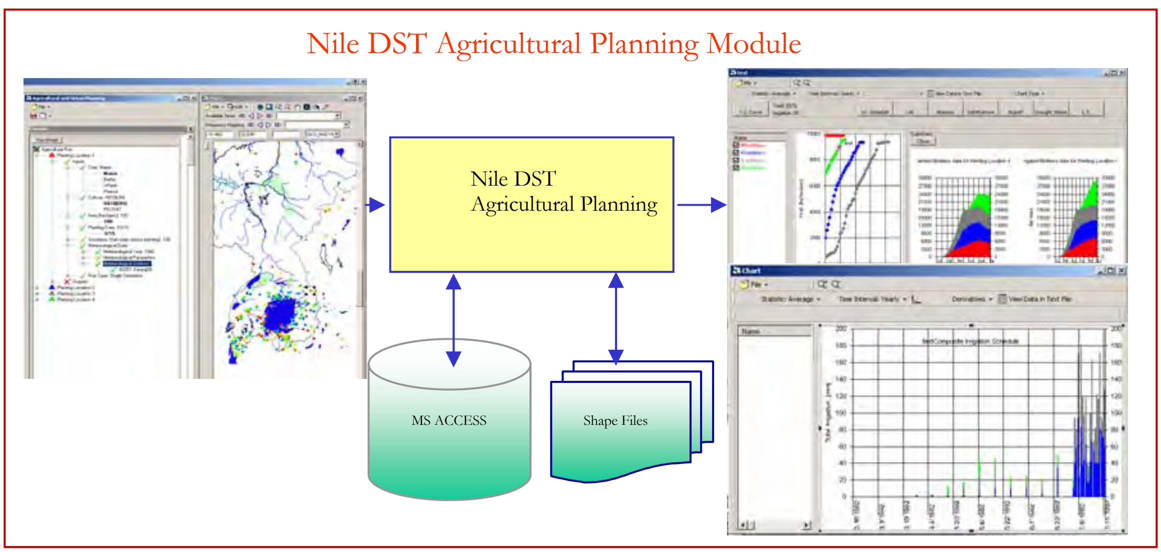


Nile DST River Simulation Module

7. Agricultural Planning Module

The Agricultural Planning module in the Nile DST, through the incorporation of state of the art crop models and optimizing control algorithms, enables the user to develop planting schemes that maximize the utility of normally available precipitation and minimize the use of irrigation to produce crops.   Through a user-friendly tree-like interface, the user can build complex planting schemes and then look at the irrigation requirement for an entire plantation or even an entire country. By modifying the crops planted, the planting dates, the estimation of climatological year, and a host of other parameters, the decision maker can find the planting scheme most suited to their needs.
The inputs of an Agricultural Run includes planting locations, crop types, and many other parameters. The main output of the agricultural run is the crop-water production function (CWPF) for each planting location. Additional results such as drought stress and plant biomass are also available.

The Composite Irrigation scheduling creates a time series of total water required for one to all of the planting locations in the agricultural run. This tool can be used to develop a demand schedule for irrigation water sources.
The Agricultural Run inputs are saved in a user specified MS Access database files and can be open and retrieved later for further study.

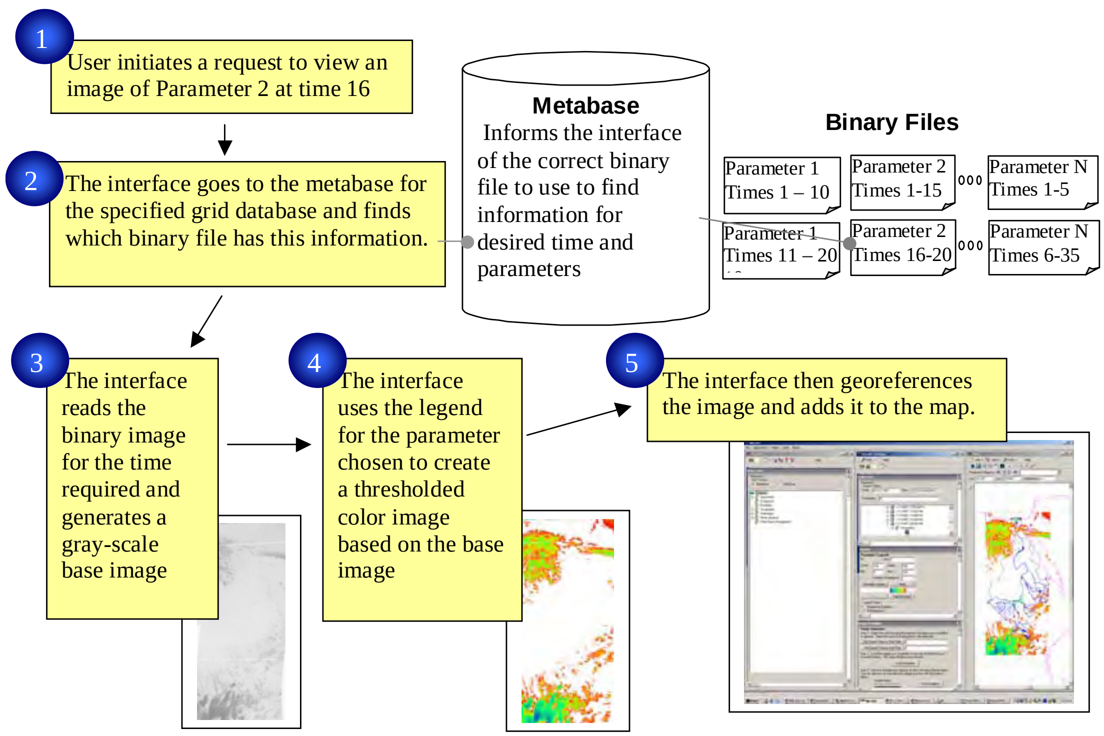


Nile DST Agricultural Planning Module

8. **Remote Sensing Module**

The Remote Sensing module in the Nile DST provides access to a large database of remotely sensed infrared, visible, and water vapor radiation recorded by the Meteosat geosynchronous satellite. This database is made viewable through a tree structure. Individual images can be found within the tree and then shown on the map. In addition, animations of groups of images can be created. Most importantly, the remote sensing module includes several models to estimate the rate and volume of precipitation falling on the basin from the remote sensing data. Together with ground measurements, these estimates create an extensive database of precipitation for the entire Nile Basin and can be used for further water resources analysis and planning.

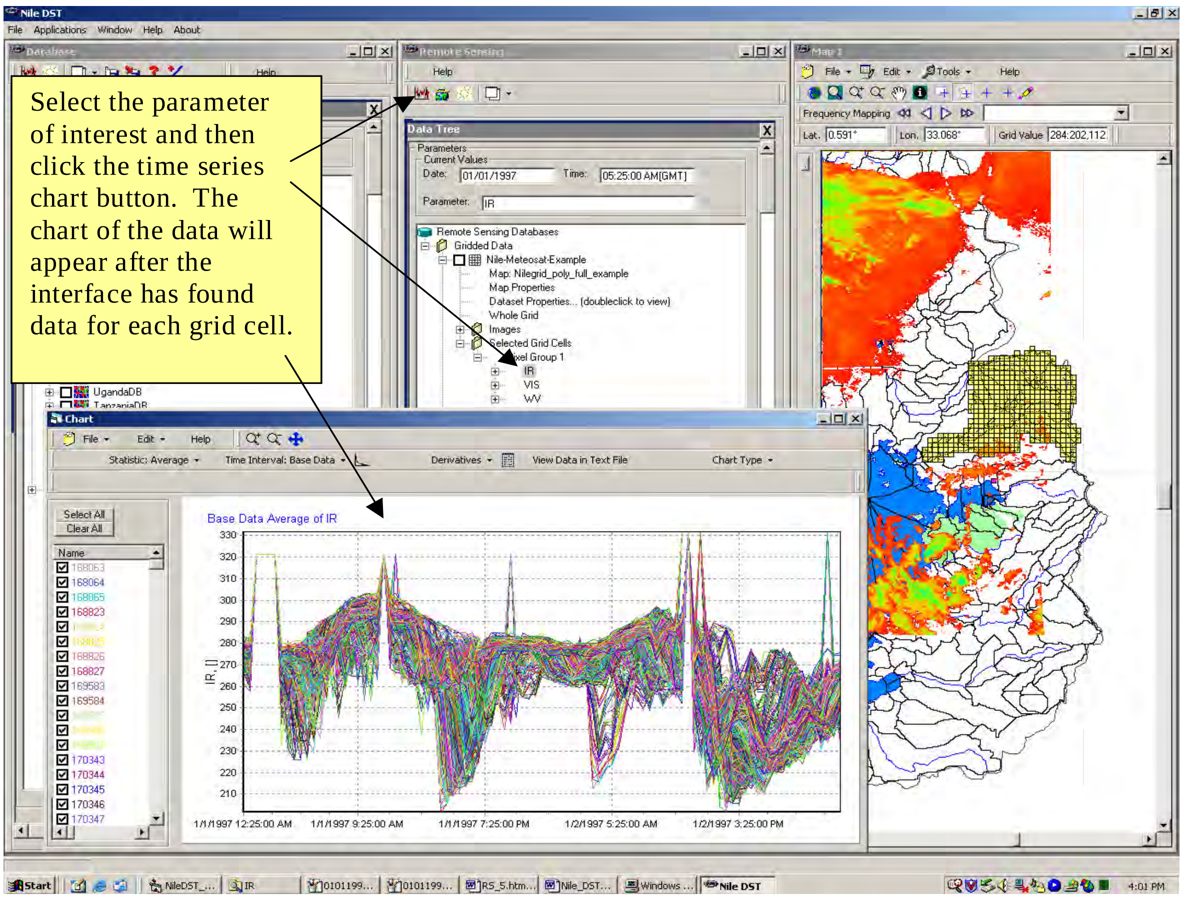
How is a grid database used to view an image?



View Grid Data

The remote sensing data are stored in the grid database in Nile DST system. The grid databases hold data pertaining to a regular rectangular grid. They are composed of a grid map layer, a meta information database (metabase), and a set of binary files containing their information (Nile DST Grid files). The user can view this information in image form for selected time and parameter. The image is generated from the binary file, whose location on the hard drive is given by the metabase. The image is added to the map and georeferenced according to the extent of the grid's map layer coordinates. There are two grid databases held within the remote sensing module:

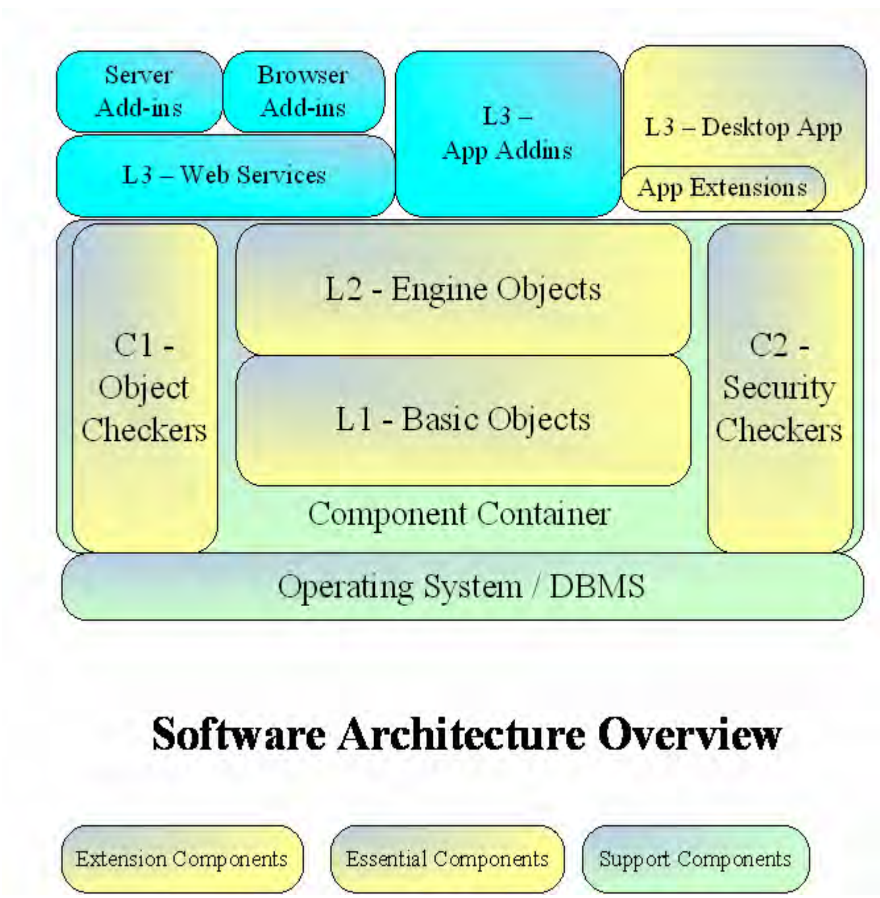
Input Data Databases – the largest grid databases are the input databases. On opening the remote sensing tree's Gridded Data Folder, there are two databases, **Nile-Meteosat-Example**, and **ModelResults.** The Nile-Meteosat-Example is the sample database included with the interface. It has data for the entire basin that for visible, infrared and water vapor radiation bands at half-hour resolution for the period Jan. 1 1997 to Jan. 7 1997. **Model Results Database** – the other grid database in the tree is the ModelResults database. This database holds all of the results of the rainfall estimation model. Each time the model is run, the resulting binary files are stored and an entry for them is included in the Model Results Database's metabase. This way, the user can view the model results with the same tools as he uses to view the input data.



Nile DST Remote Sensing Module

9. **Future Updates**

One of the main considerations in the design of the current version of Nile DST is low operating and maintenance cost. This eliminated the use more powerful relationship database management systems such as MS SQL server and Oracle. Instead, the MS Access, a part of MS Office suite available on most PCs, was used for all data management in the Nile DST. This implementation sets the operational framework of Nile DST as a single user application. The database will be diverged once the system starts operational. Data sharing and synchronization becomes very difficult. To overcome this problem, the future implementation will give users options to select more powerful RDBMS such as MS SQL Server and Oracle for the data management. All datasets will be stored in one centralized geodatabase, a common data storage and management framework provided by ESRI. The geodatabase can be accessed from all distributed desktop applications through computer network. Other updates include COM/ActiveX technology for interface and application development.



Software Architecture for Future Version

ANNEX C – NILE DST TRAINING REPORT

1. Introduction

As part of the capacity building activities under the Nile Basin Water Resources Project, a Regional Nile DST training workshop was held during the period 25th September to 6th October 2006 at the Project Management Unit (PMU) of the NBI Water Resources Planning and Management (NBI-WRPM) Project in Addis Ababa, Ethiopia. Participants to the workshop included two Engineers/Scientists from each of the Nile Basin countries (except Eritrea) and officers from the NBI WRPM PMU, NELSAP, and ENTRO. The full list of participants is attached as **Annex C1**.

The objective of the workshop was to train Engineers/Scientists from the Nile Basin Countries in the use of the updated River Simulation and Reservoir Operation Module of the Nile Decision Support Tool (Nile DST) developed by the Georgia Institute of Technology (GaTech). The workshop was funded by the Nile Basin Water Resources Project and facilitated by a team of experts from GaTech.

The workshop was officially opened by Dr. Hesham Ghany, Project Manager of the NBI Water Resources Planning and Management Project. Also in attendance were the Chief Technical Advisor of the FAO Nile Basin Water Resources Project and staff of the NBI-WRPM PMU.

2. Pre-workshop Preparations

Prior to the regional training workshop, GaTech staff organized a three-week internet-based training session during which new Nile DST trainees were introduced to the basic operations of the different modules of the Nile DST. The more experienced trainees were given specific assignments to accomplish in preparation for the regional training. Specifically, the trainees were required to identify country specific water resources planning and management "real-life" problems that would be analyzed during the regional training session, to demonstrate the applicability of the tools. The more experienced trainees were also encouraged to support and work closely with the new trainees to ensure that the latter develop a good understanding of the basics and operational structure of the Nile DST. Generally, the pre-workshop training was very useful in preparing the trainees for the more rigorous regional training workshop. Details of the pre-workshop training materials are attached as **Annex C2**.

3. Structure of the Regional Training Workshop

The regional training workshop was structured into five main sessions, i.e.:

(i) **Review Session** – A two-day review session was conducted by GaTech staff to introduce the trainees to the different technical aspects of the Nile DST in general and the River Simulation and Reservoir Operation Module (RS&RO) in particular. Detailed demonstrations of the application of the updated version of the RS&RO module were conducted in an interactive manner to ensure a thorough understanding of the module by the trainees. Examples of the module application were drawn from different parts of the basin to demonstrate the usefulness and robustness of the module in addressing diverse water resources management and planning issues in the basin. As part of this session, the participants were also introduced to basic programming and modeling techniques using Visual Basic. Technical materials used in the review session are attached as **Annex C3**.

(ii) **Hands-on Training Session** – During this session, participants were divided into nine groups (based on the countries represented) and allowed to navigate through the different components of the Nile DST and RS&RO module. The participants conducted some "dry runs" of the Nile DST and RS&RO module based on some hypothetical exercises prepared by GaTech staff. This session helped the trainees to get acquainted and feel comfortable with the operation of the Nile DST and RS&RO module and to prepare them for the more rigorous group problem solving session that followed.

(iii) **Group Problem Solving Session** – During this session, the trainees, with the guidance of GaTech staff, formulated country/sub-region specific practical water resources related problems which they then worked on and solved using the RS&RO module. This particular session was very productive because the trainees had the opportunity to appreciate the applicability of the tools in addressing "real life" problems they are faced with in their day-to-day work in their agencies.

(iv) **Group Presentations Session** – Following four days of intensive analytical work, the groups presented their results and findings. Most of the results and findings were very intuitive as they both clearly highlighted the magnitude and severity of the identified problems and also provided potential solutions to these problems. It was clear from the presentations and ensuing discussions that the trainees had gained a good level of confidence in the use of the tools and their potential application in analyzing diverse water related problems in the basin. Details of the group presentations are attached as **Annex C4**.

(v) **Certificates Award Session** – Following successful conclusion of the training session, trainees were awarded Certificates of Participation which were jointly presented to them by the Project Manager of the WRPM PMU, on behalf of NBI, and Prof. Aris Georgakakos on behalf of GaTech.

4. Field Tour

The trainees were taken on a one-day tour of the Ethiopian part of the Blue Nile Basin, including the Nile Gorge. The trainees, especially those from outside Ethiopia, used this trip as an excellent opportunity to appreciate the tremendous water resources related issues in the Blue Nile basin including its significant hydropower potential.

5. Post-workshop Follow up

During the regional training workshop, trainees were given specific assignments to accomplish from their respective home countries. Most of these assignments were a continuation of the exercises the trainees worked on during the training session. The Consultant continued giving guidance to the trainees during the post-workshop follow-up period by answering specific questions raised by the trainees on the Forum. This support was given on a demand-driven basis and the follow-up period ended when the trainees completed their exercises and there were no more questions asked and clarifications sought from the consultant.

6. Conclusion

Overall, the regional training workshop was very successful as all the intended objectives were achieved by the end of the training. Based on the feed back from the trainees, it was evident that all of them had significantly improved on their understanding and appreciation of the applicability and robustness of the Nile DST in general and the RS&RO Module in particular. Most of them were committed to continue using the tools to address some of the water resources issues they are faced with in their respective countries.

The trainees emphasized the importance of continuous refresher training in the use and update of the tools and resolved to form a basin-wide Nile DST user group to continue supporting each other in addressing some of the challenges they may encounter during the use of the tools.

Of specific concern to the trainees was the challenge of continuously updating the database with new data and information in the absence of a basin-wide data sharing protocol. The trainees recommended that this issue be given the urgency it deserves during the ongoing negotiations under the Nile Basin Initiative.

Owing to the high turn-over of Engineers/Scientists being experienced by most government agencies in many of the Nile Basin countries, the trainees recommended that additional training be conducted for more Engineers /Scientists in the basin on the use of the tools. To this regard, the trainees unanimously resolved to conduct Nile DST training sessions at national and local levels to encourage wide spread use of the tools in the relevant agencies in their respective countries.

Given the level of investment (time, technical and financial) in the development of the Nile DST, the trainees recommended that any future development of water related Decision Support Tools in the Nile basin should be coordinated in such a manner as to build on the already existing Nile DST to ensure consistency and benefit from the knowledge and experience of the existing pool of Nile DST users in the basin.

ANNEX C1 – List of Workshop Participants

	Name	Country	Organization	Phone	Email
1	Kagari Joachim	Burundi	REGIDESO	+2574224453	kagarijoa@yahoo.fr
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4	Georges Gulemvuga	DR Congo	Regie des voies fluviales & Institut Superieur des Techniques Appliquees	+243818970966	georges_gul@yahoo.fr
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7	Assefa Kebede	Ethiopia			
8	Ephrem Getahum	Ethiopia			
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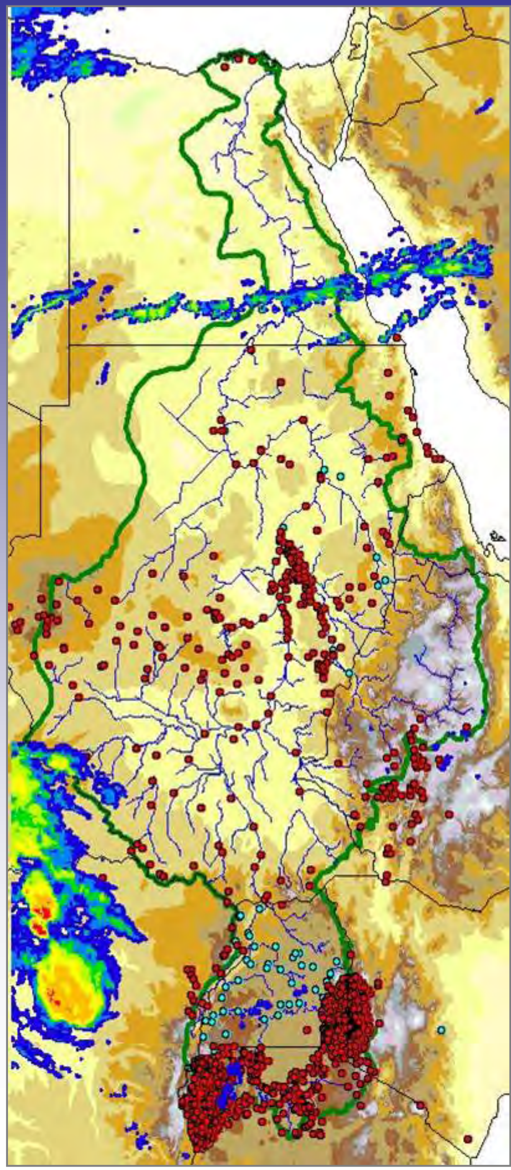
18	Hamza Sadiki	Tanzania	Pagani Basin Water Office, Ministry of Water	+255754378501	hamzasadiki@yahoo.com
19	Fred Kimaite	Uganda	Water Resources Management Department	256772 483730	Kimaite.wrmd@dwd.co.ug
20	Michael Kizza	Uganda	Makerere University	256772 614580	michael.kizza@gmail.com
21	Sewagudde Sowed	Uganda	Water Resources Management Department	256772 838697	sewagudde.wrmd@dwd.co.ug
22	Aris Georgakakos	USA	Georgia Institute of Technology		
23	Humaing Yao	USA	Georgia Institute of Technology		
24	Martin Kistenmacher	USA	Georgia Institute of Technology		

ANNEX C2 – Pre-workshop Training Materials

2006 Nile DST Training Workshop

Review Exercises: River & Reservoir Simulation & Mgt. Model

Burundi
Congo
Egypt
Eritrea
Ethiopia
Kenya
Rwanda
Sudan
Tanzania
Uganda



Burundi
Congo
Egypt
Eritrea
Ethiopia
Kenya
Rwanda
Sudan
Tanzania
Uganda

Georgia Water Resources Institute

September 2006

Burundi
Congo
Egypt
Eritrea
Ethiopia
Kenya
Rwanda
Sudan
Tanzania
Uganda

Georgia Water Resources Institute

September 2006

Self Study Scope:

As we approach the 4th Nile DST Training Workshop, we would like to initiate this training event by a self study session. This session has two purposes: For the participants that have attended previous Nile DST workshops, the exercises provide an opportunity to review the Nile DST software while working on an interesting water resources assessment. For the new Nile DST workshop participants, the exercises are an opportunity to start becoming familiar with the River and Reservoir Simulation and Management Nile DST module. Since all country teams have at least one individual with sufficient prior training, we would like to request that these individuals demonstrate the Nile DST software to their new colleagues and assist them in becoming familiar with its features. Namely, we ask the experienced Nile DST users to serve as instructors for the new users during the self-study session.

Nile DST RRSM Applications

1. Water Balance and Water Uses Assessments

This exercise aims to determine the magnitude of the water balance terms in various Nile River reaches. The river reaches are defined as follows:

- (a) Southern Nile system up to the border of Uganda and Sudan (Nimule);
- (b) Nimule to Malakal upstream of the Sobat junction;
- (c) Malakal (upstream of the Sobat junction) to downstream of Gebel El Aulia Dam; (Namely, before the junction of the White and Blue Niles;)
- (d) Ethiopian Blue Nile up to the Sudanese border;
- (e) Sudanese Blue Nile up to the junction with the White Nile;
- (f) Main Nile from the Blue and White Nile junction up to the entrance of Lake Nasser (High Aswan Dam reservoir);
- (g) Egyptian Nile, including Lake Nasser, to the Mediterranean Sea.

1.1 Consider first a baseline basin development scenario with existing projects and water use targets. For each one of the above-mentioned reaches, determine and graph the following quantities: (Generate one graph per river reach.)

- Average monthly and annual reach outflows over the period of record;
- Average monthly and annual reach outflows over the driest five years of the record; (Indicate the drought years;)
- Average monthly and annual reach outflows over the wettest five years of the record; (Indicate the five wettest years of record;)
- Develop quantitative measures of the outflow variability (e.g., percent difference of dry and wet periods from normal) and determine if wet and dry climatic periods occur at the same time across the various river reaches; Specify which river reaches behave similarly in this respect.

Nile DST RRSM Applications

1.2 For the baseline scenario and each one of the above-mentioned river reaches, estimate and graph the following quantities: (Generate one graph for each river reach.)

- Average monthly and annual reach water use and losses (separately) over the period of record;
- Average monthly and annual reach water use and losses (separately) over the driest five years of the record;
- Average monthly and annual reach water use and losses (separately) outflows over the wettest five years of the record;
- Develop quantitative measures of the water use and losses variability (e.g., percent difference of dry and wet periods from normal);
- Determine the reliability of meeting water use targets in each reach;
- Compare water losses to reach outflows;

Note : Reach water losses include evaporation and other water abstractions not related to human water uses.

1.3 For the baseline development scenario and each river reach, estimate and graph the following quantities: (Generate one graph per reach.)

- Average monthly and annual reach energy generation over the period of record;
- Average monthly and annual reach energy generation over the driest five years of the record;
- Average monthly and annual reach energy generation over the wettest five years of the record;
- Develop quantitative measures of energy generation variability (e.g., percent difference of dry and wet periods from normal).

Nile DST RRSM Applications

1.4 Consider now a full basin development scenario including all potential projects incorporated in the Nile DST. For this scenario, you are free to select any regulation policy and water use targets you like. For the development scenario you just defined, repeat exercises 1.1, 1.2, and 1.3. Then,

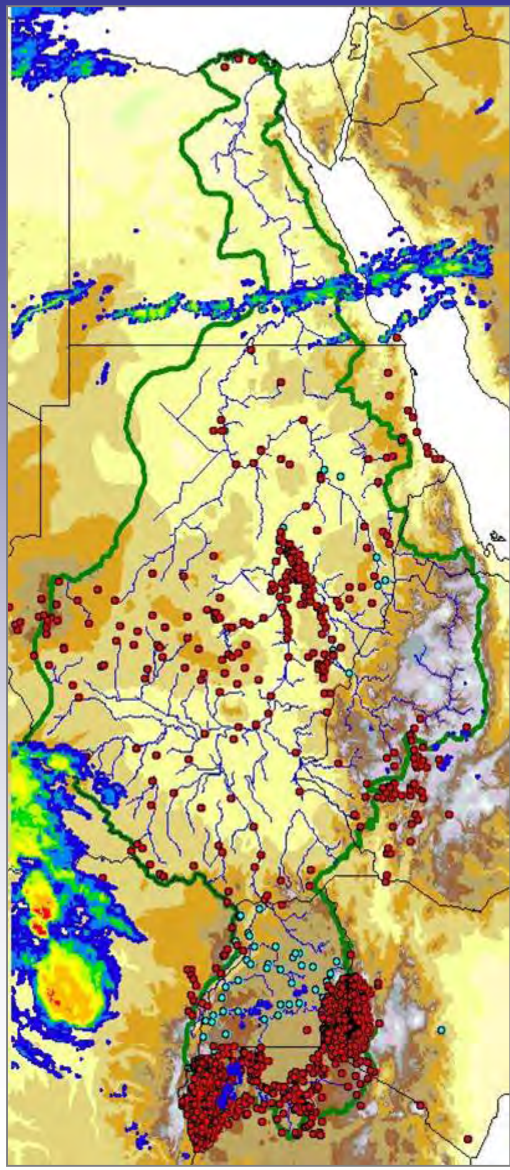
- Compare annual and monthly reach outflows, water use, losses, and energy generation on an average, five-year driest, and five-year wettest basis;
- Comment on your comparison findings; What issues do you see emerging from this comparison, and what strategy would you recommend to begin to address them?

1.5 Work with your country workshop participant and prepare a short presentation (~ 30 minutes) to deliver at the beginning of the upcoming workshop. In this presentation, you are expected to state your scenario assumptions, present your results, and highlight your findings.

2006 Nile DST Training Workshop

Review Exercises: Database Tool

Burundi
Congo
Egypt
Eritrea
Ethiopia
Kenya
Rwanda
Sudan
Tanzania
Uganda



Georgia Water Resources Institute

Overview

The following exercises are meant acquaint trainees with the basic operations that can be performed with the Nile DST Database Tool. These operations include storing, retrieving, visualizing, and manipulating various water resources related data. An example will be given to illustrate how the basic operations can be used to help solve real-life problems.

Burundi
Congo
Egypt
Eritrea
Ethiopia
Kenya
Rwanda
Sudan
Tanzania
Uganda

Georgia Water Resources Institute

October 2006

Burundi
Congo
Egypt
Eritrea
Ethiopia
Kenya
Rwanda
Sudan
Tanzania
Uganda

Georgia Water Resources Institute

Exercise 1

Finding data stored in the data base

- Find all the stations in Uganda that contain Discharge data.

- Locate one of the stations on the map.

- For this station:

    - Check if it also contains Gage Height data.
    - Find Longitude and Latitude information.
    - View the actual raw data in the Data Table and export it to Excel.
    - Add some discharge data to the station.

- Select a watershed and find all of the stations containing precipitation data within the selected watershed.

Exercise 2

Viewing and manipulating individual data series in the Chart Tool

- Select a station for a certain parameter of choice and plot the time-series.
    - Familiarize yourself with the chart options and preferences. This chart should be similar to the charts used in the Simulation Model.
    - Replot the time-series for several different Time Intervals and Statistics.
    - Create a Frequency Curve.
    - Show a plot of the average monthly values over the entire period of record.
- Select multiple stations and repeat the above exercises.

Burundi
Congo
Egypt
Eritrea
Ethiopia
Kenya
Rwanda
Sudan
Tanzania
Uganda

Georgia Water Resources Institute

October 2006

Exercise 3

Performing elementary data analysis / manipulation with the Data Analysis Tool

Exploring Single-Series Operations:

- Create an input node and assign it the raw data from the stations of interest
- Aggregate the data at each station to a certain Time Interval and Statistic
- Repeat some of the operations that were done with the Chart Tool
  - Frequency Curve
  - Climatology
  - Etc.

Exercise 3 continued

Performing elementary data analysis / manipulation with the Data Analysis Tool

Exploring Cross-Series Operations:

- Aggregate multiple individual time-series at a single node
- Aggregate two time-series coming from two different nodes. Explore other operations that can be performed on two incoming nodes
    - Combining two time-series into one node
    - Analyzing Cross-Correlations
    - Double Mass Analysis
    - Etc.

Example

Data Analysis Example: Mean Aerial Precipitation

The purpose of this exercise is to evaluate the Mean Aerial Precipitation over a watershed in the Nile Basin. This type of information is often useful as input data for hydrologic models of the watershed in question.

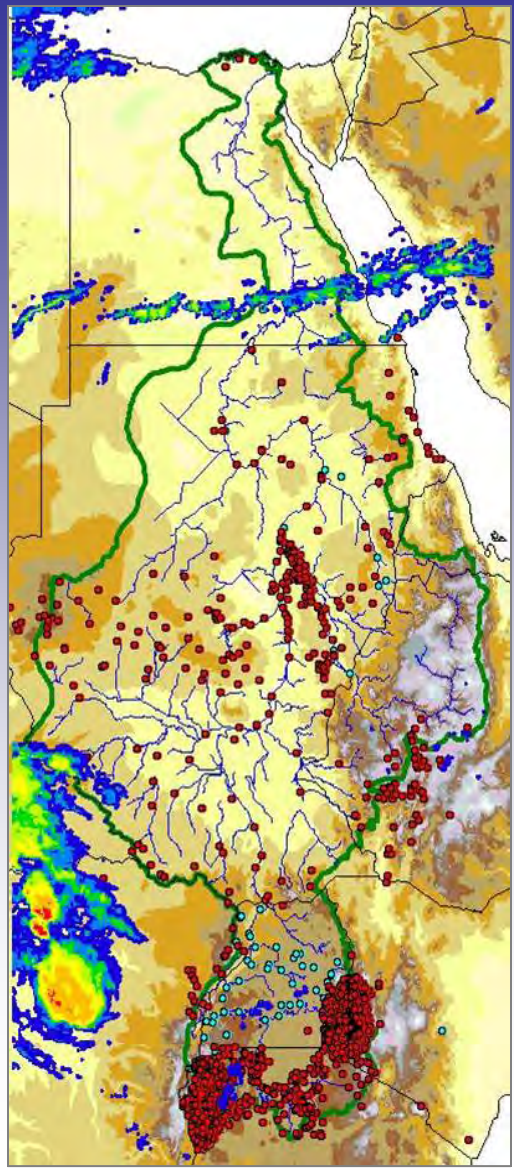
Steps:

- Delineate the basin using the map tool
- Select precipitation stations within the basin and aggregate to an appropriate time period
- Select watershed grid elements that fall within the watershed
- Apply inverse distance weighting algorithm to get precipitation values at each grid cell
- Average the precipitation values to obtain mean precipitation over the watershed

ANNEX C3 – Review Session Technical Materials

Nile Decision Support Tool – Nile DST:
4th Training Workshop

Burundi
Congo
Egypt
Eritrea
Ethiopia
Kenya
Rwanda
Sudan
Tanzania
Uganda



Nile Basin Water Resources
GCP/INT/752/ITA

Burundi
Congo
Egypt
Eritrea
Ethiopia
Kenya
Rwanda
Sudan
Tanzania
Uganda

GWRI

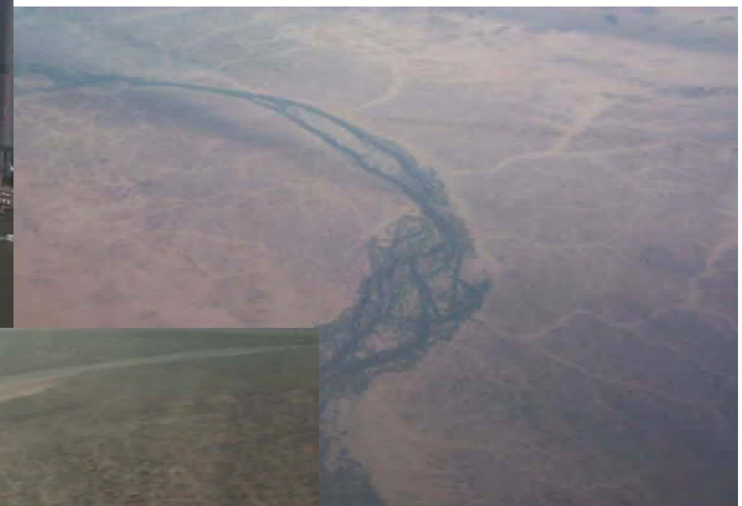
Georgia Water Resources Institute

Sept. 2003

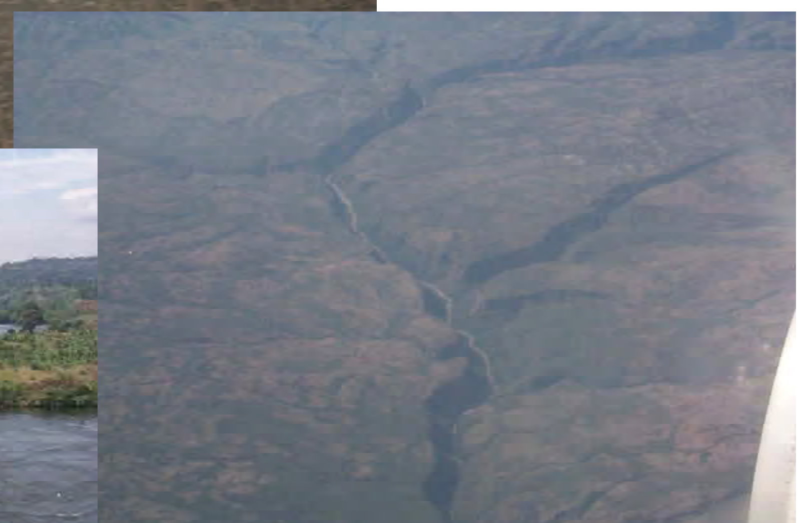
Georgia Tech

A Magnificent River

Egypt



Sudan



Ethiopia

Uganda

Nile Decision Support Tool (Nile DST) Overview

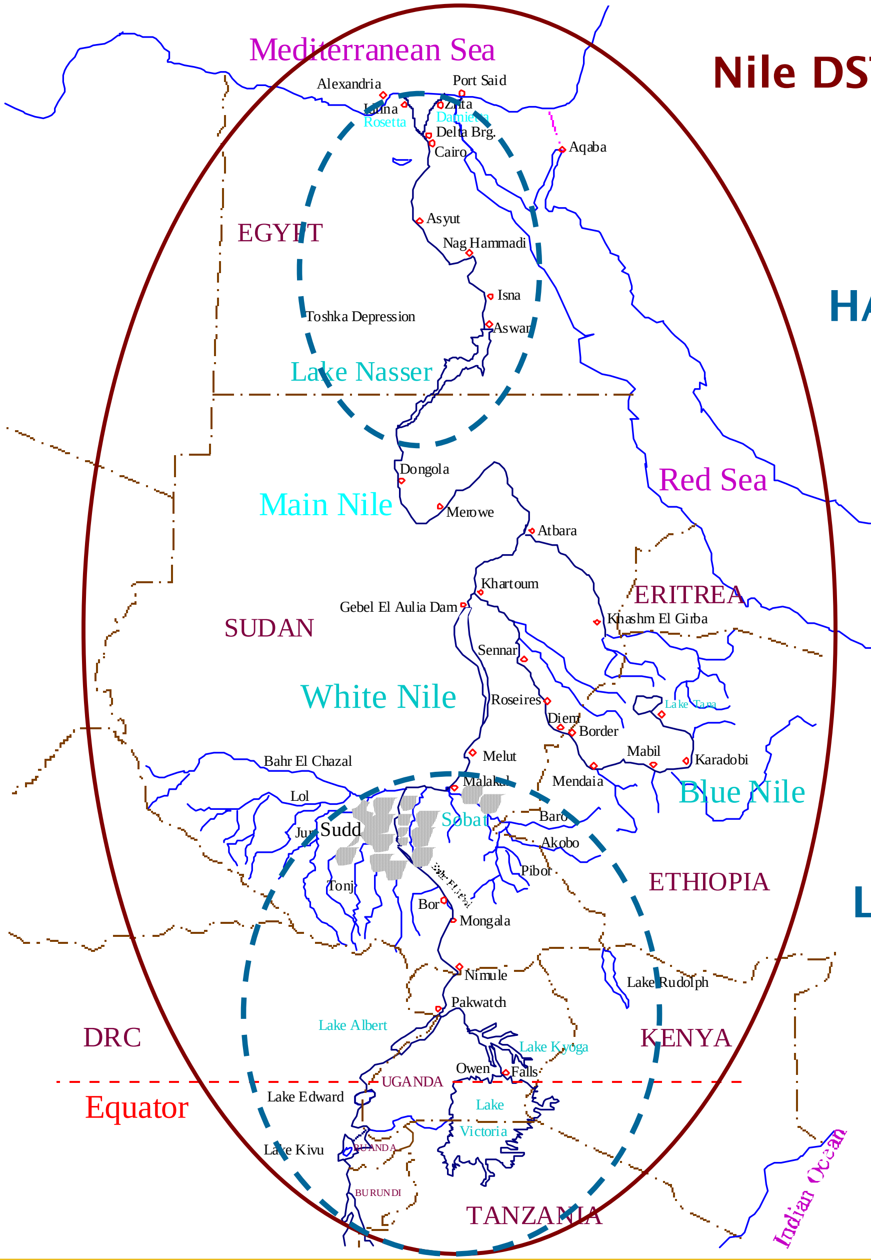
Aris Georgakakos
Huaming Yao
Fred Kimaite
Martin Kistenmacher

Georgia Water Resources Institute (**GWRI**)
Georgia Institute of Technology (**Georgia Tech**)

(Nile DST Workshop; September 2006)

- **Decision Support Systems for Water Resources Assessment, Plnn, & Mgt.**
  (Multiple Time/Spatial Scales, Multiple Objectives, Multiple Decision Makers)
- **The Nile Decision Support System (Nile DSS)**
  (Purpose, Structure, Planning and Management Applications)
- **Nile DST River and Reservoir Simulation and Management Model**
  (Data, Methods, Applications)
- **Educational Initiatives**
  (International Water Resources Institute)

Nile DSS: Planning and Management Components



Nile DST: Basin wide Planning and Assessment
(All Nile Countries)

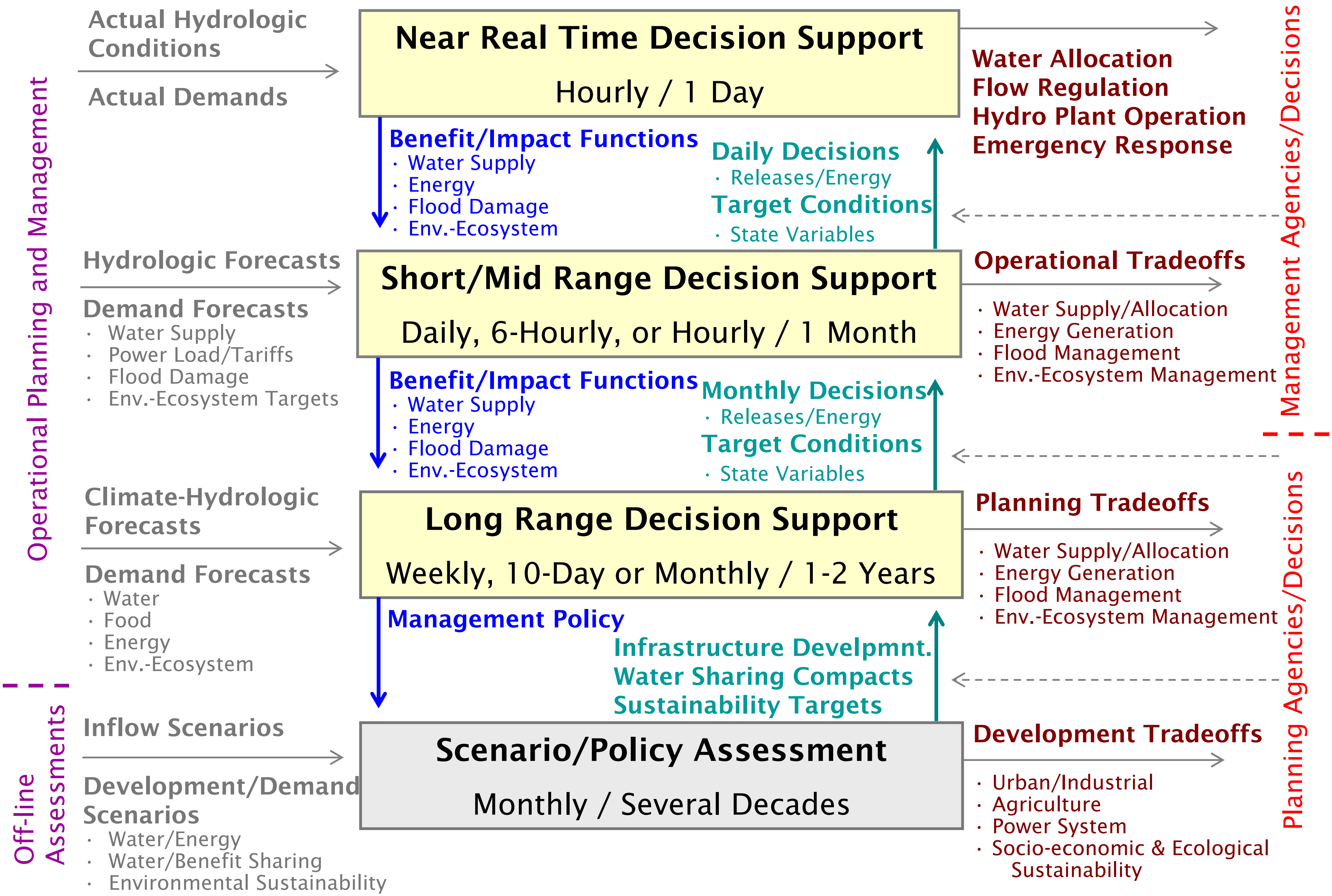
HAD DSS: HAD Operational Management
(Egypt: MWRI; NFC)

Blue Nile DSS: Blue Nile, Sobat, Atbara Operational Management

LV DST: Lake Victoria Operational Management
(Uganda: MEMD; MWLE)

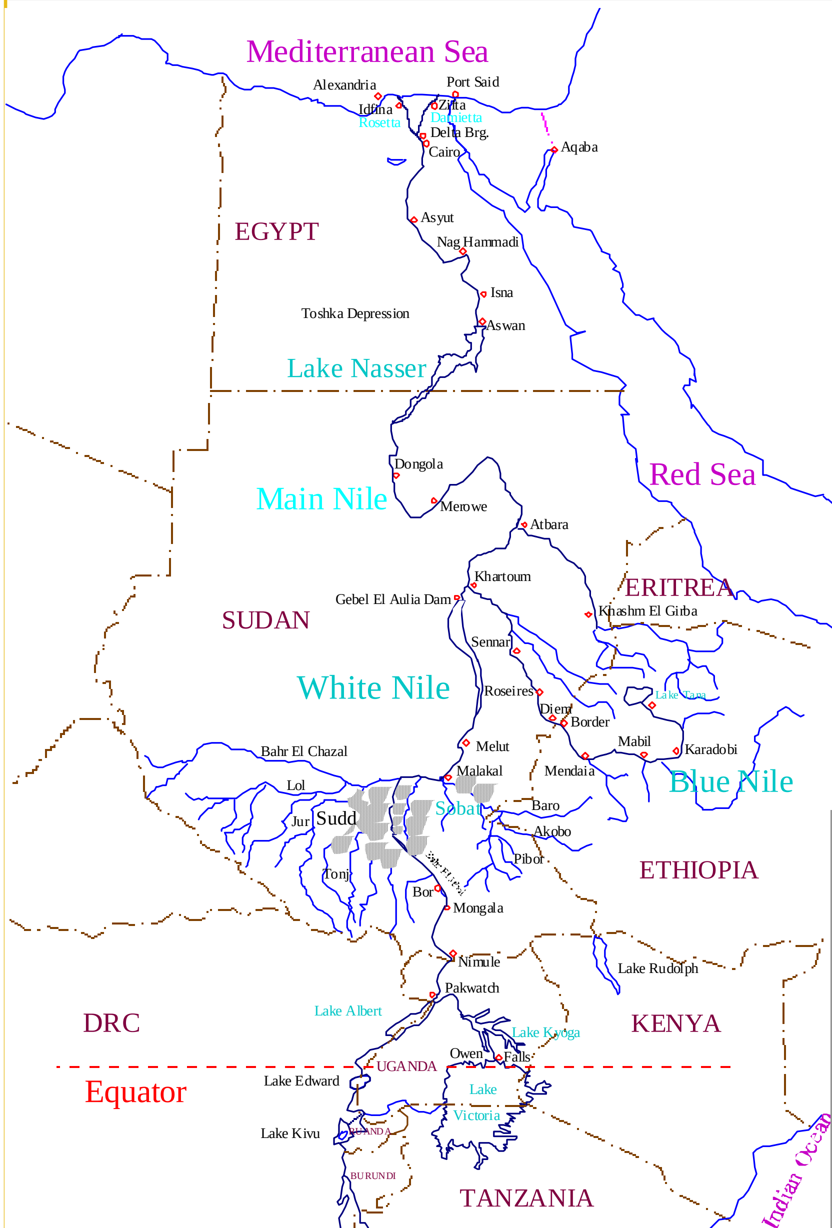
Decision Support Systems for Water Res. Assessment, Plann. & Mgt.

Multiple Objectives, Time Scales, & Decision Makers



Nile River Basin: Need for Decision Support

Egypt, Ethiopia, Sudan, Eritrea, Uganda, Kenya, Tanzania, Rwanda, Burundi, Congo



- 3,100,000 sqkm; 10 Countries; 250 million
- **Water Uses:** Water Supply (Ag./Ind./Urban), Energy Generation, Flood Mgt., Environmental/Ecosystem Protection
- **Objectives:** Poverty Alleviation; Economic Development; Environmental Sustainability

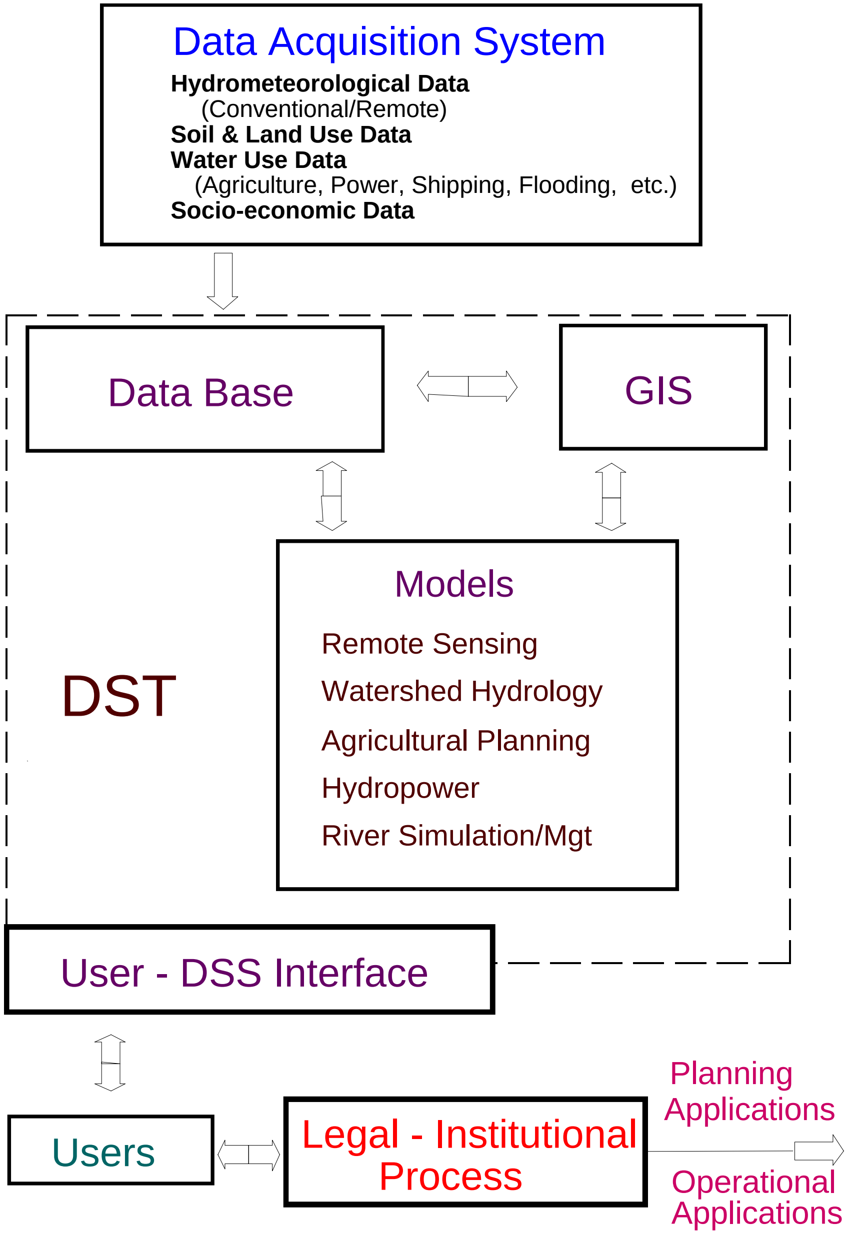
Country	GDP/Capita (US$)	Unmplmnt Rate 1995	%GDP / %Emplmnt (Agriculture)	Econ. Aid Million $	IRWR[1] (m^3 per inhab.)	ARWR[2] (m^3 per inhab.)	Present Water Consumption (bcm/yr)	2020 Water Consumption (bcm/yr)
Burundi	154	-	54 / 93	253	571	571	.1	2.8
Rwanda	188	-	52 / 93	351	811	811	.2	.9
Tanzania	120	-	58 / 90	1,076	2,733	2,998	.5	2.2
Kenya	337	35%	25 / 75	589	739	1,069	.6	1.5
Congo	107	-	-	-	21,973	23,211	.7	1.9
Uganda	297	-	55 / 86	525	1,891	3,099	.2	4.3
Ethiopia	94	-	48 / 80	1,036	2,059	1,998	2.2	35.4
Eritrea	175	-	-	-	815	2,492	-	-
Sudan	800	30%	33 / 80	387	1,279	3,150	17.7	29.3
Egypt	816	20%	18 / 34	1,713	29	926	59.2	65.7
Switzrlnd	33,850							
USA	22,350							
Total							**81.4**	**144.**

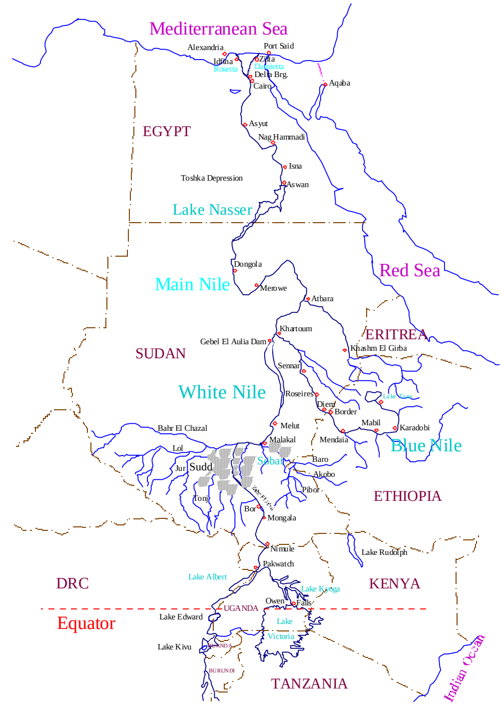
Basin-wide Decision Level (Nile Ministers)
Basin wide Development; Water and Benefit Sharing Agreements
50-year time frame; **Decadal forecasts/planning**

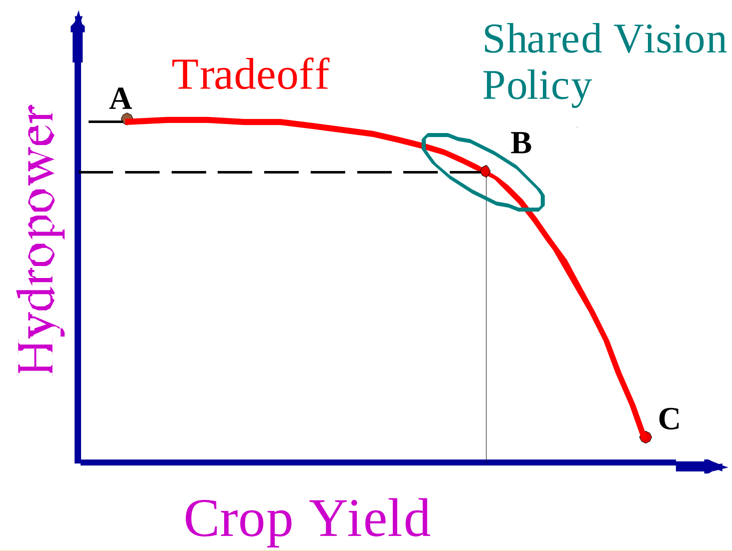
Regional Decision Level (Eastern/Southern Nile)
Regional Development Program
5 - 10 year time frame; **Inter-annual forecasts/planning**

National Decision Level (Water & Power Agencies)
Water and Energy Management
Seasonal to hourly time frame; **Seasonal forecasts/management**

Nile Decision Support Tool (Nile DST):
System Overview







Nile DST: River& Reservoir Simulation & Management (RRSM) Model Features

- **10-day Time Resolution**
- **Inflow Forecasting**

  Eq. Lakes Inflows; Torrents; Sobat; Blue Nile; Atbara
- **River Routing**

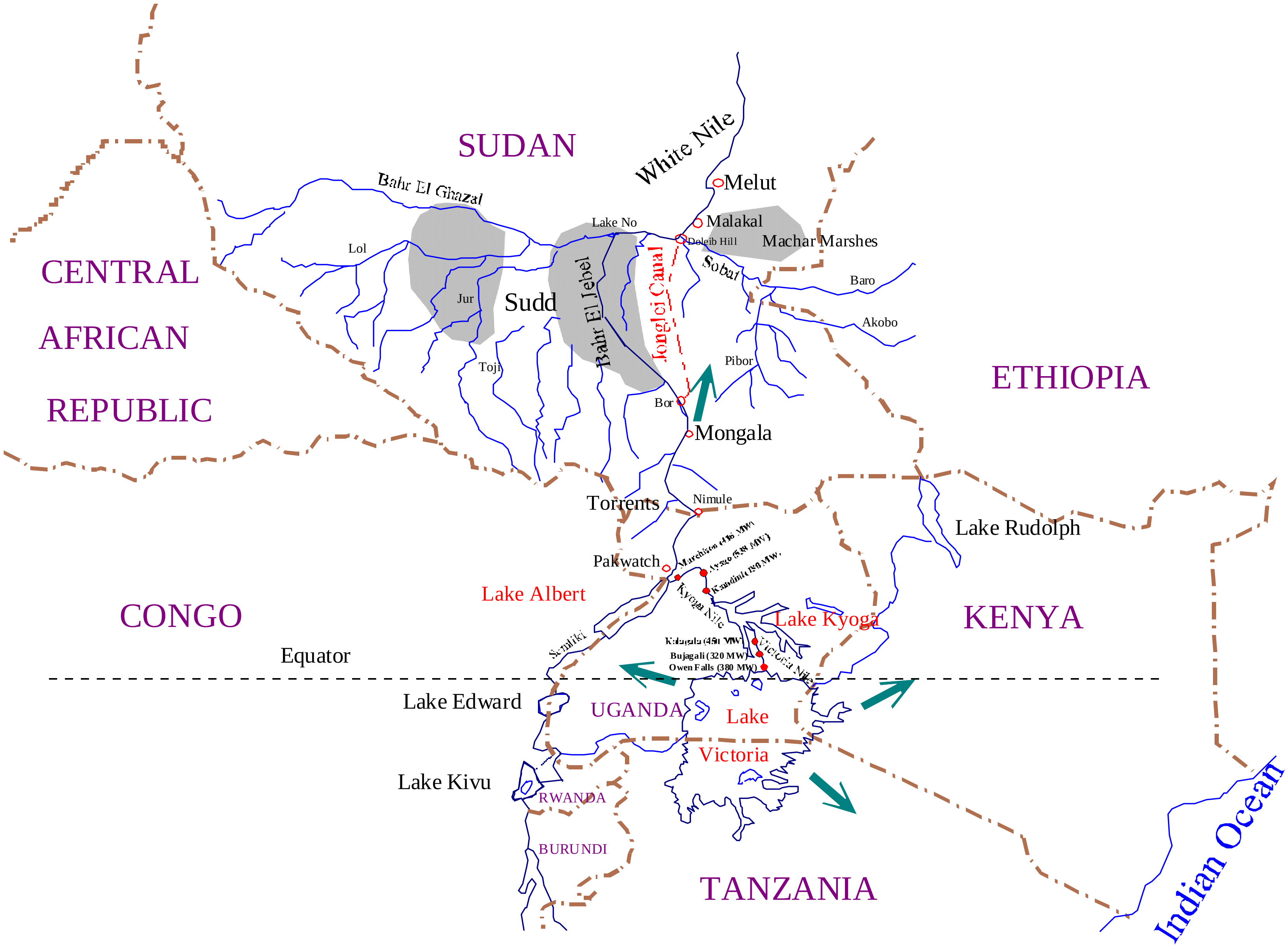
  Eq. Lakes; Sudd; Sobat; Malakal-Gebel El Aulia; Blue Nile; Atbara; Khartoum-Dongola
- **Existing and Potential Reservoir & Hydropower Projects**

  Projects Can be Included or Excluded at the Discretion of the User
- **Existing and Planned Irrigation Areas**

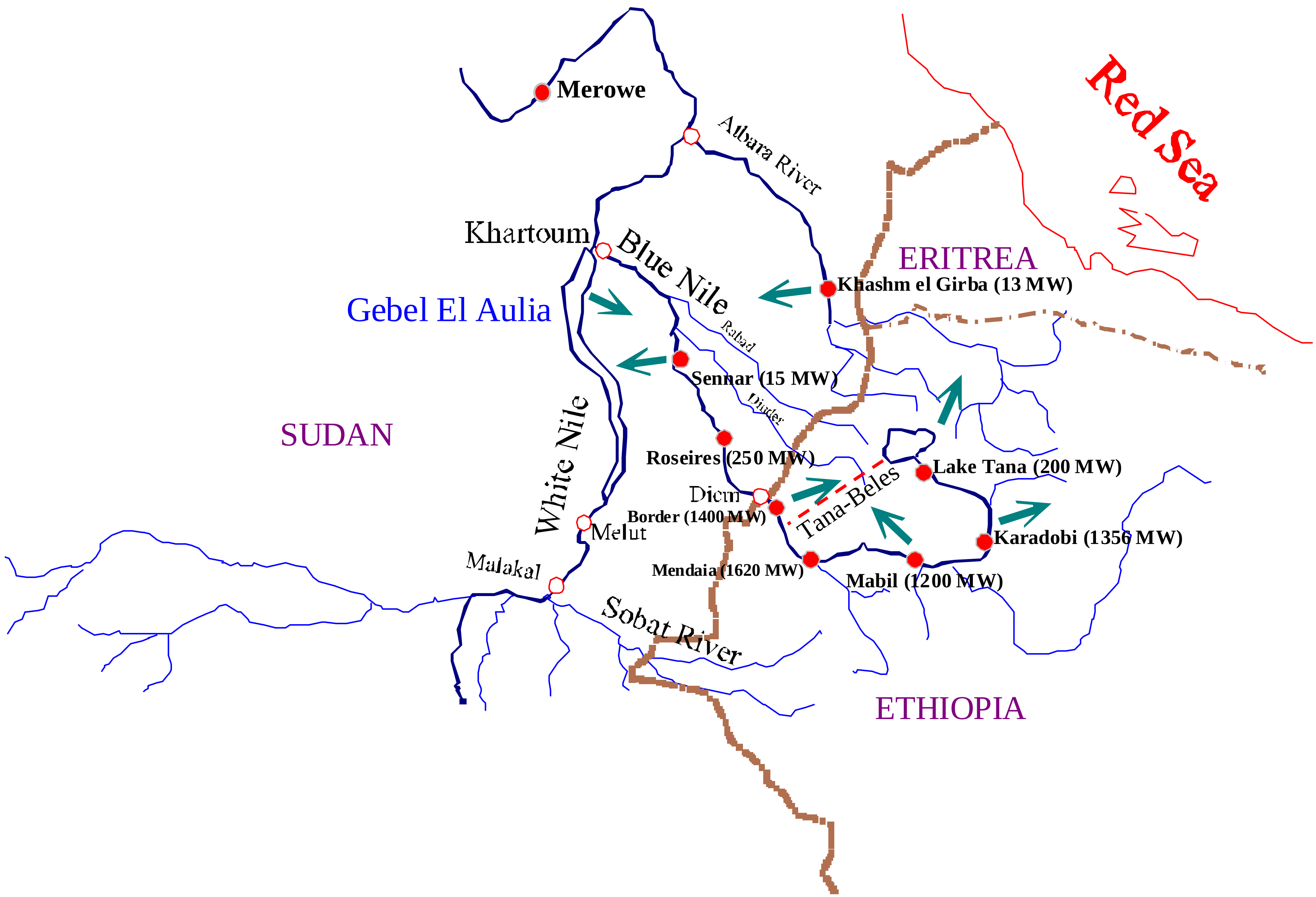
  Irrigation Areas & Amounts User Specifiable
- **Progressive Model Sophistication**

  Sub-regional Simulation to Basin-wide Management.

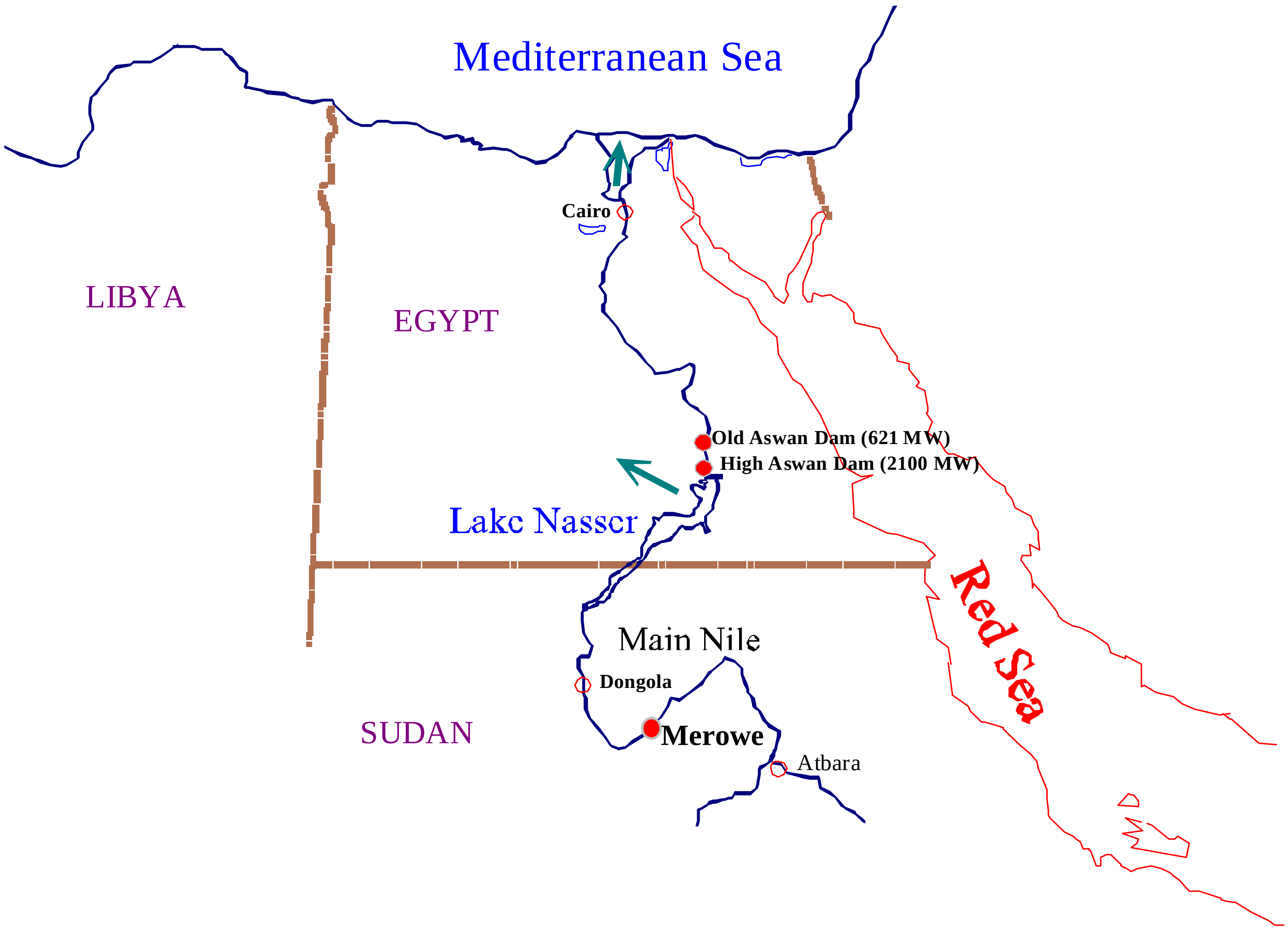
Nile DST: Southern Nile System



Nile DST: Eastern Nile System



Nile DST: Main Nile System



Nile DST: RRSM Model Data

Database:

River network configuration; Hydrology; Hydro facility, and Water use

River Network Data:

- River network configuration (i.e., maps indicating the location of main river reaches and tributaries);
- System node locations (indicated on maps along with location longitude and latitude); System nodes include major tributary confluences; river locations where reliable flow records are available; sites of existing and planned reservoirs, barrages, or other hydraulic works (such as diversions); locations of water supply withdrawals (for agricultural, domestic or industrial use); and locations of flood prone or environmentally sensitive areas;
- Longitudinal bed slope for main river stem;
- Typical river cross sections for main-stem river reaches with uniform bed slope;

River Flow and Stage Data:

- Streamflow discharge and river stage measurements (at daily or 10-day time resolution) at system nodes;
- Rating curves at measurement nodes;
- Estimated river flow losses between network nodes;

Nile DST: RRSM Model Data cont'd

Hydro Facility Data:

- Facility name and location on major river reaches and tributaries, i.e., location relative to river network;
- Year of construction and reservoir filling;
- Elevation vs. storage vs. surface area curves;
- Active reservoir (or barrage) storage/level ranges (i.e., buffer zone, conservation pool, top of flood control pool);
- Change of reservoir (or barrage) storage over time due to siltation (i.e., siltation rate);
- Tailwater curve (i.e., downstream discharge versus downstream elevation curve);
- Spillway and other outlet characteristics (i.e., outflow discharge capacity vs. reservoir level curves);
- Penstock hydraulic loss functions, if known;
- Penstock and other outlet leakage, if significant, as function of reservoir level;
- Minimum and maximum discharge limits;
- Number and type (i.e., Francis, Kaplan, Pelton) of hydropower turbines;
- Individual turbine characteristics (power vs. net hydraulic head vs. discharge curves, operational turbine ranges, i.e., minimum and maximum power limits);
- Typical turbine maintenance schedule;
- Reservoir or barrage operating rules (i.e., seasonal level targets and relationship to releases);
- Historical (evaporation-rainfall) rate sequences (daily, 10-day, or monthly);
- Historical temperature data (minimum, maximum, average; daily, 10-day, or monthly);
- Historical sequences of reservoir inflows, levels, discharges, and energy generation at daily, 10-day, or monthly time resolution);
- Location of irrigation and water supply withdrawals relative to reservoir or barrage sites (e.g., withdrawal from the river *upstream* of the reservoir, withdrawal *directly* from the reservoir storage, or withdrawal from the river *downstream* from the reservoir);

Nile DST: RRSM Model Data cont'd

Water Use Data:

- Location of irrigation and water supply withdrawals relative to system nodes;
- Current water use requirements (e.g., irrigation requirements on daily, ten-day, or monthly time resolution);
- Historical water use withdrawals (daily, 10-day, or monthly) from various river network nodes;
- Future (potential) water use scenarios at system nodes consistent with national water development plans (formulated as low, medium, and high demand scenarios at daily, 10-day, or monthly time resolution);
- Power demand country-wide (hourly demand for typical weeks in each month of the year);
- Flood prone areas (relative to the river network);
- Flood severity as a function of river stage and discharge;
- Environmental flow requirements at system nodes, if any.

Nile DST: Equatorial Lake Data

		Victoria [1900 – 1977]	**Kyoga** [1912 – 1977]	**Albert** [1905 – 1977]
Minimum	Level (m)	1133.08	1030.31	618.75
	Storage (10^9 m^3)	2905.73	5.44	145.88
	Outflow (10^9 m^3/yr.)	10.94	8.83	10.82
Mean	Level (m)	1134.28	1031.81	620.51
	Storage (10^9 m^3)	2985.65	10.49	155.20
	Outflow (10^9 m^3/yr.)	25.48	24.82	28.38
Maximum	Level (m)	1136.28	1034.11	623.97
	Storage (10^9 m^3)	3121.32	20.35	175.68
	Outflow (10^9 m^3/yr.)	55.22	62.78	64.64

Nile DST: Project Data—Southern Nile, Blue Nile, and Atbara

Existing and Potential Projects on the Victoria and Kyoga Nile Reaches

	Hydroelectric Site	**Power Capacity** (MW)
Victoria Nile	Nalubaale/Kiira	380
	Bujagali	320
	Kalagala	450
Kyoga Nile	Kamdini	180
	Ayago	538
	Murchison Falls	416

Existing and Potential Projects on the Blue Nile and Atbara

	Tana/ Beles	Karadobi	Mabil	Mendaia	Border	Roseires	Sennar	Khashm El Girba
Max. Level (m)	1787.57	1156.00	910.60	743.60	575.00	481	421.7	473
Max. Storage (bcm)	13.84	34.20	14.11	16.72	10.75	2.72	1.07	1.35
Min Level (m)	1783.80	1041.00	837.80	724.81	563.43	467	415	450
Min. Storage (bcm)	2.34	3.94	3.22	11.39	6.30	0.156	0.180	0.061
Design Capacity (MW)	200/470	1356	1200	1620	1400	250	15	13

Nile DST: Project Data—Main Nile

	Merowe	High Aswan Dam	Old Aswan Dam
Maximum Level, m	298	178	113
Maximum Storage, bcm	11.8	137.5	0.10
Minimum Level, m	285	147	107.5
Minimum Storage, bcm	4.9	31.6	0.044
Installed Capacity, MW	125	2100	621

Nile DST: Current Water Demands and Tentative Future Scenarios

		Water Demand Target Levels		
Location	**Current**	**Low**	**Medium**	**High**
Lake Victoria Basin	0	5	7.5	10
Sudd (Mongala)	0	1.5	3	4.5
Gebel el Aulia	1.5	1.5	1.5	1.5
Lake Tana Basin	0	1	2	3
Karadobi Basin	0	0.5	1	1.5
Mabil Basin	0	1.5	3	4.5
Border Basin	0	2	4	6
Sennar	15.62	19.62	23.62	27.62
Khashm el Girba	1.38	1.38	1.38	1.38
Lake Nasser	0	3	5	7.5
Downstream HAD	55.5	57.5	60.5	63

Nile DST: River Basin Planning & Management

System Dynamics: $S(k+1) = f[S(k), u(k), \xi(k), k]$

$$
f(k) = \begin{bmatrix}
f_1(k) = S_1(k) + W_V(k) - u_1(k) - D_V \\
f_2(k) = S_2(k) + W_K(k) + u_1 - u_2(k) - D_K \\
f_3(k) = S_3(k) + W_A(k) + u_2 - u_3(k) - D_A \\
f_4(k) = \dfrac{a_1}{U_F(k)} u_3 + a_2 Q_{trnt}(k) + a_3 Q_{trnt}(k-1) + a_4 S_4(k) + a_5 + \varepsilon_1(k) \\
f_5(k) = b_1 f_4(k) + b_2 S_4(k) + b_3(k) S_5 + b_4 + \varepsilon_2(k) \\
f_6(k) = f_4(k) + Q_{sbt}(k) - f_5(k) \\
f_7(k) = c_1 f_6(k) + c_2 S_6(k) + c_3(k) S_7 + c_4 + \varepsilon_3(k) \\
f_8(k) = S_9(k) \\
f_9(k) = -\dfrac{0.04}{0.48} S_9(k) + \dfrac{0.52}{0.48} S_8(k) - \dfrac{1}{0.48} u_4(k) - D_{GA}(k) - \dfrac{052}{0.48} D_{GA}(k-1) \\
- e_{GA}(k) A_{GA}(k) - \dfrac{0.52}{0.48} e_{GA}(k-1) A_{GA}(k-1) + \\
U_F(k) f_7(k) + \dfrac{0.52}{0.48} U_F(k-1) S_7(k) + \varepsilon_4(k) \\
f_{10}(k) = u_4(k) \\
f_{11}(k) = S_{10}(k) \\
f_{12}(k) = S_{12}(k) + W_{TA}(k) - u_5(k) - e_{TA} A_{TA}(k) - D_{TA} \\
f_{13}(k) = S_{13}(k) + W_{KA}(k) + \beta_{TAKA} u_5 - u_6(k) - e_{KA} A_{KA}(k) - D_{KA} \\
f_{14}(k) = S_{14}(k) + W_{MA}(k) + \beta_{KAMA} u_6 - u_7(k) - e_{MA} A_{MA}(k) - D_{MA} \\
f_{15}(k) = S_{15}(k) + W_{ME}(k) + \beta_{MAME} u_7 - u_8(k) - e_{ME} A_{ME}(k) - D_{ME} \\
f_{16}(k) = S_{16}(k) + W_{BO}(k) + \beta_{MEBO} u_8 - u_9(k) - e_{BO} A_{BO}(k) - D_{BO} \\
f_{17}(k) = S_{17}(k) + W_{RO}(k) + \beta_{BORO} u_9 - u_{10}(k) - e_{RO} A_{RO}(k) - D_{RO} \\
f_{18}(k) = S_{18}(k) + W_{SE}(k) + \beta_{ROSE} u_{10} - u_{11}(k) - e_{SE} A_{SE}(k) - D_{SE} \\
f_{19}(k) = \beta_{RAKT}(W_{RA}(k) + \beta_{DDRA}(W_{DD}(k) + \beta_{SEDD} u_{11}(k) - D_{SEDD}(k)) \\
- D_{DDRA}(k)) - D_{RAKT}(k) \\
f_{20}(k) = S_{19}(k) \\
f_{21}(k) = S_{21}(k) + W_{KG}(k) - u_{12}(k) - e_{KG} A_{KG}(k) - D_{KG}(k) \\
f_{22}(k) = \beta_{KGAT} u_{12}(k) - D_{KGAT}(k) \\
f_{23} = \dfrac{d_1}{U_F(k)} u_4(k) + \dfrac{d_2}{U_F(k-1)} S_{10}(k) + \dfrac{d_3}{U_F(k-2)} S_{11}(k) \\
+ d_4 f_{19}(k) + d_5 S_{19}(k) + d_5 S_{20}(k) + d_7(k) f_{22}(k) \\
+ d_8 S_{22}(k) + d_9 S_{23}(k) + d_{10} S_{25}(k) + d_{11} + \varepsilon_5(k) \\
f_{24}(k) = S_{25}(k) \\
f_{25}(k) = S_{25}(k) + u_{13}(k) + U_F(k) f_{23}(k) \\
- e_{HAD}(k) A_{HAD}(k) - SPL_{HAD}(k) + \nu_{HAD}(k)
\end{bmatrix},
$$

Victoria
Kyoga
Albert
Routing Reach
Sudd
Routing Reach
Gebel Aulia
Ethiopian Reservoirs
Sudanese Reservoirs
Routing Reaches
Egyptian Reservoirs

25 State Variables

$$
S(k) = \begin{bmatrix}
S_V(k) \\ S_K(k) \\ S_A(k) \\ Q_{mngl}(k-1) \\ Q_{ls}(k-1) \\ Q_{mlkl}(k-1) \\ Q_{mlt}(k-1) \\ S_{GA}(k-1) \\ S_{GA}(k) \\ u_{GA}(k-1) \\ u_{GA}(k-2) \\ S_{TA}(k) \\ S_{KA}(k) \\ S_{MA}(k) \\ S_{ME}(k) \\ S_{BO}(k) \\ S_{RO}(k) \\ S_{SE}(k) \\ Q_{KT}(k-1) \\ Q_{KT}(k-2) \\ S_{KG}(k) \\ Q_{AT}(k-1) \\ Q_{HAD}(k-1) \\ Q_{HAD}(k-2) \\ S_{HAD}(k)
\end{bmatrix},
$$

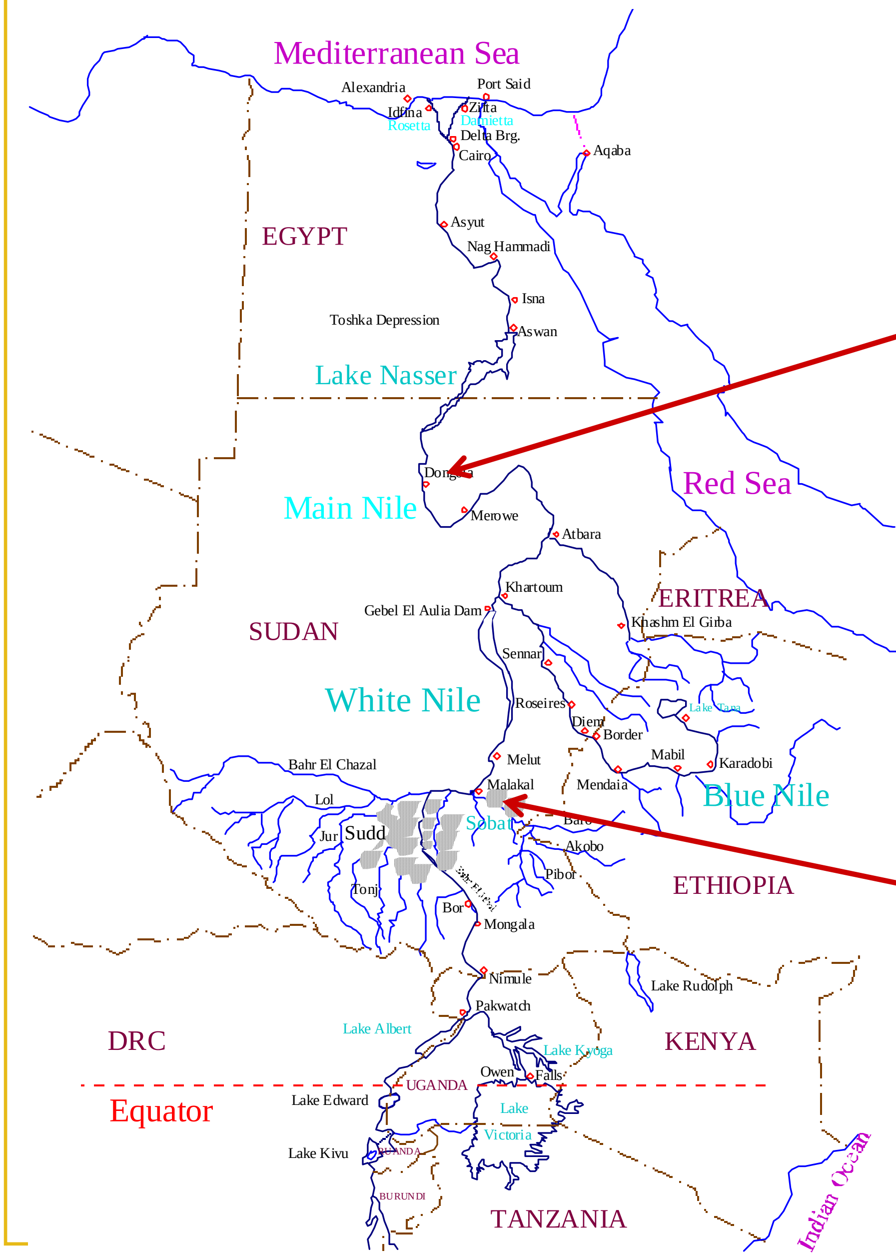
13 Decision Variables

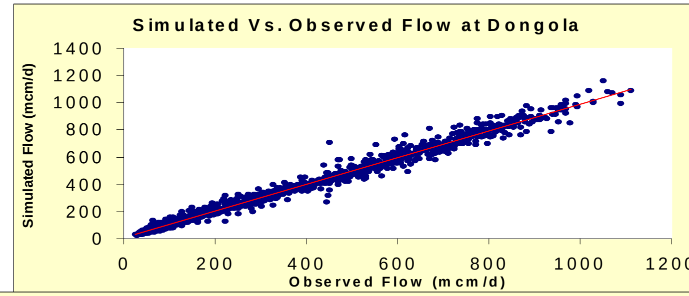
$$
u(k) = \begin{bmatrix}
R_V(k) \\ R_K(k) \\ R_A(k) \\ R_{GA}(k) \\ R_{TA}(k) \\ R_{KA}(k) \\ R_{MA}(k) \\ R_{ME}(k) \\ R_{BO}(k) \\ R_{RO}(k) \\ R_{SE}(k) \\ R_{KG}(k) \\ R_{HAD}(k)
\end{bmatrix},
$$

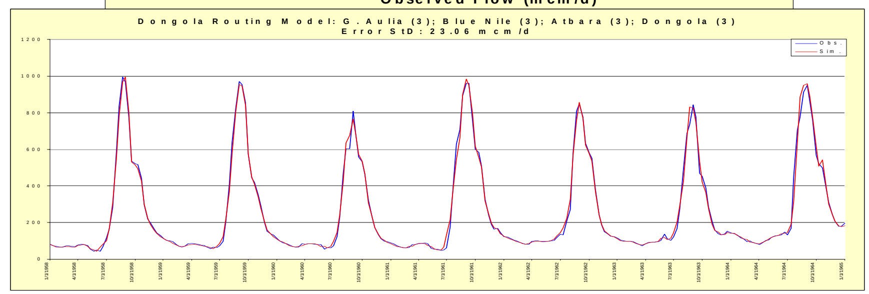
$\xi(k)$

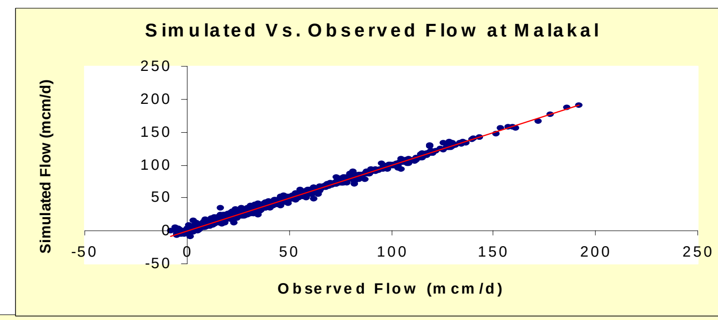
Inflow and Model Uncertainty Sources

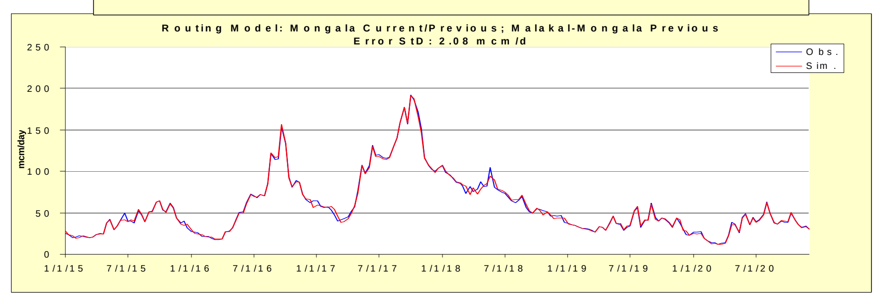
Nile DST: River Routing Models



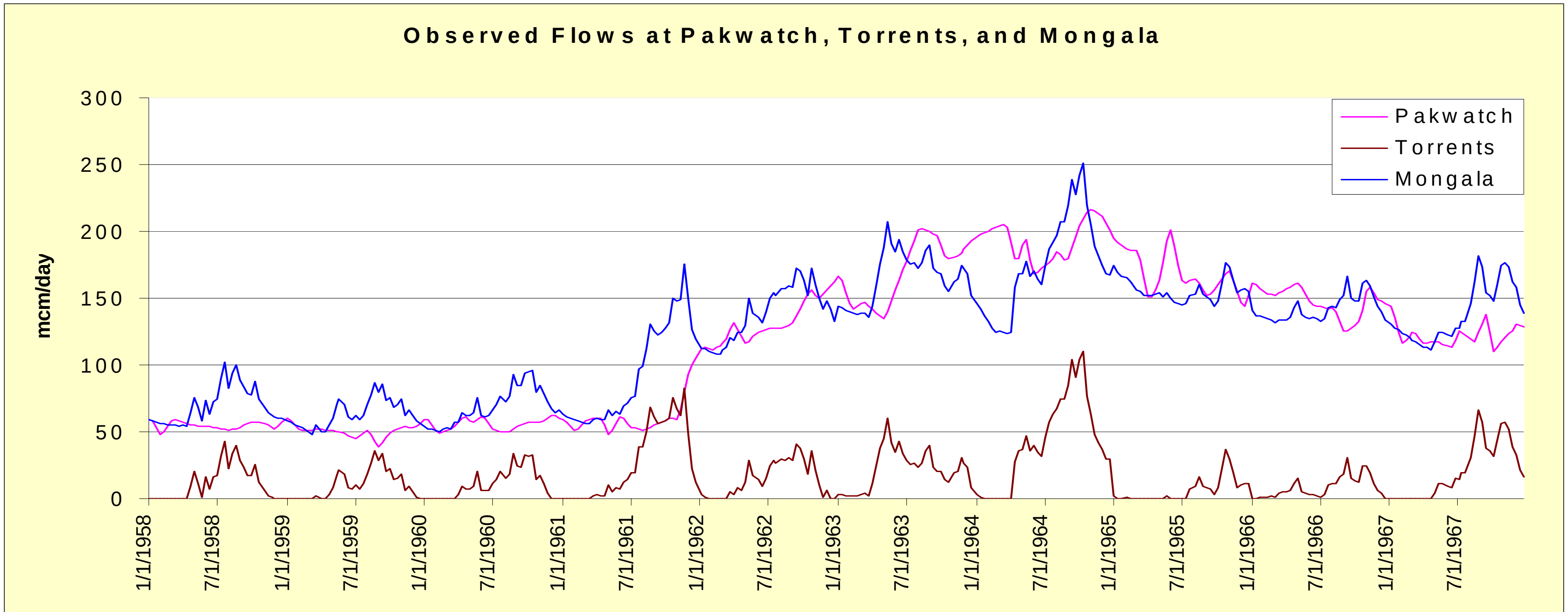


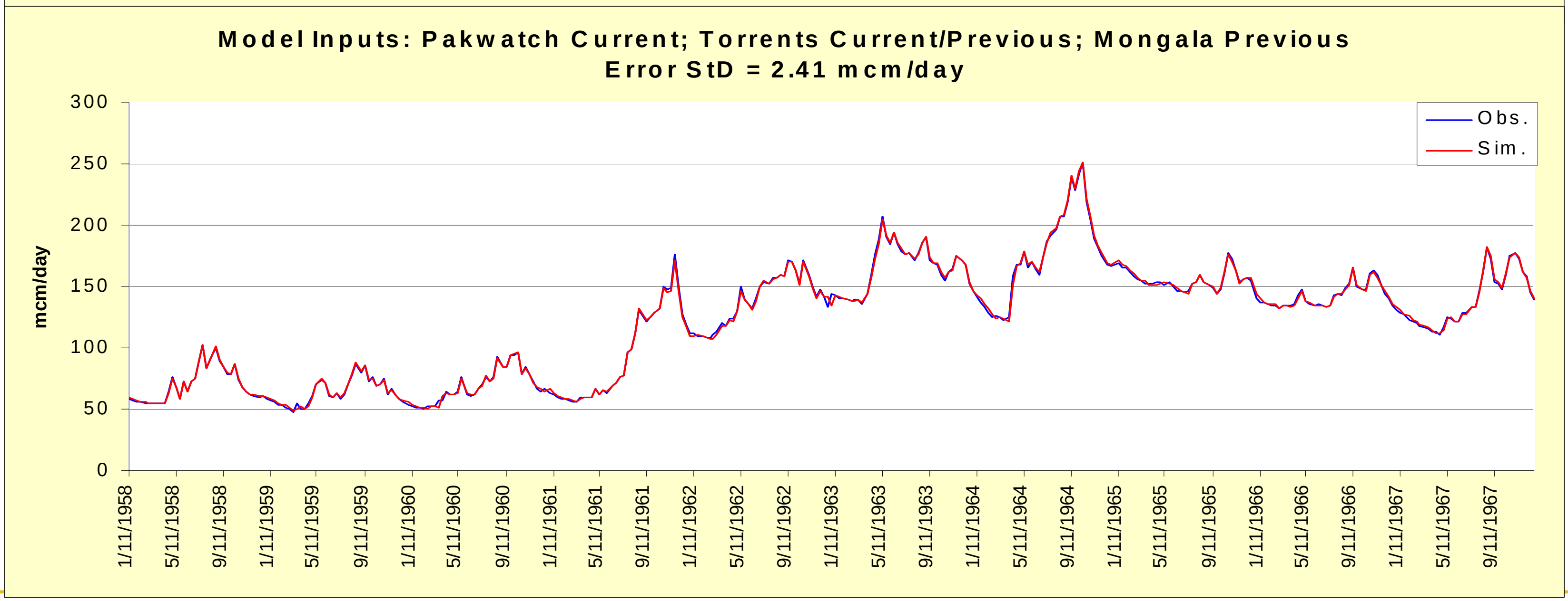






Nile DST: River Routing Models Cont'd





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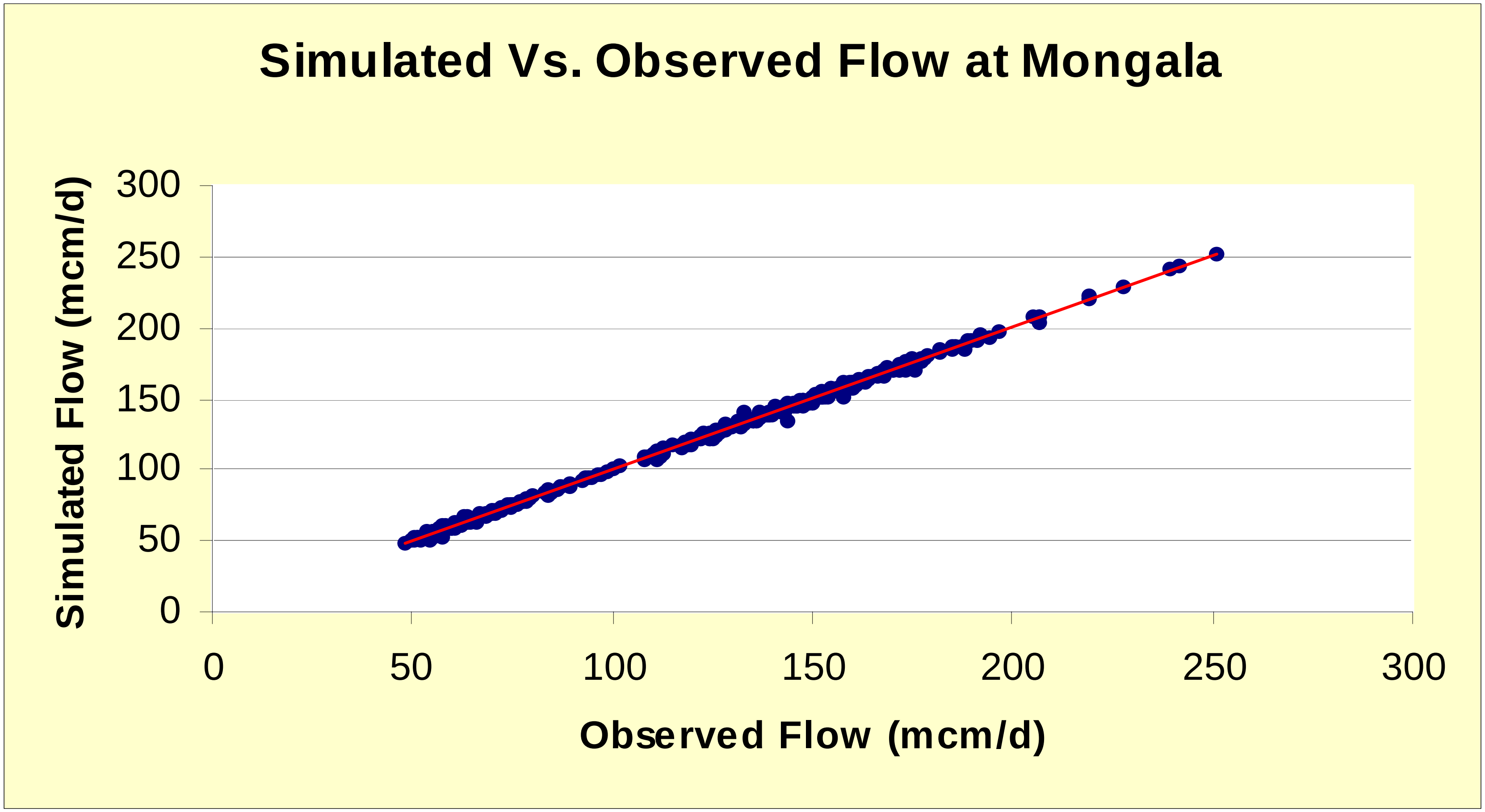

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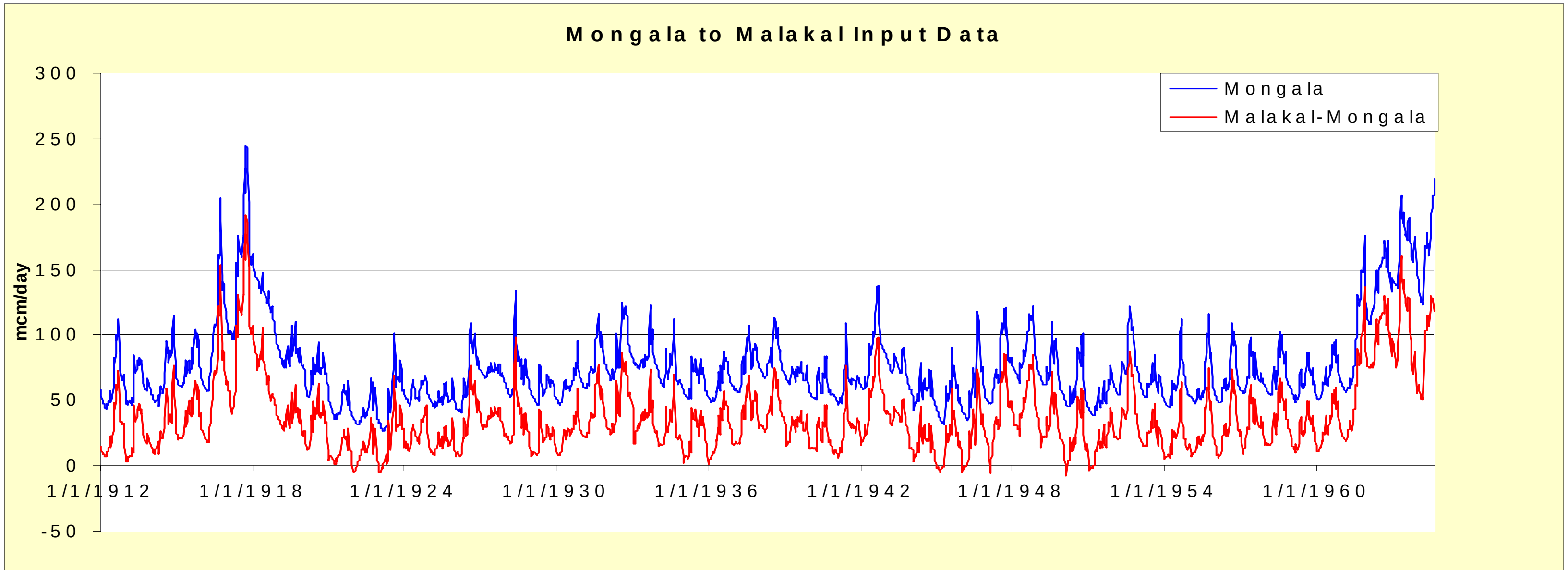

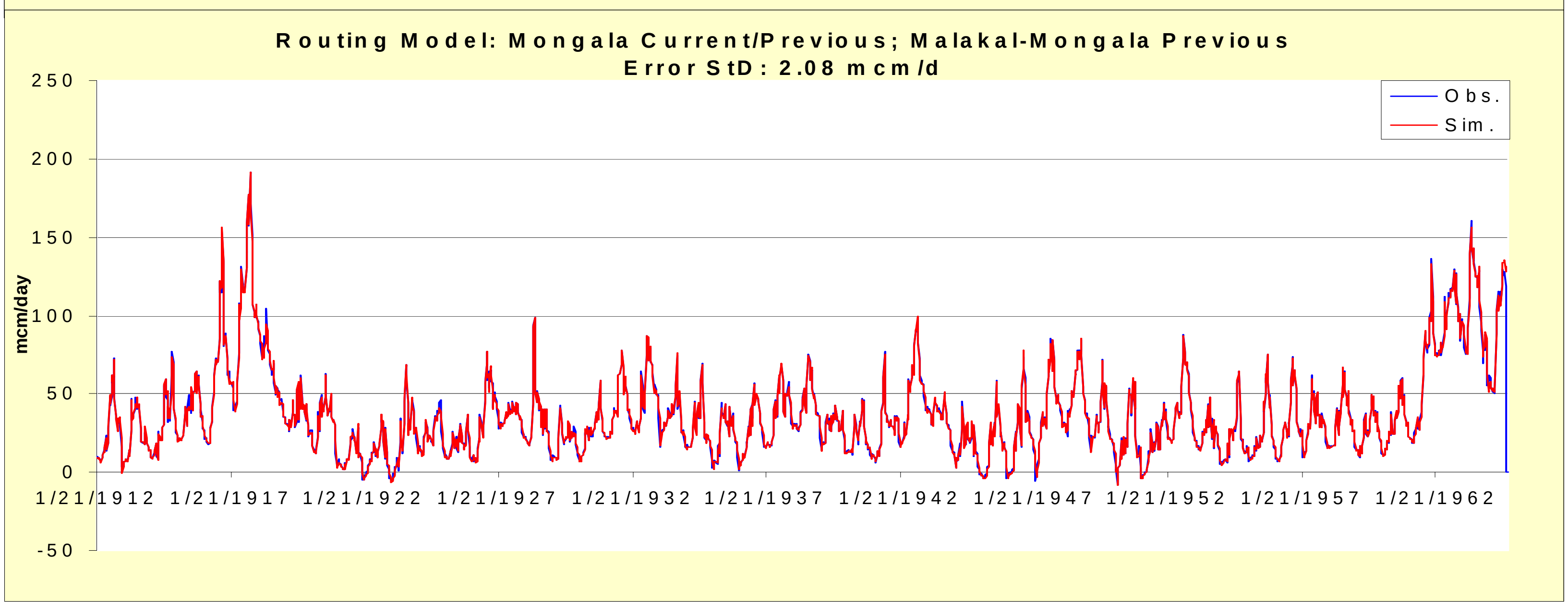

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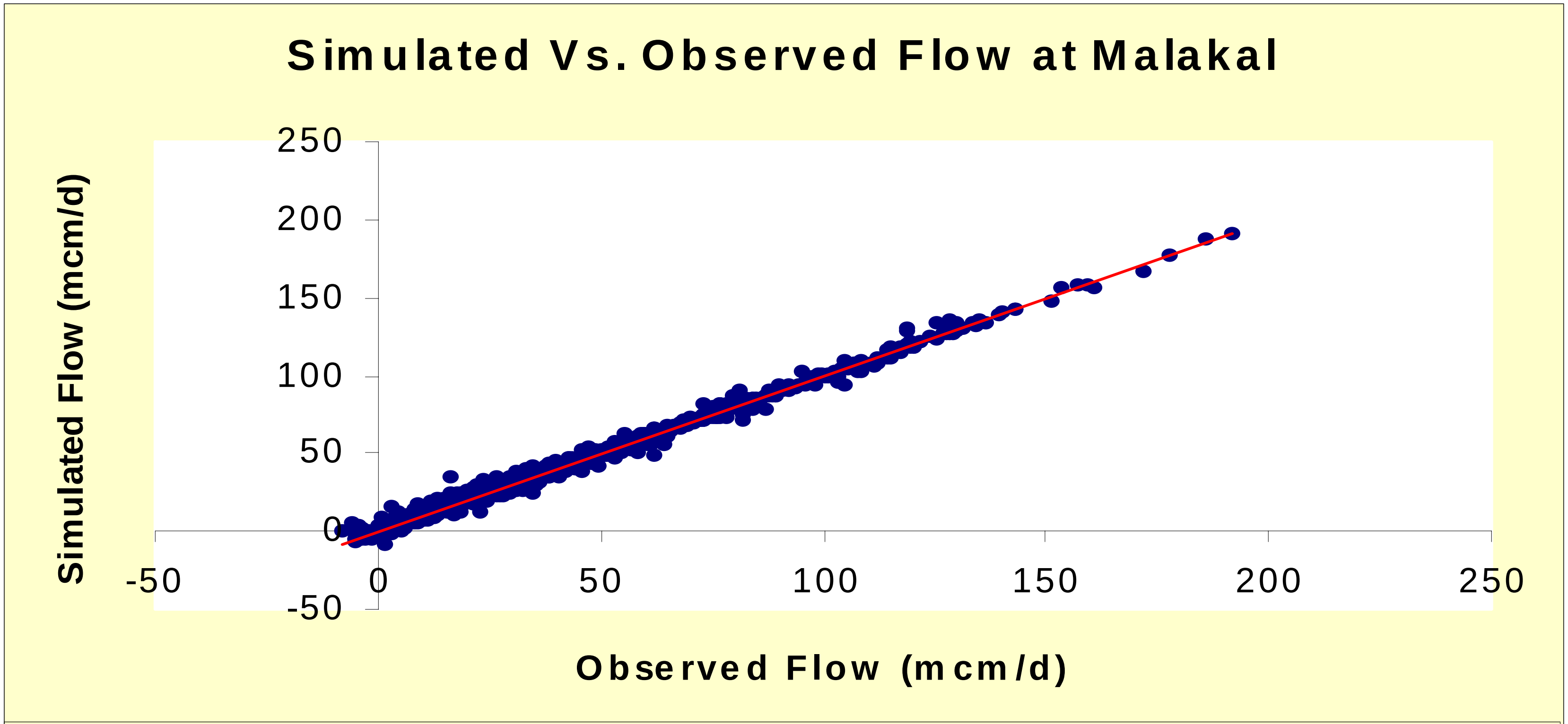

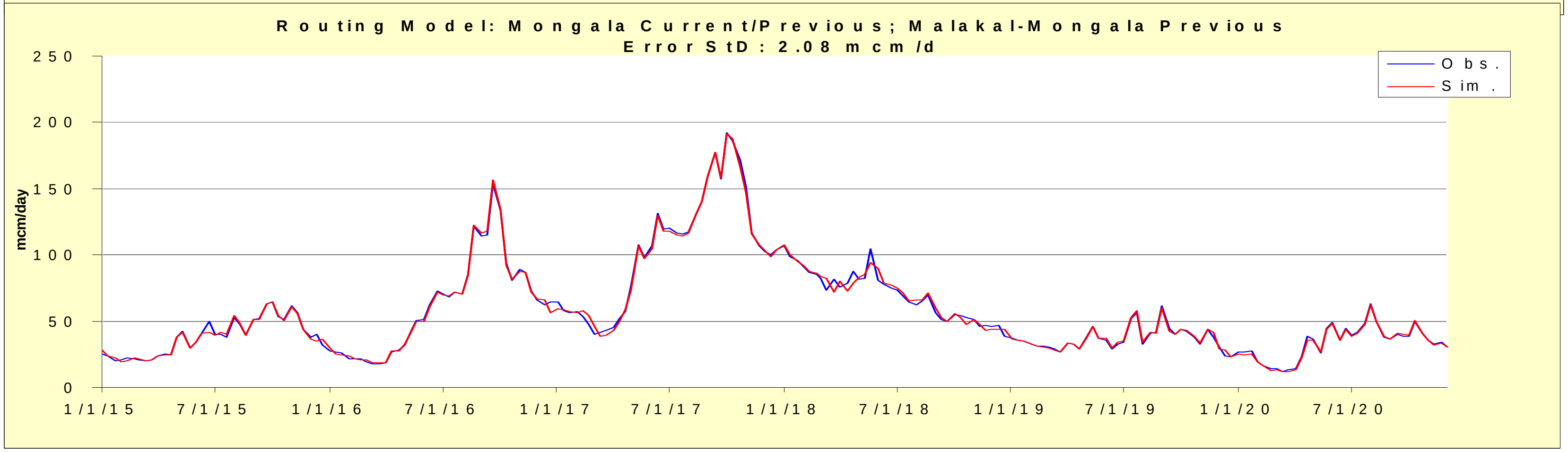

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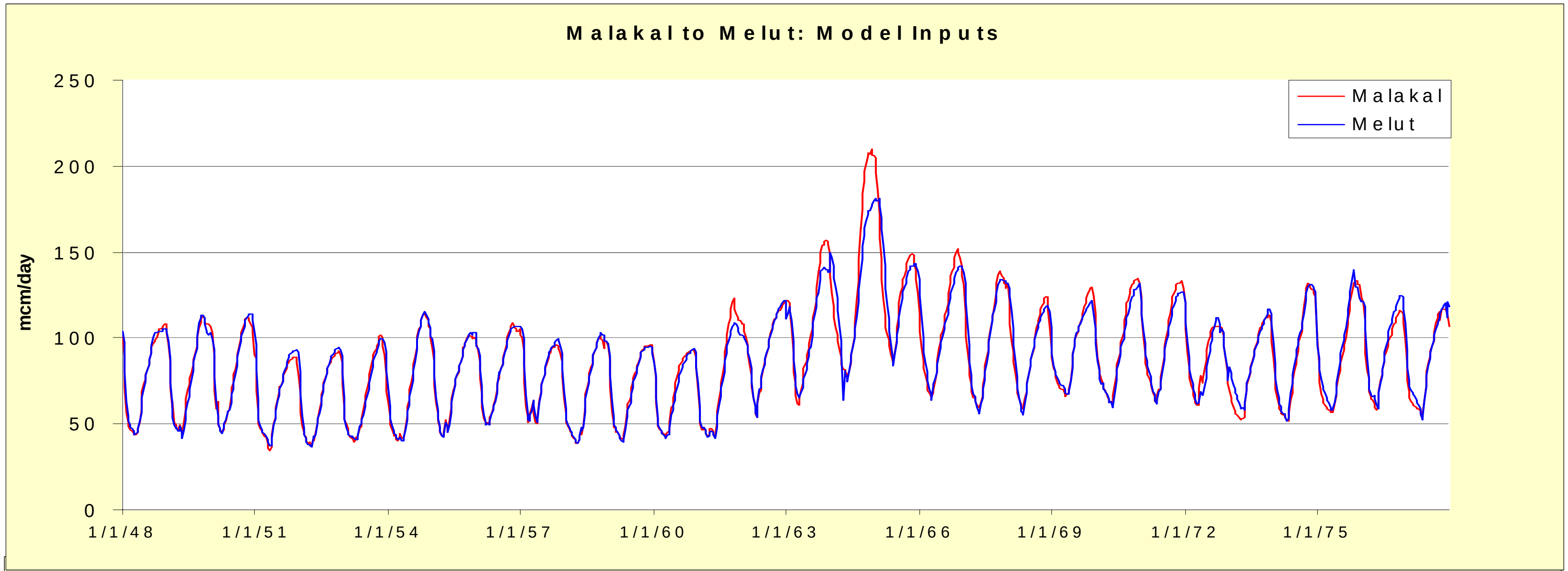
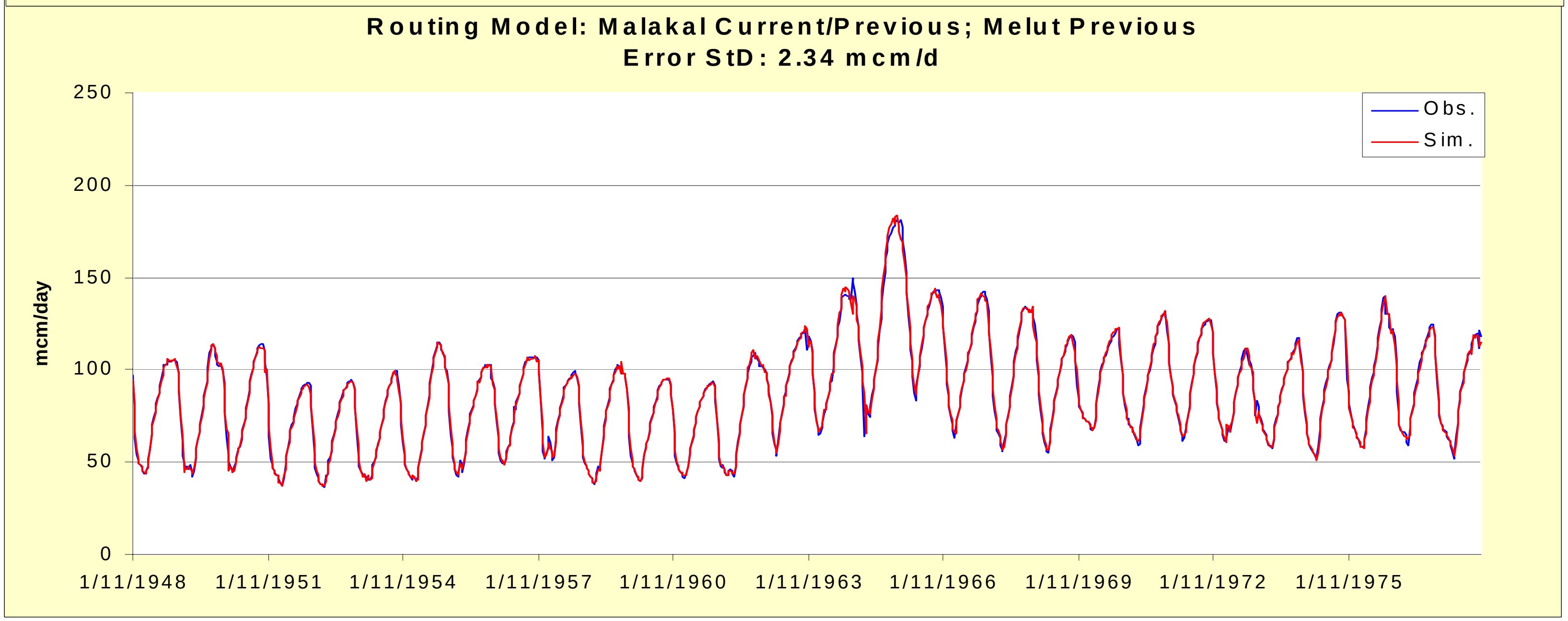
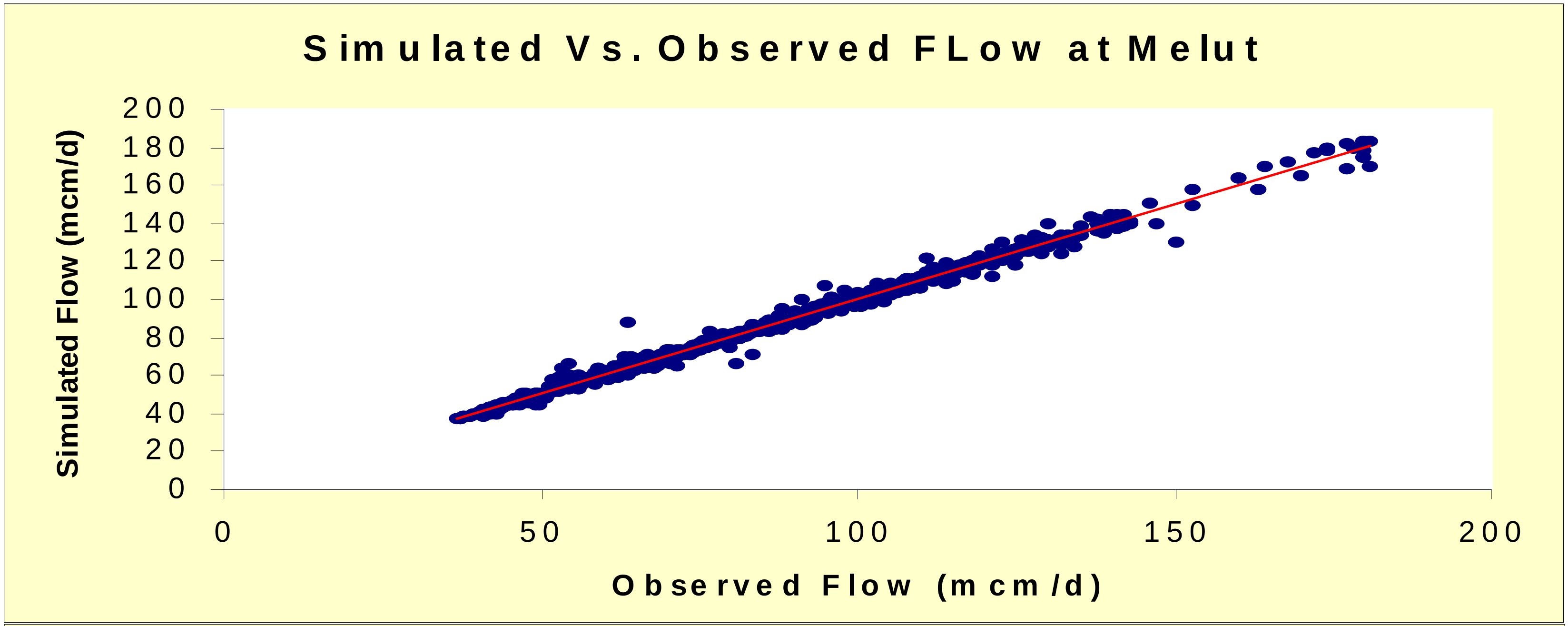
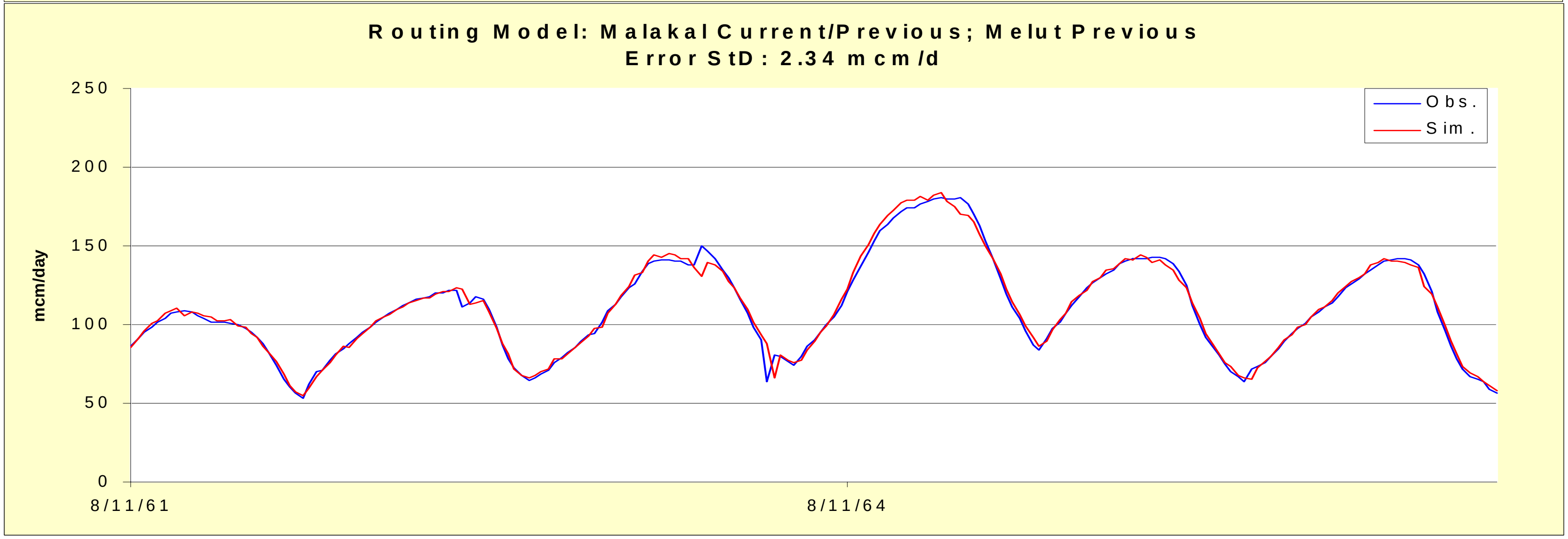
Nile DST: River Routing Models Cont'd





Nile DST: River Routing Models Cont'd





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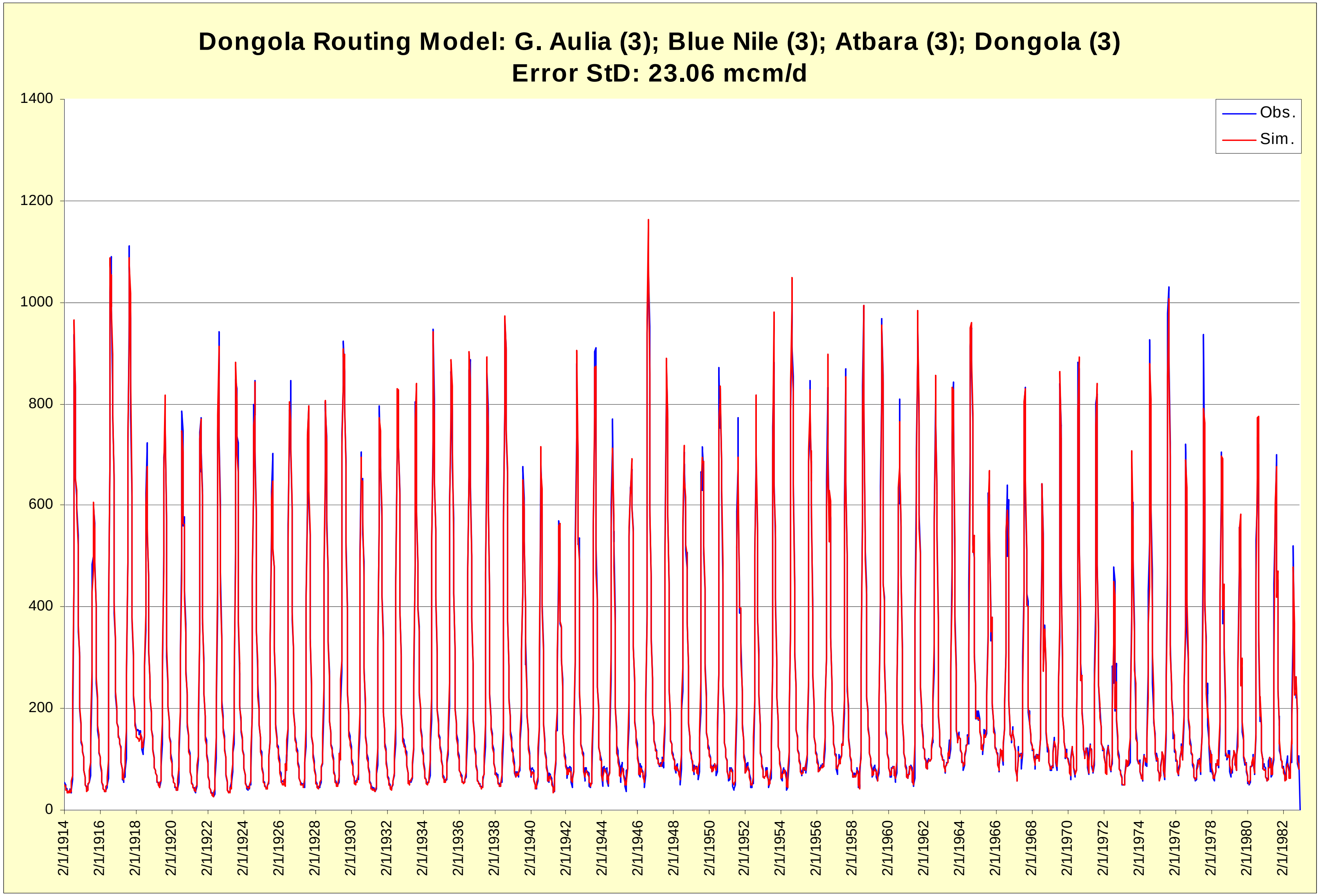
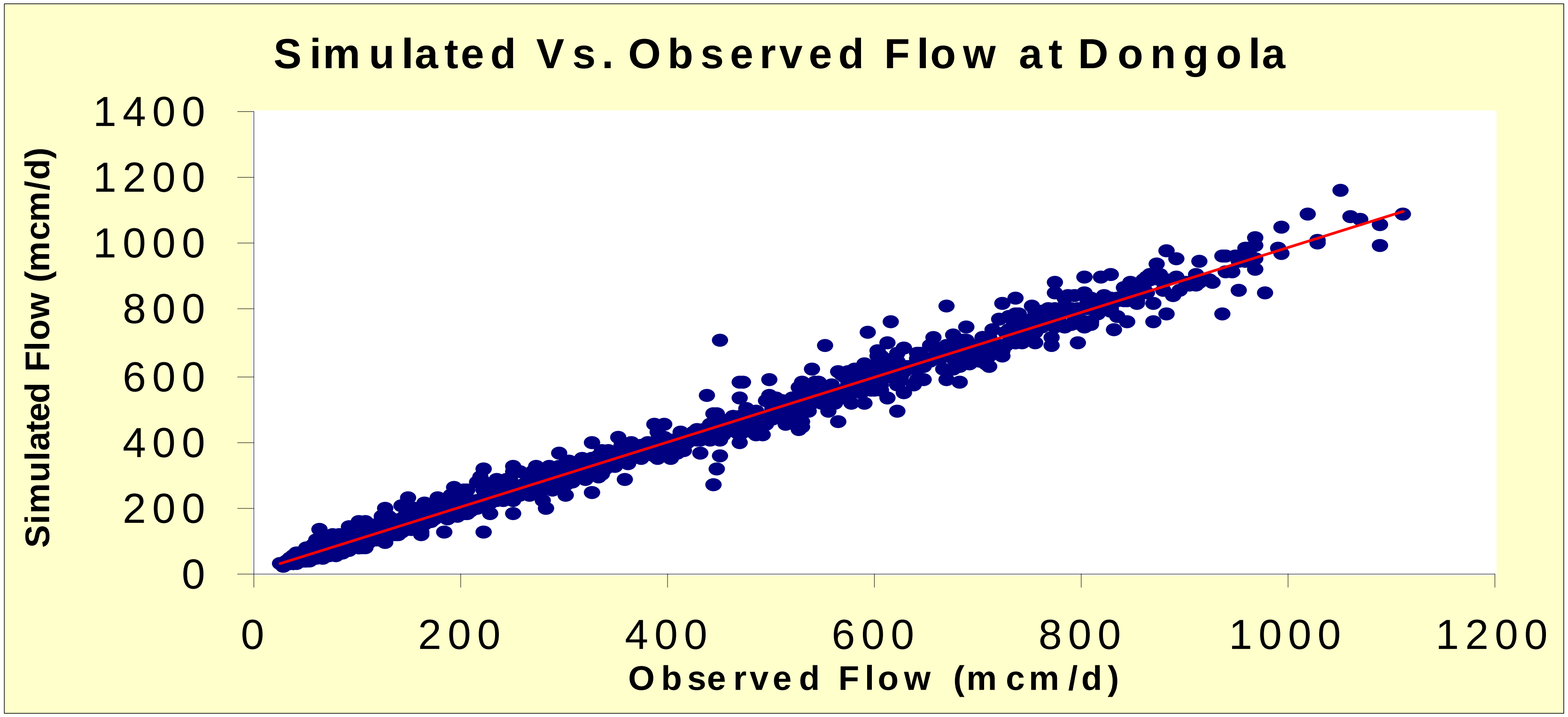


Nile DST: River Routing Models Cont'd



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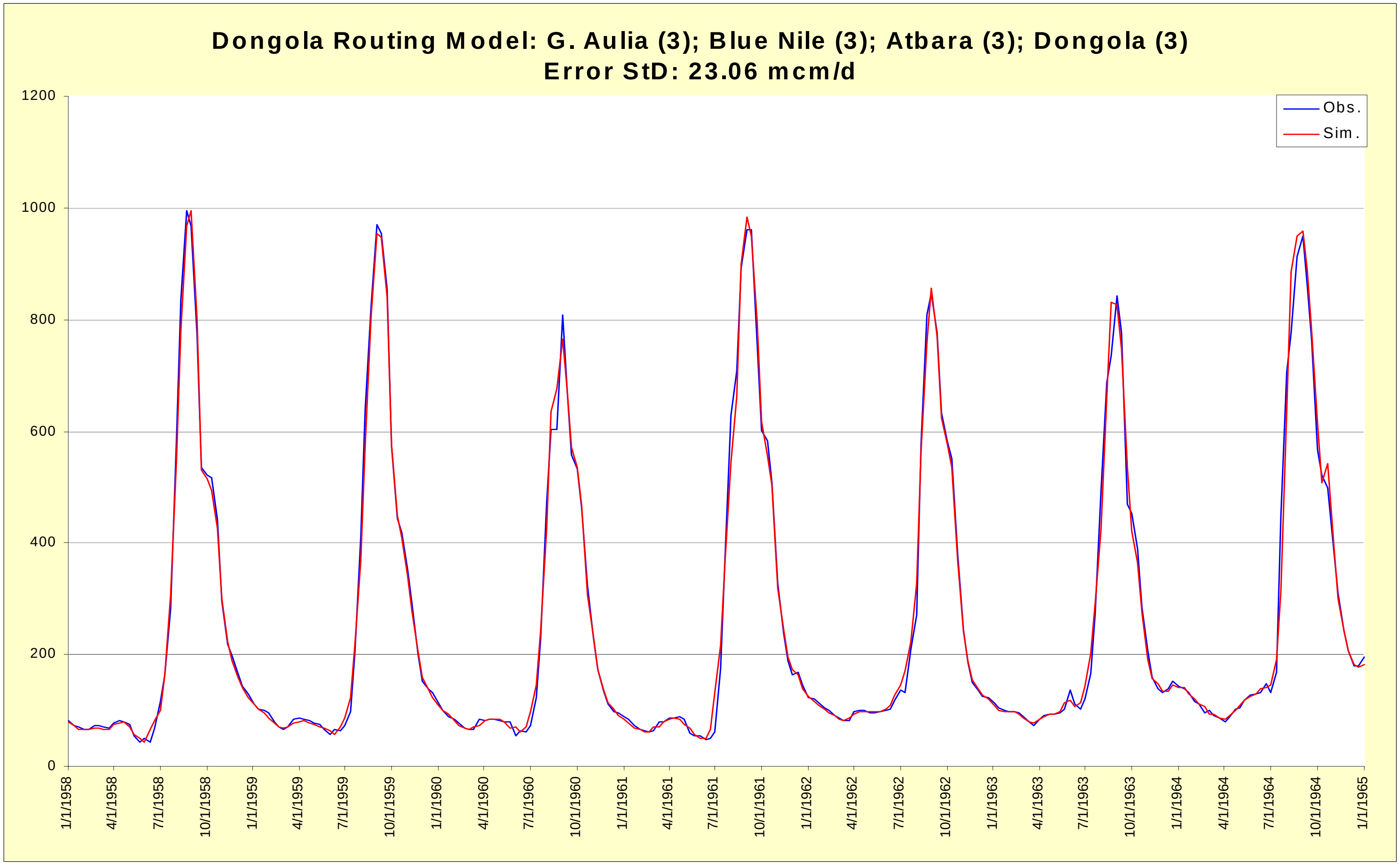
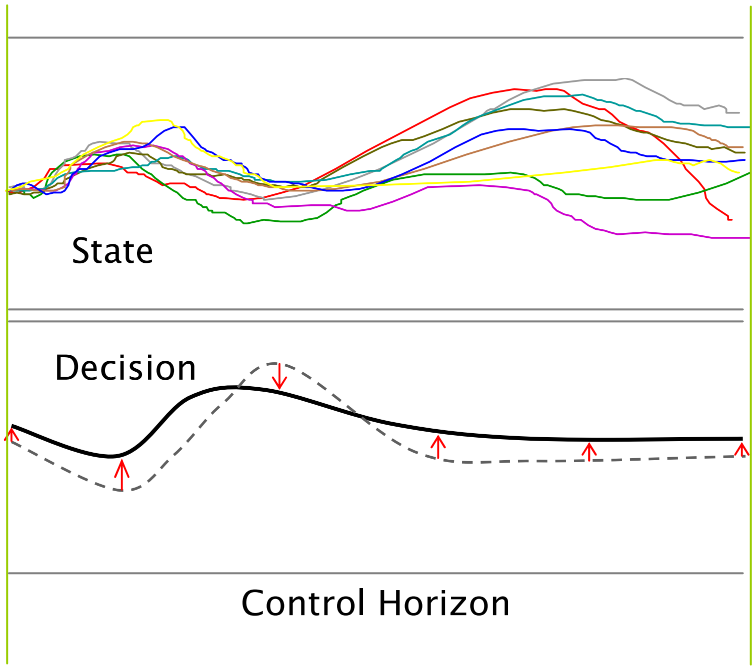
Nile DST: River Routing Models Cont'd



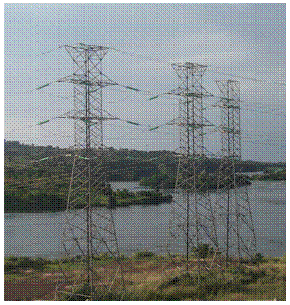
Nile DST: River Basin Management Methods

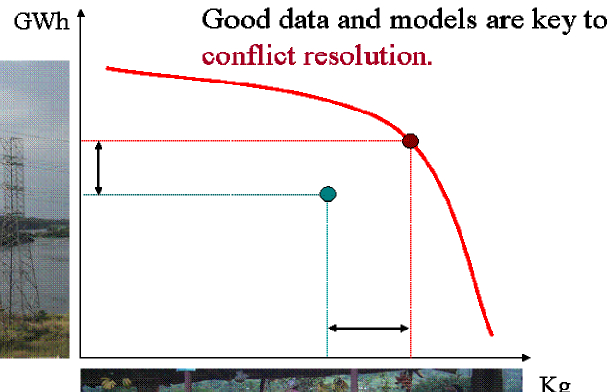
Optimization Algorithm: Extended Linear Quadratic Gaussian Control (ELQG)



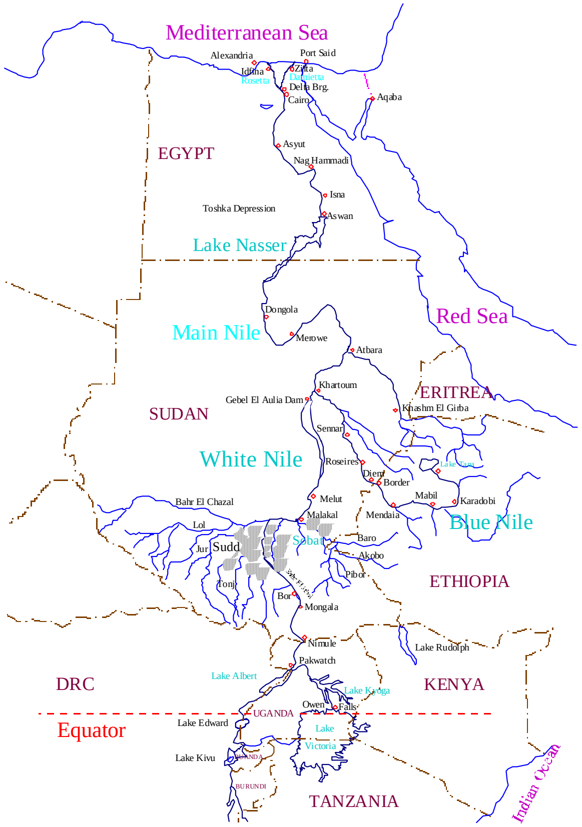
- Sequential, Adaptive (OLFC)
- Trajectory Iteration
- Analytical Optimization Directions (Efficient; No Dimensionality Limitations)
- Decision Constraints: Projected Newton
- State Variable Constraints: Barrier Methods
- Ensemble-based Uncertainty Characterization
- System-wide Uncertainty Management

Tradeoffs: Basin wide → Regional → National
Risk based

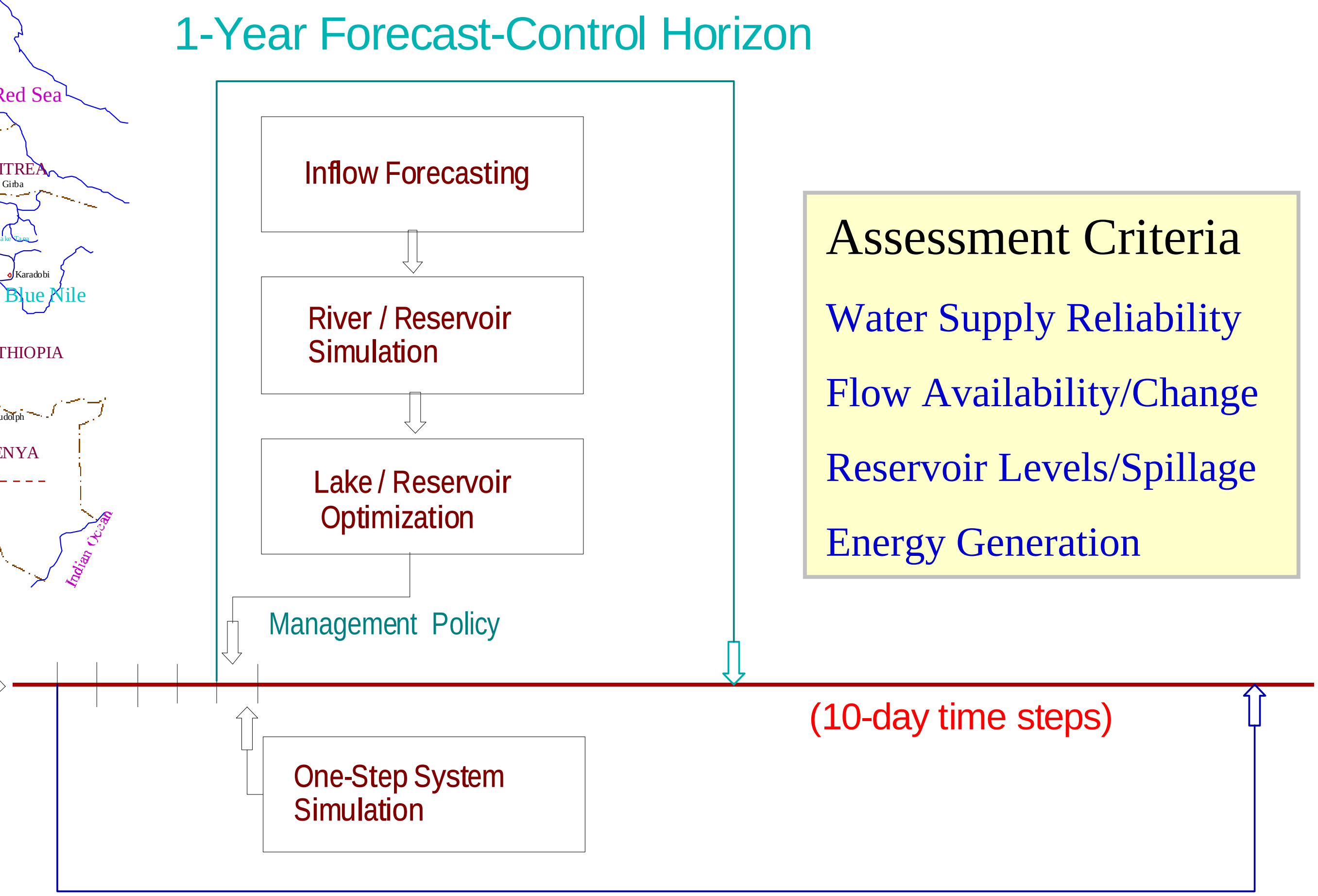




Nile Decision Support Tool (Nile DST):
Scenario Assessment Process



Streamflow Scenario
Irrigation Scenario
On line Reservoirs
Regulation Policies

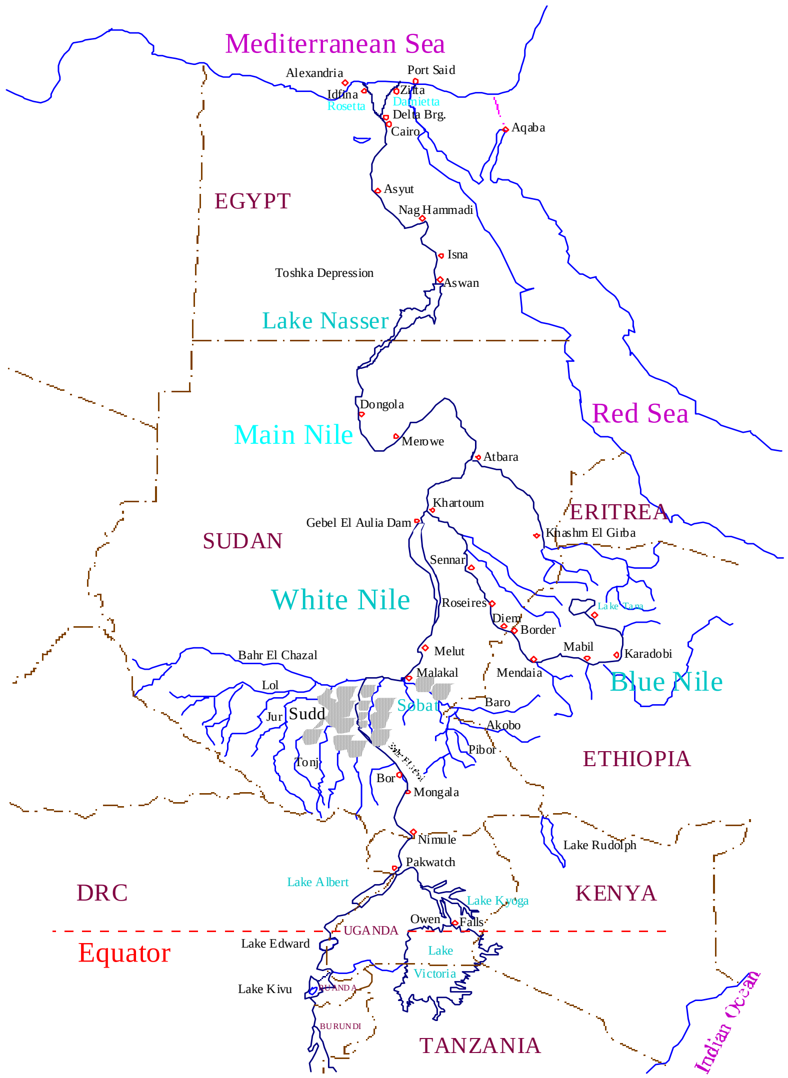


Assessment Criteria

- Water Supply Reliability
- Flow Availability/Change
- Reservoir Levels/Spillage
- Energy Generation

Simulation Horizon (e.g., 1913 to 1977; 65 years)

Nile DST: Scenario Assessment Process cont'd



Scenario Assessment Process

- Determine a **baseline scenario** using current facilities, irrigation demands, and lake/reservoir regulation policies;
- Develop **alternative scenarios** of project facilities, regulation policies, and/or irrigation demands;
- Use Nile DST to **assess the benefits and tradeoffs** of the alternative scenarios versus the baseline scenario for the up/down-stream riparians.

Example Demonstrations

- Eastern Nile

Nile DST: Scenario Assessments

Examples of Basin Development and Management Scenarios

	Current Condition	Full Development in Eastern Nile (Ethiopia/Sudan)	Full Development in Southern Nile (Wetland Projects + Eq. Lake Regulation)	Basin wide Management
Scenario I	Yes			
Scenario II	Yes	Yes		
Scenario III	Yes		Yes	
Scenario IV	Yes	Yes	Yes	Yes

Wetland Projects imply a 12 bcm annual increased yield, 4.75 bcm of which is attributed to the Machar Marshes and Ghazal projects, and the rest to Jonglei.
Full Development in Ethiopia includes projects at Lake Tana, Karadobi, Mabil, Mendaia, and Border.

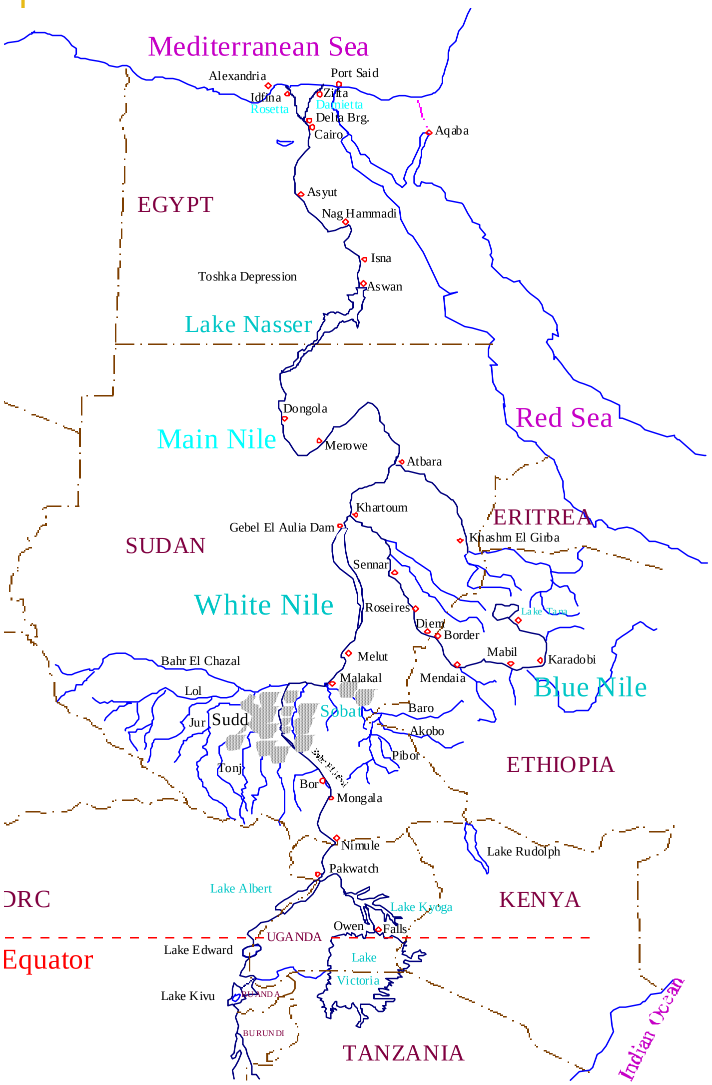
Examples of Water Withdrawal Scenarios (Billion Cubic Meters per Year)

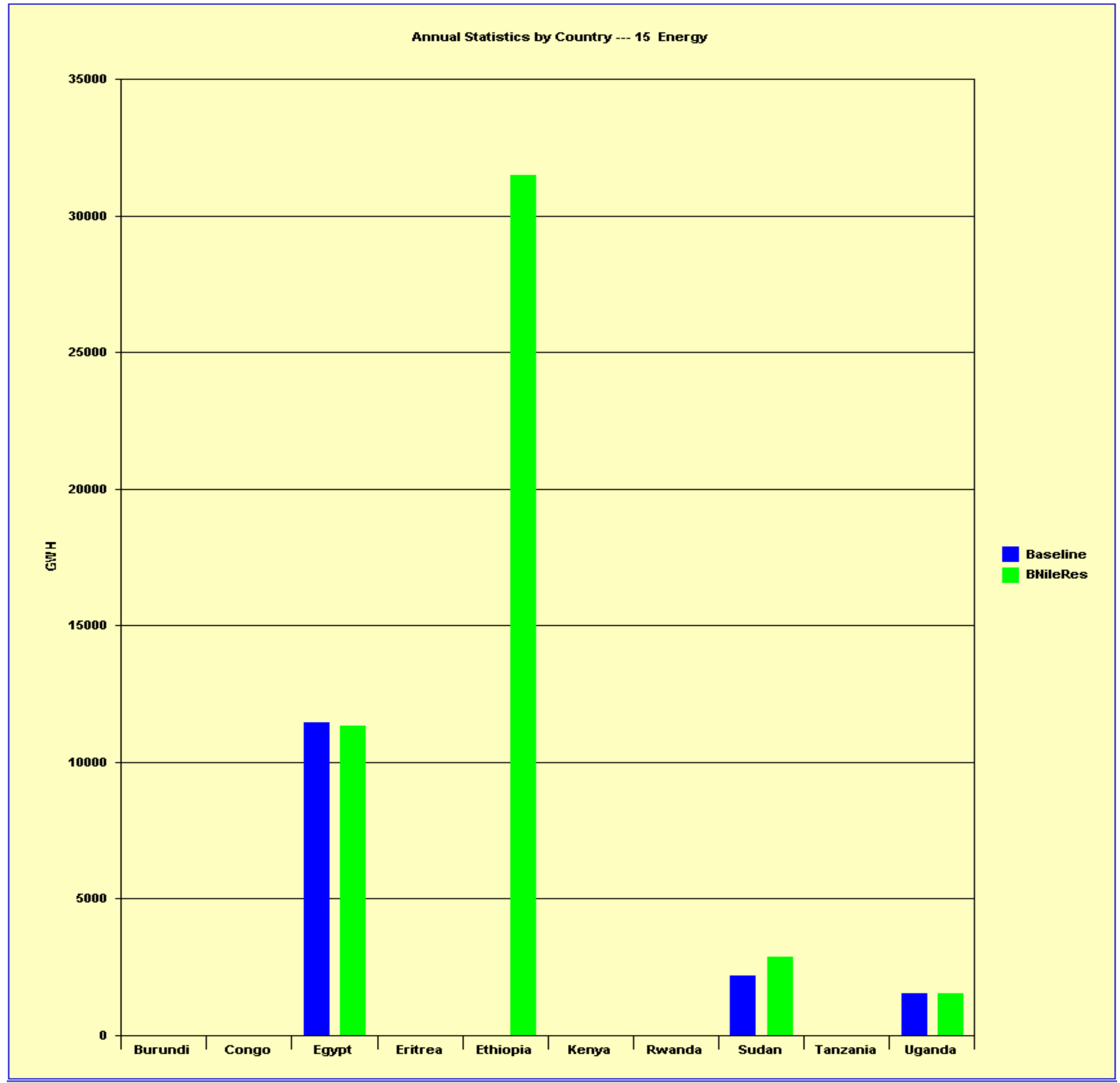
	Eq. Lake Region	Sudan	Ethiopia/Eritrea	Egypt
Current Condition	0	18.5	0	55.5
Low Demand Increase	2.5	21	5-15	58
High Demand Increase	5	23.5	15-35	60.5

Nile DST: Eastern Nile Case Study

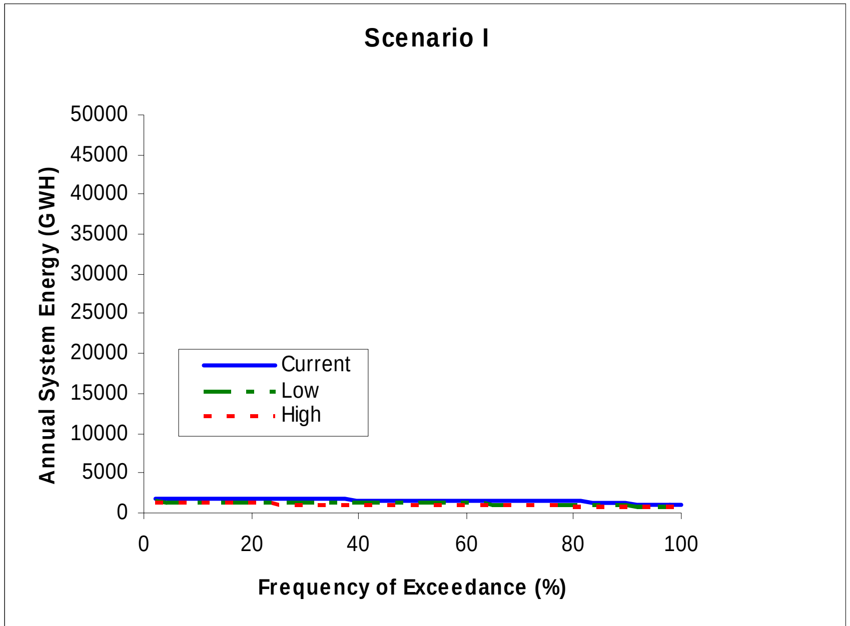
Ethiopian Hydropower Development

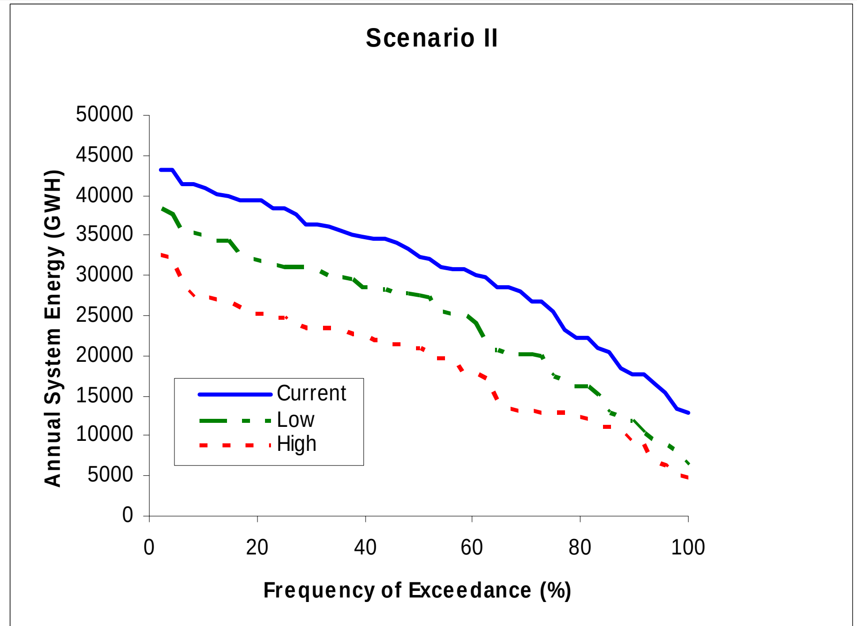
(Tana, Karadobi, Mabil, Mendaya, Border)

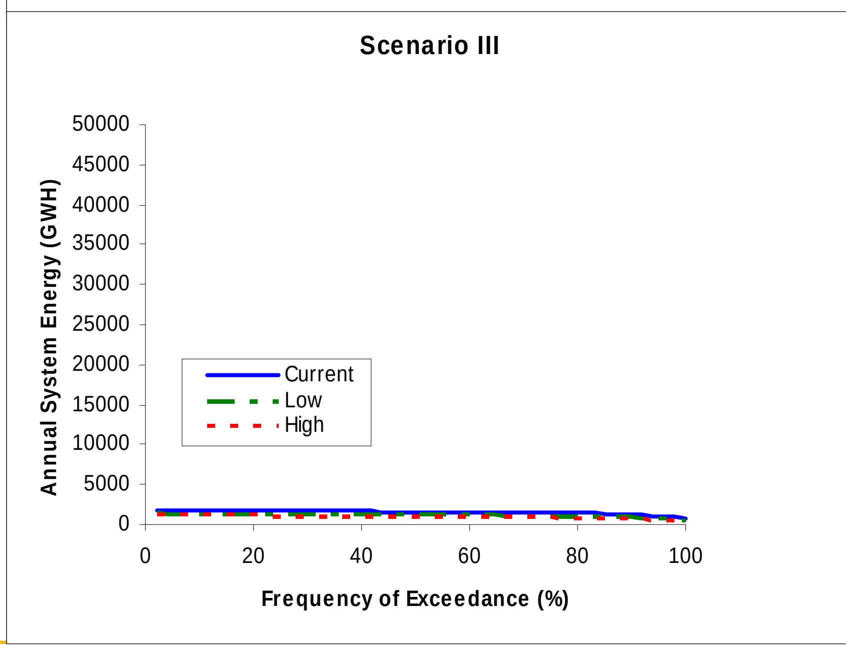


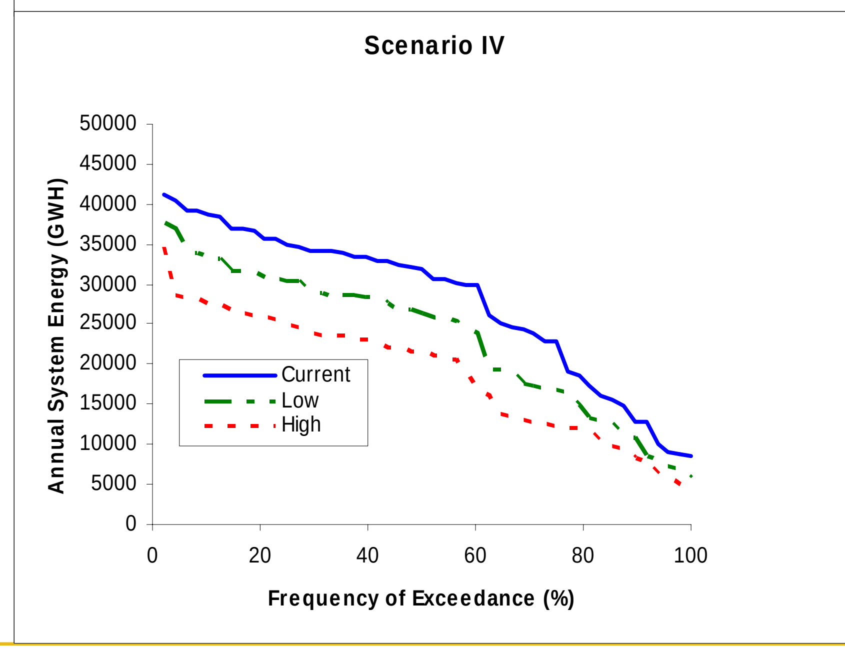


Nile DST: Eastern Nile Case Study
Hydropower Generation Frequency Curves



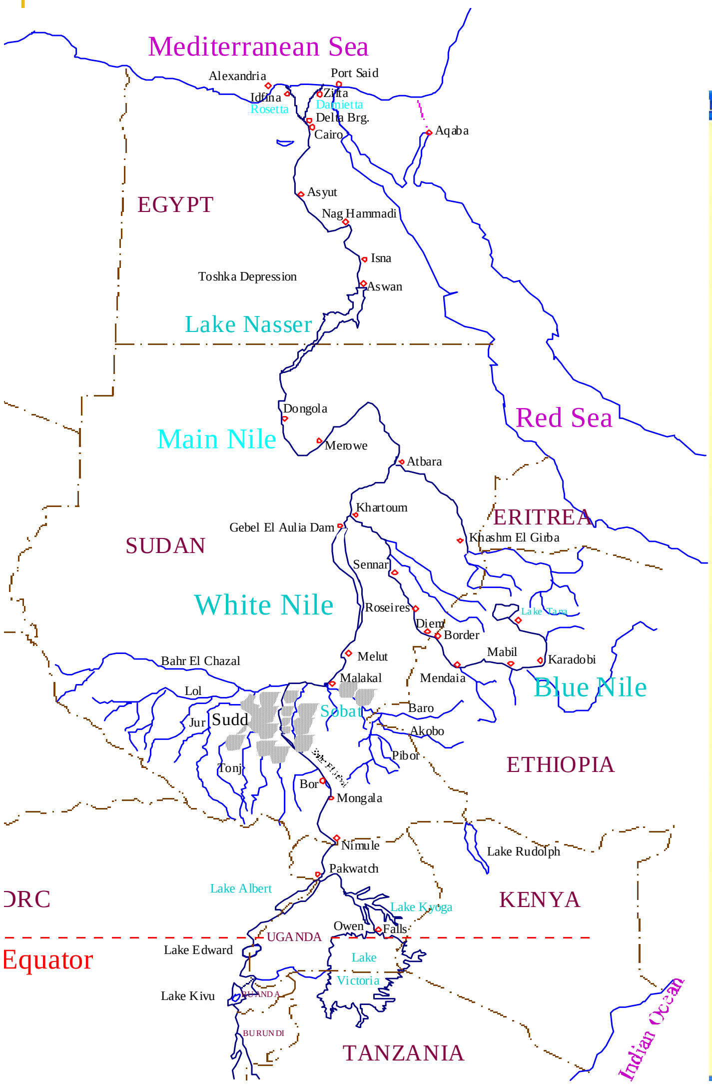


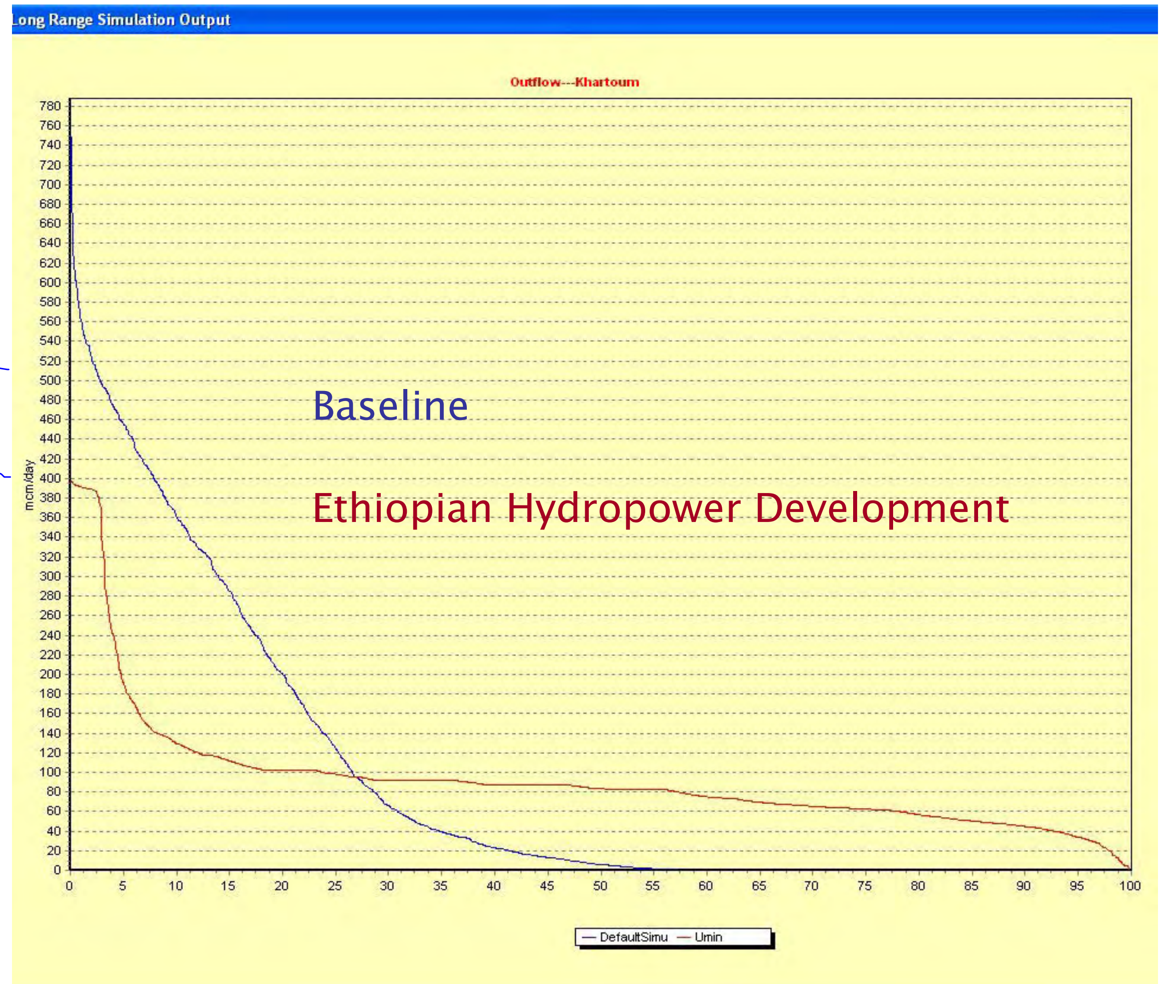




Nile DST: Eastern Nile Case Study

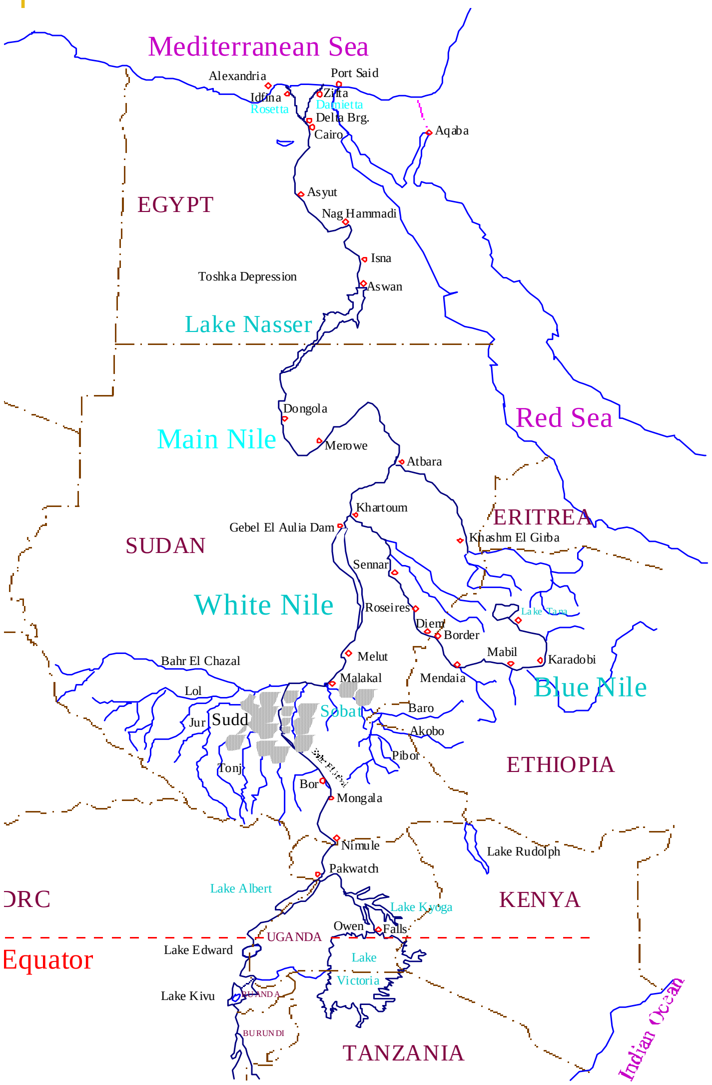
Eastern Nile Tradeoffs: Flow at Khartoum

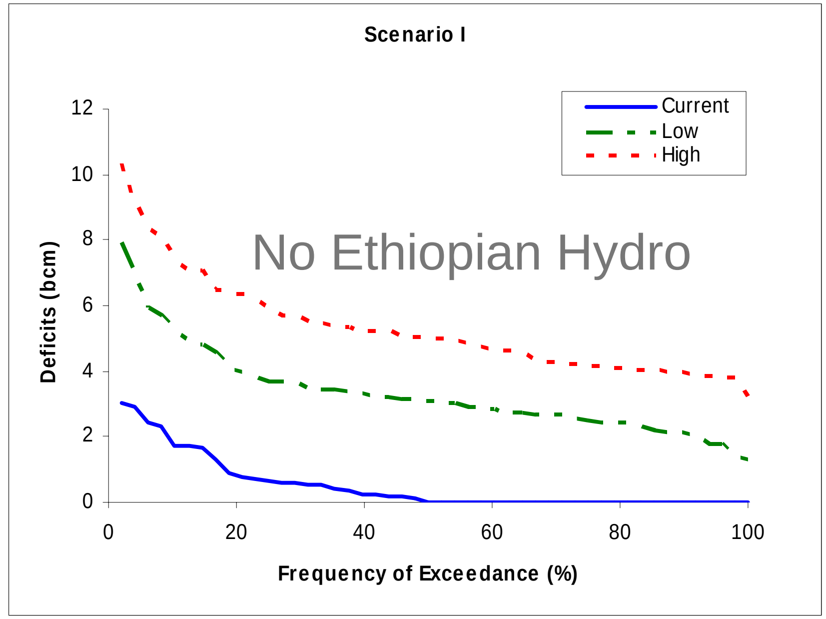


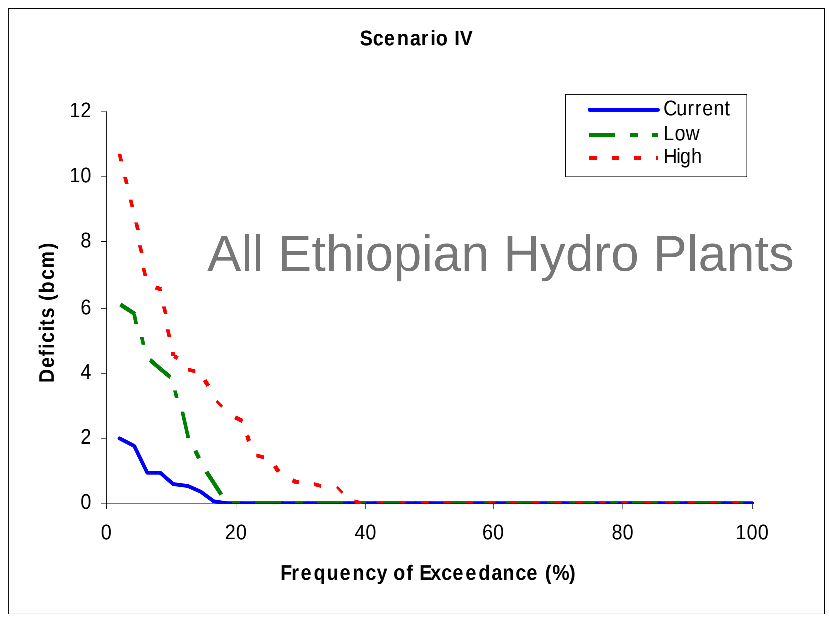


Nile DST: Eastern Nile Case Study

Eastern Nile Tradeoffs: Sudan Water Supply

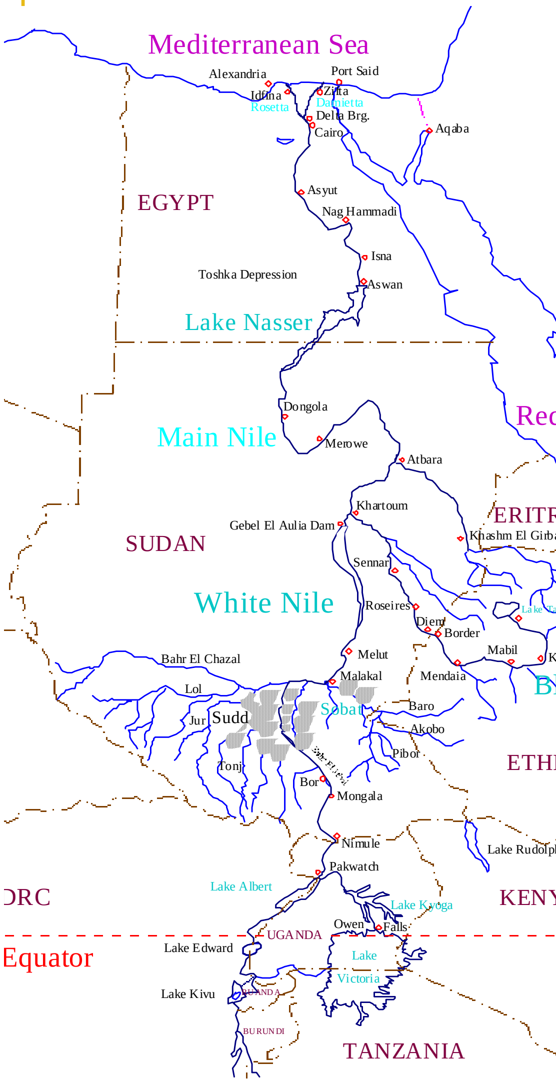






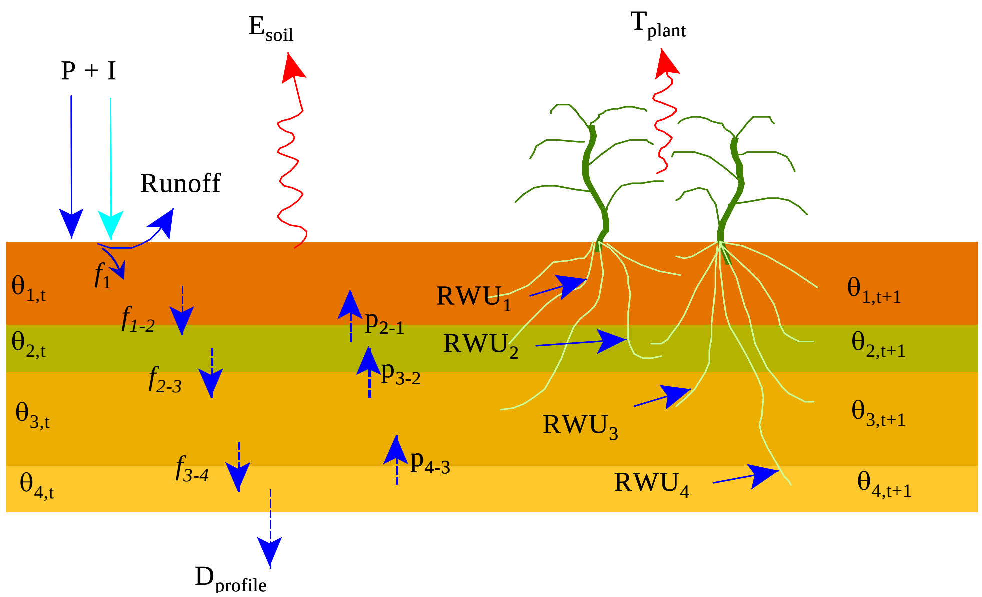
Nile DST: Eastern Nile Case Study

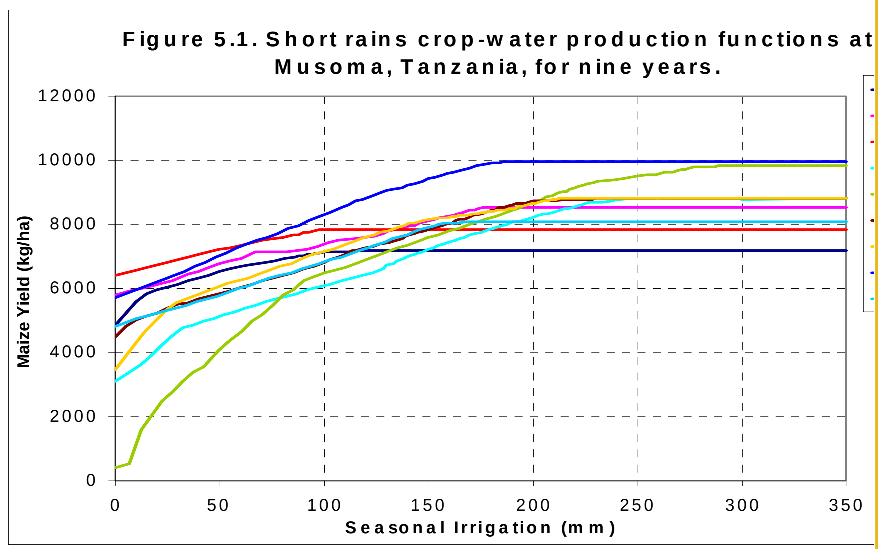
Eastern Nile Tradeoffs: Downstream Impacts



Nile DST: Agricultural Planning

- Data
  - Hydro-meteorological; Soils; Land use; Crop; GIS integrated
- Models
  - Crop growth models for 11 crops; Irrigation optimization
- Applications
  - Crop water production functions;
  - Irrigation requirements and scheduling;
  - Vulnerability to droughts (climate variability)





GWRI
Georgia Institute of Technology
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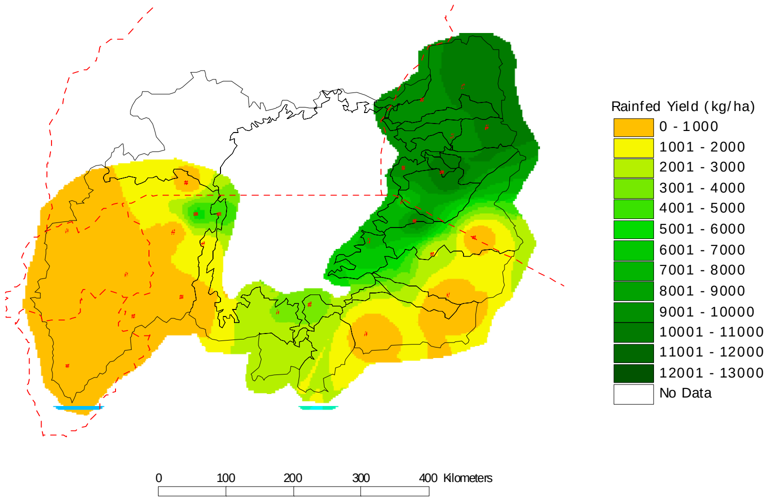
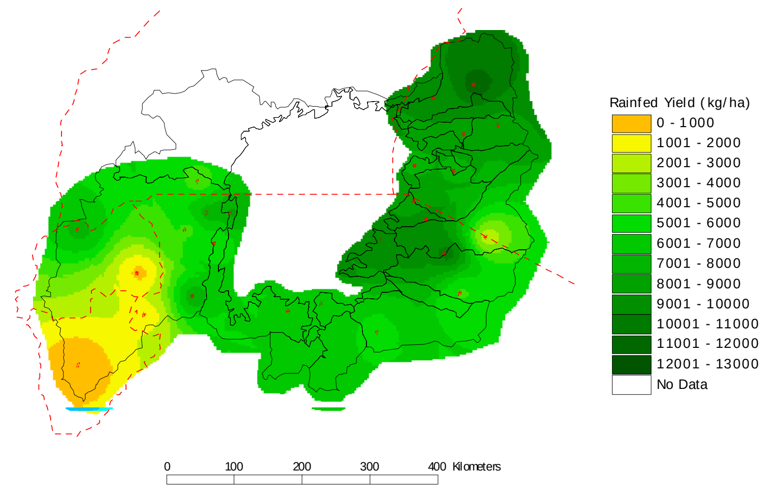
Nile DST: Agricultural Planning
Southern Nile Tradeoffs: Food Production & Water Sharing

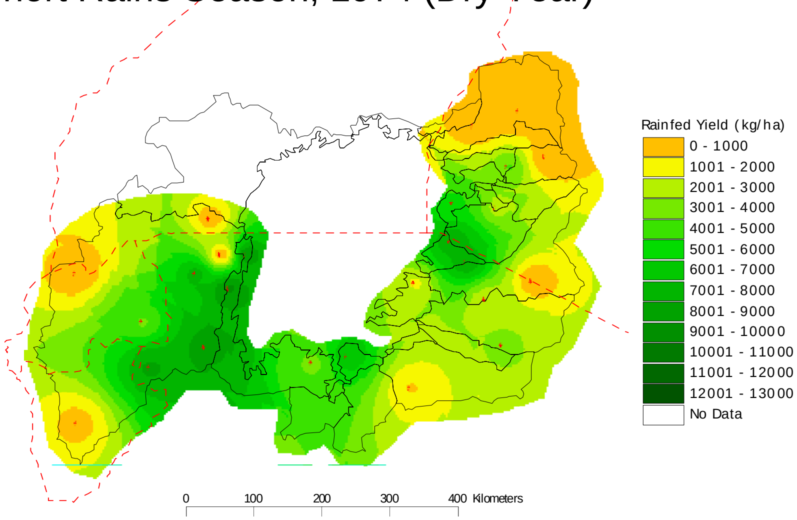
Long Rains Season; 1984 (Dry Year)



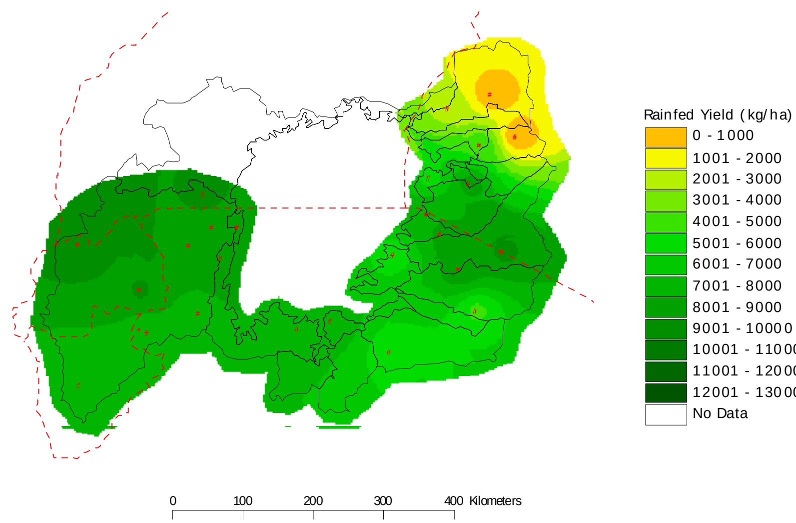
Long Rains Season; 1985 (Wet Year)



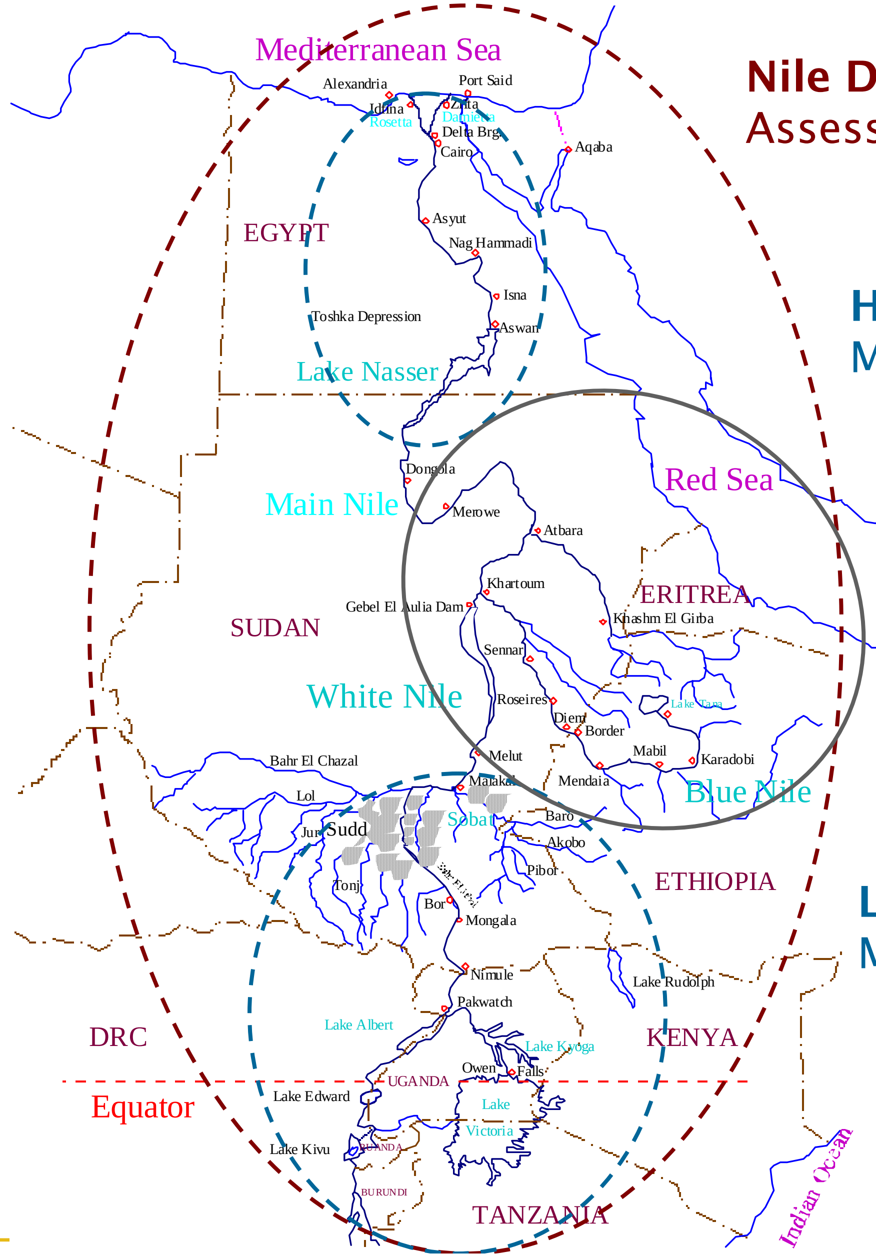
Short Rains Season; 1974 (Dry Year)



Short Rains Season; 1972 (Wet Year)



Nile Operational Management: Further Needs—Eastern Nile



Nile DST: Basin wide Planning and Assessment

HAD DSS: HAD Operational Management

Blue Nile DSS: Blue Nile, Sobat, Atbara Operational Management

Remote Sensing; Hydrology; River Hydraulics; Reservoir Mgt., etc.

LV DST: Lake Victoria Operational Management

Africa Water Institute for Education and Applied Research (AWARE)

- University **Consortium** (Georgia Tech, Un. Pretoria, …
  Cairo, Khartoum, Addis Ababa, Nairobi, Makarere, Dar es Salaam,…);
- **Distance and traditional learning** approach;
- Interdisciplinary **Graduate and Professional** Education, Research, and Tech Transfer.

Climatology;

Meteorology;

Hydrology;

Remote Sensing;

River Hydraulics;

Power Systems;

Water Resources Systems;

Agricultural Planning;

Water Quality;

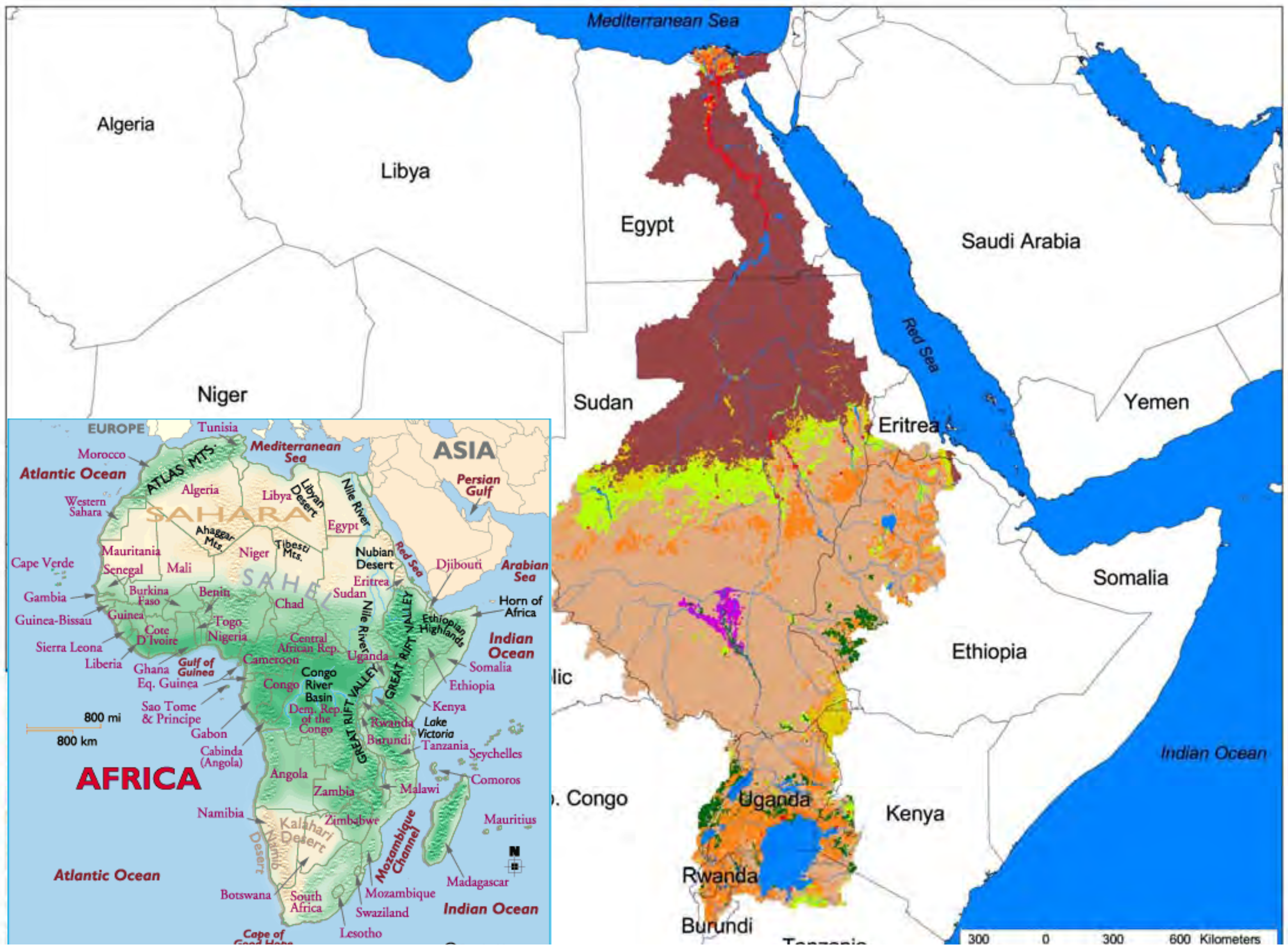
Public Health;

Socio-economics;

Conflict Resolution;

Information Technol.;

…



AWARE Dual Masters Program

Application Requirements

Applications to both GT and UP under the AWARE Program; Applications shall be submitted online at the GT and UP websites:

GT: http://www.gradadmiss.gatech.edu/apply/

UP: http://www.up.ac.za/up/web/en/student/undergraduate/admission/

Admission Requirements

To enroll in the AWARE Dual Masters program, students must be admitted by both GT and UP. A summary of the admission requirements is provided next:

- B.S. Civil Engineering degree or 4-yr science degree;
- Undergraduate grade point average of 3.0 out of 4.0 (75%); or subject to faculty approval;
- GRE of 700 (Quantitative), 400 (Verbal), and 3.5 (A); or subject to faculty approval;
- TOEFL (for students whose native language is not English) of 79 (computer based) or 550 (paper based);

The following student categories are eligible for admission to the Dual GT-UP Masters Degree Program:

- Students who are citizens of any African country;
- US and international students enrolled at the main Georgia Tech campus in Atlanta, Georgia, US;
- Students who are not African citizens but have received an undergraduate degree at UP..

Degree Requirements

Successful completion of (i) a minimum of eight semester courses, and (ii) a Thesis;
Under GT and UP regulations, courses counting toward other degrees cannot count toward the Dual GT-UP Masters Program; The Thesis is to be supervised and approved by GT and UP faculty;

Upon successful completion of the above-stated requirements, the students will receive two Masters Degrees, one from GT and a second from UP; Students with a B.S. in Civil Engineering will receive a Masters Degree designated “Masters of Science in Civil Engineering, International Georgia Tech-University of Pretoria Water Institute Program”; Students without a B.S. in Civil Engineering will receive a degree designated “Masters of Science, International Georgia Tech-University of Pretoria Water Institute Program”; These designations shall apply to both GT and UP Masters Degrees;

MSc. program length: ~ 2 years.

AWARE Dual Masters Program cont'd

Other Program Operating Procedures

The courses of the Dual GT-UP Masters Program will be offered at the University of Pretoria Campus in Pretoria, South Africa;

Course content shall be jointly developed and/or co-taught by GT and UP faculty, and students shall be advised by Academic Advisory Committees of GT and UP faculty;

GT faculty will be teaching at UP from May 15 to August 15. In the event that a particular course cannot be offered by GT faculty on-site, the course will be delivered at UP through distance learning (from GT Loraine or other GT campuses);

For the first two years, the academic program shall include one general track. More courses and tracks will be added in subsequent years, depending on student interest and funding levels.

Tuition and Fees

For 2007-2008, full time tuition and fees of the Dual GT-UP Masters Program shall tentatively amount to 6,000 US dollars (~39,000 Rand) per academic semester (see Section 6.2 for explanation of this figure), except for non-Georgia residents enrolled at the main Georgia Tech campus in Atlanta, Georgia, US, for whom the tuition and fees shall amount to the 2007-2008 "out of state" tuition and fees determined by Georgia Tech. Program Tuition and Fees may change in subsequent years.

AWARE Fellowships

A number of fellowships (15 ~ 25) will be awarded annually to students who show promise in water resources science and engineering. The fellowships shall be sponsored by a cadre of international organizations and shall cover student tuition, fees, and living expenses. International fellowship programs abound in Africa, and GT and UP have been particularly successful in leveraging them in the past. The existence of a highly regarded Institute such as AWARE is expected to facilitate the fund raising process.

The AWARE Fellows will be selected by an adhoc committee of AWARE participating GT and UP faculty.

AWARE Dual Masters Program cont'd

1st Year, 1st Semester:

1. Statistical Methods for Environmental Data Analysis and Prediction
[Georgakakos, Yao, Luo, Di Lorenzo, and other GT and UP Faculty from the Schools of Civ. and Env. Eng. (CEE) and Earth and Atmospheric Sciences (EAS)]

2. Physical Hydrology (Climatology, Meteorology, Surface and Groundwater Hydrology) [Rautenbach, Stieglitz, Luo, Fu, Dickinson, Webster, and other UP and GT faculty from CEE and EAS]

3. River Hydraulics (Open Channel Flow; Sediment Transport; Design of Spillways, Weirs, Culverts**)** [Sturm, Stoesser, and other GT and UP faculty from CEE]

1st Year, 2nd Semester:

4. Water Supply (Urban, Rural, Agricultural, and Industrial**) and Sanitation** [Cloete, Schutte, Annandale, Saunders, and other UP and GT faculty from CEE]

5. Natural Resources and Environmental Economics [Hassan, Sharp, Kellenburg, and other UP and GT faculty from the College of Management and Ind. Sys. Eng.]

2nd Year, 1st Semester:

6. Water Resources Systems Analysis (Simulation and Optimization Methods and Models**)**
[Georgakakos, Yao, Esogbue, and other GT and UP faculty from CEE and the School of Ind. Sys. Eng.]

7. Water Quality and Ecology in Lakes and Rivers (Processes and Modeling Tools**)** [Roberts, Webster, and other GT and UP faculty from CEE]

8. Legal, Institutional, and Policy Frameworks for Water Resources Planning and Mgt. [Olivier, Turton, Ashton, Elliott, and other UP and GT faculty from CEE, the School of Public Policy, and the College of Architecture]

2nd Year, 2nd Semester:

Thesis: [Co-advised by GT and UP Faculty]

In addition to the above courses, students will be required to attend two short courses offered as part of the Professional development program, unless they have enough prior educational or working experience to warrant an exemption.

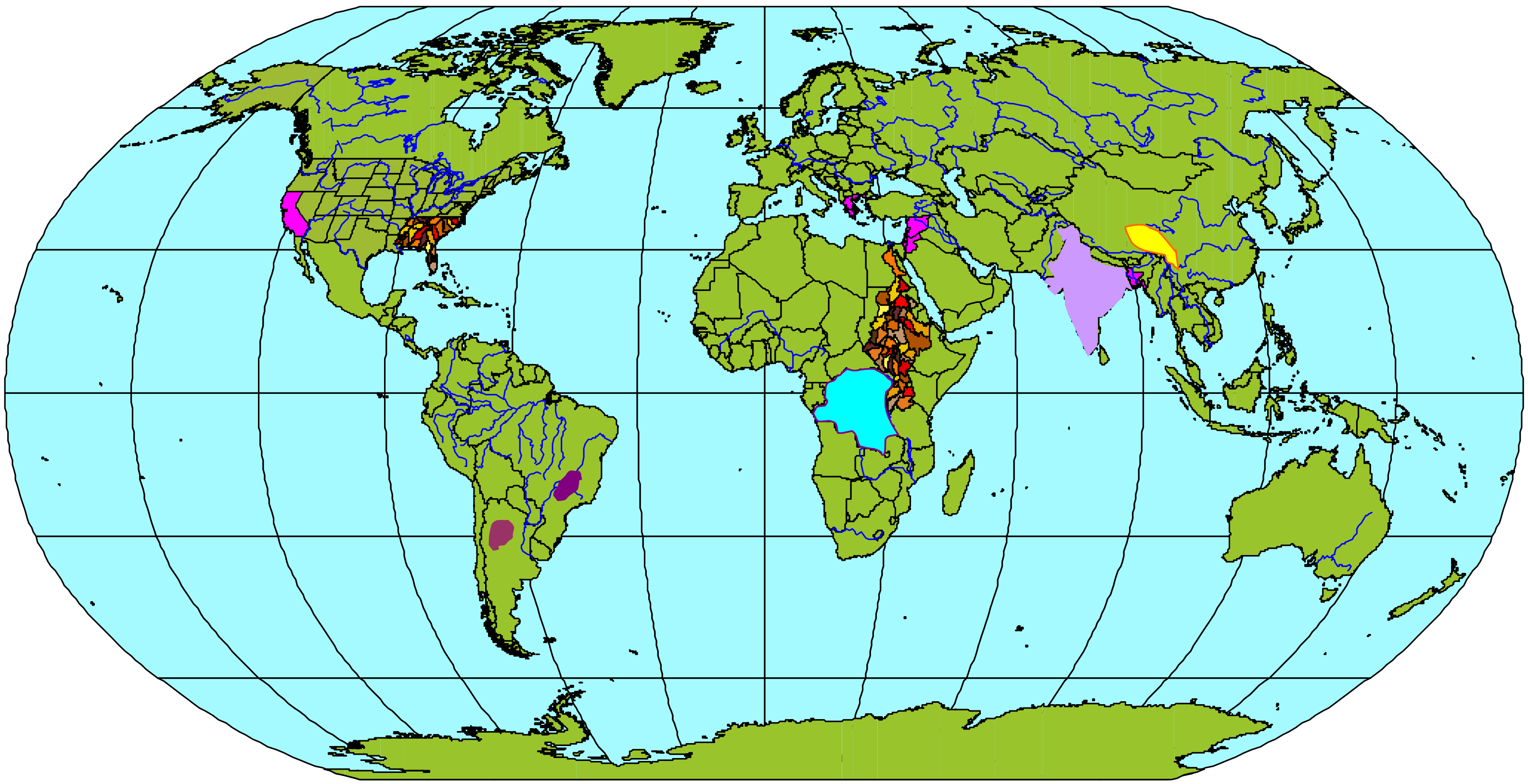
1st Year: Hydro-informatics (Databases, Programming Languages, Spreadsheets, GIS) [Yao, other GT and UP Faculty from CEE, City Planning and Computer Science]

2nd Year: Environmental Planning and Impact Assessments [Fergusson, other UP and GT faculty from CEE, City Planning, and other academic units]

Georgia Tech faculty will take the lead in teaching courses 1, 3, 6, and 7. UP faculty will take the lead in teaching courses 2, 4, 5, and 8.

GWRI DSS Involvement

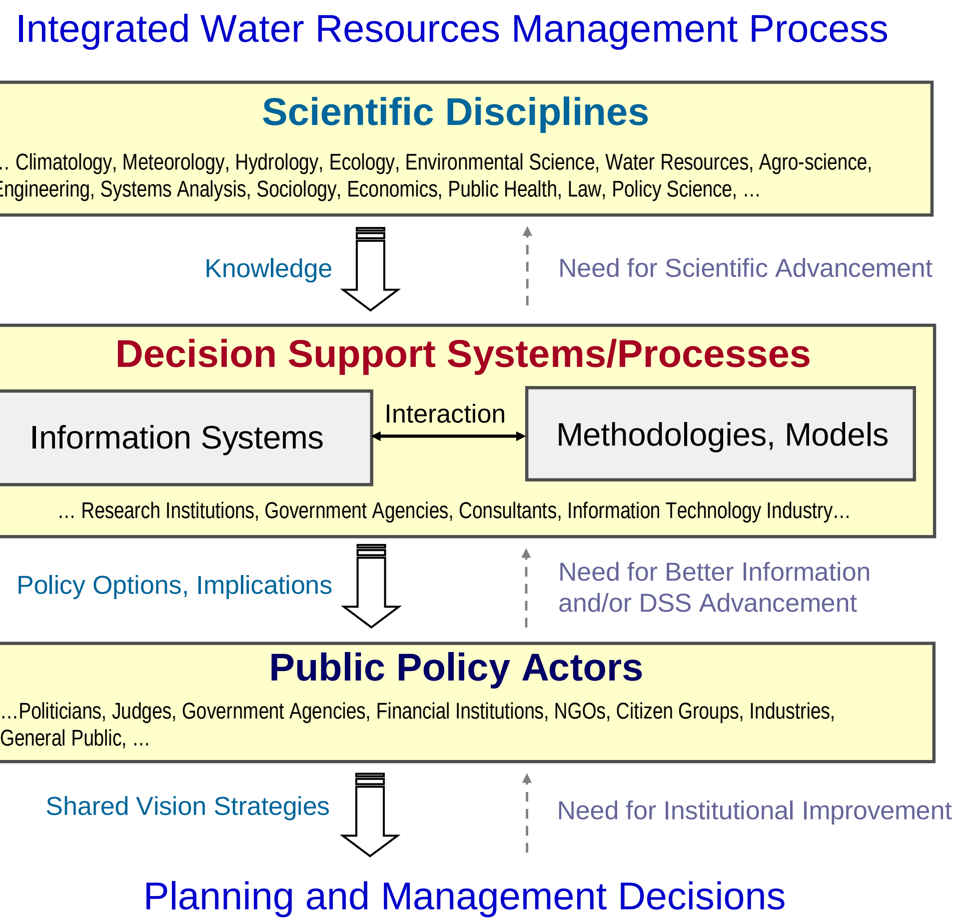
Southeast US, California, Argentina, Brazil, Greece, E. Africa, Middle East, China, India



Sponsoring Organizations: USGS, NOAA, NSF, NASA, EPA, CALFED, CEC, COE, Utilities, Municipalities, Environmental Organizations, FAO/UN, World Bank, USAID, European Aid Agencies (Netherlands, Italy) , Governments

Decision Support Systems: Role in Integrated Water Resources Management

DSS Role: Make scientific advances available for use by Decision Makers; Shorten the gap between scientific advances and practice.



Nile DST Training Workshop (Dar es Salam, Tanzania, 2002)

Nile DST Training Workshop (Entebbe, Uganda, 2003)

Nile DST Training Workshop (Entebbe, Uganda, 2004)