NILE BASIN INITIATIVE

Eastern Nile Subsidiary Action Program

EASTERN NILE TECHNICAL REGIONAL OFFICE (ENTRO)

EASTERN NILE MULTI-SECTORAL INVESTMENT OPPORTUNITY ANALYSIS

INCEPTION REPORT

SEPTEMBER 2014

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ACRONYMS

AfDB	African Development Bank
AHD	Aswan High Dam
BCM	Billion Cubic Meter
CC	Country Consultation
COMESA	Common Market for Eastern and Southern Africa
CRA	Cooperative Regional Assessment
CRGE	Climate Resilience Green Economy
EAC	East African Community
ECCAS	Economic Community of Central African States
ECGLC	Economic Community of the Great Lakes Countries
EEPCO	Ethiopian Electric Power Corporation
EIA	Environmental Impact Assessment
ENID	Eastern Nile Irrigation and Drainage
ENCOM	Eastern Nile Committee Of Ministers
ENIMIS	Establishment of Eastern Nile Irrigation Management Information System
ENPT	Eastern Nile Power Trade
ENSAP	Eastern Nile Subsidiary Action Plan
ENSAPT	Eastern Nile Subsidiary Action Plan Team
ENTRO	Eastern Nile Technical Regional Office (NBI)
EWUAP	Efficient Water Use for Agricultural Production
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
GEF	Global Environment Facility
GERD	Grand Ethiopian Renaissance Dam
GIS	Geographic Information System
GWh/y	GigaWatt hour/year
HCENR	Higher Council for Environmental and Natural Resources
HDI	Human Development Indices
HSU	Hydrological Similar Units
IDEN	Integrated Development of Eastern Nile
IGAD	Inter-Governmental Authority on Development
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature and Natural Resources
IWMI	International Water Management Institute
IWRM	Integrated Water Resource Management
JICA	Japan International Cooperation Agency
JMP	Joint Multipurpose Project
MCA	Multi Criteria Analysis
MEDIWR	Ministry of Electricity, Dams, Irrigation and Water Resources
MoE	Ministry of Environment
MoWI	Ministry of Water and Irrigation
MSIOA	Multi Sector Investment Opportunity Analysis
MW	Mega Watt
NBI	Nile Basin Initiative
NCORENile	Cooperation for result project
NELCOM	Nile Equatorial Lakes Council of Ministers
NELSAP	Nile Equatorial Lakes Subsidiary Action Program
NELSAP-CU	NELSAP Coordination Unit
NELTAC Nile	Nile Equatorial Lakes Technical Advisory Committee
NGO	Non-Governmental Organization
NIB	National Irrigation Board

Nile-COM	Nile Council of Ministers
NWRMS	National Water Resources Management Strategy
OMM	Operation, Maintenance and Management
PMU	Project Management Unit
PRSP	Poverty Reduction Strategy Program
RATP	Regional Agricultural Trade and Productivity Project
RPSC	Regional Project Steering Committee
RSS	Republic of South Sudan
SAP	Subsidiary Action Program
SVP	Shared Vision Program
UNDP	United Nations Development Program
WB	World Bank
WRMA	Water Resources Management Authority
WRMD	Water Resources Management and Development
WSTF	Water Services Trust Fund
WUA	Water Users Association

1 INTRODUCTION AND BACKGROUND

The Nile Basin Initiative (NBI) is a partnership between the riparian states of the Nile River: Burundi, Democratic Republic of Congo, Egypt, Ethiopia, Kenya, Rwanda, South Sudan, Sudan, Tanzania and Uganda. The NBI seeks to develop the river in a cooperative manner, share substantial socio-economic benefits, and promote regional peace and security. The NBI started with a participatory process of dialogue among the riparian countries that resulted in an agreement on a shared vision, namely, to "achieve sustainable socioeconomic development through the equitable utilization of, and benefit from, the common Nile Basin water resources," and a Strategic Action Program to translate this vision into concrete activities and projects.

The Eastern Nile Subsidiary Action Program (ENSAP) of the NBI was launched by Egypt, Ethiopia and the Sudan to initiate concrete joint investments and action on the ground in the Eastern Nile sub-basin in the areas of power generation and interconnection, irrigation and drainage, flood preparedness and early warning, watershed management, development of planning models and joint multipurpose programs. ENSAP is governed by the Eastern Nile Council of Ministers (ENCOM) and implemented by the Eastern Nile Technical Regional Office (ENTRO) in Addis Ababa, Ethiopia. Funding for ENSAP accrues from Eastern Nile countries and varied bilateral and multilateral development partners.

The Integrated Development of the Eastern Nile (IDEN)**,** the first ENSAP project, was agreed in 2002 with a first set of seven sub-projects aimed at tangible win-win gains in the areas of watershed management, flood preparedness, early warning and response, irrigation and drainage, power supply interconnection and regional power trade and later the Joint Multipurpose Program [JMP]. Some of these projects have successfully completed their preparations, and are advancing to implementation.

As part of implementing the projects identified for the 5 year Strategic Plan period, NBI has applied for funding from the Nile Basin Trust Fund/Cooperation in International Waters in Africa entitled Nile Cooperation for Results Project (NCORE) supporting the three NBI centres – the Nile-SEC, NELSAP-CU and ENTRO Review of available information.

The Nile Cooperation for Results (NCORE) Project is the first phase of the Nile Basin Climate Resilient Growth Program and is part of the overall NBI Strategic Plan. The development objective of the NCORE is "to facilitate cooperative water resource management and development in the Nile Basin."

The Project consists of the following three components:

- Component 1: Advancing Nile Basin-Wide Cooperation and Analysis: This Component will support activities at the NBI Secretariat related to its core functions of Facilitating Cooperation and Water Resource Management
- Component 2: Promotion of Sustainable Development and Planning in the Nile Equatorial Lakes Region: This will support the NBI in its efforts to advance investment opportunities in the Nile Equatorial Lakes region
- Component 3: Promotion of Sustainable Development and Planning in the Eastern Nile Region: This Component will support NBI in promoting cooperative activities, water resource management and sustainable development in the Eastern Nile.

ENTRO's Component, Component 3, will support results related to its core function under two sub-programs:

- The first provides a foundation for improved understanding of issues specific to the Eastern Nile sub-basin and aims to improve public domain access to the Eastern Nile knowledge base while
- The second promotes holistic approaches to preparing and operating water investments, to better take into consideration and communicate environmental and social issues.

The EN-MSIOA study is one of several specific studies that is being undertaken to achieve the general objective of the NCORE from the Eastern Nile perspective. The overall objective is to develop a regional water investment strategy for the EN region that broadly supports socio-economic development, poverty reduction, and the reversal of environmental degradation.

The EN-MSIOA study will be carried out over 12 months and is is divided into four (4) main tasks, namely:

- Task 1: Inventory and Situation Analysis;
- Task 2: Strategic Scoping of EN Multi-Sectoral Investments;
- Task 3: Multi-Sectoral Analysis of Investment Opportunities;
- Task 4: MSIOA Final Products.

The objectives of the Inception Phase of the project are to:

- Initiate the study and meet with ENTRO and confirm terms of reference and approach to the study;
- Collect data and documents already available at ENTRO. The detailed review of these documents will be undertaken during Task 1: Situational Analysis;
- Undertake Country Consultations and meet with officials from each of the four Eastern Nile countries in order to identify priorities in terms of water resource development and investment projects.

The Inception Report is divided into 13 Sections, namely:

- Introduction and background (Section 1.1);
- Rationale for the study (Section 1.2);
- Objectives of the study (Section 1.3);
- Overview of the study area (Section 1.4);
- Study team (Section 1.5);
- Key tasks and deliverables (Section 1.6);
- Assumptions and limitations (Section 1.7);
- Implementation Arrangements (Section 1.8);
- Methodology (Section 1.9);
- Work program (Section 1.10);
- Water resources and modelling tools (Section 1.11);
- Key documents and information sources (Section 1.12);
- Country consultations (Section 1.13).

2 RATIONALE FOR THE STUDY

Rapid Population growth, severe land degradation, and lack of adequate storage infrastructure are among the key challenges that hindered development in the Eastern

Nile (EN). The findings of the Cooperative Regional Assessment studies conducted by ENTRO for the ENSAP Projects reveals the followings:

- Unilateral, uncoordinated planning of expansions and Lack of "no-borders" analysis /basin-wide perspective for irrigation development in the EN could lead to Water Conflict in the EN Region. The projected water requirement per EN country master plans is estimated to be 108 BCM/Year.
- The EN region has huge untapped Hydropower potential. There is a need for a coordinated investment plan in power trade
- Through the Cooperative Regional Assessment (CRA), Power generation and interconnection, irrigation and drainage, watershed management as well as the Joint Multi-purpose Project have provided valuable information. However, the assessments have not been carried out from the wider basin resource optimization and efficiency considerations.

A multi sector investment opportunity assessment (MSIOA) is thus needed to identify a coordinated water infrastructure investment strategy for the EN, comprised of prioritized water-related investments (regional or national with regional significance), that promotes shared, sustainable economic growth and development in the EN region.

3 OVERVIEW OF THE STUDY AREA

The aim of this section is to provide a brief overview of the Eastern Nile study area. A more detailed description of the study area will be provided in the Inventory and Situation Analysis (Task 1).

3.1 General overview of Eastern Nile region

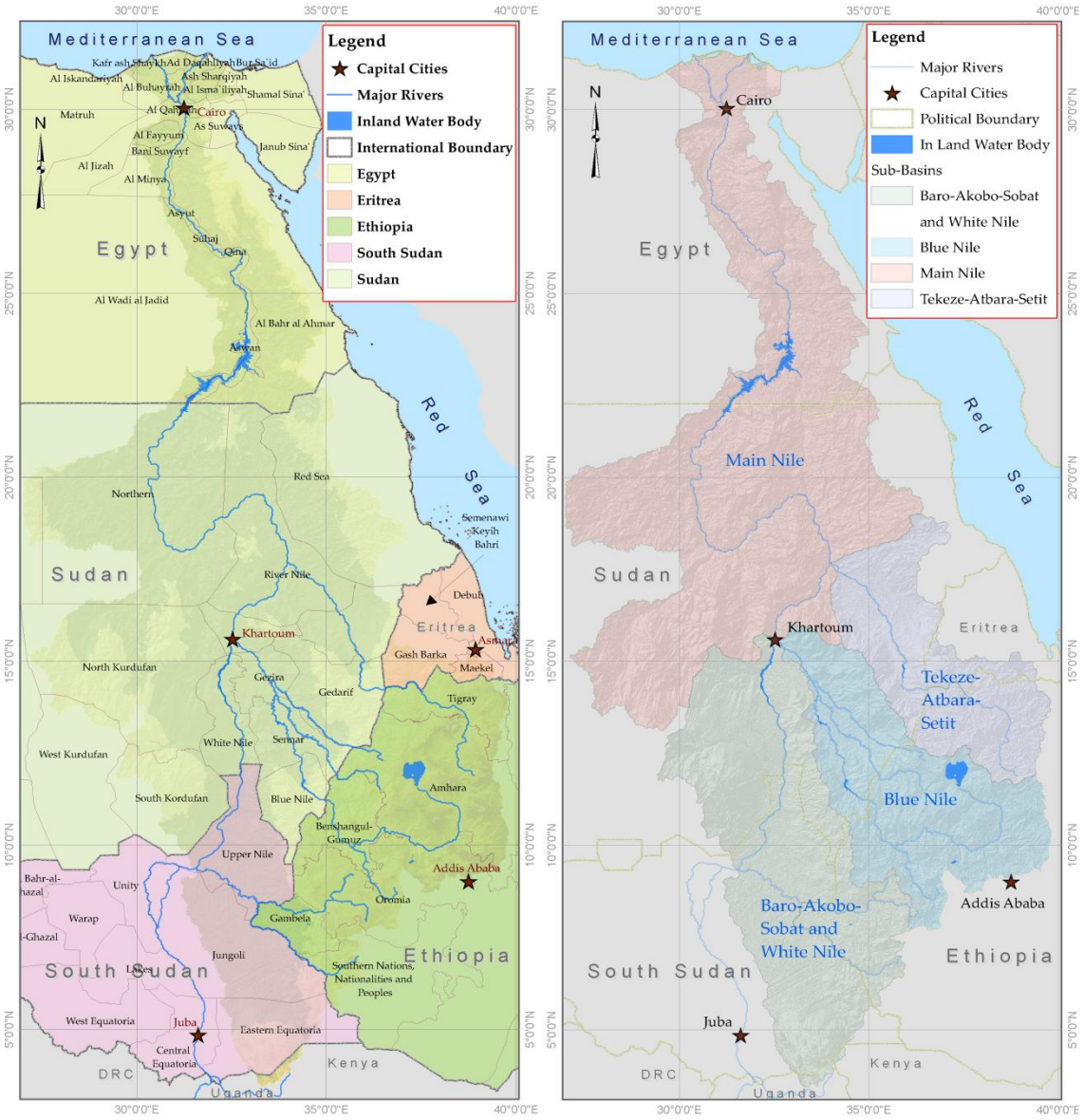
The Nile River traverses about 4,185 miles (6695 km) from its sources in the Equatorial Lakes Region and the Ethiopian highlands to its outlet into the Mediterranean Sea. During this long journey the Nile encompasses all or parts of 11countries and crosses wetlands, marshes, lakes, waterfalls, cataracts and deserts. The Nile has connected peoples, cultures, and civilizations in this region of Africa for millennia. Though it is one of the longest rivers in the world it is comparatively small in terms of flow because of the extremely high evaporation rates and the limited rainfall over vast expanses of the basin. Nevertheless, over the millennia people have clustered along the main Nile River and its principle tributaries and wetlands to ensure access to water for drinking, livestock and crops. These Nile Basin water resources have been sufficient to support the development of advanced civilizations and rich cultures over many millennia.

The Eastern Nile (EN) Basin constitutes over 60%of the area of the Nile River Basin and contributes over 86% of the average annual flow of the main Nile River, which is about 84 Bm^3 at the Aswan High Dam in southern Egypt (NBI,2012). The Eastern Nile supports an extraordinary range of ecosystems from high mountain moorlands, afromontane forests, savanna woodlands, extensive wetlands, intensively cultivated catchments, groundwater

systems, and arid deserts. A summary of the main characteristics of the Eastern Nile sub-basins is outlined in Table 1.

Table 1 Summary Characteristics of the main Eastern Nile Sub-basins

Sub-basin	Area (km^2)	Flow (BCM)	Annual rainfall (mm)	Population	Salient Features
Baro-Akobo-Sobat	205,775	13	500 – 1750	15,100,000	• Important wetland areas • Complex ethnic and tribal context • Little water infrastructure
White Nile	262,441	15	<300 – 500		
Blue Nile	311,548	54	500 – 1800	44,600,000	• Contributes majority of the water to Eastern Nile system • Sediment flows are high • Hydrologic variability is high • Significant potential for economic development • Gezira Irrigation • Blue Nile Mainstem Dam potential (GERD recently initiated)
Tekeze-Setit-Atbara	227,128	12	200 – 1500	16,271,000	• Water availability is highly variable • Little water infrastructure (except for new Tekeze hydropower dam and largely silted Kashm-el-Girba dam) • Sediment flows are high • Potential for small and medium-scale projects
Main Nile	656,398	84	0 – 200	78,425,160	• Very low rainfall • The Aswan High Dam and Lake Nasser • Extensive irrigation systems • The Nile delta


Mediterranean Sea
Legend
Capital Cities
Major Rivers
Inland Water Body
International Boundary
Egypt
Eritrea
Ethiopia
South Sudan
Sudan
Cairo
Khartoum
Addis Ababa
Juba
Red Sea
River Nile
Blue Nile
White Nile
Main Nile
Tekeze-Atbara-Setit
Baro-Akobo-Sobat and White Nile
Sub-Basins
Political Boundary
In Land Water Body
Kenya
DRC
Uganda

The Eastern Nile riparian countries include Ethiopia, Sudan and South Sudan, Egypt, and a small portion of Eritrea (about 3,500 km^2). The Eastern Nile Basin covers approximately 1.7 million $km^2$and comprises four sub-basins: the Baro-Sobat-White Nile in the west, the Abbay-Blue Nile, the Tekeze-Atbara on the east and the Main Nile from Khartoum to the Nile delta (Figure 1). It is home to about 154million people (ENTRO, 2008a).

The four riparian countries that share the Eastern Nile Basin include:

- ***Ethiopia***, the most upstream country in the Eastern Nile Basin and the poorest with a population of 84.7 million and a GDP per capita of 374 current US$ (World Bank, 2012a). The highlands of Ethiopia are the source of over 80% of the main Nile flow. Ethiopia is seeking to develop its water resources for both hydropower and irrigation in order to sustain high economic growth.
- ***Sudan***, formerly the continent's largest country by land area with a population of 34.3 million and a GDP per capita of 1234current US$ (World Bank, 2012a), has traditionally used the Nile mostly for flood recession agriculture and pastoralism, but has constructed one of the world's largest irrigation schemes from a single water source at Gezira just downstream of the confluence of the White Nile and the Blue Nile Rivers.
- ***South Sudan***, which became independent from The Sudan in July 2011 encompasses portions of the White Nile and the Nile above the confluence of the Sabat and White Nile Rivers. The population of South Sudan is 10.3 million (World Bank, 2012a). This area includes the extraordinary wetland called the Sudd that because of evaporation controls the volume of flow from the Equatorial Lakes region into the White Nile. Following the long period of civil strife and war in South Sudan, development of water for agriculture, drinking and livestock is expected to be a very high priority. This report also includes South Sudan data when available.
- ***Egypt***, the most downstream country in the Nile basin, with more than 96% of its freshwater inflow originating from outside its national boundaries, is the most economically developed country in the region with a population of 82.5 million and a GDP per capita of 2781 current US$ (World Bank, 2012a). The Nile waters, which flow into Lake Nasser created by the Aswan High Dam, generate hydropower at the power plant associated with the dam and the electricity generatedis transmitted to the national grid.

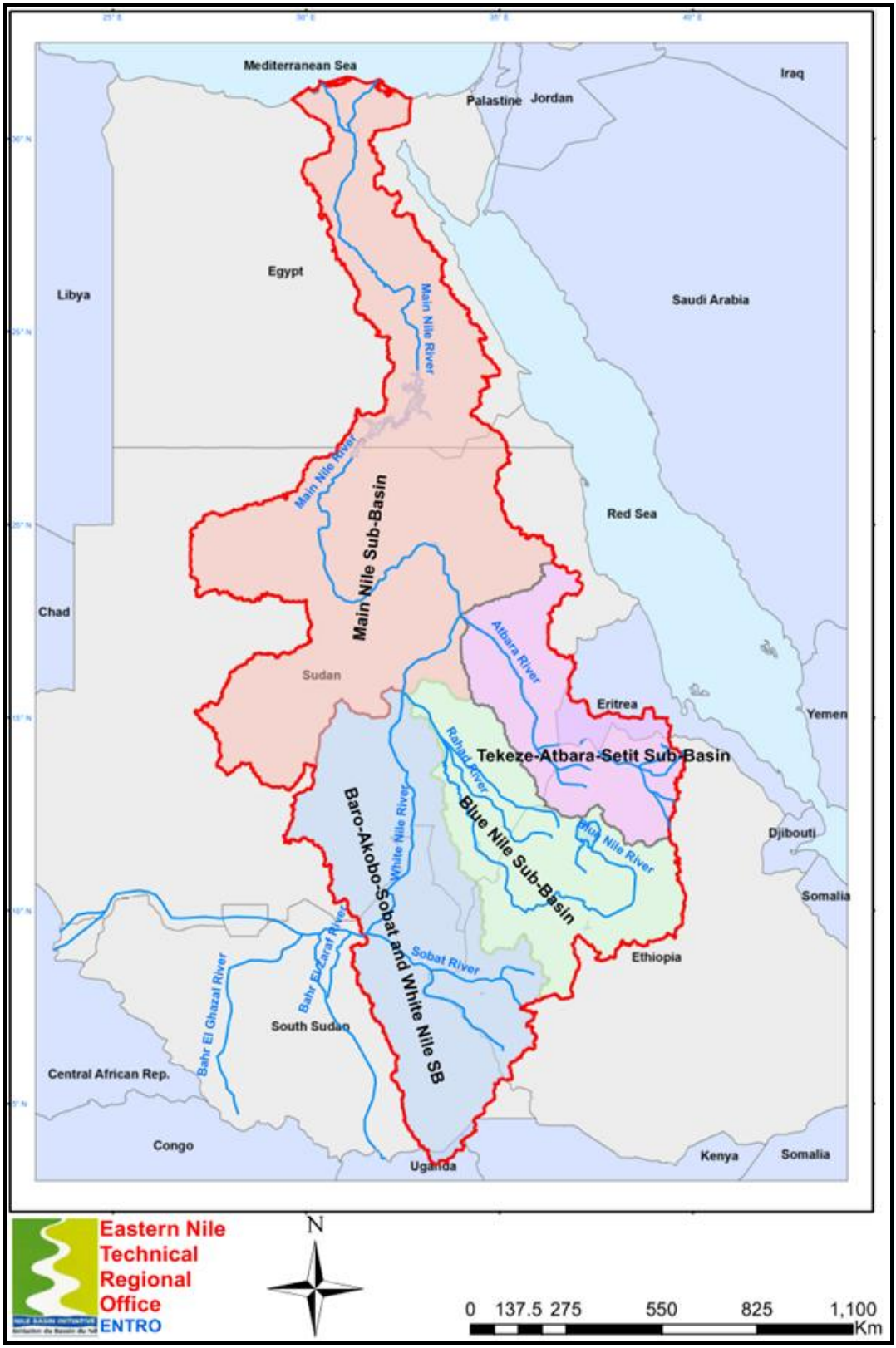


Figure 1: Eastern Nile region and the four sub-basins

3.2 Main Nile sub basin

The Main Nile Sub Basin extends from the confluence of the White and Blue Nile at Khartoum to the Nile Delta and Mediterranean Sea to the north. This sub-basin is the largest of the four sub-basins and covers 656 400 km², which corresponds to 40% of the Eastern Nile Basin. The Nile Delta covers and area of 10 000km². The main feature is the large S shaped loop made by the Nile, beginning at confluence of the Blue and White Nile at Khartoum and ending in the High Aswan Dam in the north, a distance of ~1500 km. There is only one perennial river that enters the Main Nile north of Khartoum, the Atbara, which drains from Eritrea and northern Ethiopia. Approximately 95% of the sub basin is classified as desert or semi-desert. The annual water inflow to the Main Nile is ~ 74 bm^3 per annum, of which a third comes from the White Nile and the remainder from the Blue Nile (Abbay).

3.3 Tekeze-Setit-Atbara sub basin

The Tekeze-Setit-Atbara sub-basin is located on the north-eastern section of the Eastern Nile Basin and covers an area of approximately 227 000 km². The area is mountainous and includes sections of the central northern highland plateau of Ethiopia and descends down to Humera at the Ethiopian-Sudan border. Parts of the sub-basin are also located with the border of Sudan and Eritrea. About 70% of the area falls within the Ethiopian highlands. The main rivers in the sub-basin are the Tekeze in Ethiopia and Setit in Sudan, the Angereb and the Goang in Ethiopia and Atbara in Sudan. In the Ethiopian and Sudan Lowlands, the topography is almost flat or slightly undulating. The lowland region between the Atbara River and the Blue Nile is occupied by the Butana Plains. The Tekeze River basin has been a focal point of the Ethiopian Wildlife Conservation Organization due to Simien Mountains And Sheraro Katfa National Parks.

3.4 Blue Nile (Abbay) sub basin

The Blue Nile (Abbay) sub basin covers a total area of 311 500 km², with a 65% falling within Ethiopia and 35% in Sudan. The Abbay/Blue Nile and its two major tributaries, the Dinder and Rahad, rise in the Ethiopian Highlands near Lake Tana. From Lake Tana the Abbay flows within a deeply incised gorge with a relatively gentle gradient of 645 m over 600 km from an elevation of 1030 masl at Kessie Bridge dropping to 485 masl at the Sudan border. The river drops a further 120 m between the Sudan-Ethiopia border and Khartoum. The flow in the Abbay/Blue Nile exhibits significant seasonal and yearly flow variations, with peak discharges normally occurring in August and the low flows in January to March. The annual average flow near the Ethiopian border at El Deim has been measured at approximately 49 billion m^3, with an additional 4 billion m^3 linked to the Rahad and Dinder.

3.5 Baro-Akobo-Sobat and White Nile sub basin

This Baro-Akobo-Sobat sub basin is located in the southern most portion of the eastern Nile Basin and covers a total area of ~ 468 100 km2. Of this total ~ 16 % (76 700km²) of the sub basin falls within in Ethiopia and 85% (391 400 km²) within Sudan and South Sudan. The Baro-Akobo river basin forms the watershed of the Sobat River, which enters the White Nile at Melut, north of the Sudd swamp and ~ 600 km south of Khartoum. The Baro-Akobo basin covers an area of 75,912 km2 and has an annual rainfall varying

between 3000 and 600 mm/annum, with an average of 1,419 mm, with an average of 1,800 mm/annum. The total mean annual flow from the basin is estimated at 23.6 BMC.

For most of the White Nile's course through Southern Sudan, from Mongalla in the south to its confluence with the Sobat River, the White Nile is known as the Bahr el Jebel which fans out to form a vast swamp or marsh area commonly known as the Sudd (meaning block or barrier). The Sudd is one of the world's largest wetlands and the largest freshwater wetland in the Nile basin, extending 500 km in length and 200 km wide. During the wet season the Sudd may extend to over 130,000 km2. Discharge from Lake Victoria is the main control factor for flood levels and inundation area. However, significant flow into a north-eastern branch of the Sudd also occurs from the Sobat-Baro-Akobo basin that occupies south-western Ethiopia. This river forms a large Machar seamp along the lower reaches of the Sobat River before its confluence with the Nile. The Gambella National Park is located in the eastern part of the Machar marsh. At Malakal, the Sobat River flows into the White Nile which joins the Blue Nile at Khartoum to form the Main Nile.

3.6 Major water management issues

Flood

The ENB has a long recorded history of flooding. The region is characterized by highly variable river flows and a significant proportion of the annual runoff volume of the Eastern Nile, contributing over 86% of the total River Nile flows, which occur in only three months, July to September. During high rainfall periods, major rivers in the region often give rise to large scale riverine flooding, particularly in the floodplains of the Sudan and Ethiopia, with devastating effects on lives, livelihoods, and properties. The estimated average annual damage is USD 25.77 million and USD 5.54 million in rural settlements riparian to the Blue Nile and the Main Nile in the Sudan and in the Fogera and Dembiya floodplains adjoining Lake Tana respectively. The 2006 flood in Ethiopia, for example, resulted in 700 deaths and 242,000 people became displaced. Furthermore, in the Fogera and Dembiya floodplains, flooding is still considered as a necessary annual occurrence and most of the communities have adequate knowledge of how to live with, and benefit from floods. In the Gambella plain severe flooding, estimated to be of annual exceedance probability 2%, occurred in 1988, during which most of the city of Gambella and other towns along the Baro River were inundated.

Over the last ten years, heavy flooding was experienced in the Sudan in 1998, 1999, 2001, 2002, 2003 and again in 2006. The 1998 flood in the Sudan had caused a direct flood damage of US$ 24.3 million. Prior to this period, the country experienced very severe floods in 1878, 1946, and 1988. The socio-economic impacts of these floods included the displacement of large numbers of people, loss of agricultural crops, damage to agricultural inputs such as seeds and pumps, deterioration of health conditions due to the increased incidence of malaria and water-borne diseases, and disruption of social services such as education and health.

Drought

Egypt has been drought prone since time immemorial. Egypt is a very arid country where rainfall is virtually non-existent.Two of the worst droughts occurred in 1067-1072 and 1199-1202. The droughts that occurred in 1199-1202, referred to as "the years of starvation" were due to very low levels of the Nile. Around 2/3 of the population died in

that famine. In the beginning of the 20th century there was also a prolonged drought following the years 1913-1914 and around the years 1939-1942. The years 1972 -1973 were dry and the period 1979-1984 coincided with the drought in the Sahel that extended to Ethiopia and the Sudan. In 1913-1914, Egypt suffered one of its worst droughts in recorded history (since 1695). The natural yield of the river at Aswan was 42 Bm^3 (Fahmy, 2006). The available storage water plus the natural summer flow were too little to fulfill the irrigation requirements at that time which badly affected agriculture.

Salt water intrusion

In the ENB salinity intrusion might be a problem in the Nile delta which is located in Egypt. Egypt has a relatively long coast line, including more than 950 km along the Mediterranean Sea in the north and 1200 km along the Red Sea in the east (Fahmay, 2006). The coastal region is one of the most densely populated areas in Egypt facing the challenges due to sea level rise. The most important coastal lowland in the Nile basin lies along the Mediterranean Sea and there is possibility of hydraulic contact between the Nile Delta aquifer system and underlying the formations directly by embedded faults. The fresh groundwater thickness of this region increases with time, most probably due to increasing surface water diversions and also as an effect of the construction of the Aswan High Dam.

The movement of seawater has a natural response to geological change in the past. Previous studies have predicted that relative rise in sea level in the Mediterranean Coast could lead to increased flooding and saltwater intrusion. The current simulation of the compaction phenomena has provided understandable view about the saline water near the base of the Nile Delta aquifer within the fresh water part at south of Delta as a geologic evolution is the main sources of the salt in groundwater aquifer system (Fahmay, 2006). In summary there are three main reasons of salt water intrusion: reduced fresh water flow in the dry season, increasing water wathdrawl for irrigation and sea level rise due to climate change. The Ministry of Water Resources and Irrigation (MWRI) of the Sudan is already looking into the use of low salinity brackish groundwater in irrigating certain seasonal crops as an adaptation strategy to climate change.

Sedimentation

The sedimentation problems in the ENB originate from the Ethiopia Highlands. Rainfall in the Ethiopia Highlands falls on bare lands at the beginning of the rainy season in July and brings high sedimentation load before the maximum runoff occurs in the area. The highest sediment concentrations occur in the rising flood waters in late July to the first ten days of August. The average specific sediment yield rate of the basin is 9000 ton/sq. km/yr (Shenkut, 2006). The Hydraulics Research Station (HRS) under the MWRI, the Sudan measures sediment concentration and discharge in several locations of the Gezira Scheme canalization system. It has concluded that 5% of the sediment settles in the main canals, 23 % in the major canals, 33% in the minor canals and 39% passes into the farm fields. The huge reduction of the original capacity of the Sudan reservoir due to sedimentation is easily noticeable. The Sennar lost 66%, the Girba 60% and the Roseires 30% (Ahmed, 2006).

Surface water quality

Several areas and cities in the ENB depend on the Nile system for their drinking water. Watershed erosion and heavy sediment movement during flood season especially the flood season cause high turbidity and suspended solids in the Nile River water making the water unsuitable for domestic use and drinking purposes. For example at Khartoum, the turbidity has tremendously increased during the last decade. It was increased from 5000 NTU to above 20,000 NTU during the floods of 1999 to 2003 (Ahmed, 2006). Many water treatment plants have been affected by such heavy sediment load. For example, the Khartoum water treatment plant, which was designed initially to treat raw water of maximum turbidity of 8000 NTU (Ahmed, 2006), now produces water of poor quality when the sediment dose is greater than the maximum allowable quantity. Besides sedimentation discharge of untreated or partially treated industrial and domestic wastewater, leaching of pesticides and residue of fertilizer as well as navigation are often factors that affect the quality of water of the Nile River.

4 OBJECTIVES OF THE STUDY AND SCOPE OF WORK

Based on the terms of reference for the Team Leader the study will be carried out by a multi-disciplinary Team of Experts comprising of ENTRO staff supported by specialist consultants. The objective of the Study Team will be to conduct a multi-sectoral assessment aimed at the identification, scoping and development of project profiles for water related potential investment options in the following EN sub-basins:

- The Main Nile sub-basin;
- Tekeze-Setit-Atbara sub-basin;
- Blue Nile sub-basin; and,
- Baro-Akobo-Sobat sub-basin.

This includes both Hardware (e.g. infrastructure) and Software (e.g. institutional and information) activities. The scope of work include:

4.1 Identification of Investments of Regional Significance

Hardware

- Storage/Hydropower (incl. storage-backed and run-of-river)
- Irrigation&Drainage
- Watershed Mgmt. (incl. rainfed agriculture)
- Wetland Management (incl. fisheries)
- Transport (incl. Navigation, Ports)
- Tourism (incl. Eco-tourism)
- Flood Management
- Water Supply
- Other Hardware

Software

- Hydro-meteorological network
- Capacity Development
- Coordinated Management
- Other Software

4.2 Multi-criteria Scoping of the Investment Options (using analytical tools and stakeholder inputs to scope impacts, benefits, and trade-offs)

Technical
Economic and Financial
Environmental
Social
Institutional (incl. PPP options)
Overall (status, key knowledge gaps and additional work required)

4.3 Preparation of Investment Profiles (after mapping, packaging and sequencing)

Individual Investment Profiles
Overall MSIOA Report
By Sub-basin (Baro-Akobo-Sobat and White Nile, Abbay-Blue Nile, Tekeze-Setit-Atbara, Main Nile)
By Theme (e.g. Storage, Hydropower, Irrigation, Watershed management, Wetland management, Software options)

In terms of meeting its objectives the study is expected to have significant benefits. These include:

- Assisting to integrate basic information and analysis to identify and explore regional investment opportunities across water-related sectors;
- Identify packages of potential investments to be prepared outside the MSIOA (e.g. with pre-feasibility/feasibility studies, detailed designs);
- Help provide advice and information for sourcing financing for regionally-significant investments including via the ENTRO and NBI portals;
- Help inform the dialogue on regional cooperation among countries and with development partners.

5 STUDY TEAM

Table 1 lists the team members and their roles. Table 2 lists the key ENTRO staff involved in the study.

Table 1: List of team members and areas of responsibility

Name of specialist	Position	Key role
Dr. Fady Hamadé	Team Leader	Coordination and economic issues
Mr. Tony Barbour	Social and Environmental expert	Social issues
Dr. Yohannes Daniel Gebretsadik	Water resource modeler & CC Expert	Hydrological & Climate change issues

Khalid A. Alansary	Environmental expert	Environmental issues
Eng. Ayalew Nigussie	Irrigation expert	Irrigation issues
Dr. Fatma Moustafa	Hydropower expert	Hydropower issues
Pr. Elfatih Eltahir	Climate Change Expert	Climate Change issues
To be identified	GIS	GIS

Table 2: List of key ENTRO staff involved in the study

Dr. Yosif Ibrahim Dr. Solomon Abate Dr. Wubalem Fekade Mr. Michael Abebe Mr. Jackson Elisoma Mr. Awoke Kassa Ms. Azeb Mersha Mr. Tesfaye Gudeta Ms. Genet Alemayehu	Senior WR Planner/ENTRO-OIC Regional Project Coordinator for Watershed Head, SDCU Hydropower Expert Regional Project Coordinator for BAS Monitoring & Evaluation Officer Junior Water Resources Modeler	
Mrs. Selamawit Haile	Program Assistant	

6 KEY TASKS AND DELIVERABLES

The study is divided into four (4) main tasks, namely:

- Task 1: Inventory and Situation Analysis
- Task 2: Strategic Scoping of EN Multi-Sectoral Investments
- Task 3: Multi-Sectoral Analysis of Investment Opportunities
- Task 4: MSIOA Final Products

The key deliverables linked to each Task are:

- Task 1: Situation Analysis Report
- Task 2: Strategic Investment Scoping Report
- Task 3: Multi-Sectoral Investment Scenario Analysis Report
- Task 4: Final MSIOA Report, which will include: Investment Profiles for selected projects and Implementation Strategy and Action Plan.

Each task is described in more detail below.

6.1 Task 1: Inventory and Situation Analysis

- Inventory and characteristics of existing water resources management and development projects and potential investment options in the Eastern Nile. These should focus on projects of regional significance and are expected to include:
  - "Hardware" Investments (e.g. Storage/Hydropower (incl. storage-backed and run-of-river), Dam Safety, Irrigation & Drainage, Watershed Mgmt. (incl. rainfed agriculture), Wetland Management (incl. fisheries), Transport (incl. Navigation, Ports), Tourism (incl. Eco-tourism), Flood Management, Water Supply, etc.

- "Software" Investments (e.g. Hydro-meteorological network, Capacity Development, Coordinated Management, etc.)

1.4 Baseline mapping of the physical resource base (climatic, hydrologic, geographic, hydro geological, environmental, & Scio-economic conditions; review the existing water related policies & strategies);

1.5 Identification and mapping of areas with constraints/emerging challenges ("hot spots") and opportunities (economic growth potential areas)

1.6 Development of EN basin development scenarios (e.g. combinations of investments based on different development paradigms).

6.2 Task 2: Strategic Scoping of EN Multi-Sectoral Investments

- Determination of Economic, Social, and Environmental Baseline[1];
- Identification and mapping of key stakeholders associated with each investment;
- Assessment of major issues, hotspots, constraints/risks and opportunities;
- Identification of strategic economic, environmental and social issues relating to proposed investments based on project characteristics, locations, experience from similar projects, expert opinion, and rudimentary analysis.

6.3 Task 3: Multi-Sectoral Analysis of Investment Opportunities (Scenario Analysis)

Framework Analysis
Work with ENTRO to develop a framework for analyzing investments (considering both national and regional perspectives), including methodology, objectives, criteria, and indicators (reflecting inputs from strategic scoping) for evaluating potential investment projects;

Scenario Building
Work with ENTRO to effectively utilize its range of modeling tools (e.g. simulation, optimization, and multi-criteria) and spatial analysis tools (e.g. GIS, remote sensing) to undertake strategic analysis of water resources investment options/scenarios, prioritize and sequence potential investment projects of regional importance with the aim to identify investments that spatially optimize water use at a regional level and that highlight potential opportunities associated with high economic returns, investment viability, and those that contribute to, or are enabled by, regional cooperation. Use the analytical tools and stakeholder inputs (as possible) to scope impacts, benefits, and trade-offs of various investment scenarios.

This should include analyses relating to various aspects including:

- Technical
- Economic and Financial (including potential for contributing to economic growth)
- Environmental
- Social (including potential for contributing to poverty alleviation)
- Institutional (incl. PPP options)
- Overall (status, key knowledge gaps and additional work required).

[1] Based on the approach the determination of the economic, social, and environmental baseline will be largely undertaken as part of Task 1

6.4 Task 4: MSIOA Final Products

Work with ENTRO to prepare, based on scenario analysis, individual ***Investment Profiles*** (including location, multi-sectoral scoping and analysis summary, summary of potential benefits, challenges, and required next steps). These should be organized as short (e.g. 2-4 pg) factsheets that can be grouped as necessary (e.g. according to theme, type, basin, investment period, etc.). These should be available both in print and electronic formats.
Work with ENTRO to prepare ***Overall MSIOA Report*** summarizing priority investments:

- By Sub-basin (Baro-Akobo-Sobat and White Nile, Abbay-Blue Nile, Tekeze-Setit-Atbara, Main Nile)
- By Theme (e.g. Storage, Hydropower, Irrigation, Watershed management, Wetland management, Software options)

For each investment type (for profiles and report), identify institutional, financing & sustainability arrangements necessary to support prioritized & sequenced investment options.

Work with ENTRO to advise on conceptualizing and developing an interactive tool (that can be used offline or integrated with their website) to explore the implications of various multi-sectoral investment options in an interactive manner.

Develop an MSIOA Implementation Strategy and Action Plan***.*** The plan should contain:

- An investment timetable that shows the interrelated projects and programs over time and in relation to supporting activities,
- Project-evaluation framework that will help decision-makers analyze the action plan
- Preliminary cost estimates for prioritized and sequenced regional investments.

7 ASSUMPTIONS AND LIMITATIONS

Assumptions and limitations of the project are:

7.1 Assumptions

- The Eastern Nile Multipurpose Optimization System (ENMOS) will be used as the primary modelling tool for the study;
- The Grand Ethiopian Renaissance Dam (GERD) is currently under construction. The GERD will therefore not be assessed as an investment opportunity as part of this study;
- However, the actions of Coordinated reservoir operation to maximize benefits to EN, the power interconnection and trade and other filling scenarios with different hydrological traces will be considered as options;
- The focus of the study will be on existing projects identified by the Team during the inception phase. Where the potential for new investment opportunities exists these will be discussed with ENTRO;
- The study will rely on existing information and studies that have been undertaken in the EN Basin and on the projects identified by ENTRO. No primary data will be collected as part of the study;

- ENTRO will supply all relevant and available reports and technical documents in ENTRO's possession and the Team will collect other additional information required;
- Previous projects identified by ENTRO as part of the other studies will also be assessed as part of the study;
- ENTRO will be responsible for the overall implementation of the study and managing the interfaces between this Consultancy and other relevant studies.
- ENTRO staff, technical groups composed of EN countries and reviewers, as deemed necessary, will be engaged to provide support to and review the key outputs of the studies.
- ENTRO will be responsible for the organization of regional and national consultations, training programs and study tours with the help of the Consultant.
- ENTRO will provide office space suitably furnished with electricity, telephone and internet connections;
- ENTRO shall make available data and information on the EN at its disposal.
- ENTRO will facilitate the Consultant's access to the different government departments/utilities//institutions with data and information relevant to the consultancy.

7.2 Limitations

- There is limited baseline information for South Sudan;
- There is limited detailed baseline information available for some of the sub-basins in the EN;
- Some of the projects may be located in areas where there is limited site specific information available;
- Since country consultation has not been carried out in Egypt, the Team must rely on assumption regarding the country's priorities.

8 IMPLEMENTATION ARRANGEMENTS

Under the heading, Implementation Arrangements, the ToR for the Team Leader notes that the study requires a team of multi-disciplinary experts working in an integral manner and with experience in undertaking diagnostic work and project development of multi-sectoral water resources projects in river basins.

However, based on a review of the ToRs for each specialist it appears that each expert is expected to prepare separate reports. Also the terminology for the deliverables required for the specialists is not consistent with the terminology contained in the ToR for the Team Leader.

Table 3 lists the outputs associated with the experts compared to those of the Team Leader.

Table 3: Deliverables associated with team leader and specialists

	TOR Team Leader		TOR Social Expert	TOR Env Expert	TOR Irrigation Expert	TOR Hydropower Expert	TOR Hydro-modeler expert
	Deliverables	**Description**	**Deliverables**	**Deliverables**	**Deliverables**	**Deliverables**	**Deliverables**
D1	Inception Report	Elaborated approach, Team build-up and updated work plan	**Inception Report**	**Inception Report**	**Inception Report**	**Inception Report**	**Inception Report**
D2	EN basin Situation Analysis Report	As outlined in Task 1	EN Basin Knowledge Base	EN Basin Knowledge Base	EN Basin Situation Analysis	EN Basin Situation Analysis	EN Basin Knowledge Base
D3	Strategic Scoping of Multi-Sectoral Investment Opportunities	As outlined in Task 2	EN Multi-Sectoral Investment Opportunity Analysis	EN Multi-Sectoral Investment Opportunity Analysis	Analysis of Irrigation Options	Analysis of power Options	EN Multi-Sectoral Investment Opportunity Analysis
D4	EN Multi Sectoral Investment Opportunities Analysis Report	As outlined in Tasks 3 & 4	EN Value of Cooperation EN Climate Risk Analysis	EN Value of Cooperation EN Climate Risk Analysis	Analysis of Irrigation Options	Analysis of Power Options	EN Value of Cooperation EN Climate Risk Analysis
D5	Investment Profiles, Interactive Tool, and Strategy & Action Plan	As outlined in Task 4	EN Knowledge Products	EN Knowledge Products	EN Knowledge Products	EN Knowledge Products	EN Knowledge Products

In order to ensure effective co-ordination of specialist studies it was agreed with ENTRO that the activities and deliverables expected from the specialists would be linked to the deliverables associated with the four (4) Tasks listed in the ToR for the Team Leader as opposed to submitting separate products to ENTRO. The Team Leader will therefore be responsible for ensuring that the specialist inputs into the study enable the key objectives to be met.

The team believes that this approach will be more effective and efficient in terms of project management. ENTRO will be required to review one deliverable associated with each Task as opposed to separate deliverables from each specialist. This approach is also better suited to meeting the objective of Implementation Arrangements, namely to establish a "a team of multi-disciplinary experts working in an integral manner".

Table 1 in the ToR for the Team Leader outlines the key tasks assigned to each team member. For the purposes of the study the information contained in Table 1 has been

used to inform the role of each of the specialists. An additional column has been added to Table 1 which links the assigned tasks for each specialist to the 4 Tasks listed in the Scope of Work for the EN MSIOA study as set out in the ToR for the Team Leader namely:

- Task 1: Inventory and Situation Analysis;
- Task 2: Strategic Scoping of EN Multi-Sectoral Investments;
- Task 3: Multi-Sectoral Analysis of Investment Opportunities;
- Task 4: MSIOA Final Products.

For the purpose of the study Table 4 indicates the role that each specialist will play in terms of their input and contribution to achieving the overall objectives of the MSIOA study.

Table 4: EN MSIOA: Role of specialists and alignment with key project tasks

Position in Study	Organization	Assigned Tasks	Task
Senior Water Res. Planner	ENTRO	• Overall MSIOA Coordination • Contribution and quality review of reports particularly on Water Resources • Linkages with EN Development countries and Development Partners	
Water Resources Development Economist	Dr Fady Hamade	• Study Team Leader • Help the client to prepare the TOR of experts –key sectors include: Hydropower, irrigation & drainage, watershed mgmt. (incl. rainfed agriculture), wetland management (incl. fisheries), transport (incl. navigation, ports), tourism (incl. Eco-tourism), flood management and water supply. In addition, soft interventions could include: Hydro-meteorological network, Capacity Development, Coordinated Management, Others; • Coordinate and control the quality of outputs, coordinate production of all reports and organization of workshops with ENTRO Team • Review of data, and analysis tools focusing on economic models • Responsible for specific tasks: Multi-sectoral Analysis, Design of Basin Development Scenarios, Development of Strategy and Action Plan	• Task 1-4 • Completed • Task 1-4 • Task 1-4 • Task 2, 3 and
Environmental Specialist	Khalid Abdelrahman	• Review existing data/information on the nature of the entire EN river ecosystem and related linkage to various uses and systems; scope environmental baseline, major issues, hotspots, constraints/risk and opportunities • Prepare respective section of the Environmental and Social Strategic Investment Scoping Report; • Propose environmental flow for basin development scenario in consultation with Water the Resources Planner • Develop environment indicators for scenario analysis; • Participate in country visits & consultations; • Participate in workshops for the Identification of projects, development/ review scenarios and project profiles; • Contribute to MSIOA Report (Investment strategy, project profiles, updated EN SoB Report, Report on EN in a changing Climate…) with a view to ensure the triple bottom line sustainable development (ecological integrity, social justice and economic development).	• Task 1 • Task 2 • Task 2 • Task 2 • Completed • Task 3 and 4 • Task 4
Social Development Specialist	Tony Barbour	• Carry out social assessment (social baseline, major issues, hotspots, constraints/risk and opportunities including improvement of livelihoods) and identification of key stakeholders; • Prepare respective section of the Env. And Soc. Strategic Investment Scoping Report ; • Develop social indicators for scenario analysis including gender, health (water related), HIV, etc.; • Participate in country visits & consultations; • Participate in workshops for the Identification of projects, development/ review scenarios and project profiles; • Contribute to MSIOA Report (Investment strategy, project profiles, updated EN SoB Report, Report	• Task 1 • Task 2 • Task 2 • Completed • Task 3 and 4

		on EN in a changing Climate…) with a view to ensure sustainable development.	• Task 4
Climate Change Specialist	Pr. Elfatih Eltahir	• Develop approach to climate screening and risk assessments; Analyze historical climate variability and change data analysis for EN • Climate screening of project profiles • Develop/update climate risk assessment framework; EN in a changing climate report • Climate risk assessment for investment options (incl. vulnerability, mitigation, adaptation) • Participate in country visits & consultations; • Participate in workshops for the Identification of projects, development/ review scenarios and project profiles; • Contribute to MSIOA Report (Investment strategy, project profiles, updated EN SoB Report, Report on EN in a changing Climate…).	• Task 2 • Task 2 • Task 2 • Task 3 and 4 • Task 4
Irrigation Specialist	Ayalew Nigussie	• Review agriculture and irrigation related data/ information and master plans; scope the resource base, & regionally significant opportunities & options in agriculture, irrigation and watershed management • Develop agricultural production, irrigation efficiency and food security related indicators for scenario analysis; • Contribute to the identification, analysis and elaboration of scenarios; • Provide the economist and modelers with all needed data regarding agriculture and irrigation in the EN; • Participate in country visits & consultations; • Participate in workshops for the Identification of projects, development/ review scenarios and project profiles; • Contribute to MSIOA Report (Investment strategy, project profiles, updated EN SoB Report, Report on EN in a changing Climate…).	• Task 1 • Task 2 • Task 2 • Task 2 • Completed • Task 3 and 4 • Task 4
Hydropower Specialist	Dr. Fatma Moustafa	• Review existing energy sector related data/ information and master plans; scope the resource base, & regionally significant opportunities & options • Develop energy and hydropower performance related indicators for scenario analysis; • Contribute to the identification, analysis and elaboration of scenarios; • Provide the economist and modelers with all needed data regarding energy and hydropower in the EN; • Participate in country visits & consultations; • Participate in workshops for the Identification of projects, development/ review scenarios and project profiles; • Contribute to MSIOA Report (Investment strategy, project profiles, updated EN SoB Report, Report on EN in a changing Climate…).	• Task 1 • Task 2 • Task 2 • Task 2 • Completed • Task 3 and 4 • Task 4
GIS/Information Specialist	ENTRO	• Develop GIS platform • Knowledge base, mapping, and spatial analysis (by region, country, sub-basin, economical	• Task 1 • Task 1 & 2

		sectors…) • Support to various reports	• Task 2, 3 and 4
Water Resources Modeller	Dr. Yohannes Daniel	• Compile all data and information as well as sectoral indicators needed for modelling • Develop hydrologic indicators for scenario analysis • Contribute to the identification, analysis and elaboration of water resources related scenarios • In close collaboration with the economist, undertake water resources modeling for multi-sectoral and Basin Development Scenarios; • Participate in country visits & consultations; • Participate in workshops for the Identification of projects, development/ review scenarios and project profiles; • Contribute to MSIOA Report (Investment strategy, project profiles, updated EN SoB Report, Report on EN in a changing Climate…).	• Task 1 • Task 2 • Task 2 • Task 2 • Completed • Task 3 and 4 • Task 4
Technical Writer	Consultant	• Support the structuring and production of various reports • Ensure quality of all reports	• Task 1-4

9 METHODOLOGY

The study is divided into four (4) main tasks, namely:

- Task 1: Inventory and Situation Analysis;
- Task 2: Strategic Scoping of EN Multi-Sectoral Investments;
- Task 3: Multi-Sectoral Analysis of Investment Opportunities;
- Task 4: MSIOA Final Products.

The approach to and key activities associated with each task are outlined below. The proposed timeframes for each task are also identified. In order to ensure that the study is completed by the end of 2014 there will be overlap between the tasks. The areas of overlap are outlined below:

Task 1 and 2

There is overlap between the activities associated with the Situational Analysis and the Strategic Scoping of EN Multi-Sectoral Investments. This overlap will enable work to be undertaken on Task 2 at the same time as the preparation of the Situational Analysis. The key deliverables for Task 1 and 2 will therefore be delivered in the 1st week of November 2014.

Task 3 and 4

There is considerable overlap between the activities associated with the Strategic Multi Sectoral Analysis of Investment Opportunities and preparation of MSIOA Final Products. The key deliverables for Task 3 and the Investment Profiles (Task 4) will therefore be delivered in the 1st week of December 2014. The MSIOA Implementation Strategy and Action Plan will be submitted in January 2015.

Figure 2 outlines the proposed activities, with specific emphasis on input from the modelling component of the study into the key tasks. As indicated in Figure 2, the modelling component of the study will commence with Task 1, Situational Analysis. The major contribution of the modelling component to the study will however be during Task 2 and 3, Scoping and Scenario Analysis.

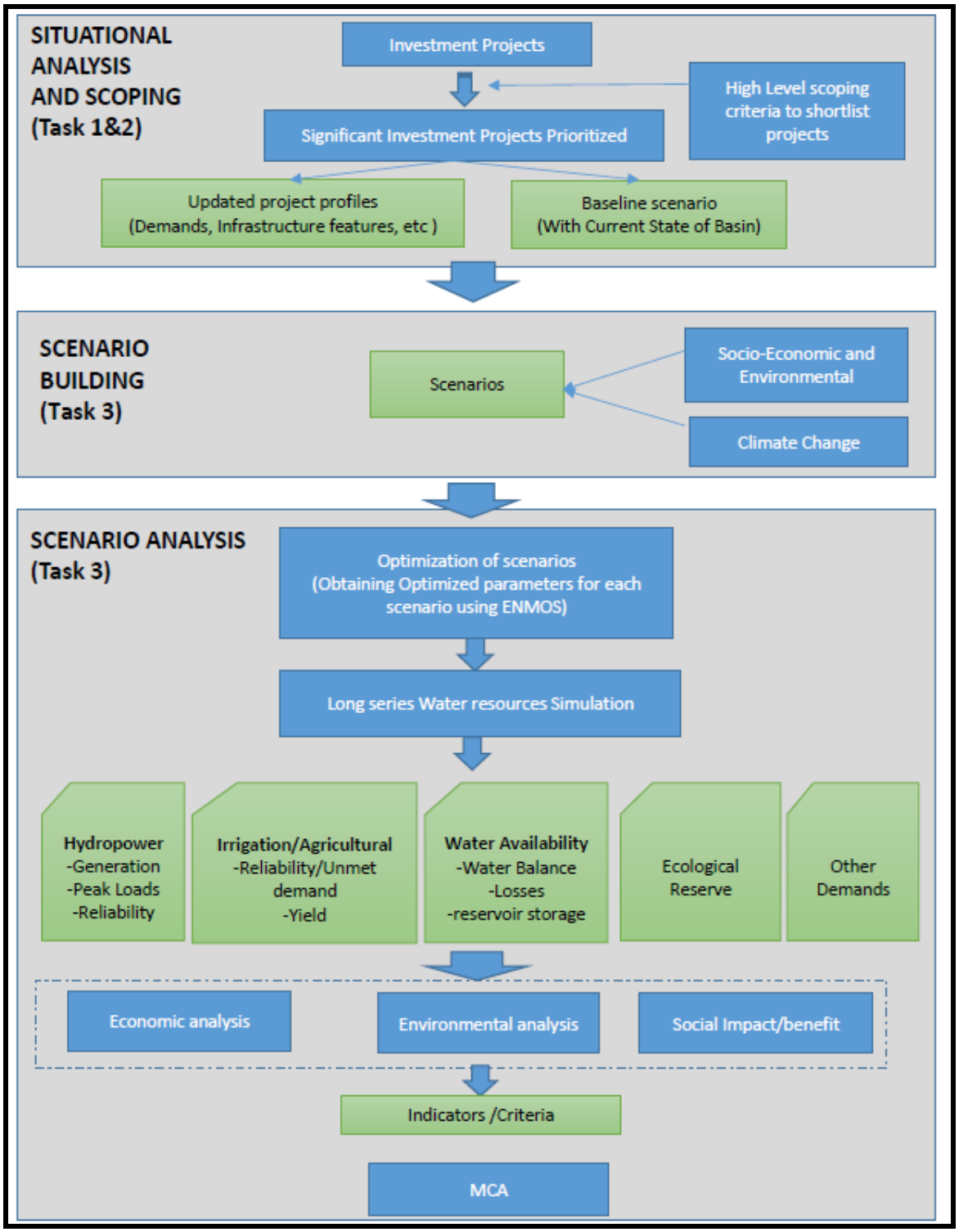


Figure 2: Flow diagram illustrating modelling input into key task

9.1 Task 1: Inventory and Situation Analysis

Objective

The key objective of Task 1 will be to undertake an inventory and situation analysis of the EN Basin area and the four sub-basins. This will include an assessment of the existing water resources management and development projects in the region. Task 1 will also include a review of the existing environmental and social baseline for the EN Basin and four sub-basins. This will provide the study with the information required to identify the opportunities and risks associated with the potential investment options in the EN Basin.

Key activities

The key activities to be undertaken by the team during Task 1 will include:

- Identification of current and planning investment projects in the study area. This includes hard projects (infrastructure related investment projects) and soft projects (capacity building, catchment management, optimization of water allocation, improving efficiency etc.);
- Review of current water availability and demand conditions and links between key economic sectors and water consumers (current and future);
- Review of energy and agricultural sector;
- Review of key planning and policy documents, with a specific focus on the water resource management, energy, agriculture, socio-economic and environmental sectors;
- Review of current baseline socio-economic and environmental conditions. The aim of this will be to identify potential social and environmental "hot spots" and also current trends, such as loss of biodiversity, increase in rural poverty etc.;
- Identification of key stakeholders;
- Identification of potential opportunities and constraints. The opportunities and constraints will be informed by the current baseline socio-economic and environmental conditions, which in turn will be linked to the current and proposed investments projects;
- Mapping of baseline conditions in the EN-Basin and four sub-basins. The GIS specialist will map the key baseline conditions (environmental, socio-economic, land uses, current and planned infrastructure projects, etc.) and develop a set of baseline maps for each sub-basin. These maps will used to generate overall maps which will be used to identify and assess potential opportunities and constraints associated with the identification of investment opportunities;
- Perform water resources simulation analysis and establish the baseline scenario
- Stakeholder consultation. The findings of Task 1, Situational Analysis, will be presented to country representatives for comment and discussion. A workshop is proposed to be held in November 2014 to present the findings of Task 1. This workshop will also be combined with presenting the findings of Task 2, Strategic Scoping of EN Multi-Sectoral Investments;
- A project team workshop will be held prior to the Stakeholder Workshop to be held in November. The aim of the workshop will be discuss the outcomes of Task 1 and 2 with ENTRO prior to Stakeholder Workshop.

Key deliverables

The key deliverables associated with Task 1 include:

- Situation Analysis Report;
- List of investment opportunities (existing and proposed). The list will include "hardware" and "software" investments;
- Set of baseline maps for each of the four sub-basins. The maps will provide spatial information on the biophysical resources (climate, hydrology, topography, soils, geology etc.), socio-economic resources (land uses, population density, key infrastructure etc.) and location of investment opportunities;
- Workshop Report summarising the key issues and comments from the Consultation Workshop to be held in November 2014.

Timeframe

The Situation Analysis Report will be submitted in first week of November 2014. The workshop will be held in the third week of November 2014.

9.2 Task 2: Strategic Scoping of EN Multi-Sectoral Investments

Objective

The key objective of Task 2 will be to identify a short list of investment projects ("soft" and "hard" investments) that will be taken forward and assessed in more detail during Task 3, Multi-Sectoral Analysis of Investment Opportunities (Scenario Analysis). The identification of investment projects will be informed by the information collected and assessed in Task 1 and the modelling undertaken during Task 2.

Key activities

Identification of criteria / indicators
Each of the specialists will identify a set of criteria / indicators that will be used to inform the strategic level screening and scoping of investment opportunities identified in Task 1. The criteria will include economic, social, environmental and technical criteria and will be informed by the Situational Analysis (Task 1).

Situational analysis and Scoping
As indicated above, the situational analysis phase (Task 1) of the study will identify a list of potential investment projects with in the Eastern Nile basin extent for each of the key sectors. The project list will be informed by previous studies conducted at ENTRO and the input from the country consultation which was undertaken as part of this assignment. A set of high level strategic criteria/indicators developed as part of the Task 2 and informed by Task 1 will be used to further prioritize the list of significant investment options. The outcome will be a short list of investment options that will then be taken for further analysis and scenario building process.

The key indicators/criteria will include environmental, social, economic, hydrological, energy, agriculture and irrigation criteria/indicators. These indicators will be used to screen and scope the current and planning investment projects in the study area.

This includes hard projects (infrastructure related investment projects) and soft projects (capacity building, catchment management, optimization of water allocation, improving efficiency etc.).

Scenario building
The scenario building process will involve the development of a series of potential investment scenarios through the combination of infrastructure, climate and social scenarios and implementation of the identified development scenarios into the appropriate descriptive modelling system. Inputs from the environmental, social development, climate change, irrigation and hydropower specialist will be aggregated to form a selected set of scenarios which will be then be modelled for analysis.

The scenario building and modelling exercise will include:

- Assessment of the water balance of the EN region, taking into account the characteristics of the region, by sub-basins (precipitation, evaporation, climate change, scarcity, groundwater, water quality, etc.);
- Assessment of baseline water demand per sector (agriculture, domestic, environmental etc.);
- Calibration of EN water planning model and comparison between the measured and modelled flows, by sub-basin (The suite of the configured water resources simulation analysis tools developed under the ENPM together with the configured use cases under the Nile DSS will be used to undertake the modelling);
- Assessment of economic, social and environmental baseline;
- Identification of strategic economic, environmental and social issues relating to proposed investments based on project characteristics, locations, experience from similar projects, expert opinion, and rudimentary analysis.

One of the key products of this phase will be updated profiles of the shortlisted prioritized investment projects. The existing state of the baseline will be established to form the base case scenario which will enable a comparison of the different scenarios to be undertaken.

Project team workshop
A project team workshop will be held prior to the Stakeholder Workshop to be held in November. The aim of the workshop will be discuss the scenarios and the short list of prioritised investment opportunities.

Stakeholder consultation
The findings of Task 2 will be presented to country representatives for comment and discussion. One of the key objectives of the workshop will be to confirm the short list of investment opportunities with the country representatives. A workshop is proposed to be held in November 2014 to present the findings of Task 2. As indicated above, this workshop will be combined with presenting the findings of Task 1, Situational Analysis.

Key deliverables

The key deliverables associated with Task 2 include:

- Strategic Investment Scoping Report. The report will identify the short list of investment projects for the EN Basin. In doing so the report will clearly outline indicators and criteria used to identify the short listed investment projects.

- Set of criteria / indicators that can be used by ENTRO to screen/scope investment opportunities;
- Workshop Report summarising the key issues and comments from the Consultation Workshop to be held in November 2014. The aim of the Stakeholder Workshop will be get confirmation of the prioritised, short list of investment opportunities in the EN-Basin and each of the 4 sub-basins.

Timeframe

Task 1 and 2 will be undertaken in parallel. The Strategic Investment Scoping Report will therefore be submitted together with the Situation Analysis Report in first week of November 2014. The workshop will be held in the third week of November 2014.

9.3 Task 3: Multi-Sectoral Analysis of Investment Opportunities (Scenario Analysis)

Objective
The key objective of Task 3 is to undertake a strategic analysis of the short list of water resources investment options/scenarios and prioritize the potential investment projects that are of regional importance and support regional cooperation between the four EN countries.

This will be achieved by developing a framework for analyzing investments (considering both national and regional perspectives), including methodology, objectives, criteria, and indicators (reflecting inputs from strategic scoping) for evaluating potential investment projects.

Key activities

Analytical Framework and Scenario Building
Task 3 involves the development of an Analytical Framework, followed by Scenario Building. The key activities associated with development of the Analytic Framework and Scenario Building consists of four key steps, Conducting Optimization and parameter determination of scenarios, performing descriptive modelling by making use of simulation models to obtain detailed water system response to the different scenario configuration, sectoral analysis to identify values of indicators and criteria measures and multi-criteria analysis to prioritize scenarios.

- *Optimization and parameter determination of scenarios*: The first step of scenario analysis will be conducted to identify key optimized modelling parameters for each of the identified scenarios. This is will be conducted using the optimization based modelling tool ENMOS. The objective of this step is to identify the optimal values for key decision variables such as sizes of proposed reservoirs and their operation rules, planned irrigated agricultural area and their cropping patterns, water abstraction for irrigation etc. based on maximizing or minimizing a specified objectives (e.g. net benefits in the basin) subject to physical and policy constraints.

- *Water Systems Simulation:* During this stage detailed descriptive simulation modelling will be undertaken to analyse the various scenarios. Based on the

parameters obtained at the optimization step, an extended period of simulation will be carried out to simulate how the water system responds to the scenario configurations to get key time-series model output corresponding to each relevant sector such as hydropower generation, irrigation unmet demand, water availability and water balance at nodes, ecological reserves etc. Maximum use of existing modelling practice will be utilized to avoid the repetition of tasks. Simulation modelling tools available at ENTRO, set up and configured as part of the ENPM project, will be utilized for this task. Selection of appropriate simulation model from the ENTRO's inventory or the Nile Basin DSS tools will be carried out once all project profiles have been updated and draft version of scenarios are outlined.

- *Sectoral Analysis:* The objective of sectoral analysis is to translate simulation output into higher level indicators. This involves Economic, Environmental social impact/benefit analysis to be undertaken by the corresponding experts in the team. Appropriate tools from ENTRO inventory will be utilized to aid in this process.

- *Multi-Criteria Analysis of options:* Multi Criteria Analysis provides an appropriate tool for evaluating different alternatives. MCA describes a structured approach to determine overall preferences among different alternative options, where the options accomplish several objectives. Identification of performance criteria and weights shall primarily be conducted through stakeholder consultation which will be revised by the experts to resolve conflicting criteria and refine to produce the final list of specific system performance criteria and measures. As indicated above, Multi-criteria Analysis Toolkit developed at ENTRO and MCA component of Nile DSS are possible candidates which can be utilized to carry out this assessment. The Nile Basin DSS implements the MCA Decision Matrix has the capability to compares criteria for various scenarios, weighted by preferences in matrix form.

Stakeholder consultation

The findings of Task 3 will be presented to country representatives for comment and discussion. One of the key objectives of the workshop will be to confirm the final list of investment opportunities with the country representatives. A workshop is proposed to be held in December 2014 to present the findings of Task 3.

Key deliverables

The key deliverables associated with Task 3 include:

- Multi-Sectoral Investment Scenario Analysis Report. The report will list the final list of selected investment projects for the EN Basin;
- Analytical Framework Tool that can be used by ENTRO to assess and identify future investment projects;
- Workshop Report summarising the key issues and comments from the Consultation Workshop to be held in December 2014. The aim of the Stakeholder Workshop will be get confirmation of the final list of investment opportunities for

Timeframe

The Multi-Sectoral Investment Scenario Analysis Report will be submitted in first week of December 2014. The workshop will be held in the third week of December 2014.

9.4 Task 4: MSIOA Final Products

Objective
The prepare Investment Profiles for each of the selected investment projects identified in Task 3. The profiles will identify institutional, financing and sustainability arrangements necessary to support prioritized and sequenced investment options.

Key activities

The key activities associated with Task 4 include:

- Working closely with ENTRO to develop Investment Profiles (including location, information of potential benefits, challenges, and required next steps etc.). The Investment Profiles will be in the form of short (2-4 pages) factsheets that will be grouped according to theme, type, sub-basin, investment period, etc. Copies will be provided in both hard and soft (electronic) formats. The profiles will also provide information on institutional, financing and sustainability arrangements necessary to support prioritized and sequenced investment options;
- Assist ENTRO with the design and development of an interactive tool (that can be used offline or integrated with the ENTRO website) to explore the implications of various multi-sectoral investment options in an interactive manner.
- Development of an MSIOA Implementation Strategy and Action Plan. The plan should contain. The plan will include an investment timetable, project-evaluation framework and preliminary cost estimates for prioritized and sequenced regional investments;
- Stakeholder Workshop in December 2014. The workshop will be held in the third week of December 2014. The Investment Profiles will be presented for comment;
- Stakeholder Workshop in January 2015: The aim of the workshop will be to present and discuss the Draft *MSIOA Implementation Strategy and Action Plan* with *the* country representatives. A workshop is proposed to be held in the third week in January 2015.

Key deliverables

The key deliverables associated with Task 4 include:

- Individual Investment Profiles for each of the selected investment projects;
- MSIOA Implementation Strategy and Action Plan, including Workshop Report summarising the key issues and comments from the Consultation Workshop to be held in early 2015. The aim of the Stakeholder Workshop will be get confirmation of the MSIOA Implementation Strategy and Action Plan and Investment Profiles.

Timeframe

The individual Investment Profiles will be submitted together with the Multi-Sectoral Investment Scenario Analysis Report in first week of December 2014. The workshop will be held in the third week of December 2014. The MSIOA Implementation Strategy and Action Plan will be submitted in early January 2014. The workshop will be held in the third week of third week of January 2014.

10 WORK PROGRAMME

The work program for each of the four tasks associated with the study is outlined in Table 5.

Table 5: Work program for EN-MSIOA study

	Task/Activities	2014																2015				2015			
					September				October				November				December					January				February			
		jun	jul	aug	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4	W1	W2	W3	W4
1	**Inception Phase**																											
1,1	Data Collectetion																											
1,2	Consultation with client & Field Work																											
1,3	Inception Report																											
2	**Task 1 : Inventory and Situation Analysis**																											
2,1	Desk Review																											
2,2	Baseline mapping of the physical and social economic resource base																											
2,3	Basin wide water res. analysis (Water Budget, Dem/Supply & Water Availability)																											
2,4	Identify existing and planned projects (Hard and Soft)																											
2,5	Perform Climate change / variability risk assessment																											
2,6	Identify and Map Hot spot Area and Opportunities in the basin																											
2,7	Prepare and Deliver Preliminary Situation Assessment Report																											
3	**Task 2 : Strategic scoping of EN-MSI**																											
3,1	Determination of a Social and Environmental criteria for evaluation																											
3,2	Scoping of regionally-signif. MS. Options (e.g storage, irrig, hydro, w'shed..)																											
3,3	Identification and mapping of Stakeholders associated with each inves.																											
3,4	Assessment of major issues, hotspots, constraints/risks and Opportunities																											
3,5	Identification of strategic environmental and social issues for each project																											
3,6	Conduct Stakeholder consultation to examine investment options																											
3,7	Prepare and Deliver EN Multi sectoral Strategic Social and Environmental																											
4	**Task 3 : Scenario analysis**																											
4,1	Develop a framework for Analysis																											
4,2	Scenario building																											
4,3	Strategic analysis identify, prioritize and sequence projects of regional significance																											
4,4	Prepare and Deliver the EN Multi Sectoral Analytical Report																											
5	**Task 4 : MSIOA - Final product**																											
5,1	Prepare project profile																											
5,2	Develop an implementation strategy and action plan																											
5,4	Conduct Consultation Workshop																											
5,5	Prepare and Deliver the final strategy Report																											
	Deliverables																											
	Workshop																											
	Working days																											
	Physical coordonation meeting																											

11 WATER RESOURCES AND MODELLING TOOLS

11.1 Current modelling tools

As indicated in the assumptions, the Eastern Nile Multipurpose Optimization System (ENMOS) will be used as the primary modelling tool for the study. However, a number of other tools have been developed by ENTRO. The section outlines the existing capacity at ENTRO in terms of modelling tools, data and information system and previous modelling activities conducted which will assessed in terms of the providing inputs to the study.

Considerable effort has been made in component 1, Knowledge Base Development, of ENPM project to organize data that were collected from One System Inventory (OSI), public domain datasets, country level feasibility studies and master plans, Cooperative Regional Assessments (CRA) products as well as other ENTRO studies and documents.

11.2 Knowledge/information management systems

Data and information
Large data sets are presently available at ENTRO gathered primarily from one System Inventory project, Cooperative Regional Assessments (CRAs), and other ENSAPs projects. This data collection has been enhanced during component 1 of ENPM project through the addition of public domain datasets and generation of new information.

Database system
The ENTRO database has been developed to handle both spatial and non-spatial datasets collected and compiled from different ENSAP projects. The central database has two separate databases (spatial and non-spatial), which are logically linked. It can also import datasets from the Nile DSS. The spatial database has been built using enterprise spatial database engine technology for systematically organizing and handling biophysical/environmental and, socio-economic datasets of the Eastern Nile. The non-spatial database is developed to organize and store time-series hydro-meteorological, characteristic and parameter datasets, which are logically linked to the spatial datasets. Data series and applications that feed into ENTRO web portal such as web mapping and time series model data manager are stored in this database. It is expected that these datasets will be enhanced and improved in quality over time depending on evolving analysis needs.

Nile basin DSS Database
As part of the Nile DSS development initial phase, data compilation was carried out to collected and organized relevant dataset vital for modelling water resources systems. The Nile DSS maintains a comprehensive database containing dataset collected from different sources and these datasets are made available through an interface which is part of the NB DSS package called a database manager tool.

Toolkits and Data portals
ENTRO has developed toolkits and Portals to assist organize and disseminate information. Different toolkits are produced by sub-basin and thematic areas are made available in an easy-to-use interactive setting under Microsoft Excel

functionality. Furthermore, ENTRO web portal provides easy access to information that would be useful to the MSIOA study.

11.3 Analytical Tools

Currently ENTRO maintains a suite of modelling tools, configurations and interactive toolkits document. Table 66 outlines some of the main models and Toolkits available at ENTRO and modelling tools that are provided through the Nile basin DSS frame work.

Table 6: Analytical currently available at ENTRO developed under ENRM and Nile Basin DSS modelling framework

Functions	***Available Tools***
River Basin system Simulation and Optimization Tools	• RiverWare • Ribasim • HEC-RESSIM • Mike Basin platform in Nile DSS • ENMOS
Hydrologic Model (rainfall runoff)	• HEC-HMS • SWAT •
Hydraulic Models	• HEC-RAS • Hydrodynamic modelling (NILE DSS)
Irrigation and Crop Models	• CropWAT • EN Irrigation Toolkit
Other tools	• EN Irrigation and drainage tool-kit • EN Power Trade Tool-kit • EN WSM Tool-Kit • EN Multi-Commodity Trade Model • Sudan Agro-Economic Model • Egypt Agro-Economic Model • Specialized models (e.g. Geospatial Model for Soil Erosion) • Economic Analysis • EN Watershed Toolkit • Soil erosion process model Nile DSS • Time Series analysis toolkit Nile DSS • Ensemble generator (for probabilistic analysis)
Decision Analysis tools	• Multi-criteria Analysis Toolkit • MCA component of Nile DSS • Scenario management of Nile DSS • Multi-objective optimization Nile DSS • Economic analysis tools Nile DSS • ENMOS

11.4 Previous modelling activities in the EN

Two of the significant modelling activities conducted are modelling activities conducted as part of the ENPM project that was conducted to support ENTRO and case study projects modelled under the Nile Basin Decision Support System (DSS) on project cases at national as well as trans-boundary levels.

ENPM developed customized models to support ENTRO activities by using public domain-spreadsheet models and tools and models currently used in the Nile DSS to develop water balance models and schematics for each Eastern Nile basin and sub-basin. Significant modelling effort has been carried out under the project by consultant and in house experts. The modelling tools that were employed during these activities include SWAT, River Ware, RIBASIM, Mike Basin, Nile-DSS, and Eastern Nile Multipurpose Optimization System (ENMOS). Table 77 summarizes some of the main modelling activities and summary of description that were compiled from the corresponding reports submitted to ENTRO.

Table 7: Modelling activities on Eastern Nile

Title	***Remark***
Development of the Eastern Nile Water Simulation Model	**Objective** To carry out a simulation analysis of the Eastern Nile (EN) basin for a number of identified scenarios, measures and strategies on critical EN issues like water infrastructure development and climate change.
	Type of model employed: RIBASIM (River Basin Simulation Model) RIBASIM (River Basin Simulation Model) is a generic modelling package for simulating the behaviour of river basins under various hydrological conditions.
	Summary Description : • Monthly time scale model developed for the entire Eastern Nile basin to assess present and future basin conditions under different development and hydrological conditions. • River flow were derived for distinguished nodes in the basin based on natural flow at key stations; the derived flows are from 1900 to 2002. • This model contains scenarios which were derived as a combination of hydrological scenarios, agricultural scenarios, climate change scenarios, land use change scenarios, and management scenarios.
Eastern Nile RiverWare planning model	**Objective** To analyze multi-objective management and development strategies for the principal Eastern Nile sub-basins including the Blue Nile, Baro-Akobo-Sobat, Tekeze-Setit-Atbara, and portions of the White Nile and the Main Nile.
	Type of model employed: RiverWare RiverWare contains a flexible modelling environment that uses both an object-oriented workspace environment and rule-based policy language that allows a robust simulation

	of complex operational decisions and policies that govern the management of reservoir systems.
	Summary Description : • RiverWare model was setup on monthly Time step of for the period of 1956-1991. • Developed into a baseline condition representing current infrastructure and known management practices, and then configured to represent twelve potential proposed infrastructure development projects. • A simplified representation of the basin with selected number of potential infrastructure developments. • Configured to be utilized to investigate reservoir operations and management rules • Analysis was conducted on the simulated outputs of five selected configurations of development in the Blue Nile, each using a different variety of proposed reservoirs
Eastern Nile Multi-Purpose Optimization System (ENMOS)	**Objective** developed an optimization system that allows for selecting the optimal values for key decision variables (e.g. reservoir releases, cropping patterns, etc.) in order to maximize or minimize selected objectives (e.g. maximizing net benefits in the basin) subject to constraints (e.g. related to water, irrigated areas, budgets, physical infrastructure limitations, etc.).
	Summary Description : This modelling tool is developed in house by ENTRO professionals, with the support of World Bank and University College of London specialists, uses GAMS optimization software linked to an Excel Interface for inputs and outputs.
Water balance model for Eastern Nile basin	**Objective** To develop an operational water balance model and schematics for each sub-basin of the Eastern Nile indicating the basic water balance from best available information and providing hydrologic inputs for the Eastern Nile Planning Model.
	Type of model employed: SWAT (The Soil and Water Assessment Tool) SWAT is a semi distributed hydrological model which is simple, flexible and robust enough to be applied for different scale basins. It is an open source model and has been widely applied worldwide to develop water balance models.
	Summary Description : • SWAT model has been configured for forty years of simulation from in the period of 1960 to 2000.For the four main sub-basins. • Data collected as initial part of modeling activity includes, DEM, land use land cover, soil map, weather data (Remote sensing and observed), flow data and

	etc. • Sensitivity analysis and model simulation have been carried out. An auto calibration tool "SWAT-CUP4has been used for this model calibration and uncertainty analysis. • Additional analysis has also been performed to compare the water availability with respect to the environmental flow requirements at the representative locations of the four basins. • Scenario analysis was carried out for a total of 20 scenarios have been developed and simulated and compared with the long term base scenario exogenous (drought and the climate change scenario) endogenous (development scenarios) combination of both exogenous and endogenous together
Water Resources Modelling of Abbay - Blue Nile - Main Nile.	**Objective** To refine and upgrade the existing schemes by including additional irrigation abstraction sites, Lake Tana and planned cascade of hydropower dams and analyze the impact of these schemes on the overall water balance of the basin, water availability downstream of Grand Ethiopian renaissance dam, irrigation water abstraction and hydropower generation of existing schemes in Sudan and Egypt.
	Type of model employed: Hec-ResSim (Reservoir simulation model) Hec-ResSim is used to model reservoir operations at one or more reservoirs for a variety of operational goals and constraints. It simulates reservoir operations for flood management, low flow augmentation and water supply for planning studies, detailed reservoir regulation plan investigations, and real-time decision support.
	Summary Description : • The simulation of the Hec-ResSim model is done using the historical time series data from 1954 to 1980 on monthly time step. • For the simulation of future and potential situations and system configurations the Hec-ResSim contains a list of pre-defined scenarios and management actions • Scenarios were developed based on combination of different infrastructural scenarios on dam heights and consideration for historic climate variability as well as future climate change scenarios.
HEC HMS	**Type of model employed:** HEC HMS (Hydrologic Modelling System) The Hydrologic Modelling System (HEC-HMS) is designed to simulate the complete hydrologic processes of dendritic watershed systems. It includes many traditional hydrologic analysis procedures such as event infiltration, unit hydrographs, and hydrologic routing as well as procedures necessary for continuous simulation.

	Summary Description : ○ The model is simplified methods of hydrologic simulation with reduced number of parameters for model calibration and capable of modelling common types of hydraulic control structures with appropriate on and off features. ○ Time scale daily ○ Developed as part of the Eastern Nile Flood Season Monitoring program.

12 KEY DOCUMENTS AND INFORMATION SOURCES

As part of the Inception Phase each specialist identified key documents and information sources that would be of benefit to the study. A selected list of the documents identified is provided below. An internet based library housing all the documents identified by the project team during the Inception Phase was also established by the team leader. A link to the library was sent to the team members and ENTRO's staff (Annex 1: Architecture of library).

It should be noted that the list is not final. Additional documents and information sources will be identified as part of Task 1: Situation Analysis. A detailed review of the documents will also be undertaken as part of Task 1: Situation Analysis. This information will be used to prepare the Situation Analysis Report.

12.1 Irrigation sector

- ENTRO-Eastern Nile Irrigation and Drainage Study (ENIDS); Cooperative Regional Assessment (CRA) Study, BRLi, 2010:
- ENTRO-Eastern Nile Irrigation and Drainage Study (ENIDS); Engineering Diagnosis Study, BRLi, 2009:
- ENTRO-Eastern Nile Irrigation and Drainage Study (ENIDS); Pilot Study on Improving Water Use Efficiency and Productivity of the Existing Irrigation Schemes in Ethiopia and Sudan, SMEC, 2010:
- Eastern Nile - One System Inventory (OSI), 2006:
- Regional Agricultural Trade Project (RATP); Assessment of the Irrigation potential:
- EWUAP, Agricultural Water Use and Water Productivity in the Large Scale Irrigation Schemes of the Nile Basin; W. Bastianssen / C. Perry, 2009.
- EWUAP, Agricultural Water Use in the Nile Basin, an Overview; Ian McAllister Anderson, 2008.
- Special Report-QUASI Crop and Food Supply Assessment Mission to Sudan, 2012:
- Egypt National Water Resources Plan 2017, 2005:
- Others: Other documents reviewed/collected include national polices and strategies on agriculture, water and irrigation, sub basin master plan studies(Abay, Tekeze, Baro Akobo Integrated Development Master Plan Studies-Ethiopia) and feasibility studies of irrigation schemes (Ribb, Megetch, Upper Beles, Anger, Negesso schemes in Ethiopia). The documents will give use full information for the next phases of the MSIOA study.

12.2 Hydropower sector

- ENTRO – Eastern Nile Power Trade Investment Study – EDF/ SW and others. Phase I: Assessment for cooperation – 2007, and phase II: FS for Electrical interconnection – 2008.
- ENTRO – Ethiopian/Sudan Transmission interconnection – Fingrid Oyj / SOGREAH Consultants/HIFAB OY – 2006
- ENTRO – JMP1 working papers 1 and 2
- NBI – Comprehensive Wide Basin Study – RSW, Fichtner and PB – Nov 2011.
- NBI – Preliminary Basin Wide Study – May 2008.
- EAPP – Regional Power System Master Plan and Grid Code Study – May 2011 – SNC Lavalin/PB.
- Sudan long and medium term power system plans – Expansions and investment planning – Lahmeyer international – Dec 2013
- Ethiopia – Ethiopia Power System Expansion Master Plan Study – interim report – Parsons Brinckerhoff – Nov 2013.
- Pre-FS for Bahr El Jabal Hydropower project in South Sudan – SMEC international – Nov 2013;
- The Feasibility Study of Bilateral Electrical Interconnection between Sudan and Egypt: Final Report 2012.

12.3 Environment and social sector

- Eastern Nile Power Trade Program StudyStrategic Environmental and Social Assessment (2007);South Sudan: The Rapid Water Sector Needs Assessment and a Way Forward (World Bank, January 2013);
- State of Nile River Basin (2012);
- The Comprehensive Agricultural Development Master Plan (CAMP) of the Republic of South Sudan Situation Analysis (Preliminary Results) (Japan International Cooperation Agency, August 2013);
- Sudan Post Conflict Environmental Assessment (UNEP, 2007);
- Multipurpose Development of the Eastern Nile, One–System inventory report on water resource related Data and information Sudan (ENTRO, 2006);
- Watershed Management Fast Track Project, Sudan Detailed Project Preparation Study: Environmental and Social Interim Report (SWECO, 2007);
- Cooperative Regional Assessment (CAR) for Watershed Management: Transboundary Analysis Country Report: Sudan (2006);
- Cooperative Regional Assessment (CAR) for Watershed Management: Transboundary Analysis Country Report: Ethiopia (2006);
- Cooperative Regional Assessment (CAR) for Watershed Management: Transboundary Analysis Country Report: Egypt (2006);
- Ethiopia's Climate-Resilient Green Economy: Green economy strategy
- Ethiopia Environment Outlook: Environment for Development (UNEP, 2008)
- Ethiopia's Draft Programme of Adaptation to Climate Change; Multipurpose Development of the Eastern Nile, One–System inventory report on water resource related Data and information: EGYPT (2006)

12.4 Country consultations

Country consultations were undertaken over the period 26 May to 8 June 2014. Three of the four Eastern Nile Basin countries were visited during the period, namely Ethiopia, South Sudan and The Sudan. The visit to Egypt were postponed due to the political situation in the country immediately post the presidential elections. ENTRO country representatives, Mr. Jackson Elisoma (South Sudan) and Mr. Ammar Abdala (The Sudan) assisted the team in setting up meetings in each of the respective countries. The schedule of the country consultations is presented in **Table** Table 5. The Country Consultation Report (September 2014) contains a list of the people met during the consultations and minutes of the meetings.

The objective of the country consultations (CC) was twofold. Firstly to collect and update data and documents from each of the countries visited. Secondly, through consultation with government departments and universities, identify key priorities for each country regarding water resources planning and investment.

As part of the country consultation process a concept note was sent by ENTRO to the representatives of each ministry and institution to be visited. The aim of the concept note was to inform stakeholders of the objectives of the MSIOA Projects and the key components of the study.

The project team also prepared for the consultations by:

- Identifying and collecting information available at ENTRO. An internet based library housing all the documents was established by the team leader. A link to the library was sent to the team members and ENTRO's staff.
- Identifying potential information gaps that needed to be updated, by sector and by country;

Table 5: Schedule of the country consultation

Country	Date	Activity/Description	Responsible Office
ENTRO	Mon May 26	Team Meeting at ENTRO Office, Addis Ababa; Finalize consultation plans	• MSIOA Team Leader • ENTRO
Ethiopia	Tue, May 27	• Ministry of Water & Energy • Water Supply & sanitation • Meteorology • Ministry of Electricity and Utility (EEPCO)	Office of ENSAPT Leader, Ethiopia
		• Environment • Agriculture • Academia • Other relevant sectors, TBD	Office of ENSAPT Leader, Ethiopia
Travel	Wed, May 28	Travel to Juba, RSS	
RSS	Thu May 29	• Ministry of Electricity, Dams, Irrigation and Water Resources • Water Supply & sanitation • Meteorology	Office of ENSAPT Leader, RSS

Country	Date	Activity/Description	Responsible Office
		• Electricity (Utility)	
	Fri, May 30	• Environment • Agriculture • Academia • Other relevant sectors, TBD	Office of ENSAPT Leader, RSS
Travel	Sat, May 31	Travel to Sudan	
Sudan	Sun, June 1	• Ministry of Water Resources and Electricity • Dam Implementation Unit (DIU) • Water Supply & sanitation • Meteorology • Electricity (Transmission company)	Office of ENSAPT Leader, Sudan
	Mon, June 2	• Environment • Agriculture • Academia • Other relevant sectors, TBD	Office of ENSAPT Leader, Sudan
Travel	Tue, June 3	Travel to Egypt **(Postponed)**	
Addis Ababa	Wed, June 4	• Consolidation of data and documents collected • Finalizing the inception report structure • Adaptation of the work plan with ENTRO	
	Thu, June 5		
ENTRO	Fri, June 6		

ANNEX 1: ARCHITECTURE OF THE LIBRARY

The library is divided into the following sectors. Each sectos further divided in the four EN-Basin countries, namely Egypt, Ethiopia, South Sudan and Sudan.

- Irrigation
- Hydropower
- Environment/wetlands
- Hydrology
- Navigation
- Fisheries
- Tourism
- Institutional
- Socio economic
- Sub basins
- Country
- Map_GIS_Tool
- Other
- New
- EN-MSIOA deliverables
- JMP: Joint Multipurpose Project

ANNEX 2: Status of the EN Knowledge Base Development

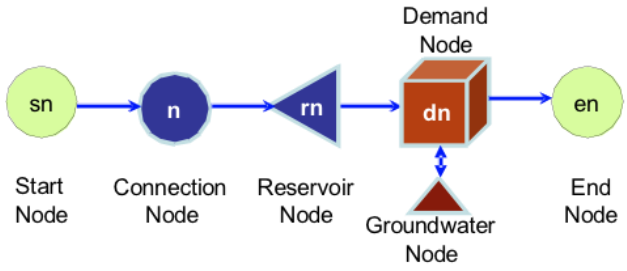
A Brief Description of ENMOS

The EN Multi-Options Scoping Optimization model was initially configured under the JMP Scoping Study and is a simple economic optimization in a basin context.

SCHEMATIC

A critical precursor to the modeling framework is to develop a workable and useful schematic for the EN. This is to be composed of simple primitives such as different nodes, shown in figure B.1, and connectors illustrating the connection between them. The schematic has to be as simple as possible to reflect data availability at this preliminary stage of scoping options. However, it should be detailed enough to represent the key joint multipurpose options and their impacts.

Figure B.1 Schematic for Upper Kabul River Basin



OBJECTIVE FUNCTION

Objective function:

Maximize

$$Net\_Benefits, Z = Irrigation\_Benefits \sum_{c}\sum_{dn}(AREA_{c,dn} * YIELD_{c,dn} * NETBEN_{c,dn})$$

$$+ Power\_Benefits \sum_{rn} HPGEN_{rn,t} * HPBEN_{rn,t}$$

$$- Costs(storage, pumping, conveyance, treatment)$$

Subject to: Constraints (technical/continuity, resource)

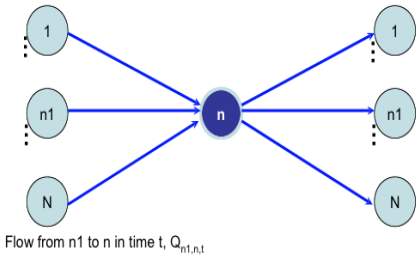
Key decision variables (computed by model):

Z	Objective function value
Q(n,n1,t)	flow from n to n1 at time t
QD(n,d,t)	qty demanded at n for demand type d at time t
SR(n,t)	storage in reservoir n at time t
SRMAX(n)	max storage in reservoir n (could be specified or optimized)
SGW(n,t)	storage in groundwater at n in t
RFS(n,n1,t)	return flow from sys use at n to n1 at time t
AREA(c,n)	area at n with crop c
HPGEN(n,t)	hydropower generation at each location n in time t

CONSTRAINTS

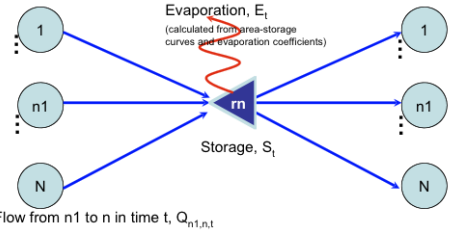
Figure Constraints in Modeling Framework

Connection Node



$$\sum_{n1} Q_{n1,n,t} = \sum_{n1} Q_{n,n1,t}$$

Reservoir Node

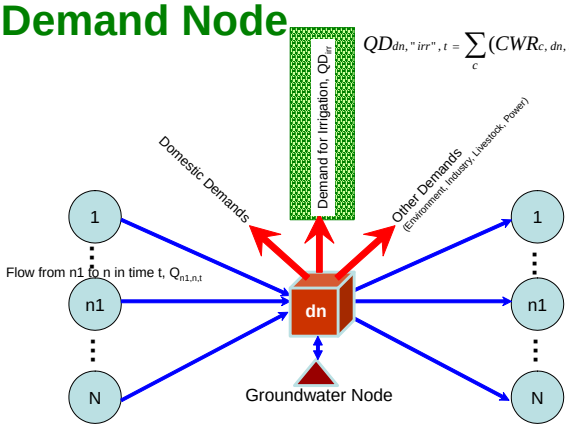


$$\sum_{n1} Q_{n1,rn,t} + S_{rn,t-1} = \sum_{n1} Q_{rn,n1,t} + S_{rn,t} + E_{n,t}$$

$$MWH_{rn,t} = MIN\{2.73 * \eta_{rn} * S_{rn,t} * HEAD_{rn,t}, 729.6 * MW_{rn} * LoadFac_{rn} * FacUtil_{rn}\}$$

Demand Node

$$QD_{dn,"irr",t} = \sum_{c} (CWR_{c,dn,t} * AREA_{c,dn})$$



$$QINFIL_{dn,t} + SG_{dn,t-1} = QPUMPING_{dn,t} + SG_{dn,t} + LOSS_{n,t}$$

$$\sum_{n1} Q_{n1,dn,t} = \sum_{n1} Q_{dn,n1,t} + \sum_{d} QD_{dn,d,t}$$

Some of these constraints are shown visually in figure B.2. In addition, there are a number of other constraints associated with:

- return flow
- hydropower generation
- minimum demand for domestic, environmental, and other uses
- crop water requirements for irrigation
- capacity constraints: reservoir storage, pumping, conveyance, hydropower
- minimum/maximum area constraint for irrigation
- capacity constraints: groundwater (will be revisited, depending on importance in this basin for the scenarios considered and information available)
- budget constraints
- special scenario constraints

ANNEX 3: Status of the EN Knowledge Base Development

2.B MIKE BASIN AND NILE BASIN DECISION SUPPORT SYSTEM – AN INTEGRATED RIVER BASIN PLANNING MODEL

APPLICATION

Objective

MIKE BASIN was developed to provide quantitative analysis of integrated water resource management for the Eastern Nile Basin and multi-sectorial analysis using the Nile-DSS indicators to assess constraints and risk opportunities.

Description

MIKE BASIN is a multi-purpose, GIS-based river basin simulation package, designed for analyzing water sharing problems and environmental issues at international, national and project scales. MIKE BASIN is powerful, yet simple to use, with various analysis capabilities for water resources engineering. MIKE BASIN's framework was used to develop the NBI-wide Nile Basin Decision Support System (NB-DSS), which is used to configure model scenarios and then to evaluate economic, social and environmental indicators. The Nile Basin DSS is intended to serve as a water resources-based DSS for use in the context of an international river basin.

NB- DSS is a compressive analytical frame work that integrates:

- An information management system(GIS, database, processing tool)
- A water resource modeling system
- A decision making/analytical tool (optimization, benefit-cost analysis, multi - criteria analysis)
    - Scenario management (including indicators)
    - Multi-objective optimization
    - Economic analytical tool

Intended Users

The intended users for this model are technical professionals such as those in academia, ministries of water and natural resources management, power utilities and research institutions, and those exploring analysis of cascade options, hydrology and water demand .

What are the model's capabilities?

The MIKE BASIN model is well suited for water resources project, because geographical information available in national resources databases and can be utilized directly and also provide basis for display of future water resources developments.

MIKE BASIN is well suited for water resources project, because it provides a simple, yet powerful framework for managers and stakeholder to address multi-sectorial water allocation in the river basin. MIKE BASIN represents all elements of water resource modeling: users, reservoirs, hydropower, surface water, groundwater, rainfall-runoff, and water quality. Its object-oriented and open-ended code allows users to write their own Visual Basic rules, and make their own decision support interfaces. MIKE BASIN uses the full strength of GIS and database integration and is ideal for communicating with non-technical audiences.

How do these functions benefit the Eastern Nile?

The Eastern Nile Basin has very large development potential in terms of multipurpose water storage, increased hydropower production and increased agriculture production and rural income. However, these development options also have potentially significant risks to important critical natural habitats and environmental assets, to the complex livelihoods patterns on the densely region, and to the sustainability of existing water uses, and extensive development of irrigated agriculture. As such, MIKE BASIN model's capability to be used as a tool for analyzing the operation of alternative cascade development options and filling scenarios under a range of hydrological conditions for the Eastern Nile is of particular importance in attempting to understand the impacts of possible development options on the hydrology of the Eastern Nile. The MIKE BASIN model can be used to examine the joint water resources development possibilities on the Abbay/Blue and Main Nile taking into account economic, social and environmental sustainability issues. In addition, the capabilities of the model, detailed above, can all be applied towards the Eastern Nile basin area.

Examples of Insights using the Model

MIKE BASIN has been used by ENTRO to address many insights regarding hydropower development along the Abbay/Blue Nile. For example, scenarios were analyzed to understand the effect of hydropower development along the Eastern Nile river network on existing downstream infrastructure, such as the High Aswan Dam, and its associated reservoir level, inflow, energy production, impacts on the overall basin, and other such parameters, under different cascade scenarios. The model has also helped by giving initial guidance for developing dynamic filling strategies, taking into consideration both initial levels of HAD and inflow to Ethiopia's soon to be operational Grand Ethiopian Renaissance Dam (GERD). Using the MIKE BASIN model, ENTRO has insights on the potential for hydro-power production in the basin under different proposed infrastructures.

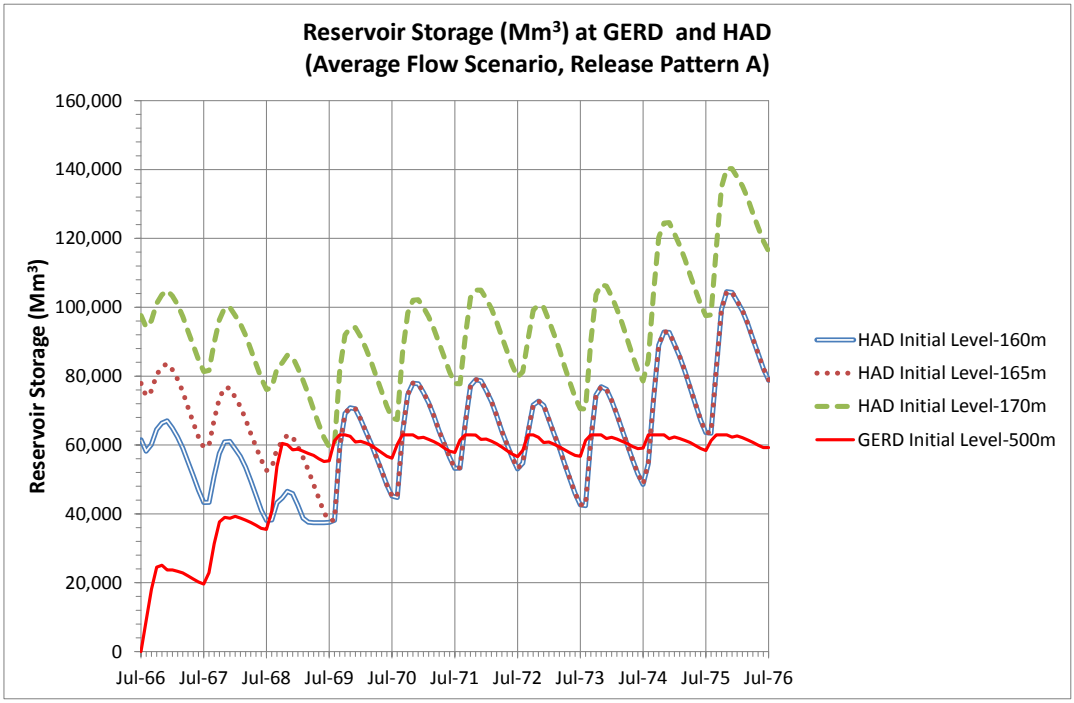


Figure2: Reservoir Storage (Mm3) at GERD and HAD (Average Flow Scenario, Release Pattern A, HAD Initial Levels 170m, 165m and 160m)

Table1: Summary of Filling Trials for GERD Reservoir

Hydrological Scenario / Release Pattern	Start Date	Initial HAD Level masl	Initial HAD Live Storage Vol. BCM	Min. HAD Level masl	Min. HAD Live Storage Vol. BCM	Time to fill GERD to MOL Months	Time to fill GERD to 50% Live Storage Months
Average Flow / A	July 1966	170	66	159.2	27.8	15	28
Average Flow / B	July 1966	170	66	156.2	19.7	15	25
Average Flow / D	July 1966	170	66	165.3	47.3	27	39
Average Flow / A	July 1966	165	46.3	**150.3**	6.4	15	28
Average Flow / B	July 1966	165	46.3	**150.1**	5.9	15	27
Average Flow / D	July 1966	165	46.3	**155.0**	16.4	27	39
Average Flow / A	July 1966	160	29.9	**150.1**	5.8	15	28
Average Flow / B	July 1966	160	29.9	**150.1**	5.8	15	27
Average Flow / D	July 1966	160	29.9	**150.3**	6.3	15	26
Moderate Drought / A	July 1992	170	66	**150.0**	6.0	16	28
Moderate Drought / D	July 1992	170	66	**150.0**	5.8	27	40
Moderate Drought / A	July 1992	165	46.3	**150.0**	5.7	16	28
Moderate Drought / D	July 1992	165	46.3	**150.0**	5.7	27	39
Moderate Drought / A	July 1992	160	29.9	**150.0**	5.7	16	28
Moderate Drought / D	July 1992	160	29.9	**150.0**	5.7	27	39

Severe Drought / A	July 1983	170	66	**150.0**	5.7	27	63
Severe Drought /D	July 1983	170	66	**150.0**	5.7	63	64
Severe Drought / A	July 1983	165	46.3	**150.0**	5.7	27	63
Severe Drought /D	July 1983	165	46.3	**150.0**	5.7	63	64
Severe Drought / A	July 1983	160	29.9	**150.0**	5.7	27	63
Severe Drought /D	July 1983	160	29.9	**150.0**	5.7	63	64

Analysis of the results of the preliminary filling trials for the GERD reservoir using MIKE BASIN simulation models suggests that it should be possible to manage the filling of GERD reservoir, while meeting water demands downstream provided that:

- Water level in HAD reservoir is at an elevation of El. 170m or higher at the commencement of filling of GERD reservoir, and
- Releases are made as provided for in the release patterns examined,
- Appropriate sharing arrangements are considered to ensure that water storage within the Eastern Nile river system is allocated on an equitable basis to foster cooperation and confidence building between EN member countries. Such arrangements might, for example, be based on live storage within the HAD reservoir in Egypt not falling below the live storage volume in GERD,
- Appropriate safeguards are in place, in the form of agreements to release additional flow from GERD, in the event that water levels in HAD and Roseires reservoirs reach or fall below agreed levels indicating an unacceptable risk of water shortage for downstream users in the forthcoming months. This would include a provision that if live storage in HAD reservoir falls to or below an agreed lower value, releases would be made from the dead storage zone in GERD.

What are benefits of the model?

The following demonstrate some of the benefits of integrating MIKE BASIN into ENTRO's modeling collection:

- Ease of use for large catchments like the Eastern Nile Sub-basins
- Optimizes basin level water allocation and distribution across various demands
- Keeps modeling simple yet provides in-depth insight for planning and management
- GIS interface makes presentation of results easy to understand, especially for policy making purposes

How was it developed?
MIKE BASIN model was developed based on the operational set-up structure used in developing the Nile Basin DSS and hence reflects many of the latter's associated quality control processes (i.e. sub-basin inflow hydrographs). The incremental flows along the Blue Nile river system have been re-evaluated to confirm consistency between simulated flows and gauge measurements at key locations; in essence, the simulated results have been validated against historical values. The configuration of the Mike Basin model of the Eastern Nile is illustrated in the schematic diagram Figure1.

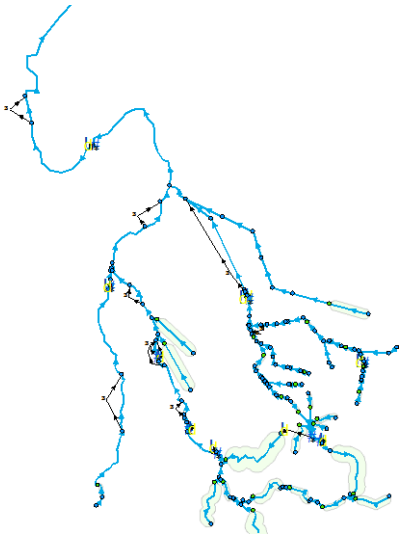


Figure 1 MIKE BASIN model Schematics

The MIKE BASIN model is developed in the Nile Basin DSS in house capacity by the interns during the second and third batch of internship program.

How can tool be expanded? How can it be improved?
The model's capabilities are being expanded to derive further detailed analysis that examines filling strategies for GERD reservoir, holding constant initial levels of the HAD reservoir. In addition, the model is also being used to examine different release patterns from GERD chosen to provide a greater flow downstream. The model's Multi-sectorial Opportunity Analysis can be done using the Nile DSS indicators. Further, the model has the ability to include even more dam characteristics such turbine type and outlet works information, making for a more comprehensive analysis of impacts of upstream dam construction on the remainder of the basin.

There are plans to also improve the model by further refining of the input data:

- Reservoir characteristics(physical heightening of Roeseries dam, and operational rules)
- Climate change scenario can be added

Nile DSS indicators are social-economic, environmental or hydrological characteristic that can be quantified across different model scenarios, for the purpose of choosing between alternative development and management scenarios

TECHNICAL SPECIFICATION

Technology platform
Mike Basin code is integrated within ArcView GIS and uses all ArcView GIS functionalities

Input Datasets and Sources
The following are input data to the model:

Dataset	Comment	Source
Hydrological data	Flow time series	ENTRO
Energy Demand	Annual and monthly demands	EN Power Trade Study
Irrigation water Demand	Irrigation demand per country and per scheme	EN Irrigation and Drainage Study
Cascade development information		Ethiopian Electric Power Corporation, Millennium Hydroelectric Project

Methods of updating data
The time series data will be regularly and consistently updated by ENTRO

Typical Outputs
Mike BASIN can simulate different results such as:

- Power generated
- Loss from the system
- Water demand deficit
- Out flow
- Inflow
- Reservoir water level

OTHER

Other Details
The data used is of Medium Sensitive to sharing.

Availability through ENTRO
License needed to operate the model

ANNEX 4: Status of the EN Knowledge Base Development

2.C: RIVERWARE RESERVOIR AND RIVER BASIN SIMULATION AND OPTIMIZATION MODEL.

APPLICATION

Objective
RiverWare was developed as a tool in to simulate potential alternative management practices in the basin like water infrastructures and irrigation water loss.

Description
RiverWare is developed by the Center of Advanced Decision Support for Water and Environmental System at the University of Colorado starting in 1993. RiverWare is a reservoir and river basin simulation and optimization modeling environment ideal for evaluating operational policy, system optimization, water accounting, water rights administration, and long-term resource planning. RiverWare is a customizable modeling environment in which the user creates a basin network model and selects appropriate methods for simulating the physical processes on each basin feature. Operating policies are expressed via rules that are interpreted during the simulation process. Its user-friendly interface and data processing and graphical output utilities simplify communicating technical information to stakeholders. The Eastern Nile RiverWare Planning Model consists of the principal Eastern Nile sub-basins including the Blue Nile, Baro-Akobo-Sobat, Tekeze-Setit-Atbara, and portions of the White Nile and the Main Nile. Each sub-basin is modeled with the primary inflow tributaries, reaches, reservoirs, demand locations and stream gages. Infrastructure included in each model reflects the actual infrastructure during the period of simulation. Historical calibration model contains the major infrastructure in operation between 1956 and 1990. The Baseline model contains the infrastructure that is currently operational, and the Scenario Model contains the proposed future infrastructure andthe current infrastructure that will likely be operational into the modeled future period.

The RiverWare model uses hydrologic inflows as direct inputs to the model, as opposed to computing inflows using a rainfall-runoff approach. Historical inflows were used to calibrate baseline and scenario conditions whenever available. When gaged data was not available, existing inflows were extracted from previous modeling efforts. Average monthly demand is also incorporated in the model using historical demand data.

Intended Users
The intended users for this model are technical professionals such as those in academia, ministries of water and natural resources management, power utilities and research institutions to support analysis of cascade options, hydrology and water demand .

What are the model's capabilities?
RiverWare has the capability to model

- Hydrology and hydrologic processes of reservoirs, river reaches, diversions, distribution canals, consumptive uses, shallow groundwater interaction and conjunctive use
- Hydropower production and energy uses
- Water rights, water ownership, and water accounting transactions
- A range of time steps with multiple solvers including simulation, rule based simulation and optimization
- Provides changing policy objectives and also provides a selection of methods for modeling physical processes
- Provides construction kit for developing and running detailed, site-specific models includes an extensible library of modeling algorithms, several solvers, and a rich "language" for expression of operating policy

How do these functions benefit the Eastern Nile?
The RiverWare model has been used as a tool to analyze the consequences of infrastructural measures and cascade options. The Riverware model was calibrated to historical conditions, then configured to a baseline condition representing the current infrastructure and known management practices, and then instructed to represent twelve potential proposed infrastructure development projects. To demonstrate the utility of the RiverWare model, an analysis was conducted on the simulated outputs of five selected configurations of development in the Blue Nile, each using a different variety of proposed reservoirs. The full documentation on data set used, methodology followed and simulation results are given in the final report "ENPM RiverWare Modeling Report_FINAL". Having this modeling tool be part of ENTRO's modeling suit is beneficial to the Eastern Nile in general as ENTRO is able to train its network of technical professional stakeholders on its use and makes it available for further analysis.

Example of Insights using the Model
Using RiverWare model, ENTRO has insight on the potential for hydro-power production in the basin under different proposed infrastructures, and is able to quantify the inflow for existing downstream dams, for proposed scenarios and able to assess different filling criteria.

RiverWare offers a variety of engineering methods that can be used to simulate characteristics such as power generation and spillways, depending on the reservoir characteristics and information available, and some of these capabilities were used under ENTRO to provide insights into the EN's hydropower development potential. Specific capabilities from the model were selected and customized for each reservoir depending on the availability of data. Rules were developed in RiverWare that operate reservoirs to meet user-selected objectives. For existing or proposed reservoirs for which no operational guidelines could be identified, rules were developed that operate reservoirs to

meet target power demands. Like all rules in RiverWare, these are user configurable and the model user is able to change targets as needed. Specific details of each reservoir's operations are described in subsequent sections.

The baseline scenario of the model and alternative conditions were simulated make projections of future conditions. The RiverWare model was configured to simulate the period from 2018 to 2052, using the same 35 years of historical hydrologic data from 1956 to 1990. In other words, historical inflow data from 1956 to 1990 was used for the 2018 to 2052 time period in the baseline and scenario models. The model was calibrated to historical conditions, developed into a baseline condition representing current infrastructure and known management practices, and then configured to represent twelve potential proposed infrastructure development projects. The Scenarios that have been considered using RiverWare are:

- Scenario1: Renaissance 640
- Scenario2: Karadobi+Beko AboLow + Mendaya + Renaissance620
- Scenario3: Karadobi + Beko Abo Low + Mendaya Upper + Renaissance 640
- Scenaro 4: Beko Abo High + Mendaya + Renaissance 620
- Scenario5: Beko Abo High + Mendaya Upper + Renaissance 640

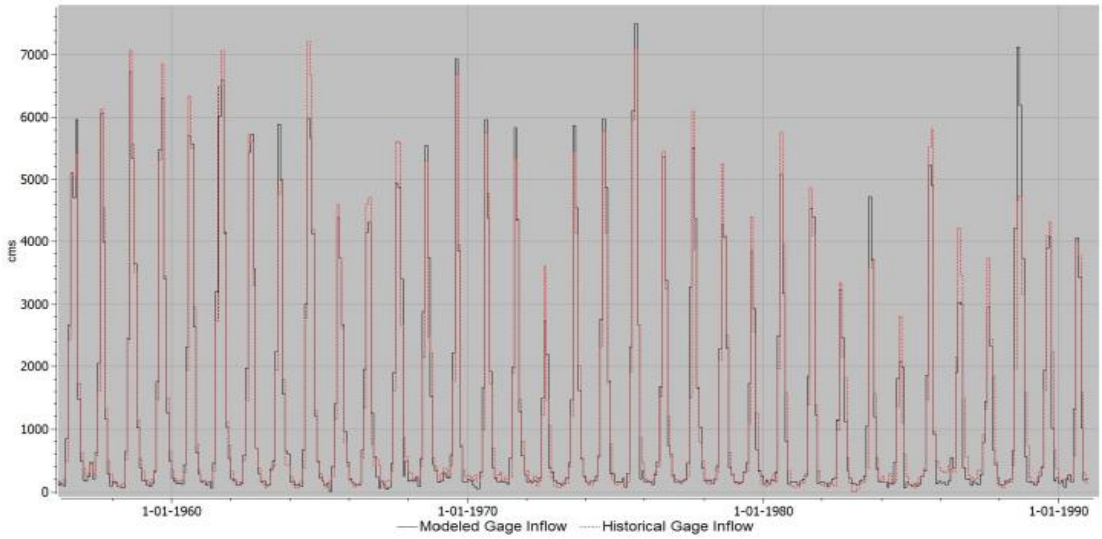


Figure 2 Flow calibration of Blue Nile, as measured at Khartoum

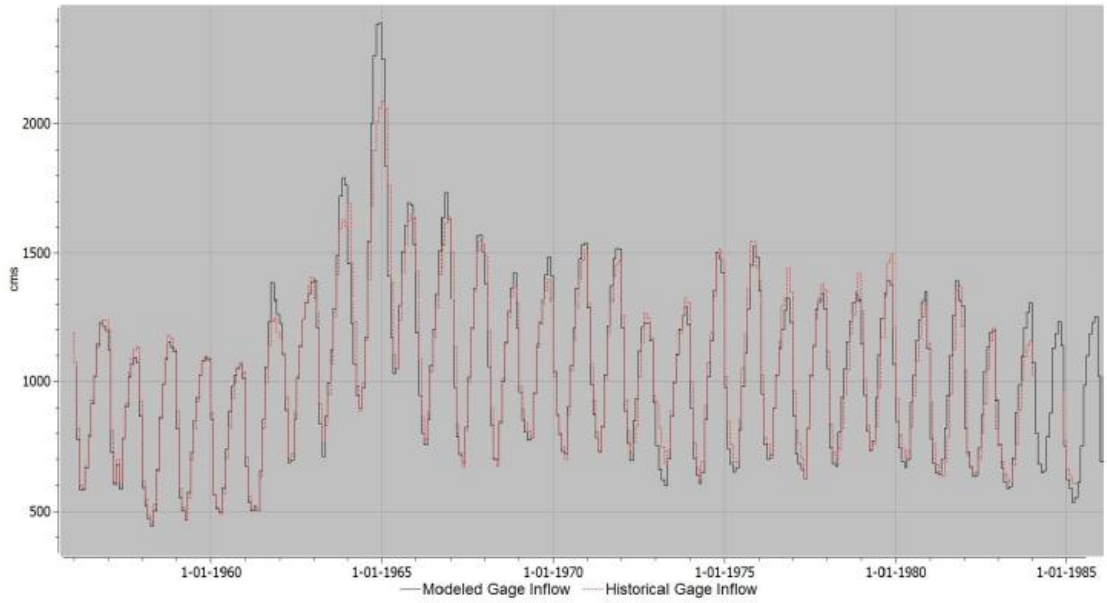
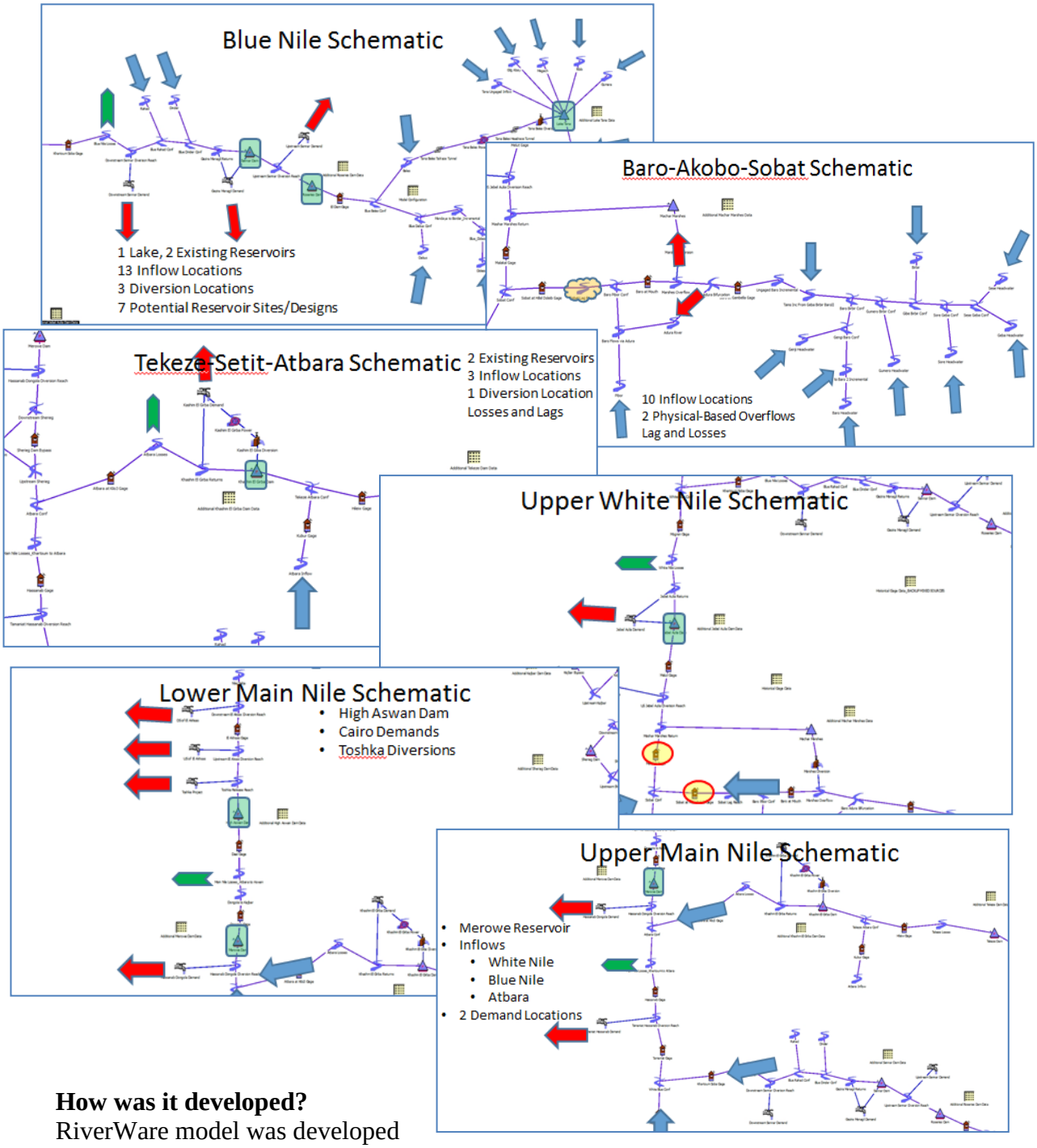


Figure 3 Flow calibration of White Nile at Melut

What are its benefits?

The following demonstrate some of the benefits of integrating RiverWare into ENTRO's modeling collection:

- It is useful for planning, designing, and simulating a complex river system
- Can provide real-time operational support
- Flexible policy modeling which can be used to test alternative policy operations for a specific region
- Prioritized rule structure
- Approximately 200 "Predefined Functions"
- Full range of Programming Functions(If-Then-Else, for Loop, While Loop, With Loop, etc)



How was it developed?

RiverWare model was developed by individual consultant (Kevin Wheeler P.E. and Steve Setzer P.E) from Water Balance Consultants, USA. ENTRO provided data for the model development, as well as quality assurance control for the input of data in the model. ENTRO oversaw the model's building processes and assumptions made, and then checked model output for validation. Finally, ENTRO reviewed the various reports made throughout the process (draft, final),

providing feedback where necessary. The development process was cost effectively completed, at an estimated budget of US$86,660.

Spatial/regional coverage
ENTRO has prepared RiverWare for the entire Eastern Nile region, which comprises of the Blue/Abbay River sub-basin, Tekeze-Atbara-Setit sub-basin, Baro-Akobo-Sobat sub-basin, and Main Nile sub-basin.

How can tool be expanded? How can it be improved?
Expansion and improvement plans are related to improving the model's capability and additional data to add more nuance to the model's functions. These plans constitute:

- New reservoir filling criteria
- Include plans to heighten the Roseires dam and its ensuing operational environment
- Add new Reservoir Operation Paradigms that simulate
    - Minimum Impact -> Run-of-River
    - Maximize Energy -> Ethiopia hydropower
    - Maximize Energy -> EN basin system hydropower
    - Maximize Net Benefit -> Quantify economics
- Refine existing schematics on
    - Projected Demands
    - Verify Evaporation Rates
    - Current Reservoir Operations
- Multiple hydrologic traces – climate change input

TECHNICAL SPECIFICATION

Technology platform
A general UNIX based river and reservoir modeling application with both operational and planning applications.

Input Datasets and Sources
The following are input data to the model:

Dataset	Comment	Source
Flow data	Monthly time series	NBI Work Product II-Stage I: NBI Work Product II-Stage II, NCS, ENTRO
Demand	Monthly water demand	NBI Work Product II-Stage I: ENTRO

Evaporation and evapotranspiration	Reservoir Evaporation	ENTRO
Reservoir data	Physical and operational characteristics of dams	NBI Work Product II-Stage I: NBI Work Product II-Stage II, ENTRO

Methods of updating data
The operation rules for existing dams will be updated by collecting actual operation characteristics used in at existing dams; time series data will be consistently updated

Preliminary model results
Some of the model's outputs are for reservoirs and include:

- Spill
- Inflow
- Outflow
- Evaporation
- Storage
- Elevation
- Power/energy
- Trubine release
- Water Use/ Depletion

Other Details
The data used is of Medium Sensitivity to be shared.

Availability through ENTRO
Needs license and ENTRO is going to give license to EN universities in order to use the RiverWare model for research use.

ANNEX 5: Status of the EN Knowledge Base Development

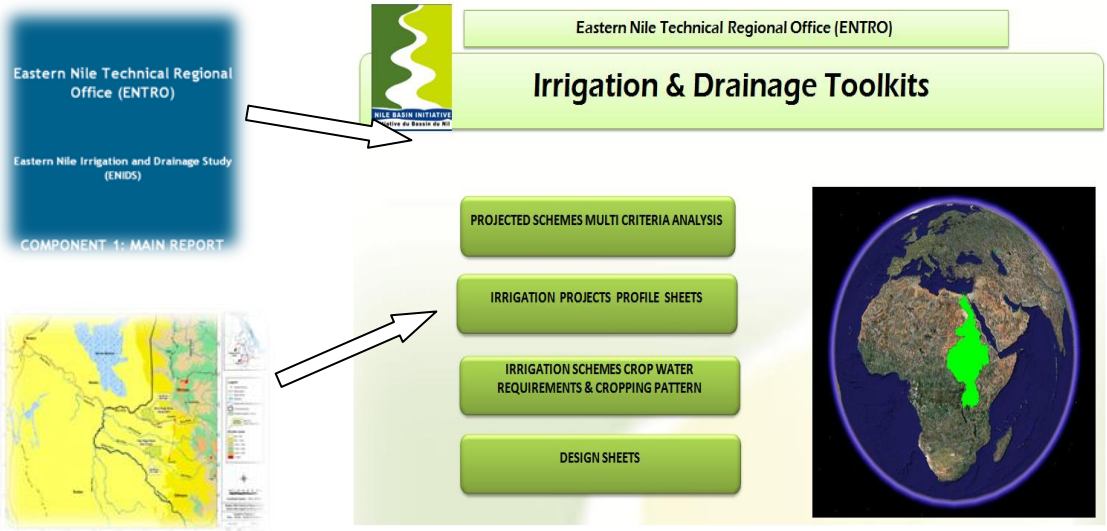
EASTERN NILE TECHNICAL REGIONAL OFFICE
EASTERN NILE PLANNING MODEL

EN IRRIGATION TOOLKIT

APPLICATION

Context

Large amount of fragmented knowledge and information from the CRA for ENID studies, country master plans, USBR studies, EIAs conducted under the ENID. Ease of accessibility for supporting decision making on a national and regional level.



Objective

Synthesize, consolidate, provide better access to information in a systematic manner that supports decision makers in EN in identifying and ranking and facilitating Irrigation projects development;; access to simple analytical tools useful for MCA and simplified design sheet for irrigation projects;

Description and components

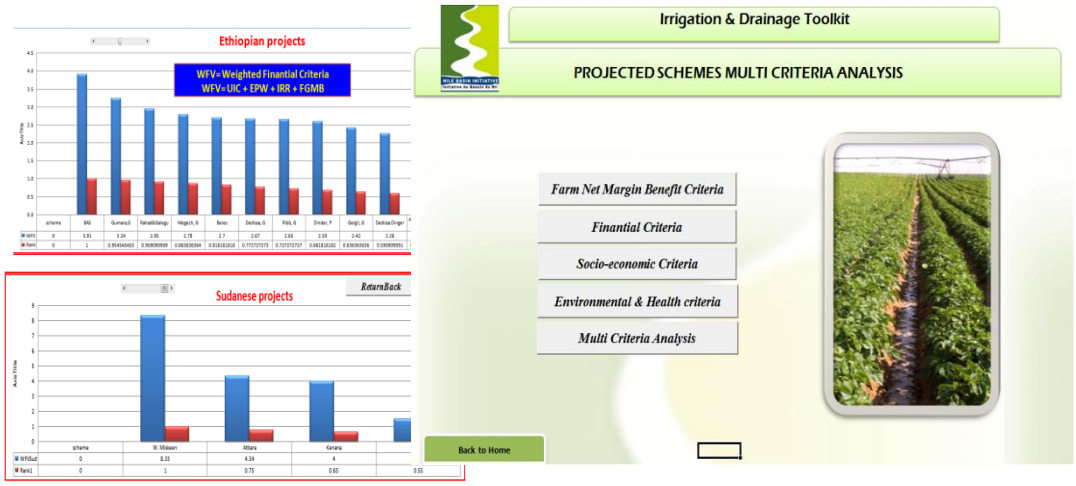
- Projected schemes multi criteria analysis: Ranking projects using different criteria.
- Irrigation projects profile sheets: Provide basic information about existing and potential irrigation projects in the EN.
- Irrigation schemes crop water requirement and cropping pattern: Provides a scheme based crop water requirement and cropping pattern for the 3 EN countries.
- Design Sheets: consolidated and automated design manuals from the countries

Intended Users

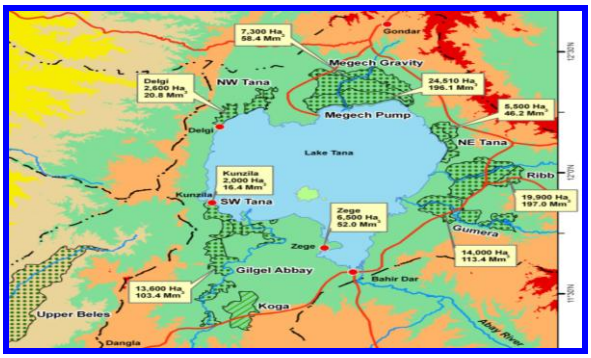
- Utilities
- Ministries of Irrigation across EN – finance, water, energy, environment..
- ENTRO/NBI centers
- Universities and outreach centers; other research centers
- Project planners and International consultants preparing feasibility and site specific studies for irrigation projects as part of detailed studies, reconnaissance.

What are the Toolkit's capabilities?

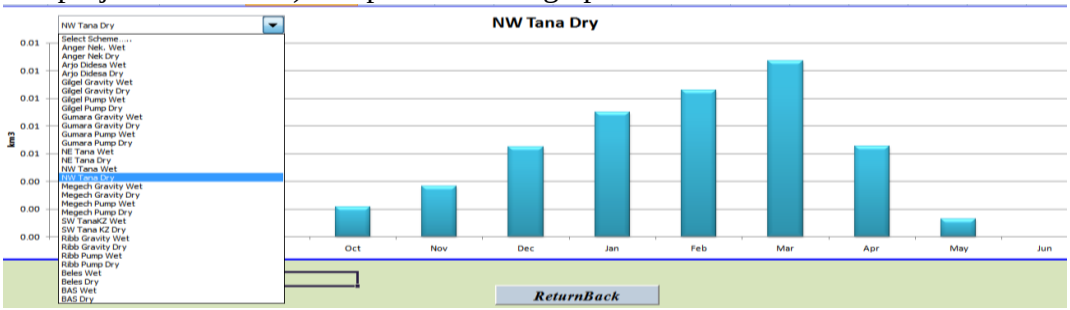
- Projected schemes multi-criteria analysis: Can assess the benefits and costs that the proposed investments could bring. Cost benefit analysis was mainly conducted for ranking projected irrigation schemes in Ethiopia (22 schemes) and Sudan (four schemes).



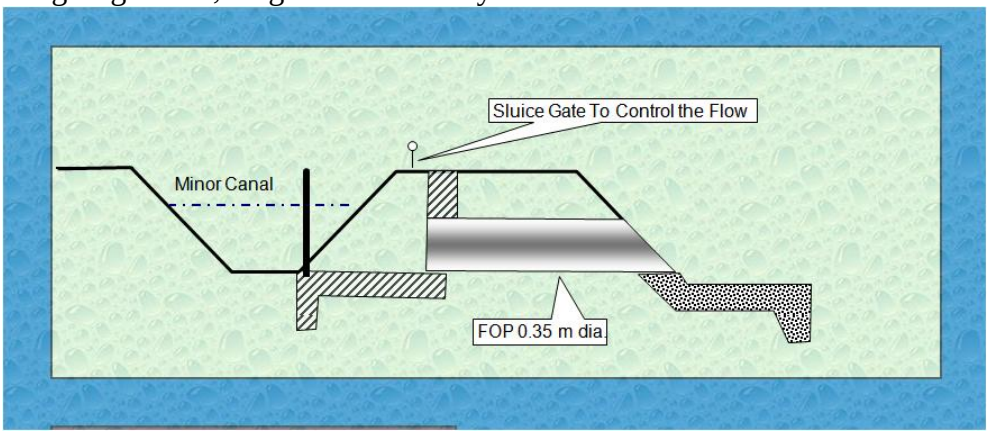
- Irrigation projects profile sheets: Can provide solid and comprehensive information about the irrigation schemes in the EN region (existing and projected), including scheme's general background, location map, physical environment (Evapo-transpiration, rainfall, minimum and maximum temperature), soil and land use and the environmental aspects.



- Irrigation schemes crop water requirement and cropping pattern: The crop water requirements (CWR) were estimated for all the EN irrigation schemes (existed and projected schemes) and provided in a graphical and numeric form.



- Design Sheets: Provides general irrigation design guidelines, canal layouts, Manning calculator, excavation sheets, on-farm water management sheets, existing Regulators, irrigation water duty.



How do these functions benefit the Eastern Nile?

- The first version of the toolkit was shared with main consultant for ENPM to help the in modeling the impact of different development scenarios on downstream users.
- ENTRO is planning to utilize the toolkits in the NCORE project to upscale it to EN Irrigation Information Management System.
- Toolkits serve as means of synthesizing the deliverables and outcomes of the ENID project.
- Toolkits will be availed through portal to relevant ministries to support the planning, design and feasibility studies of hydropower projects in EN.
    - Different means of dissemination through ENTRO web portal, CDs, workshops are in progress;

How was it developed?

- Toolkits was developed in-house through internship program, whereby a group of interns/researchers from the 3 EN countries worked together to collect, compile, consolidate information pertaining to irrigation schemes database and Economic and financial data.
- Design sheets were developed using manual guidelines from national practices from the three countries.
- The CWR were estimated using the Penman-Monteith equation on the CROPWAT environment, following the procedure mentioned in Allen et al. (1998).
- Estimated budget for the development of the toolkit is $15,000
- Challenges
    - Lack of comprehensive and easily available database related to existing and proposed irrigation scheme characteristics.
    - Sensitivity to data sharing.
    - Continuous maintenance and updating of toolkits.
    - Data availability for site specific cropping pattern, and crop water demands, historical abstraction…etc
    - Developed in a way to be usable to many types of users.
    - Limited participation and contribution from EN countries (especially official ministries) given constraints of current cooperation environment.

Spatial/regional coverage

- Spatial coverage – entire EN sub-basins (BAS, ABN, TAS, Main Nile).
- Regional coverage – EN countries.
- However, most of the tools specifically the design sheets could be used for any other regional or international sub-basin, worldwide.

How can tool be expanded? How can it be improved?

- The tool can be further integrated with the ENID Spatial database for improved visualization.
- Design sheets have the potential to be further enhanced to facilitate automated conduct and include more national as well as international practices.
- The project profile can be expanded to include recession agriculture, rain fed agriculture etc...
- The tool could be potentially shared with NBI centers in order to help the process of planning and managing existing and proposed HP projects, NBI wide.
- At the current stage, the tool is excel based with macros; however, other versions of the tool such as HTML, proper database accessibility to store and manage datasets are planned as part of NCORE and for easy dissemination as part of the ENTRO portal.
- There is a need of proper documentation of the toolkits such as manuals/guidelines,
- The toolkits allow users to update and integrate data and carry out further analysis with the potential for enhancing the available information and knowledge.
- The design sheet needs further improvement and the user interface can be developed using visual basic.

Technology

Platform

Excel based, with macros and simplified user interface
Includes inputs from GIS and other sources

Datasets used and Sources

- Information about general background, location map, and physical environment for Irrigation projects was obtained from the CRAs of ENID project.
- Evapo-transpiration, rainfall, minimum and maximum temperature was obtained from the CLIMWAT database.
- Crop data were obtained from the Allen et al. (1998), Water Management and Irrigation Institute database, Adam (2005) and the EN national master plans (obtained from ENTRO library and ENTRO staff)
- Soil and land use and the environmental aspects were extracted from the FAO database.
- Datasets used for the cost benefit analysis were entirely dependent on the ENIDS report (2009)
- Financial and economic information such as benefit cost ratio, capital investment, internal rate of returns –OSI , ENID

Source of data classification

Data Source	Project	Classifications
OSI	JMP scoping	Limited availability;

		unpublished data.
Nile Encyclopedia	Nile DSS	Published data, with public access.
Country master plans	Different ENSAPT projects	Limited accessibility, case by case basis.
CRAs for ENID	EN irrigation and drainage studies.	To be availed partially through portal.
Global datasets	Various sources	Publically domain

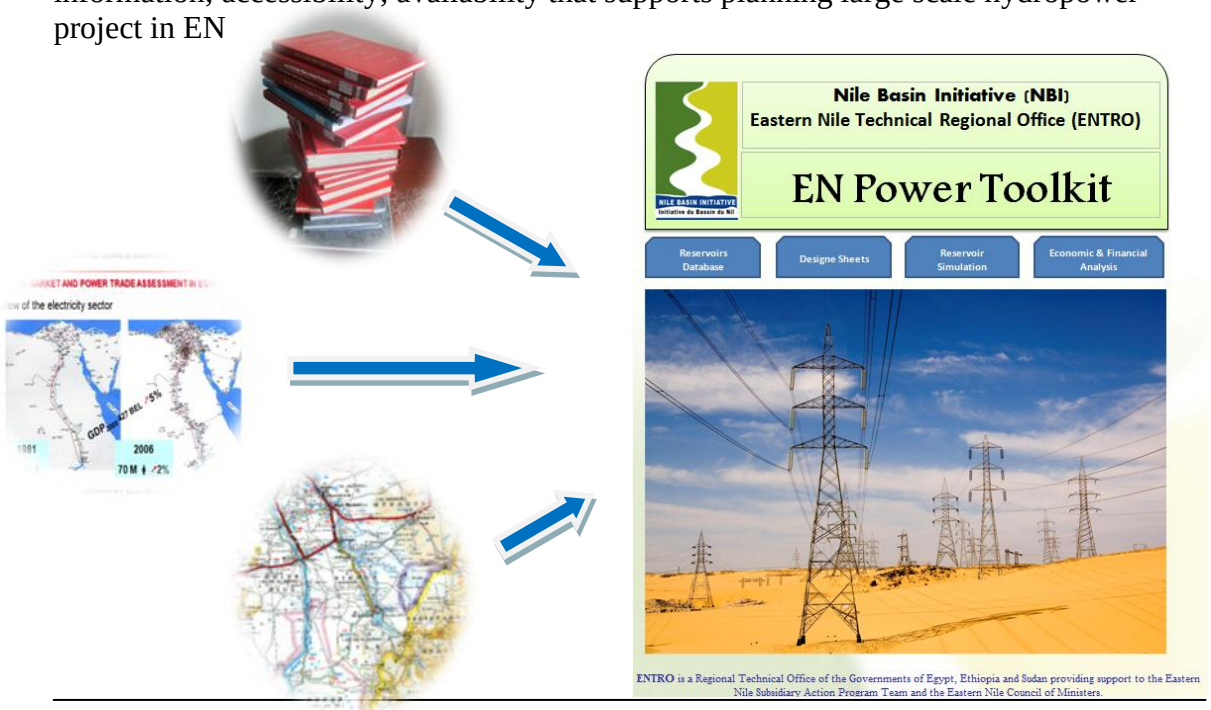
Methods of updating data
Living toolkits – to be updated on continuous basis.

Other
Sensitivity/sharing: low sensitivity with the potential to be publically shared.
Available theoretical resources: references and access to some key theoretical sources could be availed as part of the toolkit.
Public domain version toolkit will be made accessible to new ENTRO web portal.

EASTERN NILE TECHNICAL REGIONAL OFFICE
EASTERN NILE PLANNING MODEL
EN POWER TOOLKIT

APPLICATION

Context
Large amount of knowledge information, data generated from the CRA for power trade, JMP1, power interconnection, feasibility studies, and country master plan. Fragmented information; accessibility; availability that supports planning large scale hydropower project in EN

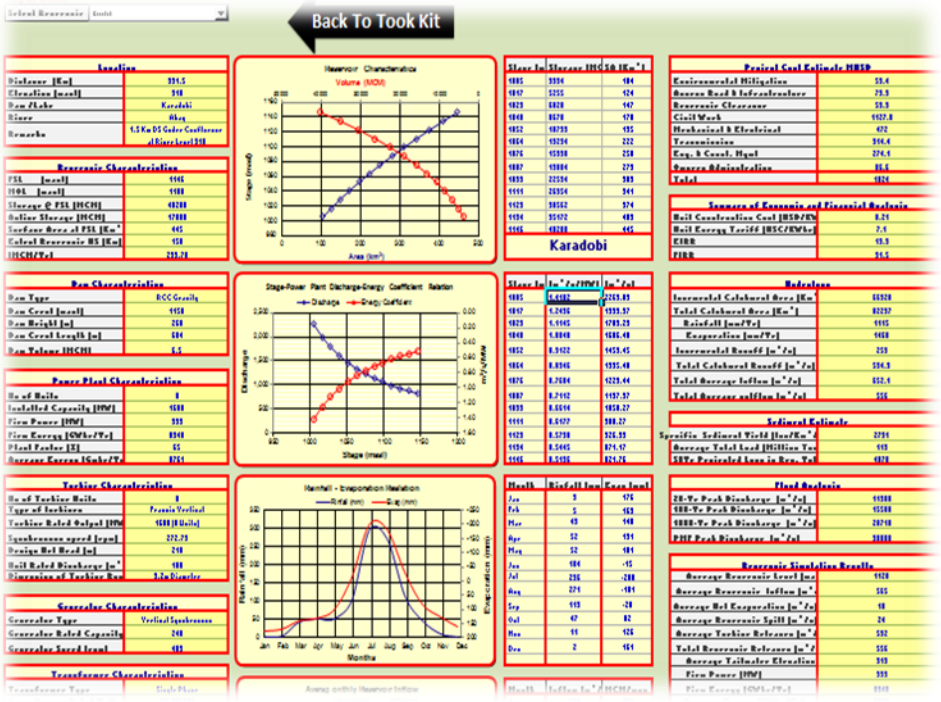


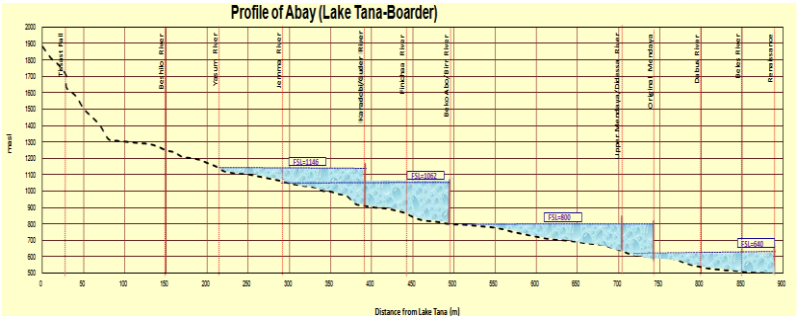
Objective
Synthesize, consolidate, provide better access to information in a systematic manner that supports decision makers in EN in identifying and ranking and facilitating hydropower project development; potential; access to simple analytical tools useful for power analysis;

Description
- Dam and reservoir database;
- design sheets;
- simulation tools;
- economic and financial analysis;

Intended Users
- Utilities
- Ministries of power and energy sectors across EN – finance, water, energy, dam implementation units, environment
- ENTRO/NBI centers
- Universities and outreach centers; other research centers
- Project planners and International consultants preparing feasibility and site specific studies for hydropower – as part of detailed studies, reconnaissance

What are the Toolkit's capabilities?
- Dam database: detailed inventory of existing and proposed dams; their major characteristics, locations, cost estimates, benefits, environmental impacts, hydrological and system analysis features, power and energy generation capabilities, cascading profiles, etc





- Provide access to climatic and hydrologic time series: inflows, reservoirs, evaporation losses from reservoirs, minimum environmental flow requirements
- Automated Design sheets that facilitate the design and analysis: detailed design procedure with guidelines, computation sheets, for different elements of hydropower projects that could assist the proper conduct of feasibility studies and design of the different perpetual structures associated with hydropower structures
    - E.g. design of intake structure, spillway design, tunnels, penstocks, turbine selections and performance charts for them, energy dissipaters, surge chambers, and outlet works etc

- Simulation of
  hydropower generation capabilities for the hydropower scheme; optimizing the firm and secondary energy generation capability of HP
- Performing economic and financial analysis to assess the feasibility of a hydropower project
- Provide access to basic information related to HP at one's fingertips

How do these functions benefit the Eastern Nile?

- The first version of the toolkit was shared with main consultant for JMP1 study to help the identification and cascade modeling of JMP1 Abbay/Blue Nile
- ENTRO is planning to utilize the toolkits in BAS joint multipurpose project
- Toolkits serve as means of synthesizing the deliverables and outcomes of ENPTS and ENPIS
- Toolkits will be availed through portal to relevant ministries to support the planning, design and feasibility studies of hydropower projects in EN
    - Different means of dissemination through ENTRO web portal, CDs, workshops are in progress; to relevant agencies of the EN in order to optimize existing hydropower schemes

How was it developed?

- Toolkits was developed in-house through internship program, whereby a group of interns/researchers from the 3 EN countries worked together to collect, compile, consolidate information pertaining to dam database and hydrologic data
- Design sheets were developed using manual guidelines from international practices and/or based on desk review to the pre-feasibility studies of large scale hydropower schemes

    - E.g. Karadobi, Mandaya, Beko Abo, and site specific studies, country master plans in attempt to avail different regional/local and international practices in a singular toolkit
- Analytical modeling techniques based on power trade studies – computation was customized in Excel interactive sheet that aim to facilitate ease of access to information, computational methods, and comparative analysis
- Estimated budget for the development of the toolkit is $15,000
- Challenges
    - Lack of comprehensive and easily available database related to dam and hydropower characteristics
    - Sensitivity to data sharing
    - Continuous maintenance and updating of toolkits
    - Developed in a way to be usable to many types of users
    - Data and input from multi-sectoral perspective e.g. economic, environmental and social aspects
    - Limited participation and contribution from EN countries (especially official ministries) given constraints of current cooperation environment

Spatial/regional coverage

- Spatial coverage – entire EN sub-basins (BAS, ABN, TAS, Main Nile)
- Regional coverage – EN countries
- However, most of the tools specifically the design sheets and the simulation tools could be used for any other regional or international sub-basin, worldwide

How can tool be expanded? How can it be improved?

- It is realized that the tool has got poor GIS/spatial capability; for the purpose of visualization it is planned as part of NCORE to have a GIS interactive version of the toolkit (zooming in, embedding in Google Earth, fly-over capabilities etc)
- Design sheets has the potential to be further enhanced to facilitate automated conduct; room for further enhancement
- Simulation tools have got limited capability for optimizing firm and secondary energy generation from a single hydropower project – there is a potential for enhancing the simulation and optimization capability to deal with cascade of HP projects and complex operating rules for reservoirs; identifying optimum operating rules of reservoirs/ optimum filling procedures, etc
- Simulation and design sheets provide support the feasibility of a hydropower project from economic perspective – there is a need to integrate social and environment indicators to facilitate the prioritization and ranking of a hydropower from a multi criteria perspective

- Interface Economic and financial analysis needs to be further enhanced and generalized as it reflects site specific economic and financial analysis for certain HP projects in the EN
- The tool could be potentially shared with NBI centers in order to help the process of planning and managing existing and proposed HP projects, NBI wide
- At the current stage, the tool is excel based with macros; however, other versions of the tool such as HTML, proper database accessibility to store and manage datasets are planned as part of NCORE and for easy dissemination as part of the ENTRO portal
- There is a need of proper documentation of the toolkits such as manuals/guidelines,
- The toolkits allow users to update and integrate data and carry out further analysis with the potential for enhancing the available information and knowledge
- Include other information that is collected (and can be updated) related to power supply and demand trends and projections and power interconnection possibilities

Technology

Platform
Excel based, with macros and simplified user interface
Includes inputs from GIS and other sources

Datasets used and Sources

- Dam and reservoir characteristics such as location profile, stage storage, stage discharge characteristics, turbine characteristics, power plan characteristics, generator characteristics, firm and secondary energy generation capabilities, etc, - power trade studies, OSI, country master plan, site specific studies, pre-feasibility studies e.g. Karadobi, Mandaya, etc
- Hydro-met information, including rainfall, evap, inflows to reservoirs, reservoir releases including spillway, environmental flows, etc – Nile encyclopedia, country master plans, OSI, power trade study
- Cost estimates of the different elements of the hydropower project such as civil works, electrical and mechanical work, site preparations, etc – site specific study, (pre) feasibility studies for different existing and proposed projects in the EN, power trade study, OSI
- Financial and economic information such as benefit cost ratio, capital investment, internal rate of returns, unit cost and benefit per energy unit generated, etc – site specific study, (pre) feasibility studies for different existing and proposed projects in the EN, power trade study, OSI
- Information about cost of resettlement, direct impact zone, environmental impacts, cost of mitigation, socio-economic costs and benefits – EIAs conducted under power trade and site specific studies, country master plans, OSI,

- Indirect benefits and impacts of regulation such as augmenting energy generated downstream and alleviation of flood damage downstream, reduction in Evap losses, impact on the need to lower reservoir levels at HAD and the associated losses in energy generated from HAD – EIAs conducted under power trade and site specific studies, country master plans, OSI, flood preparedness and early warning project, JMP scoping, JMP1 ID, data generated as part of the ENPM

Source of data classification

Data Source	Project	Classifications
OSI	JMP scoping	Limited availability; unpublished data
Nile Encyclopedia	Nile DSS	Published data, with public access
Country master plans	Different ENSAPT projects	Limited accessibility, case by case basis
CRAs for power trade	EN power trade studies	To be availed partially through portal
Environmental impact assessment	Power trade site specific study	Originally disclosable document, information has potential to be availed through portal
Pre-feasibility studies	Power trade and country site specific studies	Pre-feasibility studies for EN power trade (Karadobi, Mandaya, Border, Dal) are discloseable documents
Site-specific studies	JMP 1 and country master plans	Processed information has potential to be availed through portal (after consultation with countries)
Global datasets	Various sources	Publically domain

Methods of updating data
Living toolkits – to be updated on continuous basis

Other

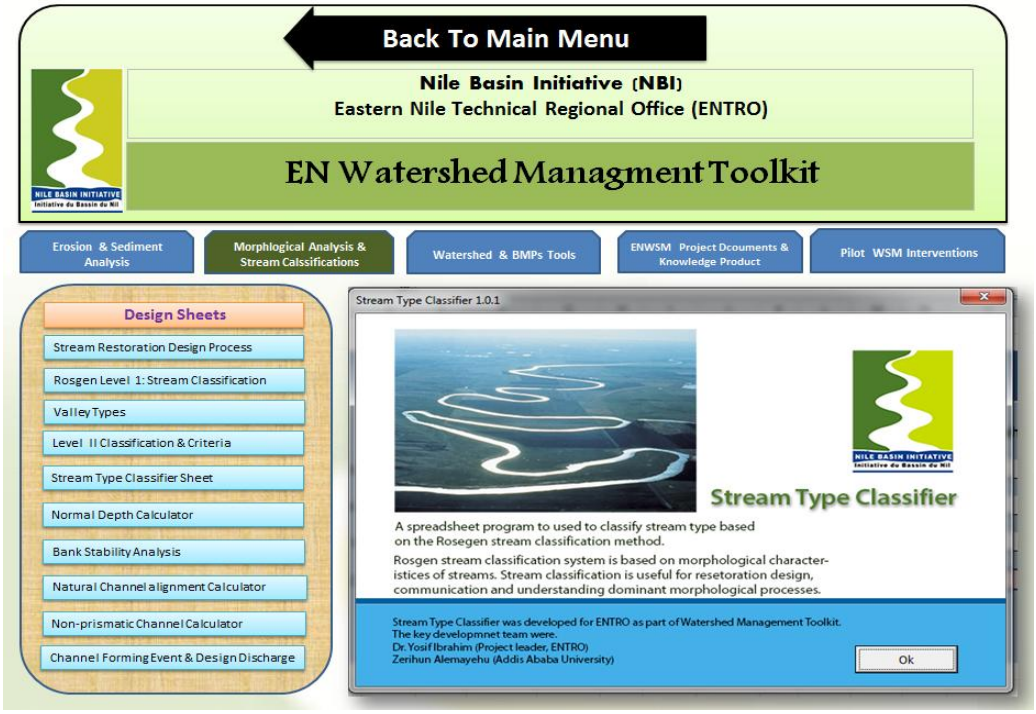
Sensitivity/sharing: low sensitivity with the potential to be publically shared
Available theoretical resources: references and access to some key theoretical sources could be availed as part of the toolkit
Public domain version toolkit will be made accessible to new ENTRO web portal

EN WATERSHED MANAGEMENT TOOLKIT

APPLICATION

Context

Watershed degradation and associated environmental impacts continue to have adverse impacts on all riparians across the Eastern Nile. Although, most of watershed degradation is located in the upstream regions of the EN, it has profound implications in far reaching downstream parts of the system. Increases in deforestation and shifting land use patterns have exacerbated the severity of this problem and has affected storage and irrigation infrastructure, contributed to an increase in the incidences of floods and adversely impacted assets and livelihood of citizens of the EN. Given the urgency of this challenge, ENTRO prioritized the need for improved watershed management in the Eastern Nile and has continued to work closely with riparian countries to carry out detailed assessments, design projects, to provide project implementation guidance and facilitate knowledge sharing among EN riparians. Through the course of its engagement, ENTRO has amassed extensive amounts of knowledge, information and data regarding watersheds of the Eastern Nile. These resources have been generated through ENTRO's Comprehensive Regional Assessments for watershed management, the Joint Multipurpose Project Phase 1 project, feasibility studies, and EN country master plans. However, this information was fragmented and inaccessible for use in supporting decision making processes for planning large scale watershed management projects at the regional and country-levels.

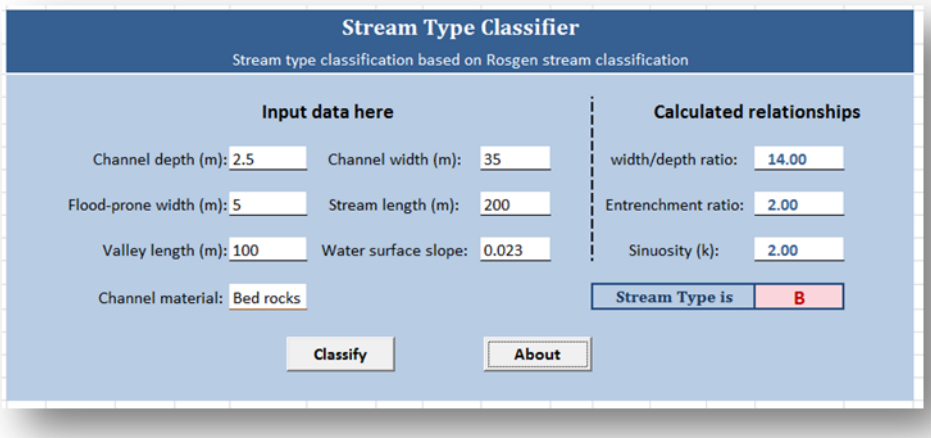


Objective

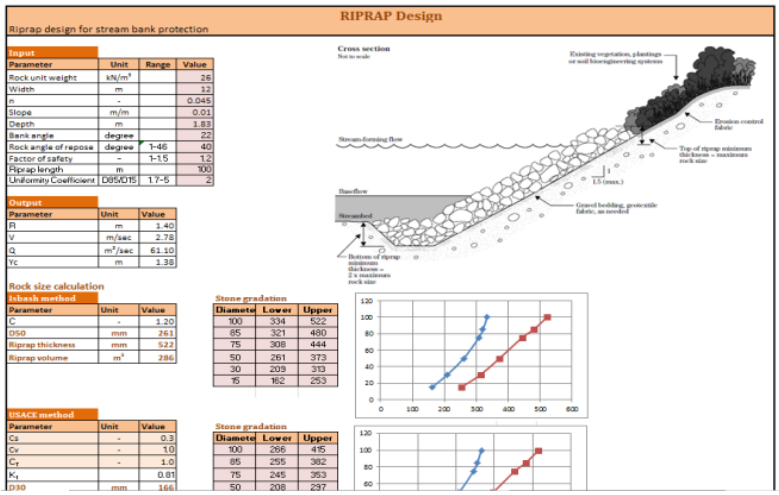
Under the above context, the objective of this toolkit is to synthesize, consolidate and provide better access to watershed management related information in a systematic manner that supports decision makers in EN in identifying watershed management project development. The toolkit also aims to support erosion and sedimentation analysis and provides access to simple analytical tools that are useful for watershed management. Finally, the toolkit aims to provide a theoretical foundation for these decision makers such as an evaluation of best practices in the region for watershed management.

Description

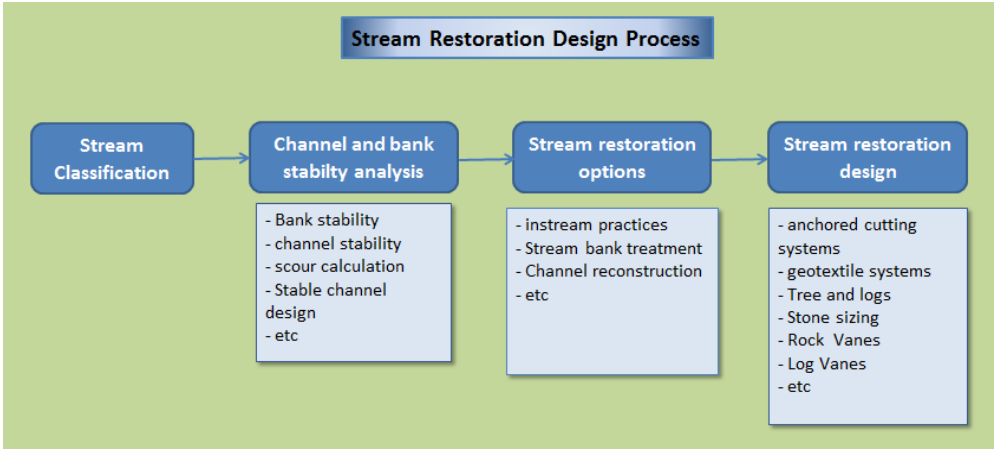
The toolkit allows for an overarching analysis of erosion and sediment conditions across sub-basins of the Eastern Nile. The toolkit's process for determining the most suitable watershed management intervention efforts can be applied at multiple spatial scales. This process begins with a characterization of the stream(s) in question, which are classified for properties such as the stream's bank type, slope, morphology, valley type, channel material, and others shown in the schematic below.



Following characterization, the toolkit allows for the assessment of the stream and bank stability, evaluating whether there is a need for a watershed management program at the given catchment. The toolkit avails watershed best management practices (BMPs) for restoring bank and stream stability where necessary. These BMPs include use of riprap gabion, check dams, retention ponds, and many others.

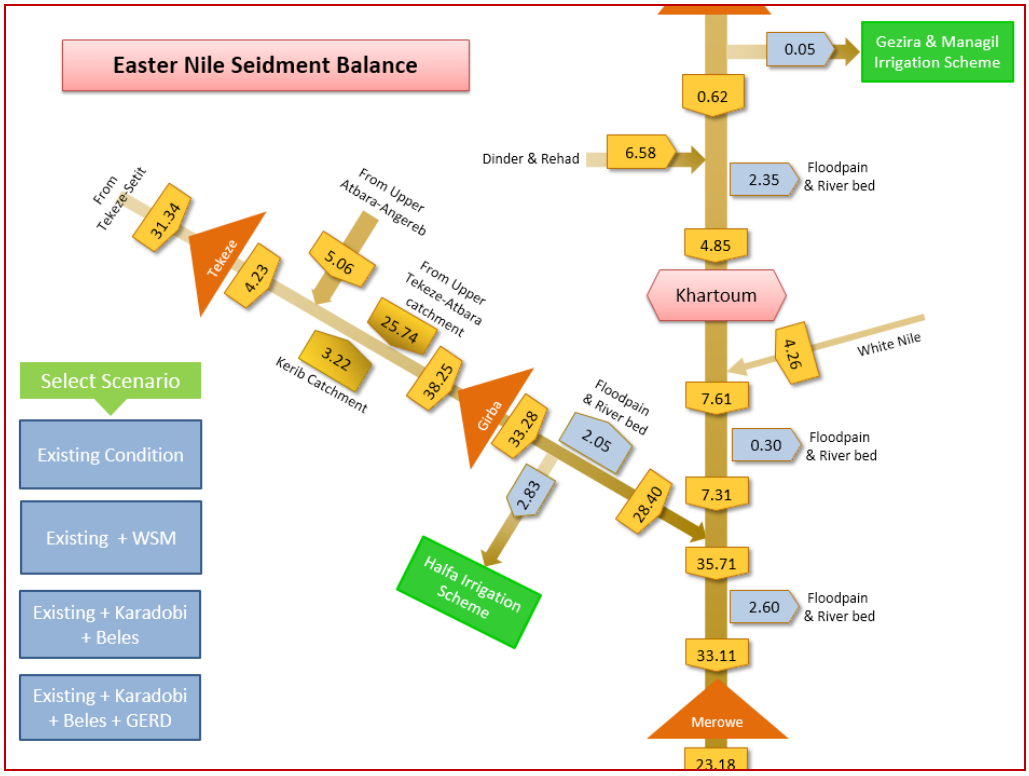


Finally, the toolkit allows for designing the stream restoration plan based on the above analysis.



The toolkit has been used to perform analysis of pilot watershed management intervention projects in several locations including Lower Atbara, Dinder, Ingassena,

Lau, Lake Nasser/Nubia, Upper Ribb, Upper Gilgel, and Upper Gumara catchments, and summary reports were produced for each. In addition, the toolkit includes documentation and a knowledge base compiled through the Eastern Nile Watershed Management (ENWSM) project.



The toolkit also contains detailed technical drawings for each BMP; factsheets about pilot and planned watershed management activities; annual sediment budget automated schematics of EN, including for existing and planned dams and irrigation sites; and a documentary movie about watershed management activities in the EN.

Intended Users

Intended users of the toolkit are ministries of water and natural resources management, community level watershed managers, and trainers, ENTRO and other NBI centers, universities and outreach centers as well as other research centers, sub-basin planners, project planners and International consultants preparing feasibility and site specific studies for watershed management, as part of the planning and evaluation process of these studies.

What are the Toolkit's capabilities?

The toolkit contains an inventory of existing erosion and sedimentation data such as sedimentation rating curves for different gage stations, sedimentation related data for existing and proposed dams in the EN and proposed dams along with their rating curves, trap efficiency, as well as calculated and measured sediment storage. The toolkit also provides access to hydrologic time series, mainly in the form of monthly inflows at

sediment gaging stations. The toolkit has analysis and characterization capabilities for conducting erosion analysis that enables characterization and classification of streams for restoration projects (such as automated Rosgen's morphological classification of streams). The toolkit's automated design sheets facilitate the development and analysis of watershed management activities and include detailed design procedures with guidelines and computation sheets for different elements of a watershed management project. These features are developed to ensure that designs of feasibility studies are based on sound technical information, which draws heavily from evaluation of best management practices. An example of this capability is designing of river bank erosion control structures, design of grade stabilization techniques, design of stream restoration, sediment control structures, detention and retention basins, gully stabilization and treatment techniques, etc.

How do these functions benefit the Eastern Nile?

The first version of the toolkit was shared with the Abbay River Basin Organization and its sub offices Tana and Beles Sub-Basin Organizations as well as watershed management planners in Sudan, to assist with their successful watershed management activities, which were themselves prepared by ENTRO. Moreover, the toolkit serves as a means of synthesizing and delivering outcomes of the CRAs for watershed management projects. In addition, the toolkit is seen as a useful tool that can enhance quality of trainings and workshops on watershed management activities for any upcoming events of the kind within the Eastern Nile and beyond. In fact, the toolkit was shared with a study group from the Malawi Shire River Basin Management Program, to assist them in their upcoming water resources, watershed and flood management and spatial hydro-met analysis activities. The toolkit will be availed through ENTRO's web portal, CDs and workshops to relevant users to support in the planning, design and feasibility studies of watershed management projects in EN and beyond.

How was it developed?

The toolkit was developed in-house through an internship program, whereby a group of interns and researchers from the four EN countries worked together to collect, compile and consolidate information pertaining to watershed management activities and practices in EN. Design sheets were developed using manual guidelines acquired through international practices as well as manuals and guidelines developed at ENTRO and in EN countries. Analytical modeling techniques based on CRA watershed management studies were used to develop computational techniques and to standardize the collected data. These techniques and datasets were customized through MS Excel interactive macros that aim to facilitate ease of access to information, computational methods, and comparative analysis. Through in-house capacity and successful internship program, the comprehensive features and functionalities found in this toolkit were developed at a very small cost, an estimated budget of $15,000. The toolkit development team encountered several challenges including: (a)the lack of a comprehensive and easily available database related to watershed management activities in the EN; and (b) the need for continuous maintenance and updating of time-series databases that are derived from multiple sectors (economic, environmental and social aspects). From structural perspective, the development team was faced with the challenge of creating a toolkit available for use by

different types of users (technical to non-technical), and to create the architectural framework for toolkit. Finally, the team experienced challenges based on the sensitive nature of data being used and shared, and relatedly, the team experienced limited participation and contribution from EN countries (especially official ministries) given constraints of the current cooperative environment.

Spatial/regional coverage
Spatial coverage of the toolkit comprises of the entire EN sub-basins (Baro-Akobo-Sobat, Abbay/Blue Nile, Tekeze-Atbara-Setit and Main Nile), while regional coverage of the toolkit comprises of the four EN countries (Egypt, Ethiopia, South Sudan and Sudan). However, most of the data made available for the toolkit were derived from studies from Abbay/Blue Nile. The tools, and specifically the design sheets and simulation tools, of the toolkit could be used for any other regional or international sub-basin, worldwide.

How can tool be expanded? How can it be improved?
Several expansion and improvement plans are currently proposed for the upcoming Nile Cooperation for Results (NCORE) project. These include: (a) enhancing the toolkit's GIS/spatial capability for improved visualization;(b) enhancing design sheets to facilitate automated processing – an improvement plan suggested through evaluation and feedback of the toolkit; (c) incorporating additional cost analyses for each BMP; (d) additional BMPs to make the toolkit more comprehensive; (e) allowing users to update, integrate and enhance the data in the toolkit; (f) expanding the limited capability for automating stream restoration and to enhance the simulation that can automate this process; and (g) include capability for characterizing, selecting restoration options, designing individual techniques and performing cost analysis of entire projects. Currently, most of the data included in the toolkit is from Abbay/Blue Nile (ABN), additional data can be acquired and included in the toolkit to enhance its utility for all EN countries and sub-basins. This version of the toolkit focuses primarily on technical aspects of watershed management; however, it can be further improved through the inclusion of socio-economic and environmental aspects of the watershed management process. Plans have also been made to customize the toolkit for other NBI centers in order to help with their planning and evaluation of existing and proposed watershed management projects, and those of the catchments they cover. At the current stage, the tool is MS Excel based with macros; however, other versions of the tool such as HTML are being considered to increase database accessibility through the ENTRO web portal. Finally, there is a need to further document this toolkit, such as through user manuals.

TECHNOLOGY

Platform
Excel based, with macros and simplified user interface

Datasets used and Sources
The following table describes the datasets used, examples of these datasets as they have been used in the toolkit, and their sources, whether from within or without ENTRO.

Dataset Used (and examples of datasets)	Sources of Data
Dam and reservoir characteristics such as storage, trap efficiency	Power trade studies, One System Inventory (OSI), country master plans, site specific studies, pre-feasibility studies e.g. Karadobi, Mandaya
Hydro-met information, stream flows, suspended sediment load, sediment rating curves	Nile encyclopedia, country master plans, OSI, power trade study
Financial and economic information such as, different cost components of planned watershed management, capital investment, internal rate of returns	Site specific study, pre-feasibility and feasibility studies for different existing and proposed projects in the EN, CRA watershed management study, OSI

Source of data classification

Data Source	Project	Classifications
OSI	JMP scoping	Limited availability; unpublished data
Nile Encyclopedia	Nile DSS	Published data, with public access
Country master plans	Different ENSAPT projects	Limited accessibility, case by case basis
CRAs for Watershed management	EN watershed management studies	To be availed partially through portal
Environmental impact assessment	Power trade site specific study	Originally disclosable document, information has potential to be availed through portal
Pre-feasibility studies	Power trade and country site specific studies	Pre-feasibility studies for EN power trade (Karadobi, Mandaya, Border, Dal) are discloseable documents
Global datasets	Various sources	Publically domain

Methods of updating data
Living toolkits – to be updated on continuous basis

OTHER

Sensitivity/sharing: low sensitivity with the potential to be publically shared
Available theoretical resources: references and access to some key theoretical sources could be availed as part of the toolkit
Public domain version toolkit will be made accessible to new ENTRO web portal

ENTRO DATABASE

APPLICATION

Context

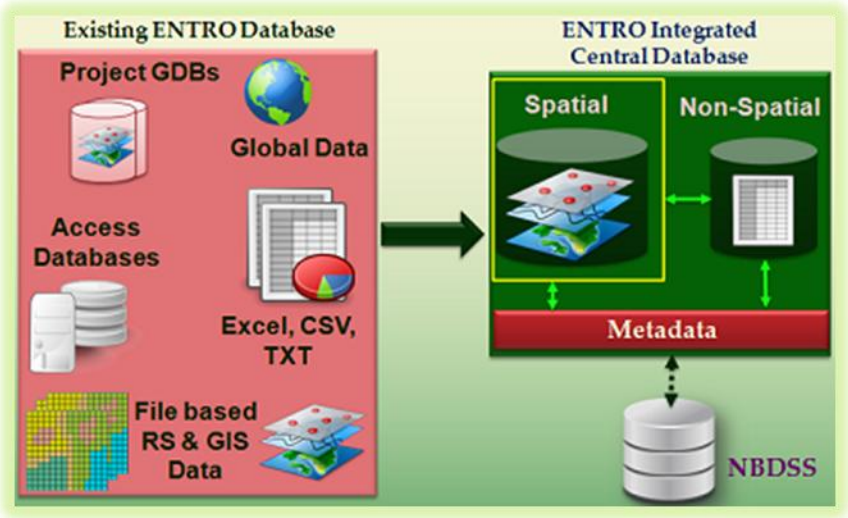
Through the courses of different projects preparations and implementations substantial amount of datasets about the socio-economic and environmental situation of the Eastern Nile have been collected and generated. These datasets need to be properly organized, quality controlled, managed , stored, and shared among various stakeholders in the region as well as to global communities.

Objective

- To systematically compile, organize and store project based datasets into centrally managed and accessed spatial and non-spatial data repository.
- To serve as main data repository for the web portal.
- To effectively provide inputs to the models used at ENTRO including the Nile Basin Decision Support System (NB DSS) and integrate the results of such models back into the database.

Description

- ENTRO database has been developed to handle both spatial and non-spatial datasets collected and compiled from different ENSAP projects.
- The central database has two separate databases (spatial and non-spatial) which are logically linked. It can also provide or import datasets from Nile Basin Decision Support System (NBDSS).
- The spatial database has been build based on enterprise spatial database engine technology for systematically organizing and handling bio-physical/environmental and , socio-economic datasets of the Eastern Nile; whereas the non-spatial database is developed to organize and store time-series



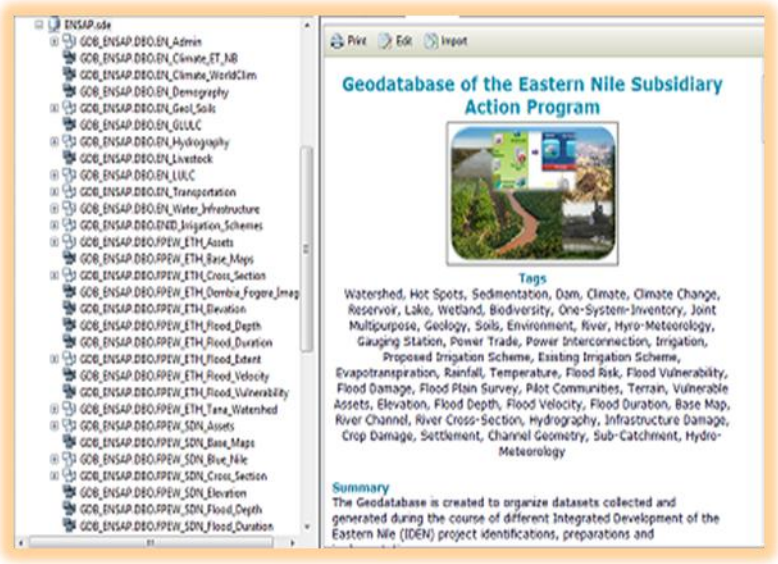
hydro-meteorological, characteristic and parameter datasets which are logically linked to the spatial datasets.

Intended users

- Different units of ENTRO and projects.
- Local, regional and International consultants working in the region.
- The Eastern Nile countries, particularly ministry of water affairs.
- Academia and research institutions.
- The general public who wish to seek for data related to the Eastern Nile region.

What are the database capabilities?

- Both spatial and non-spatial databases have the capacity to organize and maintain unlimited data size and built using enterprise database management system which enables multiple user access.
- The non-spatial database stores hydro-meteorological time series data, characteristic and parameter datasets that can be easily queried.
- The spatial database/Geodatabase can store well organized feature data into feature datasets, raster data into mosaic dataset or raster catalogs. The Geodatabase also provides storage capability to huge remote sensing data which also maintains pyramid layers with the datasets that improves display performance of large raster dataset.



- The Geodatabase has the capability to store metadata along with each dataset.
- Most of the web portal applications like web mapping and time series model data manager are accessing data from the central database.
- Major datasets contained in the spatial database include the following:

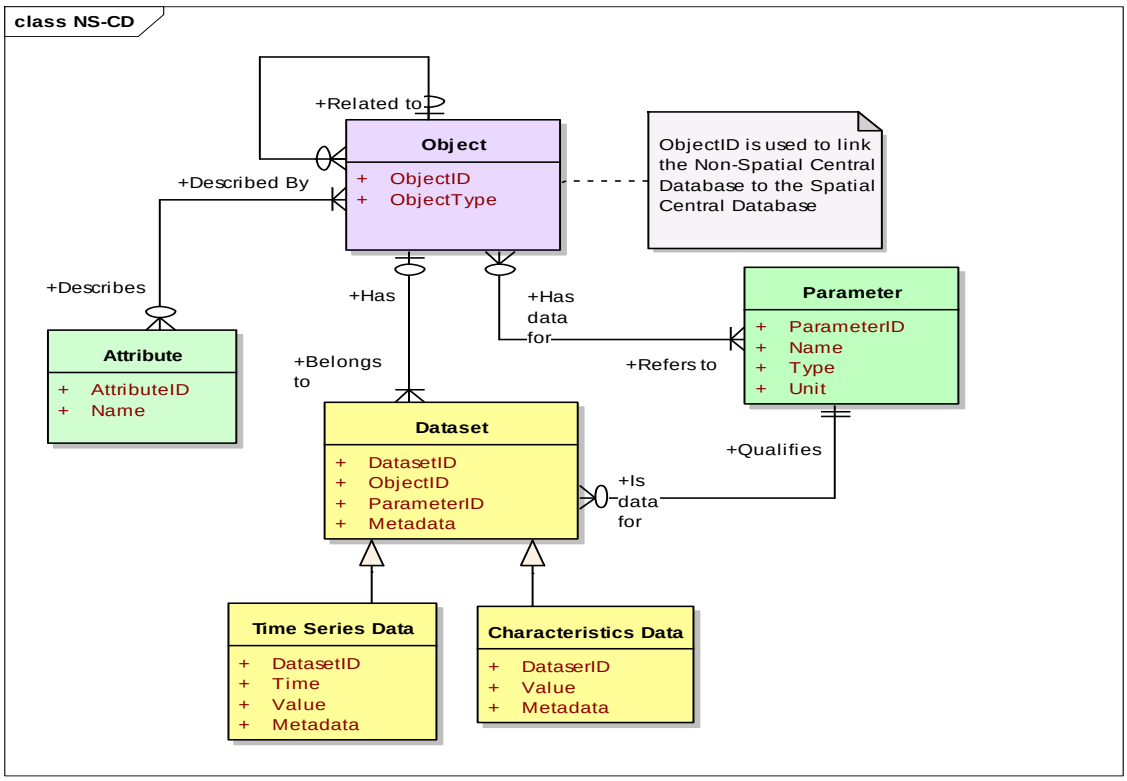
How do these functions benefit the Eastern Nile?

- The central database provides rich sets of data on water resources, environmental and socio-economic conditions of the Eastern Nile which can support preparation and implementation of water resources development projects. It can serve as data hub for the Eastern Nile.
- Modelers and water resources engineers of the Eastern Nile region can be benefited from the data to carry out modeling exercises.

- Well organized and documented, readily available and accessible data in a database can reduce cost in terms of data discovery and collection for new development studies and projects.
- Facilitates data sharing among the institutions of the Eastern Nile countries.

How was it developed?

- The central spatial database have been developed based on individual ENTRO project databases (flood preparedness and early warning, watershed, Irrigation, joint multipurpose, Ethio-Sudan Power Transmission Interconnection, Power Trade, and Baro-Akobo-Sobat projects) in-house by ENTRO staff.
- The non-spatial database have been designed, implemented and populated with sample data by individual consultant



How can it be improved and expanded?

- The spatial database is still under improvement and enhancement in terms of completing the documentation/metadata and enriching it with remotely sensed data.
- Populate non-spatial database with time series and characteristics data using web portal time series data manager or other interface tools.
- Currently, the database implemented on the external web server is not fully populated. It is planned under ENCORE to enrich the Geodatabase with data and provide more interactive published web maps.

Content Sources

- The major sources of data are the Eastern Nile countries. The data were collected and compiled during ENTRO project preparation and implementation. Others sources of contents specially, spatial data have been obtained from global sources like NASA, USGS, ESA, FAO, etc.

Technology platform and technology requirements for use

- ENTRO central database has been developed based on the following technologies:
  - Microsoft SQL Server 2008 R2 standard edition database management system for spatial and non-spatial data repository.
  - ArcGIS Enterprise (ArcSDE) 10.1 standard edition for Multiuser Geodatabase management.

Methods of updating content

- The non-spatial database is not yet populated with data. It is planned to be done under NCORE project.
- Time series remotely sensed global data will be frequently downloaded and processed.

EASTERN NILE TECHNICAL REGIONAL OFFICE
EASTERN NILE PLANNING MODEL

ENTRO REMOTE SENSING

Context

Some of the spatial datasets related to the EN environment and time-series meteorological datasets available at ENTRO that are necessary for different project studies and implementations are either outdated or missing. To fill some of these gaps, it was necessary to identify, acquire and analyze relevant remotely sensed datasets.

Objective

- To identify, procure and analyze remote sensing datasets relevant to water resources modeling needs and development activities that are available freely or commercially.

Description

- ENTRO remote sensing products are primarily derived from publically available global datasets (MODIS land cover and NDVI time series datasets).
- The land cover classification scheme is based on the global International Geosphere Biosphere Program (IGBP) and produced at 0.5 km pixel resolution. Land cover classes are assigned by processing the 32-day spectral database using decision tree and artificial neural network classifiers trained by site data.
- In general, ENTRO remote sensing products include land cover data and land cover change information, NDVI, Evapotranspiration, Nile Morphology and change at certain reaches, change detection of parks, agricultural encroachments to forest land, erosion assessment using remote sensing data, and satellite altimetry for lake level heights.

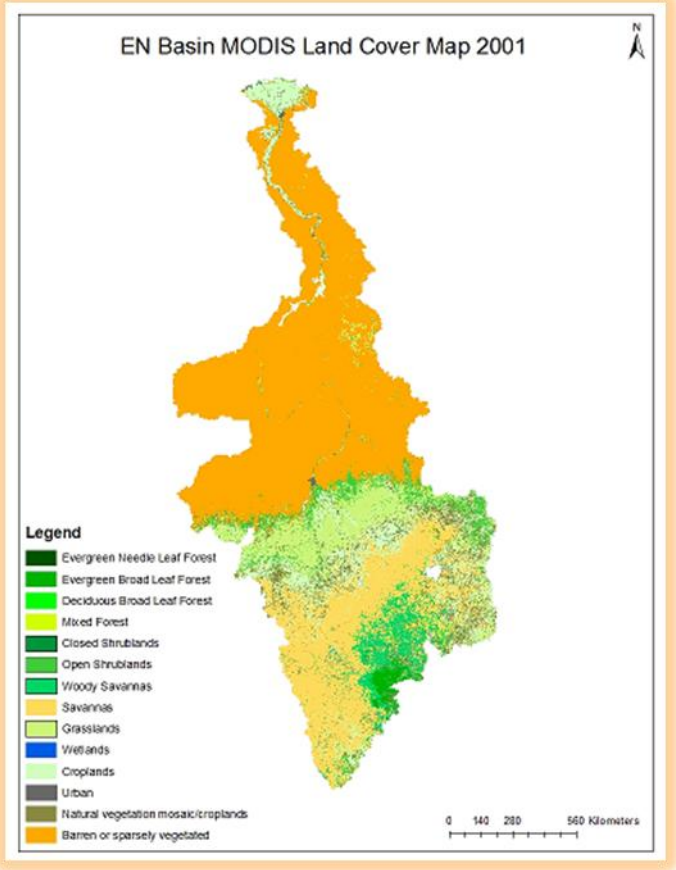
Intended users

- Different units of ENTRO and projects.
- Local, regional and International consultants working in the region.
- The Eastern Nile countries, particularly ministry of water affairs.
- Academia and research institutions.
- The general public who wish to seek for data related to the Eastern Nile region.

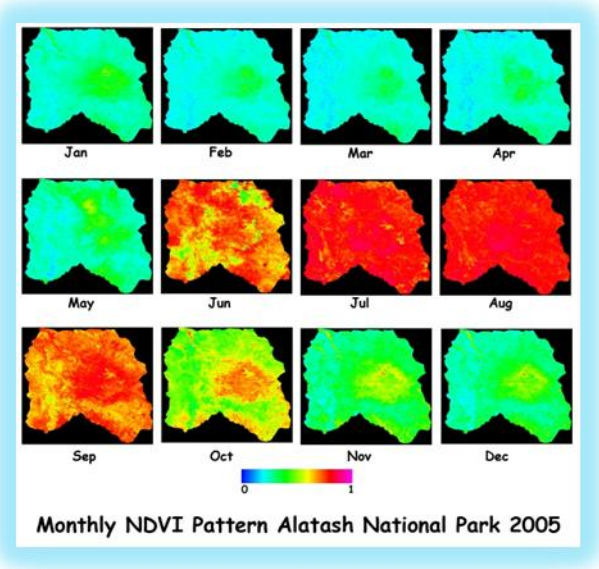
What are the remote sensing products?

The following are the major products from the remote sensing study:

- A series of land cover maps spanning the period 2001-2010 extracted from the global MODIS land cover information products for the EN basin and its sub-basins.
- Indicators of land cover change within the different sub-basins.
- Multi-temporal NDVI data.
- Evapotranspiration map estimates for the EN basin.
- Leaf area index maps for the EN basin.
- Soil moisture maps for the EN basin.
- Fire burned area maps for the EN basin.
- Status of the Nile coarse and morphology.
- Identify agricultural encroachment into forest areas.
- Land cover maps for the lake Nassir and Toshka regions.
- Status of the national parks e.g. Gambela and Alatash National Park (Ethiopia), and Dindir Naiotnal Park (Sudan).
- Commercial data procurement for detailed high spatial resolution land cover maps.



- Gravity data from GRACE, and JASON-2 altimetry measurements.
- Conduct training course for ENTRO staff and interns in remote sensing and image processing.
- Image catalogue and metadata for remote sensing data.
- Time series precipitation estimation (1998 - 2010) from Tropical Rainfall Measuring Mission (TRMM).



How do these products benefit the Eastern Nile?

- Remotely sensed data can significantly assist in the execution and implementation of various ENTRO projects by providing

derived information parameters for ENTRO hydrological and environmental monitoring tasks.
- The remote sensing products generated for the EN are useful for hydrological studies and water resources modeling.
- The repetitive nature of the observation regime that allows the generation of a time-series of observed information and derived parameters results in improved analysis, monitoring and forecasting capabilities for water resources management.

How was it developed?

- The remote sensing products and tools have been developed by international individual consultant.

How can it be improved and expanded?

- In situ measurements at selected location in the EN to carry out accuracy assessments of ET generated based on remote singing products at local and regional scales and ET model calibration.
- The current information products such as land cover or evapotranspiration are generated with a global and regional perspective and might not be accurate at local scales or location specific detailed studies. Therefore, these products need to be further enhanced and fine tuned using very high resolution satellite imagery.
- Carry out ground truthing for accuracy assessment and verifications of the remote sensing products.

Content Sources

- The major sources of remote sensing data that are in a public domain include NASA, USGS, ESA.

Technology platform and technology requirements for use

- The remote sensing products require digital image analysis and GIS software tools for analysis and visualization.
- ENTRO uses the following software:
  - ERDAS Imagine 2012 for visualization and analysis.
  - ArcGIS Enterprise (ArcSDE) 10.1 standard edition and SQL Server 2008 R2 for Multiuser Geodatabase management.
  - ArcGIS 10.1 desktop for visualization and editing metadata related to remote sensing data.

Methods of updating content

- The current products from remote sensing study are based on freely available global datasets which are frequently updated. These products will be updated

continuously by downloading, analyzing and incorporating into ENTRO spatial database.

Type	Spatial Data Reference	Attributes/Descriptions
Administration	• Eastern Nile (EN) Countries Administrative Units • Cities/Towns/Settlements of the EN and African countries • Africa and the World: Continents and Countries datasets • EN Protected Areas	• Governorates of Egypt, States of Sudan, Regions and Weredas of Ethiopia as admin units • Locations and names of capitals and other relevant cities/towns/settlements • Political boundaries of countries of the World and Africa (names and codes provided) • Parks, nature reserve areas, wild life reserves, etc. (including sources of information)
Climate	• WorldClim Global Climatic Raster Datasets • Global Potential Evapotranspiration (PET) • Global Aridity Index • Nile Basin Evapotranspiration (ET) • Koppen Geiger Climate Classification • EN Climatic Stations • One System Inventory (OSI) Climatic Feature Classes	• Climatic interpolated surfaces of the World (mean monthly/annual precipitation, min temp, mean temp and max temp representing the annual average over the 1950-2000 period); spatial resolution 30 arc-seconds • Mean monthly PET surfaces of the World produced by applying Hargreaves model to the WorldClim global climate data (for years 1950-2000); spatial resolution 30 arc-seconds • Aridity index dataset of the World computed from WorldClim precipitation and Global PET datasets • Time-series ET products for Nile Basin processed using modified MODIS algorithm; 1 km^2 spatial resolution • World climatic classification dataset calculated using publicly available global temperature and precipitation datasets; 0.5 degrees spatial resolution • Country-based climatic station datasets with relevant inventory data/info about obtainable station data such as climatic data parameters (rainfall, temperature, etc.), record period, current status (operational or not), custodian (national institutions like meteorological agency/authority), etc. • Point locations of Eastern Nile (EN) main climatic stations with names; selected main or sample EN stations with climatic data like mean annual temp and PET from OSI database
Geology	• OSI Sub-Basin Based Geology Datasets • Surficial Geology of Africa (USGS's world energy project) • Ethiopian Geological Map (Ethiopian Institute of Geological Survey/EIGS)	• Modified from FAO soil & terrain (SOTER) database, the OSI feature datasets are provided with simplified lithological descriptions • Geologic age and lithology of surficial outcrops; the Africa map compiled and synthesized from 1:5 000 000 scale geologic map of the United Nations Educational, Scientific and Cultural Organization (UNESCO) • Lithological description, geologic age, and series/group/formation names for the Ethiopian geological units (1 : 2 000 000 scale; Mengesha et al., 1996)
Hydrography	• Watershed Boundaries (Nile Basin, Eastern Nile Basin, Four Main EN Sub-Basins; EN Sub-Catchments/from Models) • Surface Water Body Datasets (Rivers/Streams, Lakes, Existing Reservoirs, Swamps, Wetlands; World, Nile Basin, Eastern Nile Basin) • Climatic & Hydrometric Stations • Weighted River Datasets	• Names and areas of basins/sub-basins/sub-catchments • River/stream networks with names (for Nile basin and Eastern Nile) • Boundaries and names of lakes and existing reservoirs • Names and types of wetlands • Weighted river feature classes considering OSI indicative water balances

Relief/Elevation	• Shuttle Radar Terrain Mission (SRTM) DEM for EN • Nile Basin HydroSHEDS DEM (Unites States Geological Survey/USGS, World Wildlife Fund/WWF and others) • EN Hillshade Raster Datasets • OSI Landscape Feature Classes for EN sub-basins	• DEM for the EN countries; ~ 90m spatial resolution • Hydrologically conditioned DEM for the Nile Basin; spatial resolution 3-arc seconds • SRTM DEM derived hillshade product for the EN • Simplified landscape class description modified from the FAO Soil & Terrain (SOTER) Database/1998
Landcover	• European Space Agency (ESA) GlobCover Landcover Map • Moderate Resolution Imaging Spectro-radiometer (MODIS) Global Landcover Products • Eastern Nile (EN) Landcover • OSI Sub-Basin Based Vegetation Cover Datasets	• Monthly GlobCover layers for year 2009 derived from remotely sensed satellite data (Envisat's Medium Resolution Imaging Spectrometer/MERIS sensor); spatial resolution 300m • RS derived (MODIS data) global landcover map processed using International Geosphere Biosphere Program (IGBP) classification scheme; available for years 2001, 2005, 2009 at 0.5km resolution • Landcover feature class for the EN compiled from regional and national datasets (FAO Africover & Ethiopian Woody Biomass project) • Simplified vegetation cover descriptions modified from FAO's SOTER database
Soils	• FAO North-East Africa Soil and Terrain (SOTER) Database • FAO-UNESCO Digital Soil Map of the World (2003) • Harmonized World Soil Database/HWSD (2009)	• Dominant soil types with different characteristics of the soils plus simplified descriptions on landscape and vegetation cover (1997/8) • Soil units (dominant soils) based on FAO-UNESCO's 1: 5 000 000 world soil map (year 2003) • FAO's recent soil map of the word compiled from different sources (including those listed above); 1 km spatial resolution (year 2009)
Demographics	• LandScan Global Population Density • Abay Basin Woreda Level Demographics Data • Egypt Governorate Population	• Global population density surfaces at 1 km^2 resolution (US Department of Energy's Oak Ridge National Laboratory) • Demographic data for Ethiopia and Abay basin using Central Statistical Agency's/CSA's database (total ppln, ppln by gender, ppln density; for years 2000 & 2008) • Several years population data for the governorates of Egypt (census 96; estimates for years 2001-2005)
Economy, Health & Education	• Estimate of Gross Domestic Product (GDP) derived from Satellite Data s of the World • Thematic kind under development; data required on health and education	• Remote Sensing derived GDP Estimates (LandScan, NOAA nighttime light, economic activity, models, etc.)
Irrigation	• Existing Irrigation Schemes • Potential Irrigation Projects • Irrigation Canals & Pumps	• Boundaries of existing medium- to large-scale irrigation schemes • EN potential irrigation projects digitized from several comprehensive and project-based master-plans/studies • Egypt's irrigation canals (between Aswan-Cairo; Nile delta) • Canals of Sudan's major irrigation schemes (Gezira-Managil/Al Jazira; Rahad) • Proposed canals for Ethiopian Abay sub-basin potential irrigation schemes • Other irrigation infrastructures (e.g. pumping stations)
Dams, Hydro-Power Plants/HPPs and Interconnection	• EN Existing Dams & Barrages • EN Potential Dam Sites • Reservoir Extents of Dams at Various FSLs • Geo-referenced Thematic and Project Layout Maps • DEMs and Elevation Contours	• Locations and names of existing dams and barrages in the Eastern Nile • Locations and names of EN potential dam sites compiled from several comprehensive and project-based master-plans/studies • Extents of inundation delineated using DEMs or digitized from available maps for potential dams at various full supply levels (FSLs); Dams considered are

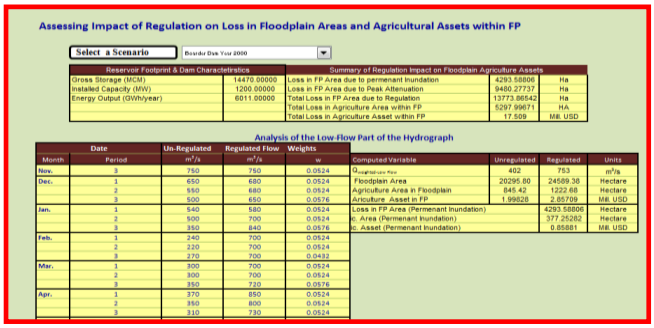
	for Proposed Dam Sites • Proposed EN Regional Power Transmission Line • Proposed EN Interconnection Substations	Border/Renaissance, Mandaya, Upper Mandaya, Lower Didessa, Dal, Baro I&II, Genji, Beko-Abo, Karadobi, etc. • Ethiopian Blue Nile (Abay) irrigation & power development plan map, hydropower project layouts, power plant designs, reservoir plans, geological and geomorphological maps; Border/Renaissance, Beko-Abo, Mandaya, Karadobi, Dal, etc. • Clipped DEMs (raster datasets) and 20m interval contours (feature classes) for proposed dam sites and their vicinity (SRTM DEM and hydrological conditioned HydroSHEDs DEM used) • Proposed line routing for the EN power interconnection project (400/500 kV, AC/DC Lines; Ethiopia, Sudan and Egypt) • Substations involved in the proposed EN power interconnection (Mandaya, Kosti & Naga Hammadi)
Transport & Communication	• Roads & Railways • Airports & Airfields • Navigation Canals	• Networks of roads and railways for the EN countries; sources are national (Ethiopian WoodyBiomas project) and public domain datasets (e.g. FAO Africover) • Nile Basin and Eastern Nile Sub-Basin airports and airfields (purpose/civil, military, combo, …) • Navigable Suez canal digitized from Landsat satellite imagery
Base-Maps	• Landsat Imageries • ASTER Imageries • World Color Shaded Relief • Standard Topographic Maps • Tourist Maps	• Mosaicked Landsat imageries (year 2000; three bands 742; 14.25m spatial resolution; pan-sharpened) • Downloaded public domain TM/ETM Landsat time-series datasets; multi-spectral i.e. visible to infrared bands available; spatial resolution 14.25m - 30m • ASTER (Advanced Space-borne Thermal Emission and Reflection Radiometer) imageries from TerraLook collection; year 2000-2010 • Global shaded relief product from ESRI database • Ethiopian 1:250 000 topographic maps (Ethiopian Mapping Agency) • Topo-maps for Egypt and Sudan (1:200 000 scale; Russian maps downloaded from the internet)

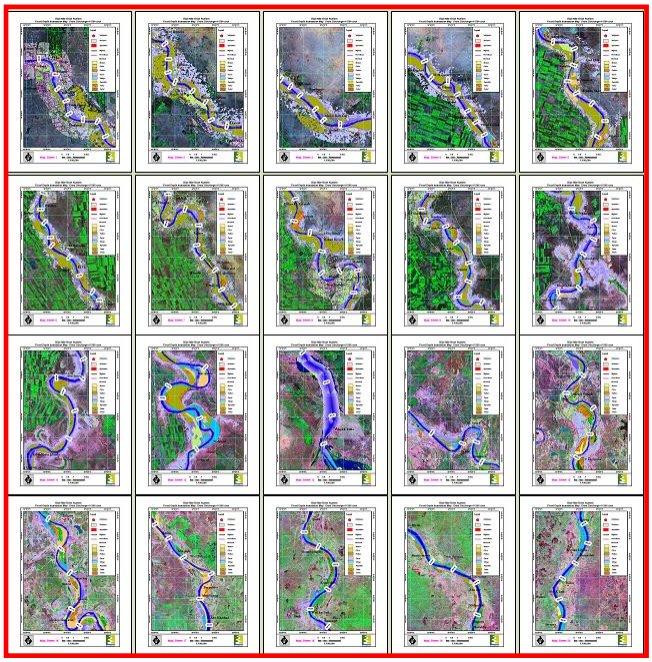
EASTERN NILE TECHNICAL REGIONAL OFFICE
EASTERN NILE PLANNING MODEL
Assessing the Impact of Regulations on the Agriculture Activities Within the floodplains of the Blue Nile River system

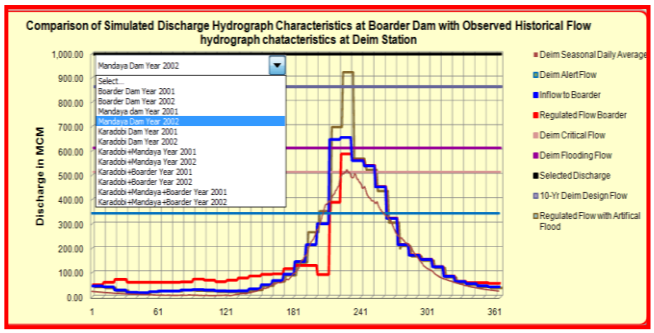
Context

Server flooding along the Blue Nile could have devastation effect on people's lives and property. On the other hand flooding along the BN has beneficial environmental effects as it supply the floodplain with fertile soil. It is estimated that , the livelihood of 147 local communities along the Blue Nile river in Sudan are totally dependent on recession agriculture within the floodplains of the Blue Nile River system. On annual basis, there is about 40,000 hectares inundated floodplain areas along the BN river from Deim station (Ethiopian Sudan boarder) to Khartoum. Such inundation reaches its peak during the months of August and early September and river stages start to recede late

September offering a great opportunity for recession agriculture. The main type of crops grown within the floodplains of the BN include Mangos, Citrus, Guava, Banana, Fodder, vegetables in addition to wheat and other agricultural assets such as Sunut and Safsaf trees. Large Scale reservoirs within the upper watersheds of the Abay Blue Nile River system could have detrimental impact on the recession agriculture activities within the floodplains of the Blue Nile River system. This tools is developed to assess the impact of regulations on the agricultural activities and the environmental functions of the Blue Nile River floodplains.







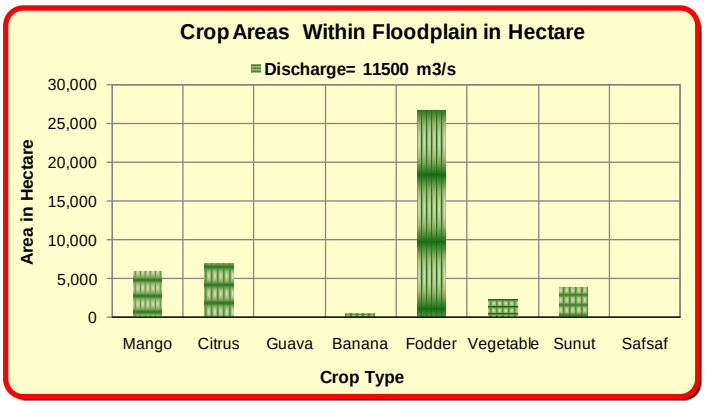
Objective

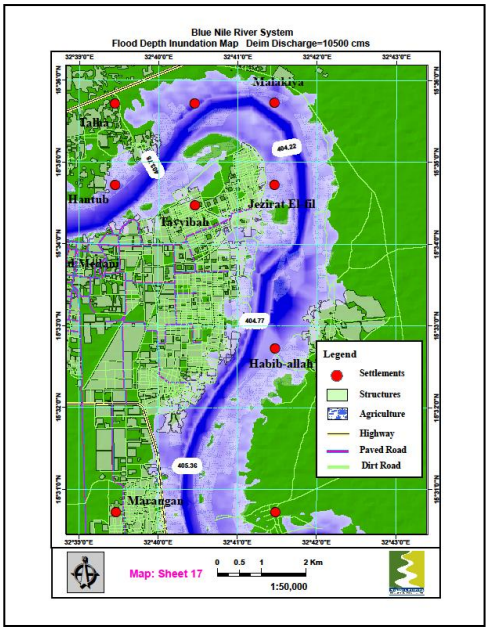
- Support the establishment of project baseline information for the first Joint Multi-purpose Project on the Abay Blue Nile River System;
- Develop analytical tool that could potentially be used to:
    - Scope key environmental and social issues associated with the construction of Large scale dam or cascade of reservoirs on the downstream floodplains of the Blue Nile River System;
    - Quantify the level/scale of impact of regulations on the agricultural activities within the floodplains of the Blue Nile River system.
    - Assess alternative mitigation options and means for proper compensation of impacted communities DS.

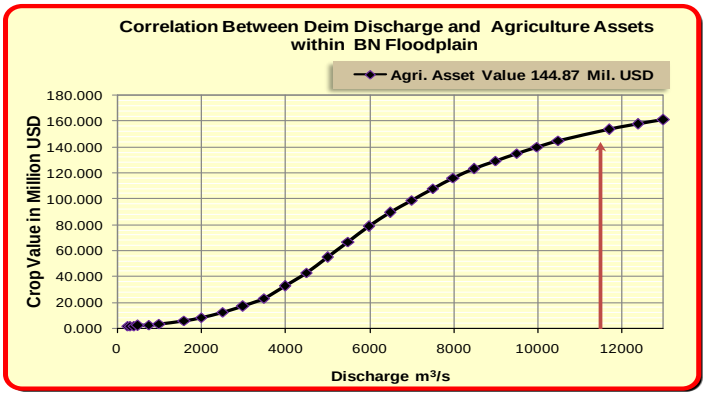
Description

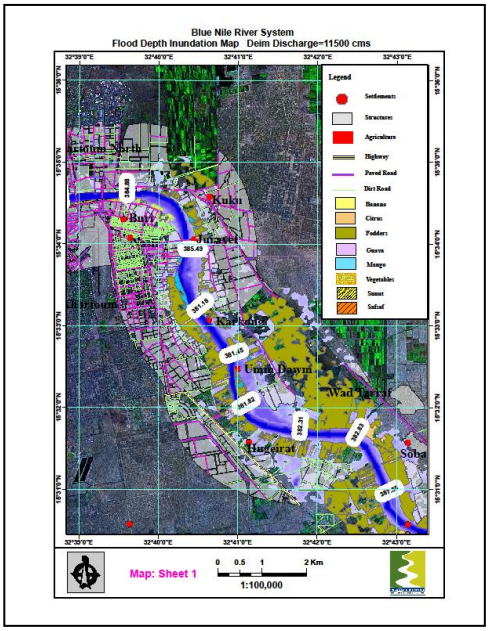
- Data collection and Preliminary Geospatial Analysis which include: Terrain Processing and development of Digital Elevation Model, Land use analysis for identifying and mapping agricultural assets, crop types, cop areas and their values and other types of uses that could potentially be impacted by flooding;
- HEC-RAS Hydraulic modeling to determine hydraulic profiles associated with different ratings of flow discharge at Deim station;

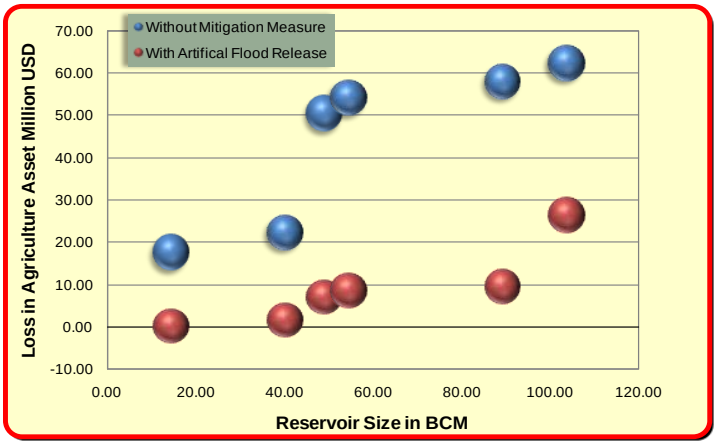
- Flood inundation mapping to determine the extent of inundation for different flood discharge values at Deim station. This include the Export of HEC-RAS results into Arc-GIS and the productions of a set of flood inundations maps and WSE profiles using HEC-GeoRas Post-Processor.
- Development of customized Excel spreadsheet for assessing impact of regulation on floodplain and for analyzing proposed mitigation measures











Intended Users and Beneficiaries

- ENTRO : Support the establishment of project baseline information for the JMP-1 and assist in scoping key environmental and social issues as part of the Strategic Social and Environmental Assessment;

- Ministries and Planning sectors across EN – finance, water, energy, dam implementation units, environment etc: Support the proper conduct of EIA and site specific studies for proposed dams in the EN.
- EN community at Large: Facilitate discussion among wide range of Stakeholders on the environmental and socio-economic impact of large scale dam project on the DS floodplains and to communicate adequate means for proper mitigations and compensation options for impacted communities.

What are the Toolkit's capabilities?

- Customized to assess wide range of scenarios/dam cascading options and not specific for particular dam project;
- The tool provide useful information for addressing the Environmental and socio-economic impact on recession agriculture activities such as the establishment of rating/correlation between the size or the footprint of reservoir and/or cascade of reservoir and the loss in floodplain areas and associated agricultural assets. Such rating correlation is based on a number of simulation runs for the hydraulic model and flood mapping tools in order to determine the loss in floodplain areas and agricultural assets associated with a wide range of routed hydrograph characteristics at a Deim station on the Ethiopia Sudan Boarder that is adequately represent the seasonal and inter-annual flow variability under both the base case scenario and any possible combination of regulation options in the Abay Blue Nile River System;
- The tools assess the impact of regulation on recession agriculture and environmental benefits of the floodplains in Monetary term and could potentially be used to facilitate fair and adequate means of compensation for impacted communities and local farmers;
- The tool offer means for assessing cost effectiveness of mitigation measures to address impact of regulation such as exploring options for artificial flood releases as part of the operation rules of the reservoir .

How was it developed and data used?

Toolkits was developed in-house by ENTRO ENPM Team. The data used include the following:

- The hybrid Terrain Model (TIN) created as part of the Flood Risk Mapping Consultancy for the BN (Riverside Technology & UNESCR-CWR Sudan, 2009). The Terrain Model was developed by merging different set of field surveyed data and the 90m Resolution DEM.
- Agriculture Asset layer which was developed as part of 2009 Field survey for the flood risk mapping study . The delineation of the shape file for Agriculture layer is prepared by first digitized all the farms and agriculture plots that are in close

proximity to the floodplains, using available Land use maps , Google Earth and Remote Sensing tools. The delineated areas are then field verified. The values of the agriculture assets are estimated based on crop values in USD (2009 rates) and after consultation with the Federal Ministry of Agriculture in Sudan and the results of field questionnaire. The developed Agricultural Asset layer has different feature classes which identify the type of crops , their areas in Hectares , unit rates values in USD/hectare, and Pro-rata values which is the product of hectares times the unit value. the main types of crops include vegetables, fodders, fruits, Sunut and Safsaf trees.

- Structural Asset Layer which was also developed as part of the flood risk mapping study using the same approach outline in the paragraph above and constitute different types of structures categorized according to the type of building material and the expected annual damage value at different flooding depth.
- Other Layers include Sudan settlement , Land sat Mosaic Msir Layers and public infrastructures layers such as roads and highways.

How can tool be expanded? How can it be improved?

- The current spatial coverage for the tool is the Blue Nile River system in Sudan. The impact of regulation on recession agriculture activities is not only limited to the Blue Nile River and there is a need to extent the spatial analysis coverage to include recession agriculture activities along the Main Nile River reaches up to high Aswan Dam;
- There is a need to enhance and field verify the baseline information used in identifying land use/recession agriculture activities and to incorporate the impact of the recently implemented projects in Sudan such as Rosaries Heightening and Merowe dam as part of the baseline information;
- The tool is tested based on the alternative cascade development scenarios as originally evaluated as part of the EN Power Trade Studies. There is a need to update the analysis to include the impact of GERD and the recently identified alternative options such as Beko Abo and upper Mendayia. options.
- The is a need to clearly distinguish between the impact of regulation on recession agriculture and irrigated agriculture such as pumping as this could lead to a significantly different conclusions about levels and scale of impact of regulations.

Technology

Platform

Excel based, with macros and simplified user interface
Includes inputs from GIS and other sources

Methods of updating data
Living toolkits – to be updated on continuous basis

Other
Sensitivity/sharing: low sensitivity with the potential to be publically shared
Available theoretical resources: references and access to some key theoretical sources could be availed as part of the toolkit . Public domain version toolkit will be made accessible to new ENTRO web portal