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Nile River Navigation - Integration of scenarios for sector development into the Strategic Water Resources Analysis

WRM-2022-02

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Document Sheet

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The purpose of the technical report series is to support informed stakeholder dialogue and decision making in order to achieve sustainable socio-economic development through equitable utilization of, and benefit from, the shared Nile Basin water resources.

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Contents

Abbreviations

AfCTA	African Continental Free Trade Area
AfDB	African Development Bank
AU	African Union
BCP	Border crossing point
CCCC	China Communications Construction Company
COMESA	Common Market for East and Southern Africa
EAC	East African Community
EAC	East African Community
ERTA	Egyptian River Transport Authority
FINW	First-class inland navigation waterways
FOB	Free on board
FTA	Free trade area
HS	Harmonized System (of traded goods)
IASC	Inter-Agency Standing Committee
ICD	Inland container depot
IWT	Inland Water Transport
IWT	Inland waterway transport
KPA	Kenya Ports Authority
KPA	Kenya Ports Authority
KRC	Kenya Railaway Corporation
KRC	Kenya Railways Corporation
LAPSSET	Lamu Port-South Sudan-Ethiopia-Transport Corridor
LoLo	Lift-on/lift-off
MSCL	Master Synchronizer and Load Control
NBI	Nile Basin Initiative
NCTTCA	Northern Corridor Transit Transport Coordination Authority
NEPAD	New Partnership for Africa's Development
NileDSS	Nile Basin Decision Support System
NRI	Nile Research Institute
OCC	Operation Control Centers
OD	Origin and destination (transport survey method)
OEC	Observatory of Economic Complexity
PICI	Presidential Infrastructure Champion Initiative
PIDA	Programme for Infrastructure Development in Africa
RoRo	Roll-on/Roll-Off
Ro-Ro	Roll on-roll off (ferry mode)
RTA	River Transport Authority
RTC	River Transport Corporation
RVR	Rift Valley Railways
SGR	Standard Gauge Railway
SGR	Standard gauge railway
WOP	Without-project
WP	With-project

Glossary

Whitewater	River section with critical flow conditions
Cataract	River section with critical flow conditions, transversing rock sill
HEC-RAS	Hydraulic modelling software
Model	Simplified mathematical representation of natural processes

Part A: Baseline Assessment

1 Introduction

The Nile River and its tributaries are key assets for international transport and trade, flowing through eleven countries in north-eastern Africa: Burundi, D.R. Congo, Egypt, Ethiopia, Eritrea, Kenya, Rwanda, South Sudan, Sudan, Tanzania, and Uganda. The Nile comprises three broad sub-systems, namely the Eastern Nile sub-system, the Equatorial Nile sub-system, and the Main Nile sub-system. Further, the basin is divided into several sub-basins: Main Nile, Atbara, Blue Nile, White Nile, Baro-Akobo-Sobat, Bahr El Jebel, Bahr El Ghazal, Lake Albert, Victoria Nile, Lake Victoria, as well as its tributaries[1].

Figure 1. The Nile River basin

The Nile River navigation study aims to integrate river navigation scenarios into the strategic water resources analysis (NileDSS) for cooperative management and development in the Nile basin. Specifically, the study purpose is to develop the data, modelling approaches, and scenarios required to integrate the navigation sector in the Nile DSS, in order to be able to assess model-based impacts of future basin

[1] NBI https://www.nilebasin.org/index.php/media-center/maps

development on current and future scenarios of navigation use of the Nile water system and vice versa, and as such enable the assessment and balancing of competing stakeholder requirements in a holistic manner. Both, river sections as well as lake sections are taken into consideration.

1.1 Stretches

For the assessment, the Nile River is divided into 13 stretches, focusing on the specific navigation characteristics of each stretch. The stretches from north to south are the following (see Figure 2):
Stretch 1: Main Nile – Nile Delta to Aswan
Stretch 2: Lake Nasser – Aswan to Wadi Halfa
Stretch 3: Main Nile – Wadi Halfa to Khartoum
Stretch 4: Blue Nile – Khartoum to Renaissance Dam
Stretch 5: White Nile – Khartoum to Malakal
Stretch 6: Sobat River
Stretch 7: Bahr el Jebel – Malakal to Juba
Stretch 8: Bahr el Jebel and Albert Nile – Juba to Lake Albert
Stretch 9: Lake Albert
Stretch 10: Kyoga Nile
Stretch 11: Lake Kyoga
Stretch 12: Victoria Nile
Stretch 13: Lake Victoria

There are further secondary stretches that are either currently being used, have been used in the past, or carry some navigation potential, that have not been covered in depth in this study. These stretches include

- Atbara River
- Lake Tana
- Baro River
- Akobo River
- Bahr el Ghazal
- Semliki River
- Akagera River
- Lake Edward

These stretches have either secondary- or isolated characteristics, and while locally important, are not major stretches of the main Nile transport system, i.e. smaller barges would be used on these stretches.

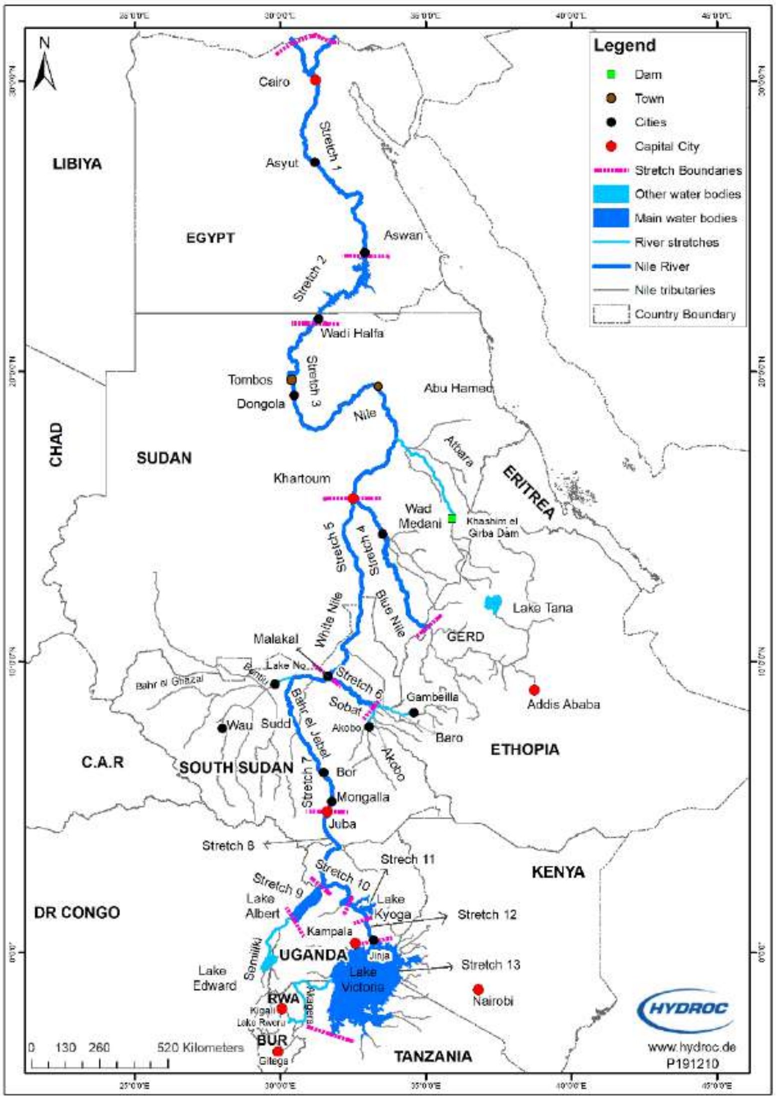

Figure 2. Stretches of the Nile River

1.2 Purpose of the Baseline Assessment

The baseline assessment describes the baseline condition of navigational use of the Nile water resources based on available information. It covers the identification of river stretches, lakes, and other water bodies (e.g. wetlands, swamps, waterfalls, cataracts) that are being used for navigation in the River Nile system and list characteristics that are relevant to navigational requirement (including cross-section characteristics, currents, tidal and/or river (velocity, direction, and duration), limitations, etc.).

Further, the assessment covers a description of the current river/lake/wetland navigation system, including all currently and potentially navigable waters. A map that marks all waters that are navigable now (or where before) is shown in Figure 2. Another key feature of this navigation study is an assessment of the major Nile River ports and their characteristics. In the context of this study, Nile River navigation has been considered where barges with drafts of 1.5m (in Egypt 2.5m) are in use. Stretches where smaller vessels are in use or may be used are recommended to be studied in site specific approaches at a later stage.

1.3 Nile Basin Regional Description with Regards to Navigation

1.3.1 Geographic Description

The Nile River is 6,695 km long with a catchment area of 3,254,555 km^2 and the basin is home to almost a quarter of the African population[2].

The Nile River features several physiographic regions with diverse topography, drainage patterns, and geomorphology. Typical physiographic regions with a unique combination of topography, water bodies, surrounding territories, and vegetation include:

- Highlands – plateaus and mountains
- Lakes (both natural and artificial)
- Wetlands and swamps
- Deserts

The Nile River basin contains unique features among the world's large river basins, e.g. the Sudd wetland, Lake Victoria, and diverse species of flora and fauna[1]. Further, the basin includes a number of artificial reservoirs of varying sizes.

1.3.2 Hydrological Parameters

The hydrology of the Nile River is characterized by a strong seasonality as a result of the distinct wet- and dry seasons with their characteristic rainfall patterns in the south, and a desert climate with hardly any precipitation in the north[3].

1.3.3 River Infrastructure

River infrastructure comprises assets of various sectors, including e.g. off-takes, dams, reservoirs, bridges, dikes, ports, etc. This assessment is specifically focused on discussing the facilities and obstacles of navigability. Hence, further chapters include information about:

- Bridges (location, width)
- Dams (location, facilities)
- Ports (location, facilities)

Various stakeholders are involved with different interests in the basin. Navigation, utilizing long river stretches for barge transport, has to deal with the river infrastructure: partly benefiting from it (e.g. ports, locks, bank protection), and partly being limited by it (e.g. dams, bridges).

The possibilities of river transport are greatly dependent on the river infrastructure. The main types of goods and services, which the inland transport is used for, comprise passengers, livestock, food, fuels, and other merchandise. Inland ports, linked to road and rail transport connections to a broad range of markets handle the key export/import traffic. Improving transportation abilities is only possible by improving and maintaining the quality of infrastructure alongside the whole Nile River.[5, 6, 9]

The Nile River is currently not navigable by night, which increases transport time. Navigation further suffers from the absence of navigation aids, contributing to vessel accidents[4, 5]

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[2] GIZ Transboundary water cooperation in the Nile Basin project. 2002-2021. https://www.giz.de/en/worldwide/14940.html

[3] NBI https://atlas.nilebasin.org/treatise/rainfall-distribution/

[4] Pre-Feasibility Study: Establishing a Navigational Route between Lake Victoria and Mediterranean Sea (VICMED) - May/2015

1.3.4 River Transport

River transport has the advantage of being cheap, energy-efficient, relatively safe, and environmentally friendly[4]. The Nile region is endowed with a number of rivers and lakes that have great potential to support inland water transport. Nine of 11 Nile riparian countries have navigable water bodies and inland water ports along them, with Egypt and Uganda having the highest number.

Historically, the main areas important for inland water transport are Lake Victoria and Lake Albert, sections of the White Nile in South Sudan, and the Main Nile in Sudan and Egypt.[5]

Inland water transport is well suited for accessing remote areas. However, conflicts and instability have an adverse effect. In addition, the sudden rise in water levels in the 1960s in the Equatorial Lakes region, which caused the submergence of piers and port facilities, and disrupted the north-south trading route, led to a refocus on road transport in the Equatorial Lakes region. This situation prevails to the present day.[5]

Inland water transport in the region is further restricted by cataracts and dams, that either do not have locks or have locks that do not function[4]. The key characteristics are discussed in the following chapters.

In the downstream section of the Nile (Sudan and Egypt) inland water transport is used without major disruption but is of lower importance than road transport. In some Nile basin countries, despite being well-endowed with surface-water resources, has no significant navigable waterways.[4]

1.4 Regional Relevance of Inland Waterway Transport

Economic growth is an important common goal for the Nile countries and regional trade is an important means to achieve this. Efficient and cheap transport is a crucial underlying assumption for growth strategies and the main justification for national and regional attention to navigation development.

Inland waterway transport in many Nile countries, however, has received less attention as a mode of transport and does not usually feature prominently in the transport planning strategies. Long stretches of navigable waters remain undeveloped.

Inland water transport, being a low-cost, energy-efficient, and environmentally friendly mode of transport, represents an ideal infrastructure for sustainable development[6]. The overall costs of all externalities for bulk transports using inland waterway transport are roughly 83% lower than road and roughly 70% lower than rail transport. In container transport, inland waterway transport costs 78% less than road transport and 68% less than rail transport. Inland waterway transport is the cheapest among the three means of transportation, cheaper than the road by about 20% and roughly 17% of the price of air transportation[7].

Given the lower cost of moving people and cargo by river transport – and the fact that port and river facilities are cheaper to develop and maintain than road and rail networks – there is potential for navigation to regain its position as an important aspect of the regional infrastructure network. An optimal mix of road, rail, and inland waterway transport will provide an efficient transport infrastructure that is flexible and cost-effective.

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[6] EU. 2019. Guidance document on Inland waterways transport and Natura 2000. A summary.

[7] Mikio Ishiwatari. (2011) Redevelopment of inland water transport for post-conflict reconstruction in Southern Sudan

Riparian governments and the private sector are presently not developing the advantages of this potential due to institutional and physical barriers within the water transport sector. Furthermore, it is difficult to convince planners and investors of the potential as long as data on water transport remains limited and incomparable. Not surprisingly, available data on the composition and growth of the inland waterway transport fleet are incomplete, inconsistent, and unreliable. The advantage of taking a regional approach to inland waterway development is that navigation itself is a transboundary activity, with the Nile crossing many borders on its way to the Mediterranean Sea.

Although there is no regional institution specific to navigation, the Northern Corridor Transit Transport Coordination Authority (NCTTCA) has been commissioned. The Northern Corridor is a multi-modal corridor, consisting of road, rail, pipeline, and inland waterways transport and is recognized as a significant corridor for logistics in East Africa. The main road network runs from Mombasa Sea Port through Kenya and Uganda to Rwanda and Burundi and to the Democratic Republic of Congo (DRC). The road network also links Kenya and Uganda to Juba in South Soudan.

Established under a multi-lateral agreement (NCTTA Agreement, 2007) between Burundi, DRC, Kenya, Rwanda, Uganda, and South Sudan (admitted in 2013), the agreement includes several protocols among which Protocol No. 7 relates to “Inland Waterways Transport of Goods”. This Protocol commits the parties to equal treatment of nationals and flagged vessels and to agree that no carrier will be granted exclusive rights to navigation or carriage of inter-state or transit traffic. The parties also commit themselves to taking measures to ensure the navigability of waterways. A Northern Corridor Infrastructure Master Plan (2011), issued for the NCTTCA, provides for a long-term strategic development of the corridor's infrastructure to cope with traffic growth.[8]

A Lake Albert, Albert Nile, and Bahr el Jebel waterway improvement project has the potential for serving greater international traffic and providing linkages to the Northern Corridor. A viable inland water transport system could contribute effectively to lowering the transportation cost and thus cost of goods, thereby facilitating trade and growth. By opening up new areas that are poorly served by other means of transport e.g., in the Eastern DRC and South Sudan, inland waterways can make a direct contribution to poverty reduction efforts and open up opportunities for growing trade and investment in the region.

[8] Northern corridor infrastructure master plan: Final report. Northern Corridor Transit Transport Coordination Authority. May, 2011.

2 Description of the Current Navigation System in the Nile basin

Features of the navigation system in the Nile River are diverse and do depend on various factors. Geographically, the river has a steep gradient in the Equatorial Lakes region down to Juba. That includes some obstacles such as waterfalls, or hydropower sites constructed at their location.

Further downstream, the river has a more gentle gradient but navigation must deal with wetlands and swamps. A general topographic structure of the Nile River is illustrated below:

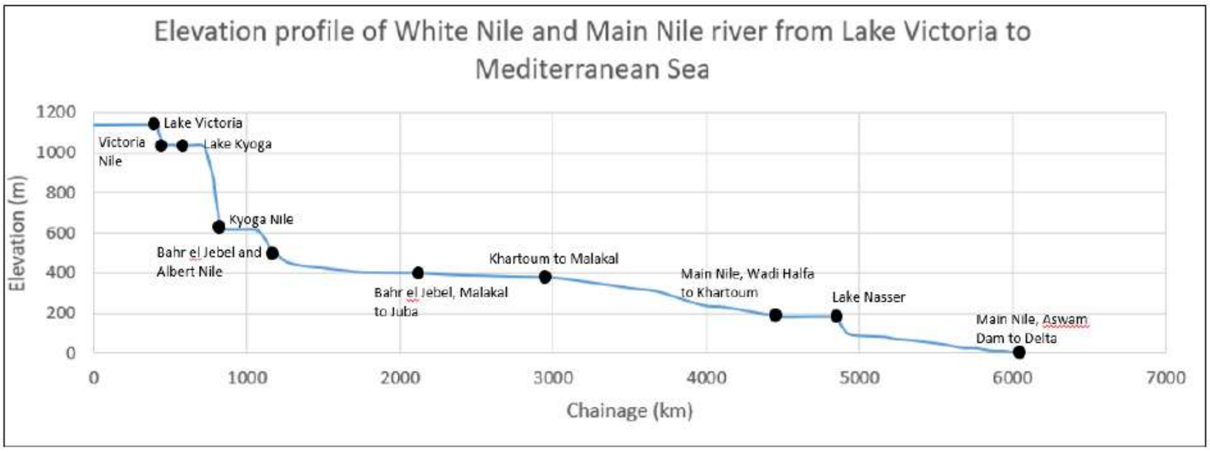


Figure 3. Differentiation of the Nile River elevation[9]

[9] Said R (1993) The Nile River: geology, hydrology and utilization. Pergamon Press, Oxford, UK. 320 p

2.1 Stretch 1: Main Nile – Nile Delta to Aswan

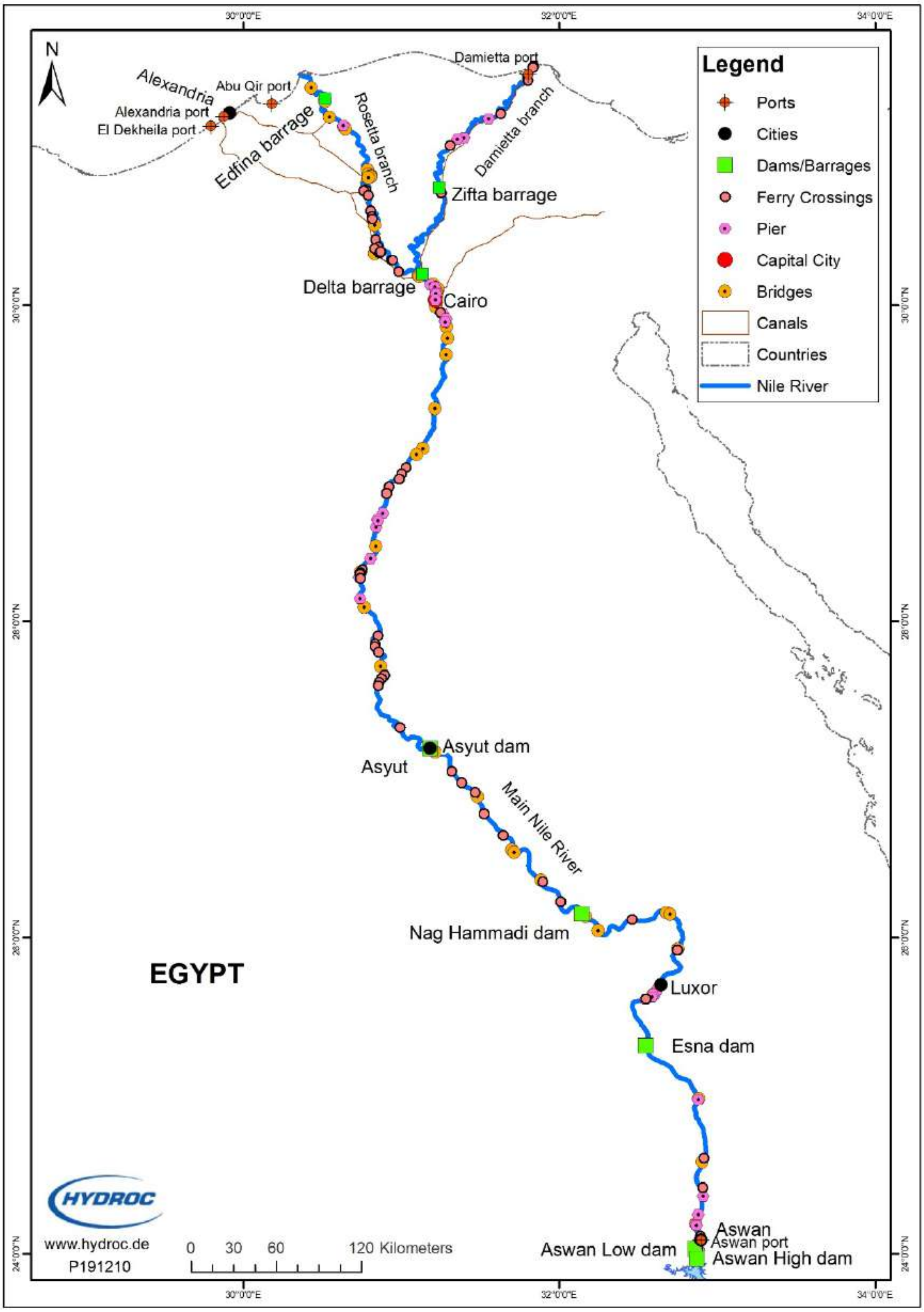


Figure 4. Main Nile in Egypt map

Table 1. Main Nile in Egypt data sheet

Navigability availability	Fully navigable due to a diverse web of artificial canals
Current physical situation	The water level is controlled by the High Aswan Dam
Number of bridges	70
Number of dams	8
Number of ports (dock stations, piers)	11 ports; 87 piers
Other obstacles	Ferry crossings: 60

The river Nile in Egypt consists of the Nile Delta on the north with its Rosetta and Damietta branch, which run into the Mediterranean Sea, as well as the main Nile stem up to High Aswan Dam. The inland waterways constitute approximately 1% of the total freight transported in Egypt per year[10].

The Nile Delta is 160 km long and up to 185 km wide, containing extensive areas of swamps and shallow lakes.[4] Damietta branch flows to the east and Rosetta flows to the west, carrying the river's water to the Mediterranean Sea. The two branches split roughly 15 km north of Cairo.

Damietta Branch

The constant demand for cargo transportation between Cairo and Damietta increases the stress on the road network of the Nile Delta. Therefore, river navigation development is under the consideration of the Government of Egypt.[11]

Rosetta branch

The route is running from the Delta split across El-Rayah-El-Behery and El-Noubarayah Canals. It is connected to the maritime transport by Alexandria Port.[7]

Main Nile

Regular river transport service is maintained between Alexandria and Aswan mainly for tourist purposes. Navigation opportunities are being implemented via the development of inter-modal terminals and dry ports for rail and waterways transport and via the upgrading of the available rail and waterway transport infrastructure.[12,13]

The stretch may be described in several sections bounded by barrages or regulators as follows:

1. section, located between Zifta Barrage and Delta Barrage, with a total length of 100 km
2. section, located between Edfina Barrage and Delta Barrage, with a total length of 200 km
3. section, located between Delta Barrage and Asyut Barrage with a total length of 409 km
4. section, located between Asyut Barrage and Naga-Hammadi Barrage with a total length of 185 km
5. section, located between Naga-Hammadi Barrage and Esna Barrage (Esna lock) with a total length of 193 km
6. section, located between Esna Barrage and Low Aswan Dam with a total length of 167 km
7. section between Low Aswan Dam and High Aswan Dam

A description of the sections is provided in Table 2. The table represents specifications: section's length; section's average width; minimum width for vessels to pass; minimum water depth for vessels to pass.

[10] Central agency for public mobilization and statistics (2011) Transport. Cairo: CAPMAS, (Feb-10-1CZ).
[11] Yasser Raslan, Nahla Sadek, Karima Attia. Impact of Navigation Development on Damietta Branch.
[12] Buuisma, F., Gorter, C. and Nijkamp, P. (2000) Multimodal infrastructure, transport networks and the location of firms. Transportation Planning and Technology, 23(1), 259-281.
[13] IRPT (2011) about the inland waterways. Available at: http://www.irpt.net/ (15 April 2011).

Table 2. Key characteristics of six sections along the Egyptian Nile[14, 15]

From - to	Length (km)	Average width (m)	Min width (m)	Min Water depth (m)
Rosetta branch (from Delta barrage) - western leg	240	639	35 two-way; 12 one-way	2.50
Damietta branch (from Delta barrage) - eastern leg	245	570		
Delta barrage - Asyut	415	1060		
Asyut - Naga Hamadi rapids	190	533-1150		
Naga Haadi rapid - Esna rapids	190	217		
Esna rapids - Aswan High Dam	169	N/a		

The River Transport Authority (RTA) reports that there are 44 private ports along the river Nile in Egypt and canals in the Nile Delta, as well as six public ports. 35 ports are owned by industrial companies involved in sugar, cement, fertilizer, aluminium, iron/steel, coke, and petroleum products. 31 of these ports are located in Upper Egypt and only four are located in the Nile Delta. Since the number of ports in the Nile Delta is too small and the existing ports belong to factories, there is a plan to construct or upgrade the river ports.[14, 15] The locations (coordinates) of private ports/docks could not be identified, they are not considered in this assessment. However, their names are provided in Table 3.

Table 3. List of private owned ports in Egypt

Port name	Facilities/ equipment available	Storage capacity (ton)
El Hadid and El Solb (Iron & Steel)	Demolished	-
Abu Zaabal Fertilizers Abu Zaabal Mines	Loader Belt conveyors	15,000
Kima	20t crane	2,000
El Nasrr Phosphate (Tanash)	Belt conveyor	2,000
El Gizera	Crane 1 loader	3,000
El Shima	2 cranes	1,000
El Nasrab	Belt conveyors	1,500
El Akaba	1 transportation gutter 1 crane 1 loader	2,000-3,000
El Biyara	--	15,000
Edfu Sugar	Fixed crane	2,000
El Morada	Dredging machine	180
Firocilicon Factory	2 cranes (10 t loading capacity)	500
El Sibaaya	Belt conveyors	30,000

[14] El-Nakib, Islam. (2011). Examining the Status of Egypt's River Transport System. Applied Scientific Research. 48. 112-123.

[15] The study on multimodal transport and logistics system of the eastern Mediterranean region and master plan. Final report. Chapter 4.

Port name	Facilities/ equipment available	Storage capacity (ton)
	Loader	
Armant Sugar	Fixed cranes	30,000
Koss Sugar	Freight terminal 2 cranes	50,000
Dishna Sugar	2 cranes	10,000
Nagaa Hammady Sugar	2 cranes	50,000
River Aluminum	1 crane bridge 2 dredging	60,000
El Balina	45t ferry	10,000
Gerga Sugar	2 buoys 2 cranes	500
Asyut Calories Station	2 suction pumps 8t crane	35,000
Petrol Port Egypt	Pumping pipes Cisterns Loading terminal	Warehouse
Asyut	E-vehicle elevators 2 cranes 4 pumps 1 packing unit 4 transportation gutters	20,000 – 60,000
Fertilizer Factory in Menkbad	2 cranes	50,000
El Nil Cotton Ginning Co	1 crane	7,000
Bany Khaled in Samllo	Belt conveyors	10,000
Limestone in El Tebbin	3 cranes (16t lifting capacity) 1 crane (16t lifting capacity)	70,000
El Tebbin El Nahree	4 cranes	17,750
Coke Factory in El Tebbin	4 gantry cranes	125,000
El Kawmiya Cement	Cement loading machine	7,000
Cement Packing on Nile Portland	1 crane 2 packing machines 4 belt conveyors	9,000
Samloot Cement Receive Portland	Immovable crane	7,000
Sugar Factory in El Hawmdiay	Immovable crane	1,000

Port name	Facilities/ equipment available	Storage capacity (ton)
Equipments Factories	Belt conveyors	7,000
El Masara	Bridge crane Movable crane	4,000
Tora	Cement tankers Belt conveyor	5,000
Athar El Nabi	1 crane	200,000
Ambaba Tankers	2 sanction machines	60,000
Sauulft	1 crane	40,000
Phospgate (Ismailiya canal)	Suction drilling machine Belt conveyors	60,000
El Nahda (El Nobaria canal)	1 crane	80,000
El Metras (El Nobaria canal)	Bridge crane Wheel movable crane	5,000

The design of first-class inland navigation waterways (FINWs) in Egypt is primarily determined by traffic intensity and cargo weight to be transported. The waterway width should be sufficient to avoid traffic congestion, and the cargo should not submerge the vessel deeper than the allowable draft. The maximum allowable ship draft for FINWs is 1.80 m, according to Egyptian River Transport Authority (ERTA) specifications (Nile Research Institute Report, 2005[16]). As a result, the vessels chosen for transportation along the Nile are of two types: self-propelled units and twin-ship barge units (coupled pusher and pushed barge). The coupled unit is the oldest and most widely used type of barge. It is up to 100 meters long and has a draft of 1.40 to 1.80 meters.[17]

The lengths of first-class waterways in the Nile Delta and Nile Valley are about 852 km and 980 km, respectively, composing a total of 1,832 km waterways. In addition, a 350 km long waterway exists along Lake Nasser, making the total length of the Egyptian Nile to be approximately 2,182 km. However, only 1,562 km of those are navigable for commercial large-size vessels, comprising the Nile mainstream. The rest of the river (Damietta branch, Rosetta branch, and Ismailiya canal) is barely used for commercial navigation but is partly navigated by sailing vessels and shallow-draft river vessels.[5, 18]

[16] NRI Report, 2005. Studying the Operational Rules of Damietta Branch Navigational Waterway. Report No., 28, Sept., 2005, National Water Research Center, El Qanater, Cairo, Egypt.
[17] W.A. Fahmy, Nasr Hekal (2021) Study of Damietta branch meander suitability for inland first-class river cargo transportation. Journal of King Saud University - Engineering Sciences
[18] NBI. Inland Water Transport

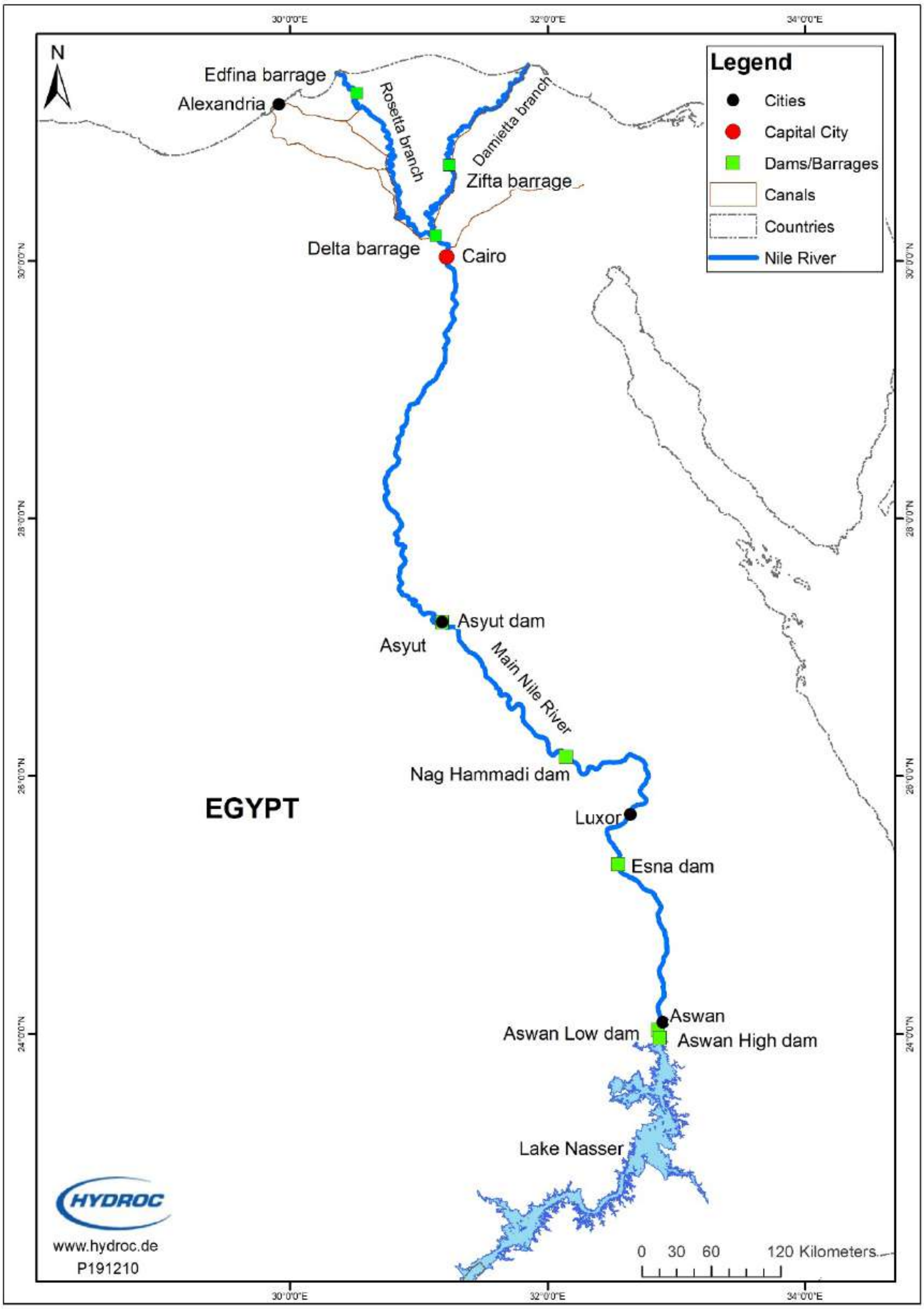


Figure 5. Map of barrages on the Egyptian Nile

The width of the Nile River varies from 200 m to more than 1000 m. Some reaches have sharp meander curves such as Naga Hammadi stretch and Damietta branch. Some other stretches are relatively straight.[5] The water depth varies according to season and reach. The river slope is generally mild.[19]

In Aswan, just downstream of Lake Nasser, two dams are placed. The distance between the High Aswan Dam and the Low Aswan Dam is about 7 km, and is not used by cargo vessels. However, some tourist boats may operate between the dams.

Next to the river channel, water from the Nile River is diverted to agricultural lands through a system of public canals that comprise carrier- or principal canals, main canals, secondary (or branch) canals and tertiary (or sub-branch) canals. The branch canals deliver water into private canals that are called mesqas.[19] The canal system is very extensive; the government is responsible for the operation and maintenance of the public system[20].

Many canals have multi-purpose, providing drainage, irrigation, water supply, and generation of hydroelectric power as well as navigation.[21] Given the opportunity to access multiple destinations, the irrigation web may be used by small vessels to carry goods.

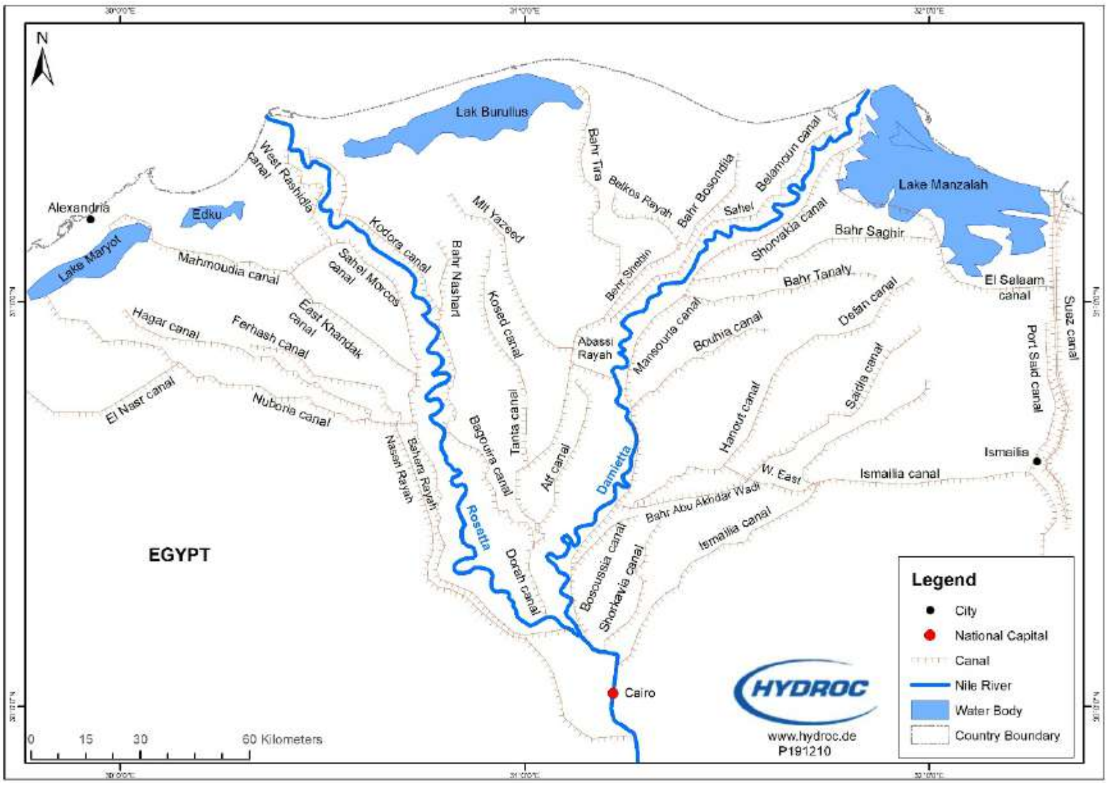


Figure 6. Irrigation canals in the Nile Delta[22]

[19] ICARDA, 2011. "Water and Agriculture in Egypt."

[20] Fanack newsletter. Water infrastructure in Egypt.

[21] Marsh, C. Marriage and Davies, . Ernest Albert John. "Canals and inland waterways." Encyclopedia Britannica, January 31, 2019. https://www.britannica.com/technology/canal-waterway.

[22] MWRI, 2005. 'National Water Resources Plan for Egypt 2017.' Available at http://extwprlegs1.fao.org/docs/pdf/egy147082.pdf,

2.2 Stretch 2: Lake Nasser (Lake Nubia) – High Aswan Dam to Wadi Halfa

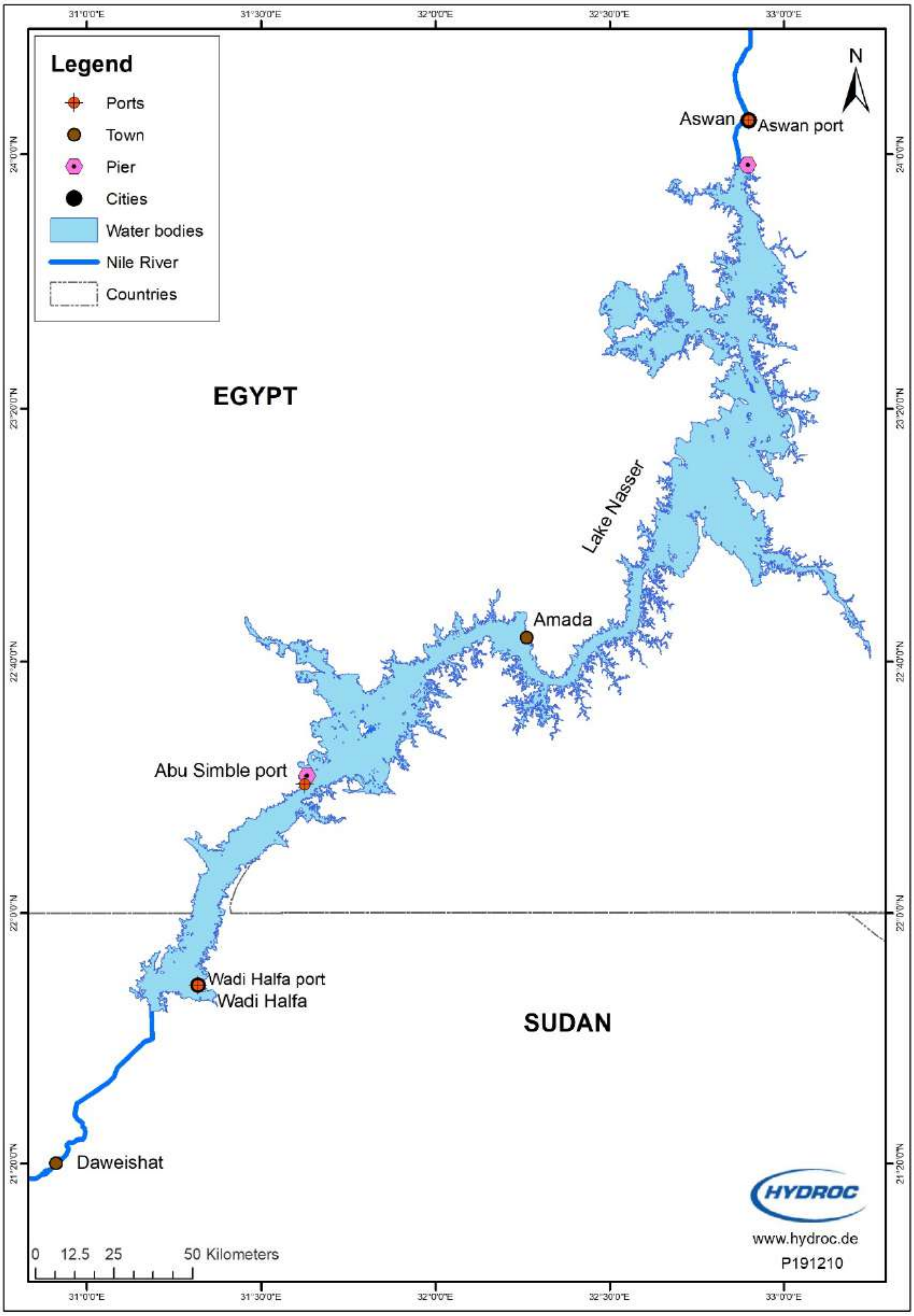


Figure 7. Lake Nasser map

Table 4. Lake Nasser data sheet

Navigability availability	Mostly navigable
Current physical situation	Navigation is limited during low water periods
Number of bridges	0
Number of dams	0
Number of ports (dock stations, piers)	5

The Lake Nasser from Aswan in Egypt to Wadi Halfa in Sudan is navigable and equipped with navigation aids. In case of low water levels, some areas in the southern part of Lake Nasser have navigation limitations due to sedimentation.[5] Lake level fluctuations are significant (Figure 8) with a range of several meters intra-annually as well as inter-annually, causing the southern end of the lake to change significantly in its characteristics over the year.

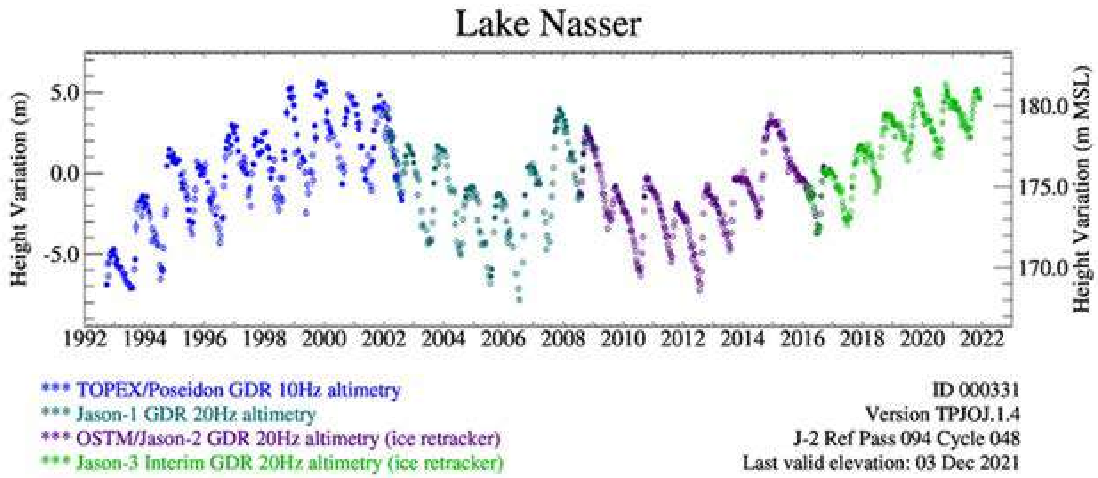


Figure 8. Lake Nasser water level fluctuations

The lake is almost 500 km long, 16 km wide, and has an average depth of 28 m. Its current capacity is 168 km^3 of water. Lake Nasser connects the ports of Aswan, Abu Simble and Wadi Halfa, which are especially important for trading between Egypt and Sudan.

The lake can be divided into three sections[23]:

- the lacustrine section, extending from the Aswan High Dam to Amada/Tushka
- the semi-riverine section, with riverine characteristics during the flood season and lacustrine characteristics during the rest of the year, comprising the southern part of Lake Nasser and the northern part of Lake Nubia, extending from Amada/Tushka to Wadi Halfa; and
- the riverine section, with all-year riverine characteristics, comprising the southern part of Lake Nubia from the southern end of the lake (Wadi Halfa) to Daweishat

The piers on Lake Nasser (Abu Simble, Aswan, and Wadi Halfa) are designed in a sloping manner to effectively manage significant water level changes without navigation interruptions.

As an example, the Abu Simble pier is illustrated below.

[23] Abdel-Latif AF. 1984. Lake Nasser (Egypt), Status of African Reservoir Fisheries. CIFA Technical Paper 10. FAO

07/2013 10/2014 11/2016

Figure 9. Changes in Abu Simble water level and their effect on the pier

2.3 Stretch 3: Main Nile - Wadi Halfa to Khartoum

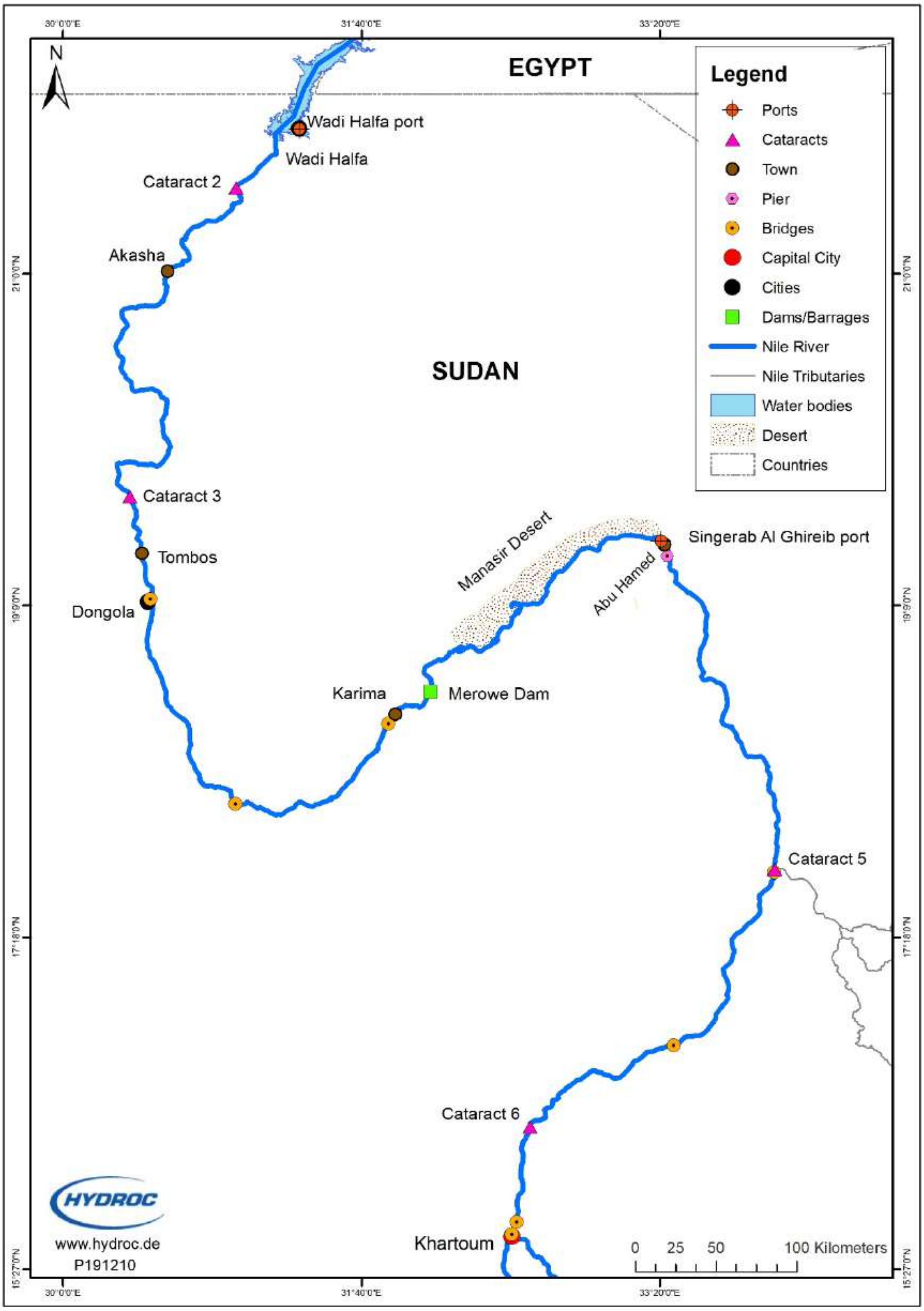


Figure 10. Wadi Halfa to Khartoum map

Table 5: Stretch data sheet

Navigability availability	Very limited for the whole reach (due to cataracts and high slopes). It has some local navigation for relatively short reaches
Current physical situation	The stretch has multiple physical obstacles for navigation (e.g. rapids)
Number of bridges	7
Number of dams	1 (Merowe dam)
Number of ports (dock stations, piers)	3

This stretch is located on the Main Nile from Wadi Halfa to Khartoum over a distance of about 1400 km. The river course consists of a series of placid stretches of mild slope separated by rocky rapids called cataracts, where the slope is greater and the flow is more turbulent. The rapids themselves are caused by bars of hard rocks crossing the course of the river.[5] One of cataracts - the Fourth cataract (18.6661, 32.0529) - is located in the Manasir Desert, and since 2008, is submerged under the reservoir of Merowe Dam.

The river stretches between Wadi-Halfa and Akasha/Dongola are at present unmarked for navigation; pilots are handling the vessels along this stretch which are known as the Dongola Reach. The pilots entirely rely on their knowledge and skills to navigate the uncharted water.[5]

Commercial crafts operate between Dongola/Karima and between Wadi-Halfa/Aswan only. The abilities of inland water transport are very limited on this reach. However, the reach is subject to an international cooperation to allow the development of exports and imports and passenger movements between Egypt and Sudan. Between these areas and from Dongola to Karima the river is relatively unobstructed apart from shoals and a number of islands and small rocky bars.

Between 2000-2010, inland waterways transported 114,000 tonnes of cargo and 13,000 passengers despite rapids, cataracts, and seasonal variations in water levels that continued to hinder river traffic.[24]

[24] Sudan: a country study / Federal Research Division, Library of Congress;edited by LaVerle Berry. – Fifth ed. 2015

2.4 Stretch 4: Blue Nile – Khartoum to Renaissance Dam

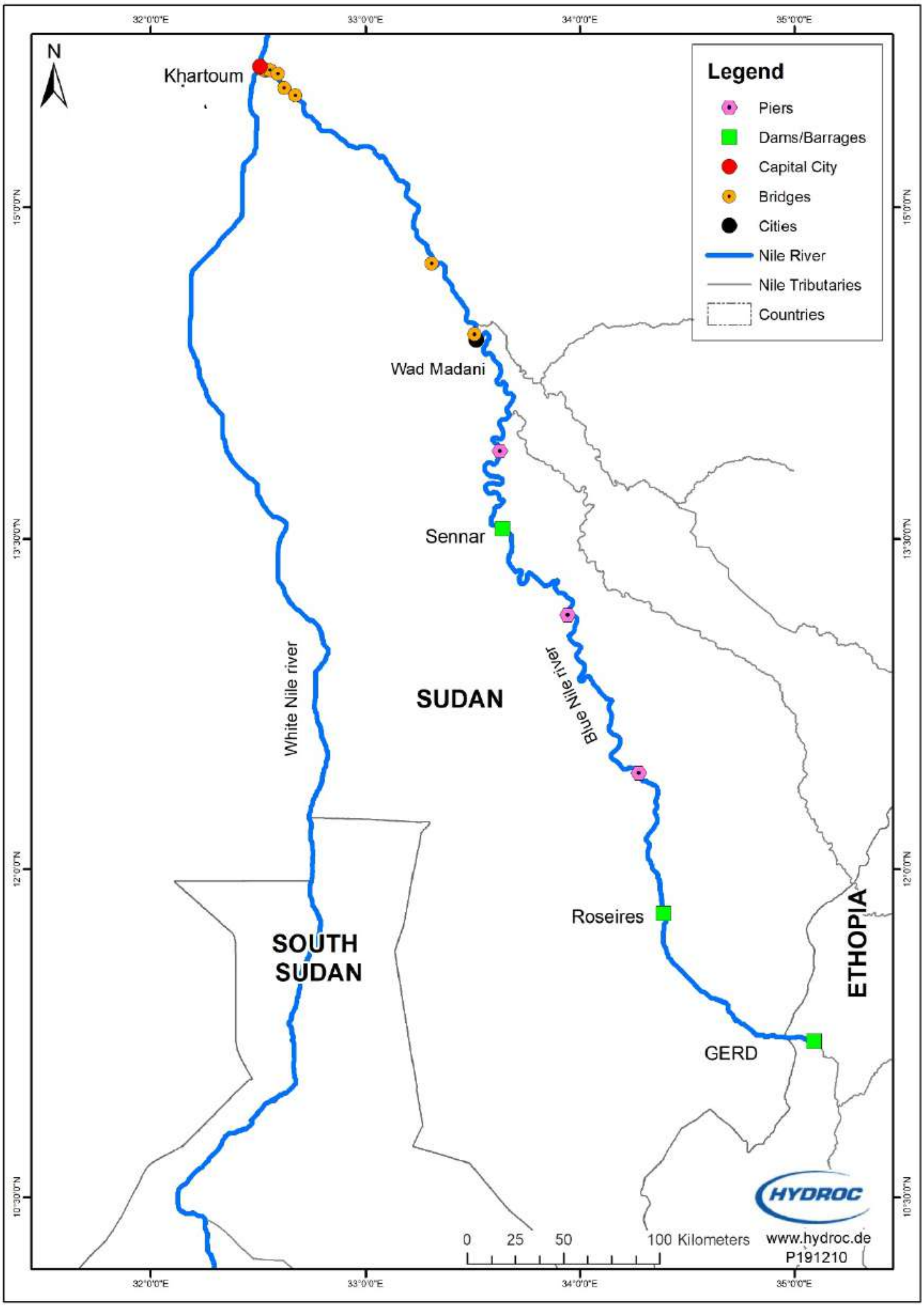


Figure 11. Blue Nile map

Table 6. Stretch data sheet

Navigability availability	Navigable during high water season
Current physical situation	River flow is characterized by seasonal variability
Number of bridges	9
Number of dams	3
Number of ports (dock stations, piers)	0 ports; 3 docking piers

The Blue Nile River is a headwater of the Nile River and the source of almost 70% of its flood water at Khartoum. The Blue Nile rises at 1,800 m above sea level, near Lake Tana in north-western Ethiopia. Its total length is about 1,460 km.[25] The stretch, which is discussed in this study, has two dams on its way in Sudan: The Roseires and Sannār dams, and one dam in Ethiopia - the Grand Ethiopian Renaissance Dam (GERD). None of them have locks while a web of artificial channels with locks is going alongside the Blue Nile. Two parallel canals are following the Blue Nile flow, bringing water from the reservoir behind the Sennar dam. The canals are 70 m and 40 m wide. Under Um Al Gura they split into 3 parts, going in different directions and splitting into smaller channels.

The Blue Nile stretch is navigable only during the high-water season.[26] The water flow of the Blue Nile River is characterized by seasonal variability, with 82% of the annual flow occurring from July to October[27] leading to significant water level fluctuations.

[25] Britannica, T. Editors of Encyclopaedia. "Blue Nile River." Encyclopedia Britannica, March 5, 2014. https://www.britannica.com/place/Blue-Nile-River.
[26] Britannica, T. Editors of Encyclopaedia. "Blue Nile River." Encyclopedia Britannica, March 5, 2014. https://www.britannica.com/place/Blue-Nile-River.
[27] Mellander P-E, Gebrehiwot SG, Gärdenäs AI, Bewket W, Bishop K (2013) Summer Rains and Dry Seasons in the Upper Blue Nile Basin: The Predictability of Half a Century of Past and Future Spatiotemporal Patterns. PLoS ONE 8(7): e68461.

2.5 Stretch 5: White Nile – Khartoum to Malakal

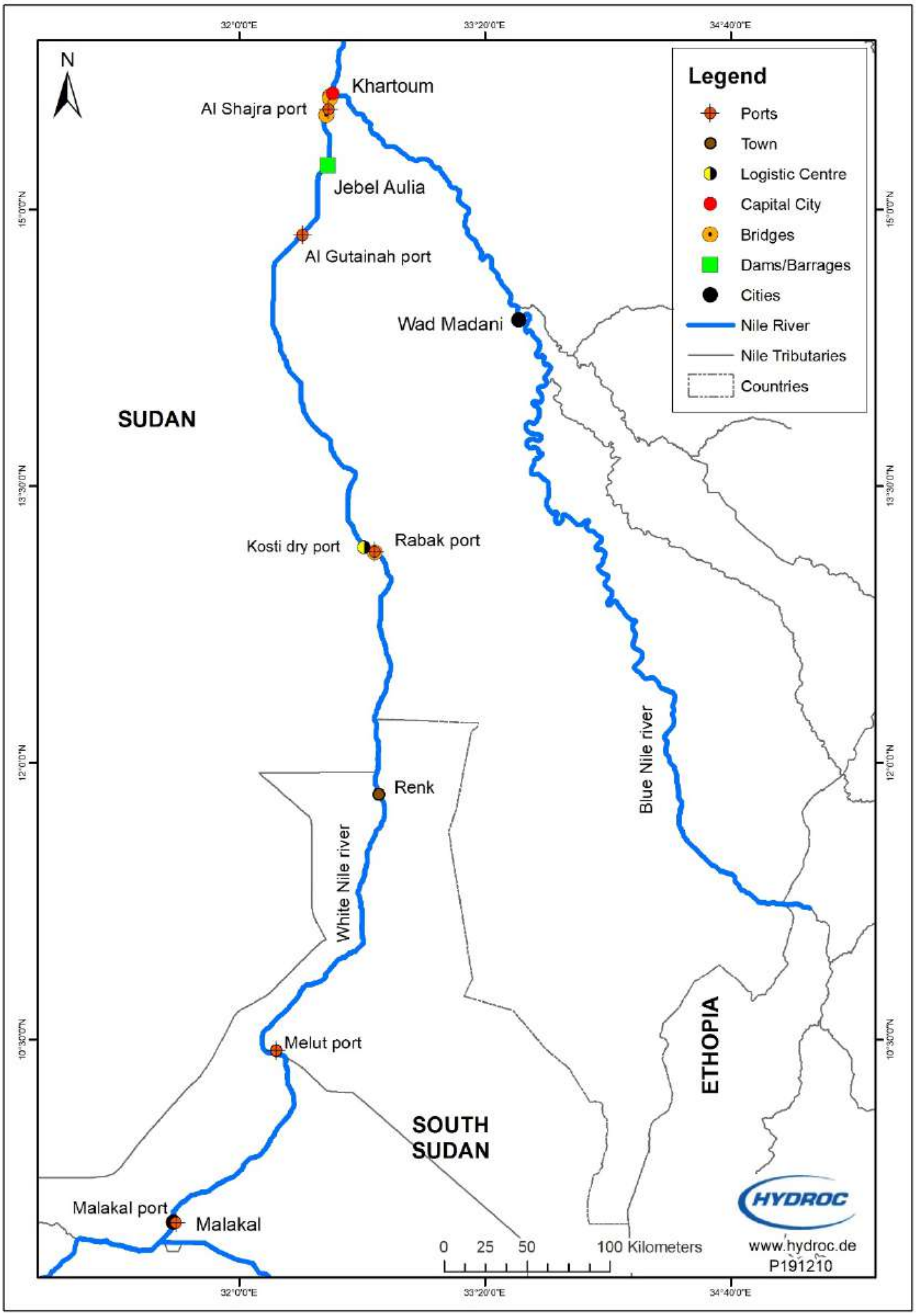


Figure 12. Khartoum to Malakal map

Table 7. Stretch data sheet

Navigability availability	Navigable but affected by low water levels
Current physical situation	The northern part of the channel of the White Nile is almost free from swamps. In South Sudan, the river is considered sluggish
Number of bridges	4
Number of dams	1 (Jebel Aulia; has non-operational locks)
Number of ports (dock stations, piers)	5; 1 dry port (Kosti)

The White Nile stretch between Sudan and South Sudan is one of the most important Nile River corridors because it provides the most reliable transport connection during the rainfall season. It is currently witnessing significant expansion by private operators, which will increase total shipping capacity.[5]

The White Nile River channel within Sudan is almost free from swamps. Going upstream, on the territory of South Sudan, the river is considered sluggish. Artificial features have also introduced restrictions, the most important of which is the Jabel-Aulia dam, about 40 km south of Khartoum. This dam has locks which are currently not operational.

A further important navigable route is the 1,436 km stretch on the White Nile from Kosti to Juba (known as the Southern Reach: Kosti, Renk, Malakal, Shambe, Bor, Mongalla, Terakeka, Juba), which provides the only generally usable transport connection between Sudan and South Sudan. This stretch is used all year round, though impeded by non-functioning or non-available navigation aids, shifting sand, shallow waters, and exposed rocks.[5] A fast transit time for barges going upstream (south) from Kosti to Juba is 21 days, and downstream (north) from Juba to Kosti is 7 days. Loading and unloading time is not included[33].

Although upstream from Renk, the White Nile has shallow stretches that restrict the carrying capacities of barges, especially during the period of low flows, the river has sharp bends. The section Renk to Malakal is characterised by an average slope of 3 cm/km over a distance of 340 km. The average width between the banks and islands is 442 m.

Width and depth are varying due to the many channel islands. Mostly, water depths are sufficiently deep for the barge transport, with possible shallower sections around 100 km upstream of Renk. Flow velocities are mostly low, in the range of 1-2 m/s, but increase in the shallower river sections to up to 4 m/s.[33]

The river transportation authority in Sudan has been privatized, thus private authorities are now competing in constructing and operating the river transportation system and river ports. The dry port of Kosti, which is the largest logistic centre in Sudan, is a clear example of privatization policies in Sudan. In South Sudan, existing river ports are belonging to the government while the private entities are now investing in the in-land ports (which consist of inland warehouses with storing facilities, which are connected to ports by roads and railways) that are tied with the river ports.[5] In South Sudan, inland waterway transport still provides the only means of transport facilities, especially where road transport is not usually possible from May to November, during the flood season.[18]

The River Transport Corporation (RTC) is the largest barge operator in Sudan. It is a public enterprise, which operates on the Nile River, while private operators mostly operate on tributaries. Operators offer a range of facilities and services that include pusher tugs, general cargo, flat deck, oil fleet, and self-propelled barges, thus providing a cost-effective logistics delivery option to Sudan's central and southern locations.[28]

[28] United Nations Joint Logistic Centre. South Sudan Snapshot. River Transport and Barge Operators.

Kosti Port is connected by rail and asphalt road to Khartoum, Port Sudan, and other major towns in Sudan. It has a riverbank line of 800 m and 115 m of vertical quay made of masonry with mooring rings and a track for mobile and floating cargo handling cranes (operational). The rail siding beside the quay is out of service. There is a dockyard for small to medium size boat repairs – access to spare parts and maintenance has been problematic[5].

Malakal Port is accessible year-round and has a concrete pier. No barge maintenance facilities exist at Malakal while limited space for potential usage of cranes for cargo handling exists.[6, 33]

2.6 Stretch 6: Sobat River

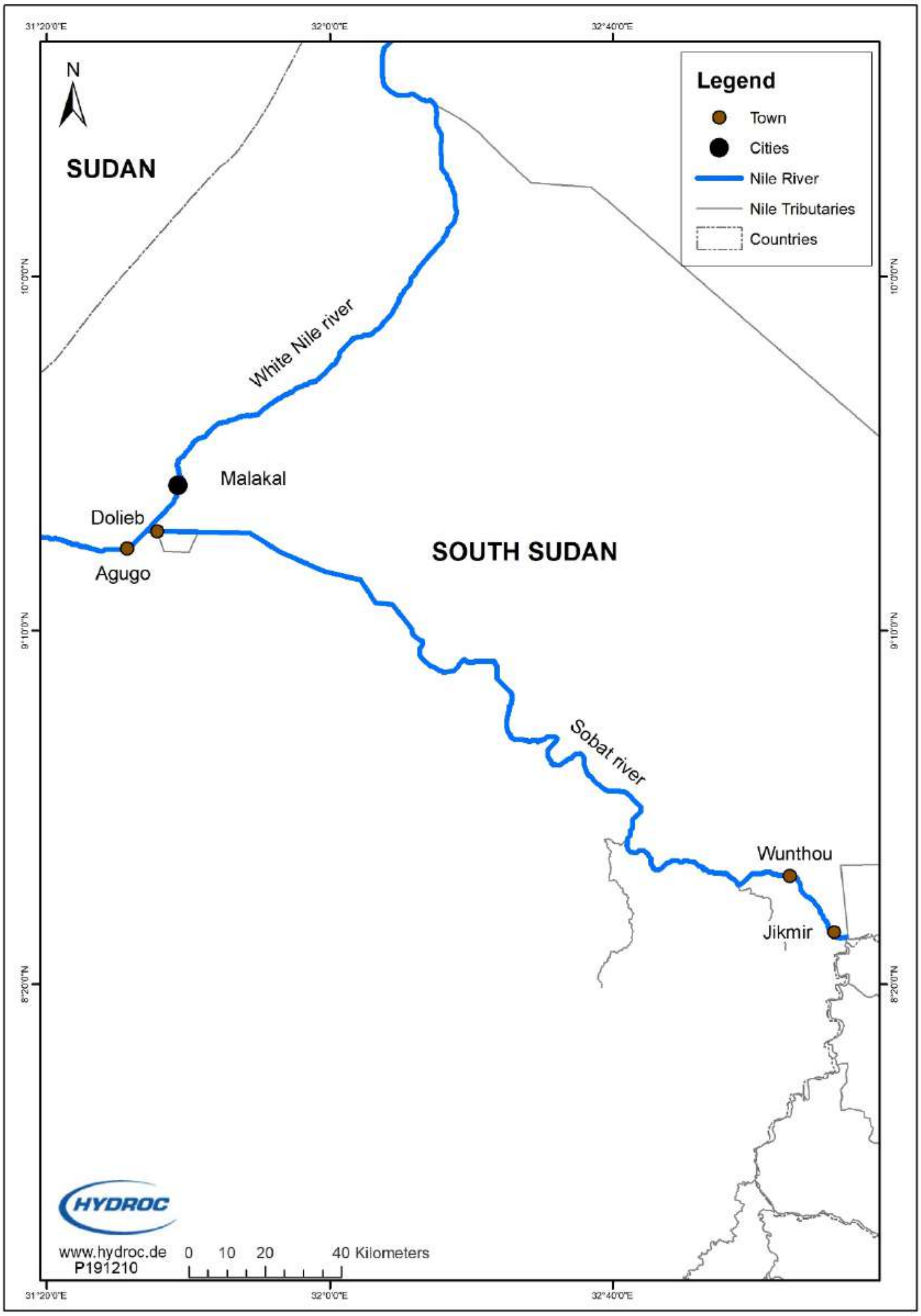


Figure 13. Sobat river map

Table 8. Sobat River data sheet

Navigability availability	Navigable during high water season for light boats
Current physical situation	Narrow and shallow river
Number of bridges	0
Number of dams	0
Number of ports (dock stations, piers)	0

The Sobat River is an easterly tributary to the Nile, joining the river just upstream of Malakal from Eastern Equatoria. The Sobat River is one of the largest tributaries of the White Nile with a minimum-, average-, and maximum flow of 99 m^3/s, 412 m^3/s, and 680 m^3/s respectively. [29]

The Logistics Cluster, a coordination mechanism established by the Inter-Agency Standing Committee (IASC) with the task to ensure an efficient and effective emergency response, is the main institution operating on the Sobat river supported by WFP. They use a strategy that cargo to be delivered along the Sobat river will first be transported with boat convoys from either Bor or Malakal to Agugo (close to the Sobat river mouth). Their operation on the Sobat river covers the stretch from Dolieb up to Jikmir.

During the peak of the dry season from February to May, water levels along the Sobat river are low. The Cluster explores using smaller-sized boats during this time. However, organizations are encouraged to pre-position their cargo in requested locations along the river before the low-water period.[30] The Cluster is in close cooperation with the WFP regarding the maintenance of the Sobat river navigability.

As per information provided by WFP, the Sobat River operations are served with a capacity of (max) 30 t light boats. Other higher volume boats are available as needs and river capacity increase during the rainy season.[31] Cargo loading and offloading are performed by manual labor only.

[29] Source: https://dlca.logcluster.org/display/public/DLCA/2.5+South+Sudan+Waterways+Assessment
[30] Source: https://reliefweb.int/sites/reliefweb.int/files/resources/logistics_cluster_south_sudan_river_movement_strategy_2021.pdf
[31] South Sudan Logistic Cluster. Logistics Snapshot Malakal, Sobat Corridor River Assessment June 2011.

2.7 Stretch 7: Bahr el Jebel – Malakal to Juba

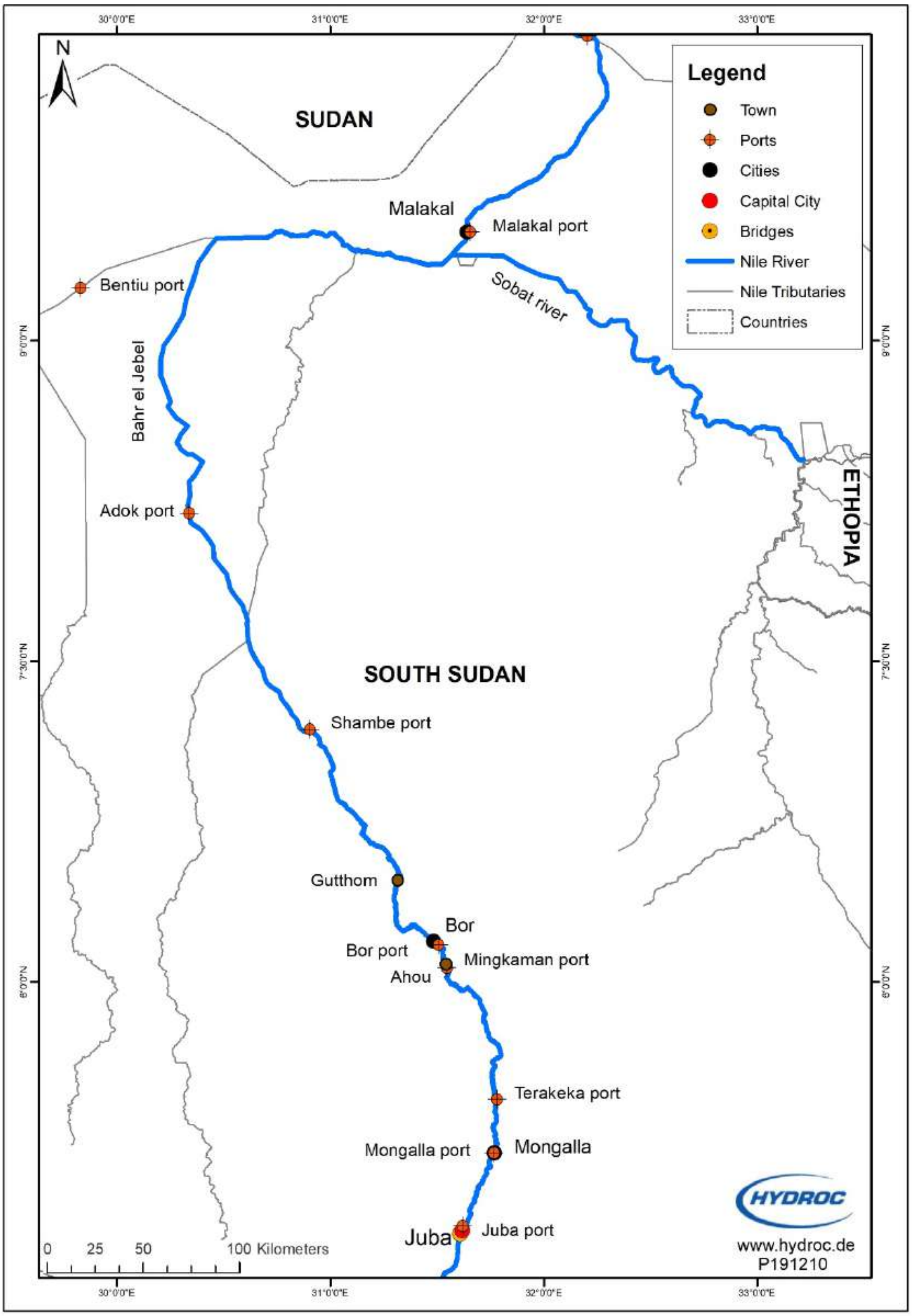


Figure 14. Malakal to Juba map

Table 9. Stretch data sheet

Navigability availability	Navigable but Low & seasonal Navigation
Current physical situation	Flat and steep
Number of bridges	1
Number of dams	0
Number of ports (dock stations, piers)	10

Upstream from Malakal, the course of the river is flowing through the Sudd, a flat and swampy inland delta, with strong vegetation growth, and part of the White Nile's Baḥr el-Jebel section.

The stretch may be divided into two sections with Bor being a cross-point: Malakal to Bor (774 km) and Bor to Juba (188 km). Both sections are characterised by a gentle slope (4 cm/km and 17 cm/km respectively) and low water levels.[32, 33]

A sub-section of over 45 km from Mongalla to Juba receives several small torrential streams which run full after heavy rains. The slope is still gentle (average slope is 30 cm/km), increasing gradually further to the south.[32] In 2018, HYDROC has reported that the depth is not sufficient for barge traffic in most locations within 140 km to Juba. Maximum flow velocities are mostly in the range of 1-4 m/s, increasing at about 75 and 100 km downstream of Juba, where velocities are projected to be higher and where barge traffic may encounter difficulties during the highest discharges[33].

Variations in the Nile water levels (from February/March to May/June) significantly threaten navigation, especially between Mongalla and Juba. Unlike the recent HYDROC study (2018), the VICMED study reports that, during the dry season, the water level drops allowing only barges with drafts of 1.2 m or less to pass, compared to the wet season when drafts can safely range between 1.6 m and 1.85 m. During the dry season, barges carry around 60-75% of their normal cargo volume to reduce draft.[5]

Exposed rocks around Juba present an additional hazard when water levels are low, carrying the risk of damaging and possibly sinking vessels. Dredging projects have been earmarked along several points and ports to mitigate this problem.

As a tributary to the Bahr el Jebel, during the rainy season, the Bahr el Gazal River, is accessible up to Bentiu by commercial river operators.

The Malakal-Juba stretch is navigable in the period from January to November. Adding to the above-described issues, low water levels during the dry season between the Bor-Juba section significantly affect barge cargo capacity.[29] Between Juba, Malakal and Melut transit times of 10 days have been reported by the Logistic Cluster. In partnership with IOM (International Organization for Migration), the Logistics Cluster offers both boat and barge services with deliveries between Malakal and Juba. If demand exists, the ports of Melut and Renk can also be serviced. The capacity for barge shipping services is 200 t per vessel depending on the cargo type.[33]

The Malakal-Juba stretch has four main ports (Adok, Bor, Mongalla, and Juba). Juba Port is operated by the RTC as no private companies have undertaken regular services to Juba. Barges travel from Kosti to Juba in convoy. Access to Juba is only possible during the wet season. Ports are incapable of handling more than two barges at a time. Juba's old port is no longer operational due to silting and Juba's new port has very limited infrastructure. On occasions during low water levels, barges must be partially off-loaded in Terakeka.[28]

---

[32] HYDROC (2018). Report on River Barge System Feasibility Study Project, South Sudan.

[33] Logistic cluster. South Sudan. Common Transport Service: White Nile - Snapshot

Generally, for this reach, ports lack equipment for loading and unloading cargo. Manual labor is used. Only Malakal has limited spaces to potentially use cranes. All other ports, including Juba, do not have jetties.[35]

Since 2016, four ports have been closed due to safety measures: Limkethi, Ahou, Gutthom and Wunthou.[34] Gotthom had used to be a main river port together with Bor and Adok[35].

[34] https://radiotamazuj.org/en/news/article/eastern-lakes-governor-closes-another-port
[35] Logistics Cluster-WFP, UNOCHA, SIM, UNMAO, UNMIS, SSCCSE, CGIAR, ILRI, NASA, Univ. of Berne

2.8 Stretch 8: Bahr el Jebel – Juba to Lake Albert

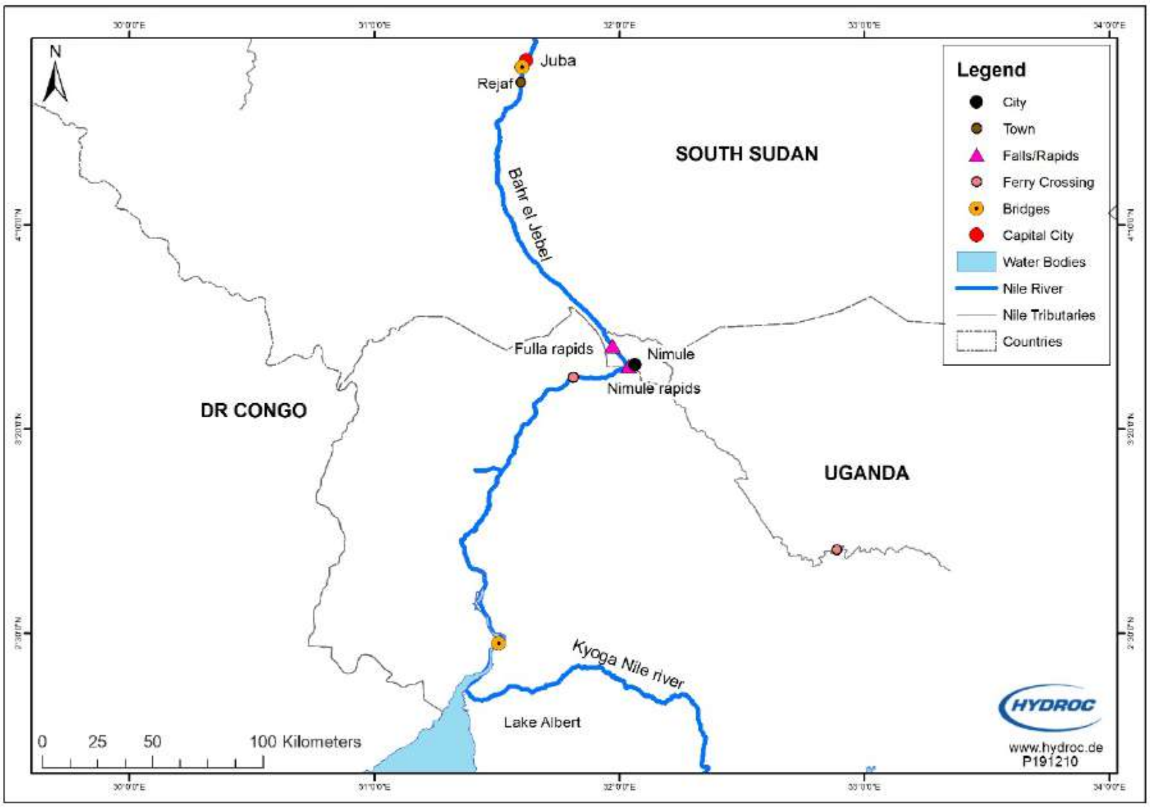


Figure 15. Juba to Lake Albert map

Table 10. Stretch data sheet

Navigability availability	Limited navigation and partly - Rejaf to Nimule - not navigable at all
Current physical situation	Changing conditions, covering both fast stream and steep swamps
Number of bridges	2
Number of dams	0
Number of ports (dock stations, piers)	1

Continuing from Juba to the south to Nimule, the river is a narrow and fast stream cutting through hilly terrain and interrupted by rocky rapids. The section is relatively steep with a level difference of about 150 m over 300 km distance, the average slope is nearly 1 m/km.[5]

Upstream of Nimule, the river is shallow, broad and sluggishly flowing. Its width varies from 100 m to 300 m. The average slope is only about 2.2 cm/km. The river is fringed with swamps and lagoons along a stretch of 225 km. It meanders east and west through a narrow flood plain between a hilly country on either side so that the area of the swamp is well defined.

2.9 Stretch 9: Lake Albert

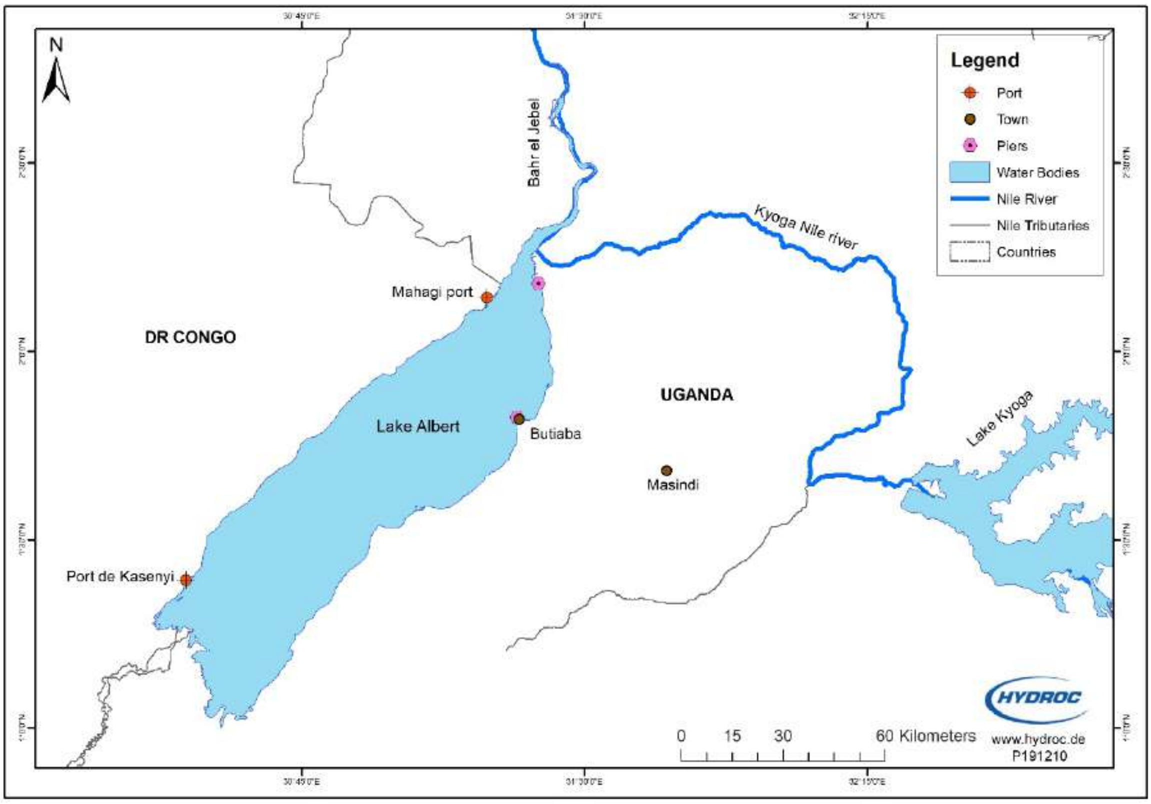


Figure 16. Lake Albert map

Table 11. Stretch data sheet

Navigability availability	Limited navigation. No significant commercial traffic in lake Albert Navigable at Ugandan side along a 200-km reach from its northern tip to its southern shores
Current physical situation	Shallow water body with cliffs in some areas
Number of bridges	0
Number of dams	0
Number of ports (dock stations, piers)	3 ports, 1 not in use; 1 docking pier

Lake Albert is located on the border between Congo and Uganda. With a length of 160 km, and an average width of 35 km, averaging about 25 m in depth. Its maximum depth is 60 m.[36]

There is a considerable expanse of lowland at the northern end of Lake Albert, where the Kyoga Nile enters as a sluggish stream in a swampy delta. The Albert Nile outflow is located close to the Kyoga Nile inflow. In the west and east, the lake is bordered by forested cliffs and ravines. Because of the high rate of evaporation, the waters are somewhat saline, and free phosphate is also present.[37]

[36] World lake database. Lake Albert.

[37] Britannica, T. Editors of Encyclopaedia. "Lake Albert." Encyclopedia Britannica, October 31, 2021. https://www.britannica.com/place/Lake-Albert.

Since the 1970s, there are no more commercial transport lines on the lake, but only informal small-scale transport. Reviving navigation on Lake Albert could contribute to regional trade just like in the past. Oil deposits have been discovered in the Lake Albert basin and the exploration will likely resuscitate the port in the future to play a role in the transportation of equipment, manpower, and petroleum products.[38]

In addition to ports illustrated on the map, Lake Albert has an old port of Butiaba on the eastern shores. During the first half of the 20th century, Butiaba was an important transportation hub, where merchandise from eastern Democratic Republic of the Congo (DRC) and from South Sudan was transported by boat across Lake Albert to Butiaba port.

The transportation route completed the following plan:
- At Butiaba, merchandise was transported overland, through Masindi to Masindi Port.
- At Masindi Port, the produce would be loaded on barges, ferried across Lake Kyoga to Soroti.
- At Soroti, it would be loaded onto railway wagons for transportation by rail to Mombasa, Kenya, on the Indian Ocean, for export.

Imported goods and merchandise were transported along the same route, in reverse[39].

When the East African Railways Corporation was dissolved in the 1970s, Butiaba's prominence declined and the port became dormant. Reviving Butiaba port to play a role in the transportation of equipment, manpower, and petroleum is being considered.[40]

[38] JICA, 2017. Project for Master Plan on Logistics in Northern Economic Corridor. Final Report
[39] Andrew Bagala (22 April 2008). "Butiaba Port To Be Redeveloped As Route For Oil Transportation". Daily Monitor via AllAfrica.com.
[40] New Vision (October 2020). "Uganda inches closer to oil revenue". New Vision. Kampala, Uganda.

2.10 Stretch 10: Kyoga Nile

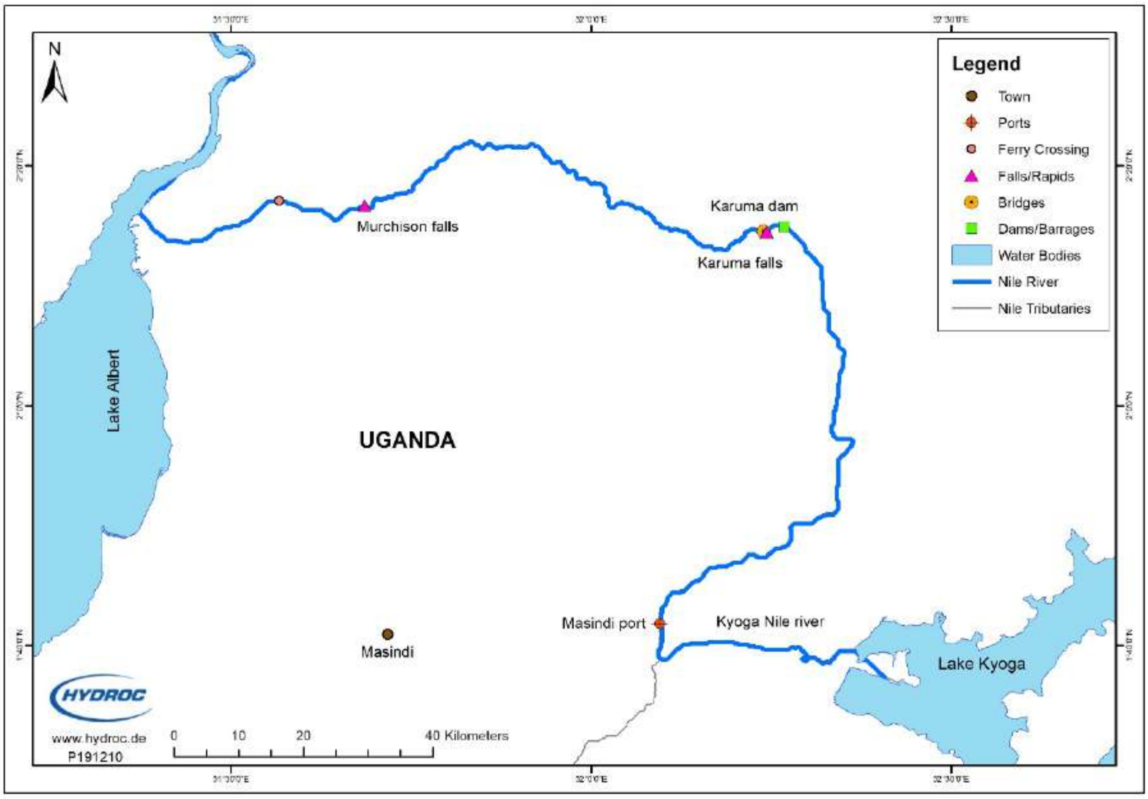


Figure 17. Kyoga Nile map

Table 12. Kyoga Nile data sheet

Navigability availability	Limited navigation
Current physical situation	Significant waterfalls
Number of bridges	1
Number of dams	2
Number of ports (dock stations, piers)	2 docking piers
Other	2 waterfalls
	1 ferry crossing

Kyoga Nile is a part of Victoria Nile reach, which is located between Lake Albert and Lake Kyoga. Despite being a short stretch, it contains a cascade of 3 waterfalls on the way. The first is Murchison Falls. A number of suggestions to build a hydropower plant here have been rejected by now[41].

At 35 km upstream from Murchison, the Kiba waterfall is located. At the end of 2020, the Ugandan government has agreed to build a hydropower plant at Kiba. However, the construction details are not published yet.[42]

At 43 km upstream of Kiba, the Kamdini (Kuruma) waterfall is located. Here, a hydropower plant is at its final stage of construction, expectedly to be opened in June 2022.[43]

[41] Alice McCool. The Guardian. “Uganda's thirst for hydropower raises fears for environment”. Jan, 11 2020
[42] State-owned Assets Supervision and Administration Commission of the State Council (8 January 2021) “Energy China Group to Contribute to Uganda's Hydropower Development”.
[43] The EastAfrican (12 August 2021). “Completion of Karuma Dam pushed to 2022”

The stretch has 1 port (Masindi) and 2 docking piers at Parra ferry crossing with the Karuma bridge next to it.

2.11 Stretch 11: Lake Kyoga

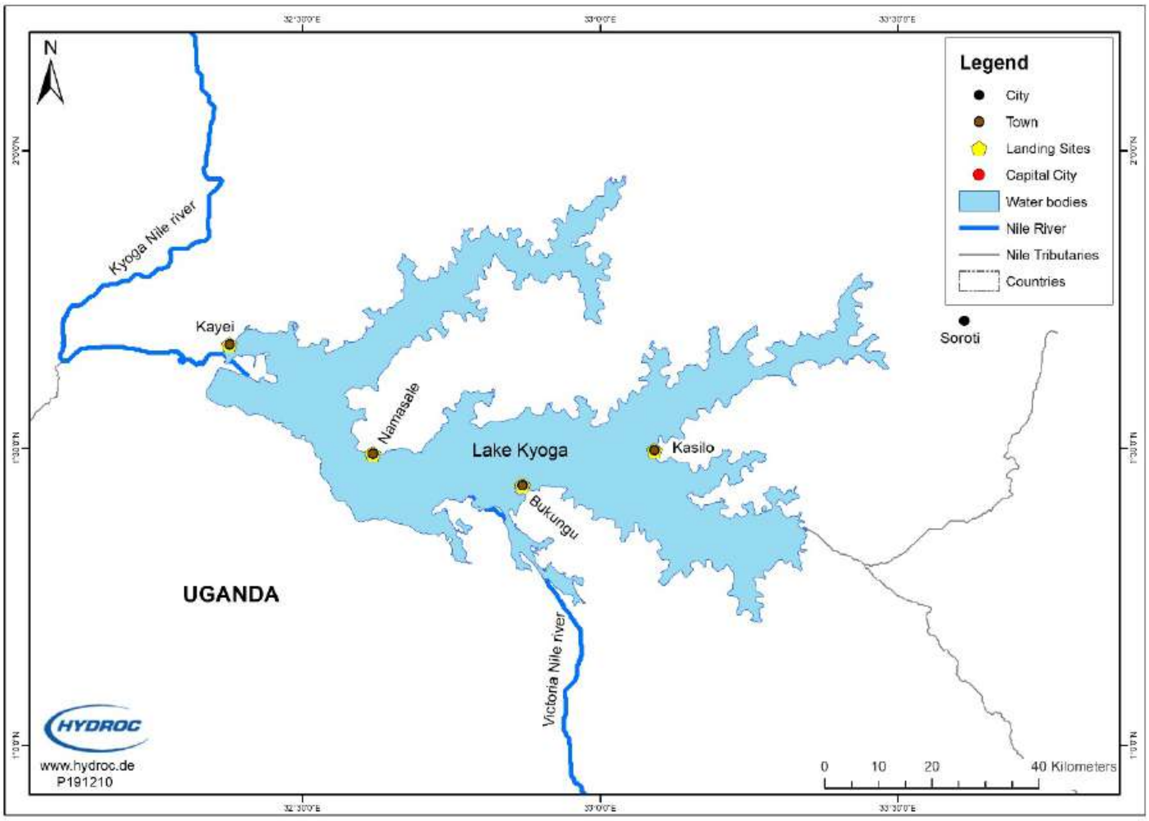


Figure 18. Lake Kyoga map

Table 13. Lake Kyoga data sheet

Navigability availability	Not connected & limited navigation
Current physical situation	Shallow lake filled with swamps
Number of bridges	0
Number of dams	0
Number of ports (dock stations, piers)	4 landing sites

Lake Kyoga is about 129 km long,[44] located north of Lake Victoria in central Uganda and formed by the Victoria Nile in its middle course. It is relatively shallow, being 3-5 m deep at its western end and shallower in its upstream arms. The wider parts of the lake were previously open water fringed with papyrus and floating vegetation, while the narrower arms and inflow tributaries were overgrown with papyrus; this is related to the moderate range of lake water level fluctuations (Figure 19). However, the southern fringes of the lake have recently been invaded with water hyacinth.[45]

Floating papyrus, moved by strong winds, has sometimes completely blocked the lake outflow[46]. Navigation for shallow-draft vessels is possible between Masindi Port and Namasagali.

[44] Britannica, T. Editors of Encyclopaedia. "Kyoga Lake." Encyclopedia Britannica, March 21, 2016. https://www.britannica.com/place/Kyoga-Lake.
[45] Ntale, H. K. (1996) Lake Kyoga, The Nile 'green' lake that is dying unnoticed. In: 4th Nile 2002 Conf. (Kampala).
[46] Britannica, T. Editors of Encyclopaedia. "Victoria Nile." Encyclopedia Britannica, June 11, 2010. https://www.britannica.com/place/Victoria-Nile.

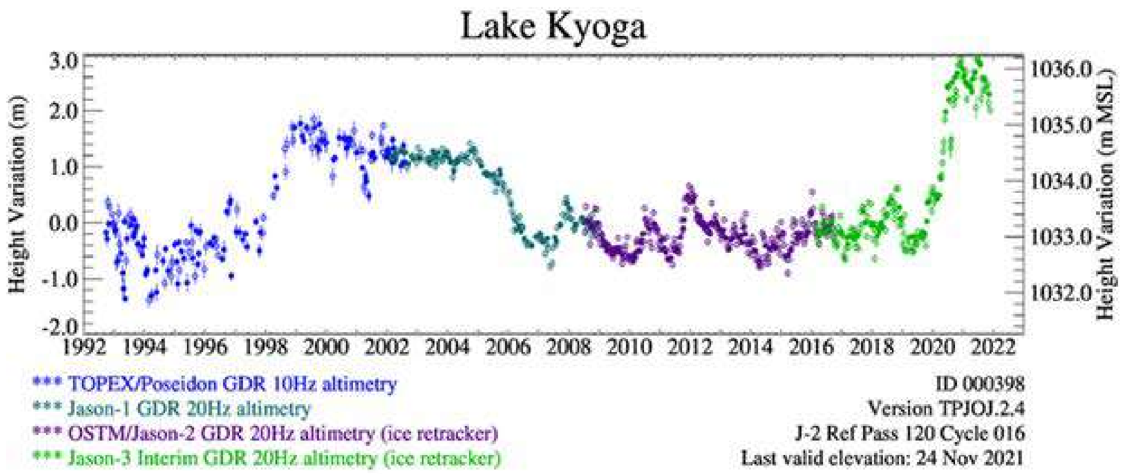


Figure 19. Lake Kyoga water level fluctuations

2.12 Stretch 12: Victoria Nile

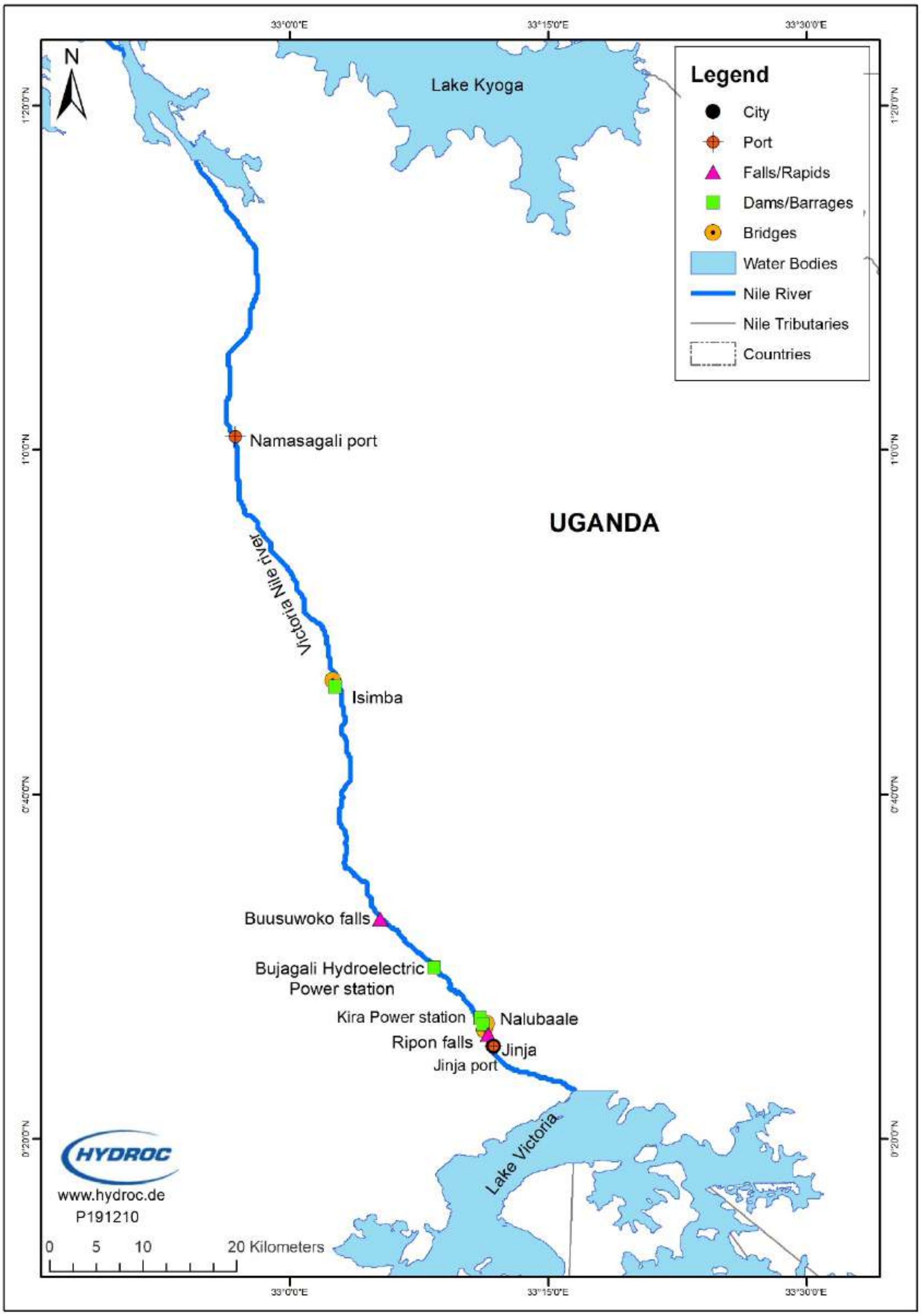


Figure 20. Victoria Nile map

Table 14. Victoria Nile data sheet

Navigability availability	Limited navigation
Current physical situation	Multiple rapids and waterfalls
Number of bridges	3
Number of dams	3
Number of ports (dock stations, piers)	1 port
Other	Waterfall - Busowoko falls

The Victoria Nile in Uganda has a length of approximately 480 km. It connects Lake Kyoga to Lake Victoria through Ripon Falls, west of Jinja, and Owen Falls.

The stretch has three dams (Isimba, Bujagali, and Owen Falls), and several rapids and white-water sections. Bridges are found close to Jinja and one port (Namasagali) is on this stretch.

There is no any significant navigation conducted on this stretch, though whitewaters are used for rafting as a sports attraction.

2.13 Stretch 13: Lake Victoria

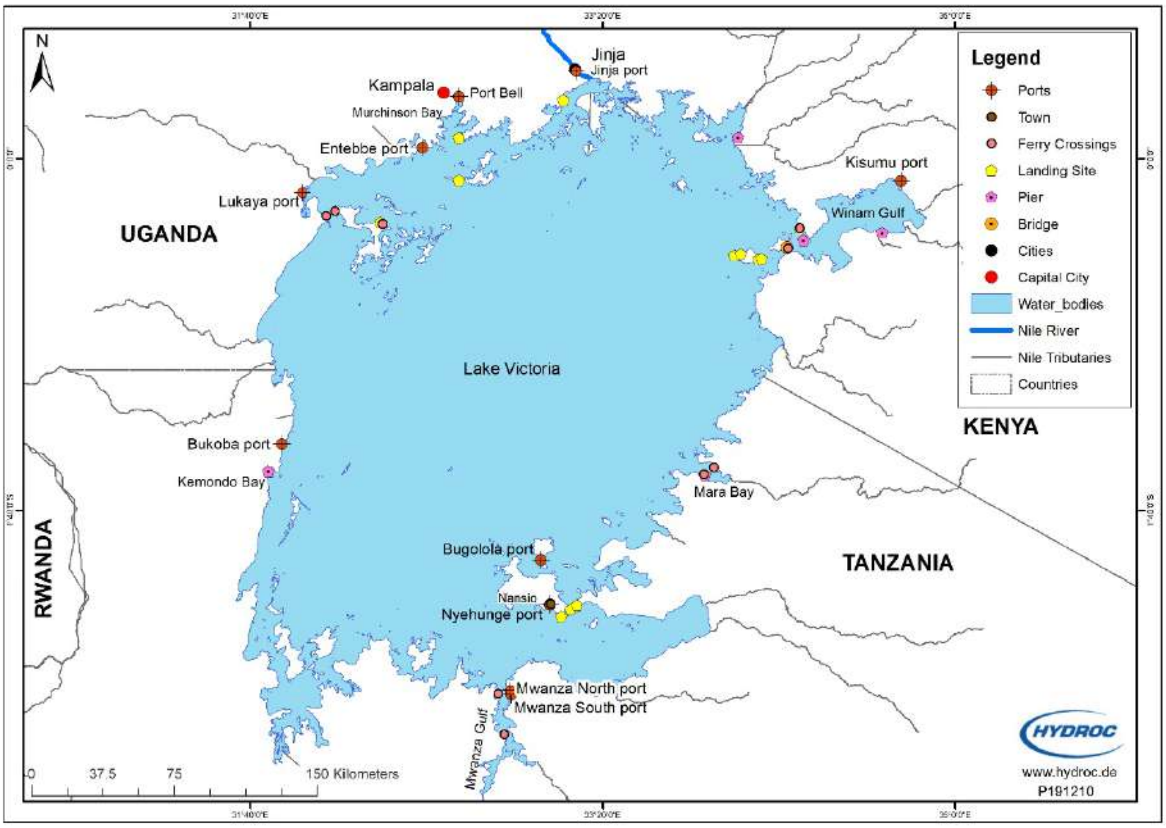


Figure 21. Lake Victoria map

Table 15: Lake Victoria data sheet

Navigability availability	Although many vessels, cargo, train & passenger ferries are sailing, generally, water transport is not efficient. The lake ports are connected to road and train networks in Uganda and Kenya
Current physical situation	Navigable
Number of bridges	1
Number of dams	0
Number of ports (dock stations, piers)	6 ports; 10 landing sites; 11 ferry terminals; 11 docking piers (main sites only)

Lake Victoria has a surface area of about 69,000 km^2 and a shoreline of about 3,500 km. It has a large number of small islands occupying about 4% of the lake surface area. The lake has a round shape, with an average depth of 40 m, and a maximum depth of about 79 m.[4]

Lake Victoria acts as a principal waterway with commercial traffic. In conjunction with train services, Uganda and Tanzania operate train wagon ferries on the lake between railhead ports of the two countries and Kenya. Traffic across all public ports on Lake Victoria is estimated at 500,000 t a year.[18]

The safety of navigation on Lake Victoria has been established for water levels above 1133.0m MSL, which corresponds to the lowest level observed in 1957 for which navigation experience exists. More recent lake levels are shown in Figure 22. The operation of vessels below the above level would potentially be risky and if such extremely low water levels would appear, reassessment of the navigation routes to ensure safety would be required. Low lake levels would also compromise most of the operation of the port- and maintenance structures' functioning, leading to a high operational cost of navigation.[18]

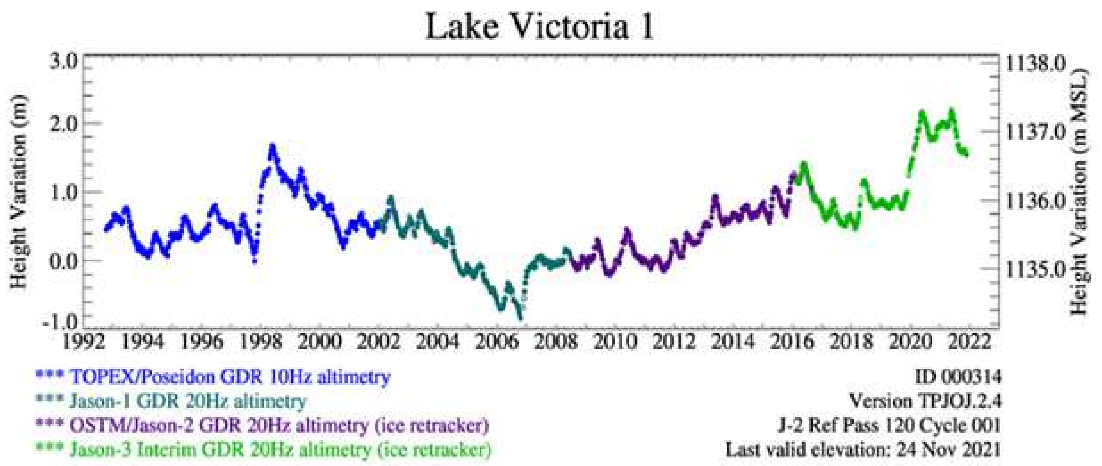


Figure 22. Lake Victoria water level fluctuations

In Kenya and Tanzania, a lake level range between 1135.0 and 1136.5 m MSL is optimal for navigational activities, with expected positive effects on the livelihood and environmental sector.[47] As of 2013, the domestic lake transport, like river transport, was used to be mainly a small-scale private sector activity with minimal fixed infrastructure support.[48] However, this has been subject of change since then due to water level increase.

The three main lake ports are:

- Kisumu in Kenya, located in the north-eastern part of the Winam Gulf, being Kenya's third-largest city
- Mwanza South in Tanzania, located within a natural shallow bay on the Eastern shore of Mwanza Gulf, and
- Port Bell in Uganda, located at the end of Murchison Bay, south-east of Kampala. They are directly included in the regional multimodal trade routes, namely the Northern and Central Corridors.[18]

Traffic across all public ports on Lake Victoria is estimated at 500,000 t a year. However, it should be noted that local traffic has increased since 2005 while international transit traffic has been decreasing (imports to Uganda are estimated to be about 3,000 t lower annually in Port Bell over the last years).[18]

Port infrastructure has also been deteriorating for many years, but improvements are underway and it is planned to return the assets to good condition so that waterways can fulfill their vital role in servicing the needs of passenger and cargo traffic. The main issues to confront are those concerning sustainability, requiring that revenues will be sufficient to keep the assets in good repair.

In 2016, African Development Bank approved a 26m USD loan to a multinational project to establish a safety-of-life communication system for Lake Victoria. Broad objective of the project is to facilitate transport and trade on the lake by improving maritime transport infrastructure including maritime communications, navigation aids, maritime emergency search and rescue services, and inland waterways for Lake Victoria.[49]

[47] https://atlas.nilebasin.org/treatise/inland-waterway-transport/
[48] Uganda waterway assessment.
https://dlca.logcluster.org/display/public/DLCA/2.5+Uganda+Waterways+Assessment
[49] Lake Victoria Basin Commission, Nile Navigation Workshop, 24-25 February, 2022

Further studies conducted regarding the Lake Victoria port conditions include the "Lake Victoria public-private partnership due diligence" report of 2018, which provides a detailed situation analysis for Lake Victoria.[50]

Port Bell, Uganda

Port Bell is situated along the northern shores of Lake Victoria at the head of the Murchison Bay, south-east of Kampala. In the past, the port handled approximately 500,000 t of cargo per year. Although facilities for the transfer of goods have existed at Port Bell since 1901 (and between Port Bell and Kampala since the subsequent construction of a 9 km long meter-gauge railway line in 1931), Port Bell was constructed in the 1960's as a rail-wagon terminal, although the port also has one general cargo berth of about 85m. The port terrain is about 0.7 ha including buildings and the pier, but excluding the rail shunting yard located north-west of the port. The rail-wagon terminal was constructed on reclaimed land, and has a pier of about 85 m long and 28 m wide. This pier acts as a causeway to the "Roll-on/roll-off" RoRo rail wagon linkspan and the rail ferry berth with about 3.5 m water depth. The linkspan has two hoisting towers (designed to raise and lower the rail linkspan depending on the freeboard of the ferry and differences in water levels), guide walls, and berthing dolphins for mooring the ferries for stern loading/offloading.

The pier also has a sheet piled wall construction (length about 80 m) with a reinforced concrete deck, the eastern part of which can be used for loading/offloading ships using "Lift-on/lift-off" (LoLo) equipment. Furthermore, the pier has two dolphin moorings (at a distance of 38 m from each other) on the west side of the pier and they are connected by a gangway with a length of 20 m each. The head of the pier next to the rail ferry berth on the east side is currently in use to berth a floating dock (dimensions about 95 m x 26 m).

The Port Bell rail infrastructure (meter gauge) is in a poor state but still functional. However, the port has no rail accessibility, as an encroachment on the connecting rail line prohibits trains from entering the port. Furthermore, the wharf pavement is poor but operational. There is an old crane on the eastern quay to facilitate LoLo operations. The mooring facilities are poor with broken fenders and deformed gangways on the jetty. The port operates a refurbished floating dock which is operational and in fair condition. The port buildings consist of a warehouse, toilets and customs house which are in a dilapidated state. The warehouse is not used due to the poor state. The port has limited operating space but the port is fenced and has a simple gate. Mooring spaces for RoRo vessels (except for the rail ferry) do not exist and the mooring space of 80m for general cargo vessels is rather limited as the same berth is used for general mooring for non-cargo related activities. The road access is very poor and rather congested when the port is loading/discharging general cargo due to the lack of proper truck waiting for areas. A small local fishery village is located near the entrance on the east side of the port. In terms of hinterland connectivity, the port is connected to the main Jinja road through a 6 km two-lane asphalt road. Additionally, the port has a direct rail connection to the Kampala main station, which has been rehabilitated over 11 years and got back in force in 2018.[51]

Kisumu, Kenya

The port of Kisumu is situated in the north-eastern corner of Lake Victoria, on the southern shore of a bay, fronting Kenya's third-largest city. Port facilities are grouped in a wide area of land some 20 ha in size. Most of this area is occupied by dockyard facilities and rail sidings, the latter which run to the main-quay or the rail-wagon terminal located at its western end. The main quay is some 260 m in length with an apron about 12 m wide. A single warehouse of 80 m by 16 m is provided on the main quay, behind which is a paved open storage area of approximately 3,000 m^2. The rail wagon terminal is constructed on artificial (reclaimed) land almost perpendicular to the main quay. It, like those developed in Mwanza, Port Bell and

[50] Lake Victoria Transport PPP Due Diligence | 27th of March 2018

[51] "Gov't redeems Port Bell-Kampala rail line after 11 years". By George Mangula. 24.04.2018

Jinja consists of a linkspan bridge, hoisting towers, guide walls and inner and outer mooring dolphins (connected by a suspended walkway). While being in detiorated state for a long time, rehabilitation and improvement works have been recently carried out in the port, significantly improving its cargo handling abilities. Additionally, the rail line connecting Kisumu has not been used for over 10 years, as for a long time Rift Valley Railways (RVR) deemed the Kisumu rail route uneconomical. This has nevertheless changed recently with revitalization works being carried out and the line becoming operational again.

Jinja, Uganda
The rail-wagon terminal at Jinja is located 80 km east of Kampala. The port is located outside the outflow of the Victoria Nile. The rail-wagon terminal design is similar to that at Port Bell, with two mooring jetties on the east and west side. However, the pier is only 15 m in width and has a sheet pile quay wall of 60 m on the east side. The port area is around 0.4 ha, excluding the rail shunting yard located in the north-east section of the port. The linkspan has a length of around 30 m and a width of 6.5 m. Additionally, the port has a slipway.

Jinja port is in very poor condition with most of the rail wagon linkspan planking deteriorated and fendering systems completely decayed. The water depth was said to be 4 m. The general cargo berth mooring facilities (quay wall and bolders) are damaged and the quay pavement is very poor. The main winches for the linkspan require an overhaul. The port's rail infrastructure, consisting of tracks to the linkspan and a rail shunting yard, is not functional and is in very poor condition. The rail track connection to the national rail network is missing. The rail jetty is missing proper fenders and the jetty gangway requires refurbishments. The oil pipeline at the western jetty to bunker vessels is not functional. The slipway is derelict and overgrown with plants. The road pavement in the port is in very poor condition; the access roads to the port are either unpaved or also in very poor condition. Fencing is not available and the gate is very poor, whilst navigational lights are present. The general cargo berth is currently used for berthing vessels most of the time. Additionally, there is a fishing village to the west (about 120 m down the road) of the Jinja pier and a floating fish farm inside the lagoon towards the east.

Mwanza, Tanzania
Mwanza port consists of two parts: Mwanza South and Mwanza North. Mwanza South Port is the centre for all cargo operations, whilst Mwanza North port is the passenger terminal. Mwanza South is situated within a natural shallow bay on the eastern shore of Mwanza Gulf; Mwanza North is situated on the south-eastern shore of Massenga Bay. The Mwanza South port facilities are dispersed over an 8.5 ha area. The majority of this area is either unused or is occupied by railway lines that are used for parking railcars, before they are shunted onto ferries via the rail linkspan (which was constructed in 1964). The main quay (constructed in the late 1930's) is 250 m long and consists of a sheet pile wall with a reinforced concrete deck. A rail line loop runs along the quay. The southern end of the quay (adjacent to the linkspan) is currently used to load/discharge oil products to tankers/ships. The quay apron is unusually constructed on a two-tier level with a difference of 0.7 m in height over a length of 190 m. The upper level fronting the cargo and transit sheds is some 7 m in width and this reduces the effective working area on the quayside to some 5 m in width, greatly hindering horizontal transfer operations. Recent block work modifications at the northern end of the quay have raised the apron to similar levels over a length of 60 m. This area is currently used as a docking and maintenance wharf and provides hard-standing storage and yard space.

Mwanza North port is the passenger terminal, located immediately adjacent to Mwanza city. Port facilities have been constructed on a promontory of artificial land (developed in the late 1930's) and consist of two berths: a main berth of 82 m in length, and a secondary berth of some 50 m in length. Both berths are of a sheet piled wall design with a reinforced concrete deck. Part of the secondary berth and apron has been raised 0.6 m in height. The port has a central passenger/cargo shed and is served by a rail spur that terminates on the main berth. A concrete ramp has been constructed at the head of the secondary berth to allow RoRo operations. The proximity of the outlet of the River Kenge, Mwanza's main river/stormwater/sewerage outfall, artificially extended into the lake, has led to considerable siltation preventing the use of the RoRo facility.

Bukoba, Tanzania
Bukoba port serves as the gateway to the region west of Lake Victoria and is the second-largest port after Mwanza. Bukoba is the capital of Kagera region situated on the western shore of Lake Victoria. The port is located south of the city. It is served by a regular connection via Kemondo Bay to Mwanza, on Mondays, Wednesdays, and Fridays. The service is provided by MV Victoria, MSCL's (Master Synchronizer and Load Control) largest cargo-passenger ship, which is capable of carrying 200 tonnes of cargo and 1,200 passengers. Bukoba Port has three berths built in 1945, which are still in use. The main one is Berth No. 1, where the MV Victoria is accommodated. Berths No. 2 and No. 3 serve smaller ships. The port has three cargo sheds and one passenger shed. The city is also served by ground transport to Kampala every day. Due to the well-developed road network on the western shore of Lake Victoria, bus transport operated by the private sector is competitive between Bukoba and Mwanza.

Kemondo Bay, Tanzania
Kemondo Bay (originally Lubembe port), which was developed in 1974, is located approximately 18 km south of Bukoba. It is situated in a circular bay of moderate depth, protected from the open waters of the lake by a small headland to the south. The port covers an area of approximately 2.2 ha. Although principally a rail ferry port, there is no rail hinterland, which hinders the use of the port as a transit route for Rwanda/Burundi. Berthing facilities consist of a rail wagon terminal (a linkspan) with a passenger/cargo quay (the main quay). The berth comprises a sheet-piled wall construction with a reinforced concrete deck, measuring 7 m wide and 47 m long. An offshore mooring dolphin, connected to the quay by a suspended gangway, forms part of the main berth. A 20 m general berth has a similar construction. Reclaimed land on the southern part of the port is fronted by a sheet piled wall, providing additional berthing space (originally used as a cattle berth). An extension of reclaimed land, with rock armoring, on the northern side of the port has allowed the construction (in 1993) of a RoRo facility for ramped vessels at the head of the main berth. A large passenger building is located to the north, adjacent to the fenced yard area, in which the port offices are located.

Musoma, Tanzania
The port of Musoma is situated in Mara Bay, a large sheltered bay bound by a hilly country that characterizes the eastern shore of Lake Victoria. The original port pier was constructed on the leeward side of Musoma Point, a narrow peninsula that extends into the lake on the southern shore of the bay - now a hotel. The existing port, constructed between 1966 and 1968, is located south-east of Musoma Point, on a small headland adjacent to the town. Port facilities, constructed on artificial land consist of a rail wagon terminal with a fixed linkspan bridge, shore abutment, long and short guide walls. The opposite face of the long guide wall (SE) forms the passenger berth, which is 100m in length with an apron 4.5 m in width and 3 m in height. Perpendicular to the landward end of the passenger berth is a general cargo berth of 55 m, a paved apron area of 9.5 m width and a cope height of 2.1 m. All wagon ferry guide walls, passenger and general cargo berths are of steel sheet pile wall construction with a reinforced concrete deck. The port area of 3 ha is dominated by railway tracks required to load/offload and shunt rail wagons within the yard area. Due north-west of the existing port site, adjacent to Musoma Point, there are two offshore mooring dolphins for berthing tank-ships for ship to shore petroleum transfers. There are no cargo handling facilities of any kind and throughput has steadily declined due to competition from road transport taking advantage of the paved road network linking Musoma to Kenya (via Tarime and Sirari) in the North, and Mwanza (via Bunda) in the south.

Port development plans:

- Lake Victoria Transport Program – Under the Lake Victoria Transport Program, which is to be (partially) funded by the World Bank and the European Union, rehabilitation and improvement works are ongoing on all the major lake ports and their connecting infrastructure. Additionally, technical assistance towards the implementation of lake safety and navigability measures is included in the program.
- Bukasa Port (Uganda) – The Bukasa port project comprises the development of a new port in Kampala, near the existing Port Bell. The port project is partially funded by the Government of Germany and is currently in the preliminary design phase, for which a consultant has been procured. Additionally, a high-level financial and economic assessment has been completed. The port development is aimed at enabling the accommodation of the expected future cargo volumes on Lake Victoria. The port is to be developed in two phases; the first phase will provide an annual cargo capacity of 2.3 million tons, whereas the second phase will add an annual capacity of 5.2 million tons. In the long term, the Uganda Railways Corporation (URC) aims to develop Bukasa as the main cargo port and connect the port to the Standard Gauge Railway (SGR) network. As Bukasa will be connected to the SGR, the URC envisions keeping the meter-gauge connection at Port Bell. While it seems that a draft preliminary design of Bukasa port has been completed.
- Lukaya Port (Uganda) – During stakeholder consultations, the Chinese-owned Mango Tree Group presented plans for port development at Lukaya, approximately 100 km southwest of Port Bell. The rationale behind this location is twofold; its location near an arterial road and outside of the congestion of Kampala enables efficient transport activities to the port's hinterland and its location is well suited to serve mines in Western Uganda. The plans for the Lukaya port include a 40,000 lt of oil depot that can be used for Uganda oil reserves, a dry bulk cargo terminal aimed at handling iron ore and copper ore from mines in Western regions of Uganda, and the development of an industrial zone adjacent to the port.
- Kisumu SGR Port (Kenya) – While the current Kisumu port has been formally transferred from the Kenya Railaway Corporation (KRC) to the Kenya Ports Authority (KPA) through a Gazette Notice and an alteration of the KPA Act, the KRC plans to develop a new SGR rail port at Kisumu as part of phase 2b of its SGR project. A USD 5.4 billion commercial agreement for the phase 2 SGR works, which includes the development of the new Kisumu port, was signed between the KRC and China Communications Construction Company (CCCC) in 2016.

Another aspect is the usage of the port for operational needs. A report by HPC Hamburg Port Consulting GmbH (2017)[52] provides an overview of traffic in the Tanzanian sector of Lake Victoria. It outlines that the key aspects regarding the situation for domestic cargo transports on and around Lake Victoria comprise:

- Transports between Bukoba and Mwanza (and Dar es Salaam) are conducted in large parts by road (truck). Cargo is only to a limited extent transported via the lake. Presently only one private shipping company serves Bukoba with three cargo vessels (tramp services).
- Kemondo Bay is currently not served by lake transport.
- Transports to/from Nansio (Ukerewe Island) are conducted predominantly via the lake, using the ferries of a private operator between Kirumba/Mwanza and Nansio or state-owned shipping line MSCL between Mwanza North Port and Nansio. There is an alternative by road (truck), but it is a long detour and mostly used for traffic coming from/going to Musoma.
- Transports between Musoma and Mwanza are entirely[44] organized by road (truck) since the rehabilitation of the road to Mwanza a few years ago. Currently, there is no lake transport between Mwanza and Musoma as there seems to be no demand.

The two main routes that are potentially relevant for lake transport, and thus for the present analysis, are the routes Mwanza – Bukoba and Mwanza – Nansio.[52] Kisumu and Port Bell are not included in this

[52] HPC Hamburg Port Consulting GmbH (2017). Reviving Green Inland Water Transport in Africa.

estimation due to a lack of information. Figure 23. Current Annual Domestic Lake and Road Traffic at Lake Victoria (Estimates) represents annual estimates of cargo transfer in southern part of Lake Victoria.

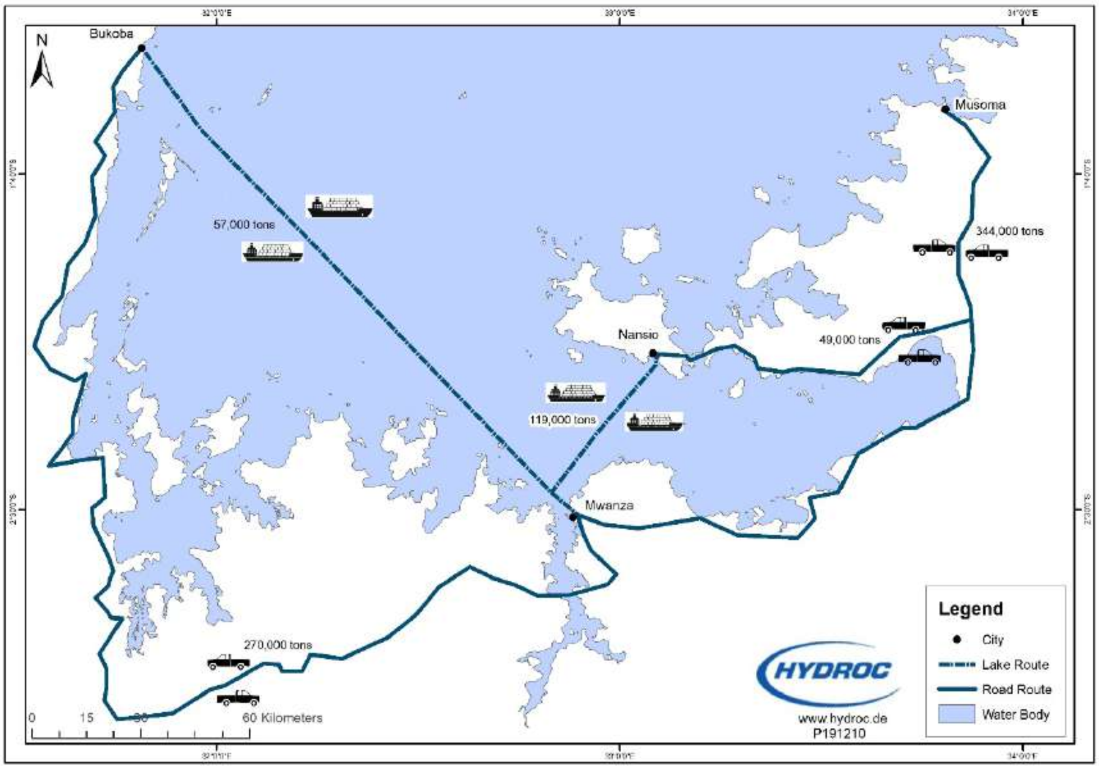


Figure 23. Current Annual Domestic Lake and Road Traffic at Lake Victoria (Estimates)
Source: HPC Hamburg Port Consulting GmbH (2017)

Information regarding the northern part of Lake Victoria is very limited. It is well-known that cargo services operate mainly at Port Bell and Jinja Port. In 2015, the annual throughput in Port Bell was approximately 30,000 t, down from around 500,000 t in the late 1990s.

According to situational analysis, conducted by Cardno International Development in 2020, the infrastructure faces specific issues, some of which are:

- Port/landing infrastructure and vessels are in poor conditions and there is no funding to develop them
- Infrastructure to support modal shift / transfer (like roads, storage facilities, cranes, parking yards, etc.) is mostly absent
- Lake and water transport, in general, has declined in significance compared to the times when the road network system was completely underdeveloped
- Most of the hard infrastructure is in poor condition due to neglect and lack of maintenance[53]

Overall, Lake Victoria is fairly used due to its transboundary location and countries' capabilities. It has a great potential for development to support international trade and cooperation.

2.14 Other Stretches with Navigation Potential

[53] Situational Analysis Report for the Master Plan and Development Strategy. Inland Water Transport (IWT) Corridor. May 2020. Cardno International Development

There are several other stretches in the Nile basin (see Figure 2) that are used for navigation or have navigation potential, that are used by smaller barges or are isolated from the main Nile transport system, with the main ones as follows:

- Atbara River
- Lake Tana
- Baro River
- Akobo River
- Bahr el Ghazal
- Semliki River
- Akagera River
- Lake Edward

Atbara River, Sudan

Atbara River is navigable for part of the year from the confluence with the Nile up to Khashim el Girba Dam during high flows, i.e. between July to October when water levels rise sharply up to five meters and flows of 2000 m^3/s may be reached as compared to nearly zero flows during the low flow season. There is no navigation infrastructure on the river.

Lake Tana, Ethiopia

Lake Tana ist he source oft he Blue Nile and the largest Lake in Ethiopia, with a surface area of 3000 km^2, a lake crossing distance of about 70 km, and a shallow average depth of 8m. According to Vijverberg (2009)[54], water levels in the lake fluctuate at around 1.5-2.5 m depending on the seasonal rainfall patterns. Catchment degradation and resulting high erosion rates ar a problem in Lake Tana, leading to high rates of siltation in the lake. The lake has several islands and shallows. Outflow from the Lake into the Abbay (Blue Nile) and respectively lake water levels are regulated by the Chara-Chara Weir. As of 2008, twelve vessels were operated on the lake by Lake Tana Transport Enterprise, carrying people and cargo. Vessels originate from Italian-Eastafrican times, i.e. from the first half oft he twentieth century[55]. Main ports include Bahir Dar, Gorgora and Konzula, with a variety of other small ports along the lake and islands shores. In 2008, the Lake Tana Transport Infrastructure Project had been initiated with the objective to develop the transportation infrastructure that facilitates the current transportation needs of the local population around Lake Tana. As of 2019 the status of this project is unknown.

Baro River, South Sudan and Ethiopia

Baro River is navigable from the confluence with the Sobat to the town of Gambela. At a mean annual discharge of about 240 m^3/s, river water levels are highly seasonal restricting navigation. At Gambela a bridge spanns the Baro, further, the town owns an airport and a good road network. Due to the high seasonality, river transport is not used in a wide scale as only at flood stage water levels are high enough to allow river transport – as the entire surrounding area of the Baro may get flooded boats are a main means of transport at that time (July). In 2018/2019 a real-time navigability assessment and decision support tool for Baro-Akobo-Sobat waterways have been undertaken by HYDROC GmbH for UN-WFP with the tool allowing for real time navigation decision support.

Akobo and Pibor River, South Sudan and Ethiopia

Akobo River and Pibor River, forming the border between South Sudan and Ethiopia, are navigable from the confluence with the Sobat to Akobo town. River water levels are highly seasonal, restricting navigation. There are no formal ports on this stretch.

Bahr el Ghazal, South Sudan

[54] Vijverberg, J.; F.A. Sibbing; E. Dejen (2009). "Lake Tana: Source of the Blue Nile". In H.J. Dumont (ed.). The Nile. Monographiae Biologicae. Vol. 89. Springer Science + Business Media B.V. pp. 163–193. ISBN 978-1-4020-9725-6.)

[55] Ethiopia: Lake Tana Transport Reels in U.S.$18.1 Million for New Boats auf allAfrica.com

The Bahr el Ghazal is generally navigable from Lake No up to Bentiu, with potential for small vessels also up to Wau during part of the year. Nevertheless flows are seasonal and vegetation blockages are a frequent problem, requiring constant clearing/dredging. Flows of the Ghazal are relatively small, ranging up to 50 m^3/s during high flow times, as most of ist waters are evaporated in the large swamp systems borderingt he Sudd. A river bridge is located at Bentiu. The Bentiu port is operated as necessary and depending on vegetation conditions in the river channel. In 2012 the Bahr el Ghazal was dredged. In 2011 the UN-Logistics Cluster assessed Bentiu Port, reporting on ist features, including a 150m long berth with water depth of 3-5m and good mobile phone coverage[56].

Semliki River, DRC and Uganda

Semliki River is navigable between Lake Albert and Lake Edward but currently little used. The river has a defined bed in ist upper reaches while it meanders significantly in ist lower reach. The mean flow is about 140 m^3/s, relatively constant year round. Two road bridges are spanning the river. In 2022 a ferry has been installed on the river to connect Haibaale (Uganda) with Burasi (DRC).

Lake Edward, DRC and Uganda

Lake Edward has a size of about 40km x 80km and is little used for anny commercial navigation. No formal ports are available

Akagera River, Rwanda

The Akagera is the border river between Burundi, Rwanda and Tanzania, with the border located in the middle of the river and respective shared responsibilities between countries. Mean monthly river discharge is varying between 161 and 324 m3/s, with high flows recorded in May and the low flows in October. The Akagera is generally navigable from Lake Victoria up to Lake Rweru, though with obstacles at Kagera falls and without any developed navigation assets. Currently, there are no significant navigation activities. Navigability and upgrading needs and options have been studied in the “Akagera River Transport Study – Feasibility study of navigability on Akagera River” (not dated)[57], by ITECO for the Ministry of Infrastructure in Rwanda. A survey that has been conducted as part of the study in 2010 showed that the Akagera River was navigable by small boat continuously from its mouth (Km 290) to about Km 69 (near Kasese) at which point the Rusumu Falls prevent the passage of vessels. The width of the river varied from 39 to over 100 m and the depths as measured in October 2010 ranged up to nearly 13 m. The study nevertheless concluded that a project for upgrading navigation infrastructure would not appear to be economically feasible at the likely level of demand that exists at present. The relatively low importance of navigation aspects is also visible in the construction of Rusumo Hydroelectric Power Station, started in 2017, for which no locks have been foreseen that would allow bypassing the dam. The Akagera River Transport Project[58] aims to make Akagera River navigable through the construction of canals, locks, river cut offs, river improvement works (removal of rocks, islands), and river bank protection. The entire project covers 260 km of river, from Lake Victoria to Kagitumba, i.e. the lowest flat section of the river.

[56] Logistics Cluster, Bentiu Town, Port Assessment Report, 3. July 2021
[57] https://www.rtda.gov.rw/fileadmin/templates/documents/akagerafrom_Jose.pdf
[58] https://pp2.au-pida.org/approved-project/entry/d3chr/

3 River Navigation Development Scenarios

Inland water transport has a big potential for socio-economic benefits for the Nile basin countries. In this context, establishing a navigable waterway between Lake Victoria and the Mediterranean Sea could be a very promising and important mega project for all involved countries. This trade corridor, upon completion, is expected to be more efficient in connecting the countries and will provide a low-cost transport route for bulk cargo from Kampala (Uganda) to Alexandria or Damietta (Egypt) and further to Europe and worldwide. To expand inland water transport abilities, the VICMED project was established, which includes regional integration, capacity development, sustainable transport, green growth and south-south cooperation.[5]

The VICMED project aims to develop possible solutions for defining transport routes. The pre-feasibility study discusses options to improve the Nile to become navigable from Lake Victoria to the Mediterranean Sea and suggests six alternatives[5] for the transport system. Alternatives 1-4 are presented below.

3.1 Alternative 1

Under this alternative, the Nile course from Lake Victoria to the Mediterranean is made navigable. This requires different types of engineering works to overcome obstacles and to enhance transportation efficiency and connectivity with the railway networks of Uganda and the northern corridor in the East African Community (EAC). This alternative enables plans to expand navigation in Lake Victoria, with a potential to include direct navigation for vessels from Kenya & Tanzania. It may also enable linking Lake Edward & Albert if it becomes possible.

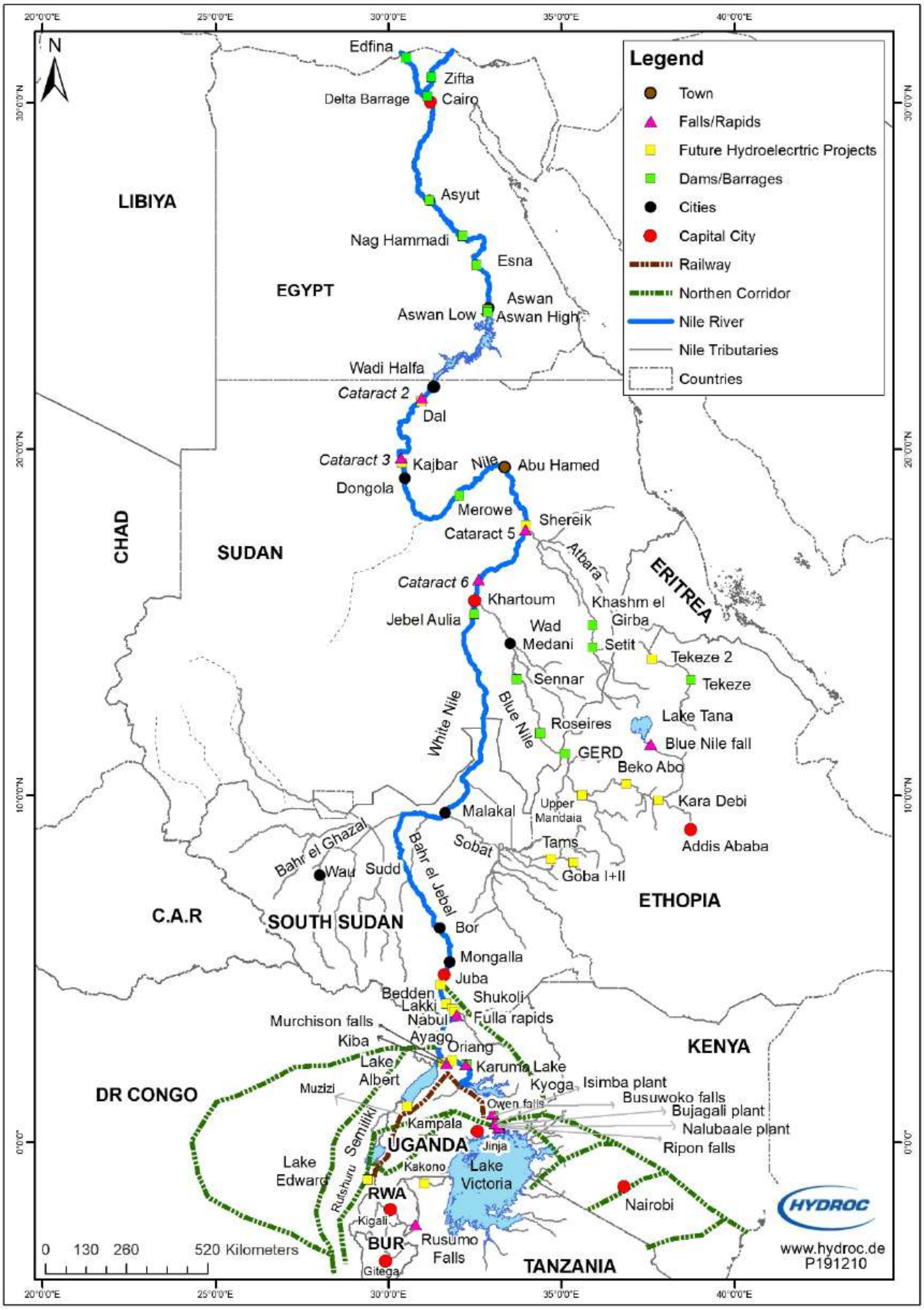


Figure 24. VICMED Alternative 1

3.2 Alternative 2

In this alternative, two reaches of the Nile will not be navigated but surface transportation means will be used instead. The first reach is the one before Lake Albert, i.e. Victoria Nile and Lake Kyoga. This is substituted by strengthening the Uganda railway network and terminal at Packwash, as well as the enhancements of the Northern corridor networks and facilities, with extending them to Juba. For the second reach, it is suggested to build a port at Abu-Hamed and to connect it with Aswan. The roadway length is about 800 km, instead of 2300 km on the river (current Nile stream from Abu-Hamed to Wadi-Halfa then Aswan through Lake Nasser).

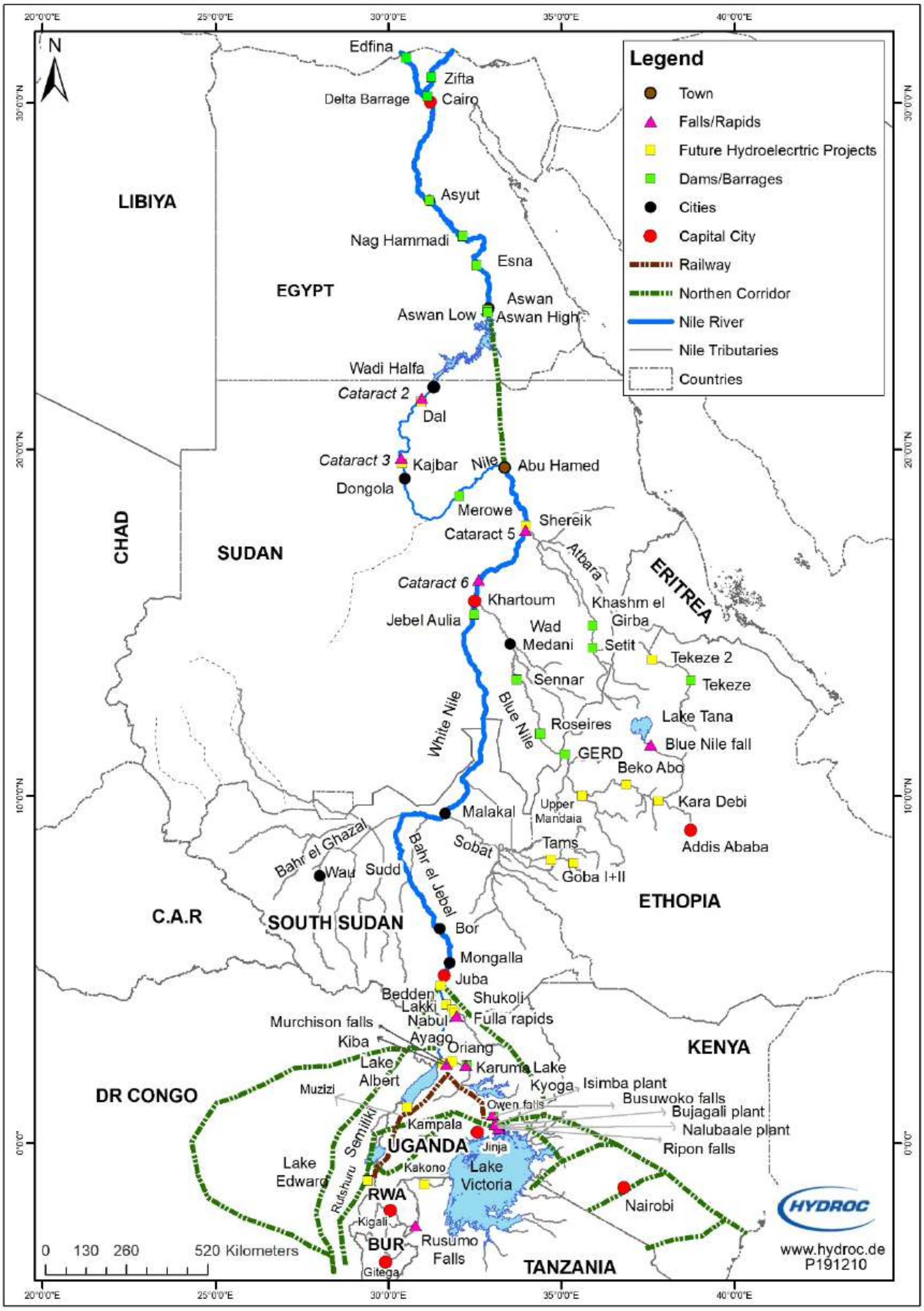


Figure 25. VICMED Alternative 2

3.3 Alternative 3

This alternative is similar to Alternative 2, but with establishing or strengthening railway transportation from Packwash to Juba to avoid the big engineering works in this reach. All other works are the same as Alternative 2.

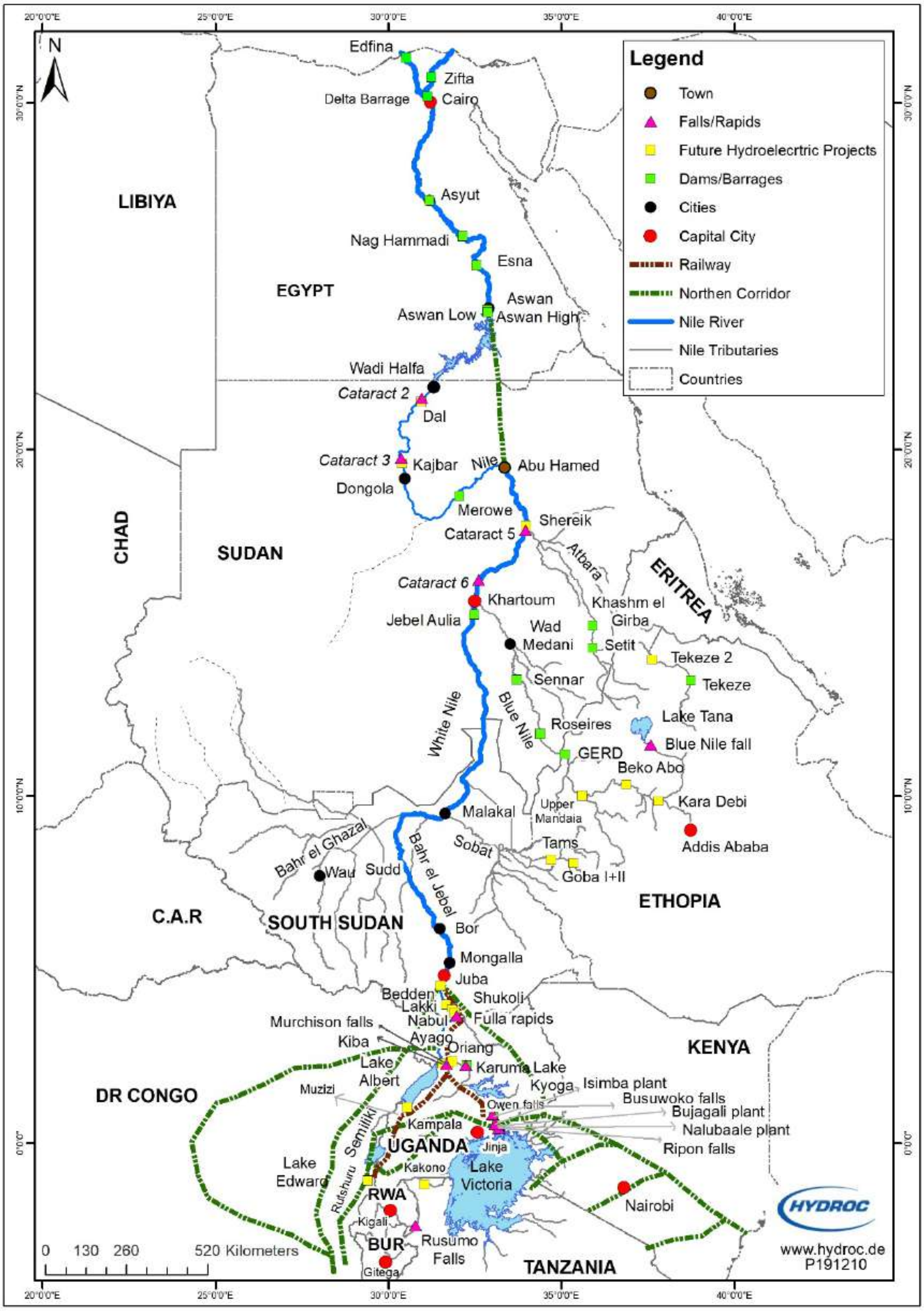


Figure 26. VICMED Alternative 3

3.4 Alternative 4

This alternative is similar to Alternative 1 but includes chances to link Rwanda with Lake Victoria (if possible to connect with the lower Akagera or Katonga river). It also considers the establishment of navigation lines in Lake Victoria with Kenya (Kusumo port), and Tanzania (Mwanza port). In this case, vessels and shipments can go to the Mediterranean Sea in continuous navigation.

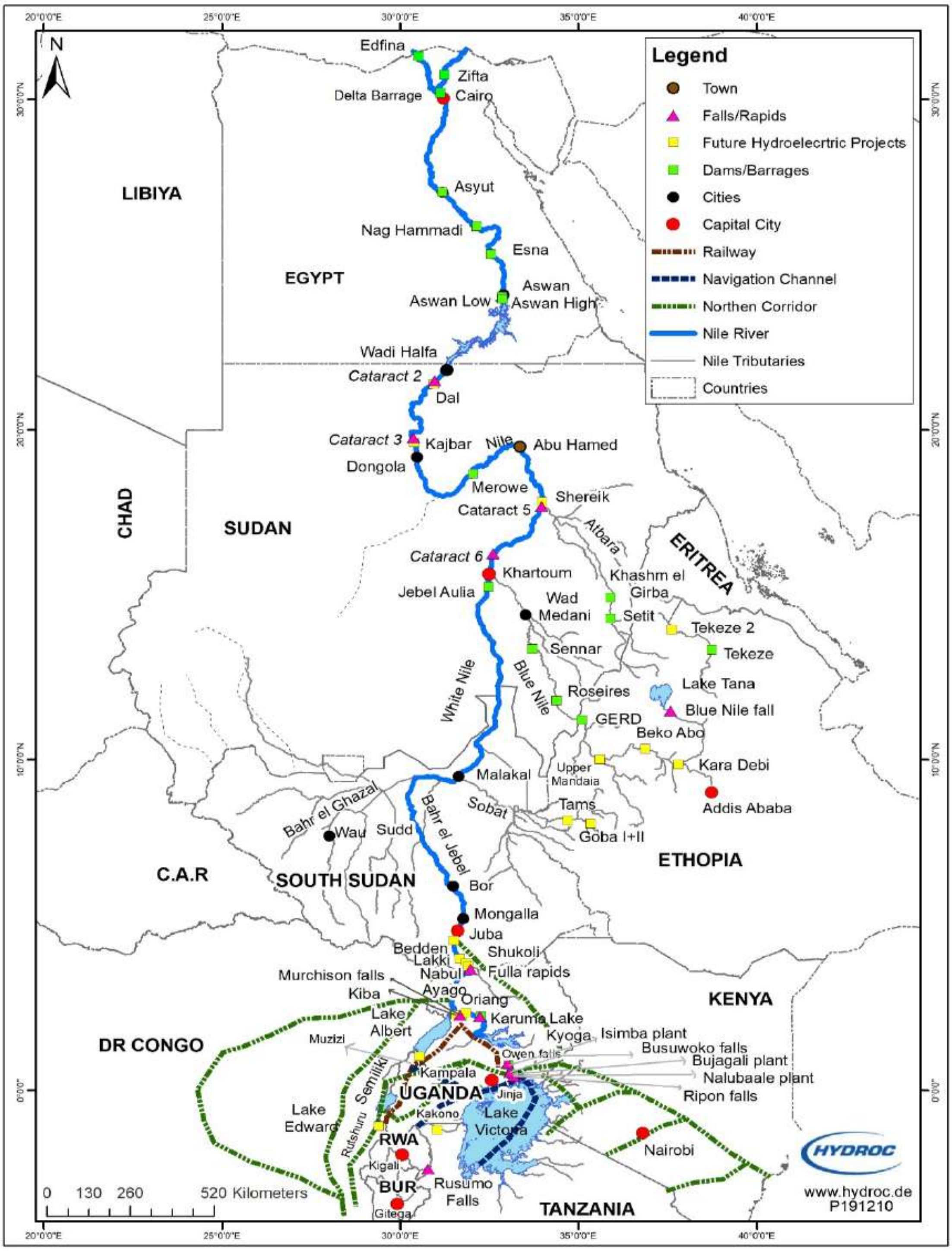


Figure 27. VICMED Alternative 4

4 River Obstacles

4.1 Bridges

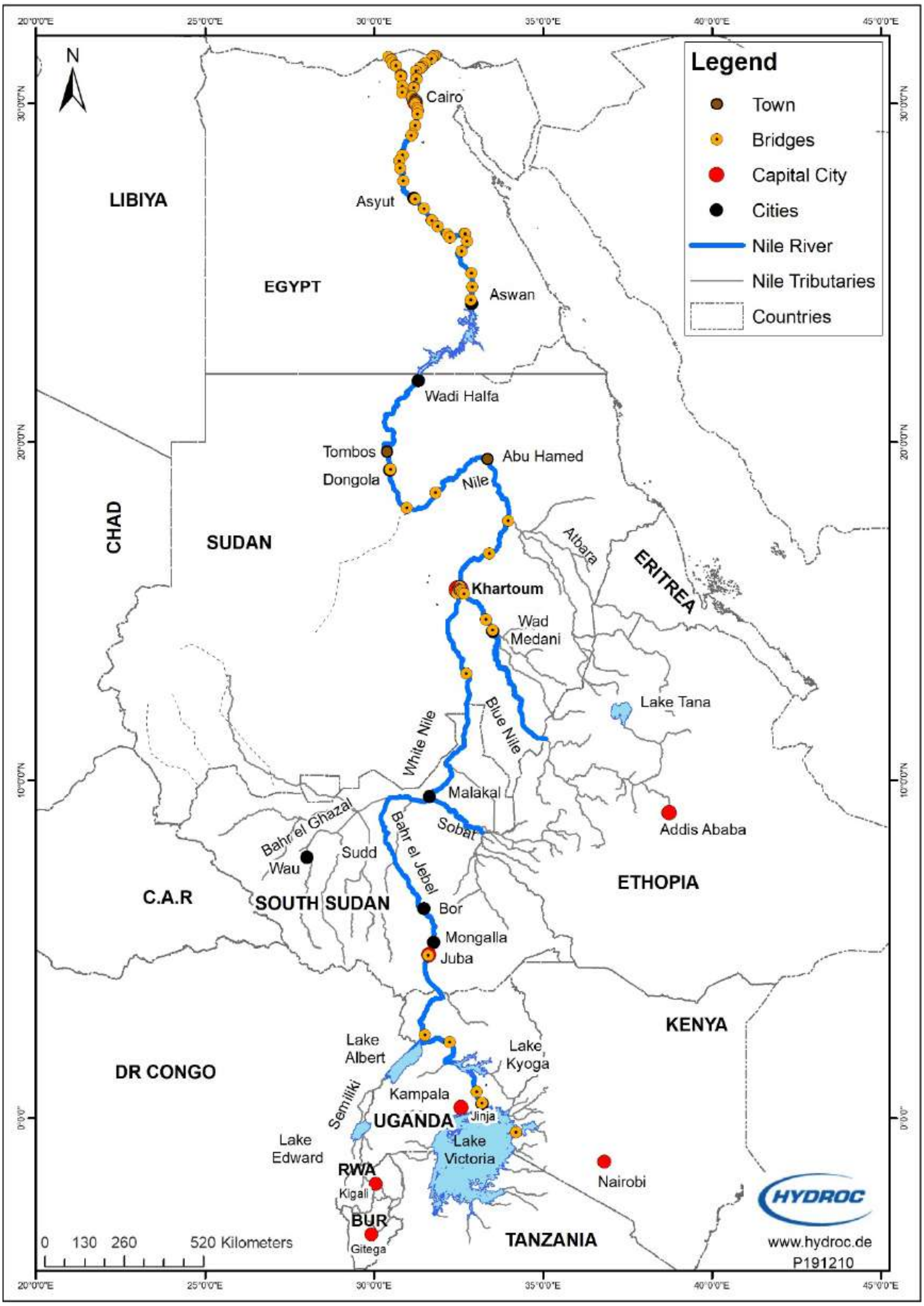


Figure 28. Nile bridges map

Bridges may create an obstacle for some sizes of vessels. To consider that, the list of all bridges along described stretches is provided.

Table 16. Bridges data sheet

Stretch	Country	Bridge	Nile width
Stretch 1: Main Nile – Nile Delta to Aswan	Egypt	**Rosetta branch**	
		Rasheed Bridge 31.375519, 30.431807	340 m
		Edfina Bridge 31.305773, 30.519443	500 m
		Edfina Bridge 2 31.287424, 30.519787	260 m
		Fuva Bridge 31.192432, 30.546290	440 m
		Desouk Bridge 31.130426, 30.636598	160 m + 330 m
		Desouk Bridge 2 31.115956, 30.649747	180 m + 340 m
		Kufur Belshay Bridge 30.856767, 30.787774	130 m + 290 m
		Kafr El Zayyat Bridge 30.819372, 30.811387	250 m
		Tanta-Alexandria road Bridge 30.815715, 30.809627	350 m
		Kafr Al Zaiat – Berket Al Sabea road Bridge 30.813959, 30.807969	280 m
		Al Birijat bridge 30.508542, 30.833208	180 m
		Izbat at Taju Al Qibliyyah bridge 30.327174, 30.833809	190 m
		Manshiyyat Al Qanatir bridge 30.188981, 31.109602	490 m
		Kafr Al Fokaha – Alkanater Kheireya road 30.184427, 31.116700	420 m
		Damietta branch	
		Damietta Dumyat bridge (with ferry crossing) 31.425054, 31.803809	150 m
		Damietta bridge 2 31.419685, 31.808949	130 m
		Damietta Dam and Bridge 31.409488, 31.786202	290 m
		Internationa lcoastal road bridge 31.391916, 31.748718	250 m
		Kafr Saad Bridge 31.323908, 31.706414	260 m
		Sherbin Bridge 31.188782, 31.519840	240 m
		Sherbin Bridge 2	150 m

		31.189767, 31.511081	
		Shrangash bridge 31.094296, 31.422483	190 m
		Talkha Bridge (Talkha) 31.050272, 31.388323	180 m
		Salah Salem Bridge (Talkha) 31.048731, 31.380165	190 m
		University First Ring Bridge (Talkha) 31.046706, 31.349069	190 m
		Sammanoud Steel Bridge (Samannoud) 30.959270, 31.246092	150 m
		Mit Ghamr – Tanta Bridge (Kafr Abu Nabhan) 30.739186, 31.249851	250 m
		Mit Ghamr – Zafna Bridge 30.722520, 31.250850	190 m
		Warwarah Bridge (Warwarah) 30.493536, 31.190808	200 m
		Bahna Bridge (Bahna) 30.483420, 31.180344	190 m
		Kafr Al Gazar Bridge (Bahna) 30.470545, 31.175083	260 m
		Bahna Bridge 2 (Bahna) 30.467185, 31.175582	290 m
		Shelqan Bridge (Shelqan) 30.214208, 31.113029	200 m
		Mohamed Ali Bridge (Derwah) 30.193453, 31.129412	380 m
		El Warraq Bridge (El Warraq) 30.133074, 31.203600	300 m + 530 m
		Rod El-Farag West Axis Bridge (El Waraq) 30.112486, 31.218211	390 m
		Long-live Bridge (Cairo) 30.102742, 31.236882	520 m
		Al Falag Bridge (Cairo) 30.085772, 31.229030	440 m
		Imbaba bridge (Cairo) 30.074928, 31.225627	400 m
		15th May Bridge (Cairo) 30.057830, 31.226944	240 m
		6th October Bridge (Cairo) 30.049129, 31.229552	280 m
		Qasr El Nil Bridge (Cairo) 30.043701, 31.229851	340 m
		Cairo University bridge (Cairo) 30.043701, 31.229851	450 m
		Addas Bridge (Giza) 30.015826, 31.220049	390 m

		Ring Road (Gazirat Ad Dahab) 29.988132, 31.222660	220 + 420 m (separated by island)
		The Middle Ring (Helwan) 29.864022, 31.288389	400 m
		Al Marazeek Bridge (El Tebbin) 29.793287, 31.293774	320 m
		Regional Ring Road Bridge (Al Ikhsas Al Qibliyyah) 29.689590, 31.286538	340 m
		Wasta Bridge (Wasta) 29.346894, 31.213935	510 m
		The new Beni Suef bridge (Ezbet Sherif) 29.093892, 31.138722	370 m
		Beni Suef Bridge (Beni Suef) 29.057182, 31.097538	520 m
		Ras Ghareb – Minya Road Bridge (El-Shaikh Fadl) 28.477809, 30.841423	250 m
		Samalout Bridge (Samalut) 28.314199, 30.743903	460 m
		Nile Bridge (Minya) 28.092083, 30.768111	320 m
		Upper Mallawi Bridge (Mallawi) 27.717245, 30.871722	410 m
		Assiut Bridge (Assiut) 27.174905, 31.216276	355 m
		Tema Nile Bridge 26.892548, 31.483967	570 m
		Sohag Bridges (Sohag) 1 - 26.558652, 31.702793 2 - 26.541506, 31.715523	1 – 510 m 2 – 400 m
		Bridge Gerga 26.365781, 31.885558	650 m (islands)
		Abu Tesht Bridge (Abu Tesht) 26.136578, 32.169002	900 m
		Nagaa Hammadi Bridge (Nagaa Hammadi) 26.045157, 32.249379	340 m
		Qena Bridge (Qena) 26.160270, 32.681574 (railways)	530 m
		Dandara Bridge (Qena) 26.149431, 32.702072	690 m
		Qous Bridge (Nakada) 25.931448, 32.752132	880 m
		Luxor Bridge (Luxor) 25.636261, 32.592045	450 m
		Edfo Bridge (Edfy) 24.983416, 32.886260	680 m

		Al Raghama – Kalabsha Bridge 24.583453, 32.905903	710 m
		New Aswan City Bridge 24.194081, 32.866342	540 m
Stretch 2: Lake Nasser – Aswan to Wadi Halfa			
Stretch 3: Main Nile – Wadi Halfa to Khartoum	Sudan	Dongola Bridge (Dongola) 19.186313,30.489929	630 m
		Aldabba Bridge (Aldabba) 18.044976, 30.962905	260 m
		Merowe Bridge (Merowe) 18.492403, 31.817760	360 m
		Qureir-Atbara Road (Atbara) 17.662369, 33.970399 (on Nile River)	210 + 250 m (island in-between)
		Shendi bridge (Shendi) 16.696444, 33.409528	380 m
		Al-Halfaia Bridge (Khartoum) 15.713797, 32.532251	600 m
		Shambat bridge (Khartoum) 15.644101, 32.506804	520 m
Stretch 4: Blue Nile – Khartoum to Renaissance Dam	Sudan	Tuty bridge (Khartoum) 15.608121, 32.512746	150 m
		El Mak Nemer Bridge (Khartoum) 15.614002, 32.532705	400 m
		Blue Nile Bridge (Khartoum) 15.615919, 32.543881	340 m
		Armed Forces Bridge (Khartoum) 15.616539, 32.554792	240 m
		Manshia Bridge (Khartoum) 15.599187, 32.590286	280 m
		Umm Dawm bridge (Umm Dawn) 15.535578, 32.619672	100 m
		Soba Bridge (Sawba) 15.502730, 32.672014	300 m
		Al-Hasaheisa bridge (Al-Hasaheisa) 14.746764, 33.308374	230 m
		Wed-Madani bridge (Wed-Madani) 14.427468, 33.507215	210 m
Stretch 5: White Nile – Khartoum to Malakal	Sudan	White Nile bridge (Khartoum) 15.613008, 32.492662	55 + 130 m (separated by island)
		Victory bridge (Khartoum) 15.603026, 32.493270	560 m
		Wed Ageeb brdge (Khartoum) 15.512721, 32.471972	1800 m
		Rabak Bridge (Rabak) 13.140765, 32.735494	1300 m
Stretch 6:			

Sobat River			
Stretch 7: Bahr el Jebel – Malakal to Juba	South Sudan	Nile street bridge (Juba) 4.822823, 31.608706	220 m
Stretch 8: Bahr el Jebel and Albert Nile – Juba to Lake Albert	South Sudan	Freedom bridge (Juba) 4.810700, 31.603275	420 m
	Uganda	Pakwach bridge (Pakwach) 2.459656, 31.507342	200 m
Stretch 9: Lake Albert			
Stretch 10: Kyoga Nile			
Stretch 11: Lake Kyoga			
Stretch 12: Victoria Nile	Uganda	New Karuma Bridge (Karuma) 2.242351, 32.239835	80 m
		Road to Isimba dam (Bugumira) 0.776960, 33.041393	250 m
		New Jinja Bridge (Jinja) 0.438640, 33.188029	310 m
		Kampala-Jinja Highway bridge (Jinja) 0.444883, 33.190422	110 m (on a side of the dam)
Stretch 13: Lake Victoria			

4.2 Unknown Structures

Besides bridges, the following unknown structures were found.

Table 17. Unknown structures

Stretch	Country	Bridge	Nile width
Stretch 1	Egypt/ Rosetta branch	Binufar unknown structure 30.828432, 30.792795	220 m
		Unknown structure 30.807306, 30.794343	250 m

4.3 Navigation Limitations

4.3.1 Artificial Obstacles

4.3.1.1 Dams

This sub-chapter describes dams along the Nile River. The key mitigation of these limitation is the locks construction, which are not present nowadays.

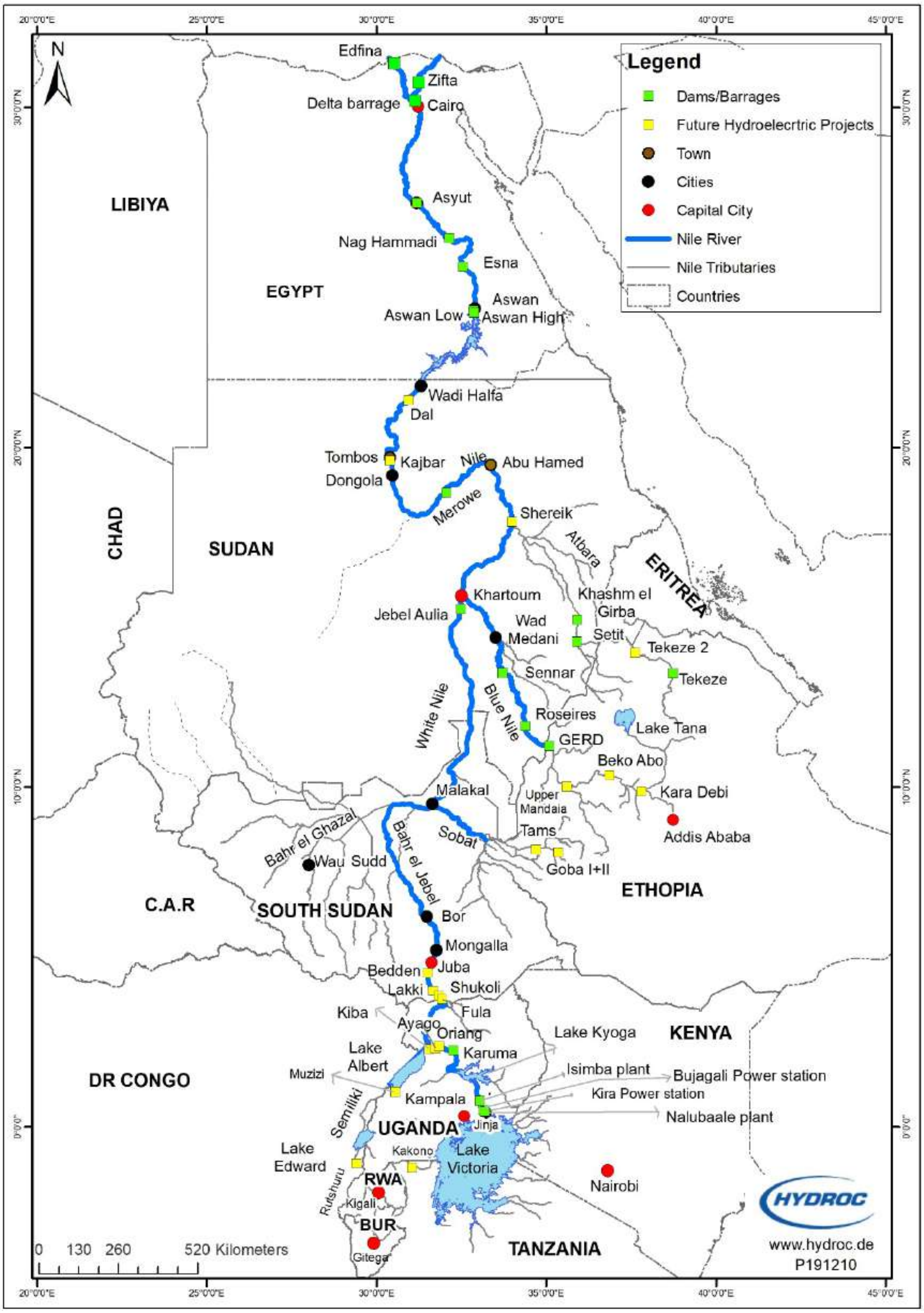


Figure 29. Nile River dams

Zifta barrage, Egypt

The Zifta Barrage, located about 100 km north of Cairo City, was built in 1902 and remodeled in 1954. It supplies water for about a quarter of the total irrigable agricultural land area. The dam serves electricity for domestic and industrial use and has one operational lock.


Figure 30. Zifta barrage

Edfina barrage, Egypt
Edfina Barrage is a dam in Muhafazat al Buhayrah, Egypt. The barrage has one operational lock.

Delta barrage, Egypt
The Delta barrage is located at the split of the Nile into Rosetta and Damietta branches. When being built, the Barrage succeeded in raising the water level in the irrigation canals by more than one meter, allowing for year-round irrigation in the whole delta region. With the water level in the canals higher, there was no longer any need for them to be so deep, and as such, they required less maintenance and less frequent clearance.[59]


Figure 31. Delta barrage

[59] Jakub Mazanec (2017). The Delta Barrage — the Most Expensive Bridge of Its Time? The First Attempts at Taming the Nile. Prague papers on the history of international relations

Asyut barrage, Egypt

The Asyut Barrage is a dam on the Nile River in the city of Asyut in Upper Egypt (400 km to the south of Cairo). The barrage includes two navigation locks (120 x 17 m chamber) on the right side of the Nile and eight semi-diagonal gates.

Figure 32. Asyut barrage

Naga-Hammadi barrage, Egypt

The 330 m long dam at Naga Hammadi in Upper Egypt is located 130 km north of the city of Luxor and 360 km downstream of the Aswan Dam. The barrage includes 170 m long navigation locks with a width of 17 m and a 330 m long low-level public road bridge over the dam. Fully operational since spring 2008, the project is a central feature in the water infrastructure of the Nile Valley.

Figure 33. Naga-Hammadi barrage

Esna barrage, Egypt

An original Esna barrage was completed in 1908 and replaced by a new one in 1995, which has got equipped with a hydropower station. It was replaced to improve the performance and to meet the different water needs. The new Esna barrage was constructed on the Nile River in Esna, 90 km upstream

Luxor city. The Barrage upstream water level has been maintained at a level of 79 m (+msl) throughout the year and it supplies the aquifer with water from the Nile.[60] Esna barrage has one operational lock.

Figure 34. Esna barrage

Aswan Low Dam, Egypt

The Aswan Low Dam or Old Aswan Dam is a gravity masonry buttress dam on the Nile River in Aswan, Egypt. The dam was built at the former first cataract of the Nile, and is located about 1000 km up-river and 690 km (direct distance) south-southeast of Cairo. On completion, it was the largest masonry dam in the world. The dam was designed to provide storage of annual floodwater and augment dry season flows to support greater irrigation development and population growth in the lower Nile. However, a rising pressure on dam's operation capacity led to the investigation and construction of the Aswan High Dam 6 km upstream.

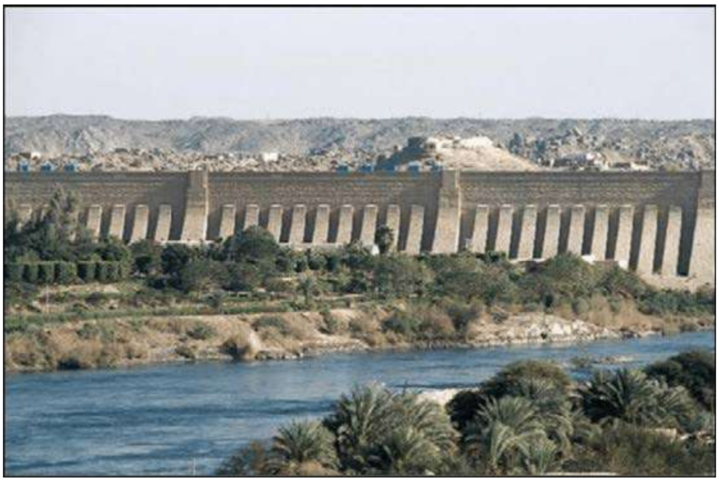


Figure 35. Aswan Low Dam

Aswan High Dam, Egypt

The Aswan High Dam is 4,000 m long, 980 m wide at the base, 40 m wide at the crest, and 111 m tall. It contains 43,000,000 m^3 of material. At maximum, 11,000 m^3/s of water can pass through the dam. There are further emergency spillways for an extra 5,000 m^3/s. The dam has 4 locks. Their functioning status is unknown.

[60] Zeinab El-Fakharany & Akram Fekry (2014) Assessment of New Esna barrage impacts on groundwater and proposed measures, Water Science, 28:1, 65-73, DOI: 10.1016/j.wsj.2014.09.003


Figure 36. Aswan High Dam

Merowe Dam, Sudan
The Merowe Dam is a large dam near Merowe town in northern Sudan, about 350 km north of the capital Khartoum It is situated close to and inundating the 4th Cataract where before inundation the river divided into multiple smaller branches with large islands in between.

The dam has a length of about 9 km and a crest height of up to 67 m. It consists of concrete-faced rockfill dams on each river bank (the right bank dam is the largest part of the project, 4.3 km long and 53 m high; the left bank is 1590 m long and 50 m high), an 883 m long 67 m high earth-core rockfill dam in the left river channel, and a live water section in the right river channel (sluices, spillway and a 300 m power intake dam with turbine housings). It contains a reservoir of 12.5 km^3, or about 15% of the Nile's annual flow of 84 km^3; the intended reservoir level is 300 m above sea level, with the Nile level downstream of the dam being about 265 m. The dam has no locks.


Figure 37. Merowe Dam

Sennar Dam, Sudan
The Sennar Dam is an irrigation dam on the Blue Nile near the town of Sennar in the Al Jazirah region of Sudan. The dam is 3025 m long and has a maximum height of 40 m. The dam has been operating since 1926. The dam has no locks.


Figure 38. Sennar Dam

Roseires Dam, Sudan

The Roseires Dam is a dam on the Blue Nile at Ad Damazin, just upstream of the town of Er Roseires, in Sudan. It consists of a concrete buttress dam 1 km wide with a maximum height of 68 m, and an earth dam on either side. The earth dam on the eastern bank is 4 km long, and that on the western bank is 8.5 km long. The reservoir has a surface area of about 290 km^2.

The dam was completed in 1966, initially for irrigation purposes. A power generation plant, with a maximum capacity of 280 megawatts, was added in 1971. A heightening (and lengthening) project was completed in 2013 and the dam is now 25 km long. The dam has no locks.


Figure 39. Roseires Dam

Grand Ethiopian Renaissance Dam, Ethiopia

The Grand Ethiopian Renaissance Dam (GERD) is a gravity dam on the Blue Nile River in Ethiopia under construction since 2011. The dam is in the Benishangul-Gumuz Region of Ethiopia, about 45 km east of the border with Sudan. The dam has no locks.

Figure 40. GERD

Jebel Aulia Dam, Sudan, White Nile

The dam was constructed 377 m above sea level. The reservoir surface area ranges from 600 to 1500 km^2, maximum depth is 12 m with a mean from 2.3 to 6.0 m. The reservoir's level starts to drop in February and continues until the end of May. It then begins to fill with increasing White Nile flows and reaches its maximum level in September. The amplitude of the water level movement is about 6 m.[61] The dam has one lock of 17 m width. However, its operation is permanently interrupted.

Figure 41. Jebel Aulia dam

Karuma hydroelectric power station, Uganda

The main components of the Karuma hydropower plant include a dam, powerhouse, a surge chamber, pressure shafts, a cable shaft, and tailrace tunnels. The dam includes six 238 m long tunnels with a diameter of 7.7 m as well as six concrete pressure shafts of 7.7 m diameter and lengths ranging between 328.59 m and 379.18 m.[62] The dam has no locks.

[61] https://www.fao.org/3/V4110E/V4110E05.htm
[62] https://www.power-technology.com/projects/karuma-hydropower-plant/

Figure 42. Karuma hydropower plant

Isimba dam, Uganda, Victoria Nile

Figure 43. A scheme of Isimba dam (planned)

Bujagali Hydroelectric Power Station, Uganda

The Bujagali Power Station is a hydroelectric power station across the Victoria Nile that harnesses the energy of the Bujagali Falls in Uganda. Construction concluded in 2012. The power station is located across the Victoria Nile, about 15.5 km northwest of the central business district of the city of Jinja and immediately north of the former location of the Bujagali Falls. It is at the border between Buikwe District to the west and Jinja District to the east. The dam has no locks.


Figure 44. Bujagali hydropower plant

Owen Falls Dam (Nalubaale Hydroelectric Power Station), Uganda
The dam sits across the Nile River between the town of Jinja, in Jinja district, and the town of Njeru in Buikwe District, approximately 85 km, by road, east of Kampala, Uganda's capital and largest city. The dam has no locks.


Figure 45. Owen Falls hydropower plant

Summary of dam characteristics

Table 18. Nile dams data sheet, existing dams

Reach	Dam	Key characteristics
Stretch 1: Main Nile – Nile Delta to Aswan	Zifta barrage	1 lock
	Delta barrage	1 lock
	Edfina barrage	1 lock
	Esna barrage	1 lock
	Assiut barrage	2 operational locks (120 x 17 m chamber)
	Naga-Hammadi barrage	2 operational locks (170 x 17 m chamber)
	Aswan Low dam	4 locks
	Aswan High dam	No locks
Stretch 2: Lake Nasser – Aswan to Wadi Halfa	None	-

Reach	Dam	Key characteristics
Stretch 3: Main Nile – Wadi Halfa to Khartoum	Merowe Dam	No locks
Stretch 4: Blue Nile – Khartoum to Renaissance Dam	Sennar Dam	No locks
	Roseires Dam	No locks
	Grand Ethiopian Renaissance Dam	No locks
Stretch 5: White Nile – Khartoum to Malakal	Jebel Aulia Dam	Locks: width 17 m, length 67 m Fish ladder is installed
Stretch 6: Sobat River	None	-
Stretch 7: Bahr el Jebel – Malakal to Juba	None	-
Stretch 8: Bahr el Jebel and Albert Nile – Juba to Lake Albert	None	-
Stretch 9: Lake Albert	None	-
Stretch 10: Kyoga Nile	Karuma hydroelectric power station	Under construction
Stretch 11: Lake Kyoga	None	-
Stretch 12: Victoria Nile	Isimba dam	No information
	Bujagali Hydroelectric Power Station	No information
	Owen Falls Dam (Nalubaale Hydroelectric Power Station)	No information
Stretch 13: Lake Victoria	None	-

Table 19. Nile dams data sheet, planned dams

Country	Name
Sudan	Dal
	Kajbar
	Shereik
Ethiopia	Tekeze 2
	Tams
	Goba I+II
	Upper Mendaia
	Beko Abo
	Kara Debi
South Sudan	Bedden

Country	Name
	Lakki
	Shukoli
	Fula + Grand Fula
Uganda	Ayago
	Oriang
	Kiba Power station
	Muzizi
Tanzania	Kakono
Congo	Rutshuru

4.3.1.2 Ferry crossings

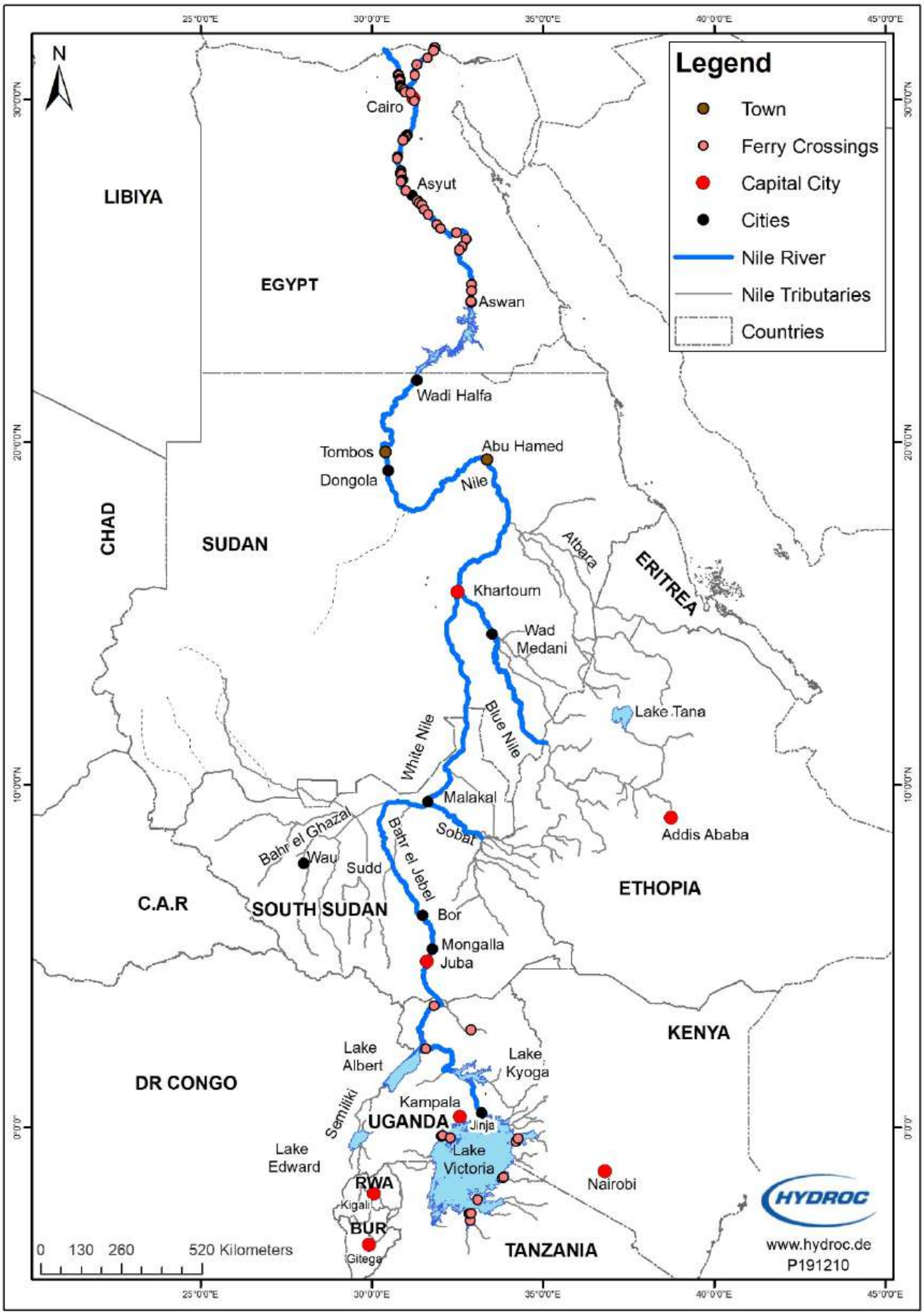


Figure 46. Map of ferry crossings along the Nile

The following ferry crossings were identified:
Stretch 1: Rosetta branch
Ferry crossing in An Nijaylah (30.726933, 30.776332)
An island river-wide (30.722537, 30.762534)
Tonub Ferry crossing (30.695339, 30.790647)

Abu Al Khawi ferry crossing (30.597410, 30.808424)
Monshaat El-Sadat Ferry crossing (30.561561, 30.813888)
Natural obstacle (river-wide) (30.544719, 30.816504)
Car crossing service (30.415366, 30.837581)
Ferry Abu Nashaba crossing (30.367714, 30.855203)
Ferry crossing Izbat Madkour (30.358156, 30.830662)
Ferry crossing (30.332982, 30.864158)
River-wide obstacle (30.339276, 30.872242)
Abu Awali WA Monshaateha ferry crossing (30.285787, 30.937548)
Ferry crossing (30.284736, 30.945886)
Ferry crossing (30.211506, 30.983890)

Stretch 1: Damietta branch (very tensed in the north)
Ferry crossing (31.511585, 31.837579)
Ferry crossing (31.510049, 31.836643)
Ferry crossing (31.510049, 31.836643)
Ferry crossing (31.506611, 31.834839)
Ferry crossing (31.503724, 31.833848)
Ferry crossing (31.436374, 31.798495)
Ferry crossing (together with bridge; 31.424424, 31.804006)
Ferry crossing (31.210702, 31.630005)
Ferry crossing Awich stone Kfarahsan (31.010176, 31.309066)
Ferry crossing (30.715412, 31.250677)
Ferry crossing (30.712247, 31.252016)
Ferry crossing (30.190865, 31.132199)

Stretch 1: Main Nile
Manial Shehah Ferry crossing (29.954608, 31.248481)
Ferry crossing (28.974553, 31.033123)
Ferry crossing (28.933881, 31.004873)
Ferry crossing (28.901724, 30.987653)
Ferry crossing (28.852700, 30.923536)
Ferry crossing (28.811523, 30.907613)
Ferry crossing (28.328552, 30.755235)
Ferry crossing (28.309054, 30.741197)
Ferry crossing (28.298626, 30.737849)
Ferry crossing (28.298626, 30.737849)
Ferry crossing (28.274273, 30.741779)
Ferry crossing (27.907926, 30.852465)
Ferry crossing (27.859686, 30.835843)
Ferry crossing (27.842326, 30.833933)
Ferry crossing (27.807238, 30.857880)
Ferry crossing (27.660273, 30.894235)
Ferry crossing (27.638510, 30.874387)
Ferry crossing (27.614936, 30.858401)
Ferry crossing (27.593654, 30.855560)
Ferry crossing (27.329747, 30.991885)
Ferry crossing (27.051855, 31.321063)
Ferry crossing (26.980675, 31.382232)
Ferry crossing (26.919601, 31.467483)
Ferry crossing (26.784312, 31.524641)

Ferry crossing (26.647828, 31.645666)
Ferry crossing (26.353853, 31.896870)
Ferry crossing (26.228339, 32.009189)
Ferry crossing (26.115331, 32.462802)
Ferry crossing (25.924183, 32.747406)
Ferry crossing (25.703439, 32.637217)
Ferry crossing (25.613556, 32.549118)
Ferry crossing (24.606350, 32.915173)
Ferry crossing (24.419542, 32.909801)
Ferry crossing (24.113939, 32.895339)

Stretch 12: Victoria Nile
Paraa ferry crossing (2.284742, 31.566429)

4.3.2 Natural Obstacles

4.3.2.1 Waterfalls

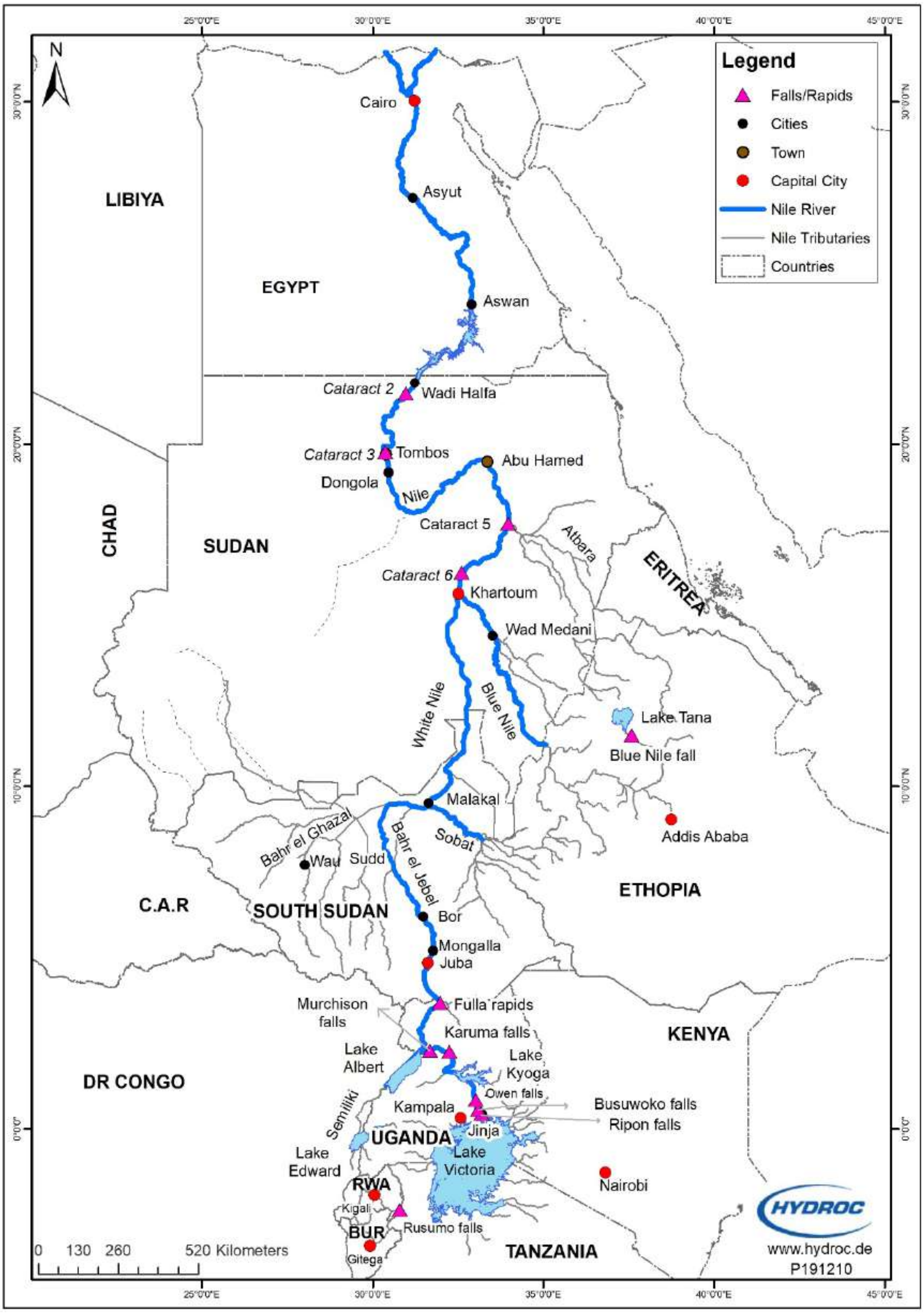


Figure 47. Nile waterfalls map

Fula rapids, South Sudan

Figure 48. Fula rapids

Karuma Falls/rapids, Uganda

Figure 49. Karuma falls

Murchison Falls, Uganda

Figure 50. Murchison falls

Busowoko falls Uganda

Figure 51. Busowoko falls

4.3.2.2 Cataracts

The cataracts of the Nile are shallow lengths (or white-water rapids) of the Nile River, between Aswan and Khartoum, where the surface of the water is broken by many small boulders and stones jutting out of the river bed, as well as many rocky islets. In some places, these stretches are punctuated by white-water, while at others the water flow is smoother but still shallow.

Counted going upstream (from north to south):

In Egypt:

- The First cataract (23.9737, 32.8821) cuts through Aswan. Its former location was selected for the construction of Aswan Low Dam, the first dam built across the Nile.

In Sudan:

- The Second cataract (or Great Cataract - 21.8159, 31.1996) was in Nubia and is now submerged under Lake Nasser.

- The Third cataract (19.8369, 30.2945) is at Tombos/Hannek.

Figure 52. Third cataract
Source: By Clemens Schmillen - Own work, CC BY-SA 4.0

- The Fourth cataract (18.6661, 32.0529) is in the Manasir Desert, and since 2008, is submerged under the reservoir of Merowe Dam.
- The Fifth cataract (18.3859, 33.7768) is near the confluence of the Nile and Atbarah Rivers.

Figure 53. Fifth cataract
Source: By Fdevillard - Own work, CC BY-SA 3.0

- The Sixth cataract (16.2861, 32.6697) is where the Nile cuts through the Sabaluka luton, close to Bagrawiyah (Sudan).

Figure 54. Sixth cataract
Source: By Gerd Hoffman, 2010

4.3.3 Obstacles Management

Several potential navigation limitations are encountered in the Nile River. These include, but are not limited to:

- Limited water depth
- Narrow Channels
- Sharp bends
- Vegetation blockages
- Shifting channels
- Bridges
- Ferries

Such potential navigation limitations are overcome with one or more of the following approaches:

- Using navigation aids
- Dredging, and maintenance dredging

Using navigation aids to overcome limitations

Several methods can be used collectively to support and facilitate navigation – these are known as navigation aids and these include but are not limited to the following:

- Installation of navigation aids
- Bathymetric map / navigation chart production
- Intelligent transport systems including GPS and radar applications with operation control centres (OCC)[5]

Poorly maintained port infrastructure and inefficient operations remain major limitations for maritime transport. The dwell time (i.e. the time container units/cargoes remain in the port between vessel discharge and leaving, or between entering and vessel loading) is generally high – over 10 days in most ports.[4]

RTA (River Transport Association) has observed 71 potential locations as navigational bottlenecks along the River Nile.[63]

4.3.4 Potential Organizational, Political and Financial Limitations

- Limited access to ports
- Cross-border administration, fees and delays
- Challenges to constantly adapt and improve logistics efficiency
- Deterioration in quality of transport infrastructure (maintenance and operation)
- High fuel/ oil prices on various industries that are customers of IWT
- Limited political support and funding resulting in poor condition of many waterways & ports
- Increased restriction of banks for investment as a consequence of the crisis
- Inability to adapt to new market requirements

4.3.5 Potential Safety Aspects

- Security issues and their impacts on trade volume and revenues

4.3.6 Other

- The negative impact of transport on the environment
- Water quality may be affected

4.3.7 Trade Case

Transport and trading are closely interlinked in the Nile basin. The following figure typically shows the main activities occurring across international borders and particularly the main issues and obstacles that are present at borders of African nations and that hinder trade.

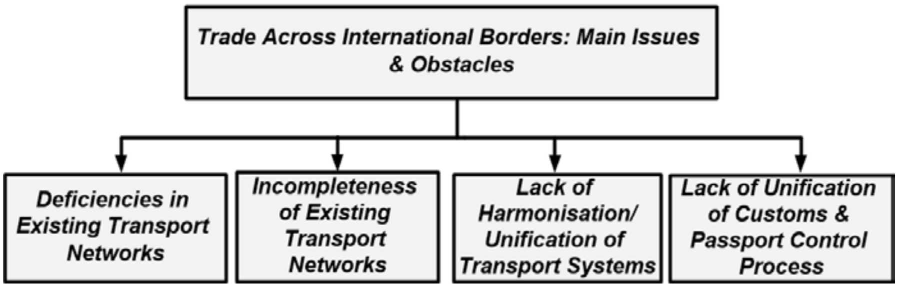


Figure 55. Activities, issues & obstacles at borders of African nations[5]

Towards this end, it is inevitable to work on trade facilitation to overcome hindering issues and obstacles. This can take several forms as follows:

- Transport and trade facilitation sectors should be strengthened.
- Develop multimodal transport corridors to reduce transport costs
- Focus on non-physical barriers
- Disciplines on fees imposed on imports and exports
- Work on integration/cooperation with neighboring countries/ regions
- Encourage private sector participation in operations/maintenance

Trade with global markets is conducted through transport corridors to and from seaports via neighbouring states in several countries. The existing transport systems in the region are outward-looking, designed

[63] Noha Kamal, Nahla Sadek, Evaluating and analyzing navigation efficiency for the River Nile (Case study: Ensa-Naga Hamady reach), Ain Shams Engineering Journal, Volume 9, Issue 4, 2018, Pages 2649-2669, ISSN 2090-4479, https://doi.org/10.1016/j.asej.2017.08.006.

with overseas markets as opposed to interlinking neighbouring states. As a consequence, there is a relatively low level of integration of the physical transport networks in the Nile region.[5]

4.4 Ports

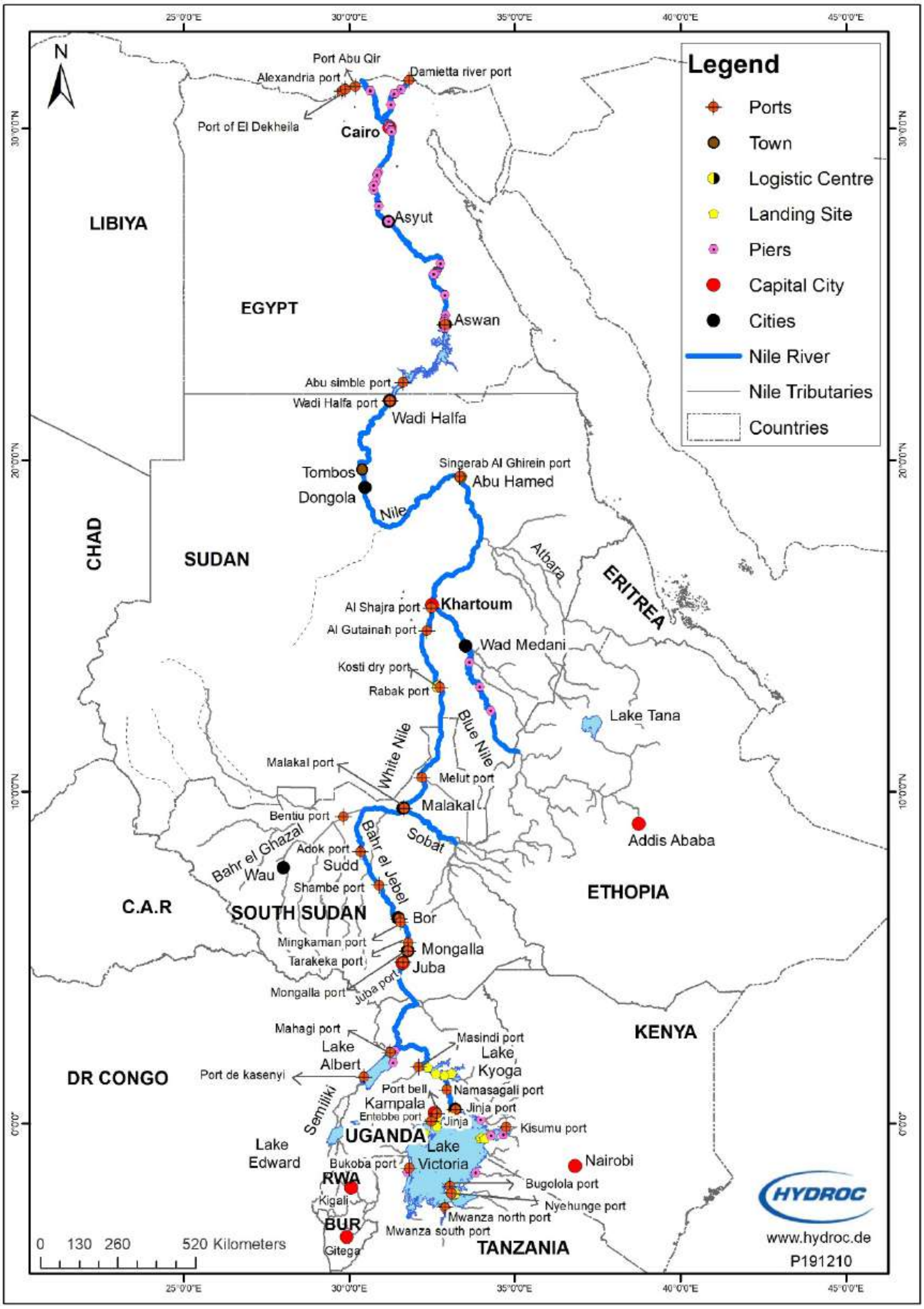


Figure 56. Nile River ports

River ports are an essential part of a river barge transportation system, facilitating the effective loading and offloading of goods and passengers at key locations. Next to the important accessibility from both land- and river-side, the port infrastructure itself is important and needs to relate to the services that the port is expected to provide. A table, containing general ports' descriptions, is provided below.

Table 20. Ports data sheet

Reach	Country	Port	Facilities/ equipment available	Storing capacity (ton)
Stretch 1: Main Nile – Delta to Aswan	Egypt	Rosetta: Port of El Dekheila 31.134750, 29.797324	Dockside Crane: 9 Panamax, 6 super post Panamax; With twin spreader 29 Container Gantries 27 Mobile Cranes 8 Reach stackers 75 RoRo Tugmasters (with Trailer) Grain Elevator with Bagging Machines 16 transtainers 15 Forklifts	27,000
		Alexandria Port 31.193368, 29.877741		15,500
		Al Noor Mosque dock station 31.138033, 30.634823	Not available	Not available
		Damietta River Port 31.460344, 31.756536	Repairs/Dry docks: Ship lift 40 x 10 m. up to 450 tons. Fuel: Available. Cranes: 4 mobile Gantry Cranes cap. 40 t; 2 mobile cranes cap. 20 t; 4 mobile cranes cap.15 t.; 22 forklifts with cap. ranging from 5 t to 40 t Bulk cargo facilities: Grain silo with a capacity of 100,000 t vessels up to 80,000 dwt; two suction unloaders with a capacity of 700 t/h	Tons are not available The storage area is 258000 m^2.
		Pier 31.180549, 31.556245	No information	No information
		Talkha pier 31.059511, 31.398000	No information	No information
		Talkha pier 2 31.048407, 31.357553	No information	No information
		Zifta riverbank docking 30.710902, 31.255163	No information	No information
		Suqayl riverbank docking 30.131273, 31.185357	No information	No information
		Pier 30.115057, 31.215250	No information	No information
		Yacht club	No information	No information

Reach	Country	Port	Facilities/ equipment available	Storing capacity (ton)
		30.079142, 31.224827		
		Cairo pier 30.072791, 31.221339	Not available	Not available
		Cairo pier 2 30.034658, 31.220007	Not available	Not available
		Maadi yacht club 29.954544, 31.253379	Not available	Not available
		House of Works yacht club 29.946793, 31.267096	Not available	Not available
		The port of Misr Aluminum Company (Cairo) 29.915825, 31.284411	No information	No information
		Giza Shipyard 29.900567, 31.278905	No information	No information
		Port of Hawamdiya Sugar Factory 29.894034, 31.280007	No information	No information
		Nazlat Awlad El Sheikh docking point 28.685109, 30.884684	Not available	Not available
		Riverbank docking 28.644666, 30.850221	Not available	Not available
		Quay 28.636738, 30.855821	Not available	Not available
		Abbad Sharona Ferry pier 28.598375, 30.842689	Not available	Not available
		Marsa Abbara-Sheikh Hassan-Matay pier	Not available	Not available

Reach	Country	Port	Facilities/ equipment available	Storing capacity (ton)
		28.399450, 30.806787		
		Sharayneh pier 28.279791, 30.735062	No information	No information
		Port of Nile Marine Engineering LLC 28.146755, 30.740721	No information	No information
		Tel Bani Omran pier 27.660045, 30.896081	No information	No information
		Armed Forces Officers Club yacht club 27.203837, 31.192715	No information	No information
		Port Abu Qir 31.273918, 30.182401	Bulk Cargo facilities: Grain silo, converted from a bulk carrier, permanently moored at the quayside in the port. Equipment includes conveyor belts, cranes and an automatic packaging system for cereals. Terminals: Mainly used for food products, urea, petroleum offshore activities and some project cargoes also and a lot of citrus exporting activities.	No information
		Asyut 27.21328109451, 31.167109247074	E vehicle elevators 2 Cranes 4 Pumps 1 packing unit 4 Transportation gutters	20,000 – 60,000
		Pier 25.922793, 32.749638	No information	No information
		Pier 25.710766, 32.645693	No information	No information
		Pier 25.697832, 32.637067	No information	No information
		Pier	No information	No information

Reach	Country	Port	Facilities/ equipment available	Storing capacity (ton)
		25.678309, 32.625581		
		Mercy Coral pier 25.652112, 32.612611	No information	No information
		Marsa Elwatanya pier 25.638165, 32.597033	No information	No information
		Mercy Viking deck 25.627892, 32.588621	No information	No information
		Shipyard 25.612240, 32.549697	No information	No information
		Shipyard 25.552467, 32.467694	Repair services	No information
		Sugar factory port 25.047241, 32.858762	No information	No information
		Dock Edfu 24.975943, 32.881918	No information	No information
		Mansourieh western port (alternative) 24.460445, 32.907058	No information	No information
		Dock alhirbiab 24.365708, 32.913265	No information	No information
		Dock alaieqab Aswan 24.249890, 32.883186	No information	No information
		+ Aswan has 31 dock stations on the right shore	No information	No information
		+ 17 on the left shore	No information	No information
		Amarco docking area 24.186152, 32.864087	No information	No information

Reach	Country	Port	Facilities/ equipment available	Storing capacity (ton)
		Dock Abercrombie 24.182300, 32.870331	No information	No information
		Tora port 31.137956, 30.634715	Cement tankers Belt	5,000
Stretch 1: Egyptian Nile	Egypt	Aswan port 24.032799, 32.879872	No information	No information
		Dock island haysah 24.038260, 32.881624	No information	No information
		Marina Philae Temple dock station 24.035427, 32.886446	No information	No information
		Philae Temple dock (island) 24.024063, 32.884341	No information	No information
Stretch 2: Lake Nasser	Egypt	Abu Simple Port 22.341387, 31.625371	No information	No information
		Dock Ship Abu Simbel tourism 2 22.363749, 31.631867	No equipment	None
		Dock Aswan High Dam, Dock Sudan ship, Dock Ship Abu Simbel tourism 23.972333, 32.896590	No information	No information
Stretch 3: Main Nile – Lake Nasser to Khartoum	Sudan	Wadi Halfa Port 21.808351, 31.318904	No information	No information
		Singerab Al Ghireib port 19.511645, 33.339166	No information	No information
		Sout Island port	No information	No information

Reach	Country	Port	Facilities/ equipment available	Storing capacity (ton)
		19.425783, 33.374677		
Stretch 4: Blue Nile – Khartoum to Renaissance Dam	Sudan	Riverbank docking 12.438242, 34.272867	-	No information
		Sinar - Wad Medani Hwy dock station 13.898125, 33.626678	No information	No information
		Sinjah dock station 13.154747, 33.942775	No information	No information
Stretch 5: White Nile – Khartoum to Malakal	Sudan	Al Shajra port (Khartoum) 15.542341, 32.484016	No information	No information
		Al Gutainah Port 14.861263, 32.343916	No information	No information
		Rabak port, Sudan (White Nile) 13.143591, 32.735946	No information	No information
	South Sudan	Malakal port 9.507300, 31.657644	Manual up- and offloading	No information
Stretch 6: Sobat River	None			
Stretch 7: Bahr el Jebel – Malakal to Juba	South Sudan	Malakal port 9.507300, 31.657644	Manual up- and offloading	No information
		Adok port 8.185254, 30.321112	No information	No information
		Bor port 6.203742, 31.553581	Freelance porters do the loading and offloading	Not available
		Mangalla river port 5.200506, 31.768177	No equipment	Not available
		Juba river port 4.857651, 31.621050	The service provided is limited to loading and offloading and minor repairs on the barges.	No common storage facilities

Reach	Country	Port	Facilities/ equipment available	Storing capacity (ton)
			One jetty and one crane for loading at the port. The crane capacity is 20-25 mt. Loading is mostly done manually from the bank of the White Nile[64]	
		Mingkaman port 6.061091, 31.515739	1 tower rotating crane (broken), forklift, crane truck-both broken down	Not available
		Shambe port 7.106714, 30.774213	Pumping equipment (but no power)	Not available
		Bentiu 9.283784, 29.810405	No equipment	Not available
		Melut 10.439526, 32.220407	No equipment	Not available
	South Sudan	Terakeka port 5.453373, 31.756959	No equipment	Not available
Stretch 8: Bahr el Jebel and Albert Nile – Juba to Lake Albert	Uganda	Laropi crossing point 3.545352, 31.811161	None	None
Stretch 9: Lake Albert	Congo	Port de Kasenyi 1.393020, 30.443207	No equipment	No information
		Mahagi port 2.142757, 31.240563	No information	No information
Stretch 10: Kyoga Nile	Uganda	Masindi port – Kungu 1.696926, 32.095417	No information	No information
Stretch 11: Lake Kyoga	Uganda	Kasilo landing site 1.496752, 33.090701	No equipment	Not available
		Bukungu landing site 1.438235, 32.869528	No equipment	Not available
		Namasale landing sites	No equipment	Not available

[64] Logistic Cluster leaflet: Common Transport Service: White Nile – Snapshot

Reach	Country	Port	Facilities/ equipment available	Storing capacity (ton)
		1.491259, 32.617923		
		Kayei landing site 1.674721, 32.377052	No equipment	Not available
Stretch 12: Victoria Nile	Uganda	Namasagali Port 1.015256, 32.946392	No information	No information
Stretch 13: Lake Victoria	Uganda	Port Bell 0.295822, 32.653148	Dry dock facilities; Equipment: • One operating mobile crane • Load-on Load-off (LoLo) facilities for cargo handling • Roll-on Roll-off (RoRo) rail wagon loading dock; State of infrastructure - Rail and road infrastructures in a fairly good state; The port is connected by rail to the Northern corridor. A marshaling yard with 4 tracks is located along to the access to the port.	Superstructures - Warehouse (75 x 20m). No information about capacity
		Jinja port 0.414136, 33.207824	State of infrastructure: It is in very poor condition with most of the planking and fendering systems decayed beyond use. Connected to the railroad Other comments: mainly used as a relief port for Port Bell when it was congested.	Not available
		Entebbe port terminal 0.054989, 32.481117	No information	No information
	Kenya	Kisumu Port -0.103343, 34.744916	Lake-wagon terminal; Equipment: Kisumu has the most fully equipped machine, carpentry, and fabrication shops of the ports of Lake Victoria; Lake connectivity: The major problem faced at the port is the presence of hyacinth which hinders the movement of vessels in and out of the port. Land connectivity: The rail-wagon terminal in the port of Kisumu is connected by a side branch to the	Superstructures: • warehouse of 80x16m • paved open storage is approximately 3,000m².

Reach	Country	Port	Facilities/ equipment available	Storing capacity (ton)
			Northern railway corridor, it is also associated with the ICD that is approximately three kilometres from the port.	
	Tanzania	Mwanza north port -2.535793, 32.900489	There is no grain and bulk handling operations; 1 portal crane; 1 dockside crane; 2 mobile cranes[65]	No information
		Mwanza south port	Portal crane 1 Nos Forklift 1 Mobile crane Dredger Tug Linder Floating Dock Land connectivity: Road and rail Connection to the central railway in reasonably good shape; the rail line inside the port is of a poorer state, and looped along the main quay, with two spurs, one (disused) running along the cope edge and the other fronting the goods sheds. Wagons can be parked here in readiness for shunting onto ferries through a rail-wagon terminal and located at the southern end of the quay facilities Equipment: • Weighbridge (recently acquired) • Only 1 jetty crane is operational at a max of 3 tons. • Old crane is out of use • 3 fork lifts have been acquired recently • one farm tractor used for shunting the rail cars on and off the wagon ferry State of infrastructure: Generally poor: poor condition of entire yard area: area is not paved and very uneven; poor condition of railway tracks	Superstructures: • 3 sheds and storage area. One storage shed along the quay has been rehabilitated recently. • Other structures require maintenance or upgrading.
		Musoma pier	Lake connectivity: • No traffic	Superstructures:

[65] https://www.ports.go.tz/index.php/en/ports/lake-victoria-respective-ports

Reach	Country	Port	Facilities/ equipment available	Storing capacity (ton)
			Land connectivity: • no railway connection, but railway track within the yard area to load/offload and shunt rail wagons road connection of good quality with Kenya and Mwanza Equipment: • no cargo handling facilities State of infrastructure: Poor	• two offshore mooring dolphins for berthing tank-ships for ship to shore petroleum transfers
		Lutoboka landing site (-0.3, 32.2833)	Not available	Not available
		Landing point (0.100090, 32.652172),	Not available	Not available
		Kemondo pier/dock (1.478640, 31.750694),	Land connectivity: no railway connection at the hinterland Equipment: • Superstructures • Offshore mooring dolphin • RoRo facility for ramped vessels State of infrastructure: Poor Other comments: • Kemondo Bay depends largely on the performance of TRL and the Lake ferry wagons. • Unfortunately, neither is performing well at present. The wagon ferry will continue to call Kemondo Bay, but because Bukoba is the preferred port for passengers and local cargo, the development potential for Kemondo port is considered to be reduced. Significant investments are unlikely to be justified. • An alternative port is Bukoba	No information
		Kikongo ferry terminal (-2.725939, 32.868469)	No information	No information
		Busisi ferry terminal (2.714546, 32.893652)	No information	No information

Reach	Country	Port	Facilities/ equipment available	Storing capacity (ton)
		Kigongo ferry terminal (-2.533003, 32.838031)	No information	No information
		Nyehunge port (2.507253, 32.897463)	No information	No information
		Bugolola ferry port (1.982943, 33.017818)	No information	No information
		Bukimwi landing site (-2.167274, 33.138503), Tanzania	Not available	Not available
		Ngoma landing site (-2.131916, 33.181881), Tanzania	Not available	Not available
		Masahunga landing site (-2.112587, 33.210452), Tanzania	Not available	Not available
		Mwigobelo (Musoma) Ferry Terminal (-1.494986, 33.810965), Tanzania	No information	No information
		Kinesi Ferry Terminal (-1.461471, 33.858524), Tanzania	No information	No information
		Kamanga ferry terminal (-2.519364, 32.895328), Tanzania	No information	No information
		Bukoba port (-1.349739, 31.815719), Tanzania	No information	No information

Reach	Country	Port	Facilities/ equipment available	Storing capacity (ton)
		Nansio port and lake ferry terminal (-2.110104, 33.084193), Tanzania	No information	No information
		Milundu landing site (-0.456748, 33.955837), Kenya	Not available	Not available
		Wakula landing site (-0.449230, 33.986648), Kenya	Not available	Not available
		Mfangano island landing site (-0.473315, 34.069399), Kenya	Not available	Not available
		Takawiri landing site (-0.472156, 34.086148), Kenya	Not available	Not available
		Mbita Rusinga Bridge site (-0.419059, 34.205868), Kenya	Not available	Not available
		Mbita: Luanda-Mbita ferry terminal (-0.423529, 34.210418), Kenya	No information	No information
		Luanda: Luanda K'Otieno pier (-0.383894, 34.283576), Kenya	Not available	Not available
		Uyoma ferry station/landing site (-0.329065, 34.265176), Kenya	No information	No information

Reach	Country	Port	Facilities/ equipment available	Storing capacity (ton)
		Kendu Bay pier (-0.349355, 34.656021), Kenya	No information	No information
		Port Bunyala pier (0.101357, 33.974265), Kenya	No information	No information
		Kiyindi landing site (0.278778, 33.148119), Uganda	Not available	Not available
		Chimpanzee island landing point (-0.099902, 32.652558), Uganda	Not available	Not available
		Bukakata ferry terminal (-0.271900, 32.026242)	No information	No information
		Bugoma ferry terminal (-0.247845, 32.066865)	No information	No information
		Kalangala ferry terminal (-0.309680, 32.291656)	No information	No information

5 National Navigation Policies and Projects

5.1 Navigation Policies

5.1.1 Egypt

The following laws and regulations are currently in force in Egypt in the area of inland water transport.

Table 21. Laws and Regulations relevant to IWT[66]

Ref. No.	Responsible authority	Summary
№ 10/1956		The inland navigation
№ 130/1975	Ministry of Transport	Berth and organizing berthing at the Internal water
№ 09/1983	All (Ministerial Decree)	Protecting river Nile and its waterway from pollution (amending in 2013)
№ 12/1984	Ministry of Water Resources and Irrigation	Irrigation and draining
№ 04/1994	Ministry of Environment and Egyptian Environmental Affairs Agency	Environmental protection
№ 290/1969	Presidential decree	The transfer of responsibilities of regulations departments to the local administration organization
№ 474/1979		Establishment of the river transport authorities
№ 117/2008		Amendment of №474/1979
№ 2272/1971	Prime ministry decree	Authorizing governor with responsibilities of Ministry of Transport
№ 294/1999	Ministry of the Public Works and Water Resources	Protecting river Nile clean
№ 8921/ 1956		Licensing of units and their safety and validity conditions and specifying shipping lines
№ 8922/1956	Minister decree	Organising units traffic and using in the internal water and the conditions for working on it
№ 9040/1957		The licensing conditions for public ferries traffic and organising the tender regulations
№ 189/1962		Conditions of licensing for private berth and organising berthing at private berths and the temporally berthing including the fees
№ 15/1983		Licensing of engine ships and their safety and validity conditions and organising ships traffic in internal water
№ 126/1986		Bridges construction over the waterways
№ 282/1998		Navigation licenses in the internal water

[66] Japan international cooperation agency (2012). MiNTS – Misr national transport study. the comprehensive study on the master plan for nationwide transport system in the Arab republic of Egypt. Final report. Technical report 3. Inland waterway transport sector

5.1.2 Sudan

Law on inland waters navigation of 1993

This Law consisting of 23 articles aims at providing for the navigation in inland waters and establishes a Technical Advisory Committee with the following main tasks (i) make recommendations to the Minister of Transportation with regard to licensing applications for mechanically managed ships, ferryboats, trailers, or riverboats, whatever the method of its operation or the purpose of its use, with a tonnage of ten tons or more, and public boats and sailboats, whose length exceeds ten meters, or whose tonnage is ten tons or more; and (ii) submit recommendations and reports to the Minister regarding renewal of licenses. Article 9 deals with procedures to obtain the license. As for the local authorities and their powers, each locality shall have the following powers (i) the license to operate boats for hire for the transport of passengers or goods or to carry out any other commercial activity related to the operation of boats on the banks of rivers, after the applicant submits a technical validity certificate to the auxiliaries of the authority; (ii) defining public places for the passage of boats in coordination with the authority from the technical point of view; (iii) determining the terminals of berthing, linking, loading or unloading of vessels in coordination with the authority from the technical point of view; and (iv) impose and determine the fees for licensing boats.

The Inland River Navigation Authority at the Ministry of Transport is responsible for (i) registering the boats; (ii) keeping the general register of the boats in which the vessels operating in inland river navigation are registered; and (iii) may refuse to register a vessel that bears the name of another one, or a name similar to it, if it is possible that this similarity may lead to confusion. Article 12 regards inspections and related procedures. Article 14 lists the data that shall be recorded in the register. If any modification occurs in any of the data contained in the registry, the owner of the vessel must, within a month from the date of that amendment, submit a request to the registrar to amend the registry (art.16). The Minister of Transportation, in consultation with the Minister of Finance and National Economy, may specify the fees to be paid in relation to any of the procedures stipulated in this Law (art.20).

The following Laws are repealed: the Boats Law of 1970, the Public Places of Transit Law of 1932, and the Inland River Navigation Law of 1980, however their regulations shall remain in effect[67].

5.1.3 South Sudan

Regulation and policy framework in South Sudan do remain at a primary stage due to a recent recognition of the independent state. However, Southern Sudanese authorities actively interact with international organisations with an aim to apply good practices.

Transport policy

A Transport Sector Policy was developed and passed by South Sudan Legislative Assembly on 3rd October, 2007. The policy framework covers a five-year period with a two phase implementation strategy, which included the recovery and development phases between 2007-2008 and 2009-2011 respectively[68].

The policy paper has twelve objectives, namely to: (i) strengthen the Ministry of Transport and Roads to play an effective coordination and regulation role; (ii) create capacity to meet the transport requirements of the economy; (iii) optimize the allocation of available resources among the various transport modes; (iv) improve mobility in rural areas through the promotion of the use of appropriate means and modes of transport; (v) facilitate the return and settlement of the Internally Displaced People (IDP) and refugees; (vi) encourage and promote increased private sector participation in the provision, management and maintenance of transport infrastructure and services; (vii) contribute to job creation and income generation, and provide equal opportunities for men and women in transport sector; (viii) ensure safety

[67] FAOLEX Database. Law on inland waters navigation of 1993. Sudan National policy.

[68] AfDB. 2013. South Sudan: An Infrastructure Action Plan. A Program for Sustained Strong Economic Growth

standards in all modes of transport; (ix) ensure coordinated disaster management in all modes of transport by enforcing appropriate protective and control measures; (x) introduce sound management through appropriate policies and institutions in the transport sector that will lead to rapid sustainable development and poverty eradication; (xi) provide links with the states and neighbouring countries; and (xii) recognize and account for environmental concerns in line with the national environmental plan. Recognizing the negative impact of a poor transport system on the performance of the economy, the new Government of the Republic of South Sudan has reaffirmed its commitment to reform the sector to catalyse the social and economic development process of the country.

The SSRA will develop a Road Investment Program (RIP), containing both development and maintenance priorities and submit it to the Minister who shall present it for approval to the Council of Ministers. Notably, annual budgets and work programs shall be based on the RIP. Activities outside these approved work programs will only be undertaken with the concurrence of the Board and approval of the Minister[68].

5.1.4 Uganda

At present, the sub-sector is regulated under the Vessel (Registration) Act, Cap 362; the Ferries Act, Cap 355; Part XII of the Uganda Railways Corporation Act, Cap 331. Most of these laws were enacted during colonial times when this sub-sector was performing at a minimal level.[69]

Vessel Registration Act, Cap 362, 1904

The Vessel Registration act describes Ugandan procedure for vessels registration. The classes for vessels distinguishing are as the following:

1. first class: vessels of fifteen burden and upwards;
2. second class: vessels of less than fifteen burden, navigated otherwise than by oars, paddles, or poles only;
3. third class: boats navigable by oars, paddles, or poles only.[70]

The Ferries Act, Cap 355, 1905

This act regulates the approval of the licence for all types of vessels.

Part XII of the Uganda Railways Corporation Act, Cap 331

This is the most important act for navigation. It regulates vessels exploitation, ports usage and maintenance, etc.[71]

5.1.5 Kenya

Unknown

5.1.6 Tanzania

Unknown

5.1.7 Lake Victoria states

Protocol for Sustainable Development of Lake Victoria Basin to the Treaty for the Establishment of the East African Community. Article 31. Safety of Navigation.

The Partner States shall implement and review existing agreements relating to the promotion of safety of navigation on Lake Victoria by:

a) Implementing and where necessary, reviewing existing agreements relating to the promotion of the safety of navigation, maritime safety and preservation of the marine environment; and

[69] The Inland Water Transport Bill, 2020
[70] Vessels (Registration) Act, 1904 (Ch 362), Chapter 362
[71] Chapter 331. The Uganda railways corporation act. 1992

b) Initiating and promoting programmes as well as establishing a mechanism that will enhance maritime safety on the Lake[72].

5.2 Navigation Projects

5.2.1 Egypt

Unknown

5.2.2 Sudan

Unknown

5.2.3 South Sudan

Unknown

5.2.4 Uganda

Uganda has released a National Integrated Transport Master Plan 2021 – 2040[73], which in particular addresses the limitations of inland water transport and mitigation measures. For example, it states the following:

1. Water improvements include a new multipurpose port in Lake Victoria, Bukasa Port, and additional ferry services on Lake Victoria and other waterways
2. Regarding the transport sector specifically, the NDP III defines the following core objectives and interventions:
   a) Objective 1: Optimize transport infrastructure and services investment across all transportation means:
      i. Implement an integrated multi-modal transportation hub (air, rail, road, water etc.).
      ii. Construct and upgrade strategic transport infrastructure (tourism, oil, minerals, and agriculture).
      iii. Increase capacity of existing transport infrastructure and services.
      iv. Implement an inclusive mass rapid transport system (Light Rail Transport, LRT), Bus Rapid Transit (BRT)/Mass Bus Transport (MBT) and cable cars).
      v. Provide Non-Motorized Transport (NMT) infrastructure within urban areas.
      vi. Rationalize development partners and government financing conditions.
   b) Objective 2: Prioritize transport asset management
      i. Rehabilitate and maintain transport infrastructure.
      ii. Enforce loading limits.
      iii. Adopt cost-efficient technologies to reduce maintenance backlog.
      iv. Develop local construction hire pools.
   c) Objective 4: Reduce the cost of transport infrastructure and services
      i. Implement cost-efficient technologies for provision of transport infrastructure and services.
      ii. Strengthen local construction capacity (industries, construction companies, access to finance, human resource, etc.)
      iii. Promote Research, Development and Innovation (RDI) including design manuals, standards, and specifications.
   d) Trade route security is critical, which is why Government requires the use of road, rail, water and air as well as different geographical alternatives. For inland waterways to play a greater part in trade, Lake Victoria ports and hinterland infrastructure will be improved. While Lake Victoria and hinterland is developed and economically significant, Lake Albert and hinterland

[72] Protocol for Sustainable Development of Lake Victoria Basin to the Treaty for the Establishment of the East African Community. 2003

[73] National integrated transport master plan 2021 – 2040. Draft. Uganda

is totally undeveloped and as such provides huge opportunities. The NITMP also includes initiatives to make a use of Lake Albert.

Projected interventions include:
1. Preparation and implementation of the National Transport Act
2. Review and update transport policies, regulations and standards
3. Produce bilateral agreements, international conventions and protocols

5.2.5 Kenya

Mahathi Infra project (Uganda-Kenya) aims to provide fuel transport and storage depot under construction in Uganda. Upon completion, gasoline, kerosene, diesel fuel and Jet A1 will be delivered by ship from Kisumu across the lake. Fuel is stored here and carried by 150 trucks to final destinations in Uganda, Rwanda, Burundi and South Sudan, significantly reducing delivery times and transportation costs.

Commissioned in August 2020, this project promises several direct and indirect benefits to the country and its economy. The economies of scale obtained provide benefits such as reduction of fuel transportation costs, control pollution, adulteration of fuel and ease traffic congestion from Mombasa to Kampala.

5.2.6 Tanzania

Unknown

5.2.7 Lake Victoria Transboundary Organisations

5.2.7.1 Multinational Lake Victoria Maritime Communication (MLVMC)

MLVMC is aimed at contributing to a broad-based poverty alleviation and improvement of livelihoods of people through increased investment in maritime transport and fishing on Lake Victoria. The project established a maritime safety coordination search and rescue centres on the lake and produced a maritime transport strategy for the EAC. It has also been supporting initiatives geared towards improved safety of navigation in the Lake. It has undertaken construction of Maritime Rescue Coordination Centres in Mwanza, Kisumu and Port Bell supported by several search and rescue units along the lake. The project was approved in October 2016 but was launched in May 2018, and some initial activities are taking place in some Partner States in order to enhance the strategic mission and direction of the project[74].
The project has the following components:

- Establishing Maritime Safety Coordination Centre
- Establishing Search and Rescue Centres on the Lake
- Developing Maritime Transport Strategy-EAC

[74] Report of the committee on accounts on oversight activity to the Lake Victoria basin commission (LVBC) to assess the status of implementation of the assembly recommendations on the eac audited accounts. 2019. East African community. East African legislative assembly.

6 Stakeholders' Interviews Summary

As a part of the baseline assessment, significant information has been collected through direct communication with stakeholders. To optimise the communication, HYDROC has prepared questionnaires and contacted relevant stakeholders to request information related to the navigation situation. The summary of results is presented in this section and the list of contacted stakeholders can be found in the annex.

6.1 River Port Authorities

A questionnaire (Figure 59), which contained 26 questions was shared with barge operators active on the Nile River and on the navigable tributaries. These questions included requesting general contact information (name, company, position) and specific questions (available equipment, types of cargo, types of operating vessels, etc.). In total, 18 responses were received from targeted barge operators (from Sudan and South Sudan).


NILE BASIN INITIATIVE
INITIATIVE DU BASSIN DU NIL
giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

How many pushers do you have in your fleet? *

- 1-2 pushers
- 2-5 pushers
- Other:

Barge characteristics (characteristics of different barge types if you have multiple barges) - length/draft when empty/draft when fully loaded/tonnage *

Your answer

Figure 57: Questionnaire extract (river operators)

The representatives who provided their responses represent 18 companies and they are holding managing positions (general manager or operation manager). For the distribution of the barge operators per operation base, see Figure 60.

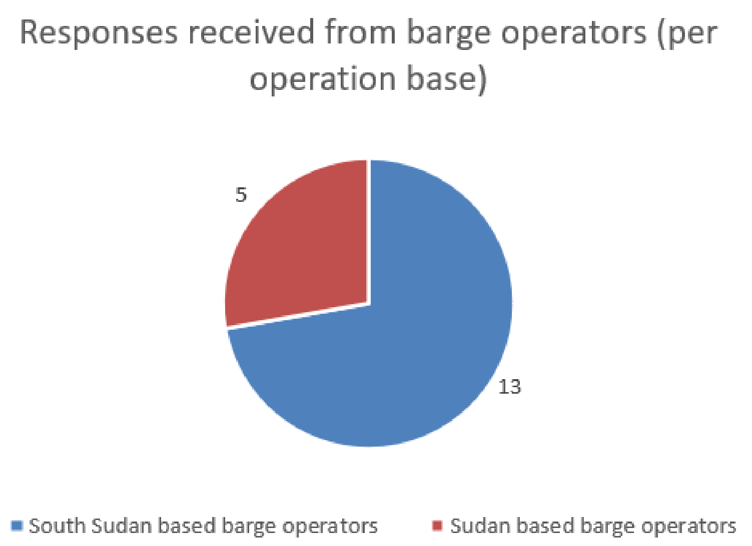


Figure 58: Distribution of the barge operators (per operation base)

Table 22 presents the questions specific to river navigation and an overview of the received answers from barge operators.

Table 22: Answers received - river operators

Questions	Received answers - South Sudan	Received answers - Sudan
How many push barges do you have in your fleet?	On average, each company has 10 push barges in their fleet. From the respondents, two operators have 20 barges in their fleet and one of them have none.	The Sudan transporters have a limited number of push barges. Only one barge operator (based in Kosti port) has 69 push barges.
How many self-propelled barges do you have in your fleet?	One half of barge operators have 2-5 self-propelled barges and the second half of barge operators have on average 11 self-propelled barges.	The number of self-propelled barges is limited. Only two from five barge operators have 1 self-propelled barge.
How many tugboats do you have in your fleet?	Only 7 from 13 barge operators have at least one tugboat in their fleet.	A barge operator based in port Rabak has 12 tugboats.
How many pushers do you have in your fleet?	14 companies have between 1-5 pushers. Two companies have no pushers, and two companies have between 12-15 pushers.	4 companies have 1-5 pushers and one barge operator based in port Kosti has 11 pushers.
Barge characteristics (characteristics of different barge types if you have multiple barges) - length/draft when empty/draft when fully loaded/tonnage	The length of the barges varies between 12 to 60 meters. On average, the draft of the barges is 1.1 meters. The tonnage of the barges starts from 10 t to 250t.	The length of the barges varies between 12 to 36 meters. On average, the draft of the barge when full is 0.3m and when full 0.9m.
Configuration of your barge-pusher combinations (e.g. 2x1, 2x2, 2x3 etc.)	The most common barge combinations are 1x1, 2x2, 2x3 and 3x3.	The most common barge combinations are 1x1, 1x2 and 2x2.
Maximum travel speed of your barge-pusher combinations	The travel speed of the barges varies from 8 knots to 25 knots.	The maximum travel speed upstream is 7 knots. The maximum travel speed downstream is 15 knots.
Type of cargo carried	The majority of boat operators are transporting food, livestock, people, fuel/oil and merchandise.	The majority of boat operators are transporting food, livestock, people, fuel/oil, merchandise and trucks.

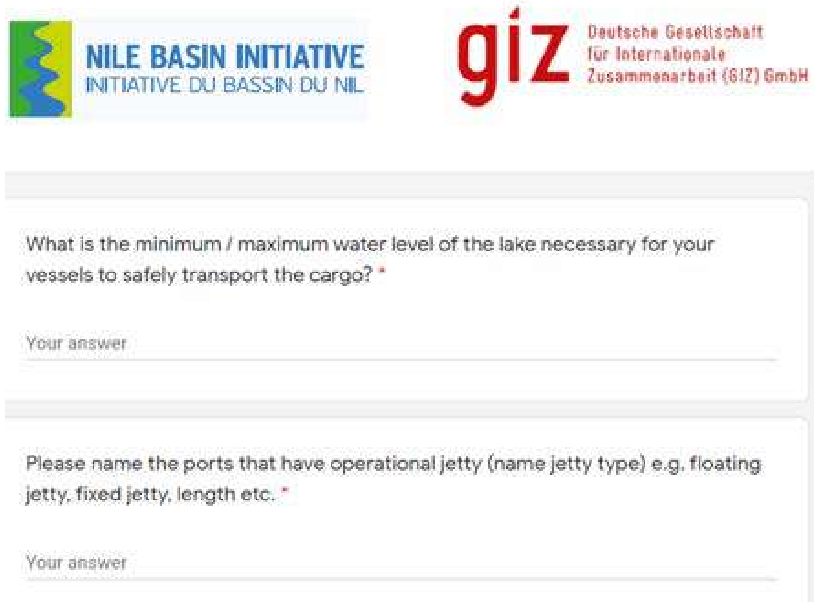
Questions	Received answers - South Sudan	Received answers - Sudan
Which routes do you operate on?	Most of the barge operators are active on Juba-Bor-Bentiu -Malakal-Renk-Kosti route and the navigable tributaries.	Most of the barge operators are active on Kosti-Malakal - Juba route and the navigable tributaries.
Which are the ports where you frequently dock?	The ports where the barge operators frequently dock are Juba, Bor, Adok, Malakal, Melut and Renk ports.	The ports where the barge operators frequently dock are Renk, Kosti, and Rabak ports.
What physical problems do you encounter in your transport business (state route)?	Some of the mentioned physical problems encountered are: - Armed robberies - There are large rocks and short sharp bents at Mangala point on the Juba-Bor route - There are thick silts that damage boats on the Juba-Tayar route - The Ganyliel-Nyal water way is narrow - The Bor-Old Fangak route is narrow and usually blocked by heavy silts - The Malakal-Nasir route gets shallow in February to May along Ulang point - The Jikmir-Akobo route is shallow at Kuotkeak along Gile river and usually gets blocked by thick hyacinths in January -April each year - The Pulturuk-Lanken route is blocked by thick silts and overgrown trees and grass - The Akobo-Pibor route has a heavy silt at Lol-Thanyian section in Akobo town - Low water level in Sobat river in February-May - High water current between Juba-Mangalla-Bor-Jonglei checkpoints - Lack of docking stations	- Rocks in the Zelate area

Questions	Received answers - South Sudan	Received answers - Sudan
What legal problems do you encounter in your transport business (state route)?	- Excessive number of checkpoints - High taxes - Different ports and check points are not regulated in terms of charges **- Safety issues**	**- Safety issues**
What measures do you take to get around the above-mentioned problems?	- Report the issues to authorities	- Report the issues to authorities
Average downtime due to unsuitable river conditions (high/low water, state where this occurs route)	One of the barge operators mentioned that half of the year barges have to load in Mangalla port because the water is too shallow to travel to Juba. Other responses are: -Low water level in Sobat river in February-May -High water current between Juba-Mangalla-Bor-Jonglei checkpoints	The barge operators active in Sudan did not mention any significant downtime.
Average downtime due to mechanical problems/fuel shortage	No significant downtime.	No significant downtime.
Average utilization rate of your fleet (%)	The average for all boat operators is 67%.	The average for all boat operators is 75%.
What are - in general - the most restricting factors for your operation?	The most mentioned restricting factors are: - Lack of orders - Security situation - Physical restrictions on the river	The most mentioned restricting factors are: - Lack of orders - Lack of fuel or spare parts - Security situation
At which river flow velocity can you operate?	Most of the barge operators mentioned that the river velocity does not significantly affect their operation.	Most of the barge operators mentioned that the river velocity does not significantly affect their operation.
Are there any governmental restrictions that you encounter?	The most mentioned governmental restrictions are: - High taxes - Too many checkpoints	The most mentioned governmental restriction is the security factor.

Questions	Received answers - South Sudan	Received answers - Sudan
Which of the below options would be the most beneficial for your activity?	Barge operators consider that the most beneficial options for an improved navigation system are (listed by importance from high to low): - Improved governmental administration - Navigation aids - Improved ports - River dredging	Barge operators consider that the most beneficial options for an improved navigation system are (listed by importance from high to low): - Improved ports - Improved governmental administration - Navigation aids - River dredging
Do you have the capacity to respond to a potentially increased need of river transportation?	All the barge operators mentioned that they have the capacity to respond to a potentially increased need of river transportation.	80% of the barge operations mentioned that they have the capacity to respond to a potentially increased need of river transportation.

6.2 Lake Port Authorities

To gather information specific to lake transportation, a questionnaire (Figure 61) was sent to the vessel operators active on Lake Victoria, Lake Kyoga and Lake Albert. The questionnaire was filled in by 3 respondents active on Lake Victoria and Lake Albert.


NILE BASIN INITIATIVE
INITIATIVE DU BASSIN DU NIL

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What is the minimum / maximum water level of the lake necessary for your vessels to safely transport the cargo? *

Your answer

Please name the ports that have operational jetty (name jetty type) e.g. floating jetty, fixed jetty, length etc. *

Your answer

Figure 59: Questionnaire extract (lake operators)

Table 23 presents the questions specific to lake navigation and an overview of the received answers from vessel operators active on Lake Victoria and Lake Albert. Additionally, an online interview was organized with Lake Victoria Basin Commission (LVBC) where they have been asked the same questions from the questionnaire. Their answers can be found in the below table.

Table 23: Answers received - lake operators

Question	Received answer - vessel operators	Received answers - LVBC
What type of vessels do you have in your fleet? (e.g. tugboats, pushboats, lakers, fast freighter, container vessel)	Most of the active vessels on the lakes are pushboats and container vessels.	On Lake Victoria, there's just one barge operator. The majority of the other vessels include cargo vessels, passenger vessels (ferries) and ferry wagons (fuel).
How many vessels do you have on your fleet? (based on the previous question)	On average, each vessel operator has 3 vessels in his fleet.	-
Vessel characteristics (characteristics of different vessel types if you have multiple vessels) - length/draft when empty/draft when fully loaded/tonnage	The draft varies from 0.9 m to 1.1 m. The length varies from 18 m to 27.4 m. The cargo capacity varies from 45 t to 1200 t.	-
Type of cargo carried	All the vessel operators confirmed that they are carrying food and merchandise. Other type of carried cargo: livestock, people, fuel and vehicles.	- Food - Livestock – especially port Bukoba - People - Fuel/Oil – especially between Kisumu port and Jinja port. Approximately 1 million lt of fuel transported per week - Merchandise
Which routes do you operate on? (ports)	The mentioned routes are: -Ntoroko-Kasenyi -Garuga-Koome island -Mwanza Port to Port Bell The passage transport connects the below locations: Kabarua, Kasarani, Kisumu, Kitawi, Kiwa, Luanda, Mageta, Mahanga, Mauta, Mbita East, Mbita West, Misori, Mulundu,	Most of the private operators operate in-country and between mainland and Lake Victoria's islands

Question	Received answer - vessel operators	Received answers - LVBC
	Mulundu/Ringiti, Ndere Island, Nyakweri, Nyakweri/Wakula, Nyandiwa, Remba, Ringiti, Ringiti/Mulundu, Sena, Sori, Takamul, Takawiri, Ugina, Usenge, Wakawaka Wakula, Wakula/Nyakweri, Yokia.	
What physical problems do you encounter in your transport business (state route/ports)? e.g. shallow ports, missing jetties, rocks etc.	The mentioned physical problems are: - Underwater obstacles - Shallow ports and missing jetties	- Missing port infrastructure - Missing navigation aids
What legal problems do you encounter in your transport business (state route)?	The mentioned physical problems are: - County business permits - Navigation safety	- The Lake Victoria transport act was prepared in 2007 and it was not updated since (document is outdated) **-** Standardized **vessels qualifications:** Tanzania has a number of large vessels operating on the lake. They use international standards. The standards for large boats should not be similar to the standards for smaller boats - A one stop border post should be implemented for Lake Victoria to harmonize the transport
What measures do you take to get around the above-mentioned problems?	- Community engagement - Collaboration with local authorities	- Regulatory framework needs to be implemented - The enforcement of the regulations: some countries have more experience (Kenya, Tanzania) since they have access to the ocean, but for Uganda (landlock) – they are just starting to build the Maritime Department (2021)

Question	Received answer - vessel operators	Received answers - LVBC
Average downtime due to unsuitable lake/port conditions (e.g. high/low water)	The largest downtime mentioned by the vessel operators is 5 days/month. For the other two operators, downtime due to unsuitable lake/port conditions is not applicable.	- The main delays are caused by port infrastructure (missing cranes, old cranes) - Access roads to the ports are not in good condition
Average downtime due to mechanical problems/fuel shortage	Not the case.	- No fuel shortage but the barge operators complain about the price of the fuel, and they want the government to subsidize the price
Average utilization rate of your fleet (%)	The vessel operator that focuses on people transport has an utilization rate of 95%. For the cargo transporters, the utilization rate is on average 60%.	-
What are - in general - the most restricting factors for your operation?	The majority of vessel operators mentioned the physical situation in ports as major restriction. Other restricting factors mentioned are lack of fuel/lack of spear parts, security situation and lack of investment funding in rural water transport.	- The security situation in the ports that are not regulated (especially on the islands)
Are there any governmental restrictions that you encounter?	The only governmental restriction mentioned by the vessel operators is related to the documentation aspects for DR Congo.	-
Which of the below options would be the most beneficial for your activity?	All the respondents mentioned that improving ports would be the most beneficial action for their activity.	- Navigation aids - Improved ports - Improved governmental administration
Do you have the capacity to respond to a potentially increased need of lake transportation?	2/3 vessel operators confirmed their capacity to respond to a potentially increase in need of lake transportation.	-
How many ports where you dock are state-owned and how many are private-owned? (%)	The respondents confirmed that over 90% of the ports are state-owned.	- In Uganda/Tanzania, most of the ports are owned by the government. - For Lake Victoria, 80-90% of the ports are government owned
What is the minimum / maximum water level of the lake necessary	The answers vary from 0.8 m to 2 m.	-

Question	Received answer - vessel operators	Received answers - LVBC
for your vessels to safely transport the cargo?		
Please name the ports that have operational jetty (name jetty type) e.g. floating jetty, fixed jetty, length etc.	Munyonyo, Kome, Nakiwoga and Port Bell have permanent jetties. Misori, Wakula and Sena ports also have jetties (jetty type was not mentioned).	- Most of the jetties are fixed - Only 2-3 floating jetty
General comments (LVBC)		- The majority of vessels are government owned - The operators have old navigation charts (from '50s) - The small boat operators lack minimum safety requirements - The lack of regulations on the lake (especially for small boat operators). This leads to a high number of accidents - The qualification of the crew is low and contributes to the high number of accidents - The fees for barge between the countries are not streamlined

Part B: Modelling Approach

7. Introduction

The Nile Basin Initiative is conducting a strategic analysis of future water availability and demand in the basin. While many developments in the Nile basin contribute to the safety of water, food and energy, they also affect the flows of the Nile and affect the use of rivers and lakes for future navigation. Respectively, the analysis needs to include water demands of the transport sector and how they affect the management and development of water resources in the Nile basin. This is being achieved by linking flows under the various scenarios to river depth and suitability for different vessel types. This report describes the main approach followed for the derivation of minimum navigation flow requirements that is outlined and described for the different stretches in Section 8.3. The main purpose of the minimum flow requirements is to understand the main constraints from a navigation point of view in the different sections of the Nile River.

It needs to be emphasized that the modelling approach taken in this study was designed to define minimum navigation flow requirements and does not intend to provide stage-discharge relations for a broad band of events. Respectively, the assessments have focused on flows at 2m / 3m navigation design waterdepth and the results were respectively calibrated while no attention has been paid to lower/higher water depths that are not of crucial interest for navigation. Respectively, the results provided in this report should not be used for any other purpose than the navigation assessment.

The report outlines the data collected, the main approach followed and the results from this analysis of key requirements for the various navigable inland water bodies identified in Task 1, specifically:

- The cross-sections of the various river stretches, representative for analysis of water depth and possible barge sizes
- A table of required parameters as a function of vessel types as input for calculation indicators in the NB DSS;
- Indicators to assess navigability as part of the Nile DSS approach
- This report section on the approach

8. Requirements for Nile River Navigation

In this section, the main requirements for the calculation of the matrices, as well as the procedures followed for the calculation and the validation are outlined. The requirements and the data collection were driven by the requirements of the project and also by the data availability. The main objective of this modelling exercise is to be able to depict the flow, water stage and velocity relationship in the main stretches considered within the framework of this project for navigational purposes. The results include the identification of reaches, lakes and other water bodies that are being used for navigation in the river Nile system, and list characteristics which are relevant to navigational requirement (including cross section characteristics, currents, tidal and/or river (velocity, direction, and duration); bottlenecks, etc.) In addition, current river/lake/wetland navigation system and classification (by river stretches; by vessel types/classes and fleet composition; volume of cargo transported over past 20 years

As it will be described below, one of the key things required for this assessment and to derive these relationships is bathymetry/topography data.

8.1 Methodology / General Overview

In the sections below the main methodological approach is described. The methodology has been developed in line with the Terms of Reference (ToR) as well as the inception report and as agreed with Nile-SEC and GIZ in dedicated workshops. The methodology discussed below has been adapted based on data availability.

The methodology is based on the implementation of a simple hydraulic model for the derivation of the required relationships. This is because:

- There is a requirement to have all the information geo-referenced (in a GIS format). This was a contractual requirement, in order to include all generated information directly into the existing Decision Support Systems (DSS) within NBI.
- The calculation of discharge-stage relationships is very complicated in non-uniform (i.e., rectangular) channels. While in some cases the cross-sections are defined following this shape, a hydraulic model provides a more consistent approach. The collection of all the required data for this is described in sections below. The calculation of the discharge-stage relationships was undertaken using a hydraulic model in steady state. The formulation and detailed approach are described in further sections.
- The significant number of cross-sections required are managed better using a hydraulic model. Because in order to undertake the assessment a significant number of cross-sections will be required, the management of the data will be better using a hydraulic model.
- The hydraulic model was used to facilitate the testing of different scenarios and different flows.

A steady state HEC-RAS 5.0.7 model has been chosen for the assessment approach. The U.S. Army Corps of Engineers' River Analysis System (HEC-RAS) was first released in 1995, and it is a modelling software, open-source, that is widely used for hydraulic modelling applications. HEC-RAS 5.0.7 is an integrated system of software, designed for interactive use in a multi-tasking environment. The system comprises a graphical user interface (GUI), separate analysis components, data storage and management capabilities, graphics and reporting facilities. The HEC-RAS system contains the following river analysis components for:

- Steady flow water surface profile computations
- One-dimensional and/or two-dimensional unsteady flow simulation
- Quasi unsteady or fully unsteady flow movable boundary sediment transport computations
- Water quality analysis

A key element is that all four components use a common geometric data representation and common geometric and hydraulic computation routines. In addition to the four river analysis components, the system contains several hydraulic design features that can be invoked once the water surface profiles are computed.

HEC-RAS is designed to perform one-dimensional and two-dimensional hydraulic calculations for a full network of natural and constructed channels, overbank/floodplain areas or levee protected areas.

Next to the in-stream processes, the HEC-RAS flow engine combines the properties of the left and right overbank into a single flow compartment called the floodplain.

Within the framework of this project, a single geometry file with all the cross-sections (as detailed below) is included in the model, along with all the reaches. The reach geometry is based on the digitized river banks. This geometry is combined with the flow data, and in steady state, simulations are undertaken for pre-defined scenarios. The output from the model includes calculation of the bed level and the velocity for each of the different flow scenarios.

8.1.1 DEM – Data Collection and Analysis

The acquisition and provision of a Digital Elevation Model (DEM) is one of the key requirements within the framework of this modelling exercise. Topographic data is the most important input data for any hydraulic model since it is one of the main factors governing the flow of water. While most satellite data based DEMs cannot represent the channel topography (bathymetry), the DEMs provide information about the location of river banks and their elevation, as well as channel width.

There are several global DEMs freely available (open-source). Due to the crucial nature of the DEM data, an assessment was carried out comparing the most widely used available DEM datasets in several areas in the Nile Basin. For instance, Figure 62 shows a close-up of the Sudd for the three globally available DEMs SRTM[75], ALOS[76] and MERIT[77]. These DEMs have been initially selected because they are the most widely used for these purposes and because based on the consultants experience they are providing the required accuracy for this type of assessments. As can be seen, the SRTM contains implausible surface patterns and in the ALOS, the original optical image tiles used to derive the DEM are still visible in the DEM. The pattern boundaries show a height difference in the range of 1-3m, a significant difference in a flat region like the Sudd. The MERIT-DEM is an improved and carefully processed version of the SRTM and the ALOS[78], resulting in a higher accuracy and the removal of artificial patterns and noise. Therefore, the MERIT-DEM is chosen as the dataset for use within this project. The data is available under Open Database License (ODbL 1.0) with the requirement that results derived from the DEM have to be made publicly available.

[75] https://www2.jpl.nasa.gov/srtm/
[76] https://www.eorc.jaxa.jp/ALOS/en/aw3d30/index.htm
[77] http://hydro.iis.u-tokyo.ac.jp/~yamadai/MERIT_DEM/
[78] Yamazaki et al. 2017. A high accuracy map of global terrain elevations. Geophysical Research Letters 44(11)

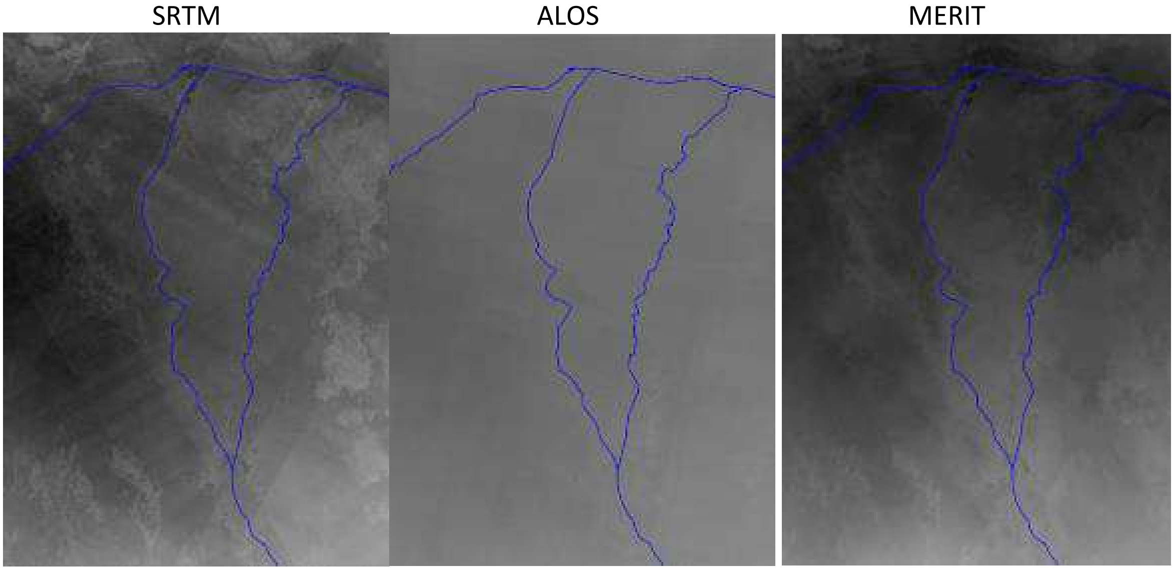


Figure 60. Comparison of SRTM, ALOS and MERIT DEMs in the Sudd (note the patterns in the SRTM and the ALOS, which are >2m along the pattern borders)

The MERIT-DEM for the Nile Basin was obtained and processed, as shown in Figure 63. As it can be seen, the MERIT DEM provides the best accuracy as compared to for instance ALOS and SRTM DEM data, and it does not yield strange features. The DEM is used to define the location of the cross-sections, with respect to the channel and also the definition of the bank levels where there is no cross-section data. The data was cropped for the catchment area and assessed for its quality along the main Nile River.

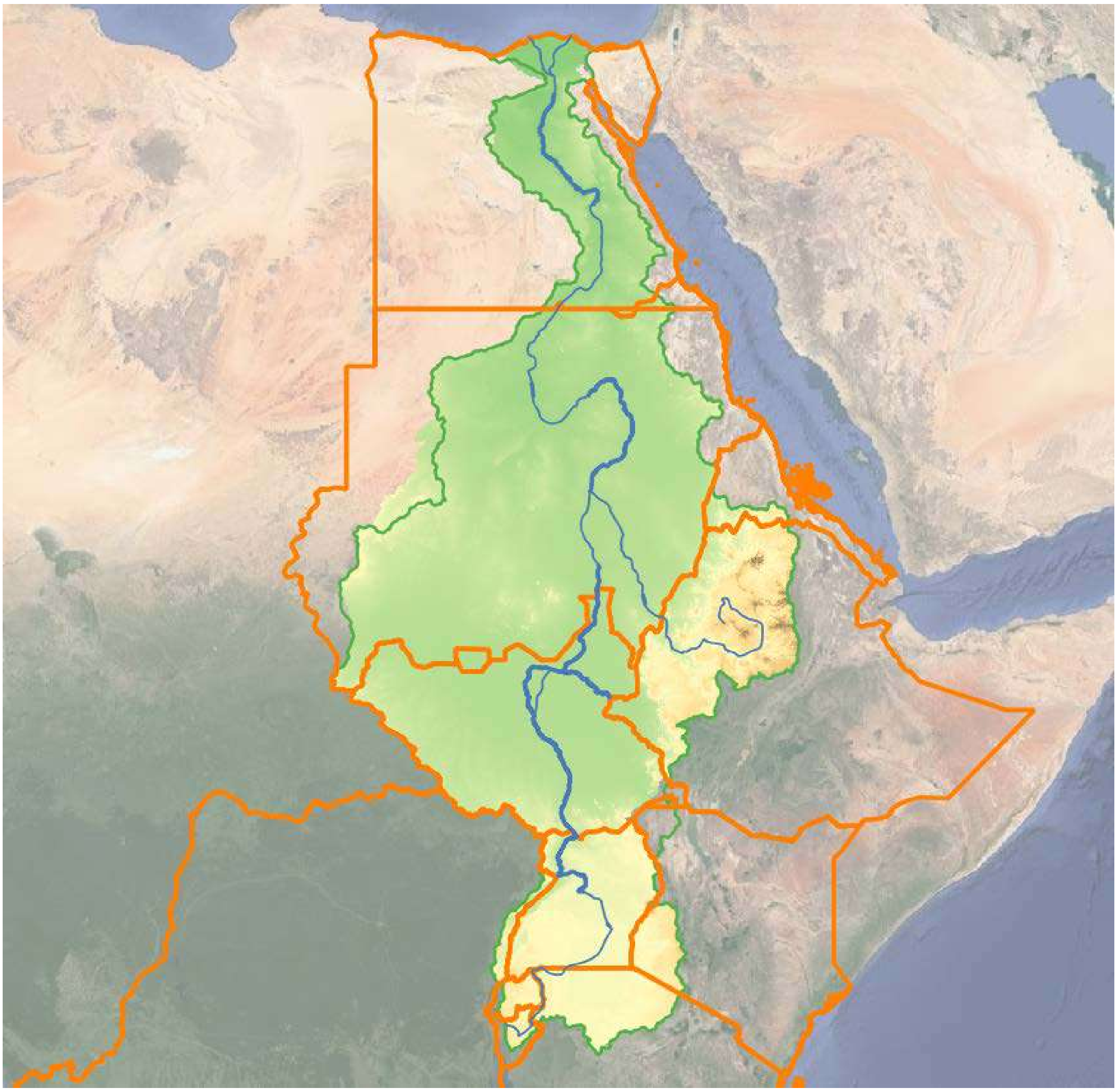


Figure 61. MERIT DEM for the Nile Basin

8.1.2 Width information – Data Collection and Digitalization Process

Cross section data is the major requirement for the derivation of stage flow relationship along each of the stretches. The availability of cross sections is limited to a number of river stretches, while for others no cross section data is available. Hence, where cross section data are available, these have been used, while for other stretches standard box cross sections were used as approximations. A box cross-section have a rectangular shape, with the bank and the invert level of the cross-section being located at the same longitudinal point. As noted, the box cross-sections are defined in areas with no pre-existing cross-section data. Figure 64 shows the availability of cross section data along different stretches.

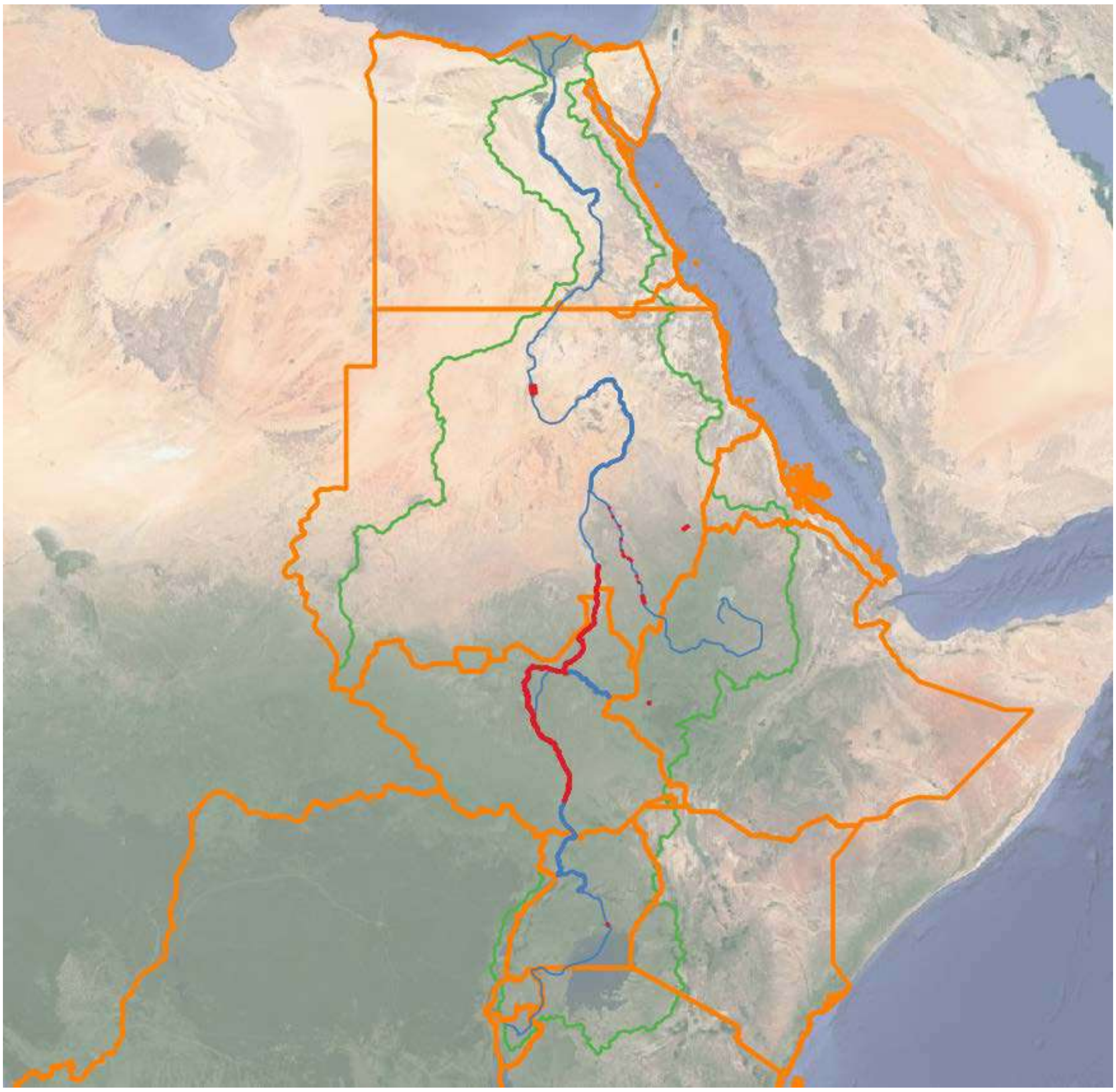


Figure 62. Red areas marked are the available cross sections

For stretches where no measured cross section data is available, cross sections are estimated. The width information is extracted from digitised bank lines based on Google Earth and is used in combination with model calculations and DEM resources to calculate cross section depth.

Similar to the above-mentioned Nile Delta portion the process was repeated for rest of the stretches.

8.1.3 Development of Cross-Sections, and Establishment of Defining/Limiting Cross-Section for Each Stretch

In addition to the DEM information, that provides the bank elevation and the main slope out of the channel, there is a need to include cross-section information in the different reaches (or stretches) in order to define stage-flow relationships based on a relation of cross-section topography, depth, slope and conveyance.

Due to the importance of the cross section data, extensive efforts were undertaken in order to collect as much cross section data as possible. Relevant member states were contacted by NBI, explaining the cross section data requirements. However, no further data were obtained.

Based on HYDROCs previous work in the Nile Basin and using data provided by NBI, cross-section data were available mostly for South Sudan and Sudan. The data has been processed and included in the HEC-RAS model. The resulting available cross-sections are shown in Figure 64.

In the stretches where no cross-section data are available, an alternative approach has been followed to define cross-sections. This has been undertaken following this approach:

1. The river width and the river centre line were digitized, as discussed in the section above.
2. Depths of the cross section at each point was adjusted based on the actual width between banks from a digitalisation process of the river centre lines. It was assumed that in wider channels the river depth is shallower, and in narrower channels the depth is deeper, but also considering information from hydrological modelling results. The main slope as defined by the DEM was followed as appropriate.
3. In addition to that, in order to verify that the depth assumed is as close to reality as possible, further information has been considered as detailed further in the sections below. Water level data for the Nile has been derived from altimetry virtual stations. As it can be seen in Figure 65, there are numerous virtual stations for altimetry sources in the Nile Basin (https://dahiti.dgfi.tum.de/en/virtual_stations/).

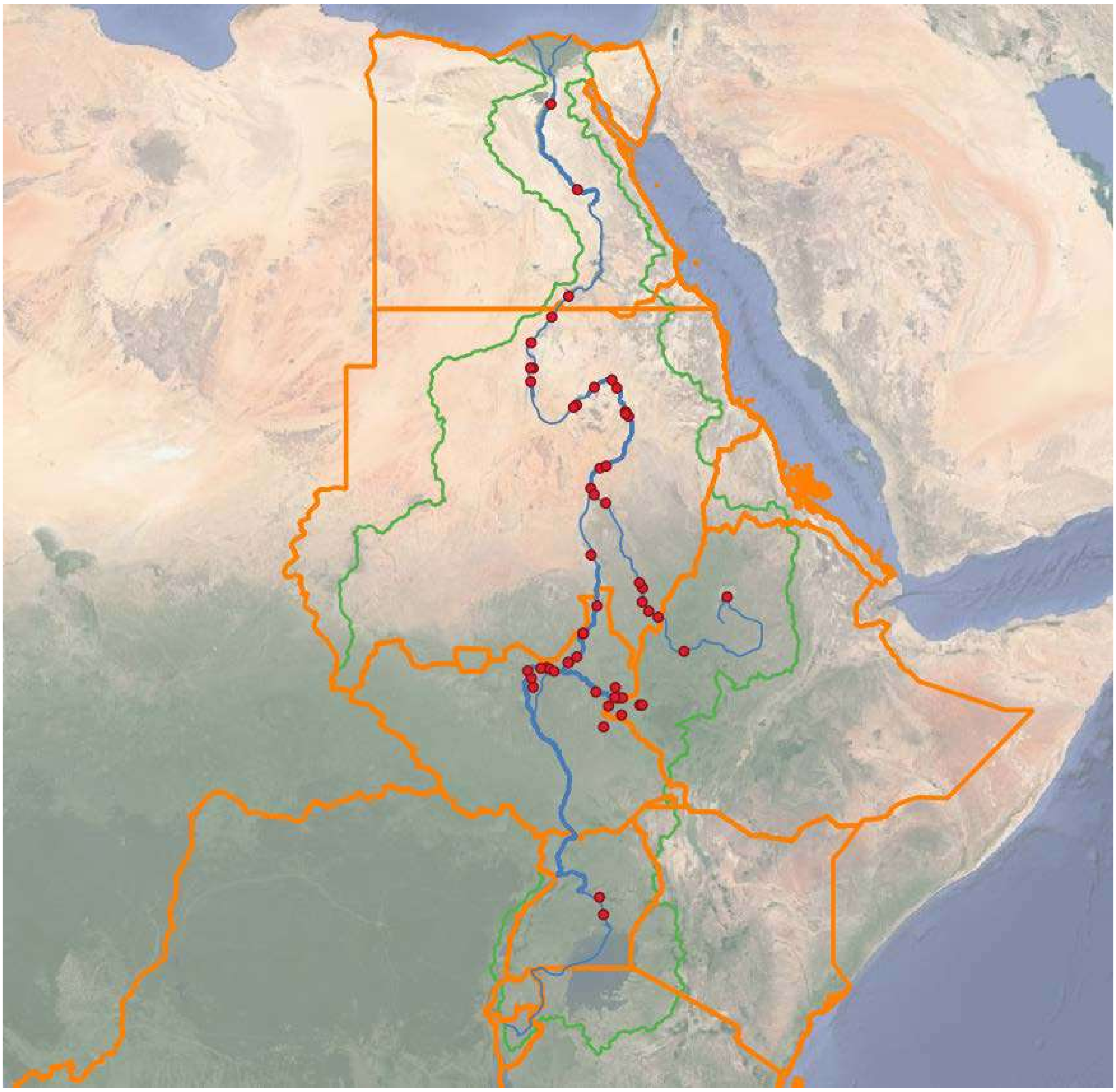


Figure 63. Altimetry virtual stations in the Nile Basin (red dots[79]).

[79] Schwatke, C., Dettmering, D., Bosch, W., and Seitz, F.: DAHITI - an innovative approach for estimating water level time series over inland waters using multi-mission satellite altimetry, Hydrol. Earth Syst. Sci., 19, 4345-4364, doi:10.5194/hess-19-4345-2015, 2015

Although data availability for the different virtual stations vary, in most cases data are available from 2002 until 2021. The use of these data is described below, in terms of the comparison with cross-sections and also considering discharge information. In order to understand the process for deriving of these data and the expected quality and accuracy a brief background regarding virtual stations is provided in Annex 2.

The number of cross-sections per stretch that has been included in the modelling framework depends on the existing survey data, or in data from previous assessments, and also on the requirements per stretch, in order define the conditions on the stretch. The total number of cross-sections per stretch that have been used is shown in Table 24.

An importantdecision that had to be made modelling the different stretches was the use of the partly limited measured cross section data as compared to using estimated cross sections for where measured data does not exist. Measured data obviously is more accurate and should be preferred, nevertheless, there are cases where measured cross sections are only available for part of the stretch while fo significant lengths there is no data available. The estmmated cross sections provide the more conservative and likely exaggerated results, i.e. demand higher minimum flows for navigation due to their flat bed profile. In order to avoid this, therefore partly an alternative approach has been used applying safety factors in order to obtain higher flow requirements, though there are no solid arguments for selecting the specific value of this safety factor they provide a margin of safety to overcome data gaps.

Table 24: Cross-sections per stretch (measured and artificial)

Stretch	Number of Cross-Sections
1 - Main Nile Egypt	17
3 - Main Nile Sudan	26
4 - Blue Nile Sudan	20
5 - White Nile	55
6 - Sobat	10
7 - Bahr el Jebel	139
8 - Albert Nile	22
10 - Kyoga Nile	14
12 - Victoria Nile	5

8.1.4 River Flows – Data Collection and Analysis

River flow data was collected for several purposes and from several sources. In a first instance, flows were analysed in order to get a range of flows that could be used for deriving flow scenarios and the subsequent flow-depth-relations and to undertake an estimation of the channel depth. The following information was considered.

- Victoria Nile: Flows in the range from 300 to 1100 m^3/s (Sutcliffe, The Hydrology of the Nile, 1999).
- Kyoga Nile: Flows between 1912-1980 ranged between 0.7-5.2 km^3/month (Sutcliffe, The Hydrology of the Nile, 1999)
- Albert Nile: Although this stretch is not gauged, outflow data have been recalculated by Petersen ("Estimation of ungauged Bahr el Jebel flows based on upstream water levels and large-scale spatial rainfall data", 2008), showing a range of 800-5700 mill m^3/month between 1896-2006.
- Bahr el Jebel u/s of Sudd: The upstream section of the Sudd has been defined considering the flows in the Mongalla station, showing a range from 0.7-7.4 km^3/month between 1905 and 1983. (Sutcliffe, 1999)
- Bahr el Jebel d/s of Sudd: In the downstream section of the Sudd, the Malakal station (removing the Sobat) has been used, showing a range of flows between 0.6-4.2 km^3/month for the period 1905-1983 (Sutcliffe, 1999)
- Sobat river: In the Sobat River, the estimated flow range is 0.0-3.3 km^3/month between 1905-1984 (Sutcliffe, 1999)

- White Nile downstream of Malakal: Flows in this stretch have been measured in the range of 0.8-6.3 km^3/month between 1905-1997. (Sutcliffe, 1999)
- Blue Nile: Based on the data from the Roseires gauge, flows are in the range of 0.1-25.0 km^3/month in the period between 1912-1997. (Sutcliffe, 1999)
- Main Nile in Sudan: There are several stations in the main Nile in Sudan, downstream of the Blue and White Nile in Khartoum. At the Tamaniat gauge flows have been observed in the range of 1.0-26.0 km^3/month between 1911-1993. At Wadi Halfa gauge in the range of 2.0-29.0 km^3/month between 1890-1995; and at Aswan gauge flows have been observed in the range of 1.0-32.0 km^3/month in the period between 1870-1992 (Sutcliffe, 1999).
- Main Nile in Egypt: the flows are based on the observations in Aswan with flows in the range of 2.0-7.0 km^3/month in the period between 1968-1992 (Sutcliffe, 1999).

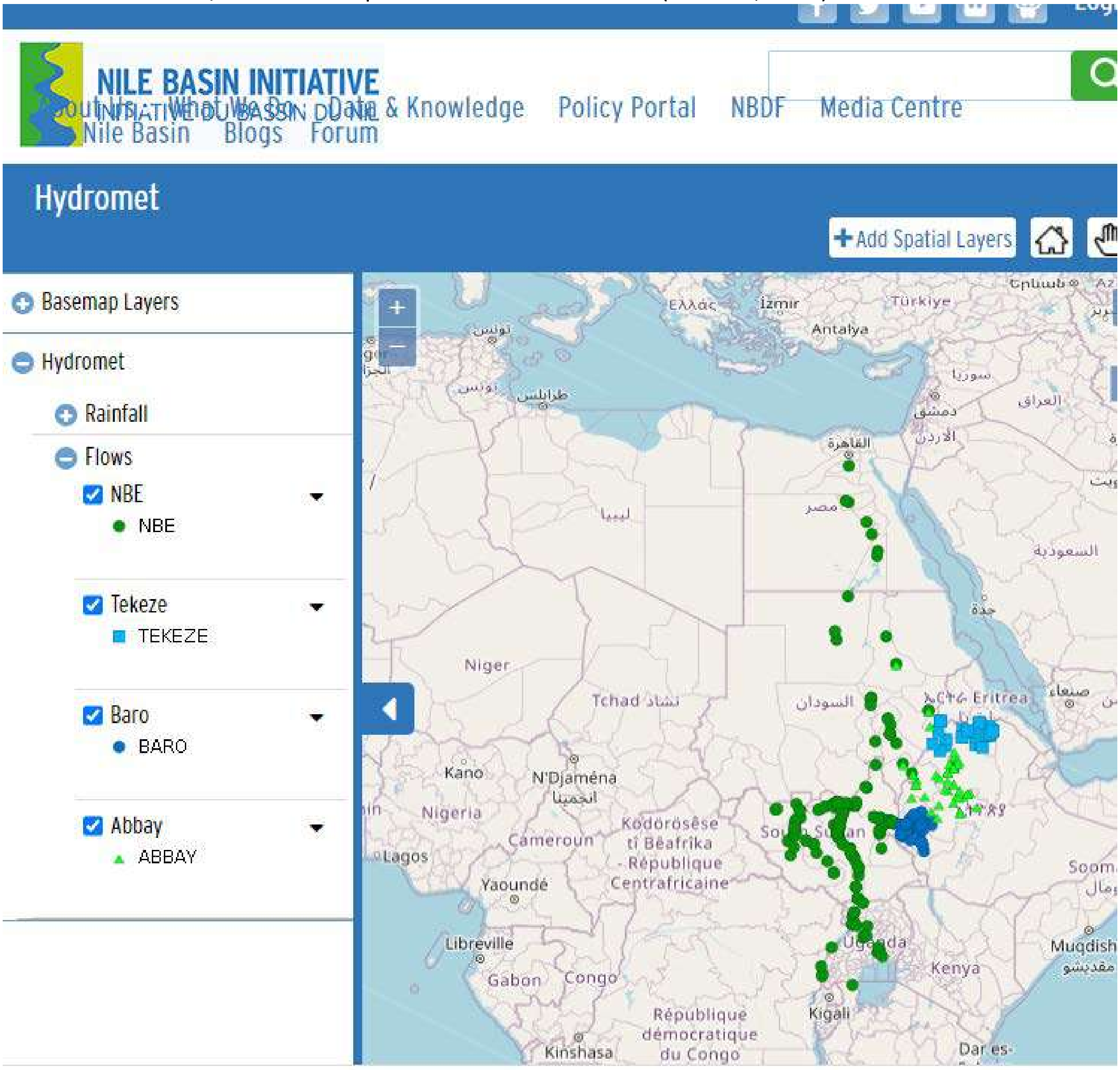


Figure 64: NBI data website

All the information above has been processed and ten different scenarios have been developed for all the watercourse stretches. A buffer of about 30% has been added to the lower and higher flows in order to produce a range that can consider more extreme scenarios. Model results have been carefully assessed for their sensitivity, and the resulting flows have been carefully checked for plausibility. Results are shown in Table 25.

Table 25. Flows used in the scenario assessment

Stretch No.	Name	Scenario Flows (m³/s)									
		1	2	3	4	5	6	7	8	9	10
1	Main Nile in Egypt (Mediterranean to High Aswan Dam)	532	760	1032	1304	1576	1847	2119	2391	2663	3462
3	Main Nile in Sudan (Wadi Halfa to Khartoum)	525	750	2214	3679	5143	6607	8071	9536	11000	14300
4	Blue Nile (GERD Dam to Khartoum	28	40	1391	2743	4094	5446	6797	8149	9500	12350
5	White Nile DS Malakal (Khartoum to Malakal)	210	300	600	900	1200	1500	1800	2100	2400	3120
6	Sobat (Confluence of Baro/Akobo to Sobat mouth)	7	10	187	364	541	719	896	1073	1250	1625
7	Bahr el Jebel u/s of Sudd (Juba)	210	300	671	1043	1414	1786	2157	2529	2900	3770
7	Bahr ej Jebel d/s of Sudd (before confluence with Sobat)	158	225	421	618	814	1011	1207	1404	1600	2080
8	Albert Nile (Lake Albert to Juba)	210	300	571	843	1114	1386	1657	1929	2200	2860
10	Kyoga Nile (Lake Kyoga to Lake Albert)	182	260	509	757	1006	1254	1503	1751	2000	2600
12	Victoria Nile (Lake Victoria to Lake Kyoga)	210	300	414	529	643	757	871	986	1100	1430

This information has been included in the HEC-RAS model in the steady flow editor and allocated to the first cross-section in the stretch.

In addition to that, river flow data for the whole catchment was extracted from the re-analysis of GloFAS (Global Flood Awareness System, https://www.globalfloods.eu/) from 1979 to 2021. The Global Flood Awareness System is one component of the Copernicus Management Service CEMS, and in addition to being used for forecasting and early warning purposes, the implemented product has been run in reanalysis mode for this 40 year period, including data from satellites, models and in-situ measurements. GloFAS discharge re-analysis is based on the latest Numerical Weather Prediction (NWP) reanalysis of the ECMWF (ERA5) coupled with the spatially distributed and calibrated rainfall-runoff-routing model LISFLOOD.

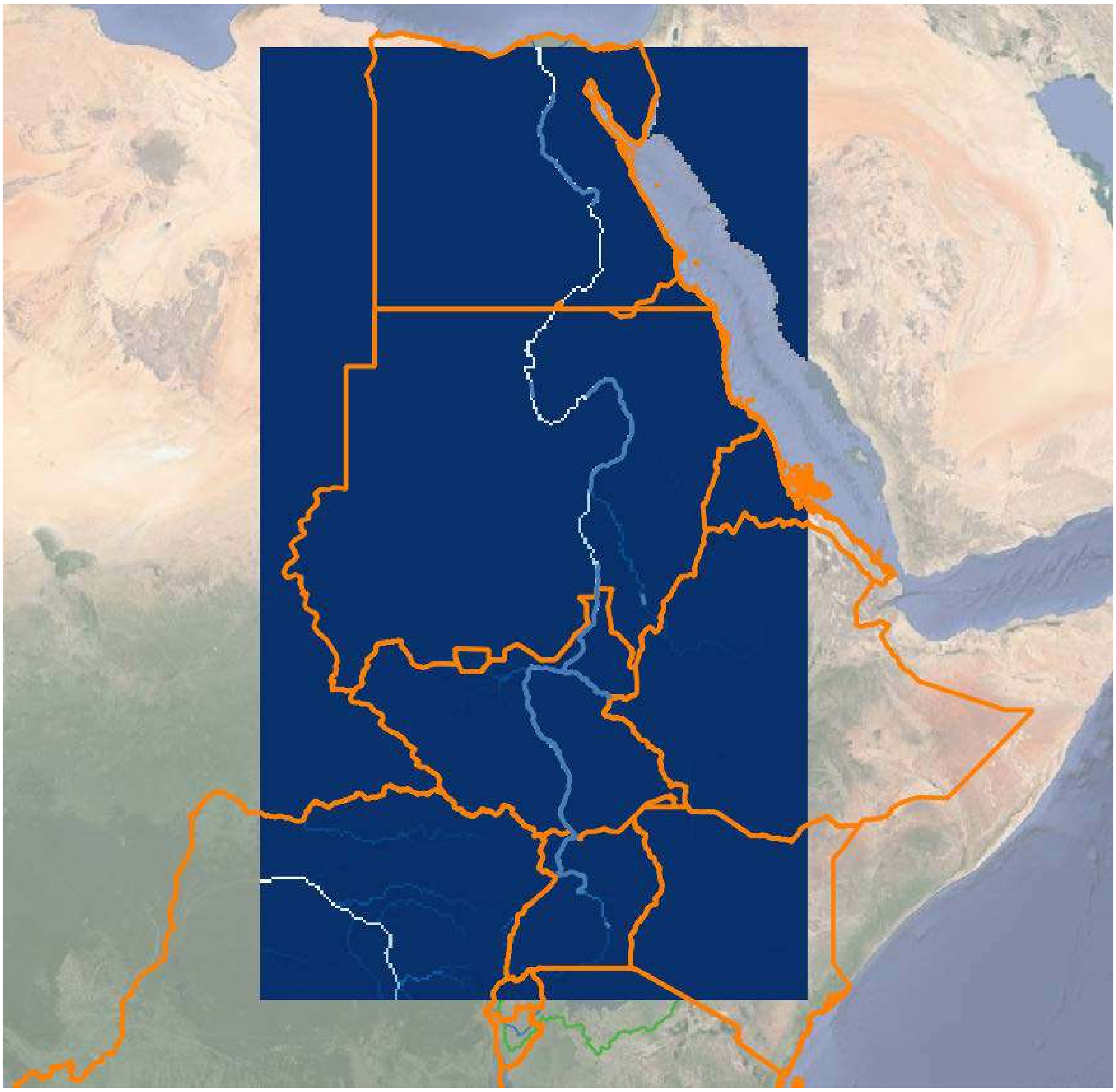


Figure 65. GloFAS data for January 2002 in the Nile Basin

Data from GloFAS was acquired from 2002 until 2021 for the whole Nile Basin and it was processed individually for all the locations where altimetry virtual stations were available. Figure 68 and Figure 69, for instance, as an example show the discharge at virtual stations 213 and 6773 (located in Roseires and the Sobat River respectively).

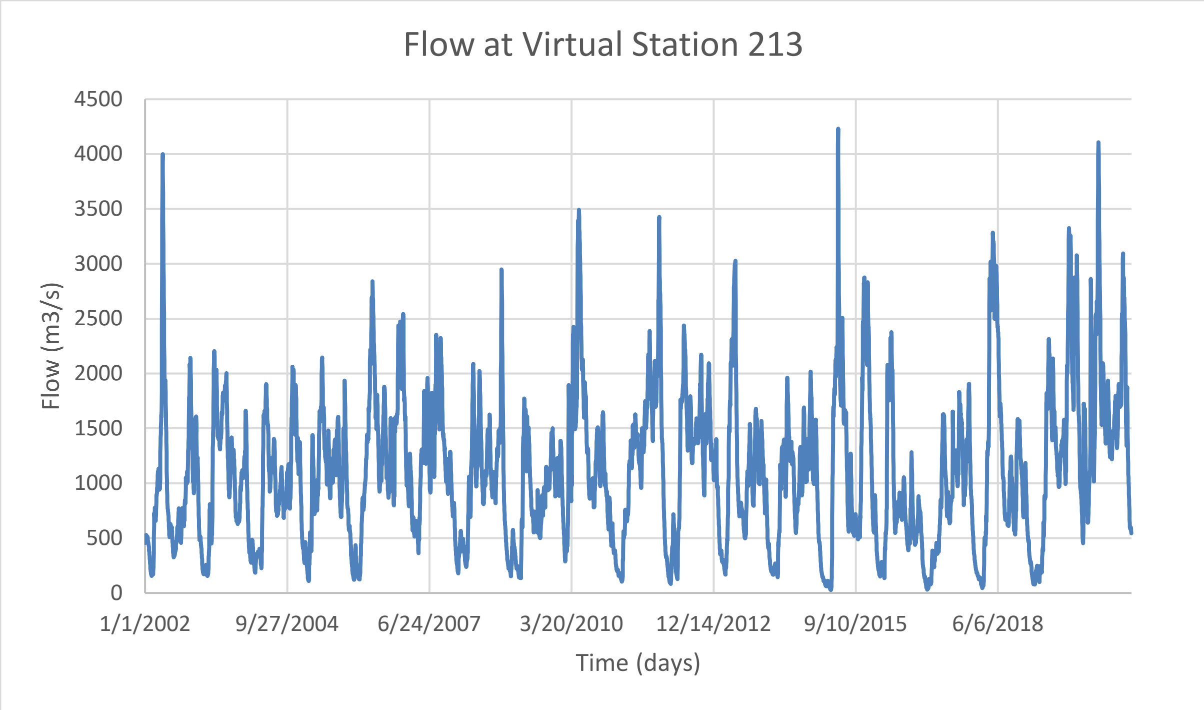


Figure 66. Example GloFAS flow at virtual station 213 at Roseires reservoir

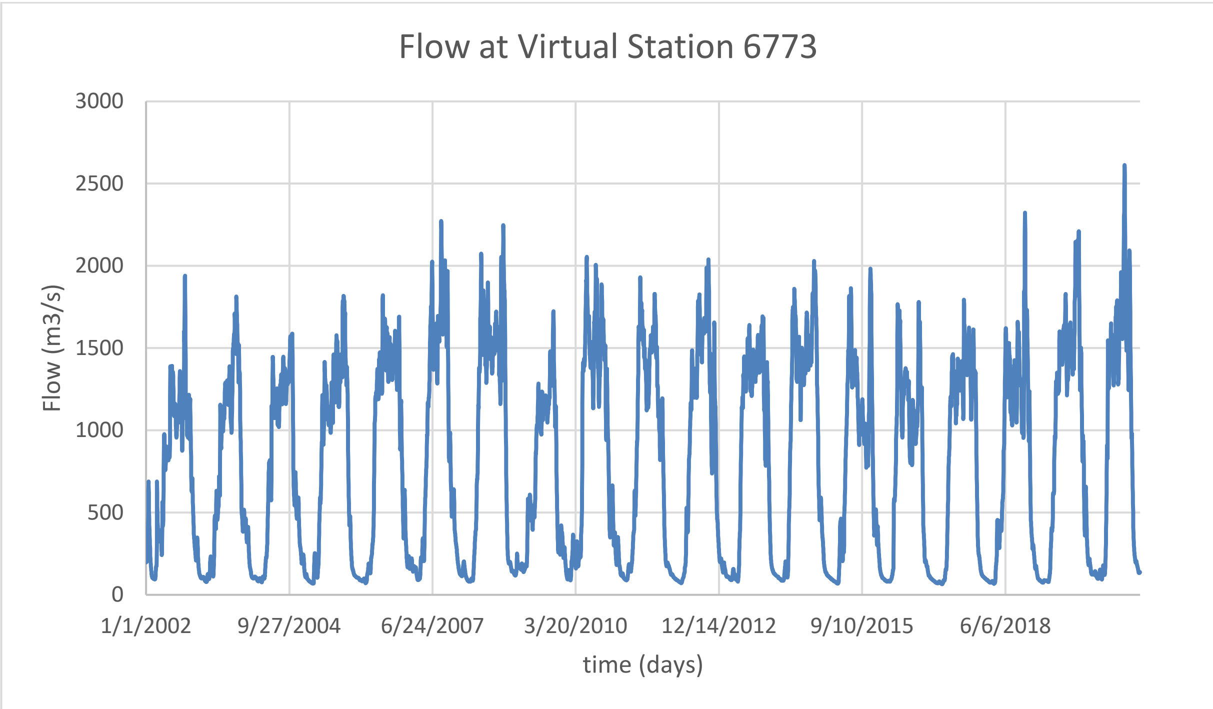


Figure 67. Example GloFAS flow at virtual station 6773 in the Sobat River

The main purpose of this assessment was to have information available for the validation of the results, especially in the areas where there was no information regarding the depth of the cross-sections. In a further analysis, the information from the discharge (in an hour time-step for the whole period 1979-2021) was combined with the altimetry data, that was available in sporadic time snaps during the 2002-2021 period. In Figure 70, the water level (from the altimetry virtual station) and the flow (from GloFAS) in the virtual station 6773 is shown.

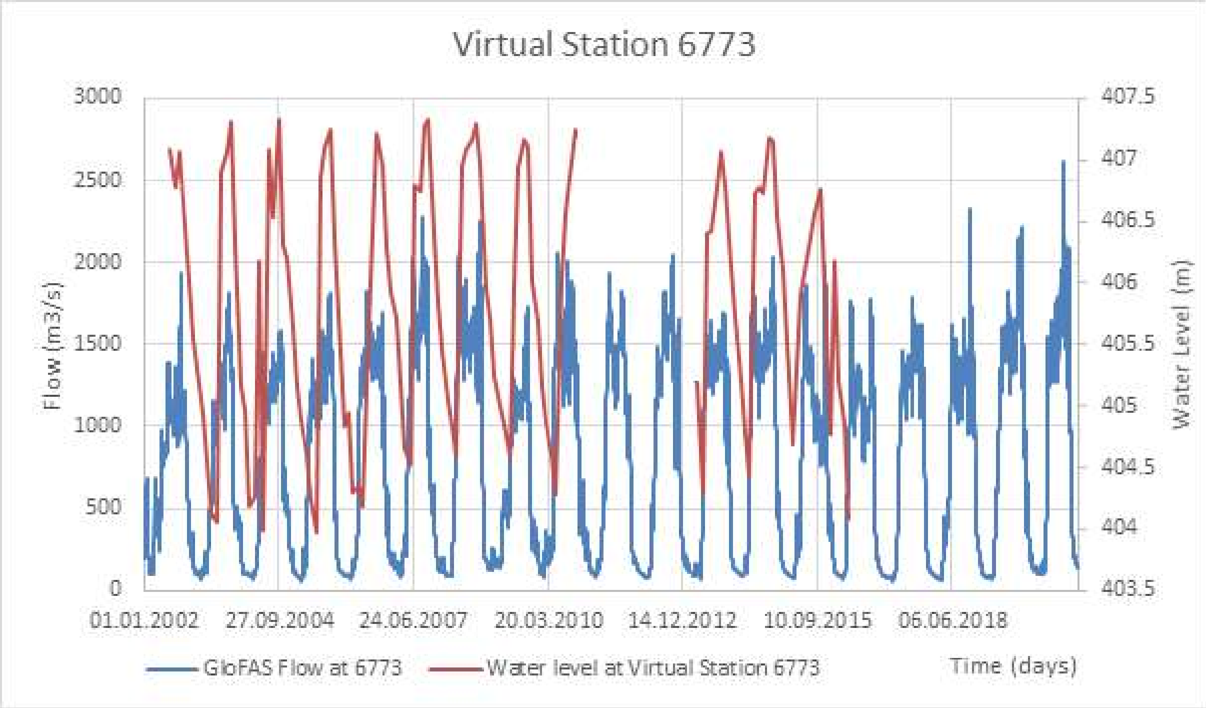


Figure 68. Example flow and water level in virtual station 6773 in the Sobat River

These data were further processed in order to have a better understanding of the flow dynamics in each of the virtual stations, and the flow-stage data was evaluated in order to obtain flow-depth-relations (or Qh relationships), as shown in Figure 71.

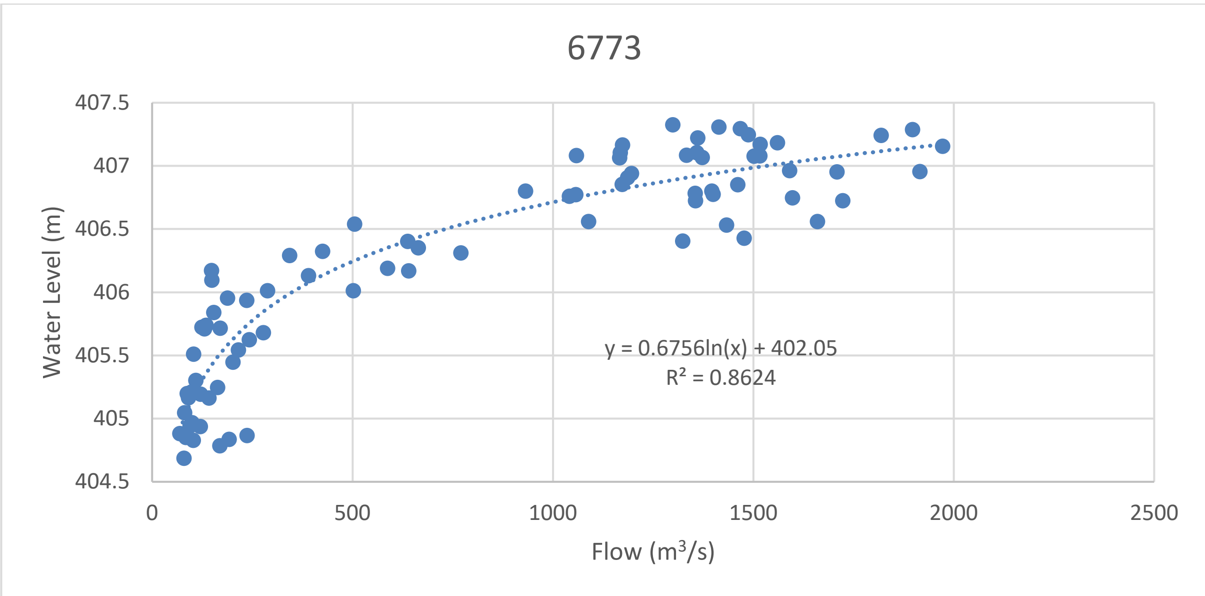


Figure 69. Example flow-depth-relation at virtual station 6773 in the Sobat River

The resulting flow-depth-relation was used to define the lowest water depth level in the virtual stations (minimum water level), to assess the cross-section depth used in the model, and to assess the roughness applied in each cross-section (depending on the curve growth). Therefore, as it will be explained further below, cross-sections were defined in the location of all the virtual stations, with also a higher frequency of cross-sections upstream and downstream of these locations, in order to ensure that the slope and the flow dynamics are properly represented.

8.1.5 Calculation of the flow-depth relation and flow-velocity relation

Using all the information above, mainly the cross-sections and the flow scenarios, steady simulations were created in HEC-RAS for each of the stretches and for the 10 selected scenarios (Table 25). The results from these simulations are water surface elevation and water velocity at every single cross-section.

The theoretical background behind the calculation of the water surface elevation and the velocity in HEC-RAS in steady mode can be explored in the technical references of HEC-RAS (https://www.hec.usace.army.mil/software/hec-ras/documentation.aspx.)

The results from all the cross-sections of every stretch have been processed for all indicated flow scenarios. In a first step, the water depth has been calculated in every cross-section, using the information from the invert level and the water stage calculations. In a second step, the data from the stretches have been averaged in terms of water depth and velocity for each scenario run.

The step-by-step procedure for this process is depicted below:

1. The geometry for all the stretches has been defined. As described, this has been undertaken using both surveyed data and estimated data based on DEM resources. Special attention has been paid to the slope as natural as possible.
2. The estimated (or artificial) cross-sections have been defined just considering the channel, taking into account the digitised width of the river, and applying a box-rectangular profile.
3. Flows have been defined for a range of scenarios, considering the lowest and highest values recorded in each stretch and applying a buffer on both ends.
4. Steady simulations with the above-mentioned geometry and flows have been undertaken. The main results from these steady simulations, per cross-section, are:
    a. Discharge: this value is constant in each stretch at every cross-section unless a change is pre-specified in the reach. This is because in steady mode the discharge is not calculated by the model, just the water level.
    b. Water level: the water level at every single cross-section is calculated by the hydraulic model following the equations outlined above and in the HEC-RAS reference manual.
    c. Velocity: the velocity at evert cross-section is calculated by the hydraulic model.

An example of the direct output from the hydraulic model per stretch is shown in Table 26.

Table 26: Results from the hydraulic model

Reach	River Sta	Profile	Q (m^3/s)	Min Ch El (m)	W.S. Elev (m)	Vel Chnl (m/s)
1	2023894	PF 1	532	57.5	59.97	2765.11
1	2023894	PF 2	760	57.5	60.56	3429.29
1	2023894	PF 3	1031.86	57.5	61.16	4102.72
1	2023894	PF 4	1303.71	57.5	61.69	4692.61
1	2023894	PF 5	1575.57	57.5	62.17	5224.3
1	2023894	PF 6	1847.43	57.5	62.6	5711.32
1	2023894	PF 7	2119.29	57.5	63	6164
1	2023894	PF 8	2391.14	57.5	63.38	6587.85
1	2023894	PF 9	2663	57.5	63.74	6989.43
1	2023894	PF 10	3461.9	57.5	64.7	8063.19
1	1933366	PF 1	532	57	59.72	2827.87
1	1933366	PF 2	760	57	60.3	3437.01
1	1933366	PF 3	1031.86	57	60.89	4052.03
1	1933366	PF 4	1303.71	57	61.41	4589.68
1	1933366	PF 5	1575.57	57	61.87	5073.92
1	1933366	PF 6	1847.43	57	62.3	5517.07

Reach	River Sta	Profile	Q (m^3/s)	Min Ch El (m)	W.S. Elev (m)	Vel Chnl (m/s)
1	1933366	PF 7	2119.29	57	62.69	5928.92
1	1933366	PF 8	2391.14	57	63.06	6314.32
1	1933366	PF 9	2663	57	63.41	6679.7
1	1933366	PF 10	3461.9	57	64.35	7656.51

5. This information has been further processed to calculate the water depth. The water depth in this case it is the water surface elevation at every cross-section minus the invert level (lowest value) at that particular cross-section. The results are shown in Table 27.

Table 27: Calculation of water depth

Reach	River Sta	Profile	Q (m^3/s)	Min Ch El (m)	W.S. Elev (m)	Vel Chnl (m/s)	Water Depth (m)
1	2023894	PF 1	532	57.5	59.97	2765.11	2.47
1	2023894	PF 2	760	57.5	60.56	3429.29	3.06
1	2023894	PF 3	1031.86	57.5	61.16	4102.72	3.66
1	2023894	PF 4	1303.71	57.5	61.69	4692.61	4.19
1	2023894	PF 5	1575.57	57.5	62.17	5224.3	4.67
1	2023894	PF 6	1847.43	57.5	62.6	5711.32	5.1
1	2023894	PF 7	2119.29	57.5	63	6164	5.5
1	2023894	PF 8	2391.14	57.5	63.38	6587.85	5.88
1	2023894	PF 9	2663	57.5	63.74	6989.43	6.24
1	2023894	PF 10	3461.9	57.5	64.7	8063.19	7.2
1	1933366	PF 1	532	57	59.72	2827.87	2.72
1	1933366	PF 2	760	57	60.3	3437.01	3.3
1	1933366	PF 3	1031.86	57	60.89	4052.03	3.89
1	1933366	PF 4	1303.71	57	61.41	4589.68	4.41
1	1933366	PF 5	1575.57	57	61.87	5073.92	4.87
1	1933366	PF 6	1847.43	57	62.3	5517.07	5.3
1	1933366	PF 7	2119.29	57	62.69	5928.92	5.69
1	1933366	PF 8	2391.14	57	63.06	6314.32	6.06
1	1933366	PF 9	2663	57	63.41	6679.7	6.41
1	1933366	PF 10	3461.9	57	64.35	7656.51	7.35

6. This information has been tabulated per stretch, and then the values per discharge have been averaged. For each cross-section, ten different flow values (flow profiles) have been calculated. For each flow value, the water depth and the velocity for all the cross-sections in one stretch have been averaged, using the mean value for the subsequent analysis. For instance, in the table below, the water depths and velocities for all the cross-section in the Stretch 1 for one flow value (760m^3/s). The arithmetic mean of these values have been processed and used, in order to provide a representative value for the stretch.

Table 28. Values per flow in Stretch 1

Reach	River Sta	Profile	Q (m^3/s)	Min Ch El (m)	W.S. Elev (m)	Vel Chnl (m/s)	Water Depth (m)
1	2023894	PF 2	760	57.5	60.56	3429.29	3.06
1	1933366	PF 2	760	57	60.3	3437.01	3.3
1	1758787	PF 2	760	56.5	59.77	3152.5	3.27

Reach	River Sta	Profile	Q (m^3/s)	Min Ch El (m)	W.S. Elev (m)	Vel Chnl (m/s)	Water Depth (m)
1	1542158	PF 2	760	56	58.05	1291.5	2.05
1	1484094	PF 2	760	55	56.93	2354.85	1.93
1	1392741	PF 2	760	54	55.9	0.3	1.9
1	1151216	PF 2	760	50	51.8	1540.3	1.8
1	1069316	PF 2	760	46.5	47.17	1411.37	0.67
1	940584	PF 2	760	40	42.83	1637.23	2.83
1	680799	PF 2	760	32.5	33.74	871.43	1.24
1	605078	PF 2	760	28	29.96	1630.9	1.96
1	529262	PF 2	760	26	28.13	1561.98	2.13
1	396805	PF 2	760	23	25.97	1784.15	2.97
1	188327	PF 2	760	21	22.39	1942.55	1.39
1	126735	PF 2	760	19	20.54	1634.45	1.54
1	48006	PF 2	760	15	16.96	1002.07	1.96
1	2831	PF 2	760	13	15.03	0.53	2.03

The whole procedure can be observed in Figure 72 below.

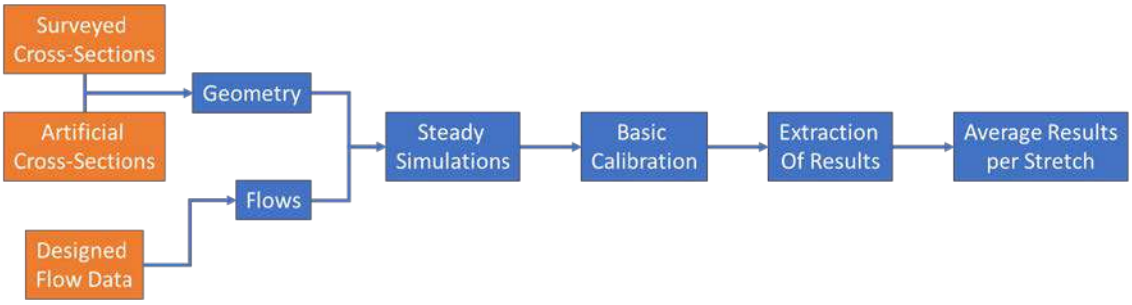


Figure 70. Calculation Procedure

8.1.6 Calculation of dredged cross-section scenarios

The information above in Section 8.2.1 described the data used in the baseline (Option 0) scenario. In this Option 0 – Baseline, the information used was the available measured cross-section data, or rectangular cross-sections with estimated (and validated when possible) depth.

In the second scenario, Option 1 – Dredging, a hypothetical dredged situation has been analysed. In this assessment the same number and location of the cross-sections as per Option 0 assessment have been used. In this Option 1 – Dredging scenario, the cross-sections have been proposed to be modified to include the possibility of trapezoidal dredging to facilitate navigation. The cross-section depth has been increased in the centre of the cross-section, while the material that hypothetically has been removed has been moved to the channel sides (within channel), creating a trapezoidal shape in the cross-section without changing the overall channel cross section area (Figure 73). This has been undertaken for both surveyed and rectangular cross-sections.

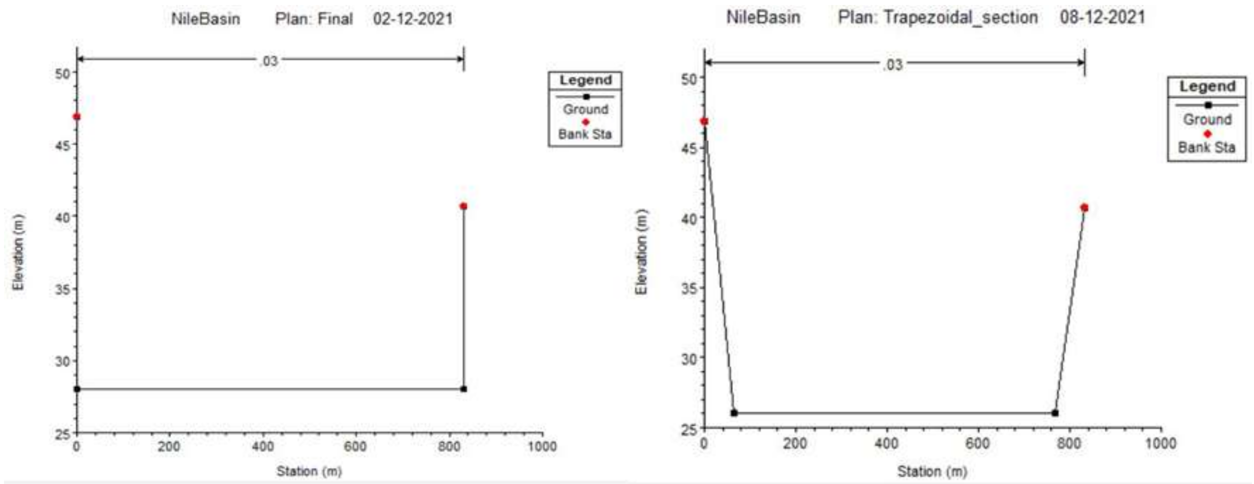


Figure 71. Examples of rectangular (Option 0) and trapezoidal (Option 1) cross-sections in the Nile in Egypt stretch

In all the stretches the existing slope has been kept, trying to increase the depth in the cross-sections constant within a reach to maintain the same flow dynamics but increasing the depth for specific flows. The results from this assessment are presented in further sections below.

8.1.7 Linking of narge types

Barges or barge packs on the Nile are available in various capacities, sizes, and stack formations. Their ability to navigate on a certain stretch of river is related to

Length	- maximum length depending on river curvature
Width	- maximum width depending on river width
Draft (submerged depth)	- maximum draft depending on river depth

It needs to be noted that barges typically are stacked, i.e. tied to each other to form barge packs that are moved forward by pushers. Several barges can be stacked next to each other and also in front of each other. The length and width are then a multiple of the individual barges included in a barge pack. Figure 74 shows examples of barge packs

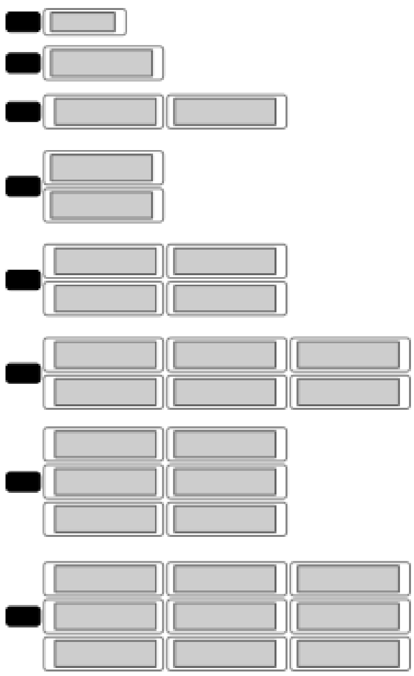


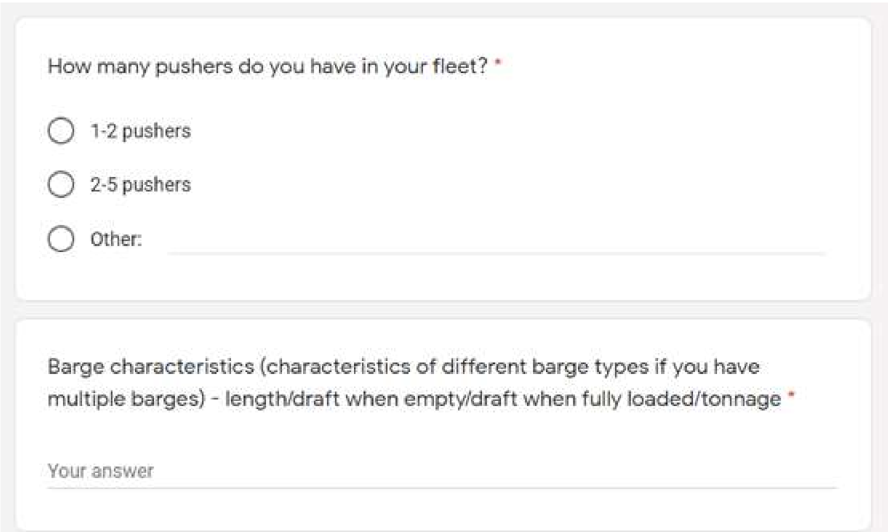
Figure 72: Possible barge pack combinations (image created by Jonathan Haas)

Further to the dimensions, engine capacity of the involved pushers (or motorized barges) are an important aspect, especially for navigating upstream against the current, though also moving downstream current velocities can be a limiting factor.

Considering the above combination possibilities and their flexibility, as well as the fact that also motorized single barges are used, single barge types with a main focus of their draft have been used in this report, linking them to the assessed water depth. Nevertheless, also here it needs to be considered, that:

- Water depth varies depending on the actual flow conditions, i.e. varies with intra-annual as well as inter-annual flow conditions
- Barge draft varies with its load. I.e. barge operators have the possibility to limit the draft of their barges by transporting less cargo than technically possible

Barge operators (Annex I) active on the Nile River and on the navigable tributaries have been contacted to fill-in an online questionnaire[80] (Figure 75) focused on navigability conditions.



How many pushers do you have in your fleet? *

1-2 pushers

2-5 pushers

Other:

Barge characteristics (characteristics of different barge types if you have multiple barges) - length/draft when empty/draft when fully loaded/tonnage *

Your answer

Figure 73: Questionnaire extract (river operators)

Based on the consultant's experience[81] and the collected information from the questionnaires, barges identified between Khartoum and Lake Victoria were found to have length of 10.0m - 70.0m, widths of 1.2m - 13.0m, and drafts of 0.7m - 1.5m.

No questionnaire feedback was obtained from Egypt, nevertheless some web information was evaluated, e.g. at https://alexyard.com.eg/NileBarge.html

For barge sizes used in Egypt the assessment shows that it is likely that larger barges with lengths over 100m and drafts of up to 2.5m are used on this stretch of the Nile River.

For the purpose of assessing required flows, necessary to keep all currently available vessels on the Nile in operation, a safety margin of 0.5m was added to the assumed drafts. This results in a minimum required water depth of 2.0m for the White Nile, Blue Nile and Main Nile upstream of Aswan, as well as a required water depth of 3.0m for the Main Nile downstream of Aswan.

Further, river curvature will have to be considered when assessing navigability under current river conditions, especially for the long barges. Considering the fact that such barges are currently operating on the respective stretches, it is assumed that they can deal with the existing curvature, while for future

[80] https://forms.gle/Z9rSe6F7nBdh6aCx7

dredging scenarios, especially for increasing margins of navigational safety and travel speed, curvature will need to be considered in dredging planning.

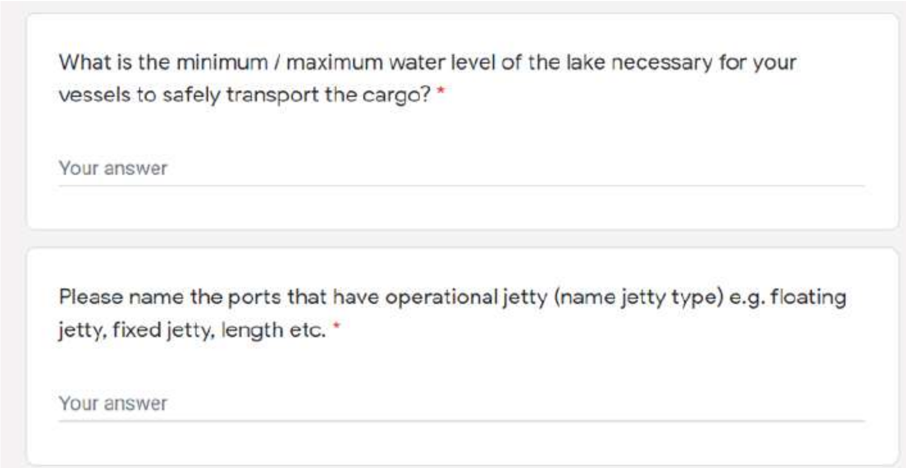
8.1.8 Lake level variations

Lake Levels of Lake Nasser, Lake Albert, Lake Kyoga, and Lake Victoria are an important parameter for navigation on the lakes, especially with regards to utilization of quay walls, piers, and jetties. Where water levels fluctuate more than the port installations are designed for, flooding of assets, or water levels too low to use assets or water depth too low to allow vessels to approach may occur. Respectively, Ports generally have a workable lake level range during which they can be used. Impacts of lake levels that drop below design limits have been observed in Lake Victoria at the beginning of the century, when lake levels dropped significantly, interrupting port utilization.

Lake level data is available from satellite observations of the Topex/Poseidon/Jason missions, e.g. :

- https://ipad.fas.usda.gov/cropexplorer/global_reservoir/gr_regional_chart_jason1.aspx?regionid=eafrica&reservoir_name=Victoria_1
- http://www.legos.obs-mip.fr/en/soa/hydrologie/hydroweb/StationsVirtuelles/SV_Lakes/Victoria.html

Data has been downloaded and analysed for lake level variations and shall be compared to port interruption event data collected from barge operators (Annex I) active on the lakes. These have been contacted with the request to fill an online questionnaire[82] (Figure 76), focused on the navigability conditions, and feedback was gathered and evaluated. Furthermore, an online interview has been conducted with the Lake Victoria Basin Commission on 06/12/2021 to gather specific data related to navigation on Lake Victoria.


What is the minimum / maximum water level of the lake necessary for your vessels to safely transport the cargo? *

Your answer

Please name the ports that have operational jetty (name jetty type) e.g. floating jetty, fixed jetty, length etc. *

Your answer

Figure 74: Questionnaire extract (lake operators)

8.2 Cross-section overview

Within this section, the cross-sections used in the model as well as the initial results obtained through this assessment are discussed.

8.2.1 Defining / limiting cross-section characteristics

An overview of the stretches defined in the study can be observed in the Figure 77.

[82] https://forms.gle/HrDUnw7zFguzcmit9

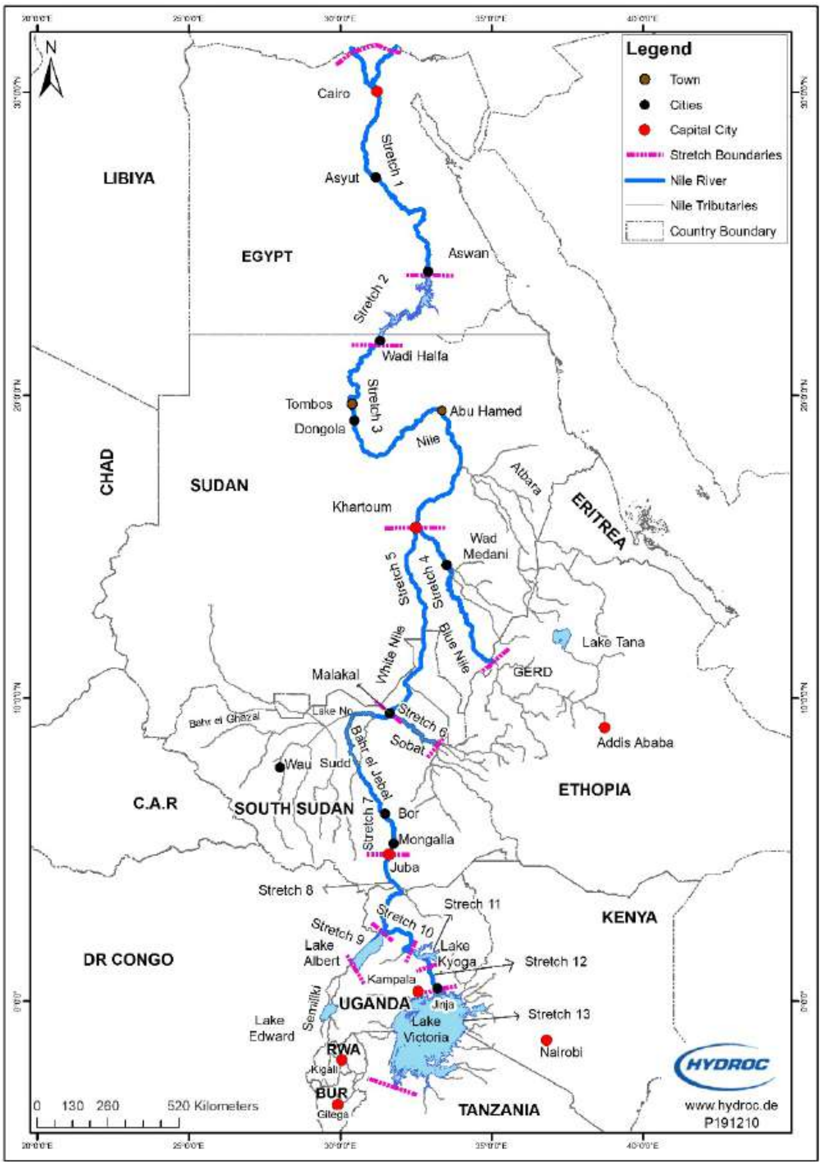


Figure 75. Overview of the selected stretches

In this section, the cross-section information used in each of the stretches is outlined. It should be added that the following approach has been followed:

- In the stretches where cross-section data were available, the cross-section data has been assessed and used where it was found that the data is plausible and that there are enough cross-sections to represent the flow dynamics.
- In areas where no cross-section data were available, cross-sections have been estimated. This has been undertaken in representative locations of the stretch in particular, but also including narrower and wider areas, in order to get a sample that is representative of that watercourse section.
- While in the inception report it was indicated that 500m stretches would be used, during the actual implementation, longer stretches have been defined, when necessary, in order to expand the cross-section sample and achieve a wider representation of the actual conditions.
- In the stretches in wider waterbodies, such as Lake Victoria, Lake Kyoga, Lake Albert or Aswan Reservoir, no flows or cross-sections have been defined, because there are no navigational constraints in these stretches from a hydraulic point of view. Therefore, in these water bodies the water level fluctuations have been assessed.

8.2.1.1 Stretch 1. Nile in Egypt

In the case of the Nile River in Egypt, no cross-section data was available, and therefore the cross-sections had to be estimated. In this stretch a total of 16 cross-sections were estimated in order to obtain a proper representation of the stretch features. As noted above, the location of the virtual stations was fully considered in the definition of the location of the cross-sections.

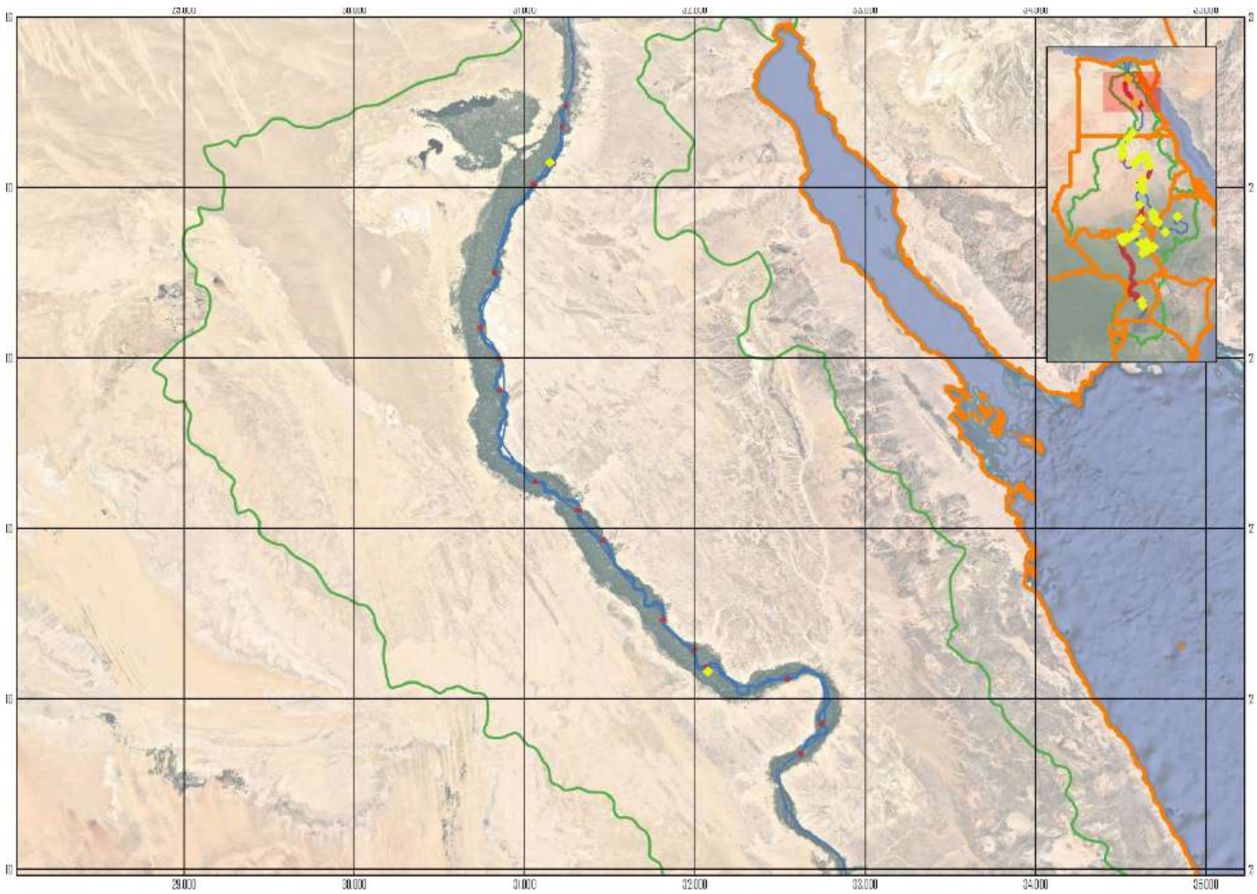


Figure 76. Cross-section and virtual stations (yellow diamonds) of representative section of Stretch 1 (Main Nile in Egypt)

The depth in the cross-sections was adjusted to the virtual stations calibrations, considering the DEM and the plausibility of the results. It should be noted that in all the stretches the upstream boundary conditions are the flows defined in sections above while a normal depth boundary condition has been used downstream when the stretches are not connected.

The results for the flow-depth and velocity relationships were extracted and processed, as shown in Section 8.3 below.

8.2.1.2 Stretch 3. Nile in Sudan

For the Nile River in Sudan, two sub-stretches have been defined for the assessment, although the results have been averaged due to the similar nature of the results. This has been undertaken because of the presence of the Merowe reservoir and the existence of cross-section data in the downstream section. Respectively, the first stretch is located downstream of the Merowe Dam, close to Dongola (Figure 79), and the second stretch upstream of Merowe Dam.

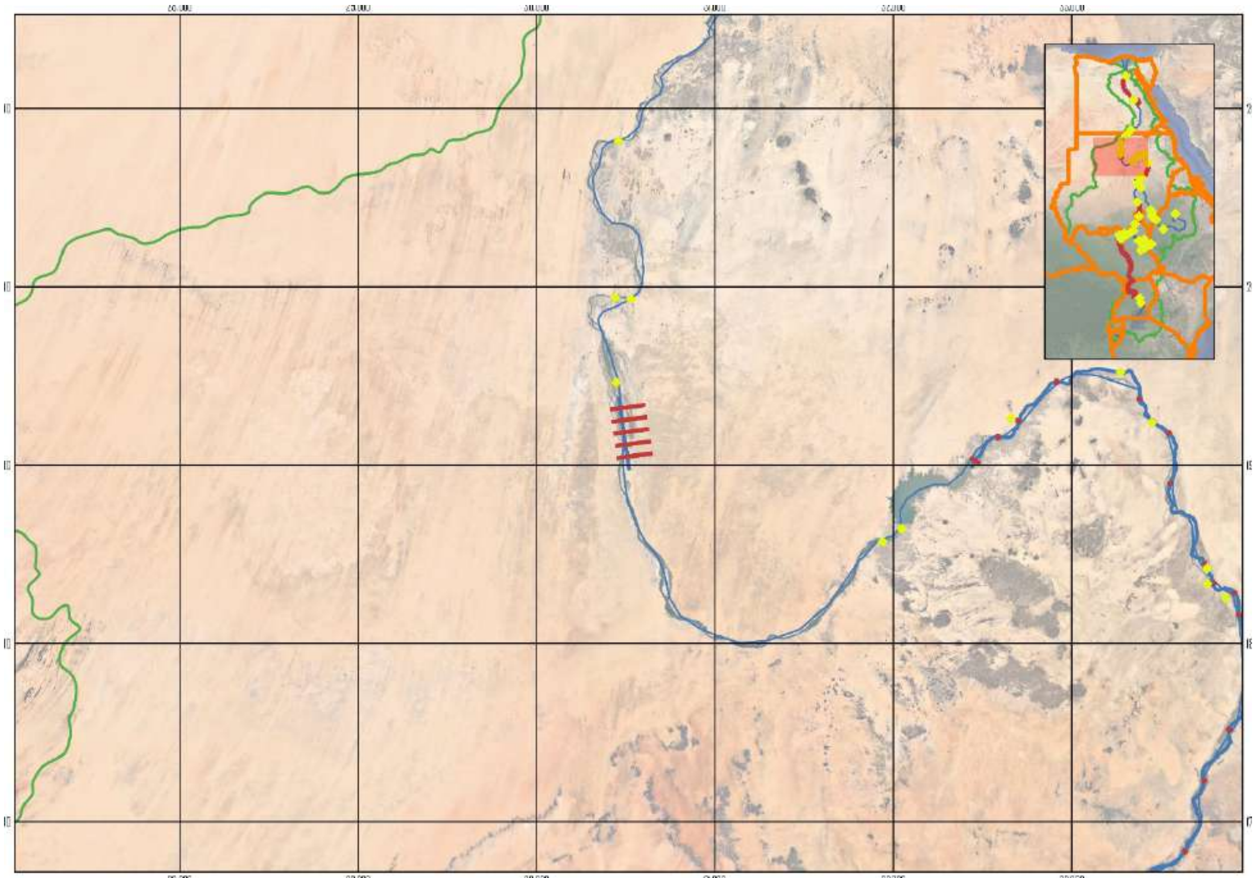


Figure 77. Measured cross-section and virtual stations (yellow diamonds) in representative section of Stretch 3 (Main Nile in Sudan, Wadi-Halfa to Merowe)

As it can be observed (Figure 79), a total of five measured cross-sections are available in Dongala. The calculated flows were routed through these cross-sections to derive water levels and velocities.

In the stretch upstream of Merowe Reservoir, no cross-section data was available, and therefore the cross-sections had to be estimated. In this stretch a total of 25 cross-sections were estimated in order to get a proper representation of the stretch features. As noted above, the location of the virtual stations was fully considered in the definition of the location of the cross-sections.

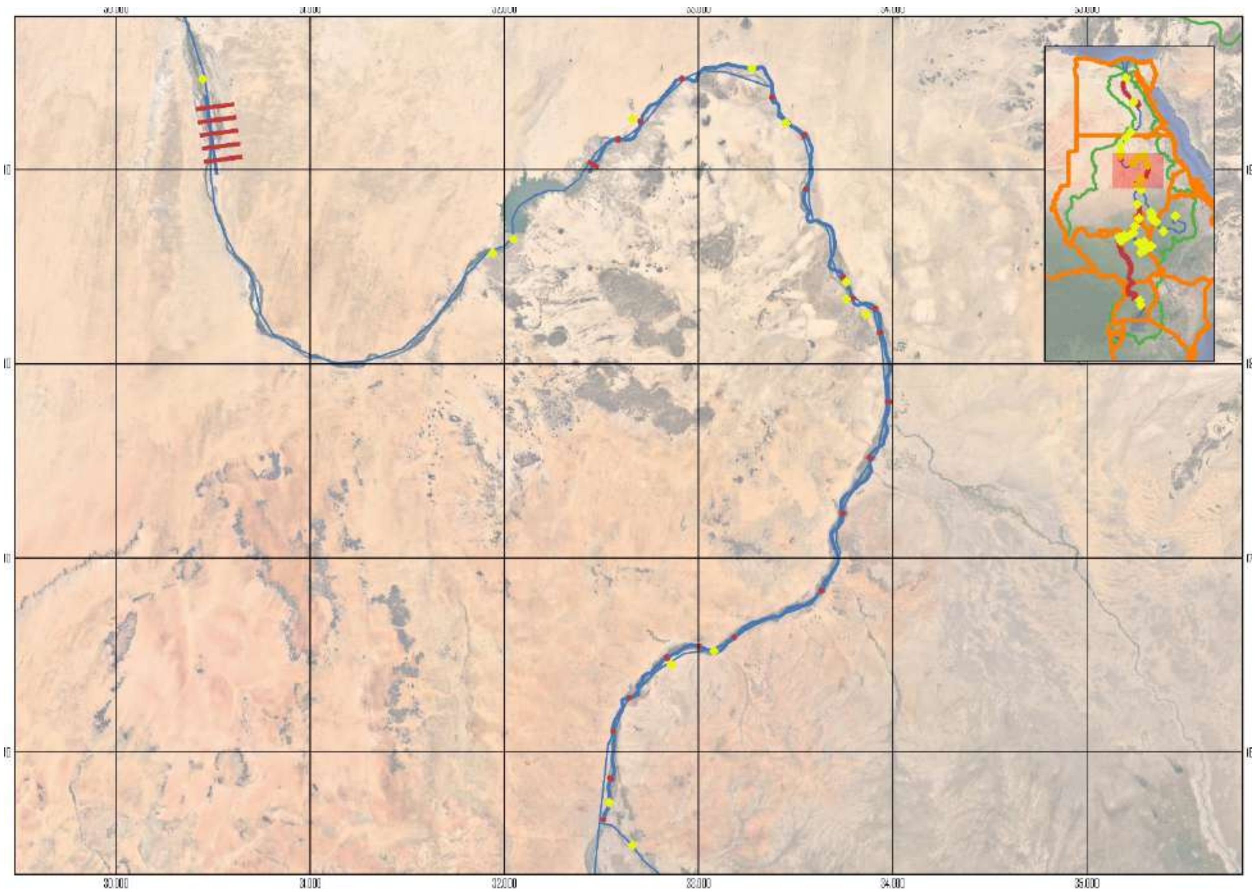


Figure 78. Cross-section and virtual stations (yellow diamonds) in Stretch 3 second section (Main Nile in Sudan, Merowe to Khartoum)

The depth in the cross-sections was adjusted to the virtual stations calibrations, considering the DEM and the plausibility of the results. In all the stretches the upstream boundary conditions are the flows defined in sections above while a normal depth boundary condition has been used downstream when the stretches are not connected.

In the downstream section the water level difference between some of the scenarios decreases due to the boundary condition. Although this has been addressed, in order to avoid any issues in the results, the last cross-section in every digitized reach has not been used in the processing. The results for the flow-depth and velocity relationships were extracted and processed, as shown in Section 8.3 below.

8.2.1.3 Stretch 4. Blue Nile

For the Blue Nile River, data for 5 surveyed cross-sections was available, and therefore no cross-sections were estimated, but the surveyed data have been used in the assessment. The location of the cross-sections is shown in Figure 81.

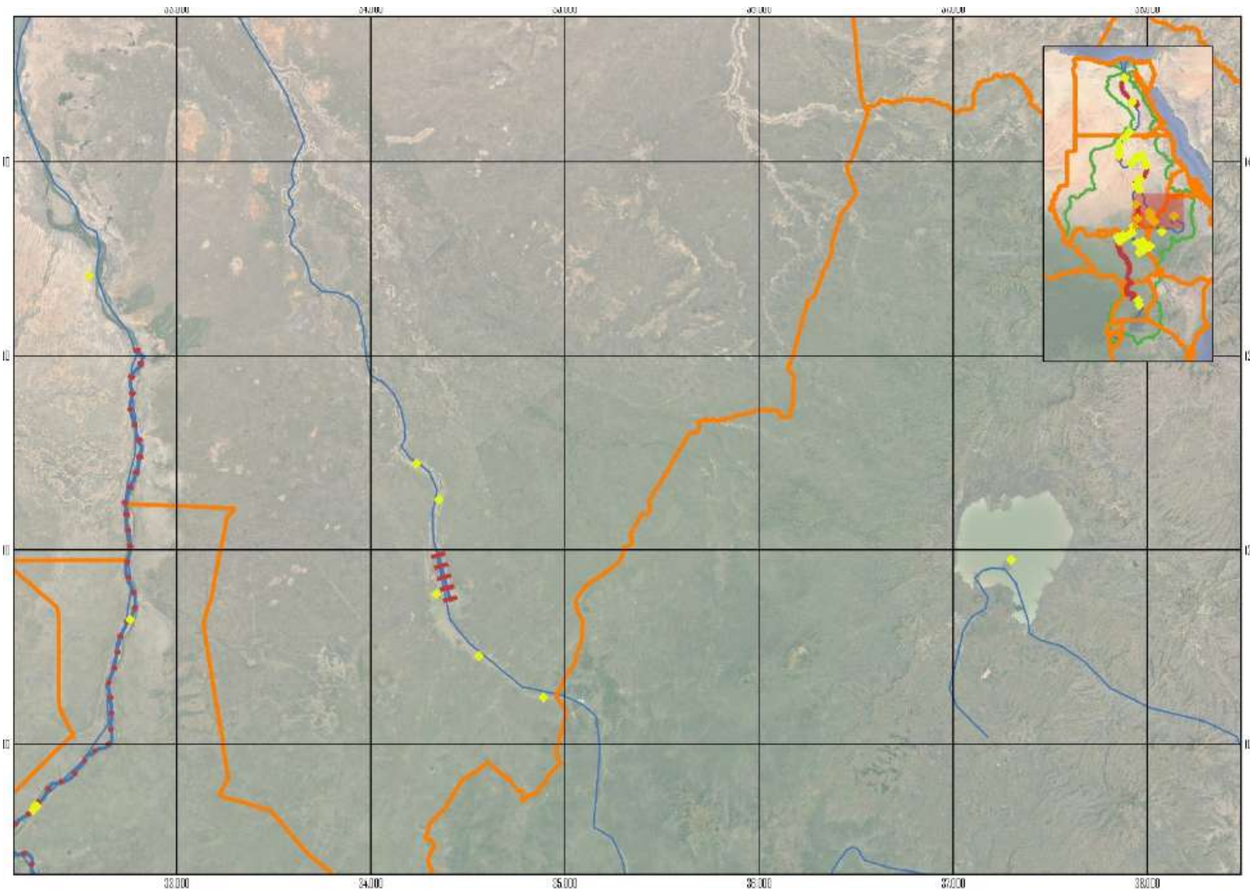


Figure 79. Cross-section and virtual stations (yellow diamonds) in representative section of Stretch 4 (Blue Nile)

The plausibility of the cross-sections and the results have been analysed. It was found that results are plausible and cross-sections did not have to be adjusted.

The results for the flow-depth and velocity relationships were extracted and processed and are shown in Section 2.3 below.

The cross-sections available in the Blue Nile, however, are located in the upstream section of the river. While, as detailed above, it was agreed that in case that there is surveyed data, these will be the only source of data for the analysis; in this case it has to be considered that this area may not be representative to the whole Blue Nile reach. Thus, in order to increase the confidence in the results, a further analysis in the Blue Nile has been undertaken, including cross-sections in the reach following the same approach as it has been followed for other reaches with no data (Figure 82).

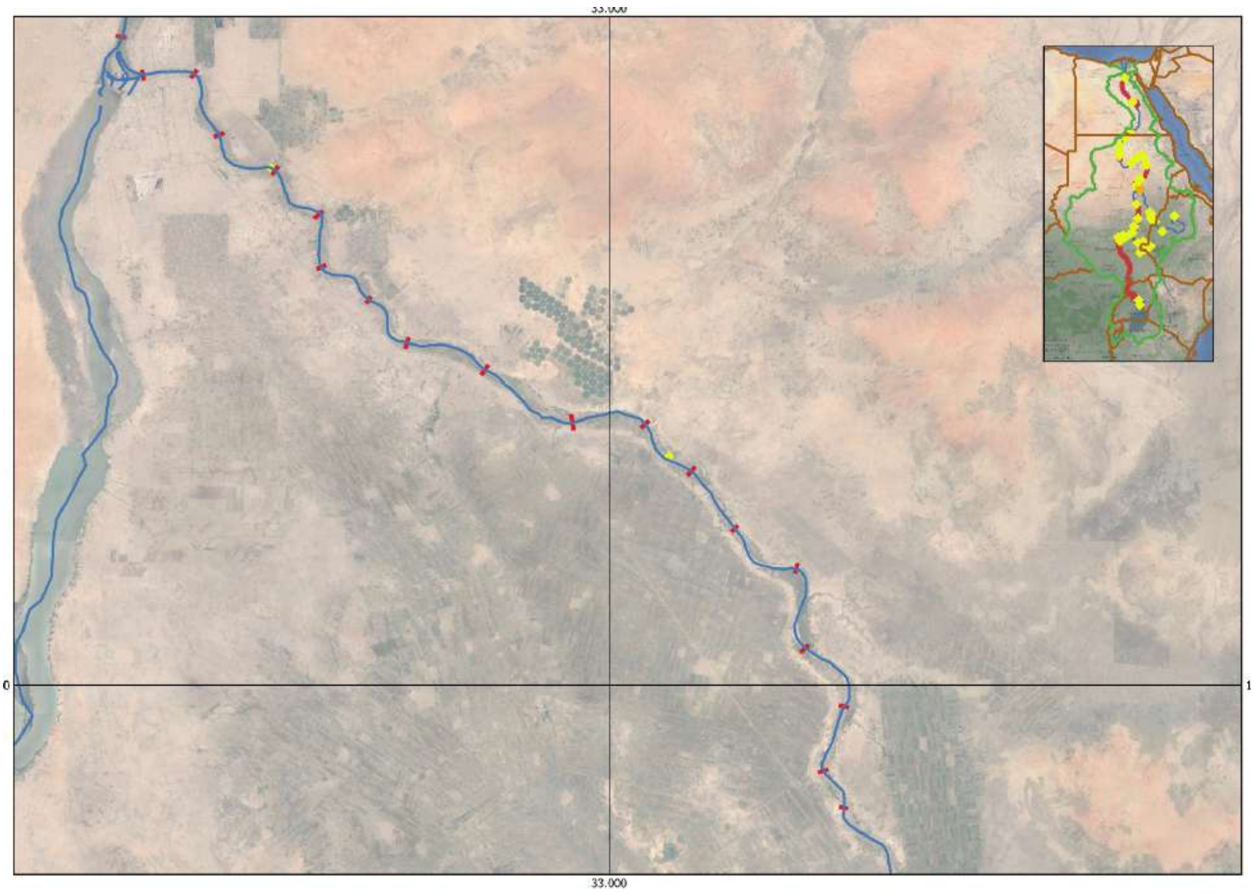


Figure 80. Cross-section and virtual stations (yellow diamonds) in a representative section of Stretch 4 (Blue Nile)

In this case, calculations using both type of source data have been undertaken and compared. It has to be considered in this specific case, that while the surveyed cross-sections data are located in the upstream end of the reach, these surveyed data may be given preference. The surveyed data provides a much better representation of the bathymetry situation as compared to the estimated box approach, that will lead to higher flow requirements based on its flat bottom geometry (Figure 83).

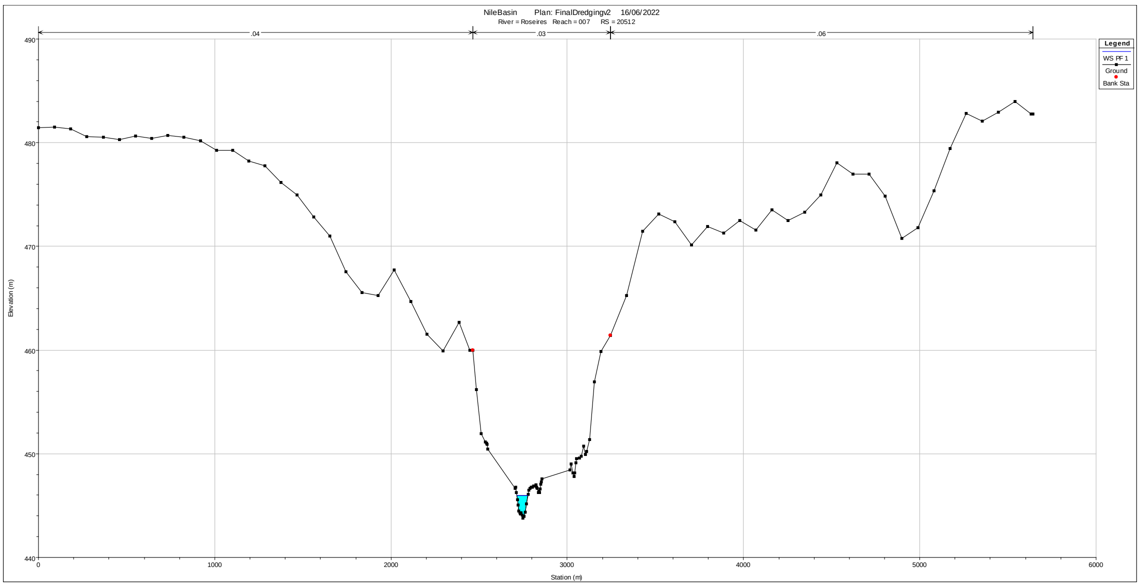


Figure 81. Surveyed cross-section in the Blue Nile

This is further discussed in the results section of this report. While it is not known if in the lower stretch of the Blue Nile in Sudan there are also narrow and deep sections as measured further upstream, river characteristics hint that morphological processes, and therefore bedforms, could be similar.

8.2.1.4 Stretch 5. White Nile DS Malakal

Information from a previous assessment undertaken by HYDROC was used for the White Nile downstream of Malakal. In this assessment a significant number of cross-sections was available, and in order to facilitate the process and the understanding of the results, the number of cross-sections was reduced (Figure 84).

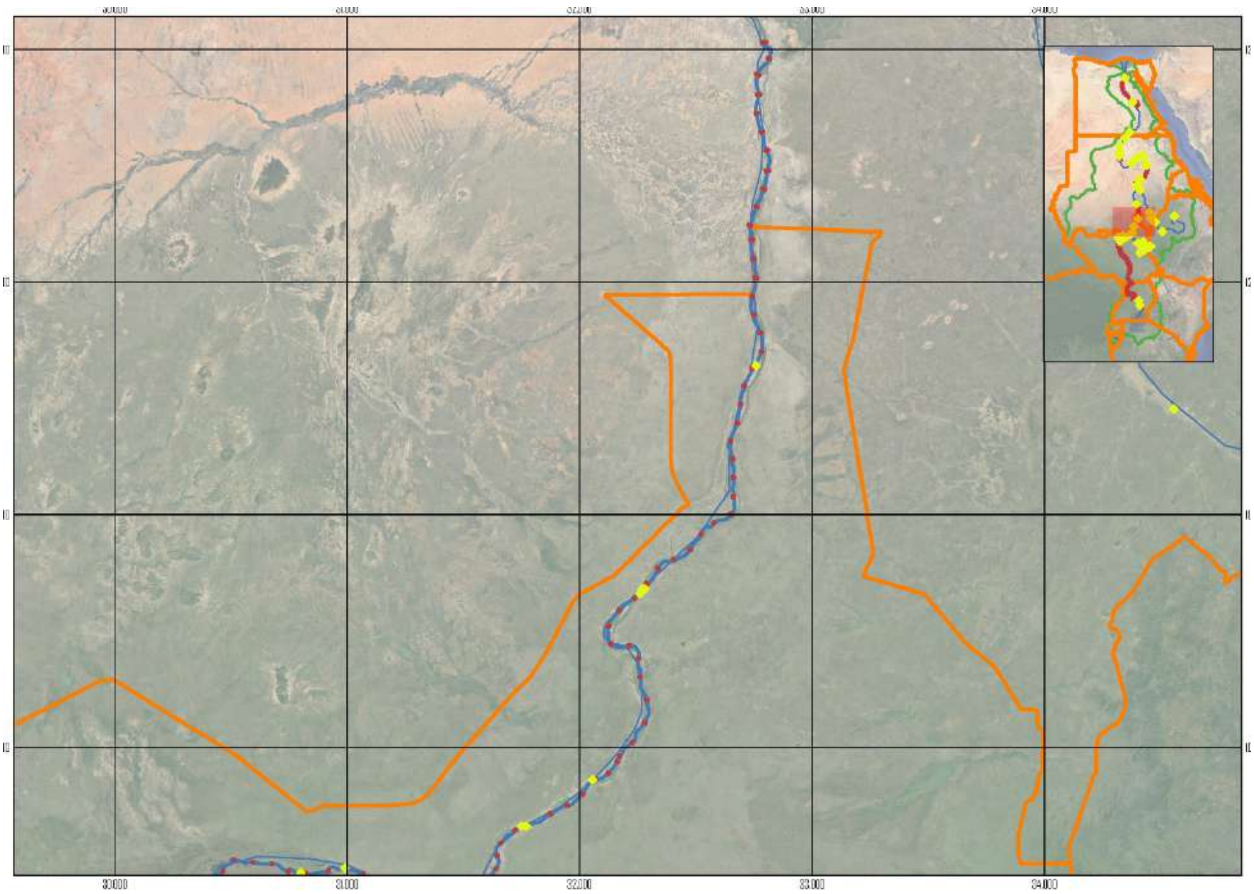


Figure 82. Cross-section and virtual stations (yellow diamonds) in a representative section of Stretch 5 (White Nile, Khartoum to Malakal)

The cross-sections as well as the results yielded by the process were assessed. The results for the flow-depth and velocity relationships were extracted and processed, as shown in Section 8.3 below.

8.2.1.5 Stretch 6. Sobat

For the Sobat River, the cross-section data available was not considered suited for the assessment after some careful assessment, due to the inconsistency on the topographic data and the extent of the data, and therefore the cross-sections had to be estimated. In this stretch a total of 10 cross-sections were estimated in order to get a proper representation of the stretch features. As noted above, the location of the virtual stations was fully considered in the definition of the location of the cross-sections.

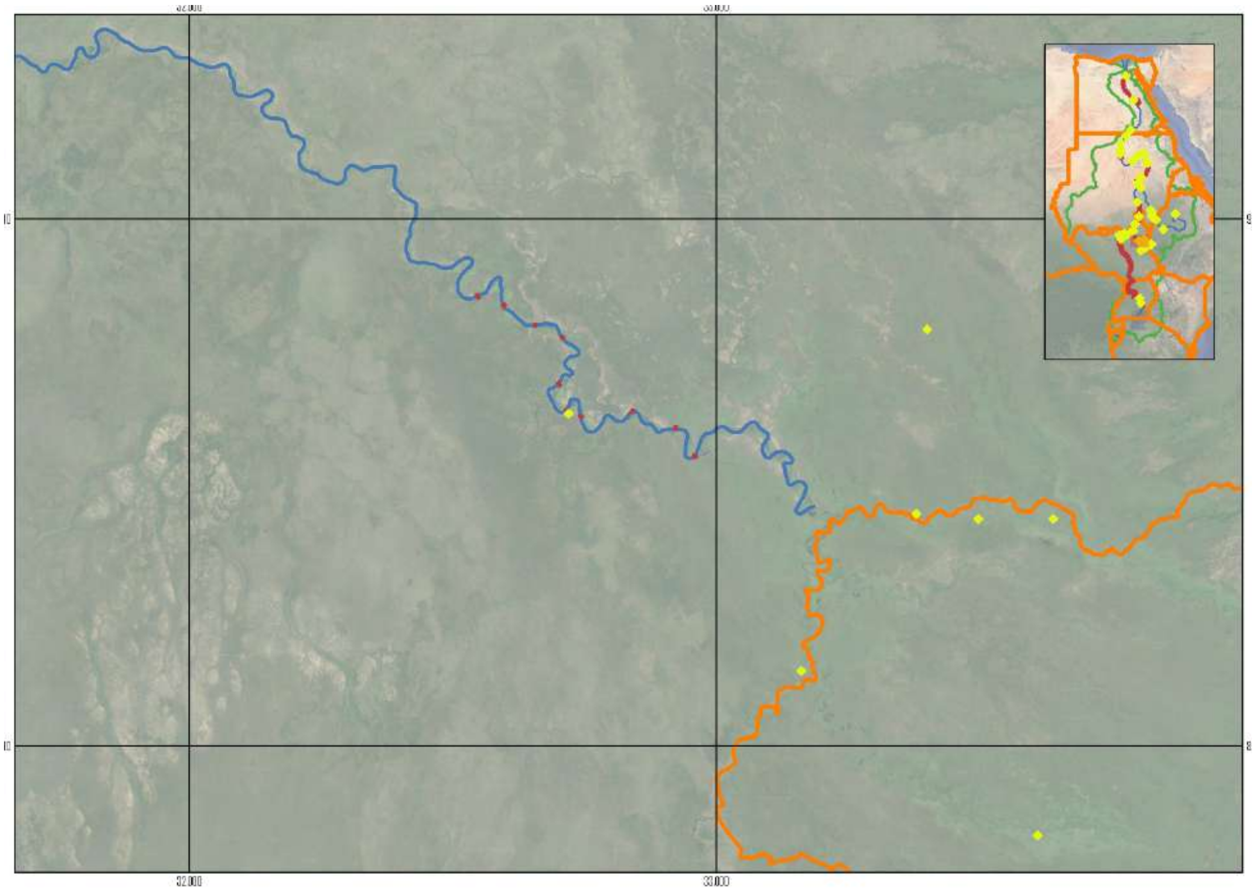


Figure 83. Cross-section and virtual stations (yellow diamonds) in representative section of Stretch 6 (Sobat)

The depth in the cross-sections was adjusted to the calibration of the virtual stations, considering the DEM and the plausibility of the results. In all the stretches the upstream boundary conditions are the flow defined in sections above while a normal depth boundary condition has been used downstream when the stretches are not connected.

The results for the flow-depth and velocity relationships were extracted and processed, as shown in Section 8.3 below.

8.2.1.6 Stretch 7. Bahr el Jebel

Information from a previous assessment undertaken by HYDROC was used for the White Nile between Juba and Malakal, including the Sudd. In this assessment a significant number of cross-sections was available, and in order to facilitate the process and the understanding of the results, the number of cross-sections was reduced (Figure 86).

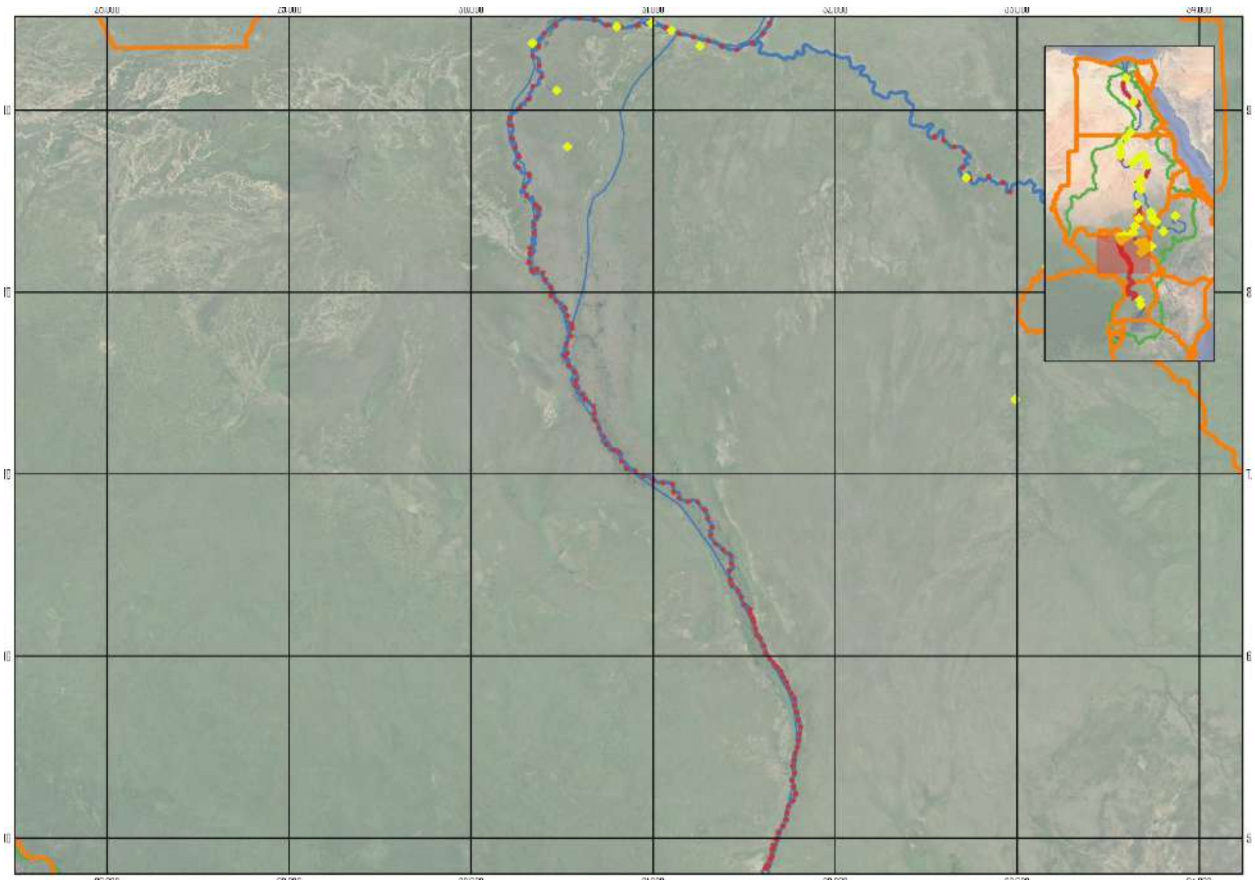


Figure 84. Cross-section and virtual stations (yellow diamonds) in Stretch 7 (Bahr el Jebel, Malakal to Juba)

The cross-sections were assessed, as well as the results yielded by the process. The results for the flow-depth and velocity relationships were extracted and processed, as shown in Section 8.3 below.

8.2.1.7 Stretch 8. Albert Nile

For the Albert Nile River, no cross-section data was available, and therefore the cross-sections had to be estimated. In this stretch a total of 22 cross-sections were estimated in order to get a proper representation of the stretch features. No virtual stations are present in this stretch.

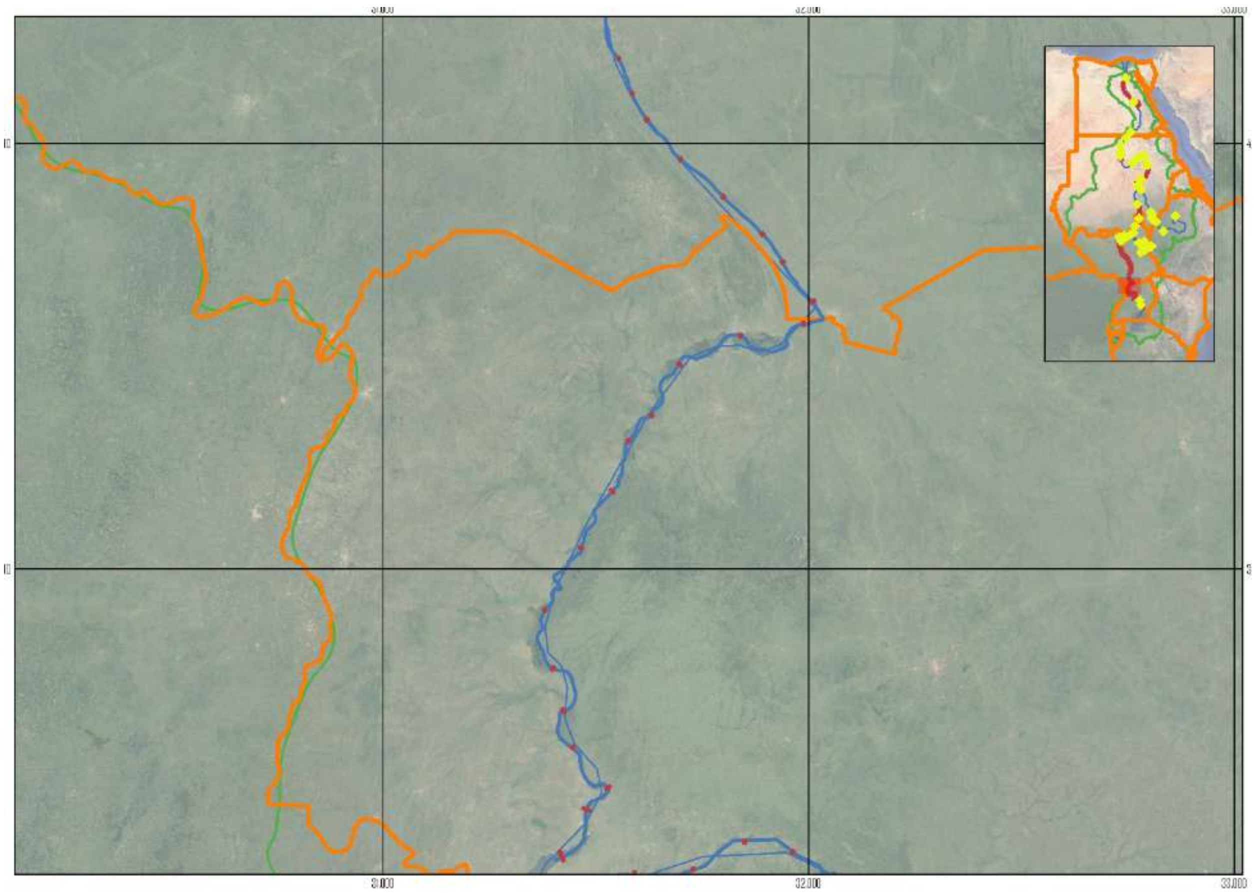


Figure 85. Cross-section in Stretch 8 (Albert Nile, Juba to Lake Albert)

The depth in the cross-sections was inferred using information from the DEM, plausibility in terms of the water content within the channel, and the slope. The results for the flow-depth and velocity relationships were extracted and processed, as shown in Section 8.3 below.

8.2.1.8 Stretch 10. Kyoga Nile

For the Kyoga River, no cross-section data was available, and therefore the cross-sections had to be estimated. In this stretch a total of 15 cross-sections were estimated in order to get a proper representation of the stretch features. No virtual stations are present in this stretch.

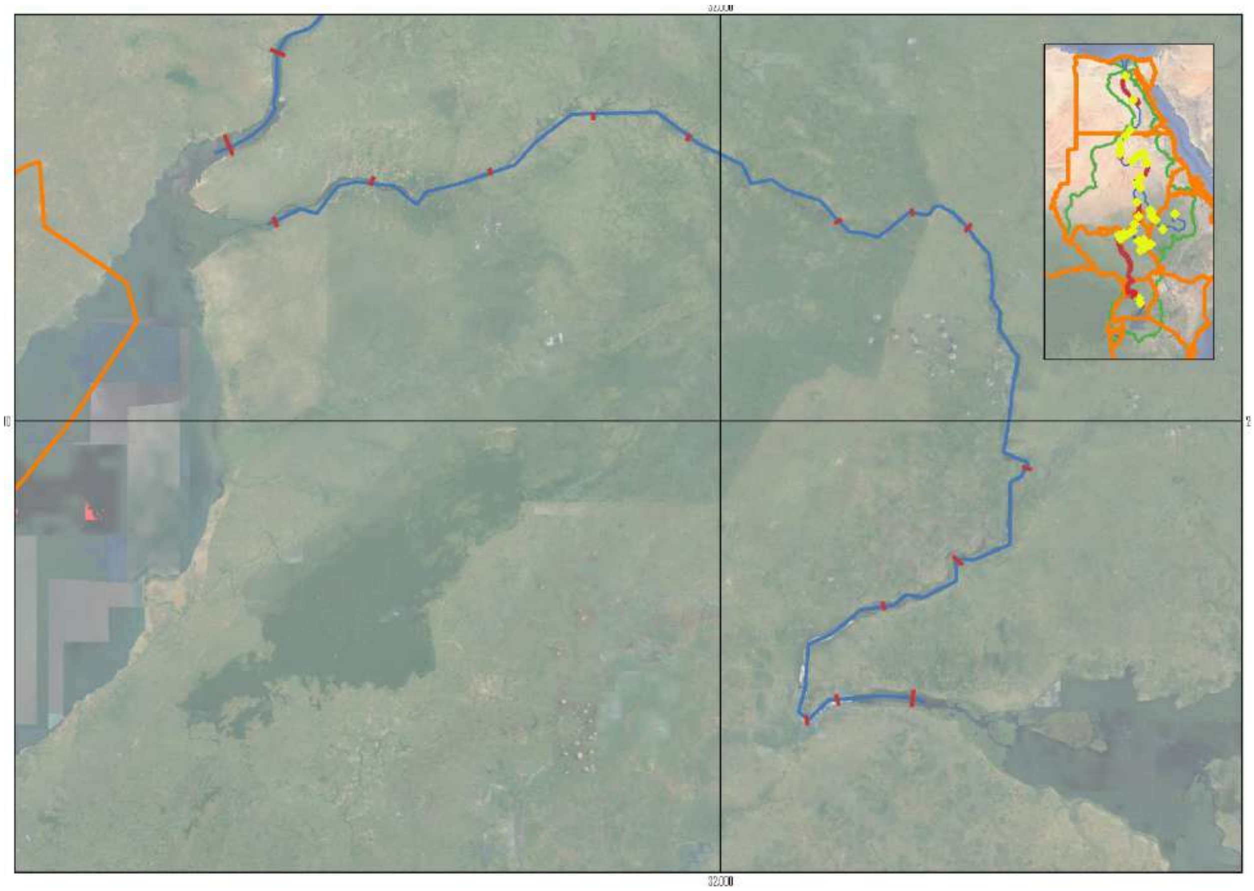


Figure 86. Cross-sections in Stretch 10 (Kyoga Nile, Lake Albert to Lake Kyoga)

The depth in the cross-sections was inferred using information from the DEM, plausibility in terms of the water content within the channel and the slope.

The results for the flow-depth and velocity relationships were extracted and processed, and are shown in Section 8.3 below.

8.2.1.9 Stretch 12. Victoria Nile

For the Victoria Nile, cross-section data was available, and therefore no cross-sections were digitized. In this stretch a total of 5 cross-sections were provided by the Nile Basin Initiative (NBI) and no further adjustments have been undertaken.

Figure 87. Cross-section and virtual stations (yellow diamonds) in Stretch 12 (Victoria Nile, Lake Kyoga to Lake Victoria)

The plausibility of the cross-sections and the results have been analysed and found to be plausible, so that cross-sections have not been further adjusted. The results for the flow-depth and velocity relationships were extracted and processed, as shown in Section 8.3 below.

8.3 Flow-depth/velocity matrix under standard (current) conditions (Option 0)

In this section the flow-depth-velocity results under standard (current) conditions are shown. As previously noted, the results have been processed per cross-section and per stretch. All the results in every cross-section have been assessed for plausibility, and the results have been averaged per stretch. The water depth has been calculated using the invert level of the cross-section and the water level calculations. An evaluation of these results with regards to navigability is provided in Section 8.5.

8.3.1 Stretch 1. Nile in Egypt

The resultsfor this stretch, including flow-depth relation and flow velocities, are shown in Table 29.

Table 29. Test values for water depth and velocity against discharge for Stretch 1

Scenario	Discharge (m^3/s)	Water Surface Elevation (m)	Water Depth (m)	Velocity (m/s)
1	532.00	39.96	1.72	0.30
2	760.00	40.35	2.12	0.41
3	1031.86	40.77	2.54	0.45
4	1303.71	41.14	2.91	0.49
5	1575.57	41.48	3.24	0.57
6	1847.43	41.79	3.56	0.60
7	2119.29	42.08	3.85	0.64
8	2391.14	42.36	4.13	0.67

9	2663.00	42.63	4.39	0.70
10	3461.90	43.35	5.11	0.78

8.3.2 Stretch 3. Nile in Sudan

The results for this stretch are shown in Table 30.

Table 30. Test values for water depth and velocity against discharge for Stretch 3

Scenario	Discharge (m^3/s)	Water Surface Elevation (m)	Water Depth (m)	Velocity (m/s)
1	266.00	344.25	1.05	0.44
2	380.00	344.51	1.29	0.48
3	1754.29	346.53	3.23	0.78
4	3128.57	347.91	4.57	0.95
5	4502.86	349.07	5.69	1.08
6	5877.14	350.10	6.68	1.19
7	7251.43	351.04	7.59	1.29
8	8625.71	351.94	8.45	1.38
9	10000.00	352.83	9.30	1.45
10	13000.00	354.47	10.87	1.60

8.3.3 Stretch 4. Blue Nile

The results for this stretch for the surveyed cross-sections are shown in Table 31.

Table 31. Test values for water depth and velocity against discharge for the surveyed cross-sections in Stretch 4

Scenario	Discharge (m^3/s)	Water Surface Elevation (m)	Water Depth (m)	Velocity (m/s)
1	28.00	447.27	1.88	0.62
2	40.00	447.59	2.20	0.70
3	1391.43	451.98	6.59	1.26
4	2742.86	453.31	7.92	1.54
5	4094.29	454.29	8.90	1.80
6	5445.71	455.13	9.74	2.01
7	6797.14	455.87	10.48	2.19
8	8148.57	456.54	11.15	2.34
9	9500.00	457.17	11.78	2.49
10	12350.00	458.33	12.94	2.77

The results for the artificial cross-sections are shown in Table 32

Table 32. Test values for water depth and velocity against discharge for the artificial cross-sections for Stretch 4

Scenario	Discharge (m^3/s)	Water Surface Elevation (m)	Water Depth (m)	Velocity (m/s)
1	28.00	377.18	0.29	0.17
2	40.00	377.25	0.37	0.18
3	1391.43	379.98	3.10	0.70
4	2742.86	381.50	4.62	0.93
5	4094.29	382.72	5.84	1.10
6	5445.71	383.77	6.89	1.23
7	6797.14	384.71	7.83	1.36
8	8148.57	385.57	8.69	1.46
9	9500.00	386.37	9.49	1.56

10	12350.00	387.90	11.02	1.75

As it can be seen, the flow requirements for the artificial sections of the Blue Nile are higher than for the surveyed sections. Although it is believed that surveyed data is more realistic and more confidence should be assigned to these data, in order to follow a conservative approach, the artificial data results will be used in further analysis. Alternatively e.g. a safety factor could have been used in order to obtain higher flow requirements, though there are no solid arguments for selecting the specific value of this safety factor.

8.3.4 Stretch 5. White Nile DS Malakal

The results for this stretch are shown in Table 33.

Table 33. Test values for water depth and velocity against discharge for Stretch 5

Scenario	Discharge (m^3/s)	Water Surface Elevation (m)	Water Depth (m)	Velocity (m/s)
1	210.00	381.23	3.00	0.28
2	300.00	381.90	3.66	0.32
3	600.00	383.64	5.37	0.43
4	900.00	385.01	6.71	0.51
5	1200.00	386.19	7.86	0.58
6	1500.00	387.23	8.88	0.64
7	1800.00	388.18	9.81	0.69
8	2100.00	389.06	10.67	0.74
9	2400.00	389.88	11.47	0.78
10	3120.00	391.89	13.49	0.86

8.3.5 Stretch 6. Sobat

The results for this stretch are shown in Table 34.

Table 34. Test values for water depth and velocity against discharge for Stretch 6

Scenario	Discharge (m^3/s)	Water Surface Elevation (m)	Water Depth (m)	Velocity (m/s)
1	7.00	391.50	0.31	0.11
2	10.00	391.56	0.37	0.12
3	187.14	393.13	1.94	0.39
4	364.29	394.07	2.88	0.51
5	541.43	394.81	3.62	0.60
6	718.57	395.45	4.26	0.67
7	895.71	396.02	4.83	0.74
8	1072.86	396.53	5.34	0.80
9	1250.00	397.01	5.82	0.86
10	1625.00	397.92	6.73	0.96

8.3.6 Stretch 7. Bahr ej Jebel

The results for this stretch are shown in Table 35

Table 35. Test values for water depth and velocity against discharge for Stretch 7

Scenario	Discharge (m^3/s)	Water Surface Elevation (m)	Water Depth (m)	Velocity (m/s)
1	210.00	442.28	2.90	0.59
2	300.00	442.72	3.35	0.65
3	671.43	444.02	4.73	0.78
4	1042.86	445.00	5.75	0.89

Scenario	Discharge (m³/s)	Water Surface Elevation (m)	Water Depth (m)	Velocity (m/s)
5	1414.29	445.86	6.65	0.98
6	1785.71	446.61	7.43	1.05
7	2157.14	447.31	8.15	1.12
8	2528.57	447.94	8.82	1.18
9	2900.00	448.55	9.46	1.23
10	3770.00	449.90	10.87	1.33

Looking at the above water depth yielded by the model, the currently reported short section of shallow water depths just downstream of Juba that does not allow barges to call at Juba port have seemingly not been captured by the model. Considering the broad scale approach covering the entire Nile basin in long stretches and the varying conditions within these stretches this is an inaccuracy that needs to be taken into account.

8.3.7 Stretch 8. Albert Nile

The results for this stretch are shown in Table 36.

Table 36. Test values for water depth and velocity against discharge for Stretch 8

Scenario	Discharge (m³/s)	Water Surface Elevation (m)	Water Depth (m)	Velocity (m/s)
1	210.00	589.76	1.65	0.56
2	300.00	590.15	2.04	0.62
3	571.43	591.08	2.97	0.76
4	842.86	591.83	3.72	0.85
5	1114.29	592.48	4.37	0.92
6	1385.71	593.05	4.95	0.99
7	1657.14	593.57	5.47	1.04
8	1928.57	594.05	5.94	1.10
9	2200.00	594.50	6.39	1.15
10	2860.00	595.48	7.37	1.26

8.3.8 Stretch 10. Kyoga Nile

The results for this stretch are shown in Table 37.

Table 37. Test values for water depth and velocity against discharge for Stretch 10

Scenario	Discharge (m³/s)	Water Surface Elevation (m)	Water Depth (m)	Velocity (m/s)
1	182.00	928.96	1.03	0.71
2	260.00	929.15	1.29	0.81
3	508.57	929.63	1.97	1.03
4	757.14	930.02	2.53	1.19
5	1005.71	930.35	3.02	1.32
6	1254.29	930.66	3.47	1.43
7	1502.86	930.94	3.87	1.53
8	1751.43	931.20	4.24	1.62
9	2000.00	931.44	4.59	1.71
10	2600.00	931.98	5.36	1.88

8.3.9 Stretch 12. Victoria Nile

The results for this stretch are shown in Table 38.

Table 38. Test values for water depth and velocity against discharge for Stretch 12

Scenario	Discharge (m³/s)	Water Surface Elevation (m)	Water Depth (m)	Velocity (m/s)
1	210.00	1086.47	3.70	0.89
2	300.00	1086.96	4.19	1.03
3	414.29	1087.48	4.71	1.18
4	528.57	1087.94	5.17	1.29
5	642.86	1088.34	5.58	1.37
6	757.14	1088.68	5.91	1.47
7	871.43	1088.98	6.21	1.55
8	985.71	1089.26	6.50	1.63
9	1100.00	1089.53	6.76	1.70
10	1430.00	1090.21	7.44	1.89

8.3.10 Summary

In the tables above, the relationships between flow and both stage and velocity has been provided. In all the cases the cross-sections are behaving as expected, with some minor locations where high speeds and/or high-water depths are predicted. As expected, the water velocities are generally higher along the upper Nile, with the changes in gradient in the Kyoga and Albert Nile leading to high velocities in respective locations. The velocities in the Victoria Nile and in the Blue Nile are predicted as significant, with values over 1.0m/s even for lesser flows (dry season), and around 2.0m/s for higher flows (wet season). Note has to be taken that due to the broad scale approach local obstacles or limitations may not have been captured individually in the model. This includes e.g. the cataracts, wrecks, or the sediment deposits just downstream of Juba.

Variability in water depth with different discharges are greater in the upper Nile, in both the White Nile and the Blue Nile. The water depth variations in the Nile downstream of the Khartoum confluence do not show a great range, with values mostly in between 1 and 5 metres.

8.4 Flow-depth/velocity matrix under dredged conditions (Option 1)

In this section, the results of Option 1 – Dredging scenario are presented. The cross-sections in all the stretches were modified to include a dredged trapezoidal section for navigation purposes. The assessment, following in the previous Option 0 results, is shown below.

8.4.1 Stretch 1. Nile in Egypt

The results for this stretch are shown in Table 39.

Table 39. Test values for water depth and velocity against discharge for Stretch 1

Scenario	Discharge (m³/s)	Water Surface Elevation (m)	Water Depth (m)	Velocity (m/s)
1	532.00	38.08	1.84	0.50
2	760.00	38.50	2.26	0.58
3	1031.86	38.93	2.70	0.65
4	1303.71	39.32	3.09	0.71
5	1575.57	39.67	3.44	0.76
6	1847.43	40.00	3.76	0.81
7	2119.29	40.30	4.07	0.86
8	2391.14	40.59	4.36	0.90
9	2663.00	40.86	4.63	0.94
10	3461.90	41.60	5.37	1.04

8.4.2 Stretch 3. Nile in Sudan

The results for this stretch are shown in Table 40.

Table 40. Test values for water depth and velocity against discharge for Stretch 3

Scenario	Discharge (m^3/s)	Water Surface Elevation (m)	Water Depth (m)	Velocity (m/s)
1	266.00	342.36	1.23	0.51
2	380.00	342.65	1.51	0.57
3	1754.29	344.90	3.65	0.87
4	3128.57	346.44	5.14	1.02
5	4502.86	347.70	6.36	1.15
6	5877.14	348.82	7.43	1.25
7	7251.43	349.82	8.40	1.35
8	8625.71	350.74	9.28	1.43
9	10000	351.64	10.14	1.51
10	13000	353.38	11.81	1.65

8.4.3 Stretch 4. Blue Nile

The results for this stretch are shown in Table 41.

Table 41. Test values for water depth and velocity against discharge for Stretch 4

Scenario	Discharge (m^3/s)	Water Surface Elevation (m)	Water Depth (m)	Velocity (m/s)
1	28.00	445.19	2.51	0.57
2	40.00	445.50	2.82	0.64
3	1391.43	450.16	7.48	1.32
4	2742.86	451.60	8.93	1.59
5	4094.29	452.67	9.99	1.80
6	5445.71	453.56	10.88	1.96
7	6797.14	454.32	11.64	2.12
8	8148.57	454.99	12.31	2.27
9	9500.00	455.61	12.94	2.42
10	12350.00	456.81	14.13	2.66

Following with the same approach as for the baseline (Option 0) analysis, in addition to the surveyed cross-sections located solely in the upstream reach of the assessed Blue Nile stretch, artificial cross sections were defined further below in order to utilize also downstream data. The results from this analysis are shown in Table 42.

Table 42. Test values for water depth and velocity against discharge for artificial cross-sections in Stretch 4

Scenario	Discharge (m^3/s)	Water Surface Elevation (m)	Water Depth (m)	Velocity (m/s)
1	28.00	375.22	0.36	0.16
2	40.00	375.30	0.44	0.18
3	1391.43	378.35	3.50	0.75
4	2742.86	380.03	5.17	0.98
5	4094.29	381.36	6.50	1.15
6	5445.71	382.50	7.64	1.29
7	6797.14	383.51	8.65	1.41
8	8148.57	384.43	9.57	1.52
9	9500.00	385.28	10.42	1.61
10	12350.00	386.89	12.03	1.79

8.4.4 Stretch 5. White Nile DS Malakal

The results for this stretch are shown in Table 43.

Table 43. Test values for water depth and velocity against discharge for Stretch 5

Scenario	Discharge (m^3/s)	Water Surface Elevation (m)	Water Depth (m)	Velocity (m/s)
1	210.00	381.23	3.00	0.28
2	300.00	381.90	3.66	0.32
3	600.00	383.64	5.36	0.43
4	900.00	385.01	6.71	0.51
5	1200.00	386.18	7.85	0.58
6	1500.00	387.22	8.87	0.64
7	1800.00	388.17	9.80	0.69
8	2100.00	389.05	10.65	0.74
9	2400.00	389.86	11.45	0.78
10	3120.00	391.87	13.47	0.86

8.4.5 Stretch 6. Sobat

The results for this stretch are shown in Table 44.

Table 44. Test values for water depth and velocity against discharge for Stretch 6

Scenario	Discharge (m^3/s)	Water Surface Elevation (m)	Water Depth (m)	Velocity (m/s)
1	7.00	390.15	0.66	0.20
2	10.00	390.24	0.74	0.23
3	187.14	392.58	3.09	0.45
4	364.29	393.82	4.33	0.58
5	541.43	394.76	5.27	0.67
6	718.57	395.53	6.04	0.74
7	895.71	396.19	6.70	0.80
8	1072.86	396.75	7.26	0.86
9	1250.00	397.26	7.77	0.91
10	1625.00	398.23	8.73	1.01

8.4.6 Stretch 7. Bahr el Jebel

The results for this stretch are shown in Table 45.

Table 45. Test values for water depth and velocity against discharge for Stretch 7

Scenario	Discharge (m^3/s)	Water Surface Elevation (m)	Water Depth (m)	Velocity (m/s)
1	210.00	441.85	3.48	0.70
2	300.00	442.34	3.97	0.73
3	671.43	443.81	5.48	0.76
4	1042.86	444.77	6.50	0.87
5	1414.29	445.61	7.38	0.97
6	1785.71	446.40	8.20	1.04
7	2157.14	447.11	8.93	1.11
8	2528.57	447.75	9.60	1.16
9	2900.00	448.37	10.24	1.21
10	3770.00	449.72	11.66	1.31

8.4.7 Stretch 8. Albert Nile

The results for this stretch are shown in Table 46.

Table 46. Test values for water depth and velocity against discharge for Stretch 8

Scenario	Discharge (m^3/s)	Water Surface Elevation (m)	Water Depth (m)	Velocity (m/s)
1	210.00	588.07	2.01	0.63
2	300.00	588.54	2.48	0.69
3	571.43	589.68	3.62	0.82
4	842.86	590.58	4.52	0.91
5	1114.29	591.34	5.28	0.98
6	1385.71	592.01	5.95	1.05
7	1657.14	592.62	6.56	1.11
8	1928.57	593.17	7.11	1.16
9	2200.00	593.68	7.62	1.20
10	2860.00	594.78	8.71	1.31

8.4.8 Stretch 10. Kyoga Nile

The results for this stretch are shown in Table 47.

Table 47. Test values of water depth and velocity against discharge for Stretch 10

Scenario	Discharge (m^3/s)	Water Surface Elevation (m)	Water Depth (m)	Velocity (m/s)
1	182.00	927.10	1.15	0.83
2	260.00	927.32	1.44	0.95
3	508.57	927.88	2.19	1.19
4	757.14	928.33	2.81	1.36
5	1005.71	928.72	3.35	1.50
6	1254.29	929.07	3.82	1.62
7	1502.86	929.39	4.26	1.72
8	1751.43	929.68	4.66	1.81
9	2000.00	929.96	5.04	1.89
10	2600.00	930.56	5.86	2.07

8.4.9 Stretch 12. Victoria Nile

The results for this stretch are shown in Table 48.

Table 48. Test values for water depth and velocity against discharge for Stretch 12

Scenario	Discharge (m^3/s)	Water Surface Elevation (m)	Water Depth (m)	Velocity (m/s)
1	210.00	1085.20	4.19	0.99
2	300.00	1085.76	4.74	1.13
3	414.29	1086.35	5.33	1.28
4	528.57	1086.86	5.84	1.40
5	642.86	1087.31	6.30	1.49
6	757.14	1087.73	6.71	1.57
7	871.43	1088.11	7.10	1.63
8	985.71	1088.47	7.45	1.68
9	1100.00	1088.77	7.75	1.75
10	1430.00	1089.51	8.49	1.92

8.5 Flow-navigation matrix

Based on the assessment in Section 8.1.7, considering uncertainties in the broad scale assessment and the fact that basically all barges have similar drafts, required water depths for navigation has been set to

- 2.0m for the White Nile, Blue Nile and Main Nile upstream of Aswan
- 3.0m for the Main Nile downstream of Aswan

A dedicated flow-barge type matrix is respectively not necessary, but a simple linkage of flow-depth relation is sufficient, with the above depth thresholds marking the respective flow thresholds under which navigation is possible. Based on this assessment, the minimum flow requirements for navigation for the different stretches have been assessed as shown in Table 49 for standard (current) conditions (Option 0) and in Table 50 for dredged conditions (Option 1).

Table 49: Minimum flow requirements under standard (current) conditions (Option 0) for the different river stretches for allowing navigation as well as observed flow ranges*

Stretch	**Required min water depth (m)**	**Required min flow (m3/s)**	**Observed flow range (for details see Section 8.1.4) (m^3/s)**	**Flow velocity at required min flow (m/s)**	**Flow velocity range (m/s) over full flow scenario range**
1 - Main Nile Egypt	3.0	1420	770 - 2700	0.53	0.30-0.78
2 - Lake Nasser	-	-	-	-	-
3 - Main Nile Sudan	2.0	920	380 - 12000	0.60	0.44-1.60
4 - Blue Nile Sudan	2.0	600	40 - 9600	0.50	0.62-2.77
5 - White Nile	2.0	210	300 - 2400	0.28	0.28-0.86
6 - Sobat	2.0	195	0 - 1300	0.42	0.11-0.96
7 - Bahr el Jebel	2.0	210	270 - 2900	0.59	0.59-1.33
8 - Albert Nile	2.0	298	300 - 2200	0.61	0.56-1.26
9 - Lake Albert	-	-	-	-	-
10 - Kyoga Nile	2.0	510	270 - 2000	1.05	0.71-1.88
11 - Lake Kyoga	-	-	-	-	-
12 - Victoria Nile	2.0	210	300 - 1100	0.89	0.89.1.89
13 - Lake Victoria	-	-	-	-	-

* Results shown in this table do not provide any judgement, but show the minimum requirements above which navigation will be possible on the Nile stretches.

Barge travel speeds have been assessed based on narrative evidence and reports of shipping companies and were found to be at a minimum of 4 m/s when loaded. Some barges, especially when empty, achieve significant higher speeds. Based on the assessment a 2 m/s threshold was set as flow velocity at which barges can still travel significant distances upstream per day, i.e. at 4-2=2 m/s, which equals about 80 km daylight travel distance. Based on our analysis, this value is only exceeded on the Blue Nile during the flood season. It can respectively be concluded that flow velocities will not be a limiting factor for barge transport on the Nile under standard conditions. The assessment has not considered individual limitations like e.g. the cataracts where higher flow velocities can be expected. Here technical solutions need to be found.

Table 50: Minimum flow requirements under dredged conditions (Option 1) for the different river stretches for allowing navigation as well as observed flow ranges*

Stretch	**Required min water depth (m)**	**Required min flow (m3/s)**	**Observed flow range (for details see Section 8.1.4) (m^3/s)**	**Flow velocity at required min flow (m/s)**	**Flow velocity range (m/s) over full flow scenario range**
1 - Main Nile Egypt	3.0	1300	770 - 2700	0.70	0.50-1.04
2 - Lake Nasser	-	-	-	-	-
3 - Main Nile Sudan	2.0	620	380 - 12000	0.50	0.51.1.65
4 - Blue Nile Sudan	2.0	500	40 - 9600	0.51	0.57-2.66

5 - White Nile	2.0	200	300 - 2400	0.26	0.28-0.86
6 - Sobat	2.0	100	0 - 1300	0.3	0.20.1.01
7 - Bahr el Jebel	2.0	200	270 - 2900	0.6	0.70-1.31
8 - Albert Nile	2.0	210	300 - 2200	0.63	0.63-1.31
9 - Lake Albert	-	-	-	-	-
10 - Kyoga Nile	2.0	495	270 - 2000	1.15	0.83-2.07
11 - Lake Kyoga	-	-	-	-	-
12 - Victoria Nile	2.0	210	300 - 1100	0.99	0.99-1.92
13 - Lake Victoria	-	-	-	-	-

* Results shown in this table do not provide any judgement, but show the minimum requirements above which navigation will be possible on the Nile stretches.

Overall, it is observed that under dredged conditions less flow is necessary to allow for navigation. as the dredged channel is more efficiently providing the necessary conditions.

8.6 Lake level variations

Lake level variations for Lake Nasser, Lake Albert, Lake Kyoga, and Lake Victoria are shown in the following graphs.

8.6.1 Lake Nasser

Lake Nasser shows significant fluctuations with a range of more than 12m which is typical for reservoirs. Nevertheless, next to the inter-annual fluctuations also intra-annual fluctuations are clearly related to the seasonal Nile flow. Port operation is generally difficult under such conditions requiring significant efforts for maintaining port functionality. At Lake Nasser this has been solved through the construction of sloping piers that extend significantly into the reservoir and at high water levels are partly submerged. Lake level fluctuations are respectively no hindrance in port operation at Lake Nasser.

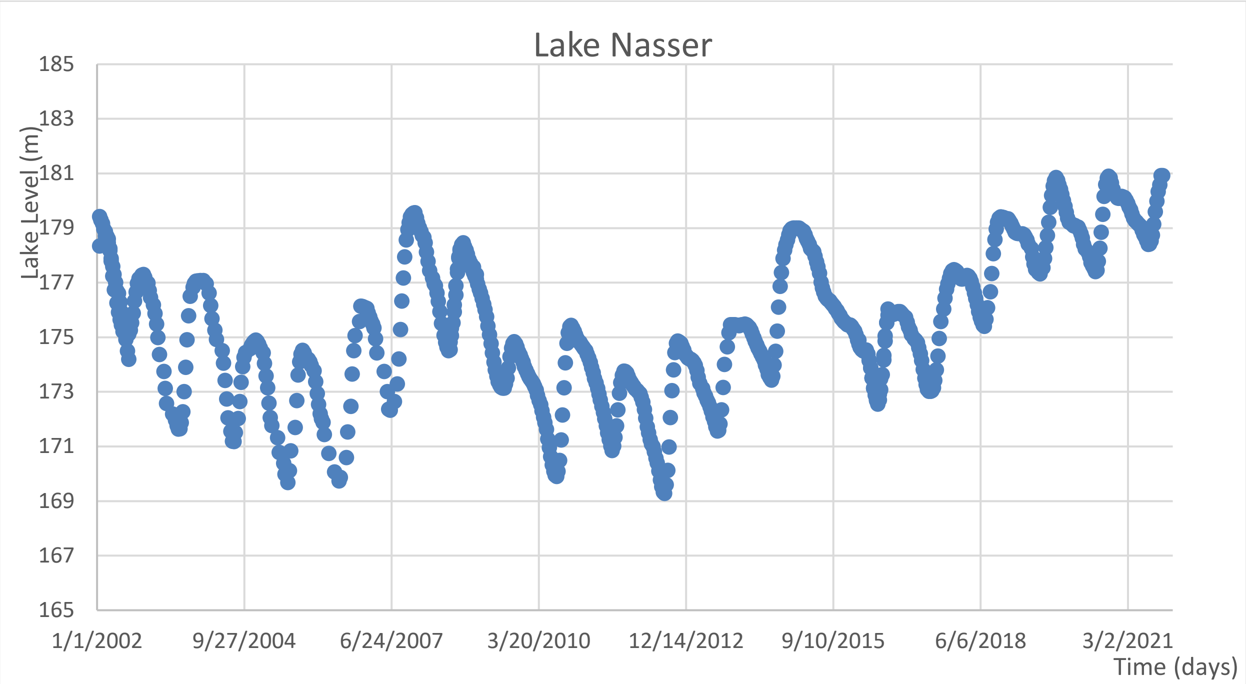


Figure 88. Lake Nasser level variations between 2002 and 2021, based on TOPEX/Poseidon, Jason-1, OSTM/Jason-2, and Jason-3 satellite observations

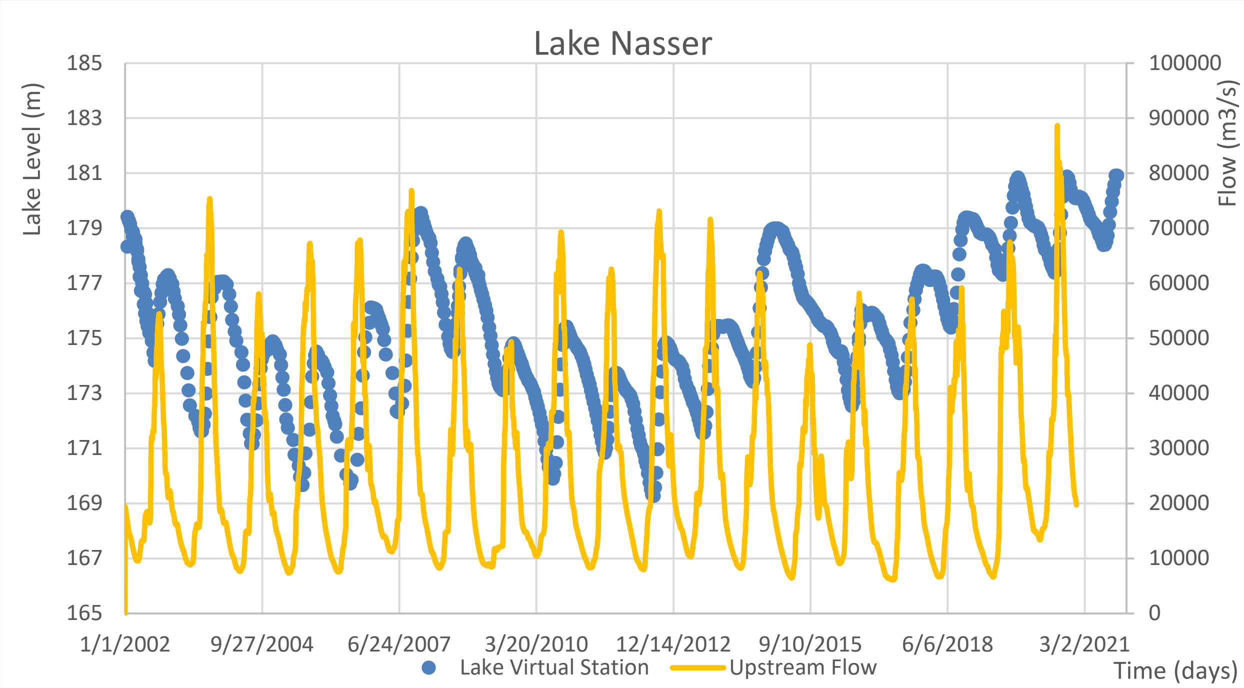


Figure 89: Lake Nasser virtual station levels (https://dahiti.dgfi.tum.de/en/210/time_series/) and discharge (from GloFAS, https://www.globalfloods.eu/) upstream of the lake for period 2002-2021

Lake levels and inflows at Lake Nasser do not correlate linearly and can respectively not be linked. Lake levels at Lake Nasser are anyhow not a limiting factor as port functionality has been assured through constructive measures.

8.6.2 Lake Albert

Water level fluctuations in Lake Albert are in the range of 5m, having respective impacts on port operations. Figure 92 shows the water levels data from 2002 until present. As it can be observed, while a yearly variation can be observed, the water level has risen in the last years, as it is the case for both Lake Victoria and Lake Kyoga upstream.

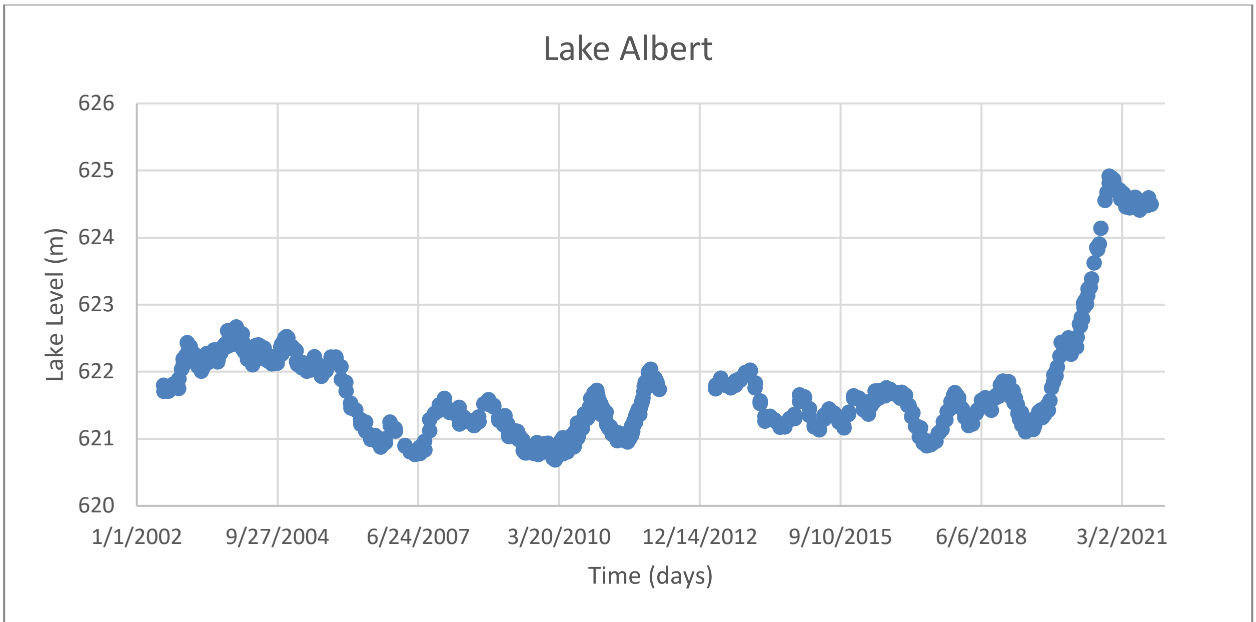


Figure 90. Water level variations in Lake Albert between 2002-2021 (from https://dahiti.dgfi.tum.de/en/85/)

As it can be observed below that there is a high correlation between the levels in both Lake Kyoga and Lake Victoria with levels in Lake Albert, as the outflow of Lake Victoria at Jinja is the main driver for the downstream hydrology. In terms of flow information, the data from GloFAS upstream of the lake have been compared with the water level in Lake Albert (Figure 93).

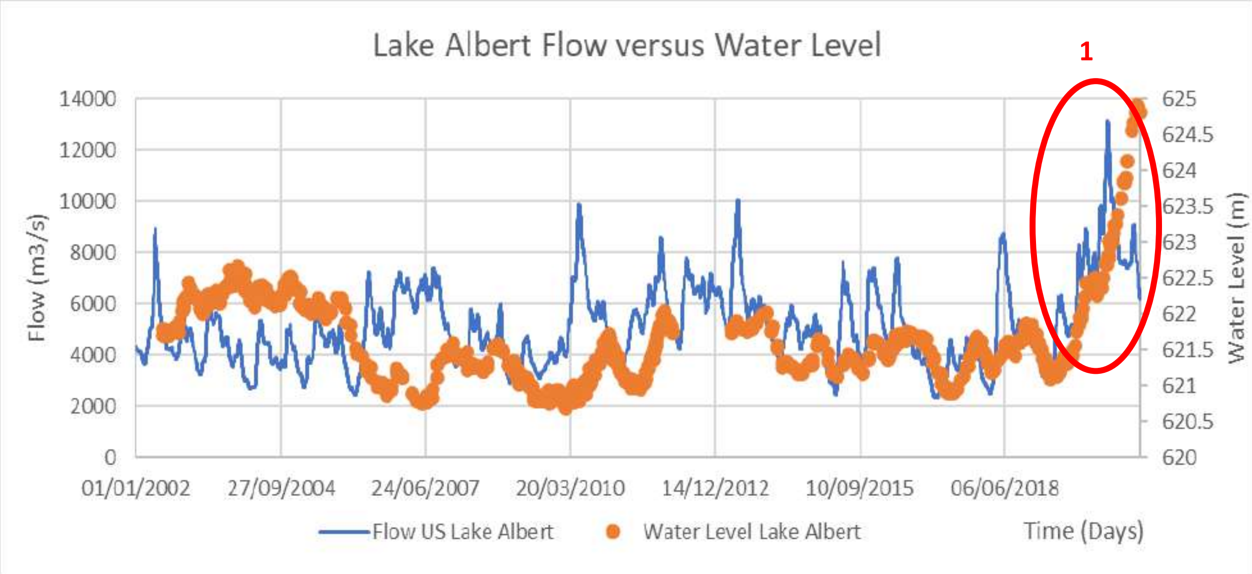


Figure 91. Water level and inflow of Lake Albert

The relationship between these two variables (flow and water level) was analysed (). While there is some relationship between the input flow and the water level on some occasions, no significant relationship between the flow and the water level could be identified.

The increasing trend of water level and inflow for Lake Albert from the GloFAS graph has been cross-checked and confirmed via online media outlets. According to the media coverage[83], Lake Albert water level started rising in mid-2019 and since then, thousands of people were displaced due to floods (see highlighted peak "1" in Figure 93). Additionally, in 2020, over 12,000 people in Ntoroko district were displaced when Lake Albert flooded and affected a considerable part of Kanara sub-county.[84]

Results show, that when correlating inflows with lake water levels, only limited correlation is observed. Due to damping effects, vegetation blockage, etc. potential respective relations may not be visible.

Based on reports received from navigation operators on Lake Albert, water levels are currently not a limiting factor as beaches are used as landing sites, hence no fixed infrastructure with defined levels are used. For future planning and development of ports anyhow historic water level fluctuations and the related flow rates should be taken into consideration. As an indicator, the recent very high lake levels may be seen as indicator for undesired conditions based on the reported high number of flooding and displacement cases of the local population. Respectively the recommended desirable water level range in Lake Albert has been defined as 621.0-622.5masl.

8.6.3 Lake Kyoga

Water level fluctuations in Lake Kyoga are in the range of four meters. Port operations are difficult under these conditions.

[83] NTVUganda, 2021 - https://www.youtube.com/watch?v=aPWwaaW_6ww
[84] NTVUganda, 2020 - https://www.youtube.com/watch?v=GPoSis1eTqQ

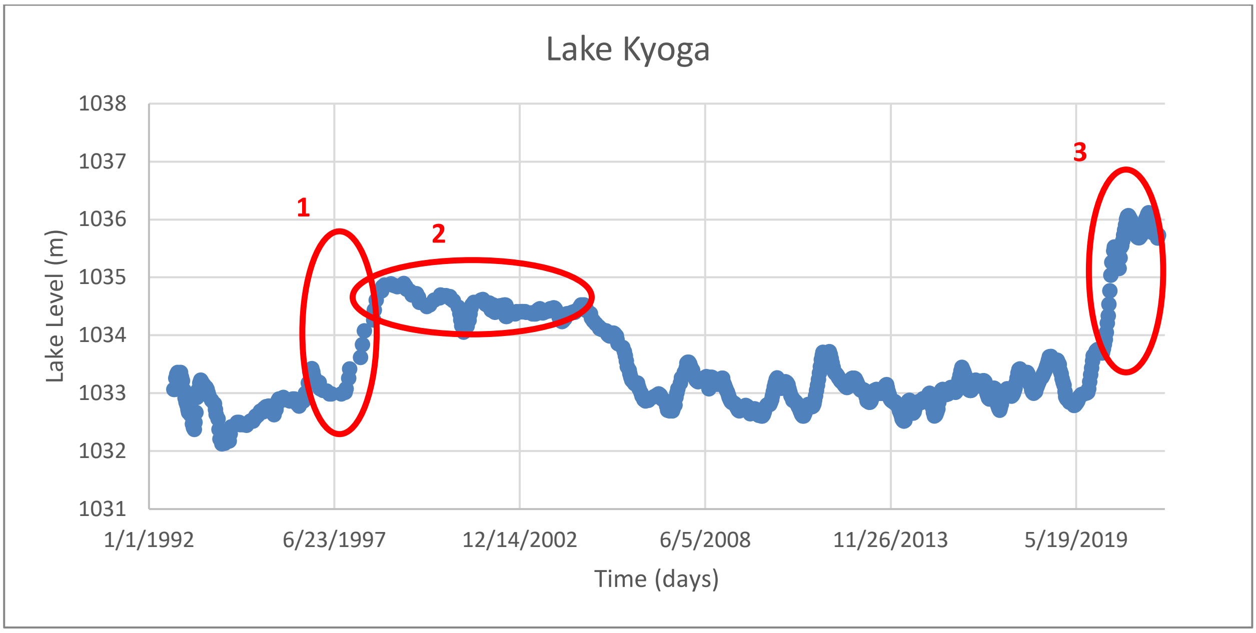


Figure 92. Lake Kyoga level variations between 1992 and 2021. Data based on TOPEX/Poseidon, Jason-1, OSTM/Jason-2, and Jason-3 satellite observations

Like for Lake Albert, the water level and the flow have been compared from a graphical point of view (Figure 94), where no clear pattern could be observed.

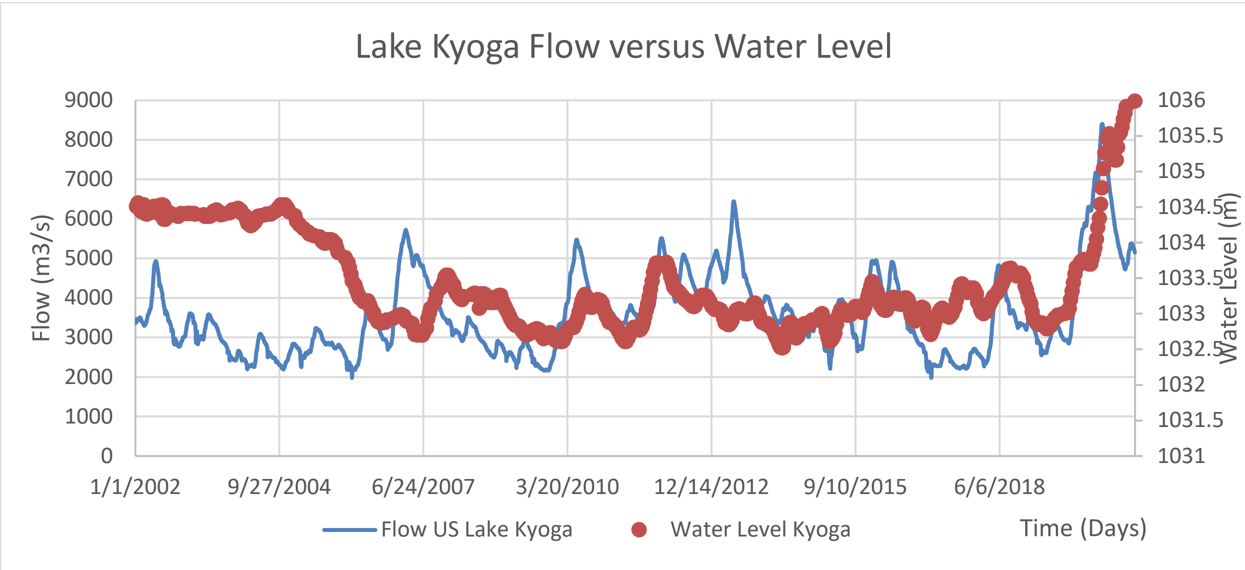


Figure 93: Lake Kyoga flow and water level

Furthermore, it was attempted to establish a relationship between the flow and the water level analysing all the different instances where there are simultaneous data (Figure 95). No significant relationship could be established.

The heavy floods caused by the 1997 El Niño event – when the water level of Lake Kyoga rose by 2 metres – and the effects of vegetation blockage[85] formed in 1998, are highlighted in Figure 94 as "1".[86] The vegetation blockage removal (2000-2007)[12], when water level of Lake Kyoga had a constant (and high) level is highlighted as "2".

[85] Climate change and water resources in Uganda: potential impacts and response strategies

[86] Pilot Integrated Ecosystem Assessment of the Lake Kyoga Catchment Area, 2008

Additionally, the water level increase from 2021 is confirmed by the floods which occurred in the region (this is highlighted as "3")[87], Amolatar being one of the most affected districts. The same source confirms that, due to the water level rising of Lake Kyoga, in 2020, over 8,700 people were displaced from the flood-prone areas of the lake.

As for Lake Albert, there have been no solid statements from navigation- or port operators about water level limits for operability. Improvised landing sites are being used to accommodate changing lake water levels. In the absence of solid information, the historic range of flows have been used as a proxy t establish suitable lake level limits, further considering the rather shallow lake bathymetry. Respectively the recommended desirable water level range in Lake Kyoga has been defined as 1032.5-1034.5masl.

8.6.4 Lake Victoria

Water level fluctuations in Lake Victoria are in the range of three meters. Port operations are difficult though manageable under these conditions when structures are respectively planned and maintained.

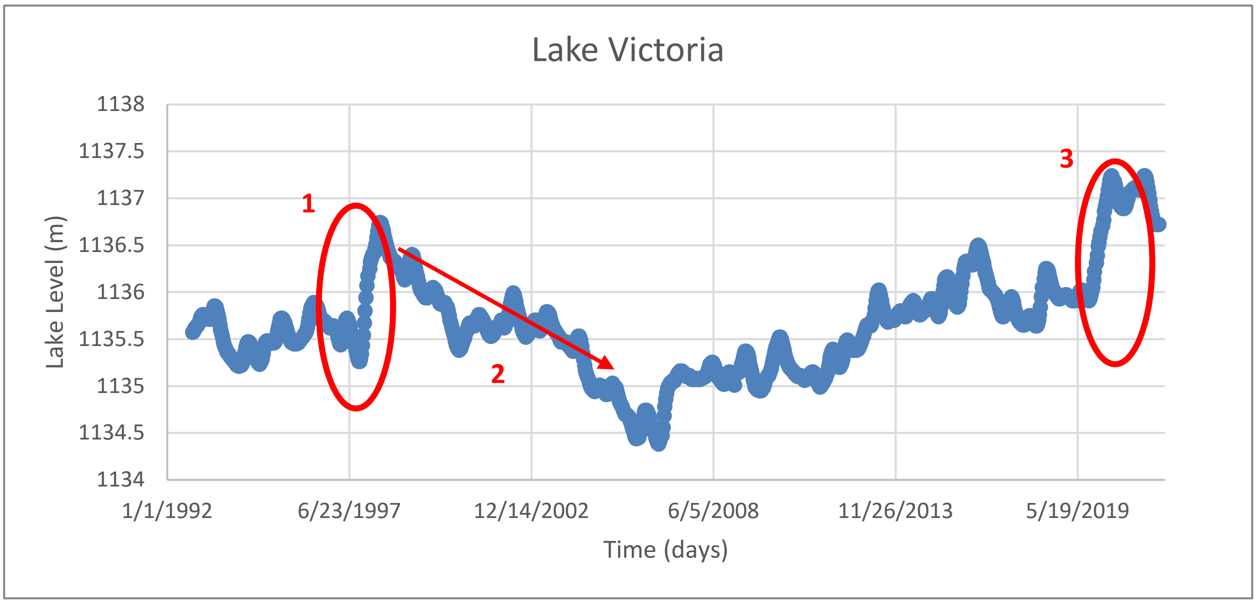


Figure 94. Lake Victoria level variations between 1992 and 2021 based on TOPEX/Poseidon, Jason-1, OSTM/Jason-2, and Jason-3 satellite observations

https://ipad.fas.usda.gov/cropexplorer/global_reservoir/gr_regional_chart.aspx?regionid=eafrica&reservoir_name=Victoria_1&lakeid=000314

The low water period during the beginning of the century is clearly visible in the graph. During that time ports could not fulfil their service functions, as water levels were too low and vessels could not enter the ports or could not use the port facilities due to high quay walls. At the current stage lake water levels are high with full accessibility but with rather a risk for port flooding.

The water level variations are confirmed by:

- The El Niño rains of 1997-1998[88] (1)
- Limited precipitation on the lake (1998-2004)[88] (2)
- Extreme rainfall recorded in 2020[89] (3)

[87] https://floodlist.com/africa/uganda-kasese-amolatar-floods-july-2021
[88] Lake Victoria Water Levels (2005)
[89] Thomas Reuters Foundation, 2020 https://news.trust.org/item/20200819141141-rb3c8

Lake Victoria receives inflow from diffuse sources (Mara, Kagera, smaller rivers), as well as significant contributions from rainfall on its surface. The outflow from Lake Victoria, while controlled by Owen Falls Dam, is governed by the 'agreed curve' that define outflows to water level measurements at Jinja station in order to mimic the natural outflow from pre-dam times.

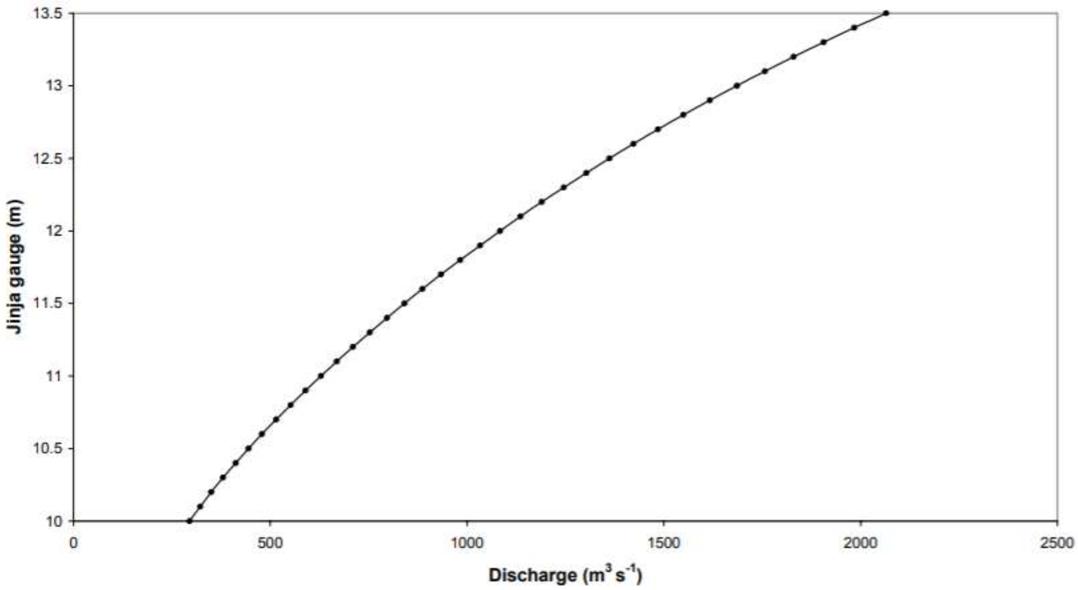


Figure 95. The "Agreed Curve" relating Jinja gauge level and lake outflow (after Hydraulics Research Station, 1966)

The values from this curve have been extracted and the following water level and flow matrix can be considered (Table 51). However, there have been cases that the agreed curve has not been followed and more water than agreed has been released by Owen Falls Dam. leading to dropping water levels in the lake with at the same time higher outflows than planned as per the curve.

Table 51: Discharge and water level based on the 'Agreed Curve'

Discharge (m3/s)	Water Level (m)
375	10
450	10.5
600	11
800	11.5
1050	12
1500	12.7
1700	13
2050	13.5

Navigation operators have provided information regarding the usability of the port facilities in Kisumu and Port Bell. Specifically, ports are expected to be usable with water levels up to near quay wall level. For lower levels no restrictions have been recorded. Respectively the recommended desirable water level range in Lake Victoria has been defined as 1134.5-1137.5 masl.

9. Plausibility checks

In order to ensure the confidence on the results, a plausibility check per assessed stretch has been undertaken. Within this plausibility check the information included in the model and the results were assessed.

Stretch 1. Nile in Egypt

No surveyed cross-section information was available in this stretch, and therefore artificial cross-sections were derived. A total of 17 cross-sections were created in this stretch in order to represent the conditions and the variability of the stretch. In the figures below the location of the cross-section and a longitudinal profile are presented.

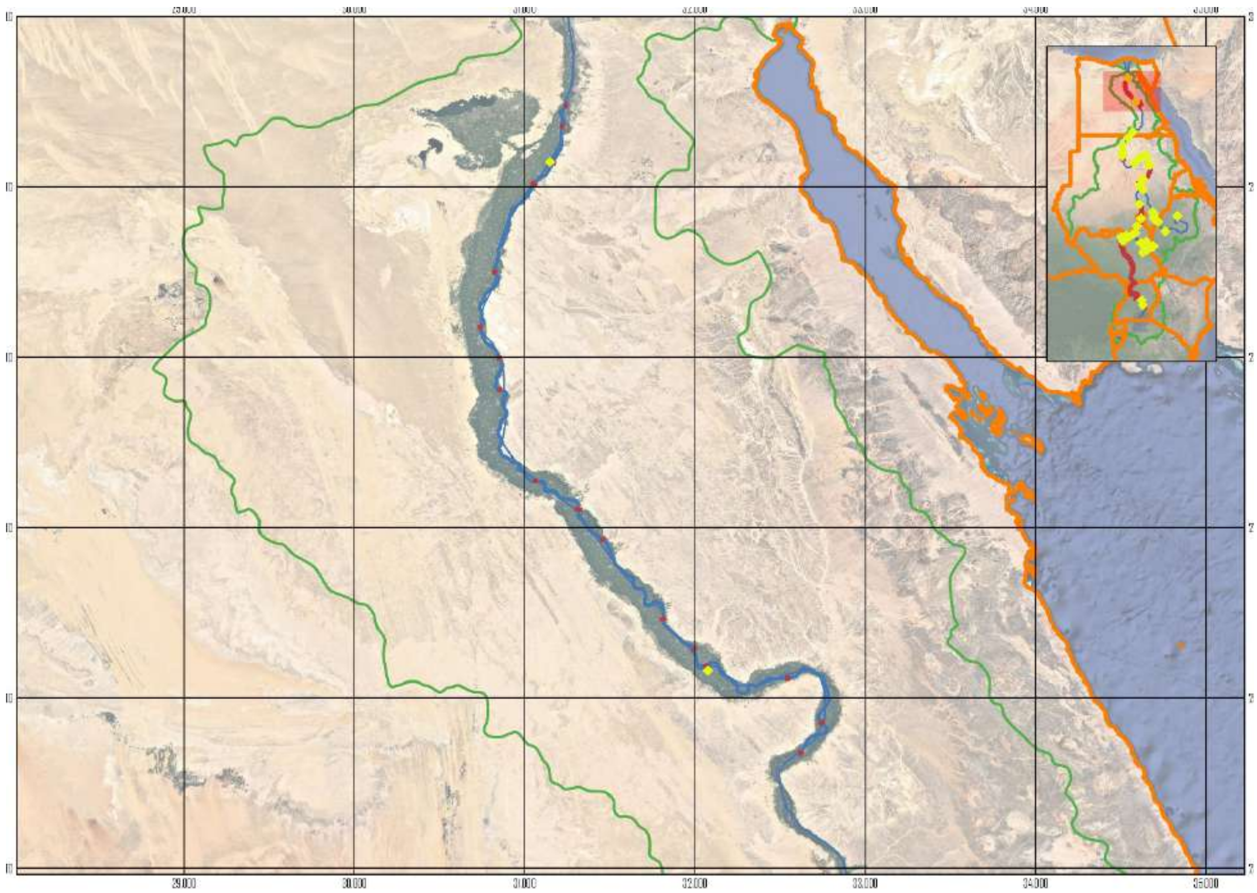


Figure 96. Cross-section location

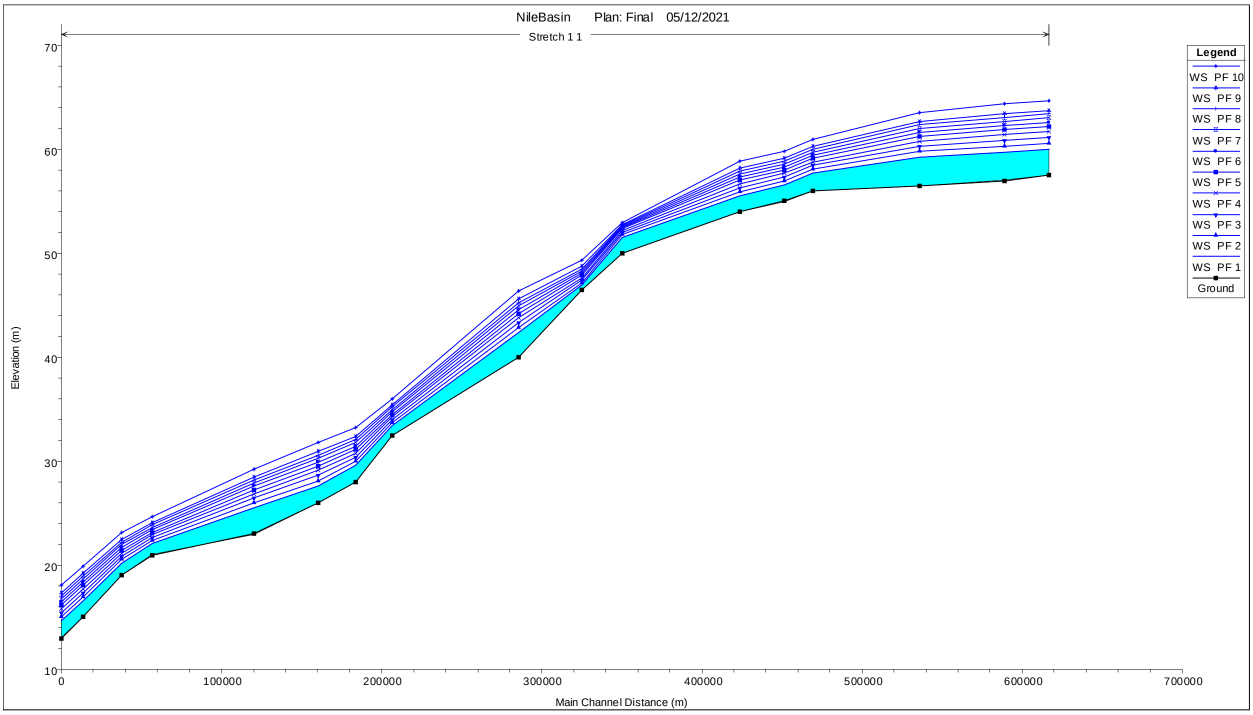


Figure 97. Longitudinal profile

Within the Main Nile in Egypt, the minimum water depth requirements are set at 3m for navigation. The corresponding flow requirements are 1300m^3/s. The cross-sections for this stretch have been defined, as per all the other stretches, considering the width of the river, the topography and also any other limitation that may have an impact on the navigability. The cross-sections defined and the results are sensible from a hydraulic modellng point of view, and therefore they are considered plausible, especially regarding the water depth and flow requirements. No other constraints need to be considered in this case, and therefore no additional safety factor is recommended.

Stretch 3. Nile in Sudan

For the Man Nile in Sudan, two different sets of cross-sections have been used. Figures 100-101 below show the location of the cross-sections and the longitudinal profile of the stretch. A total of 26 cross-sections were used, including five surveyed ones. There is no information regarding the period when these data was acquired, but it is believed to be from the beginning of this century.

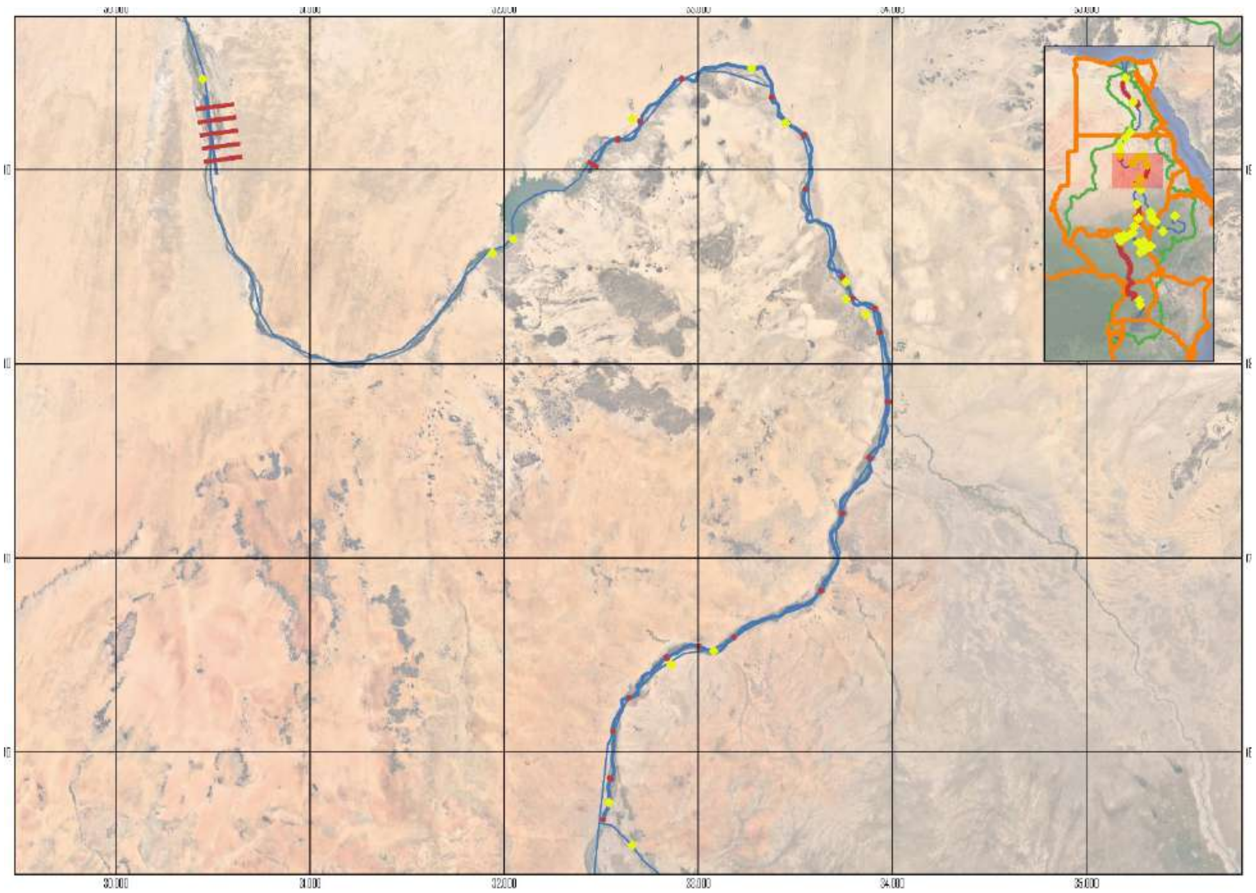


Figure 98. Cross-section location

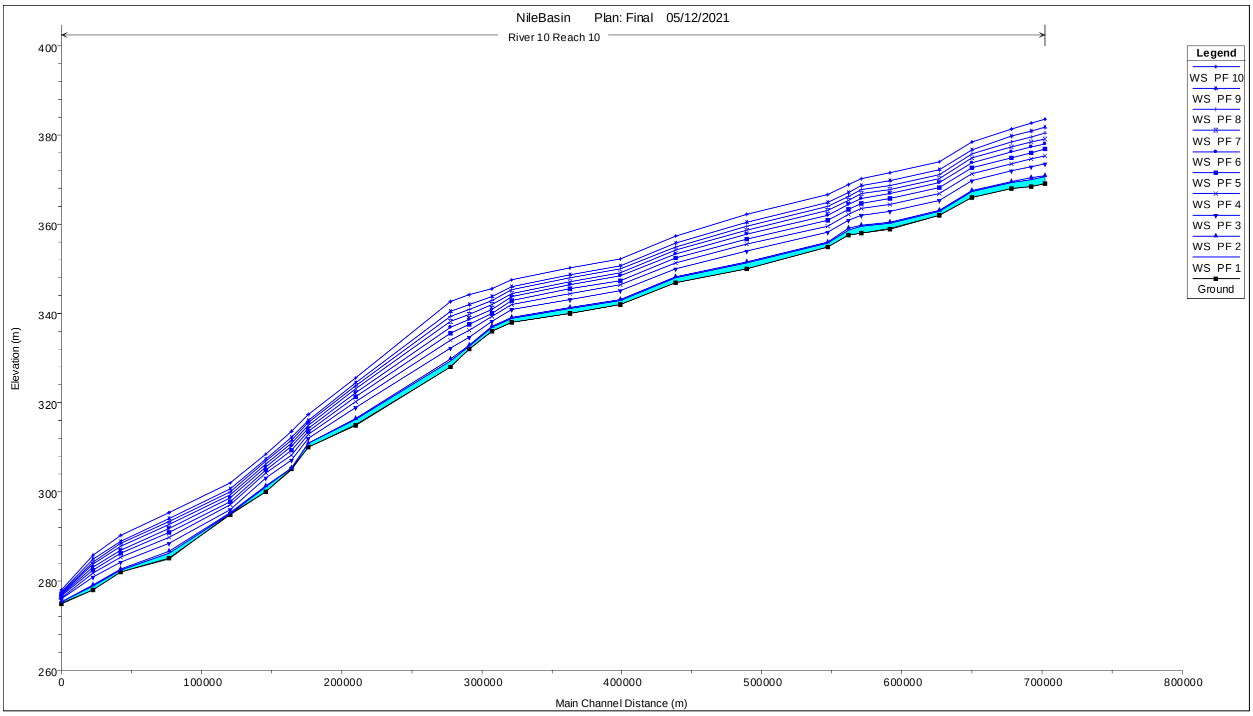


Figure 99. Longitudinal profile

The water depth requirements are 2m, corresponding to a flow of 920m^3/s. In this case, the information from the surveyed cross-sections and the artificial ones have been combined to increase the robustness of the results. The simulation results are plausible for both sets of data, and therefore the results are considered plausible. A safety factor of 10% would be recommended here, considering that the water depth requirement is less than in Egypt and given the uncertainty on the channel depths in this area. No other constraints from a hydrological or meterorological point of view are envisaged.

Stretch 4. Blue Nile

A similar approach to the Main Nile in Sudan has been followed for the Blue Nile, where information from surveyed cross-sections and artificial ones have been used, as it can be seen in the figures below, with a total of 18 cross-sections. In this case, however, just the information from the artificial cross-sections have been used for the results for conservative purposes, as there was a significant difference between the surveyed and the rectangular-box cross sections. Also, the surveyed cross-sections were located in the upstream end of the Blue Nile in Sudan only, and they may not be representative for the whole stretch of the Blue Nile in Sudan.

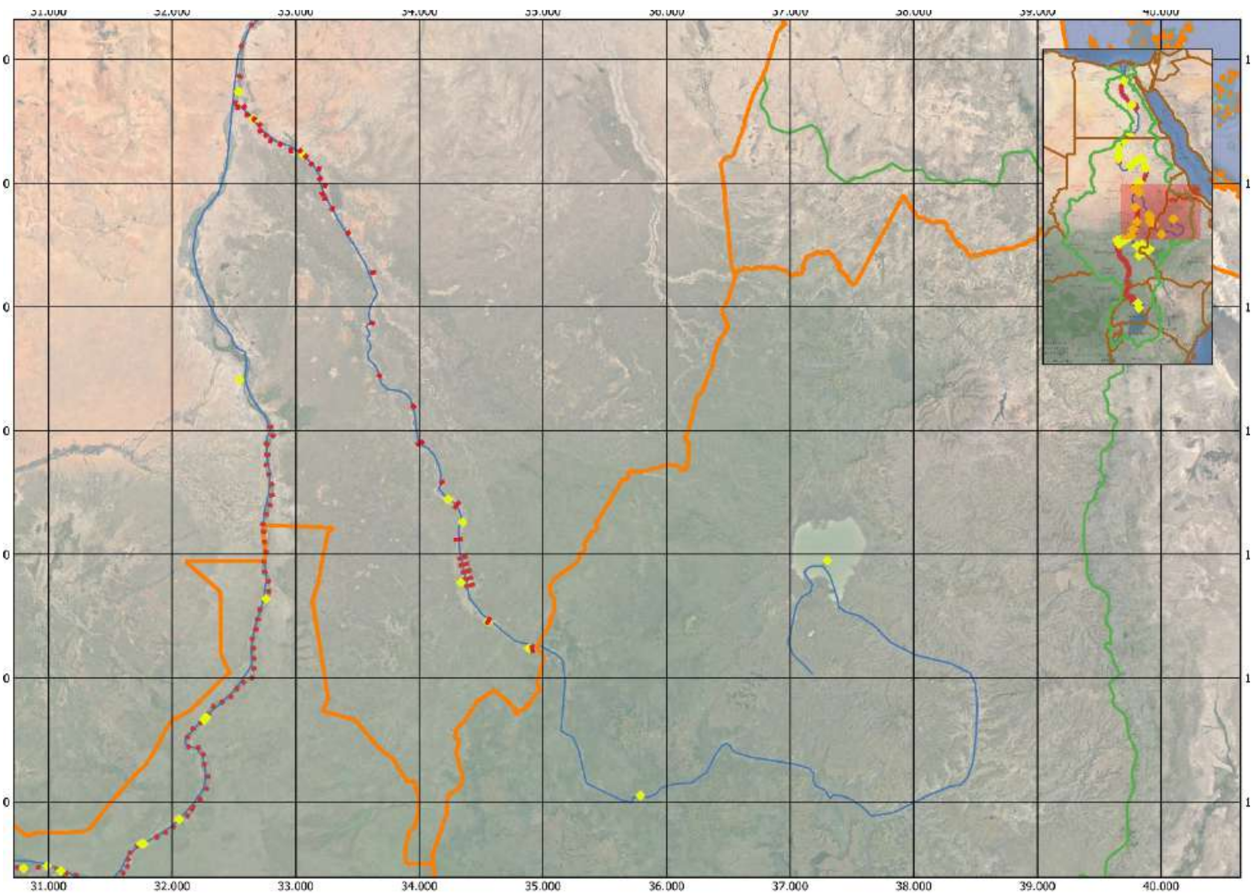


Figure 100. Cross-section location

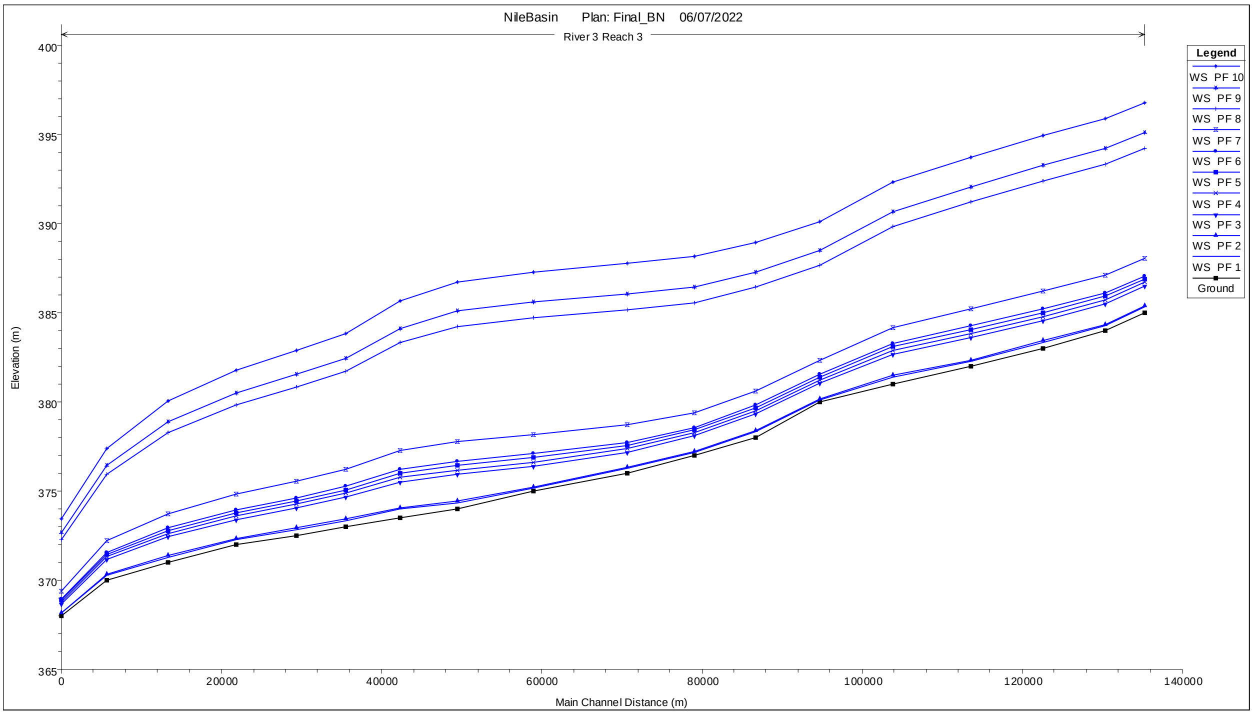


Figure 101. Longitudinal profile

The required flow to keep the 2m water depth requirement is 600m^3/s. In terms of topography and/or hydrological input, there are no additional constraints. It has been observed, however, that the channel depth in this stretch had to be modified slightly in order to ensure a natural gradient, and due to the uncertainty that this may create, a safety factor of 20% addition to the flow is recommended.

Stretch 5. White Nile DS of Malakal

The White Nile downstream of Malakal has been defined with information from previous assessments by HYDROC in the region, and a total of 55 cross-sections have been used. These cross-sections are not surveyed, but estimated ones.

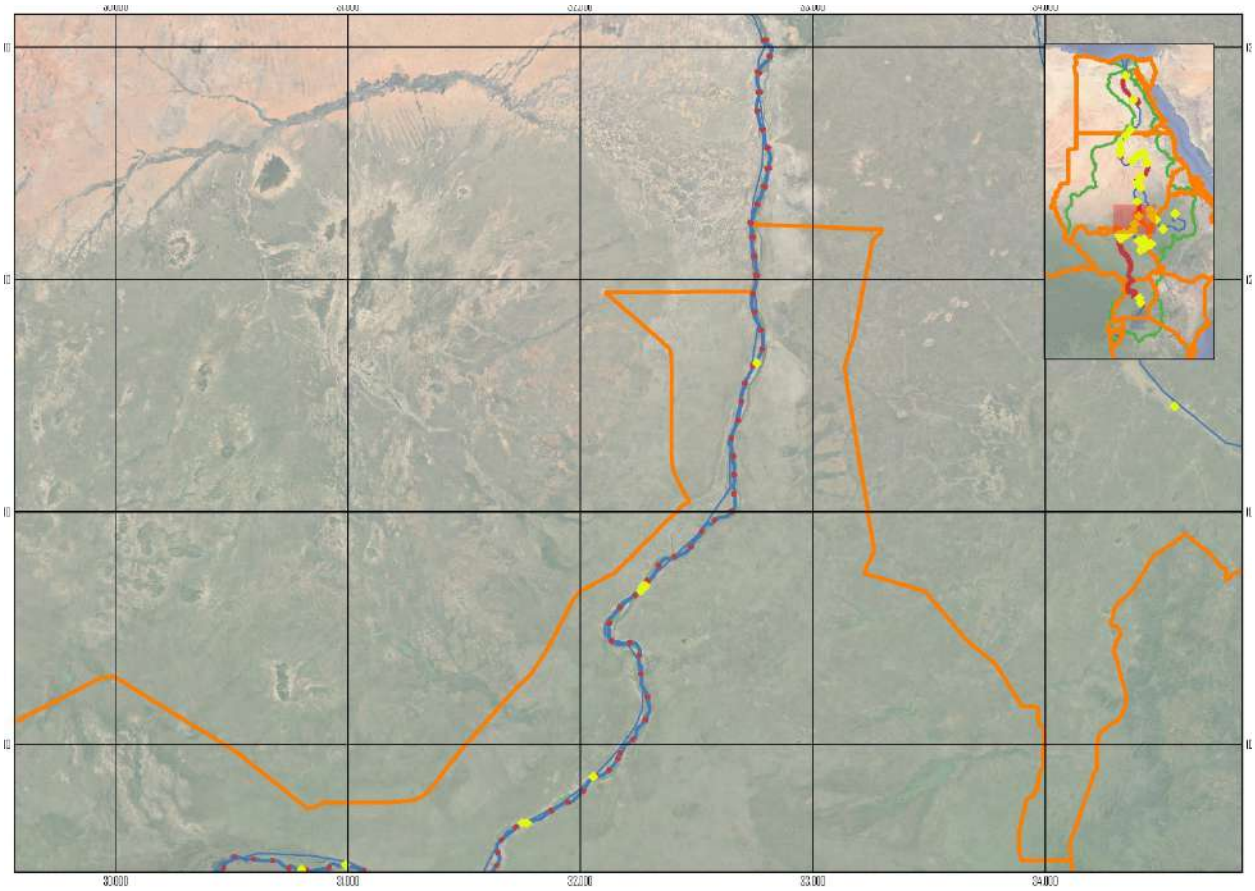


Figure 102. Cross-section location

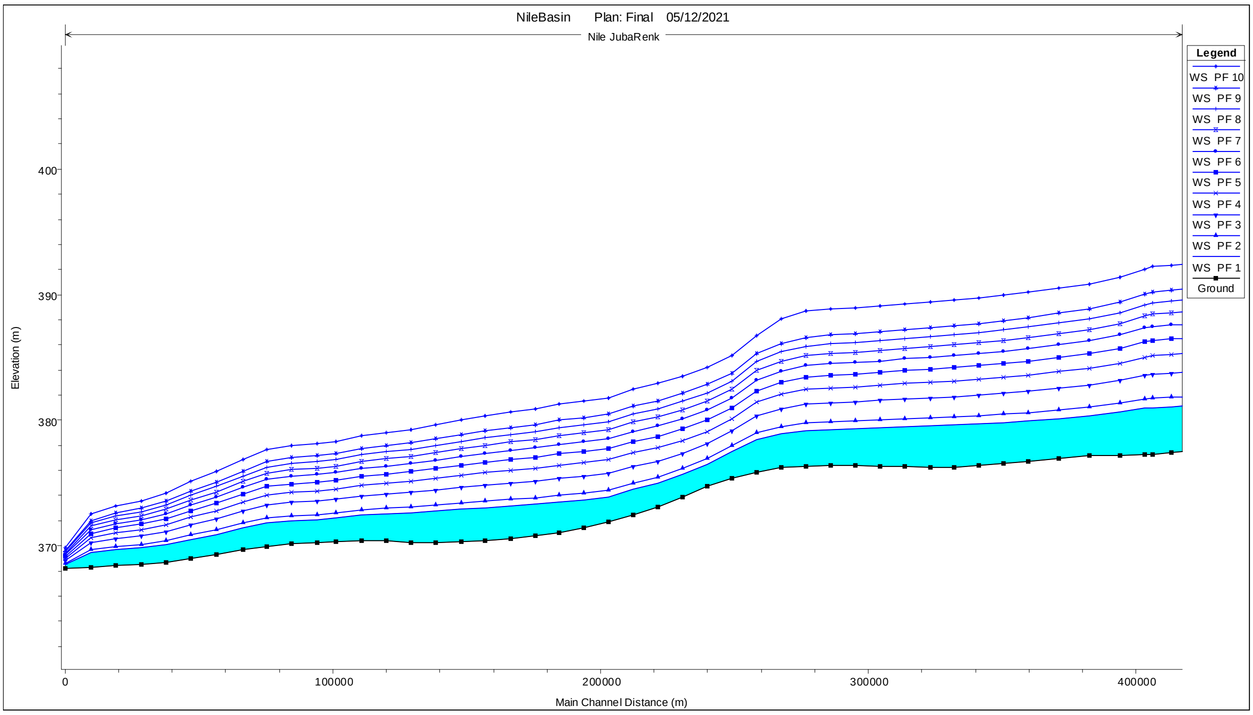


Figure 103. Longitudinal profile

The information from the cross-sectons from previous assessments is more realistic than the rectangular-box cross-sections, because more data and resources could be used for this assessment. Thus it is not believed that a safety factor should be applied for this stretch.

Stretch 6. Sobat

The Sobat stretch was defined with 10 cross-sections, to represent the flow dynamics in this river section for navigability purposes.

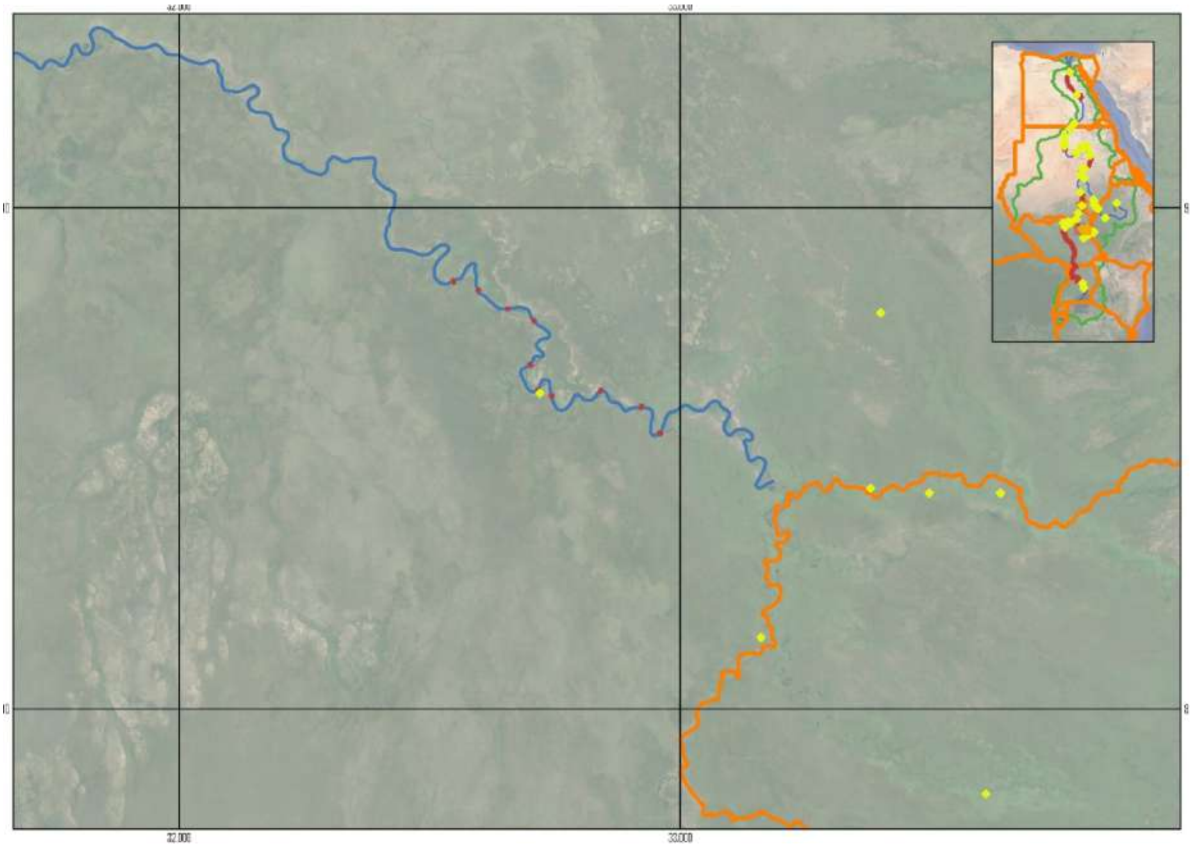


Figure 104. Cross-section location

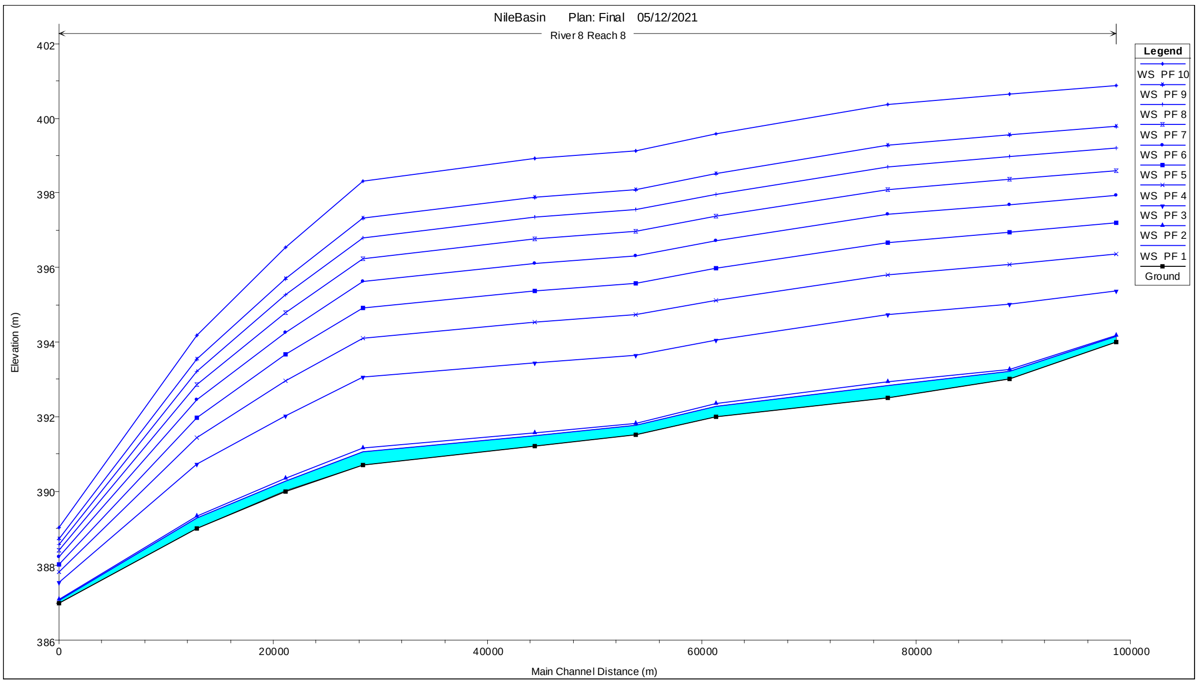


Figure 105. Longitudinal profile

Due to the limited flows available in the Sobat and due to the uncertainty observed in the topography in this region, it is recommended that a safety factor of 20% is applied to the calculated flow requirements.

Stretch 7. Bahr el Jebel

As per the White Nile downstream of Malakal, the information in the Bahr el Jebel stretch is from previous assessments of HYDROC in the region. A total of 139 cross-sections were used.

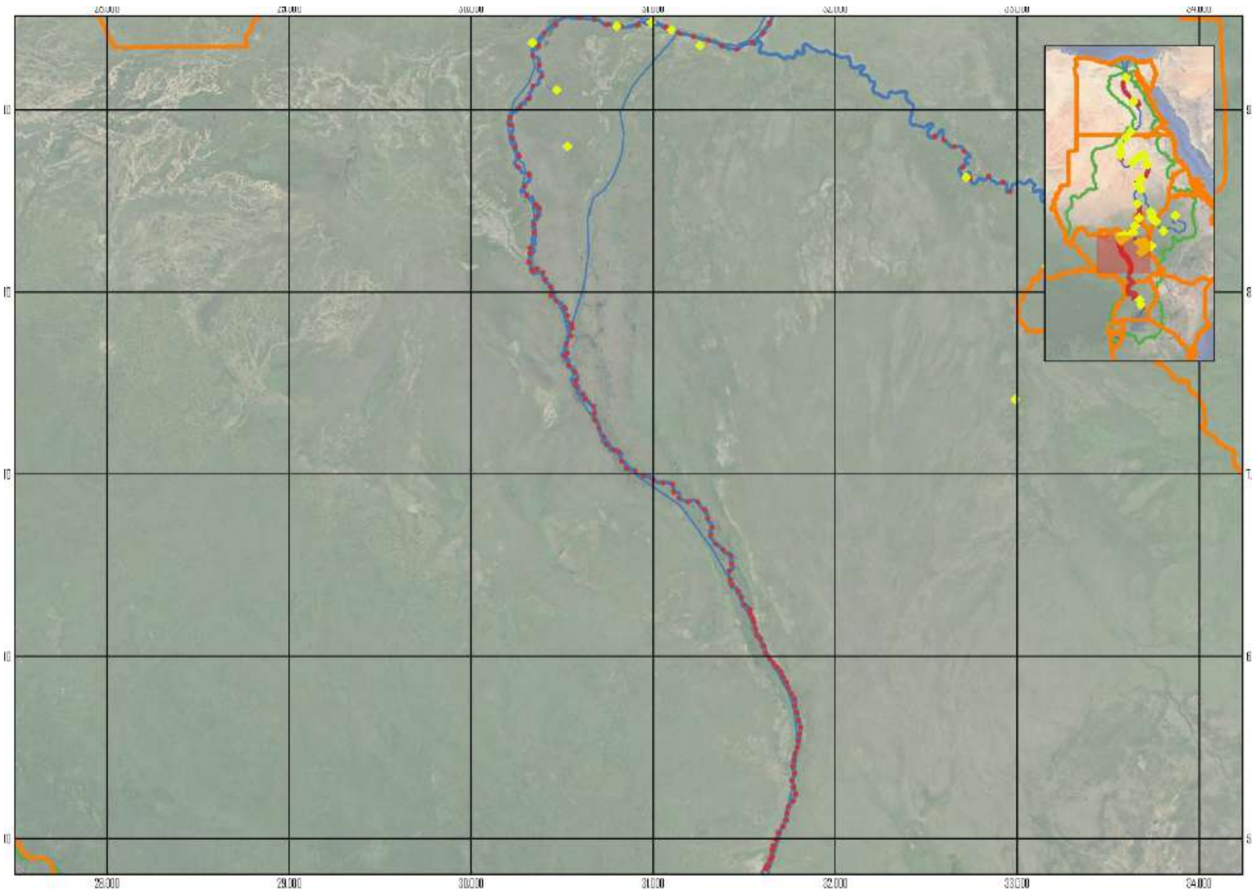


Figure 106. Cross-section location

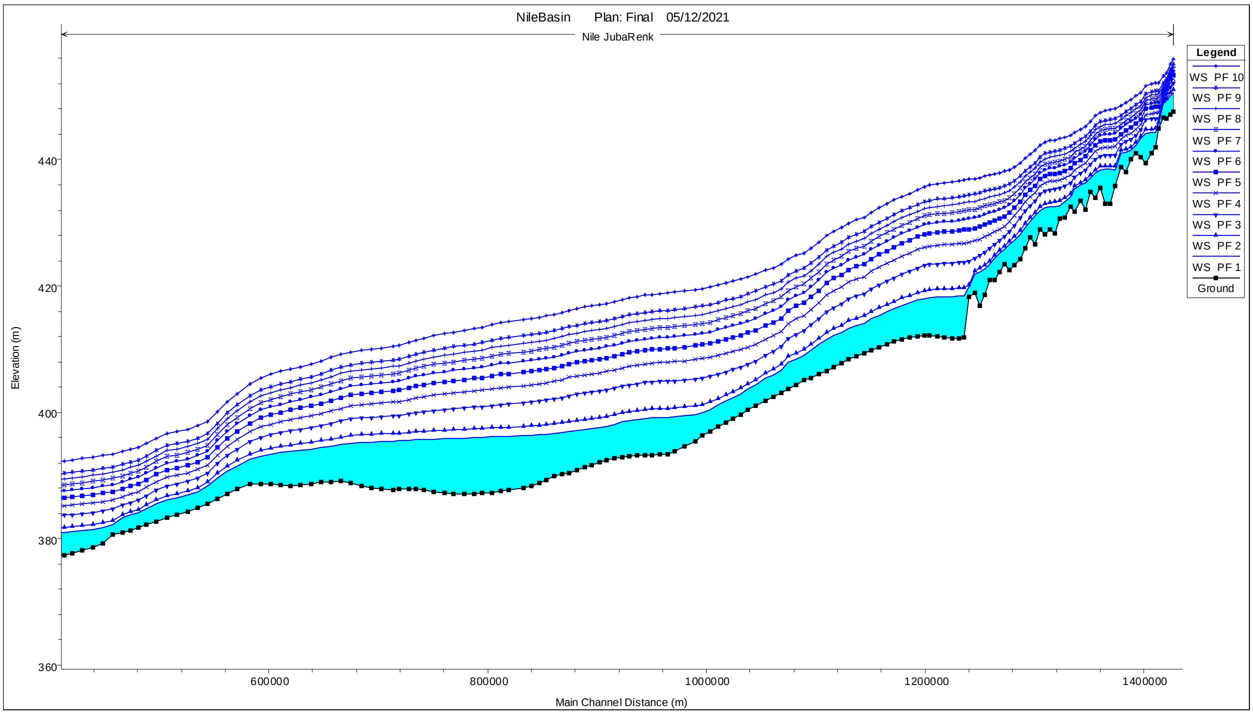


Figure 107. Longitudinal profile

Due to the source of information and the teams knowledge of this area, significant constraints are not expected. However, the hydrological features in this region, mainly on the Sudd wetland, are significantly complicated to be represented by a 1D hydraulic model, even if just the channel is considered. The contribution of evaporation, overland flow, Nile flow and other processes create a significant uncertainty on the results. Therefore, a 20% safety factor is recommended.

Stretch 8. Albert Nile

The Albert Nile stretch has been defined using artificial cross-sections (rectangular ones). A total of 22 cross-sections have been defned, as shown in the figures below.

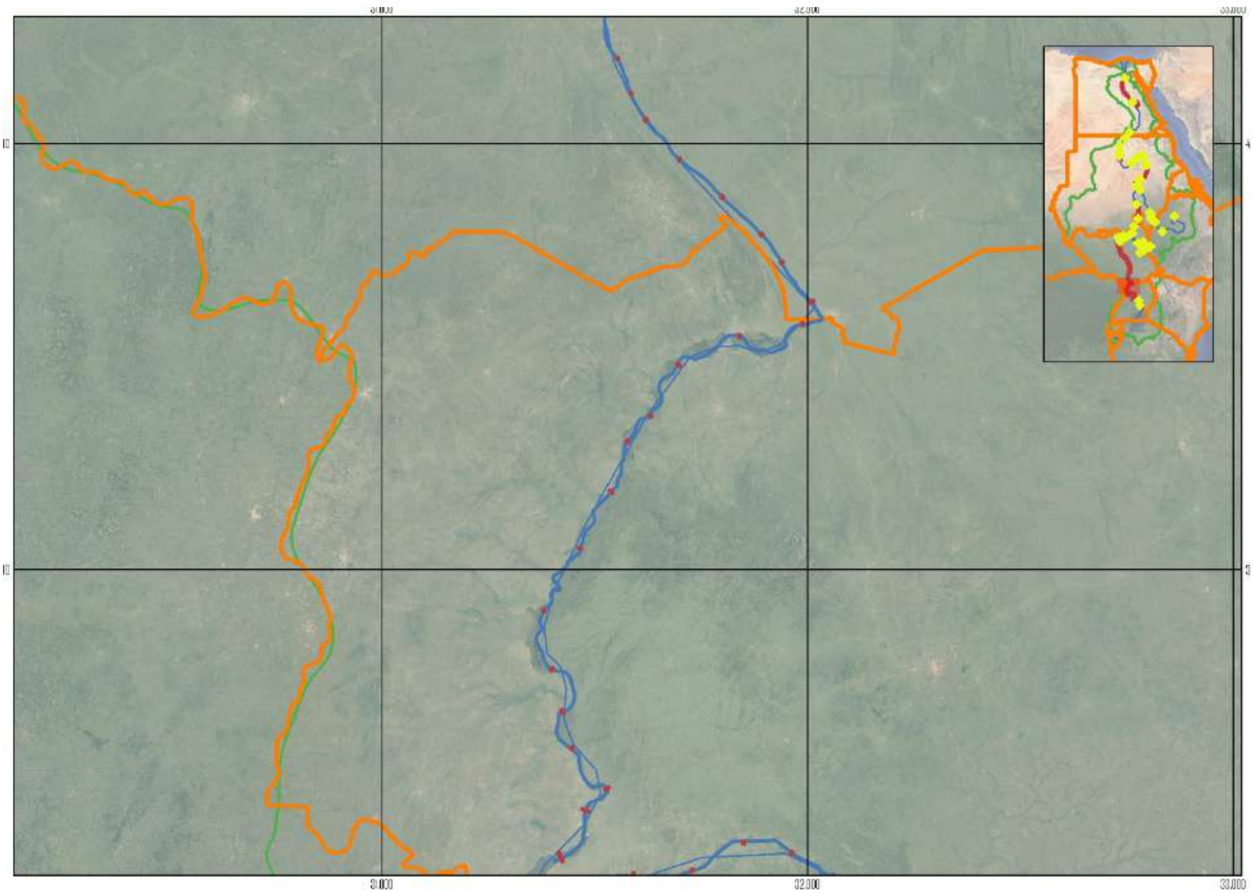


Figure 108. Cross-section location

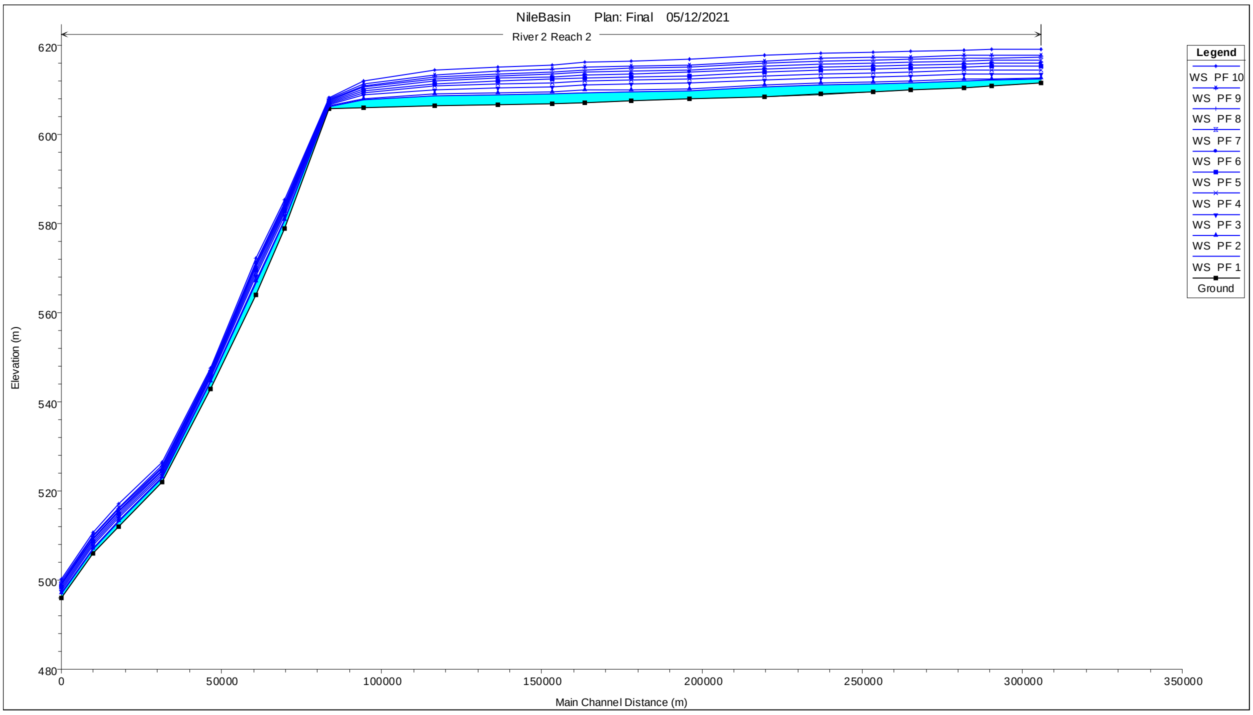


Figure 109. Longitudinal profile

As shown in the longitudinal profile figure above, there is a significant drop of channel levels in this stretch. While this information is coming from the DEM, it is expected that the channel will behave in a similar way. However, this creates some uncertainty regarding the results, and therefore, also considering the limitd flows available in this area, a 20% safety factor is recommended.

Stretch 10. Kyoga Nile

The Kyoga Nile stretch has been defined with 14 artificial cross-sections, following the DEM topography, as shown in the figures below.

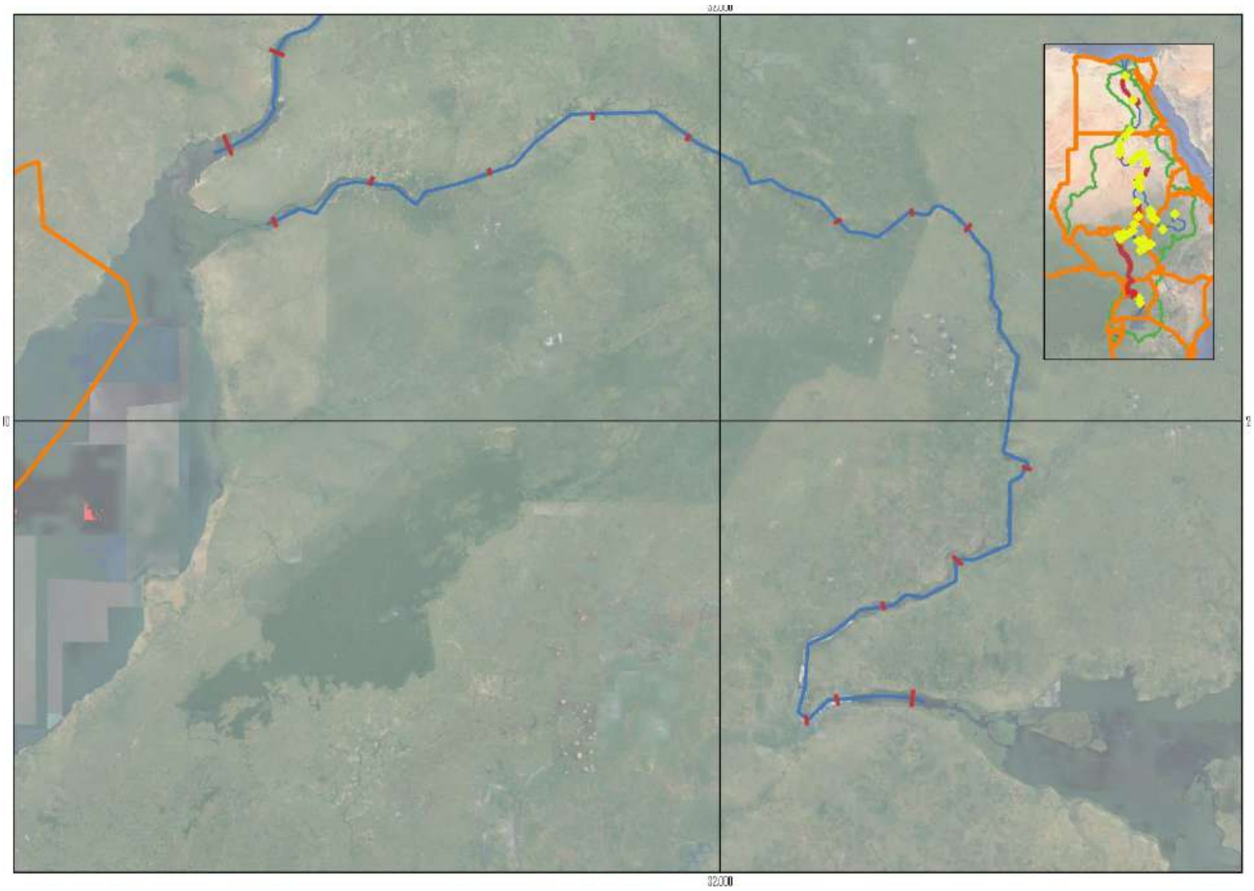


Figure 110. Cross-section location

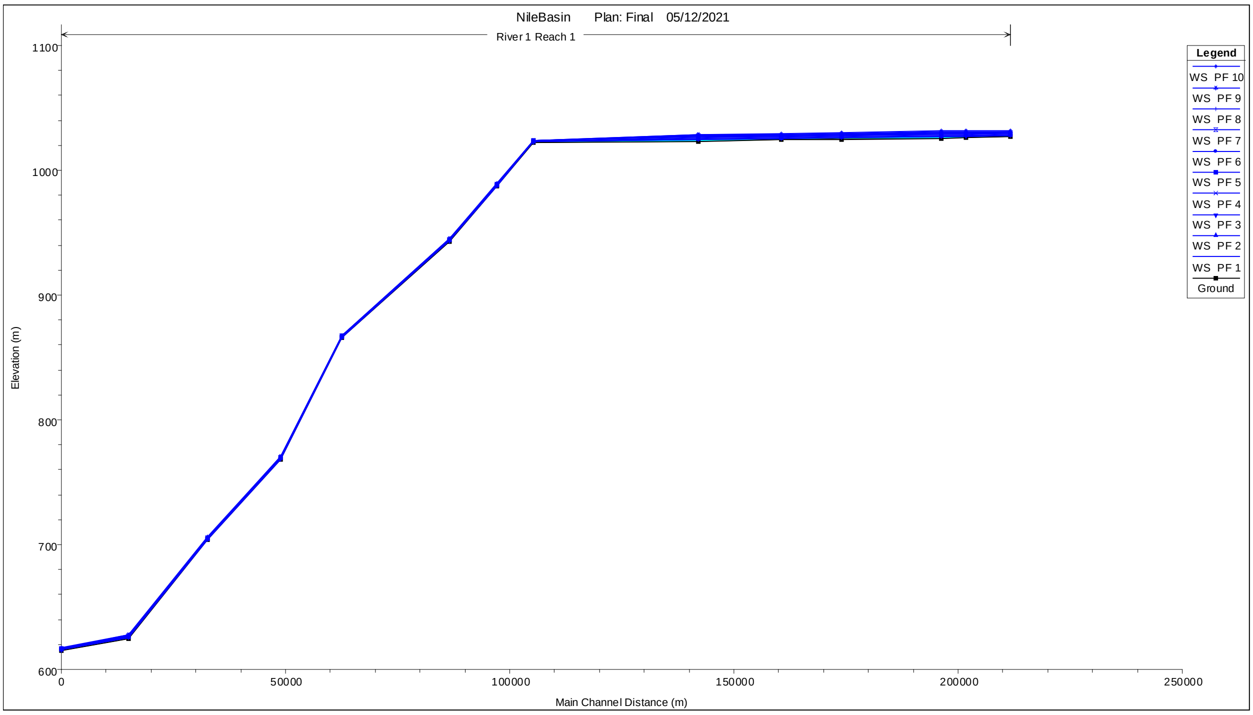


Figure 111. Longitudinal profile

The results from the Kyoga Nile are similar to the Albert Nile, as well as the topographical features, and therefore a 20% safety factor is recommended.

Stretch 12. Victoria Nile

The Victoria Nile stretch has been defined using information from 5 surveyed cross-sections. The period when these cross-section data were obtained is uncertain.

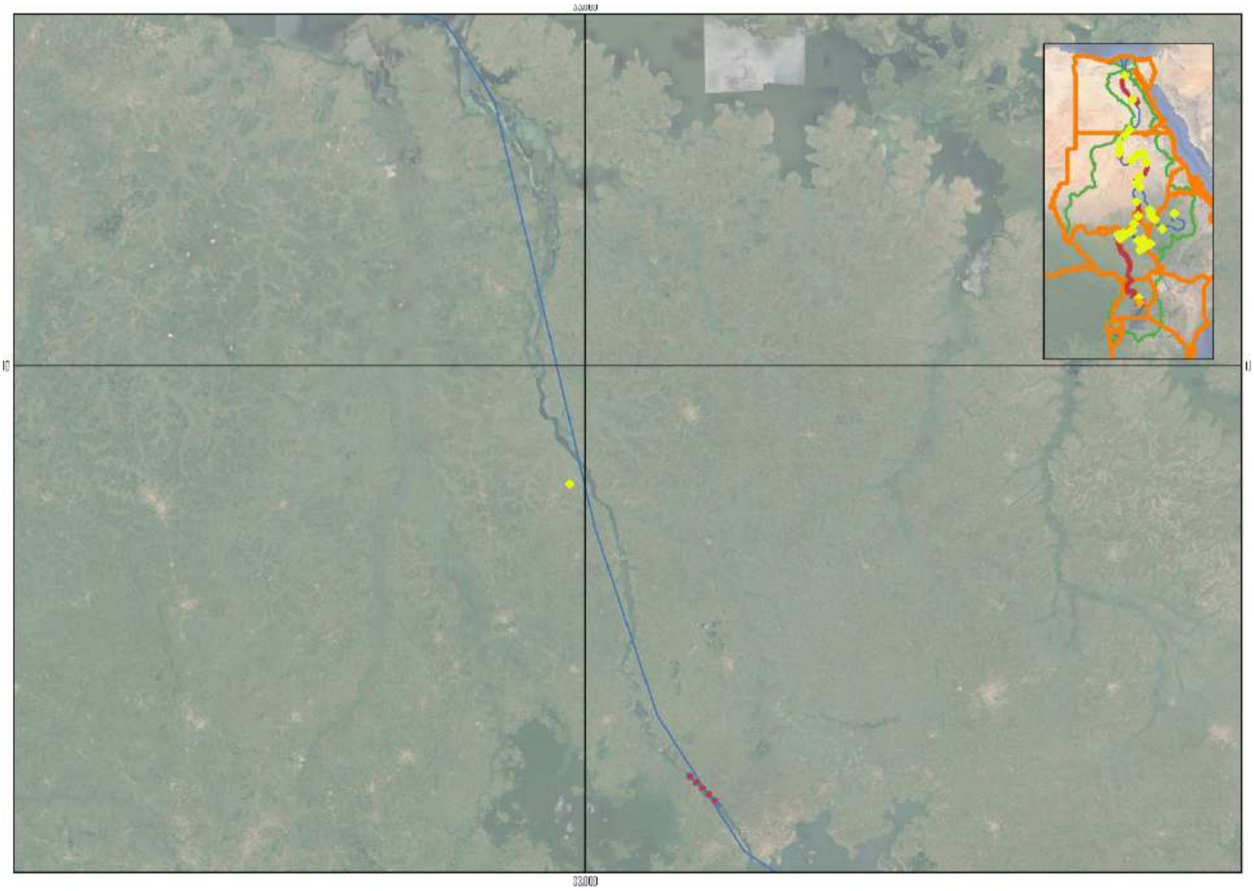


Figure 112. Cross-section location

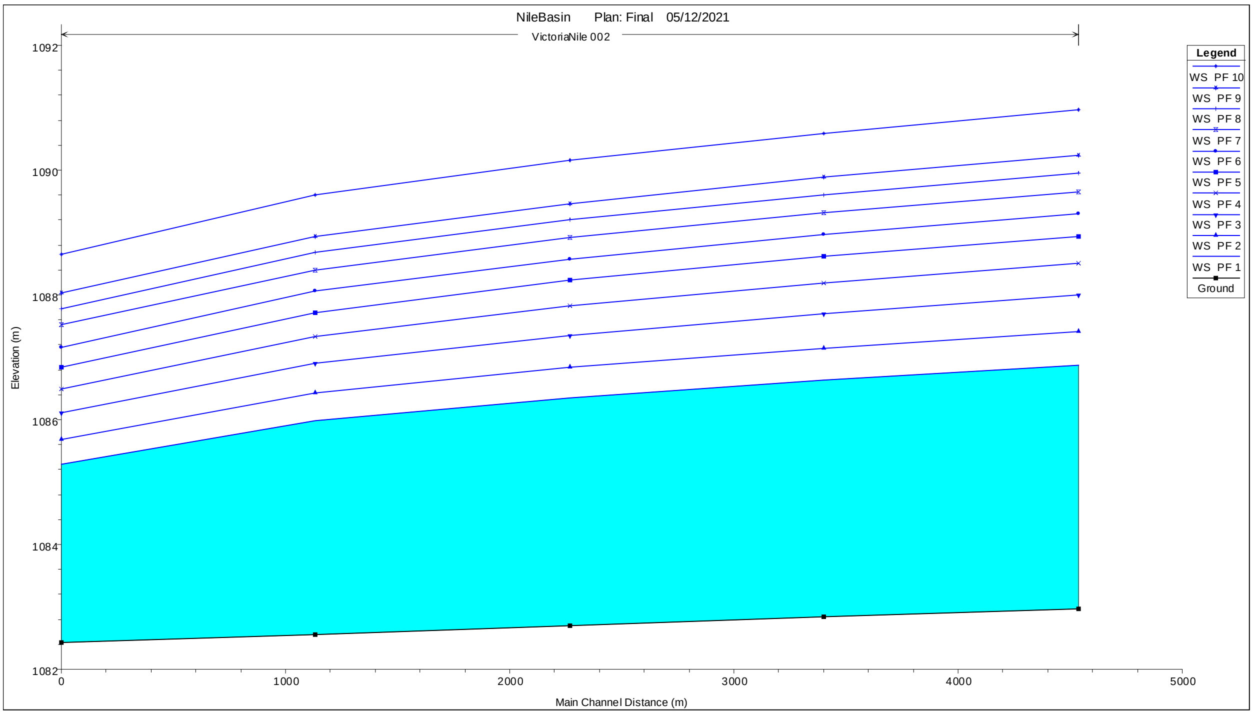


Figure 113. Longitudinal profile

While these cross-sections are defined in the upper section of the Victoria Nile, the results are believed to be representative of the full stretch, given the nature of the stretch and the observed topographical features. Considering the source of information, the location of the cross-sections and the flow patterns, no safety factor is recommended for this stretch.

10. Limitations and recommendations

Any mathematical model is a simplification of natural conditions, and therefore the results from a hydraulic model should always be treated with care. The results of a hydraulic model are as good as the input data. It is important to be critical with the results that any model produces.

The Nile Navigation hydraulic model has been implemented with very limited data, especially with regards to Nile cross sections, and therefore, it is recommended that extra care is paid to any application of the results. It is important to stress at this point that the results from this exercise should not be used for any other purpose than for a very general navigation assessment and specifically the minimum navigation flow requirements.

If a more refined assessment is required, it is recommended that first bathymetric survey data are measured in a sufficient number of locations to fully reporesent the river stretch that shall be assessed. Specifically this is the case for where in the current model estimated cross sections have been used, but also where cross sections exists, these are partly decades old and would benefit from an update. Comparing old with new cross sections would then also allow to assess the long term morphological behaviour of the Nile River cannel.

It is further recommended that flow survey campaigns are undertaken. This will facilitate the calibration of the models, mainly to define properly the rougheness on the channel, leading to a more robust calculation of both the water depth and the velocities.

Respectively, while utmost care has been taken in conducting the analysis, the limited information regarding the actual channel depth is a limiting factor, and although some basic calibration was undertaken, due to the high number of variables considered in a hydraulic model, this does not necessarily indicate that the results are the most accurate possible with the given data. The same results can be achieved with different combinatons of roughness, channel depth, slope and water flow.

It should be added that the use of flat bottom rectangular-box channel shapes implies that a conservative approach has been followed, because a natural channel would have a different shape, and therefore the flow requirements would be lesser than with a rectangular one.

Part C: Navigation Scenarios

11. Introduction

This report describes the definition and assessment of Nile navigation scenarios under baseline and future scenario conditions, assessing the potential and limitations of Nile navigation for specified river sections. Navigation assumptions have been assessed and defined in the Task 2 report of this project, linking water depth requirements of river barges to defined flow conditions as replicated in below Table 52 and Table 53 for standard (current) and dredged river conditions. The river stretches that have been analysed in this report have been selected based on their navigation potential, i.e. only stretches that are suitable for bulk barge transport with a transboundary perspective have been selected.

Based on the assessment in the Task 2 report, considering uncertainties in the broad scale assessment and the fact that basically all barges have similar drafts, required water depths for navigation has been set to:

- 2.0m for the White Nile, Blue Nile and Main Nile upstream of Aswan
- 3.0m for the Main Nile downstream of Aswan

A dedicated flow-barge type matrix is respectively not necessary, but a simple linkage of flow-depth relation is sufficient, with the above depth thresholds marking the respective flow thresholds under which navigation is possible. Based on this assessment, the minimum flow requirements for navigation for the different stretches have been assessed as shown in Table 52 for standard (current) conditions (Option 0) and in Table 53 for dredged conditions (Option 1).

Table 52: Minimum flow requirements under standard (current) conditions (Option 0) for the different river stretches for allowing navigation as well as observed flow ranges

Stretch	Required min water depth (m)	Required min flow (m3/s)	Observed flow range (for details see Section 8.1.4) (m^3/s)	Flow velocity at required min flow (m/s)	Flow velocity range (m/s) over full flow scenario range
1 - Main Nile Egypt	3.0	1420	770 - 2700	0.53	0.30-0.78
2 - Lake Nasser	-	-	-	-	-
3 - Main Nile Sudan	2.0	920	380 - 12000	0.6	0.44-1.60
4 - Blue Nile Sudan	2.0	32	40 - 9600	0.65	0.62-2.77
5 - White Nile	2.0	210	300 - 2400	0.28	0.28-0.86
6 - Sobat	2.0	195	0 - 1300	0.42	0.11-0.96
7 - Bahr el Jebel	2.0	210	270 - 2900	0.59	0.59-1.33
8 - Albert Nile	2.0	298	300 - 2200	0.61	0.56-1.26
9 - Lake Albert	-	-	-	-	-
10 - Kyoga Nile	2.0	510	270 - 2000	1.05	0.71-1.88
11 - Lake Kyoga	-	-	-	-	-
12 - Victoria Nile	2.0	210	300 - 1100	0.89	0.89.1.89
13 - Lake Victoria	-	-	-	-	-

Barge travel speeds have been assessed based on narrative evidence and reports of shipping companies and were found to be at a minimum of 4 m/s when loaded. some barges, especially when empty, achieve significant higher speeds. Based on the assessment a 2 m/s threshold was set as flow velocity at which barges can still travel significant distances upstream per day, i.e. at 4-2=2 m/s, which equals about 80 km daylight travel distance. This value is only exceeded on the Blue Nile during the flood season. It can respectively be concluded that flow velocities will not be a limiting factor for barge transport on the Nile under standard conditions. The assessment has not considered individual limitations like e.g. the cataracts where higher flow velocities can be expected. Here technical solutions need to be found.

Table 53: Minimum flow requirements under dredged conditions (Option 1) for the different river stretches for allowing navigation as well as observed flow ranges

Stretch	Required min water depth (m)	Required min flow (m3/s)	Observed flow range (for details see Section 8.1.4) (m^3/s)	Flow velocity at required min flow (m/s)	Flow velocity range (m/s) over full flow scenario range
1 - Main Nile Egypt	3.0	1300	770 - 2700	0.70	0.50-1.04
2 - Lake Nasser	-	-	-	-	-
3 - Main Nile Sudan	2.0	620	380 - 12000	0.5	0.51.1.65
4 - Blue Nile Sudan	2.0	28	40 - 9600	0.57	0.57-2.66
5 - White Nile	2.0	200	300 - 2400	0.26	0.28-0.86
6 - Sobat	2.0	100	0 - 1300	0.3	0.20.1.01
7 - Bahr el Jebel	2.0	200	270 - 2900	0.6	0.70-1.31
8 - Albert Nile	2.0	210	300 - 2200	0.63	0.63-1.31
9 - Lake Albert	-	-	-	-	-
10 - Kyoga Nile	2.0	495	270 - 2000	1.15	0.83-2.07
11 - Lake Kyoga	-	-	-	-	-
12 - Victoria Nile	2.0	210	300 - 1100	0.99	0.99-1.92
13 - Lake Victoria	-	-	-	-	-

Overall, it is observed that under dredged conditions less flow is necessary to allow for navigation. as the dredged channel is more efficiently providing the necessary conditions.

Based on the above Table 52 and Table 53, navigability over a baseline period of 1951-2018 has been assessed and described in the following sections.

Further to the technical conditions, this report describes three scenarios that are recommended to be analysed within the framework of the Strategic Water Resources Assessment (SWRA) with respect to navigation activities within the Nile basin.

The Scenario options have been discussed by working groups with participants from the Nile riparian countries as part of a workshop of the Nile Basin Initiative (NBI) on 25.02.2022 in Dar es Salaam, United Republic of Tanzania. The first scenario represents the baseline of current conditions. The second scenario is based on workshop groupwork reflecting participants preference for low impact and no regret investments, focusing on improvement of existing system elements and improving intermodal transport through land-based developments for those sections of the Nile that are not navigable. The third scenario represents a more ambitious development outlook including major changes to the navigability also for currently non-navigable stretches as a way of modelling extreme scenario for information purposes and to build broader knowledge on the navigability of the river.

In summary, the three options that may be modelled and analysed in the SWRA include:

1. Current development scenario (baseline)
2. Medium development outlook (future) recommended by stakeholders
3. Ambitious development scenario (future) for information purpose and building broader knowledge on river navigability

Various combinations are possible out of which a selected number have been discussed with stakeholders and presented in this report. Overall, the navigated stretches need to be considered in any scenario analysis where navigation is considered as a stakeholder, while the non-navigated stretches may be omitted from a navigation perspective. Combinations with any basin development scenarios considering other stakeholders may be conducted as part of a strategic water resources assessment.

12. Navigation development options, -requirements, and -results

12.1 Dredged / undredged option

Two basic options have been considered in the assessment and run for a broad range of historic flow conditions between 1951-2018:
1. Baseline conditions, i.e. the river stretches as they are with/without improvements to the main obstacles (cataracts, waterfalls, dams), depending on the scenario looked at, and
2. Dredged conditions, with all assessed river sections dredged to an optimized profile for less water requirement, with/without improvements to the main obstacles (cataracts, waterfalls, dams), depending on the scenario looked at.

12.2 Navigation flow- and lake level requirements

Navigation requirements have been assessed with regards to flow requirements on the different defined Nile River stretches and under various flow conditions. Lake water levels are as important to consider. While data is very limited, lake water level ranges suitable for navigation have been assessed based on information from port operators and shipping companies. Flow conditions of a baseline scenario have been provided by the SWRA consultant based on a Nile DSS run, providing a monthly flow timeseries for defined locations in the Nile basin between the years 1951 and 2018. The timeseries has been evaluated against minimum flow requirements as developed in the Task 2 report of this study, for the described natural and potentially future dredged conditions.

Node	N185		N368		N186		N244		N175		N272		N285		N838		N828		R130	
Name	Aswan outflow		Wadi Halfa		Main Nile downstream Khartoum		GERD outflow		White Nile at Malakal		Sobat (after confluence Baro/Akobo)		Bahr el Jebel at Juba		Lake Albert outflow		Lake Kyoga outflow		Lake Victoria outflow	
Minimum flow requirements under standard (current) conditions (Option 0)	1420		-		920		32		210		195		210		298		510		210	
Minimum flow requirements under dredged conditions (Option 1)		1300		-		620		28		200		100		200		210		495		210
	1 - Main Nile Egypt		2 - Lake Nasser		3 - Main Nile Sudan		4 - Blue Nile Sudan		5 - White Nile		6 - Sobat		7 - Bahr el Jebel		8 - Albert Nile		10 - Kyoga Nile		12 - Victoria Nile	
Date	Flow [m3/s		Flow [m3/s		Flow [m3/s		Flow [m3/s		Flow [m3/s		Flow [m3/s		Flow [m3/s		Flow [m3/s		Flow [m3/s		Flow [m3/s	
01.01.1950	1,123.18	1,123.18	1,197.09	1,197.09	510.914	510.91	92.547	92.55	313.224	313.22	309.447	309.45	736.896	736.90	736.896	736.90	574.706	574.71	491.514	491.51
01.02.1950	1,468.79	1,468.79	853.502	853.50	624.139	624.14	100.353	100.35	503.003	503.00	234.923	234.92	656.772	656.77	656.772	656.77	451.059	451.06	470.997	471.00
01.03.1950	1,914.36	1,914.36	385.367	385.37	311.612	311.61	111.48	111.48	369.361	369.36	42.246	42.25	616.35	616.35	616.393	616.39	465.238	465.24	499.671	499.67
01.04.1950	1,976.94	1,976.94	989.216	989.22	923.091	923.09	91.103	91.10	351.748	351.75	10.525	10.53	590.873	590.87	590.968	590.97	483.694	483.69	544.175	544.18
01.05.1950	2,545.43	2,545.43	1,013.74	1,013.74	955.277	955.28	100.963	100.96	410.815	410.82	68.461	68.46	573.144	573.14	573.273	573.27	505.892	505.89	569.788	569.79
01.06.1950	3,183.78	3,183.78	460.15	460.15	402.904	402.90	41.414	41.41	538.242	538.24	195.242	195.24	565.365	565.37	559.493	559.49	527.056	527.06	552.512	552.51
01.07.1950	2,268.52	2,268.52	1,353.28	1,353.28	517.974	517.97	609.703	609.70	742.385	742.39	572.86	572.86	747.873	747.87	564.959	564.96	586.876	586.88	532.751	532.75
01.08.1950	2,057.75	2,057.75	5,930.10	5,930.10	2,888.04	2,888.04	3,012.37	3,012.37	990.608	990.61	669.932	669.93	1,090.25	1,090.25	572.727	572.73	655.104	655.10	521.833	521.83
01.09.1950	1,994.56	1,994.56	2,992.73	2,992.73	1,963.04	1,963.04	2,792.63	2,792.63	1,181.53	1,181.53	719.521	719.52	970.325	970.33	579.075	579.08	652.165	652.17	502.053	502.05
01.10.1950	1,586.52	1,586.52	1,075.22	1,075.22	1,272.05	1,272.05	1,034.56	1,034.56	1,167.69	1,167.69	666.399	666.40	736.173	736.17	585.462	585.46	619.501	619.50	495.022	495.02
01.11.1950	1,510.12	1,510.12	1,033.54	1,033.54	1,255.20	1,255.20	634.25	634.25	1,095.51	1,095.51	542.932	542.93	575.531	575.53	539.715	539.72	513.937	513.94	477.59	477.59
01.12.1950	1,149.30	1,149.30	1,010.60	1,010.60	1,064.39	1,064.39	376.828	376.83	977.449	977.45	370.291	370.29	513.449	513.45	493.401	493.40	435.703	435.70	468.642	468.64
01.01.1951	1,201.19	1,201.19	1,006.60	1,006.60	1,032.81	1,032.81	223.928	223.93	826.143	826.14	161.122	161.12	459.226	459.23	444.425	444.43	381.299	381.30	463.093	463.09
01.02.1951	1,573.94	1,573.94	1,008.99	1,008.99	1,098.06	1,098.06	142.357	142.36	652.342	652.34	109.991	109.99	412.741	412.74	401.071	401.07	344.726	344.73	466.751	466.75
01.03.1951	1,437.12	1,437.12	1,008.99	1,008.99	863.604	863.60	105.236	105.24	563.987	563.99	81.944	81.94	392.847	392.85	383.26	383.26	372.143	372.14	493.539	493.54
01.04.1951	1,472.88	1,472.88	1,020.71	1,020.71	1,126.09	1,126.09	49.714	49.71	510.189	510.19	66.321	66.32	391.144	391.14	382.804	382.80	455.59	455.59	572.794	572.79
01.05.1951	1,890.83	1,890.83	1,011.03	1,011.03	1,009.39	1,009.39	222.743	222.74	570.628	570.63	151.855	151.86	420.032	420.03	399.427	399.43	599.157	599.16	617.425	617.43
01.06.1951	2,357.79	2,357.79	1,639.37	1,639.37	722.878	722.88	367.48	367.48	653.731	653.73	359.953	359.95	436.045	436.05	411.206	411.21	657.034	657.03	623.762	623.76
01.07.1951	2,365.32	2,365.32	2,677.13	2,677.13	1,162.43	1,162.43	1,286.57	1,286.57	964.592	964.59	748.256	748.26	470.384	470.38	428.287	428.29	675.304	675.30	604.376	604.38
01.08.1951	2,118.18	2,118.18	3,231.81	3,231.81	2,063.45	2,063.45	2,142.84	2,142.84	1,148.69	1,148.69	792.697	792.70	536.823	536.82	447.232	447.23	678.813	678.81	591.848	591.85
01.09.1951	1,471.81	1,471.81	1,213.25	1,213.25	1,135.79	1,135.79	1,772.28	1,772.28	1,256.34	1,256.34	837.932	837.93	492.589	492.59	453.121	453.12	664.691	664.69	571.183	571.18
01.10.1951	1,183.65	1,183.65	1,179.24	1,179.24	1,085.86	1,085.86	1,104.18	1,104.18	1,226.37	1,226.37	791.307	791.31	558.247	558.25	494.555	494.56	701.548	701.55	573.101	573.10
01.11.1951	1,122.29	1,122.29	1,198.44	1,198.44	1,237.80	1,237.80	608.416	608.42	1,131.06	1,131.06	689.861	689.86	653.531	653.53	553.221	553.22	779.709	779.71	615.904	615.90
01.12.1951	850.417	850.42	1,188.98	1,188.98	1,051.83	1,051.83	328.61	328.61	976.914	976.91	449.412	449.41	637.579	637.58	601.725	601.73	857.734	857.73	699.698	699.70
01.01.1952	884.841	884.84	1,210.43	1,210.43	982.107	982.11	141.386	141.39	842.492	842.49	272.4	272.40	619.594	619.59	601.137	601.14	780.967	780.97	683.329	683.33
01.02.1952	1,153.84	1,153.84	1,253.44	1,253.44	888.474	888.47	84.901	84.90	672.776	672.78	165.701	165.70	605.87	605.87	591.166	591.17	713.486	713.49	686.482	686.48
01.03.1952	1,495.98	1,495.98	954.578	954.58	863.291	863.29	50.147	50.15	568.953	568.95	133.514	133.51	620.916	620.92	608.666	608.67	728.78	728.78	720.627	720.63
01.04.1952	1,535.13	1,535.13	1,008.20	1,008.20	1,061.15	1,061.15	29.815	29.82	514.543	514.54	115.358	115.36	665.891	665.89	647.232	647.23	793.067	793.07	798.891	798.89
01.05.1952	1,972.36	1,972.36	598.95	598.95	690.308	690.31	20.162	20.16	532.555	532.56	150.097	150.10	763.239	763.24	710.881	710.88	941.724	941.72	889.536	889.54
01.06.1952	2,474.86	2,474.86	171.202	171.20	269.562	269.56	241.795	241.80	596.479	596.48	221.6	221.60	764.89	764.89	726.773	726.77	942.434	942.43	876.382	876.38
01.07.1952	2,540.59	2,540.59	1,322.37	1,322.37	1,396.23	1,396.23	1,593.60	1,593.60	696.042	696.04	473.897	473.90	792.647	792.65	758.492	758.49	924.492	924.49	854.435	854.44
01.08.1952	2,322.06	2,322.06	4,474.42	4,474.42	3,638	3,638.00	3,684.23	3,684.23	990.467	990.47	751.554	751.55	1,000.22	1,000.22	806.776	806.78	937.551	937.55	838.441	838.44
01.09.1952	1,585.28	1,585.28	3,754.46	3,754.46	4,484.50	4,484.50	5,353.89	5,353.89	1,124.32	1,124.32	742.731	742.73	1,060.01	1,060.01	843.813	843.81	952.937	952.94	829.296	829.30
01.10.1952	1,236.65	1,236.65	1,075.26	1,075.26	2,114.65	2,114.65	1,974.64	1,974.64	1,163.43	1,163.43	728.664	728.66	1,004.55	1,004.55	883.647	883.65	925.378	925.38	807.956	807.96
01.11.1952	1,175.53	1,175.53	1,312.77	1,312.77	1,689.59	1,689.59	1,113.11	1,113.11	1,067.19	1,067.19	593.19	593.19	926.07	926.07	877.362	877.36	847.188	847.19	797.52	797.52
01.12.1952	890.168	890.17	975.359	975.36	947.721	947.72	667.688	667.69	898.12	898.12	335.419	335.42	859.004	859.00	825.343	825.34	756.175	756.18	755.55	755.55
01.01.1953	928.785	928.79	979.936	979.94	885.746	885.75	364.129	364.13	733.011	733.01	146.905	146.91	800.89	800.89	773.995	774.00	683.004	683.00	735.409	735.41
01.02.1953	1,214.83	1,214.83	990.239	990.24	961.746	961.75	216.243	216.24	578.714	578.71	98.807	98.81	737.129	737.13	714.906	714.91	602.594	602.59	695.906	695.91
01.03.1953	1,581.19	1,581.19	997.663	997.66	1,087.98	1,087.98	97.391	97.39	507.277	507.28	74.883	74.88	699.895	699.90	681.039	681.04	579.607	579.61	694.999	695.00
01.04.1953	1,626.46	1,626.46	992.365	992.37	1,091.54	1,091.54	44.789	44.79	469.966	469.97	63.843	63.84	711.223	711.22	690.535	690.54	703.699	703.70	739.6	739.60
01.05.1953	2,096.41	2,096.41	983.574	983.57	983.238	983.24	76.341	76.34	504.604	504.60	110.365	110.37	729.362	729.36	702.62	702.62	742.405	742.41	746.658	746.66
01.06.1953	2,631.04	2,631.04	2,180.26	2,180.26	766.691	766.69	492.015	492.02	605.259	605.26	212.934	212.93	805.185	805.19	714.207	714.21	773.077	773.08	737.251	737.25
01.07.1953	2,636.71	2,636.71	4,722.24	4,722.24	2,241.92	2,241.92	2,295.51	2,295.51	798.27	798.27	588.479	588.48	874.393	874.39	720.926	720.93	750.424	750.42	703.118	703.12
01.08.1953	2,301.27	2,301.27	5,928.73	5,928.73	5,047.96	5,047.96	4,845.56	4,845.56	1,198.03	1,198.03	818.283	818.28	915.922	915.92	728.001	728.00	713.224	713.22	674.924	674.92
01.09.1953	1,541.05	1,541.05	5,243.04	5,243.04	3,203.29	3,203.29	3,885.11	3,885.11	1,321.44	1,321.44	811.593	811.59	798.523	798.52	711.043	711.04	686.835	686.84	655.923	655.92
01.10.1953	1,188.04	1,188.04	1,074.47	1,074.47	1,590.61	1,590.61	1,383.16	1,383.16	1,218.04	1,218.04	670.421	670.42	874.376	874.38	731.658	731.66	704.96	704.96	644.118	644.12
01.11.1953	1,127.74	1,127.74	1,019.22	1,019.22	1,534.63	1,534.63	814.831	814.83	1,145.96	1,145.96	554.11	554.11	821.54	821.54	722.462	722.46	662.033	662.03	651.538	651.54
01.12.1953	856.154	856.15	981.449	981.45	1,055.03	1,055.03	487.939	487.94	980.096	980.10	199.012	199.01	715.562	715.56	680.417	680.42	597.96	597.96	644.909	644.91
01.01.1954	892.795	892.80	973.869	973.87	937.174	937.17	266.021	266.02	747.274	747.27	125.305	125.31	646.824	646.82	622.349	622.35	529.847	529.85	618.062	618.06
01.02.1954	1,167.18	1,167.18	983.683	983.68	1,008.44	1,008.44	149.837	149.84	615.615	615.62	73.885	73.89	592.184	592.18	571.968	571.97	469.225	469.23	597.936	597.94
01.03.1954	1,517.31	1,517.31	988.665	988.67	796.14	796.14	80.15	80.15	553.047	553.05	55.761	55.76	563.148	563.15	545.516	545.52	467.057	467.06	581.427	581.43

Figure 114: Assessment of minimum flow requirements under current- and dredged conditions, example

Main results for the river stretches include:

- Flows in the main Nile in Egypt below minimum requirements can be observed mostly between October and February. Dredging does improve the situation, though cannot completely solve it
- The main Nile in Sudan shows problematic flow values under historic conditions in an irregular pattern. Minimum requirements can mostly be fulfilled under dredged conditions
- The Blue Nile shows very few months where minimum flow requirements under current conditions are not fulfilled, dredging is not needed to improve the situation
- The White Nile carried sufficient flows for navigation throughout the assessed time period, dredging is not needed to improve the situation
- The Sobat shows significant periods of non-navigable conditions which could be significantly reduced through dredging
- In the Bahr el Jebel flows are sufficient for navigation throughout the assessed time period. Dredging will be beneficial only at key locations considering river curvature and shallows
- In the Albert Nile flows are sufficient for navigation throughout the assessed time period

- The Kyoga Nile shows a limited number of occasions where flow was not sufficient for navigation. Dredging does not significantly improve the situation
- In the Victoria Nile flows are sufficient for navigation throughout the assessed time period

For the lakes, Lake Victoria, Lake Albert, and Lake Nasser/Lake Nubia have been assessed in detail. In the absence of navigation related records of water level suitability, navigation operators have been interviewed to obtain the required information. Results include the following:

- Lake Nasser / Lake Nubia water levels show significant level variations that have been considered by the designers of the main ports, Wadi Halfa and Aswan, implementing sloping piers. Navigation is respectively not impeded by changing water levels in the lake.
- Lake Albert water levels that are suitable for navigation have been defined as 621.0-622.5 masl
- Lake Victoria water levels that are suitable for navigation have been defined as 1134.5-1137.5 masl.

12.3 Navigation Requirements Per River Stretch

12.3.1 Rivers

The following table has been developed to show development requirements per river stretch under the assessed scenario of historic flow conditions.

Table 54: Development requirements per river stretch under the assessed scenario of historic flow conditions

Stretch	Dredging / Flows	Obstacles	Ports	New structures
1 - Main Nile Egypt	Maintaining sufficient flow rates, dredging	Locks to be implemented at Aswan high- and low dam	n/a / on demand	Locks
2 - Lake Nasser	n/a	n/a	n/a	n/a
3 - Main Nile Sudan	Maintaining sufficient flow rates, dredging	Locks to be implemented	Port development required	Locks
4 - Blue Nile Sudan	Maintaining sufficient flow rates (GERD outflow)	Locks to be implemented	Port development required	n/a
5 - White Nile	n/a	Jebel Aulia Dam locks rehabilitation	Port development required	n/a
6 - Sobat	Dredging, flow increase	n/a	Port development required	Ports and intermodal connections
7 - Bahr el Jebel	n/a	Curvature dredging, obstacle removing	Port development required	Ports and intermodal connections
8 - Albert Nile	n/a	n/a	Port development required	Ports and intermodal connections
9 - Lake Albert	n/a	n/a	Port development required	Ports and intermodal connections
10 - Kyoga Nile	n/a	Locks to be implemented, obstacle	Port development required	Locks

Stretch	Dredging / Flows	Obstacles	Ports	New structures
		removal from riverbed		
11 - Lake Kyoga	n/a	n/a	Port development required	Ports and intermodal connections
12 - Victoria Nile	n/a	Locks to be implemented, obstacle removal from riverbed	Port development required	Locks
13 - Lake Victoria	n/a (outflow as per agreed curve), stable waterlevels benefit navigation	n/a	Port development required	Ports and intermodal connections

12.3.2 Lakes

Lakes in the Nile River basin are well frequented by barges at the current stage. Main ports include Kisumu, Port Bell and Mwanza on Lake Victoria. At Lake Albert anyhow rather beach landing sites are being used as there is no functional port infrastructure in place.

All ports require developments as well as intermodal connections and logistic infrastructure for which port specific detailed assessments will be required.

Further to development needs, ports require certain stable water level ranges within which they can be operated. E.g. the freeboard between water level and quay wall level at Kisumu port is about 1.2m at the time of this study, while Lake Victoria water levels are at about 1136.7masl based on satellite measurements. Adding the two would result in lake levels of 1137.9masl at which the port would get flooded. Further, a certain safety margin to consider e.g. waves and wind setup need to be considered, based on which a maximum desirable lake water level of 1137.5masl has been set.

With regards to low water levels for all ports it has been reported that water depth are sufficient under all known (historic) water level conditions. Water depths given in nautical charts (e.g. available at Navionics) for the port areas are linked to an arbitrary datum which is unknown and could respectively be linked to the satellite based masl levels only through correlating exemplary bathymetric survey data with the chart bathymetry. Based on such correlation a full assessment of lake water depths requirements for navigation in relation to modern satellite based masl data could be conducted. Required minimum water depth would be defined by the draft of the vessels intended to be used in the respective ports.

Figure 115: Water depths in bay area near Kisumu Port / Kenya (Source: Navionics)

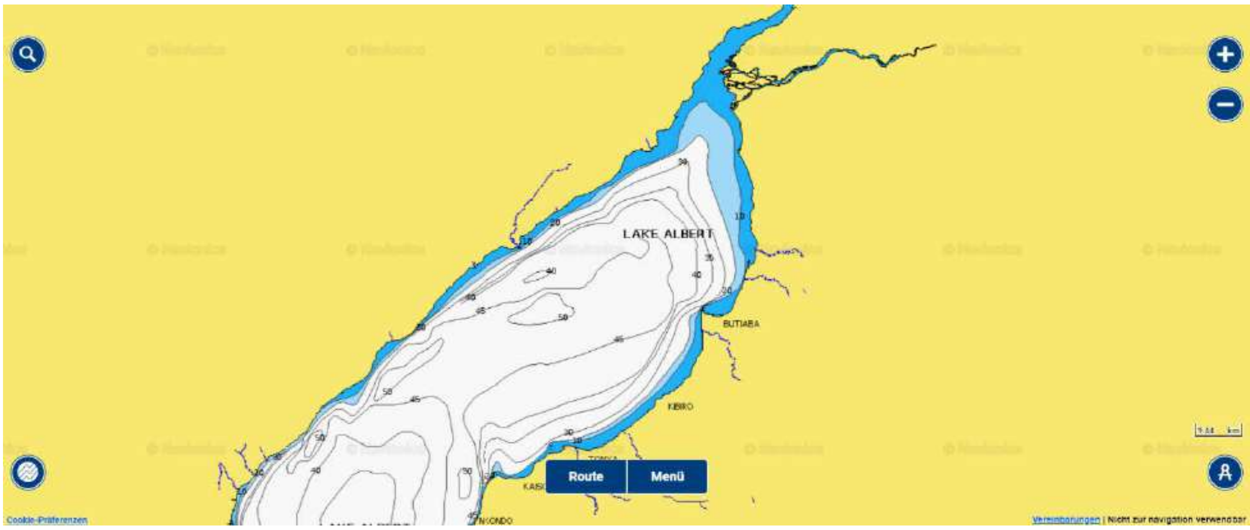


Figure 116: Water depths in Lake Albert near Butiaba / Uganda (Source: Navionics)

Figure 117: Water depths in Lake Victoria near Port Bell / Uganda (Source: Navionics)

Figure 118: Water depths in Lake Victoria near Mwanza / Tanzania (Source: Navionics)

13. Nile Basin scenario navigation requirements

Three scenario options have been discussed by working groups with participants from the Nile riparian countries as part of a workshop of the Nile Basin Initiative (NBI) on 25.02.2022 in Dar es Salaam, United Republic of Tanzania. The first scenario represents the baseline of current conditions. The second scenario is based on workshop groupwork reflecting participants preference for low impact and no regret investments, focusing on improvement of existing system elements and improving intermodal transport through land-based developments for those sections of the Nile that are not navigable. The third scenario represents a more ambitious development outlook including major changes to the navigability also for currently non-navigable stretches. as a way of modelling extreme scenario for information purposes and to build broader knowledge on the navigability of the river.

In summary, the three options that may be modelled and analysed in the SWRA include:

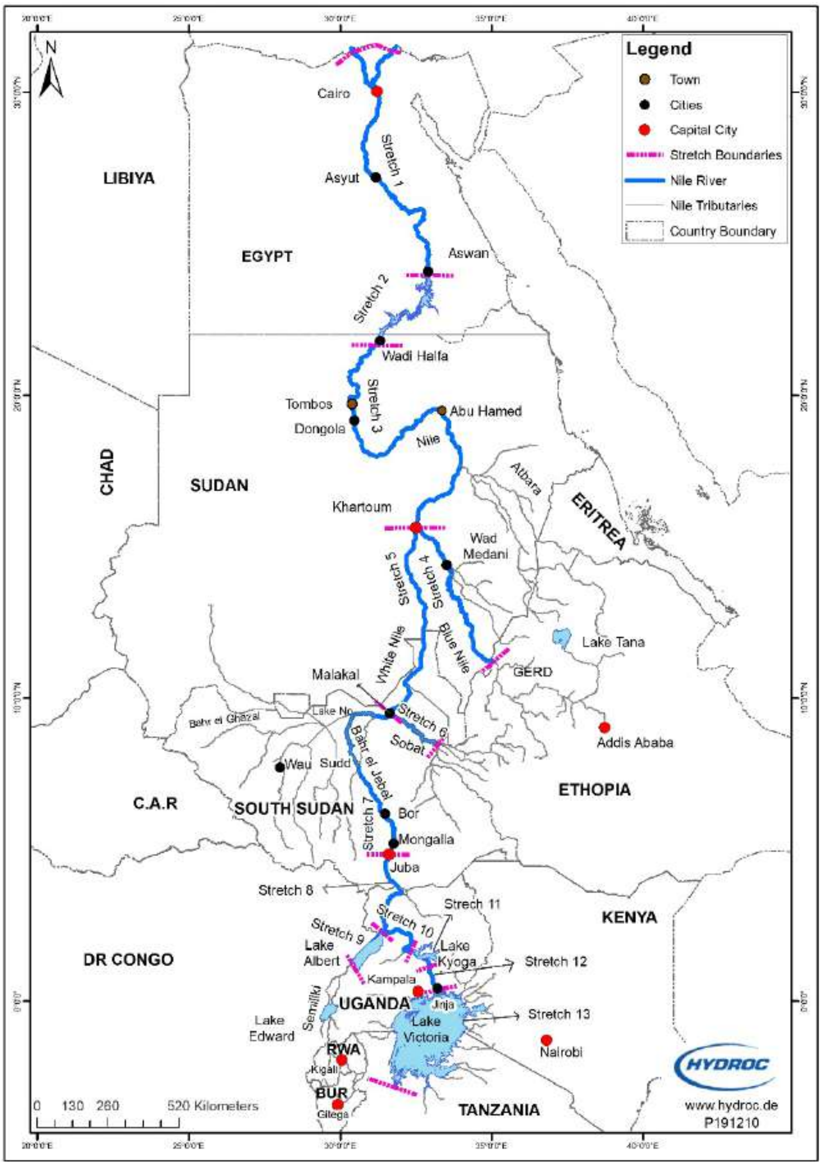
1. Current development scenario (baseline)
2. Medium development outlook (future) recommended by stakeholders
3. Ambitious development scenario (future) for information purpose and building broader knowledge on river navigability

13.1 Current development scenario (Baseline)

The current development scenario (baseline) considers the following conditions along the Nile stretches

Stretch	Description	Condition
1	Main Nile downstream of Aswan	Navigable
2	Lake Nasser	Navigable
3	Main Nile, Khartoum - Lake Nasser	Non-navigable
4	Blue Nile	Partly navigable (with GERD in place)
5	White Nile	Partly navigable (Jebel Aulia locks out of service)
6	Sobat	Partly navigable (in wet season only)
7	Bahr el Jebel, Juba – Malakal	Partly navigable (shallows near Juba)
8	Albert Nile and Bahr el Jebel u/s Juba	Non-navigable
9	Lake Albert	Navigable
10	Kyoga Nile	Non-navigable
11	Lake Kyoga	Navigable (limited to shallow draft)
12	Victoria Nile	Non-navigable
13	Lake Victoria	Navigable

Navigation in this scenario is in place as per the current opportunities and limitations, including the present river- and port infrastructure that is partly deteriorated. The locks at Jebel Aulia are out of service and shallow river stretches may limit navigation especially during low water levels during the dry season and/or during dry years. Port connections are unaltered from the current state.



Unaltered conditions as per current situation (baseline)

Channels in this scenario are unaltered, causing restrictions as follows:

- In the Main Nile in Sudan cataracts are forming obstacles to navigation during low flow periods and respectively low water levels.
- In the Blue Nile differences between dry season flows and wet season flows are significant, leading to difficulties for navigation both, during high volume wet season flows, as well as during low volume dry season flows.
- In the Sobat shallows occur during the low flow season, prohibiting barge access
- In the Bahr el Jebel downstream of Juba shallows occur during the low flow season, restricting barge navigability, especially during years of low flows.
- In the Albert Nile, Kyoga Nile, and Victoria Nile significant rapids and waterfalls are preventing navigation.

Channel profiles in this baseline scenario are natural. For modelling purposes partly measured, partly assumed cross sections have been used. These cross sections are provided in HEC-RAS format in an individual file (see Annex). Further data and information, including flow-depth-relation, flow-velocity chart, and discharge-elevation-depth-velocity relations for each stretch are provided in the modelling report and are replicated in the Annex.

Hydraulic structures in the baseline scenario maintain their current conditions, this includes ports, channels, locks and canals.

13.2 Medium development outlook (future)

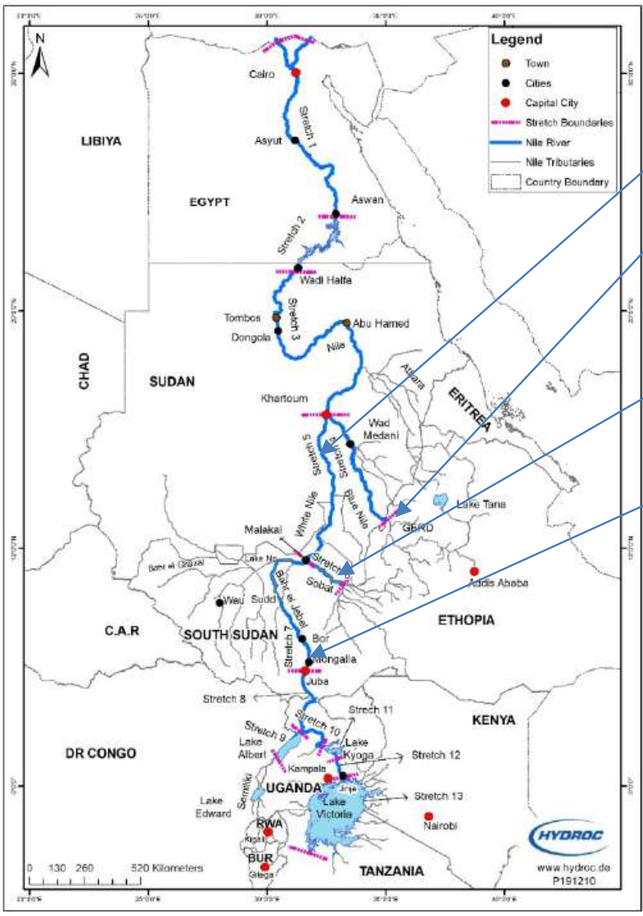
The medium development outlook (future) is mainly based on stakeholder working group discussions in Dar es Salaam on 25.02.2022, considering the following conditions along the Nile stretches

Stretch	Description	Condition
1	Main Nile downstream of Aswan	Navigable
2	Lake Nasser	Navigable
3	Main Nile, Khartoum - Lake Nasser	Partly navigable (upstream dams operated to promote flows suitable for navigation)
4	Blue Nile	Navigable (with GERD in place, operated to promote flow suitable for navigation)
5	White Nile	Navigable (Jebel Aulia locks rehabilitated)
6	Sobat	Partly navigable (partly dredged)
7	Bahr el Jebel, Juba – Malakal*	Navigable (partly dredged)
8	Albert Nile and Bahr el Jebel u/s Juba	Non-navigable
9	Lake Albert	Navigable
10	Kyoga Nile	Non-navigable
11	Lake Kyoga	Navigable (limited)
12	Victoria Nile	Non-navigable
13	Lake Victoria	Navigable

*The Jonglei Canal may be considered in addition (as a separate sub-scenario). The canal is not essential for navigation but may be used in a multipurpose manner depending on stakeholder intentions. If modelling of the Jonglei Canal is conducted, this will provide important information and knowledge on its impacts to the environment and water flows/volumes, and respectively allow for educated decision-making with solid facts. From a navigation perspective, there are two aspects to be considered:

- The Jonglei Canal was originally intended to be utilized also for navigation with a respectively designed trapezoidal shape, 4m water depth, 30m bottom width and 50m surface width, designed for 1900 ton, four-barge push/tow setups
- The Jonglei Canal is anyhow not essential for navigation, as full navigability can be achieved in the main channel of the Bahr el Jebel as well, with sufficient dredging, nevertheless with significantly longer travel distance and respectively transit time.

The medium development outlook considers future developments that can be implemented in a relatively simple manner without any significant adverse impacts or creating competition between water users. Infrastructure investments are limited, but the system is rather optimized in order to increase its benefits. This includes e.g. the operation of dams to considering navigation needs, i.e. generating rather steady flows, that also are in line with hydropower requirements, rehabilitation of existing navigation structures like the Jebel Aulia locks as well as ports along the Nile.



No hydraulic engineering works along the main Nile

Jebel Aulia Dam locks rehabilitated

Operation schedule of GERD considering navigation requirements (rather steady releases)

Partly dredging carried out along the Sobat River

Partly dredging carried out along the Bahr el Jebel downstream of Juba

Main ports along the entire Nile rehabilitated, facilities as well as intermodal connections improved, to improve port performance

Channels in this scenario are mostly unaltered, modified only along two particular sections where environmental- and social impacts are limited (never the less ESIA will be necessary). These are

- The Sobat River, where few whitewater sections will be removed, and
- The Bahr el Jebel, where shallows that currently restrict navigation in the vicinity of Juba will be removed.

Restrictions will maintain to be in place, but will be mitigated through GERD operation, leading to higher water levels during the dry season

- In the Main Nile in Sudan cataracts are forming obstacles to navigation during low flow period. Such low flows shall be prevented by GERD operation.
- In the Blue Nile significant seasonal flows historically have led to significantly altered water levels in the Blue Nile during wet- and dry season. Such flow differences shall be prevented by GERD operation.

Channel profiles in this scenario are natural. For modelling purposes partly measured, partly assumed cross sections have been used. The spot dredging proposed above does not alter the available measured or assumed cross sections as these are based on historic data when barge navigation was possible and/or broader assumptions. These cross sections are provided in HEC-RAS format in an individual file (see Annex). Further data and information, including flow-depth-relation, flow-velocity chart, and discharge-elevation-depth-velocity relations for each stretch are provided in the modelling report and are replicated in the Annex.

Hydraulic structures in the medium development outlook scenario are altered as follows:

- Dredging of the Sobat at point locations to remove whitewater sections (exact points to be established by bathymetric surveys)
- Dredging of the Bahr el Jebel downstream of Juba to re-establish channel depths suitable for navigation (as has been the case in previous times when barges used to navigate to Juba)
- Locks at Jebel Aulia Dam (White Nile) are being rehabilitated

Ports are rehabilitated and improved as follows:

- Mwanza Port (Tanzania)
- Kisumu Port (Kenya)
- Port Bell (Uganda)
- Masindi Port (Uganda)
- Butiaba Port (Uganda)
- Juba Port (South Sudan)
- Malakal Port
- Renk Port
- Kosti Port
- Khartoum Port
- Wadi Halfa Port
- Aswan Port
- Further ports may be established along the Main Nile in Sudan, especially upstream/downstream of Merowe Dam or at other suitable locations
- Other minor ports may be improved as well depending on requirements

Given the remaining obstacles in the river, mainly Merowe Dam and Aswan Dam as well as the whitewater sections and waterfalls in the Equatorial Lakes region, navigation will still be limited under this scenario, and specifically Uganda - South Sudan, as well as Sudan - Egypt will rather depend on intermodal transport options to increase their economic development potential.

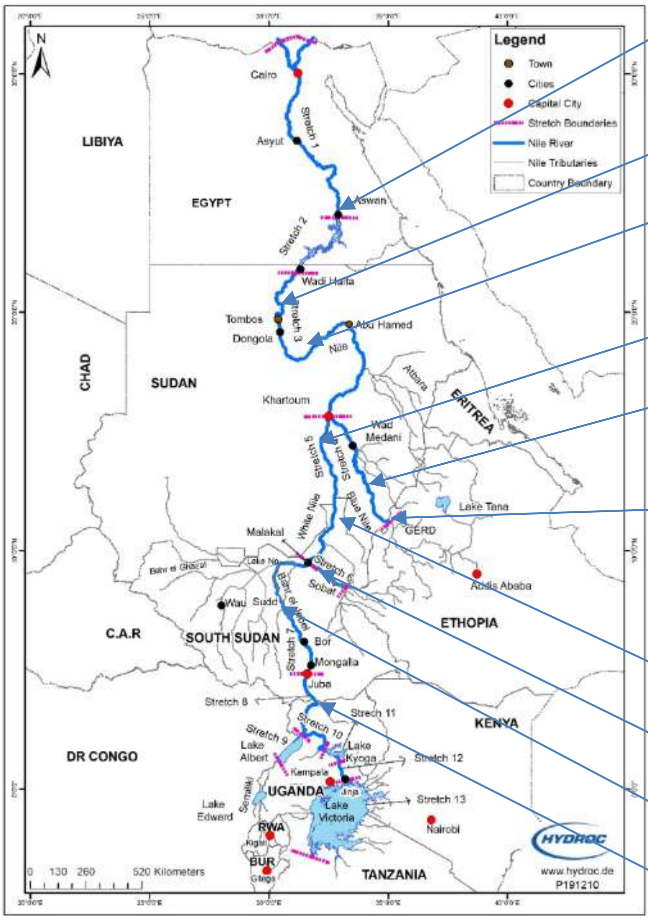
13.3 Ambitious Development Outlook (Future)

The ambitious development outlook (future) goes beyond the preferred options as discussed in Dar es Salaam on 25.02.2022 and considers the following conditions along the Nile stretches

Stretch	Description	Condition
1	Main Nile downstream of Aswan	Navigable (locks or suitable intermodal infrastructure installed at Aswan dams)
2	Lake Nasser	Navigable
3	Main Nile, Khartoum - Lake Nasser	Navigable (upstream dams operated to promote flows suitable for navigation, locks or suitable intermodal infrastructure installed at Merowe Dam)**
4	Blue Nile	Navigable (with GERD in place, operated to promote flow suitable for navigation, locks or bypasses installed at Roseires Dam and Sennar Dam)
5	White Nile	Navigable (Jebel Aulia locks rehabilitated, trapezoidal dredging)
6	Sobat	Navigable (trapezoidal dredging)
7	Bahr el Jebel, Juba – Malakal*	Navigable (trapezoidal dredging)
8	Albert Nile and Bahr el Jebel u/s Juba	Non-navigable, intermodal transport used
9	Lake Albert	Navigable
10	Kyoga Nile	Non-navigable, intermodal transport used
11	Lake Kyoga	Navigable (limited)
12	Victoria Nile	Non-navigable, intermodal transport used
13	Lake Victoria	Navigable

*Same as in the medium development scenario, the Jonglei Canal may be considered in addition (as a separate sub-scenario). See respective comments in above section with regards to impact for navigation.
**In addition, slight reshaping of cataracts may be considered, in a way that navigation is promoted, but flows and water levels are not reduced

The ambitious development outlook requires significant investments and dealing with competing stakeholder requirements. The river system is significantly changed by both dam operation optimized for steady flows, as well as dredging activities to develop a trapezoidal river shape for water saving purposes (less navigation flow requirements).



Channels in this scenario are modified to different extents. The Main Nile in Egypt is maintained in its current state. Along the Main Nile in Sudan cataracts may only be considred for facilitate passage with their general hydraulic characteristics, i.e. flows and water levels, fully maintained. The White Nile, Sobat and Bahr el Jebel are dredged in a trapezoidal shape to optimize the navigation profile and reduce navigation water demands. These trapezoidal cross sections are provided in HEC-RAS format in an individual file (see Annex).

Obstacles in the river remain with Aswan Dam, Merowe Dam, Roseires- and Sennar Dam, as well as the whitewater sections and waterfalls in the Equatorial Lakes region. Here intermodal transport options will be established.

As in the previous scenario, it is assumed that GERD will be operated in a manner considering navigation water demands, i.e. providing a rather homogeneous flow regime.

Locks at Jebel Aulia Dam (White Nile) are being rehabilitated

Ports are rehabilitated and improved as follows:

- Mwanza Port (Tanzania)
- Kisumu Port (Kenya)
- Port Bell (Uganda)
- Masindi Port (Uganda)
- Butiaba Port (Uganda)
- Juba Port (South Sudan)
- Malakal Port
- Renk Port
- Kosti Port
- Khartoum Port
- Wadi Halfa Port
- Aswan Port
- Further ports may be established along the Main Nile in Sudan, especially upstream/downstream of Merowe Dam or at other suitable locations
- Other minor ports may be improved as well depending on requirements

Part D: Benefits of An Enhanced Nile Transport Corridor

14. Introduction

The Nile Basin Initiative is conducting a strategic analysis of future water availability and demand in the basin. While these developments contribute to the safety of water, food and energy in the Nile basin, they also affect the flows of the Nile basin and affect the use of rivers and lakes for future navigation. Respectively, the analysis needs to include water demands of the transport sector and how they affect the management and development of water resources in the Nile basin.

14.1 Project description (Tasks)

Task 1: Baseline Situation assessment
This task is carried out to describe, based on the available information, the baseline condition of navigational use of the Nile water resources at the time of the study (2021). The assessment includes:

- Identification of river reaches, lakes and other water bodies that are being used for navigation in the river Nile system and listing characteristics which are relevant to navigational requirement (including cross section characteristics, currents, tidal and/or river (velocity, direction, and duration); bottlenecks, etc.)
- Description of the current river/lake/wetland navigation system and classification (by river stretches; by vessel types/classes and fleet composition; volume of cargo transported over past 20 years or so;
- List of major ports and their key characteristics
- Submission of report section on current situation

Task 2: Development of key requirements
This task outlines requirements for the various navigable inland water bodies identified in Task 1 by:

- The cross-Section (water level, depth, width); currents, tidal and/or river (velocity, direction, and duration); alignment and configuration (bends, bridge, power line crossings etc). The requirements are prepared for each segment (reach of a river or region of a lake) linked to cross-section of river monitoring stations.
- Preparation of a table of required parameters as a function of vessel types as input for calculation indicators in the NB DSS;
- Development of indicators to assess navigability as part of the Nile DSS approach
- Submission of report section on approach

Task 3: Scenarios

- Provision of a short summary of regional and national plans for river and lake navigation provided by member states
- Extraction, in consultation with the Regional Expert Working Group, a set of navigation development scenarios to be included in the Strategic Analysis, with particular focus on navigation of transboundary river/lakes.
- For each scenario, detailed specifications of requirements are provided (as outlined in Task 2)
- Submission of report sections / model configurations for navigation for the scenario definitions
- Configuration of the DSS models and carrying out model runs by Nile-SEC staff. NBI will the conduct model runs/scenario analysis of ca 4 -6 overarching basin development scenarios to assess tradeoffs by sector and countries, i.e. navigational use versus other uses (current and planned), such as irrigation, hydropower generation and urban water supply.
- Based on the model runs by the NBI team, development of a write up incl. adequate graphical representations for visualisation/communication of the results and navigation related trade-offs. The aim is to provide exemplary interpretation and assessment from a water resources perspective of strategic analysis results for the navigation sector.

- Submission of report section on interpretation of the scenarios

Task 4: Benefits of an enhanced Nile transport corridor for economic development and regional economic integration

Development of a technical report (or a section of the final report) of ca. 20 - 30 pages targeting policy makers:

- describing for policy makers the current state of the Nile transport corridor - focusing on the state of the navigation and trade volumes (consistent with Task 2).
- describing the rational for enhancing the Nile transport corridor focusing on benefits in term of economic development, regional trade and regional integration.
- providing a descriptive summary and "mapping" of the relevant (a) policies/strategies, (b) stakeholders at national regional level and (c) ongoing initiatives to advance waterway development on the River Nile, such as:
    - PIDA Nile Corridor (Project under AUDA)
    - VICMED (A Presidential Infrastructure Champion Initiative -PICI- Project under COMESA)
    - Lake Victoria Navigation (Projects under LVBC/EAC)
    - NBI NELSAP Concept Notes / Strategy
    - National plans and strategies

A file repository with all the consulted plan/strategic documents to be shared with NBI.

14.2 Report's purpose for policy-makers

Inland waterway transport, depending on the individual conditions along river stretches, caries significant potential for cost effective transport. The chances for this have so far not been assessed in detail. This report provides policy makers with background information of the potential, the options, but also the uncertainties of inland waterway transport on the Nile river to facilitate future planning and decision making. The report is nevertheless not an in-depth analysis, but provides the state of current knowledge and provides recommendations for further studies needed for in-depth analysis of the inland waterway transport potential, considering required engineering solutions.

15. Current State of Nile Transport Corridor

15.1 Overview of the current Nile navigation system

The Nile River, at the current stage, offers some limited opportunities for inland waterway transport along its course. Navigation options are limited due to various natural and artificial barriers such as dams, waterfalls, and cataracts. Respectively, navigation options are limited. This section describes the baseline condition of navigation on the Nile River.

15.1.1 Existing navigation routes

The Nile has been used for navigation since long times, and along various sections. Continuous utilization of its entire length is not possible due to cataracts, waterfalls, as well as dams that do not have locks or non-functioning locks.

Historically, Egypt has developed and improved the accessibility of navigation along the Nile. Despite having multiple artificial obstacles, ways for ships to pass were considered and locks were built at all barrages from the Mediterranean Sea to the High Aswan Dam. In addition, Egypt has a diverse network of artificial canals that allows vessels to avoid some barrages and minimise the time of travel. The water level is usually maintained sufficiently and controlled by the High Aswan Dam. Egypt is the only country that enables uninterrupted navigation along the Nile river within its national borders.

Upstream, the High Aswan Dam acts as a barrier for navigation due to the absence of locks. However, beyond Aswan Dam, the Lake Nasser is navigable. The only limitation encountered here is the low water season, which can affect the safety of certain types of vessels. Therefore, lakeside ports are designed to accommodate fluctuations in water levels and can be approached under all conditions. Lake Nasser is an important region for trade between Egypt and Sudan and is well maintained.

On the Sudanese territory, the Nile river faces multiple barriers, including cataracts and Merowe Dam that is not equipped with locks. Up to Khartoum, there are local navigation routes for short distances, but an interrupted path is impossible under current conditions. This also applies to the Blue Nile: the water level fluctuates here throughout the year and can only be navigated in high-water season. South of Khartoum, there are more options for transportation, and the river is used as a connecting link between Sudan and South Sudan called "Southern Reach". The Southern Reach connects Kosti and Juba, allowing cargo transport to major ports in South Sudan. Nevertheless, routes are highly dependent on seasonal fluctuations.

From Juba to Lake Albert, the navigability is limited due to rapids and swamps. Lake Albert has no significant traffic as well due to limited infrastructure opportunities.

the stretch between Lake Albert and Lake Victoria is not navigable. The Kyoga Nile and Victoria Nile contain several significant waterfalls with hydro-power plants on them, none of them equipped with locks. The Kyoga Lake is shallow and swampy, and is accessible for shallow-draft vessels between Masindi and Namasagali.

Finally, Lake Victoria acts as a principal waterway for commercial traffic between the lake shores. The Lake is navigable and has a strong potential for trade improvements. There are several ports on the shore of the lake that connect the major cities. The main routes are between Port Bell (Uganda) - Kisumu (Kenya) - Mwanza (Tanzania) -Bukoba (Tanzania).

16. Conditions for navigation

16.1 River conditions

Inland water transport is an important economic endeavour for the nations on the banks of the Nile. The Nile River conditions for navigation are diverse and challenging. Considering both physical and infrastructure capabilities, only isolated and adapted routes are generally used for transportation: Lake Victoria, the White Nile between Malakal (South Sudan and Khartoum), the Baro-Sobat River between Gambela (Ethiopia) and Malakal (South Sudan), and Lake Tana in Ethiopia. Shipping is believed to continue to play an important role in connecting countries in the Nile basin.

Further sections describe both physical and artificial conditions and limitations for navigation.

16.1.1 Ports (Availability)

River ports are an important part of the barge transport system, facilitating the effective loading and unloading of goods and passengers in key locations. In addition to important land and water accessibility, the port infrastructure itself is also important and needs to be related to the services that the port is expected to provide.

Port infrastructure varies from country to country. There are 40 public ports found along the Nile course and multiple private ports in Egypt, which might not be considered in this study due to unavailability of information. Public ports are unevenly distributed along the river. Most ports are located in Egypt and around Lake Victoria. South Sudan also has a good port network, but its facilities and state of maintenance are very limited and currently only able to handle smaller volumes of cargo.

17. Plans for river and lake navigation - brief overview

The 2,500-mile navigational shipping line connecting Lake Victoria and the Mediterranean Sea via the Nile River is being directed by the African Union Steering Committee that is headed by Egypt. The Nile navigation project which entails building of a shipping lane along River Nile for both small and medium sized commercial vessels is being carried out under the umbrella of New Partnership for Africa's Development and is expected to boost bilateral trade[90].

To promote economic development and enhance trade opportunities, The African Continental Free Trade Agreement (AfCFTA) was commissioned in May, 2019. The aim of the agreement is to offer member states evidence-based insights to help navigate the complexities that come with implementation, including identifying and managing trade-offs. Successful implementation of the AfCFTA could help deliver equitable human development, strengthen regional integration, and further the development agendas of African institutions including Agenda 2063[91].

17.1 River conditions

The northern corridor is a long-established road transport route that links Mombasa port with Nairobi and Kampala, with extensions to the DRC, Rwanda, Burundi and to Juba in South Sudan. Corridor development is promoted by the Northern Corridor Transit and Transport Co-ordination Authority (NCTTCA – see also Section 21.2). Goods transport along this route is provided by a competitive and mature market. It is thus a strong competitor for IWT on the Nile (see Table 59).

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[90] "Nile Navigation project to remove borders in Africa". Construction review online. February 10, 2017

[91] Conditions for Success in the Implementation of the African Continental Free Trade Agreement (2020). Frederick S. Pardee Center for International Futures; African Union Development Agency (AUDA-NEPAD)

There is anyhow also some scope for complementarity between IWT and the northern corridor. These opportunities can be found at the Lake Victoria ports of Port Bell and Kisumu (especially the former, with a good road connection to the northern corridor), and at Juba for transshipment between road freight and IWT towards Kosti.

18. Limitations for navigation

18.1 Physical limitations

18.1.1 River limitations (swamps, etc)

Various limitations to river transport are found in the Nile basin of which the major ones include:

- Extreme flow conditions leading to low water levels

Extreme low- or high flow conditions of rivers and waterways along the Nile can lead to limitations of inland transport.

- Waterfalls and cataracts

Waterfalls and cataracts are being found in two countries, Uganda and Sudan. Countries have already constructed dams on some and plan to adapt the rest in the future.

18.1.2 Ports (facilities' conditions)

Port availability is unevenly distributed along the river. The same applies to port facilities. In addition, facilities are often lacking. The most well-equipped ports are located around Egypt and Lake Victoria. The equipped port mainly provides bulk handling facilities and warehouses. Fuel and shipyards are also limited and most are available in the ports of Egypt and Lake Victoria. In addition, these ports are connected to remote areas by rail.

Other regions (especially Sudan and South Sudan) provide little support, but many ports there rely on manual labour. Also, the information available is very limited, and many ports remain blank.

18.1.3 Dams/locks

18 dams and barrages are located in the Nile basin, most of which do not have locks. In addition, 19 further dams are planned to be constructed. They cover the remainder of Sudan's cataracts, the Ethiopian region, upstream of the Blue Nile- and Sobat rivers, and upstream waterfalls from Juba to Lake Victoria. If constructed without locks, they will make the Nile difficult for navigation.

18.1.4 Bridges

The Nile has 95 bridges along its course, the majority of which are in Egypt. Most bridges lacked information and could not determine the height of the bridge (bridge clearance). Bridge clearance and the width of the passages between the supports determine the size of inland vessels and the number of container layers they can transport. The bridges' vertical clearance reduces with high water levels and increases with low water levels.

18.2 Political limitations

18.2.1 Cross-border limitations

Section 19.1 discusses the low levels of intra-NBI trade. The reasons for this are partly to be found in the combination of the low unit values of traded goods and high transport costs, but also in tariff and non-tariff barriers, as discussed below.

Five regional economic communities (RECs) are active in Nile basin countries. All have goals of regional integration. Membership of each is shown below. The two principal RECs that are relevant to intra-NBI trade are COMESA and the EAC. COMESA is a free trade area with aspirations to becoming a customs union and a single market. The EAC is a customs union, also with aspirations to become a single market.[92]

The profusion of RECs and fragmented membership of each are themselves bureaucratic obstacles to trade – hence the drive towards creating an African Continental Free Trade Area (AfCTA). Until the AfCTA

[92] A customs union has a common external tariff. A free trade area has reduced or zero tariffs on goods of internal origin, but does not have a common external tariff.

becomes a reality, countries outside the EAC, for example, face the EAC's common external tariff (CET) when exporting to the bloc. It is noticeable that none of the countries with the lowest shares of NBI exports (Table 56 in Section 19.1) – Ethiopia and Egypt – are members of the EAC.

Negotiations over revisions to the CET are often protracted, with countries seeking to protect their own economic interests seeking increases in the CET. Furthermore, although there are no tariff barriers to goods judged to be of EAC origin, member countries continue to charge excise duties.[93]

Table 55. Membership of regional economic communities

Nile basin countries	EAC	COMESA	CEN-SAD	ECCA	IGAD
	East African Community	Common Market for Eastern & Southern Africa	Community of Sahel-Saharan States	Economic Community of Central African States	Inter-Governmental Authority on Development
Burundi (BUR)	✓	✓		✓	
D. R. Congo (DRC)	✓			✓	
Egypt (EGY)		✓	✓		
Ethiopia (ETH)		✓			✓
Kenya (KEN)	✓	✓	✓		✓
Rwanda (RWA)	✓	✓			
South Sudan (SSD)	✓				✓
Sudan (SUD)		✓	✓		✓
Tanzania (TZA)	✓				
Uganda (UGA)	✓	✓			✓

18.2.2 National economic limitations

While the days of knocked-down ships being imported from Europe and then assembled locally are largely gone, lack of national shipbuilding industries at scale affects many Nile basin countries, especially those around Lake Victoria, and is bound to mean comparatively high prices.

There are small ship building and ship repair businesses around Lake Victoria, in Uganda (Bugiri-Bukasa near Entebbe), Kenya (Kisumu) and Tanzania (Mwanza), but heavy reliance on imported parts remains. Kenya recently announced a rather larger shipyard at Mtongwe, near Mombasa, but this is intended for naval ship repair and construction. Sudan has shipbuilding facilities at Port Sudan and in Khartoum North, but little information about their activities is available. Egypt has extensive facilities around the Nile delta. South Sudan has no facilities.

In terms of national economic limitations, it is the combination of low unit values and high transport costs that is the crucial impediment to trade (see also Section 19.2 below). While investment in transport may reduce transport costs, indeed that of course is the rationale for Nile corridor enhancement, the other side of this equation also needs attention. In practice this means industrialization, long advocated by development professionals (see for example Soludo et al (2004)[94] and World Bank (2021)[95]) and now adopted by several NBI states.

[93] Excise duties are duties charged on goods (both imported and domestically produced) whose consumption governments seek to reduce, typically cigarettes and alcohol.

[94] Soludo, C, Osita Ogbu and Ha-Joon Chang. 2004. *The Politics of Trade and Industrial Policy in Africa*. Trenton, New Jersey.

[95] World Bank/AFD. 2021. *Industrialization in Sub-Saharan Africa.* Washington, DC.

19. Benefits and potential impacts of enhancement of Nile transport corridor

19.1 Nile Basin trade

The benefits and costs of increased trade are well known. Increased trade promotes the efficient allocation of resources, allows a country to realize economies of scale and scope, fosters the dissemination of technical knowledge and encourages competition both in domestic and international markets. By reducing prices, it contributes to the alleviation of poverty. On the other hand, it can displace labour from existing employment and lead to local increases in poverty.

Intra-African trade is notably low. According to Brookings (2019)[96], intra-African exports in 2017 amounted to 17% of total exports, compared with 69% in Europe, 31% in North America and 59% in Asia. Economic growth and trade are closely correlated: rapid economic growth in Asia took place at the same time as rapid growth in trade (Brooks and Hummels, 2009).[97] Indeed this weak performance was one of the triggers for the signature of the African Continental Free Trade Area Agreement (AfCFTA) in 2018.

The ten riparian countries that make up the Nile Basin Initiative (NBI) are no exception to the general pattern of intra-African trade. The table below has been compiled from the UN Comtrade database using the OEC visualization tool.[98] It shows the values of exports on a fee on board (FOB) basis, as far as possible for 2019. While these data have limitations[99], they give a good overview over intra-IB trade. There is a sharp difference between the intra-NBI percentages of the DRC, Ethiopia and Egypt (with a weighted average of 3%) and the remainder (28%). Egypt has the largest GDP of all NBI states ($303m out of an NBI total of $659m) and is an open economy (trade is 43% of its GDP compared with a NBI weighted average of 39%), but clearly trades to its north rather than its south. This is hardly surprising given the Egypt's economic centre of gravity in the Nile delta.

With the exception of Rwanda, all Nile basin countries report substantial trade imbalances with their NBI neighbours. Kenya, Egypt and Tanzania enjoy surpluses; the remainder are in deficit (i.e. they export less to other Nile basin countries than other Nile basin countries export to them).

Table 56. Intra-NBI exports, 2019, $ million

		Countries of destination											All exports	NBI/all exports, %
		BUR	DRC	EGY	ETH	KEN	RWA	SSD	SUD	TZA	UGA	NBI total		
		$ million											$ billion	
Countries of origin	BUR		19.9	11.1	0.9	2.8	2.0	*[0.0]*	2.9	3.2	6.3	49.0	283	17.3%
	DRC	2.6		123.1	0.0	18.5	15.8	*[0.0]*	0.0	0.6	33.9	194.5	8,160	2.4%
	EGY	11.3	17.0		256.2	396.4	36.2	*[0.0]*	460.0	40.8	75.0	1,292.9	36,700	3.5%
	ETH	0.1	0.2	28.0		10.3	0.2	*[1.0]*	41.4	7.2	0.8	88.2	3,110	2.8%
	KEN	62.4	130.5	185.6	64.3		271.4	*[112.0]*	57.1	327.2	614.0	1,712.5	6,250	27.4%
	RWA	22.8	370.8	6.5	10.2	20.3		*[20.1]*	5.1	5.0	61.2	501.9	1,350	37.2%
	SSD	*[0.0]*	*[0.0]*	*[0.0]*	*[0.0]*	*[0.1]*	*[0.1]*			*[0.0]*	*[0.2]*	*[3.2]*	*[3.7]*	
	SUD	0.3	0.0	206.9	90.0	31.5	0.0	*[8.8]*		0.4	8.1	337.2	4,000	30.4%
	TZA	43.3	310.8	14.0	4.4	234.4	247.6	*[0.2]*	1.7		361.2	1,217.4	4,250	28.6%

[96] Brookings Institute/Vera Songwe. 2019. *Intra-African Trade: a Path to Economic Diversification and Inclusion.*
[97] Brooks D H and Hummels D. 2009. *Infrastructure's Role in Lowering Asia's Trade Costs*. Manila.
[98] The Observatory of Economic Complexity (OEC, https://oec.world) processes UN Comtrade data
[99] (i) they omit aid flows and informal trade, (ii) reported exports and reported imports do not balance, i.e. the exports reported from country A to B do not equal the imports that country B reports from country A, (iii) reported exports include re-exports, (iv) there is widespread fraud; under-reporting at BCPs is rife

	Countries of destination											All exports	NBI/all exports, %
	BUR	DRC	**EGY**	**ETH**	**KEN**	**RWA**	**SSD**	**SUD**	**TZA**	**UGA**	**NBI total**		
	$ million											**$ billion**	
UGA	35.3	203.4	8.9	11.4	281.7	38.0	*[355.2]*	59.9	67.0		705.5	3,010	23.4%
Sum	**178**	**1,053**	**584**	**437**	**996**	**611**		**628**	**451**	**1,160**	**6,099**	**67,113**	9.1%

Source: UN Comtrade database via OEC Visualization tool

Note: South Sudan (SSD) has a very poor reporting record. Available values are shown in italics but are not included in totals

Table 57 shows changes in exports from each country to other Nile basin countries from 2011 to 2019. (Data for 2011-2013 are taken from the VICMED prefeasibility study[100] and exclude Ethiopia). It illustrates one important point, namely that trade is, for almost all Nile basin countries, extremely variable, rendering growth forecasts extraordinarily difficult.

Table 57. Annual NBI trade, 2011-19, current $ million

Exporting country	Exports to other Nile basin countries			
	2011	**2012**	**2013**	**2019**
BUR	39	5	44	48
DRC	65	99	49	195
EGY	921	883	914	1,037
KEN	2,292	1,656	1,348	1,648
RWA	143	467	581	492
SSD	N/A	N/A	N/A	4
SUD	69	25	76	247
TZA	541	814	668	1,213
UGA	1,021	1,246	1,311	694

Note: table shows exports from the exporting country to all other NBI states. Data for Sudan before 2019 include South Sudan and so cannot be compared with 2019 data, which exclude S Sudan

Sources: VCMED (for 2011-2013) and this study (for 2019)

19.2 Unit values

Clearly the nature of goods traded has a bearing on the suitability of any particular transport mode. Trade in goods is reported according to the World Customs Organization's harmonized system (HS). For the purposes of this analysis trade is divided into eight commodity groups, as shown below.

[100] Presidential Infrastructure Champion Initiative (PICI). 2015. *VICMED: Establishment of Navigational Line between Lake Victoria and Mediterranean Sea*. Cairo.

Table 58. Commodity groups

Group	Description	HS range	Example relevant to NBI trade	2019 intra-NBI trade, %
1	Animal & vegetable products	1.01-2.14	Cut flowers, rice	21.1
2	Oils, fats and foodstuffs	3.15-4.24	Vegetable oils, pasta	13.3
3	Mineral products, stone articles	5.25-5.27, 13.68-13.70, 14.71	Copper ore, cement, gold	18.3
4	Chemical products, plastics, rubber	6.28-7.40	Fertilizer, plastic sheets	15.4
5	Skins, wood, wood pulp, paper	8.41-10.49	Facial tissue	5.3
6	Textiles, footwear etc	11.00-12.67	Synthetic yarn	4.8
7	Base metals & their products	15.72-15.83	Aluminium wire	11.1
8	Machinery, vehicles, arms etc	16.84-20.96	Refrigerators	10.7

Notes: commodities in group 1 and many in group 3 are considered primary products
Source: World Customs Organization

The trade in commodity groups 1 and 3 amounts to 39% of the total intra-NBI trade.

While trade quantities are not readily available, it is possible to use indirect methods to estimate unit values. For example, Kenya Ports Authority (KPA) data for 2015 can be used to estimate tonnages for Uganda and Kenya. Uganda's exports through KPA ports amounted to 384,000t in 2015. Deducting exports to its landlocked neighbours, and ignoring exports by air, gives a value of $4/kg. If all African trade is deducted the unit value drops to $3/kg. In the case of Kenya the same exercise yields $1.3 to $1.6/kg. (For comparison the wholesale price of rice in Dar es Salaam in the same year was around $1/kg).

KPA data largely reflect trade with non-African partners. Unit values for NBI trade are likely to be lower and indeed rather lower values can be derived from a 2017 study of Lake Victoria transport.[101] This study reviewed Ugandan imports and exports in 2015. For all commodities the average export value was $0.90/kg and for imports $0.83/kg. For short haul ro-ro transport (e.g. on Lake Victoria) a value of $1/kg is reasonable. NBI trade diverting to long haul barge transport is likely to be concentrated in commodity groups 1-5, for which Ugandan unit values in 2015 were $0.6/kg and $0.5/kg for exports and imports respectively.

These unit values are low by global trade standards. The value-to-weight ratio of goods carried by block train from China to Europe is much higher, at approximately $6/kg.[102] High transport costs are inevitably a more significant trade barrier for goods with low unit values. Brooks and Hummels draw attention to the role of rising value-to-weight ratios in the rise of Chinese exports.[97]

Using Table 56 data and unit values of $0.6-0.8.kg implies total intra-NBI trade of roughly 15-20 million tonnes per year. This is similar to the annual imported tonnage through KPA ports in 2015.

19.3 Rationale for Enhancing the Nile Transport Corridor

Handling costs are not included in the following table. They can be substantial and highly influential over shippers' decisions, but there is no straightforward link between handling costs and transport mode.

[101] World Bank/Uganda Ministry of Works & Transport. 2017. *Lake Victoria Transport PPP Due Diligence*.
[102] See Kosoy, V. 2017. *A Future of EU-EAEU-China Co-operation in Trade and Railway Transport*. Infrastructure Economics Centre. Moscow.

Table 59. Line-haul transport costs

Mode	Route	Cost/t-km
Road	Mombasa-Kampala (1,145km)[a]	$0.07-0.10
Rail	Mombasa-Naivasha ICD (550km)[b]	$0.05
Barge	Kosti-Juba, low efficiency (1,360km)[c]	$0.10
Barge	Kosti-Juba, high efficiency (1,360km)[c]	$0.03
Ro-ro ferry	Mwanza-Port Bell (22h, 730km by road)[d]	$0.14

Notes: (a) truck assumed to be a truck-trailer or truck semi-trailer carrying 1.5 TEUs each with a 19t payload. No backload assumed. Cost is a generalized cost (GC) that includes vehicle cost but not the agency costs of road construction and maintenance. The GC per veh-km is $1.0-1.3
(b) Mombasa-Naivasha rail rate is discounted SGR rate from June 2020 and is derived from $510 for a full twenty foot container with a 19t payload making a one way trip (see The Standard, 25.02.21). Undiscounted rate is 25% higher. Cost most likely includes a portion of infrastructure cost.
(c) barge efficiency refers to backload, hours steaming per day and price of fuel. Four barge set assumed, with a payload of 1,500t[103]
(d) estimated from limited public domain information on proposed new ro-ro service. Capital cost of vessel included but not improvements to landside structures. Cost/t-km based on road distance and 167,000t per year

As expected, the line haul costs of barge transport are competitive, but only under favourable conditions of high loading efficiency, 24h steaming and low fuel costs.[104] In addition to the cost of line haul, total transport costs have to include construction, maintenance and transshipment costs. It is not possible to generalize about this. Barge transport on a waterway needing little dredging, requiring minimal navaids and having efficient freight handling facilities may have the lowest total costs per tonne-km of all, but this can only be established after a detailed comparison of alternatives.

While reducing transport costs is the (transport economics) rationale for enhancement projects, it alone cannot justify investment. In order to justify investment from the transport economics perspective, expected benefits must exceed expected costs. This means comparing alternatives. In the case of the Kosti-Juba link, for example, discussed in Section 19.5 below this would mean comparing the total transport costs (line haul, transshipment, provision of navaids, dredging, wharfage, cranes etc etc) for commodity classes of interest and relevant OD pairs (e.g. Kampala and Khartoum). This exercise needs to be carried out for project alternatives: road-maritime-road via Mombasa might be the without-project (WOP) case while road-IWT-road and all-road could be the with-project (WP) cases. Even if this exercise produces a clear favorite it will not be sufficient to justify investment. Two further questions need to be answered:

- will shippers use the economically preferred route? They will need reassurance about not only tariffs but also insurability and delays and payments at BCPs
- can finance be raised on terms that will not compromise the financial viability of the preferred route?

The broad (minimum) conditions for investment in IWT are shown in Table 60.

[103] UNOPS. 2018. *River Barge System Feasibility Project, South Sudan.*
[104] Fuel – access and prices - are an issue at remote locations.

Table 60. Criteria for investment in IWT

Criterion	Commentary
Steady demand	Tends to rule out seasonally variable trade in agricultural products. Barge transport suits goods with a low time value. Less applicable to ro-ro transport.
High loading efficiency	All modes deliver lower unit costs when backloads are high and services can operate throughout the night
Low transshipment costs	Applies to all modes
Low maintenance costs	High recurrent dredging costs are a serious obstacle
Good and cheap access to refuelling	Particularly applies to passage through Nile reaches between Nimule (Uganda/S Sudan BCP) and Kosti
Lack of competing mode	Rail, to be an efficient alternative, has similar requirements to IWT. Road, however, while usually having higher line haul costs, is more flexible ("end-to-end"), requires fewer transshipments and easily handles containers
Containers can be handled	Nearly all trade via Mombasa is containerized, so IWT investments should also be compatible with containers.

In following the sections, we explore the viability of corridor enhancement by groups of Nile basin countries and their associated Nile river reaches.

19.4 Viability of Nile corridor enhancements – Lake Victoria basin

The six Nile basin countries that border Lake Victoria include three that are landlocked. The transport cost penalty of being landlocked has been extensively researched. For example, the World Bank estimated in 2017 that, compared with its neighbours, Rwanda has the highest transport costs, at 40% of the value of imports or exports.[105] Table 61 below reviews the scope for viable IWT investments

[105] World Bank/IDA. 2017. *Project Appraisal Document on a Proposed Scale-Up Facility Credit to the Republic of Rwanda for a Lake Victoria Transport Program – SOP1*. Washington DC.

Table 61. Lake Victoria – enhancement potential

Countries	2019 trade	Membership of FTAs or customs unions	Existing transport corridors	Existing role of IWT	Enhancement potential
BUR, RWA, TZA, KEN, UGA, DRC	Total trade $7.6bn Reduces to $5.7bn if OD pairs irrelevant to IWT (UGA-KEN, TZA-KEN, BUR-RWA, DRC-RWA, BUR-DRC) are deducted	All are members of EAC customs union	Northern (road) corridor links all countries to Mombasa and is efficient. SGR available between Naivasha ICD and Mombasa. Central road corridor links all save KEN to Dar es Salaam port. Less efficient than northern corridor. Meter gauge central line from Mwanza, part of which (Dar es Salaam to Dodoma) is currently being upgraded to electrified SG.	Commercial-scale lake transport was part of rail transport from Mombasa via Kisumu (KEN) to Port Bell (UGA) and Mwanza (TZA). Poor rail connections and antiquated vessels led to near-collapse by 2005. (Port Bell handled 480,000t in 2001-2, falling to 66,000 in 2018-19).	Private investment in a new Mwanza-Port Bell Ro-Ro service is underway with an expected initial annual volume of 167,000t. [106] Unlike barge transport, Ro-Ro ferries are compatible with high value, truck born containerized goods, and have very low transshipment costs. Improved Ro-Ro transport would be complementary with road transport on the northern corridor. However, line-haul costs suggest that this service will face tough competition from all-road transit around the lake, despite a time saving of roughly two days. There have been frequent closures of the RWA/UGA BCP in recent years and improved IWT would have significant resilience value.

[106] See https://infracoafrica.com

19.5 Viability of Nile corridor enhancements – Lake Victoria to Kosti

This part of the Nile basin, next to the direct stretch between Lake Victoria and Kosti, includes branches of includes Lake Kyoga (Uganda), Lakes Edward and Albert (connected by the Semliki river), the Sobat river from its confluence with the White Nile upstream of Malakal to the Ethiopian border and the Bahr al Ghazal from its confluence with the White Nile to Wau in South Sudan.

Kosti is the logical northern end of this reach as it has road and rail connections and was at one time a centre for barge operations on the southern reach. Riparian economic activity declines rapidly downstream of Juba.

Table 62. Lake Victoria – Kosti enhancement potential

Countries	2019 trade	Membership of FTAs or customs unions	Existing transport corridors	Existing role of IWT	Enhancement potential
Bloc 1: EGY, SUD, ETH, SSD Bloc 2: remaining NBI members	\$2.0bn if OD pairs irrelevant to IWT on this reach (EGY-SUD, ETH-KEN) are omitted. 44% are primary products (commodity groups 1 and 3). No recent trade data for SSD.	Bloc 1: all except SSD are members of COMESA FTA. SSD also member of EAC. Bloc 2: all except EGY, SUD and ETH are members of EAC customs union.	Kampala-Nimule-Juba road links northern (road) corridor to South Sudan. There are no all-weather roads between Juba and Kosti. Trade between Lake Victoria basin countries and Sudan and Egypt uses maritime transport from Mombasa to Port Sudan or Port Said. Nairobi to Khartoum by sea and road is roughly 6,500km. Meter gauge rail links from Kampala to Kasese (essentially a minerals line, but close to L Edward) and from Kampala to Pakwach (on the Albert Nile downstream of the Albert/Victoria Nile confluence) have not been operational for decades. Port Sudan is Sudan's principal port for both imports and exports. It is connected by rail and road to Kosti and by road to Khartoum.	There were regular barge sailings (typically a pusher and four barges) on this southern reach until 1983. The peak volume was 143,000t in 1981. Services essentially stopped in 1983 and were followed by infrequent aid transports of food. In 2019 there were reports that more regular services had resumed.[107]	There is no doubt that the lack of a viable transport corridor north of Juba constrains development of South Sudan. Trade between Egypt and Sudan, and the Lake Victoria states would also benefit: Nairobi to Khartoum is roughly 3,000km compared with 6,500km via Mombasa. However, it is doubtful whether a commercial operation is viable given the likely intermittent demand, difficulty of getting insurance, poor access to fuel supplies and little container-handling equipment.

[107] sudantribune.com/article66489/

19.6 Viability of Nile corridor enhancements downstream to Kosti

In addition to the Nile between Kosti and the delta, this part of the Nile basin includes the Blue Nile from its confluence with the White Nile at Khartoum to the Grand Ethiopian Renaissance Dam (GERD) and Lake Nasser between Aswan and Wadi Halfa. The riparian areas between Kosti and Khartoum on the White Nile and between Sennar and Khartoum on the Blue Nile are the centres of Sudan's agricultural industry, producing wheat, cotton, gum Arabic and livestock.

Table 63. Potential downstream of Kosti

Countries	2019 trade	Membership of FTAs or customs unions	Existing transport corridors	Existing role of IWT	Enhancement potential
Group 1: EGY, SUD Group 2: remaining NBI members	$2.6bn between groups 1 and 2. $0.7bn between EGY and SUD. Coffee exports from UGA to SUD were 90% by value of all exports. Tea exports from KEN to SUD were 60% of all exports. EGY exports oil, cement and foodstuffs to SUD. SUD exports livestock, cotton and vegetables to EGY.	All group 1 except DRC and TZA are members of COMESA FTA. All group 2 except EGY, SUD and ETH are members of EAC customs union.	IWT is limited by non-operational locks at the Jebel Aulia dam on the Kosti-Khartoum reach and by cataracts and Merowe dam without locks between Khartoum and Wadi Halfa. BCPs between EGY and SUD remain contested, in part because of a territorial dispute over the Halayeb triangle, a mineral-rich area on the Red Sea west of Wadi Halfa. As a result there is little formal goods traffic across either the land border or across Lake Nasser. Almost all freight to and from SUD is carried by road transport to Port Sudan. IWT on the Blue Nile is limited by the lack of locks at Sennar dam, Roseires dam and the GERD. The road between SUD and ETH at Metemma BCP is reportedly of good quality but the border itself is frequently closed. There are no data on the volumes of goods using this route.	Very limited. Peak goods transport on the northern reach of services from Kosti was just 37,000t in 1977. Navigability is poor downstream of Khartoum and IWT only fulfils a local role. There are no locks at Aswan; navigation for goods vessels resumes downstream of the Low Aswan dam.	IWT is well established downstream of Aswan, although its modal share has declined considerably in recent years. Upstream of Aswan the scope for increased IWT appears limited at present. The priority for increased trade must be a removal of trade restrictions between EGY and SUD (both are members of COMESA) and an improved road link. (Ferry transit of Lake Nasser, 550km long, takes 17h).

19.7 Conclusions on viability

The conclusions from the reach by reach reviews above are as follows:

a. intra-NBI trade is a small proportion (around 9%) of Nile basin countries' total trade
b. overall, intra-NBI trade has a low value-to-weight ratio of approximately $0.6-$0.8/kg. High transport costs are disproportionately significant when value-to-weight ratios are low. This particularly applies to the six Nile basin countries that are landlocked
c. the countries of the Lake Victoria basin have access to the northern corridor, an efficient (and partly multi-modal) route to Mombasa, East Africa's principal port
d. the prospects for ro-ro ferry operations on Lake Victoria are fairly good, and private sector investment in new services is now taking place. Such services will deliver reduced transport costs between basin states and additional resilience to services between the northern corridor in Uganda and Kenya and Rwanda, Burundi and (to a limited extent) the DRC
e. trade between the Lake Victoria basin states and riparian states downstream of Juba faces substantial infrastructural barriers. In practice this trade uses maritime transport from Mombasa to Port Sudan or the ports of the Nile delta. An all-weather road from Juba to Kosti (1,400 river km) would avoid transshipment costs by offering a single mode from Khartoum via Juba to Kampala or Nairobi. Such a route would be less vulnerable than IWT to seasonality and backload constraints.[108] It would also remove a significant constraint on development in South Sudan.
f. trade between Kosti and Aswan faces many obstacles. Navigation on the Nile itself is constrained by cataracts and dams either without locks or without functioning locks, and by border disputes between EGY and SUD. IWT appears to be limited. There are press reports of proposals to build a rail link between Aswan and Wadi Halfa. Trade along the Blue Nile is similarly limited by dams without locks. While road conditions between Sudan and Ethiopia via Metemma BCP are considered good, this BCP is frequently closed.

19.8 VICMED alternatives

The VICMED initiative – a Presidential Infrastructure Champion Initiative (PICI) project to develop river transport from Lake Victoria to the Mediterranean – started in 2013. It led to a pre-feasibility study of options, issued as a draft report in May 2015.[100]

VICMED sets out six alternatives. The scales of works required are not given and there are no estimates of costs or benefits.

Alternative 1 envisages a navigable Nile over its entire length from Lake Victoria to the Mediterranean. This alternative proposes no improvements to the Blue Nile, the Sobat or the Bahr al Ghazal, or between Rwanda and Lake Victoria or on Lakes Edward and Albert. The southern end of the navigable section ends at or close to Nalubaale (formerly Owen Falls) dam, where it connects to the northern corridor. The text claims that there would be a potential for direct navigation for vessels from Kenya and Tanzania, and possibly links to Lakes Albert and Edward. This alternative would face many obstacles, some of them extraordinarily costly, involving several locks and training works.

As set out it would not deliver any Lake Victoria improvements, nor would it be competitive with well-established road transport in the upper reaches. Between Juba and Kosti it would deliver positive economic impacts to South Sudan, encourage trade between South Sudan, Sudan and Egypt, and open up trading links between Sudd communities and Juba. However, it is doubtful whether a commercial

[108] Road construction in South Sudan faces many difficulties: see for example the World Bank report on the cancelled South Sudan – Eastern Africa Regional Transport Trade and Development Facility (report no NCO00004670, April 2019)

operation is viable given the likely intermittent demand, difficulty of getting insurance, poor access to fuel supplies and little container-handling equipment. A road alternative would also face many difficulties but should be considered alongside IWT.

This and the other alternatives, most of which envisage substituting other modes for certain navigable sections proposed in alternative 1-4, are set out in Table 64 overleaf.

Table 64. VICMED alternatives compared

VICMED Reach:	1	2	3	4	5
	Lake Victoria to Murchison Falls and northern shore of L Albert	**Great Lakes countries – Rwanda, Burundi, Uganda, DRC, Lakes Edward & Albert**	**Albert Nile to Malakal**	**Malakal to Wadi Halfa**	**Egyptian Nile**
Existing transport links:	All weather roads between Lake Victoria and Gulu, Pakwach and L Albert shore	Ferry services on Lake Victoria and all weather roads around the lake. Rwanda & Burundi have good connections on and around LV to northern corridor and to Juba. Uganda and DRC connect directly to northern corridor and to Juba Lakes Edward and Albert have very little IWT	All NBI states upstream of Juba have good access to roads between L Albert and Juba. Between Juba and Malakal there are no all-weather roads north of Bor. Between Juba and Malakal there are irregular barge shipments of food aid.	Between Malakal and Khartoum there are poor roads (to Sudan border), then all-weather road to Khartoum There are irregular food aid barge shipments between Malakal and Kosti. North of Kosti IWT is limited by Aulia dam but road is good. North of Khartoum navigation is limited by cataracts	Egyptian Nile is navigable between Aswan and the Mediterranean. However, its modal share has fallen dramatically in recent years. A JICA master plan study in 2012 recommended measures to reverse the trend.[109]
VICMED 1 – IWT enabled from Victoria Nile to Mediterranean	Economic opportunities:	Reach 1 – slight in view of competing road links Reach 2 – this alternative does not include links to the Great Lakes countries Reach 3 – a navigable Nile between Juba and Kosti would facilitate S Sudan trade with Sudan and Egypt (currently very low). Trading opportunities between Sudd communities and Juba would also be opened up Reach 4 – slight in view of competing road and rail links Reach 5 – it is not clear that the VICMED works will reverse the decline in IWT's modal share			
	Constraints:	Investment cost and non-physical trade barriers			
	Risks:	(i) investors are risk averse and may not invest in vessels and landside facilities; (ii) shippers are unable to insure goods in transit and if so will not use facilities; (iii) VICMED 1 does not prioritize			

[109] JICA for Transport Planning Authority. 2012. *Comprehensive Study on the Master Plan for Nationwide Transport System. Technical Report no 3: Inland Waterway Transport.* Tokyo

VICMED Reach:	1	2	3	4	5
		reacheswhere best scope for benefits can be found; (iv) cross-boundary trade facilitation agreements break down and jeopardize investment			
VICMED 2 – substitutes IWT works with (i) transshipment barge-rail in Pakwach and (ii) road link Aswan to Abu Hamad	Economic opportunities:	Reach 1 – slight in view of competing road links (and lack of demand on L Albert), but transshipment activities at Pakwach would generate employment. VICMED 2 would reduce the scope and cost of navigation works on these reaches. Reach 2 – as VICMED 1 Reach 3 – as VICMED 1 Reach 4 – the proposed road link would reduce journey times and obviate the need for locks at Aswan. However, this is one of several projects under consideration for improving cross-border links and should be appraised in that context Reach 5 – as VICMED 1			
	Constraints:	Investment cost, but slightly reduced compared with VICMED 1. Non-physical trade barriers			
	Risks specific to VICMED 2:	Delayed rehabilitation of Pakwach-Tororo rail link. It is likely that the SGR will extend to Tororo in coming years, but the further extension to Pakwach (approx 500km) remains highly uncertain. The rail link would not support Uganda-S Sudan trade.			
VICMED 3 – as VICMED 2 but with rail connection Pakwach to Juba	Economic opportunities:	Reaches 1 – slight in view of competing road links, but transshipment activities at Pakwach and Juba would generate employment. VICMED 3 would further reduce the scope and cost of navigation works on these reaches. Reach 2 – as VICMED 1 Reach 3 – the rail link would connect Juba to the SGR from Tororo to Mombasa and should expand exports of primary goods from S Sudan Reach 4 – as VICMED 2 Reach 5 – as VICMED 1			
	Constraints:	Investment cost, but may be slightly reduced compared with VICMED 2			
	Risks specific to VICMED 3:	Delayed rehabilitation/construction of Tororo-Pakwach-Juba rail link. It is likely that the SGR will extend to Tororo in coming years, but further extensions to Pakwach and Juba (approx 650km in total) remain a proposal whose realisation is highly uncertain. It has however been considered as part of other infrastructure plans, for example LAPSSET.[110]			
VICMED 4 – as VICMED 1 but with (i) navigable links between Rwanda and Lake	Economic opportunities:	Reaches 1, 3, 4, 5 – as VICMED1			

[110] LAPSSET (Lamu Port-South Sudan-Ethiopia-Transport Corridor). 2011. *LAPSSET Corridor and Lamu Port Feasibility Study and Master Plans.* Nairobi

VICMED Reach:	1	2	3	4	5
Victoria (via Akagera or Katonga rivers) and (ii) connections across Lake Victoria to Mwanza and Kisumu		Reach 2 – a feasibility study in 2009[111] examined the feasibility of Akagera river navigability from Kakitumba (Rwanda) to Lake Victoria (approx 50km north of Bukoba). It concluded that it was technically feasible but economic viability required a large proportion of northern corridor traffic to divert. At present Rwanda relies on road transport via Uganda or Tanzania. The Uganda link to the northern corridor has been prone to disruption in recent years. The main benefit of a navigable link would be resilience. No study of the Katonga river as a waterway is available. This river lies wholly within Uganda and does not connect centres of production or consumption. Its relevance to Nile connectivity appears slight.			
	Constraints:	Investment cost; legal barriers.			
	Risks specific to VICMED 4:	Doubtful viability. The Akagera river outlet (in Uganda) does not directly link to Bukoba port (in Tanzania). Bukoba has limited ferry services to Mwanza and thence to Kisumu and the northern corridor. The river also forms the Uganda/Tanzania border for much of its length. Thus there are complicated transshipment and legal issues.			

[111] ITECO for Ministry of Infrastructure (Rwanda). 2009. *Feasibility Study for the Navigability of Akagera River.*

20. Current policy situation

20.1 Country level

20.1.1 Egypt

Table 65. Egypt: legislation

Reference	Responsible authority	Summary
Law no 10/1956		Inland navigation law
Law no130/1975	Ministry of Transport	Berth and organizing berthing at the Internal water
Law no 09/1983	All (Ministerial Decree)	Protecting river Nile and its waterway from pollution (amended in 2013)
Law no 12/1984	Ministry of Water Resources and Irrigation	Law on irrigation and drainage (some references to canals)
Law no 04/1994	Ministry of Environment and Egyptian Environmental Affairs Agency	Environmental protection (licensing of waste facilities)
Presidential decree no 290/1969	Presidential decree	The transfer of responsibilities of regulations departments to the local administration organization
Presidential decree no 474/1979		Established the River Transport Authority
№ 117/2008		Amendment of №474/1979
№ 2272/1971	Prime ministry decree	Authorizing governor with responsibilities of Ministry of Transport
№ 294/1999	Ministry of the Public Works and Water Resources	Protecting river Nile clean
№ 8921/ 1956		Licensing of units and their safety and validity conditions and specifying shipping lines
№ 8922/1956	Minister decree	Organising units traffic and using in the internal water and the conditions for working on it
№ 9040/1957		The licensing conditions for public ferries traffic and organising the tender regulations
№ 189/1962		Conditions of licensing for private berth and organising berthing at private berths and the temporally berthing including the fees
№ 15/1983		Licensing of engine ships and their safety and validity conditions and organising ships traffic in internal water
№ 126/1986		Bridges construction over the waterways
№ 282/1998		Navigation licenses in the internal water

Egypt's current planning framework is contained in its Medium Term Sustainable Development Plan 2018/19-2021/22, a component of Egypt Vision 2030. None of the documentation seen contains references to inland waterways.

20.1.2 Sudan

Table 66. Sudan: legislation

Reference	Responsible authority	Summary
Law on inland waters navigation of 1993	Ministry of Transport	(i) This Law consisting of 23 articles aims at providing for the navigation in inland waters and establishes a Technical Advisory Committee and the Inland River Navigation Authority

20.1.3 South Sudan

Table 67. South Sudan: legislation

Reference	Responsible authority	Summary
Five years implementation strategies	The Ministry of Transport and Roads	The policy paper has twelve objectives covering, for example, strengthening the Ministry of Transport and Roads to play an effective coordination and regulation role; optimization of the allocation of available resources among the various transport modes;

The South Sudan Roads Authority will develop a Road Investment Program (RIP), containing both development and maintenance priorities and submit it to the Minister who shall present it for approval to the Council of Ministers. Activities outside these approved work programs will only be undertaken with the concurrence of the Board and approval of the Minister.

20.1.4 Uganda

Table 68. Uganda: legislation

Reference	Responsible authority	Summary
Vessel Registration Act, Cap 362, 1904	Maritime authority; Ministry of Works and Transport	The Vessel Registration act describes Ugandan procedure for vessels registration. The classes for vessels distinguishing are as the following: 1. first class: vessels of fifteen burden and upwards; 2. second class: vessels of less than fifteen burden, navigated otherwise than by oars, paddles, or poles only; 3. third class: boats navigable by oars, paddles, or poles only
The Ferries Act, Cap 355, 1905	The Ministry of Works and Transport	This act regulates the approval of the licence for all types of vessels.
Part XII of the Uganda Railways Corporation Act, Cap 331	The Ministry of Works and Transport; Uganda National Roads Authority (UNRA); Standard Gauge Railway and Uganda Railways Corporation (URC)	This is the most important act for navigation. It regulates vessels exploitation, ports usage and maintenance, etc

20.1.5 Kenya

Table 69. Kenya: legislation

Reference	Responsible authority	Summary
Merchant Shipping Act (Cap. 389), 2012	Minister for Transport	An Act of Parliament to make provision for the registration and licensing of Kenyan ships, to regulate proprietary interests in ships, training and terms of engagement of masters and seafarers and matters ancillary thereto;

Reference	Responsible authority	Summary
		to provide for the prevention of collisions, the safety of navigation, the safety of cargoes, carriage of bulk and dangerous cargoes, the prevention of pollution, maritime security, the liability of shipowners and others, inquiries and investigations into marine casualties; to make provision for the control, regulation and orderly development of merchant shipping and related services; generally to consolidate the law relating to shipping and for connected purposes.
The Merchant shipping (fees) regulations, 2011; Legal Notice No. 192	Minister for Transport	The Act regulates the fees, their cost, time or payment, recovery, and penalty for non-payment.
Kenya Ports Authority Act (Act No. 2), 1978	Kenya Ports Authority	An Act of Parliament to provide for the establishment of an Authority to be known as the Kenya Ports Authority, for the transfer to the Authority of the undertakings, within Kenya, of the East African Harbours Corporation, for the functions of the Authority and for purposes connected therewith. The Act provides for the creation of the Kenya Ports Authority which may administer ports and establish and operate port services. The Act also provides for acquisition of land for the purposes of the Authority. The Minister may make, subject to other legislation, Regulations for the registration, licensing, inspection and control of fishing boats.

20.1.6 Tanzania

Table 70. Tanzania: legislation

Reference	Responsible authority	Summary
National transport policy, 2003	Ministry of communications and transport	NTP includes a status of transport infrastructure and services, transports and national development, and policy development.

In areas along the coast, lakes, rivers and in islands, the use of water transport needs to be enhanced as a cheap and ideal mode at this level. In this regard, villages need to be encouraged to develop feeder services using small vessels.

The policy direction is for the Ministry responsible for transport to liase with the local authorities in order to explore, identify, and make possible the navigability of portions of rivers and other water bodies.

20.2 Regional level

20.2.1 Lake Victoria - a pearl of Central African unity

Reference	Responsible authority	Summary
Protocol for Sustainable Development of Lake Victoria Basin to the Treaty for the	East African Community	The Partner States shall implement and review existing agreements relating to the promotion of safety of navigation on Lake Victoria by: a) Implementing and where necessary, reviewing existing agreements relating to the promotion of the safety of

Reference	Responsible authority	Summary
Establishment of the East African Community. Article 31. Safety of Navigation.		navigation, maritime safety and preservation of the marine environment; and b) Initiating and promoting programmes as well as establishing a mechanism that will enhance maritime safety on the Lake
Lake Victoria Transport Program - ongoing, Rwanda (December, 2023)	The World Bank	The program development objective is to facilitate the sustainable movement of goods and people in the Lake Victoria region, whilst strengthening the institutional framework for transport safety.The project development objective for SOP1 Rwanda is to improve the efficient and safe movement of goods and people along the regional corridor from the border crossing at Rusumo to the border crossi ng at Nemba and Rusizi together with upgrades to road asset management and road safety in Rwanda.
The Lake Victoria Marine Transport (LVMT) Project - ongoing (2023)	Ministry of Works and Transport, Uganda Ministry of Transport, Tanzania	The Lake Victoria Marine Transport (LVMT) Project entails the development and financing of a small fleet of purpose-built Roll On/Roll Off vessels that will offer freight services to customers in the region. Initial service will operate between Mwanza South Port in Tanzania, and Port Bell in Uganda. Works are commissioned to improve the market for marine cargo transport in the Lake Victoria Region, by bringing modern, purpose-built cargo vessels, logistics expertise and infrastructure to the Lake Victoria Region to enhance cargo transport services to customers.
The East Africa Marine Transport (EAMT) project - ongoing	Tanzania/Uganda	The EAMT project will pioneer a scheduled roll-on/roll-off freight transport service across Lake Victoria, transporting fully laden trucks.
Lake Victoria Maritime Communications and Transport Project - ongoing (April, 2022)	EAC	The Multinational Lake Victoria Maritime Communication and Transport Project is designed within the 4th EAC Development Strategy (2011-2016) and will contribute to the EAC's Vision for the Lake Victoria basin to build "a prosperous population living in a healthy and sustainably managed environment providing equitable opportunities and benefits". The project addresses the maritime transportation and navigation safety intervention area and will contribute to the provision of safe, efficient transport links, and to the safe conduct of fishing activities that are essential to achieving the goals of poverty reduction and sustainable development. It addresses significant safety of life and transport planning issues on Lake Victoria to encourage increased transport and trade on the Lake.
Northern Corridor Transit and Transport agreement (1983, revised 2007).	Northern Corridor Transit and Transport Co-ordination Authority (NCTTCA), Nyali, Mombasa, Kenya.	The NCTTA is a trade facilitation and economic development agreement. Its goal is the free movement of goods and people throughout the territories of the signatories.

Reference	Responsible authority	Summary
	Signatories: Burundi, Rwanda, DRC, Kenya, Uganda, S Sudan	

21. Engaged stakeholders

21.1 National level

National level stakeholders are institutions or companies with an active role in IWT. They are listed in Table 71.

Table 71. National level stakeholders

Country	Stakeholder	Role
Burundi	Ministry of Works, Transport, Equipment and Regional Planning	Responsible ministry
DRC	Ministry of Transport and ways of Communications	Responsible ministry
Egypt	Transport Planning Authority, Ministry of Transport	Responsible ministry
	General Authority for River Transport (RTA)	Technical regulator
	Egyptian Tourism Authority	
	Ministry of Water Resources and Irrigation	Prescribes waterway levels
	Qalaa Holdings	Owner of Nile Logistics, transport operator
Ethiopia	Ministry of Transport and Communications	Responsible ministry
Kenya	Ministry of Transport, Infrastructure, Housing, Urban Development and Public Works	Responsible ministry
	Kenya Ports Authority (KPA)	Parastatal port operator (operates all Indian ocean ports plus Kisumu, and ICDs)
	Kenya Railways Corporation (KRC)	Parastatal rail operator. Operates all rail services
	Kisumu Kenya Shipyard Ltd	Ship repair yard (SOE)
Rwanda	Ministry of Infrastructure	Responsible ministry
	Rwanda Transport Development Agency (RTDA)	Executive agency of ministry (responsibilities include IWT)
Sudan	Ministry of Transport	Responsible ministry
	Sudan Railways Corporation	Parastatal rail operator
	River Transport Corporation (RTC) – privatised in 2007	
	Inland River Navigation Authority (part of Ministry of Transport)	
	Sea Ports Corporation	Parastatal port operator
South Sudan	Ministry of Roads and Transport	Responsible ministry
Tanzania	Ministry of Works and Transport	Responsible ministry
	Tanzania Railways Corporation (TRC)	Parastatal rail operator
	Tanzania Ports Authority (TPA)	Operates Dar es Salaam port and North and South Mwanza ports on Lake Victoria
Uganda	Ministry of Works and Transport	
	Uganda National Roads Authority (UNRA)	Executive agency for national road construction and maintenance. Also operates ten ferries

Country	Stakeholder	Role
	Uganda Railways Corporation (URC)	Also operates ferries on Lake Victoria
	Kalangala Infrastructure Services Ltd (KIS) (subsidiary of Infraco)	Private sector operator of ferries between Bugala island and mainland
	Infraco	Private sector investor, currently planning Mwanza-Port Bell ro-ro service

21.2 Regional level

Table 72. Regional Level Stakeholders

Name	Countries participating	Role
African Continental Free Trade Area (AfCTA)	All African countries have signed (except Eritrea), but not all have ratified the treaty	Aim: to create an African FTA that extends beyond goods to services, investment, intellectual property rights and competition policy
East African Community (EAC), Arusha, Tanzania	Burundi, DR Congo, Kenya, Rwanda, Uganda and Tanzania	The EAC operates a customs union and aspires to becoming a single market
Common Market for East and Southern Africa (COMESA), Lusaka, Zambia	Burundi, Comoros, Congo, DRC, Djibouti, Egypt, Eritrea, Ethiopia, Kenya, Libya, Madagascar, Malawi, Mauritius, Rwanda, Seychelles, Sudan, Swaziland, Uganda, Zambia and Zimbabwe	COMESA operates a free trade area.
Northern Corridor Transit and Transport Co-ordination Authority (NCTTCA), Nyali, Mombasa, Kenya	Burundi, Rwanda, DRC, Kenya, Uganda, S Sudan	The NCTTA oversees implementation of the NCTT agreement (1985, revised 2007). The agreement covers all aspects of transport (including IWT).
Lamu Port-South Sudan-Ethiopia-Transport Corridor Development Authority (LAPSSET), Nairobi, Kenya	Kenya, Ethiopia, S Sudan	LAPSSET aims to develop Lamu as an alternative to Mombasa. The project envisages pipelines and SGR railways to Juba and Addis Ababa. To date some minor works in Lamu have been completed.
East African sub-regional Support Initiative for the Advancement of Women (EASSI) and others	Uganda, Rwanda	In 2019 EASSI and two other civil rights organisations filed a case in the E African High Court against the Rwandan attorney general, alleging that the closure of the Rwanda/Uganda border contravened the treaty that established the EAC.
Lakes Edward and Albert Integrated Fisheries and Water Resources Management Project (LEAFII)	Uganda and DRC, co-ordinated regionally by the Nile Equatorial Lakes Subsidiary Action Program (NELSAP-CU).	Although not primarily concerned with IWT, LEAFII has procured four fisheries surveillance vessels and five fish landing sites.

21.3 International level

At an international level engaged stakeholders include the multilateral and bilateral development institutions (AU, EU, GTZ, AfDB, JICA, World Bank, USAID, DFID, AFD etc). The development agencies of Belgium, Canada, Denmark, the EU, Finland, Ireland, Netherlands, Norway, UK and the USA also support TradeMark East Africa (TMEA), an aid-for-trade body with its headquarters in Kenya. TMEA's goals are to reduce trade barriers and improve business competitiveness.

22. Ongoing Initiatives

22.1 Ongoing initiatives to advance waterway development on River Nile

22.1.1 PIDA Nile corridor (Project under AUDA-NEPAD)

22.1.1.1Description

PIDA (Programme for Infrastructure Development in Africa) is a strategic framework for the development of regional and continental infrastructure. The PIDA initiative is being led by the African Union Development Agency (AUDA-NEPAD) and the African Development Bank (AfDB). AfDB is the PIDA executive agency. Projects for inclusion in priority action plans (PAPs) are prepared by regional economic communities (RECs) or AU member states (MSs). The first PAP, PAP-1, covered the period 2012-20. PAP-2 is expected to cover the period 2021-30.

Selection criteria for infrastructure development aim to reflect an integrated corridor approach. All projects are supposed either to be a trans-border project or a single country project with regional impact. Projects are scored against eight criteria: (i) they should reflect multi-sectoral planning (e.g. combine road and rail), (ii) job creation, (iii) minimize greenhouse gas emissions, (iv) gender sensitivity, (v) urban-rural connectivity, (vi) economic viability, (vii) financial attractiveness and (viii) inclusion of smart or innovative technology. Some guidance on scoring is provided. Once scored, weightings are applied: economic impact has the highest single weight.

22.1.1.2Proposed Actions

It is important to realise that PIDA is a planning initiative, and so much of the documentation focuses on the planning process rather than projects. Even though AfDB is the EA, inclusion in a PIDA project list does not guarantee access to AfDB finance.

The 2019-20 PIDA implementation progress report lists eleven "mega-projects" that that have been championed by heads of state and are referred to as PICI (Presidential Infrastructure Champion Initiative) projects. The current list is shown in Table 73.

Table 73. PIDA PICI mega-projects as at 2019-20

Project name	Sector	Champion
Trans-Sahara Highway Missing Link and Optic Fibre Link	Road and ICT	Algeria
Kinshasa-Brazzaville Bridge Road/Rail	Road and rail	Congo
Abidjan-Lagos Highway Corridor Development Project	Road	Cote d'Ivoire
VICMED	IWT	Egypt
LAPSSET	Port, rail and energy	Kenya
Namibian Logistics Hub	Road and rail	Namibia
Trans-Sahara Gas Pipeline	Energy	Nigeria
Unblocking Political Bottlenecks for ICT Broadband and Optic Fibre Projects	ICT	Rwanda
Dakar-Bamaka Road/Rail	Road and rail	Senegal
North-South Road, Rail and Related Infrastructure Corridor	Road and rail	South Africa
Sawakin-Port Sudan Project	Ports and tourism	Sudan

Source: PIDA Progress Report 2019/2020

22.1.1.3Expected Outcomes

PIDA documentation does not discuss project outcomes. Monitoring and evaluation is referred to, but no guidance on how or when to do this is included. (We would expect outcomes to be assessed against criteria such as investment cost per net additional job or traffic diverted from road to rail).

22.1.2 VICMED (Project under COMESA)

22.1.2.1Description

VICMED – a Presidential Infrastructure Champion Initiative (PICI) project to develop river transport from Lake Victoria to the Mediterranean – was endorsed by the AU in 2013. The PICI subsequently commissioned a prefeasibility study of options, issued as a draft report in May 2015.[100] VICMED has yet to move from prefeasibility to feasibility as far as we know.

22.1.2.2Proposed Actions

VICMED sets out six alternatives. While each alternative seeks to connect Lake Victoria to the Mediterranean, some alternatives include other modes – they do not exclusively comprise IWT. The scales of works required are not given. There are no estimates of costs or benefits and no timescale. There is no counterfactual (i.e. a defined without-project scenario). The six alternatives are not compared: this is to be undertaken at the feasibility stage.

22.1.2.3Expected Outcomes

VICMED's strategic goal is socio-economic integration and cohesion, made possible by enhanced trade and tourism. There is as yet no guidance on how achievement of this outcome is to be evaluated.

22.1.3 Lake Victoria Navigation (Projects under LVBC/EAC)

22.1.3.1Description

Up till 2005 there were five state owned railway ferries on Lake Victoria. Currently, there is believed to be just one, the Uganda-registered MV Kaawa, rebuilt following a collision in 2005 and operating between Mwanza (Tanzania) and Port Bell (for Kampala). A privately financed ro-ro ferry is under construction and plans to ply the same route.[106] These are the principal freight-carrying vessels relevant to the Nile corridor. There are many small privately-owned passenger ferries. Public sector plans are briefly described below.

The EAC's 2013 regional strategy[112] concludes that rail ferries are not for the future ("not viable as an economically competitive transport mode"). It goes on to recommend dredging and general improvements at Kisumu, Port Bell and Mwanza South. More specifically it recommends a 100,000 TEU inland container deport (ICD) at Mwanza South and the procurement of MAFI system wheeled systems for shifting large static loads in ro-ro operations.[113]

Similarly, the 2021 Ugandan integrated transport plan[114] recommends improvements to the Ugandan ports of Port Bell and Jinja, but does not discuss how to divert more traffic on to IWT. The plan does however refer to recommendations for IWT on Lake Albert (the centre of Uganda's nascent oil industry) and budgets $72 million for the North Lake Albert Transport Development project, but no details are available. Both this plan and the EAC regional strategy express concern about rising lake levels and the need to invest in works to cope with this.

CIG Uganda carried out a comprehensive analysis of Ugandan IWT facilities and operations in 2020.[115] The report lists potential projects and options, and provides much baseline data that would be of use in

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[112] World Bank/EAC. 2013. *A Regional Transport Intermodal Strategy and Action Plan in the Countries of the East African Community*.

[113] MAFI GmbH is a German manufacturer of wheeled platforms.

[114] Ministry of Works & Transport, Uganda, 2021. *Integrated Transport Master Plan 2021-40.* Kampala

[115] CIG Uganda. 2020. *Situational Analysis Report for the Master Plan and Development Strategy. IWT Corridor.* Kampala

subsequent analysis, but stops short of analysis and recommendations, evidently planned for a future study.

22.1.3.2 Proposed Actions and Excepted Outcomes

None of the plans described above contain specific actions or expected outcomes.

22.1.4 NBI NELSAP Concept Notes / Strategy

22.1.4.1 Description

Two documents are reported on here. Both are part of NBI.

The NBI strategy document[116] lists the six NBI goals. Transport is part of goal 3 (enhance agricultural water use): "enhancing navigability to boost regional agricultural trade and transport corridors". However, the strategy does not elaborate on this.

The NELSAP (Nile Equatorial Lakes Subsidiary Action Programme) document is concerned with Lakes Edward and Albert and has a navigation and maritime safety sub-plan. This sub-plan refers to the lack of IWT across either lake. In the case of Lake Albert it states that, in the past, agricultural produce was exported to Uganda across the lake from two small ports (Kasenyi and Mahagi). Interestingly it attributes the demise of IWT to lack of demand, and various food relief sources confirm the decline in agriculture on the DRC side of the lake, evidently linked to continuing violence.

22.1.4.2 Proposed Actions and Outcomes

The NBI strategy does not propose actions. The NELSAP navigation and maritime safety sub-plan, however, sets out an ambitious plan that includes procurement of freight and passenger vessels and port infrastructure. Clearly the intended outcome is working commercial IWT on Lake Albert, but all these plans depend on a resumption of demand.

[116] NBI (Undated). *NBI Strategy 2017-27, Abridged Version.*

23. Recommendations for member states

Navigation policies and respectively their implementation are currently not fully developed in all NBI member states, leading to sub-optimal conditions in the inland waterway transport sector. Respective policies would be various, including, depending on needs and priorities, covering trade strategies, passenger related aspects, tourism, port operation, investments, safety, etc. While some countries run initiatives for situational improvement, transboundary consideration would be essential for harmonizing and simplifying standards and conditions especially for trans-border shipping operations. Further aspects in that regard also include taxing aspects, border controls, etc.

With regards to transport operations, current standards are relatively low and should be enhanced considering practical aspects to increase safety as well as productivity of the inland waterway transport systems. This covers practical aspects like technical vessel- and port conditions, standardization, agreements, etc. It needs to be noted that any standards would also need to be implemented and enforced to become effective.

Further, note has to be taken of the various investments necessary to improve transport in the Nile basin. While this report has shed light on the overall systems and VICMED options, detailed assessments are required considering cost-benefit aspects to decide for which development options to pursue, whether this can be achieved in a staged approach, or whether longer term goals shall be pursued. While developments are often demand driven, options with high investment volumes will need to be assessed and decided for by the governments. Considering the transboundary nature of the Nile, joint efforts are needed to develop solutions and make decisions, for which detailed knowledge, much beyond the details provided in the current report, is necessary.

Annex of the Baseline Assessment Section

River companies/ institutions	Buayet Tiger Co. Ltd
	North Gate General Trading Co. Ltd
	JBC Petroleum (SS) Limited
	Leudiergeneral trading
	TRANSWAY TRANSPORTERS & LOGISTICS
	Inter-Link Inc
	Abilities Company Ltd
	Malakal Commercial Boat Co Ltd
	Tonja for Trading and Investment Co Ltd
	Gieth Transport company Limited
	Sharow Trading & Investmnt Co.Ltd
	Solutions Quick Services Co.Ltd
	Gamo Engineering Co.Ltd
	Hiyab General Trading Co.Ltd
	Abu Kerbino Engineering Co.Ltd
	Merina Construction & General Trading Co.Ltd
	B & S Group
	Internet International
	Jodak
	Mina Kilo
	Nile Berge
	Abdel Wahab Abdel Rahman Al Amin (El Mugran)
	Nile River Transportation Co. Ltd (NRTC)
	Nile Barges for River Transport
	NRTC Keer for River Transport Co. Ltd
	Shanjkeen International for Transport and Services Co. Ltd
	Sudanese River Transportation Co. Ltd
	Talha El Yas Babiker (El Canal)
	Bright Shield Services and Investment Co. Ltd.
	Zahir Abugamza for River and Loading Transport Company
	Semliki Rift Trading
	MIASO
Lake companies/ institutions	Nile Valley Shipping
	Marine Services Company
	Earth Wise
	KIS
	WaterBus
	InfoCo
	Maersk
	BrosWest
	Jm Freight
	Nile Cargo
	Marine Services Company Limited
	Semliki Rift Trading
	Mkombozi Fishing & Marine Transport
	TRC: Mwanzo
	Wild Frontiers
	Murchison Falls National Park Uganda Safari Tours
	Lake Victoria Basin Cooperation

Annexes of Modelling Section

Background Regarding Virtual Stations

Any intersection of a continental water body with the ground track of a satellite equipped with an altimeter constitutes a potential virtual station, capable of monitoring over time the evolution of the height of the water body in relation to an ellipsoid. The principle of the measurement is summarized as follows: The altimeter sends a pulse towards nadir and measures the time it takes for it to reflect on the Earth's surface and return to the altimeter. Knowing the speed of wave propagation in the media traversed, this travel time makes it possible to calculate the distance (R) between the altimeter and the reflecting surface. Since the orbit of the satellite (and therefore its height H with respect to an ellipsoid) is known, the height of the reflective surface (h) with respect to the ellipsoid can be calculated (h=H-R). In practice, several corrections are made to the measurement to take into account disturbances due to the atmosphere, ionosphere and solid and liquid earth tides.

The frequency of measurements along a satellite path depends on the mission: 10 pulses per second for Topex/Poseidon, 20 pulses per second for Envisat and Jason. The time difference between 2 consecutive passes depends on the repetitiveness of the satellite: 35 days for Envisat, 10 days for Topex/Poseidon and Jason, which conditions the lagtime between two readings of the time series of height of the inferred water body.

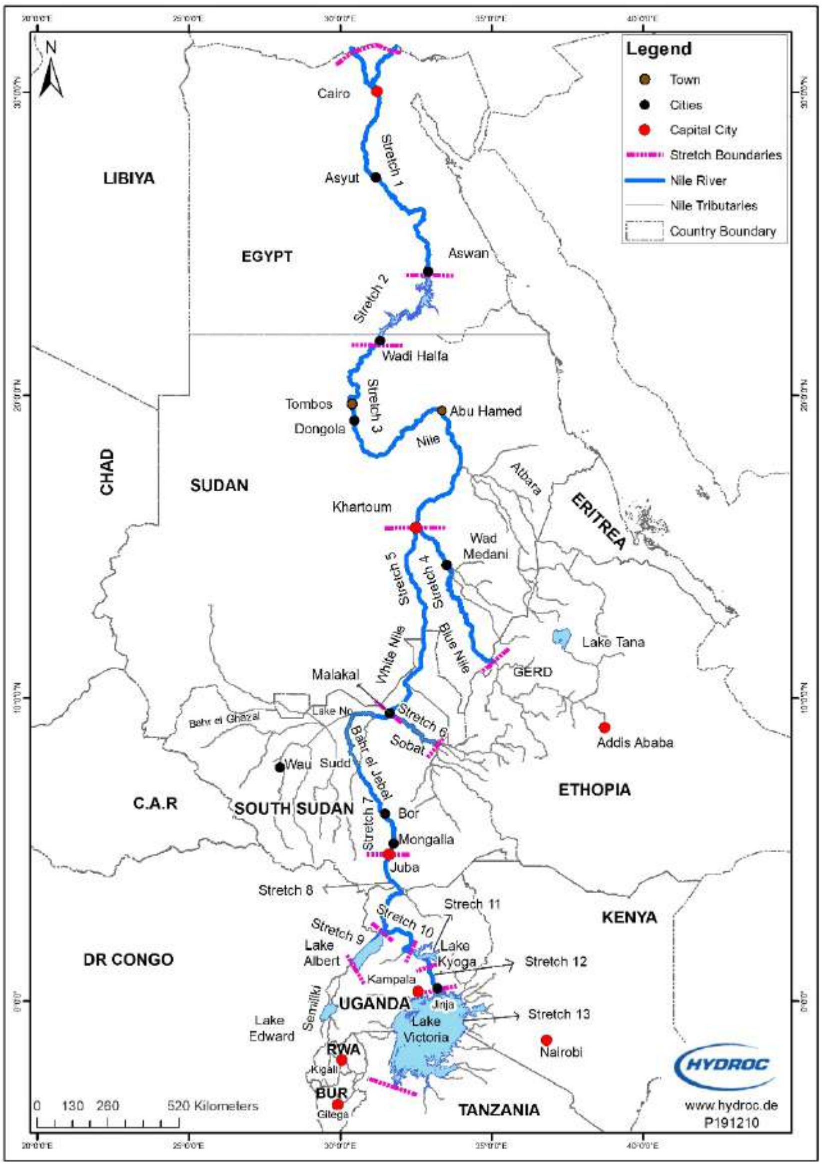
In addition, the density of the satellite's ground tracks varies due to its repetitiveness: 90 km between 2 Envisat tracks at the equator compared to 315 km between 2 Topex/Poseidon and Jason tracks; hence a lower potential virtual station density for Topex/Poseidon and Jason than for Envisat.

The water level is defined as the height, in meters above the geoid, of the reflecting surface of continental water bodies. It is observed by space radar altimeters that measure the time it takes for radar pulses to reach the ground targets, directly below the spacecraft (nadir position), and return. Hence, only water bodies located along the satellite's ground tracks can be monitored, with a quality of measurement that not only depends on the size of the water body, but also on the reflecting targets in its surroundings such as topography or vegetation.

Water level is computed as time series over lakes and over rivers, at the intersections of the river network with the satellite ground tracks, so-called virtual stations

Annexes of Scenario Section

Overview of the Stretches Graph



- Stretch 1: Main Nile – Nile Delta to Aswan
- Stretch 2: Lake Nasser – Aswan to Wadi Halfa
- Stretch 3: Main Nile – Wadi Halfa to Khartoum
- Stretch 4: Blue Nile – Khartoum to Renaissance Dam
- Stretch 5: White Nile – Khartoum to Malakal
- Stretch 6: Sobat River
- Stretch 7: Bahr el Jebel – Malakal to Juba
- Stretch 8: Bahr el Jebel and Albert Nile – Juba to Lake Albert
- Stretch 9: Lake Albert
- Stretch 10: Kyoga Nile
- Stretch 11: Lake Kyoga
- Stretch 12: Victoria Nile
- Stretch 13: Lake Victoria

Overview of the Stretches Table

Table 74. Minimum flow requirements under standard (current) conditions (Nile basin Option 0)

Stretch	Required min water depth (m)	Required min flow (m3/s)	Observed flow range (for details see Section 8.1.4) (m^3/s)	Flow velocity at required min flow (m/s)	Flow velocity range (m/s) over full flow scenario range
1 - Main Nile Egypt	3	1420	770 - 2700	0.53	0.30-0.78
2 - Lake Nasser	-	-	-	-	-
3 - Main Nile Sudan	2	920	380 - 12000	0.6	0.44-1.60
4 - Blue Nile Sudan	2	600	40 - 9600	0.5	0.62-2.77
5 - White Nile	2	210	300 - 2400	0.28	0.28-0.86
6 - Sobat	2	195	0 - 1300	0.42	0.11-0.96
7 - Bahr el Jebel	2	210	270 - 2900	0.59	0.59-1.33
8 - Albert Nile	2	298	300 - 2200	0.61	0.56-1.26
9 - Lake Albert	-	-	-	-	-
10 - Kyoga Nile	2	510	270 - 2000	1.05	0.71-1.88
11 - Lake Kyoga	-	-	-	-	-
12 - Victoria Nile	2	210	300 - 1100	0.89	0.89.1.89
13 - Lake Victoria	-	-	-	-	-

Table 75. Minimum flow requirements under dredged conditions (Option 1)

Stretch	Required min water depth (m)	Required min flow (m3/s)	Observed flow range (for details see Section 8.1.4) (m^3/s)	Flow velocity at required min flow (m/s)	Flow velocity range (m/s) over full flow scenario range
1 - Main Nile Egypt	3	1300	770 - 2700	0.7	0.50-1.04
2 - Lake Nasser	-	-	-	-	-
3 - Main Nile Sudan	2	620	380 - 12000	0.5	0.51.1.65
4 - Blue Nile Sudan	2	500	40 - 9600	0.51	0.57-2.66
5 - White Nile	2	200	300 - 2400	0.26	0.28-0.86
6 - Sobat	2	100	0 - 1300	0.3	0.20.1.01
7 - Bahr el Jebel	2	200	270 - 2900	0.6	0.70-1.31
8 - Albert Nile	2	210	300 - 2200	0.63	0.63-1.31
9 - Lake Albert	-	-	-	-	-
10 - Kyoga Nile	2	495	270 - 2000	1.15	0.83-2.07
11 - Lake Kyoga	-	-	-	-	-
12 - Victoria Nile	2	210	300 - 1100	0.99	0.99-1.92
13 - Lake Victoria	-	-	-	-	-

Table 76. Lakes water level ranges suitable for navigation

Lake	Min level (masl)	Max level (masl)
Lake Nasser / Lake Nubia	-	-
Lake Albert	621.0	622.5
Lake Victoria	1134.5	1137.5

Probabilistic Analysis of Reliabilities of Navigability

In order to derive a probabilistic approach of the required flow conditions for the river stretches, flow data have been collected from NBI and further processed. In this case, a flow duration curve has been developed for each of the fluvial stretches considering monthly flow from 1951 until 2018. The curves for all these stretches are shown below, while the probabilistic results are shown in Table 77 and Table 78 for the baseline and dredging scenarios.

Stretch 1 - Main Nile Egypt

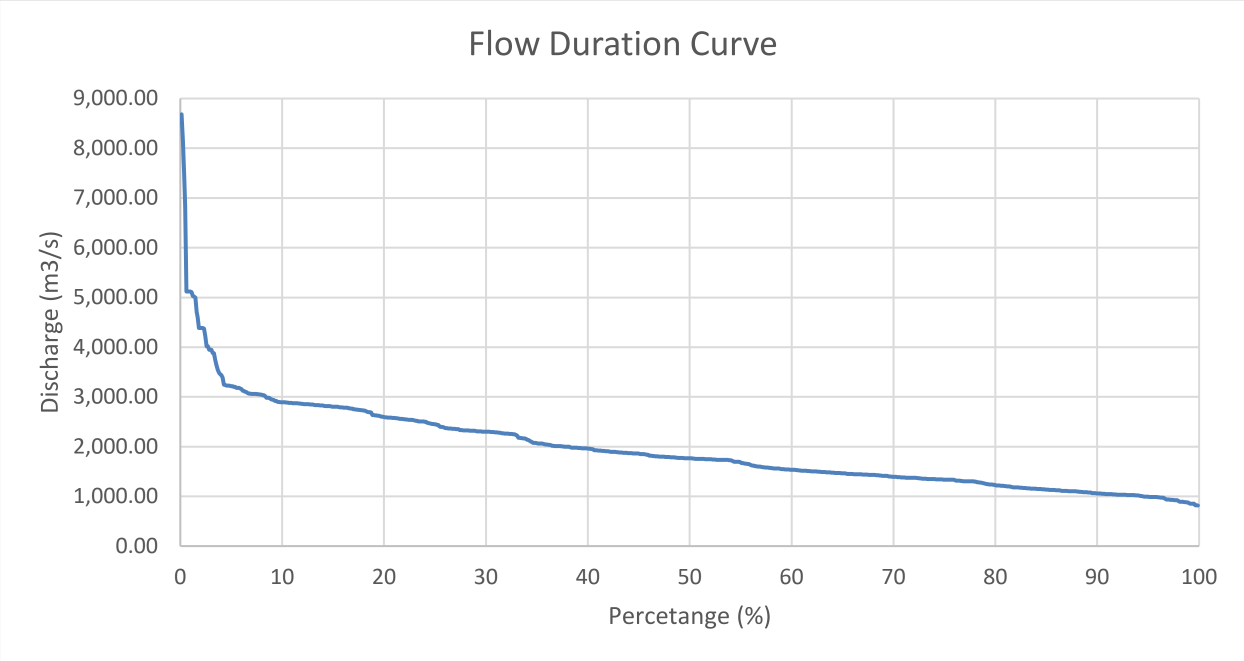


Figure 119: Flow Duration Curve for Stretch 1

The minimum flow requirement for the 1,420m^3/s for the baseline scenario and 1,300m^3/s for the dredging one. The percentage of the time when the minimum flow requirement for baseline situation is met is 68%, and this percentage for the dredging scenario is 79%.

Stretch 3 - Main Nile Sudan

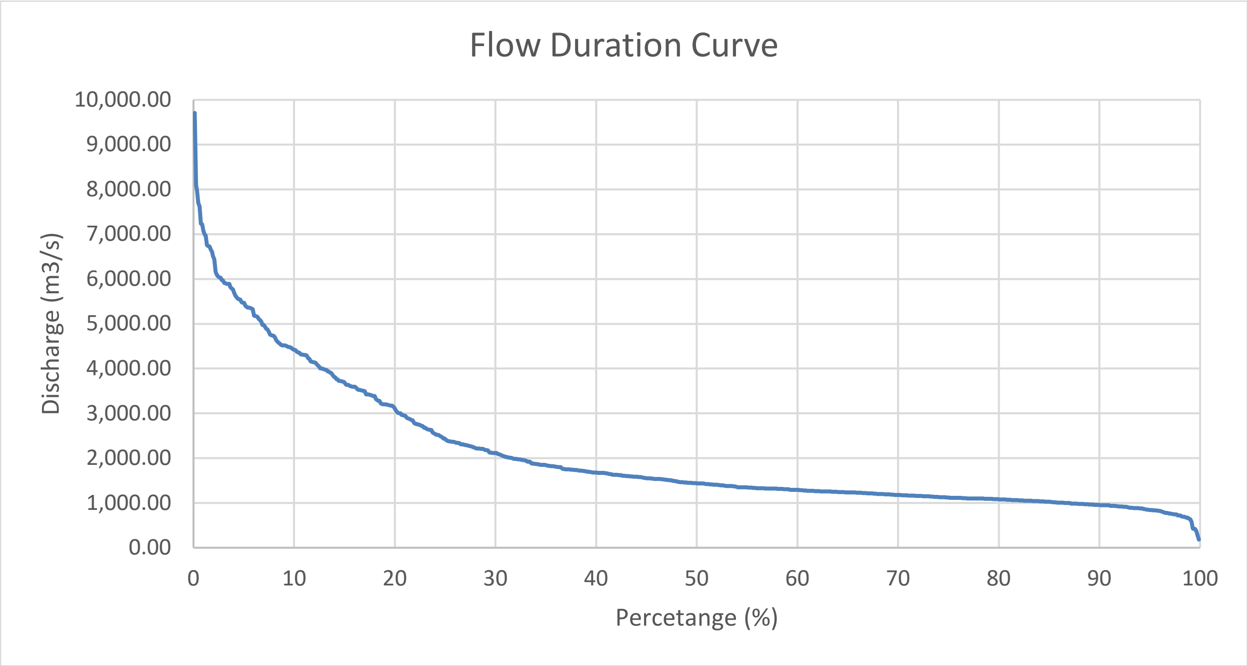


Figure 120: Flow Duration Curve for Stretch 3

The minimum flow requirement for the 920m^3/s for the baseline scenario and 620m^3/s for the dredging one. The percentage of the time when the minimum flow requirement for baseline situation is met is 92%, and this percentage for the dredging scenario is 99.1%.

Stretch 4 - Blue Nile Sudan

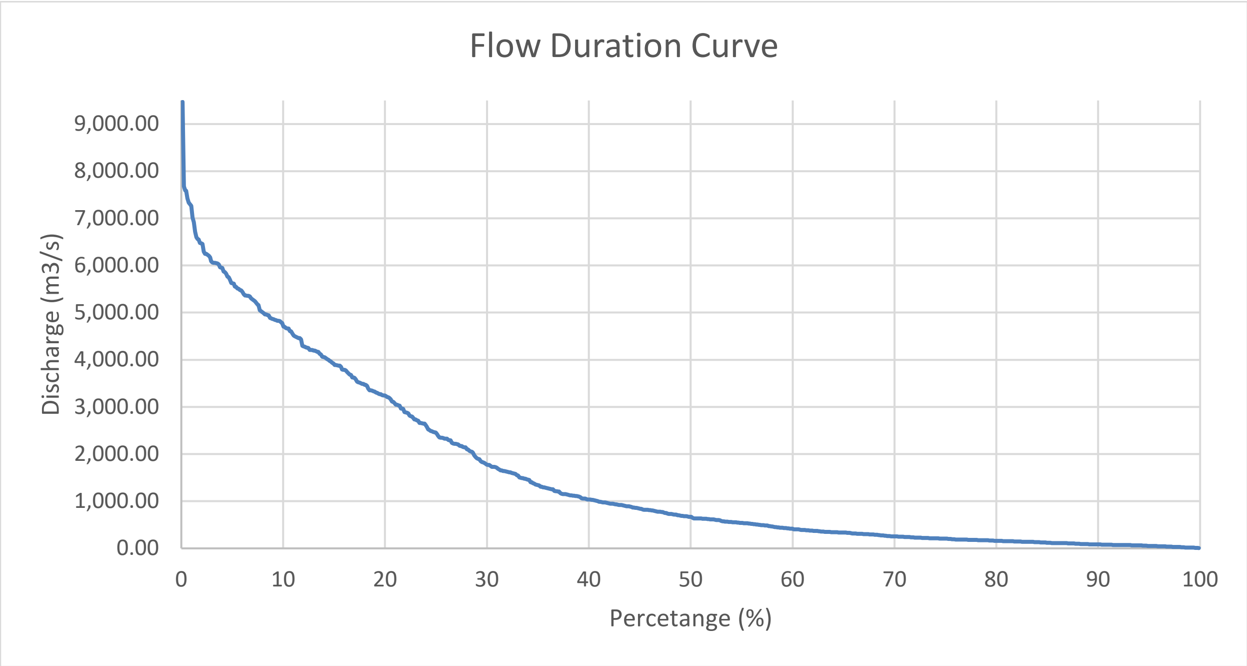


Figure 121: Flow Duration Curve for Stretch 4

The minimum flow requirement for the 600m^3/s for the baseline scenario and 500m^3/s for the dredging one. The percentage of the time when the minimum flow requirement for baseline situation is met is 40.4%, and this percentage for the dredging scenario is 48.0%.

Stretch 5 - White Nile

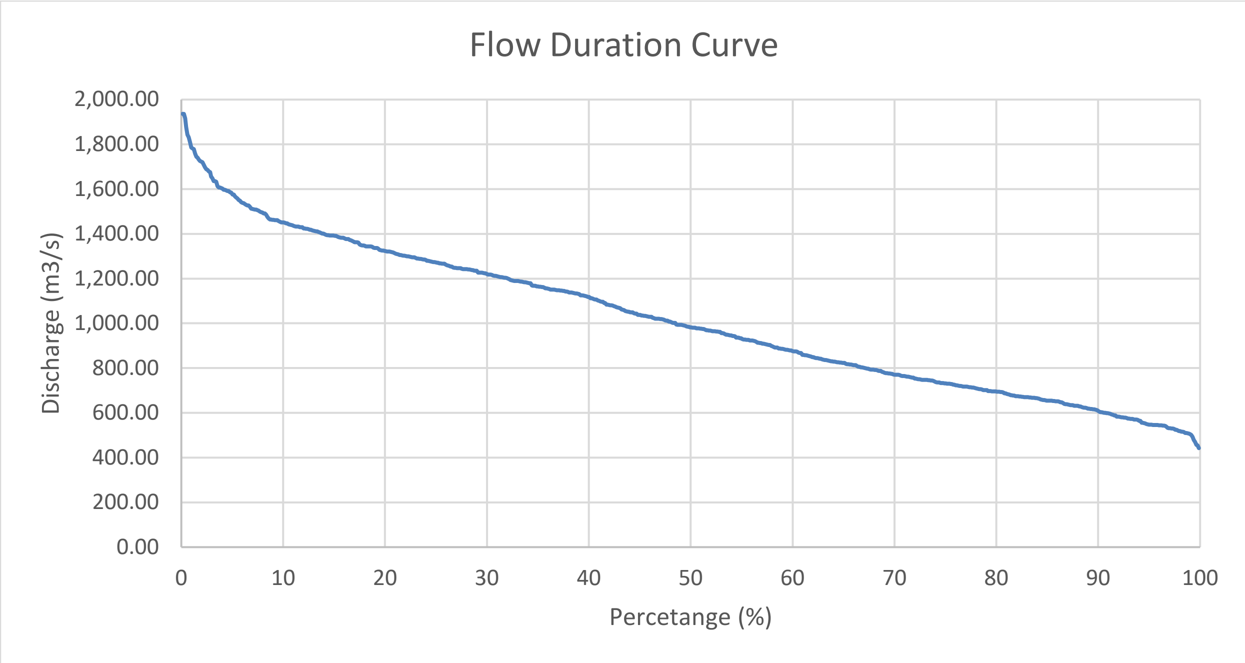


Figure 122: Flow Duration Curve for Stretch 5

The minimum flow requirement for the 210m^3/s for the baseline scenario and 200m^3/s for the dredging one. The percentage of the time when the minimum flow requirement for baseline situation is met is 100%, and this percentage for the dredging scenario is 100%.

Stretch 6 – Sobat

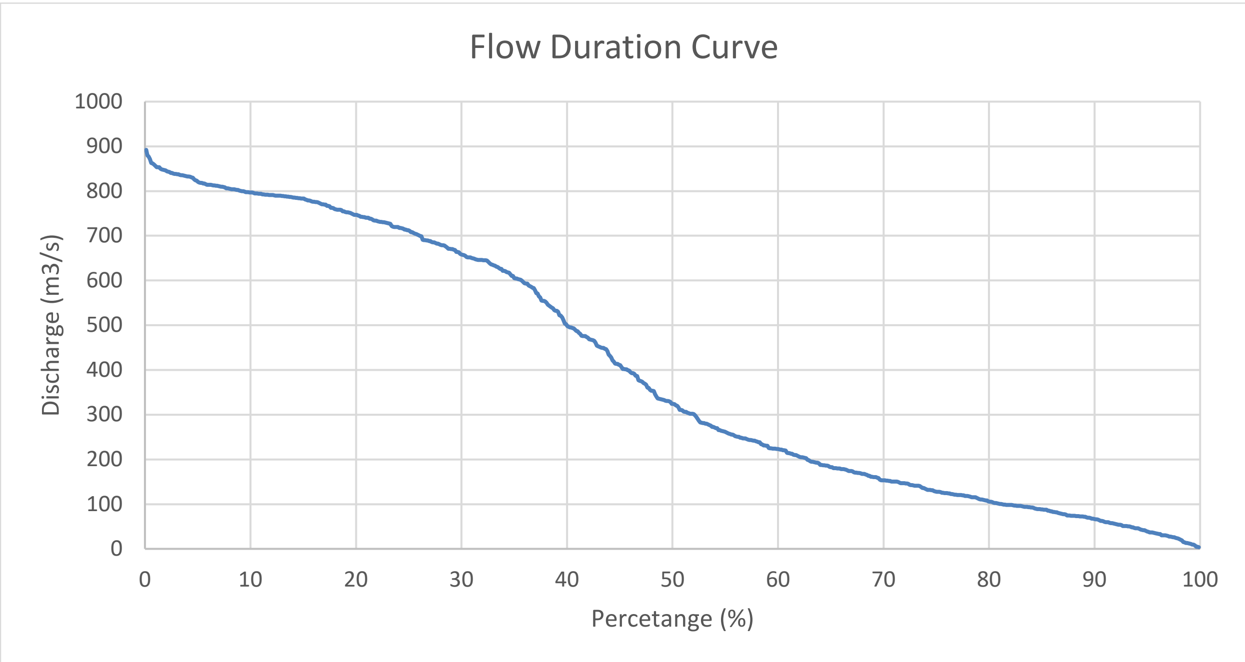


Figure 123: Flow Duration Curve for Stretch 6

The minimum flow requirement for the 195m^3/s for the baseline scenario and 100m^3/s for the dredging one. The percentage of the time when the minimum flow requirement for baseline situation is met is 63%, and this percentage for the dredging scenario is 81%.

Stretch 7 - Bahr el Jebel

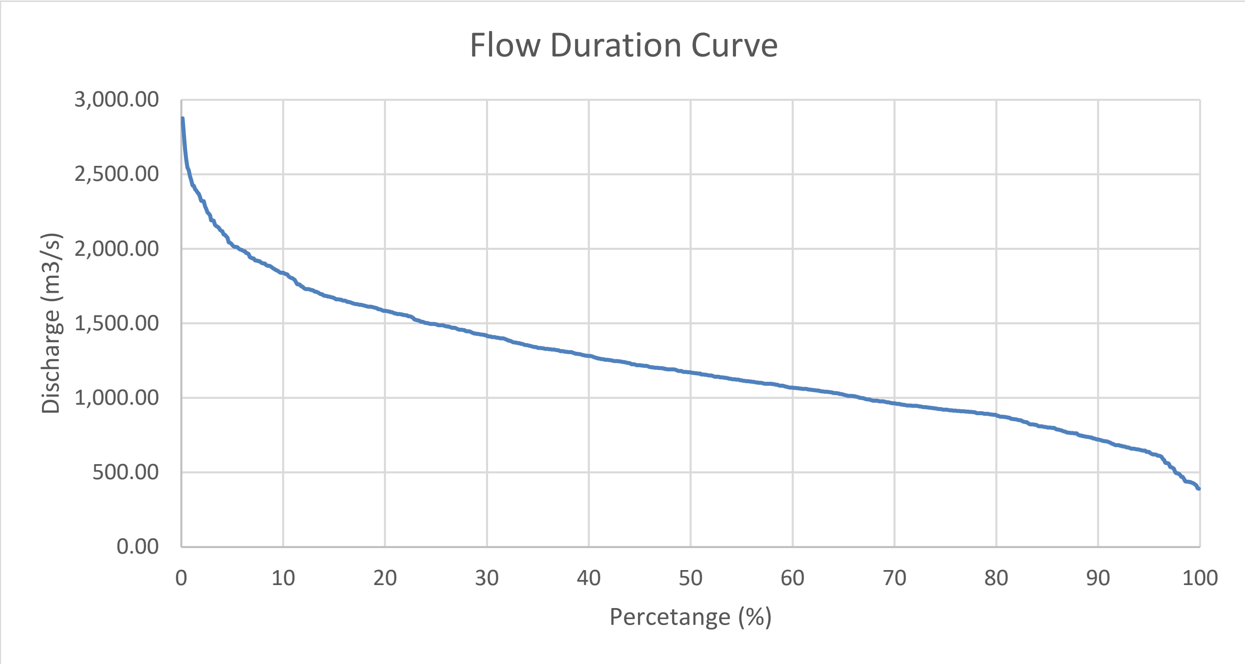


Figure 124: Flow Duration Curve for Stretch 7

The minimum flow requirement for the 210m^3/s for the baseline scenario and 200m^3/s for the dredging one. The percentage of the time when the minimum flow requirement for baseline situation is met is 100%, and this percentage for the dredging scenario is 100%.

Stretch 8 - Albert Nile

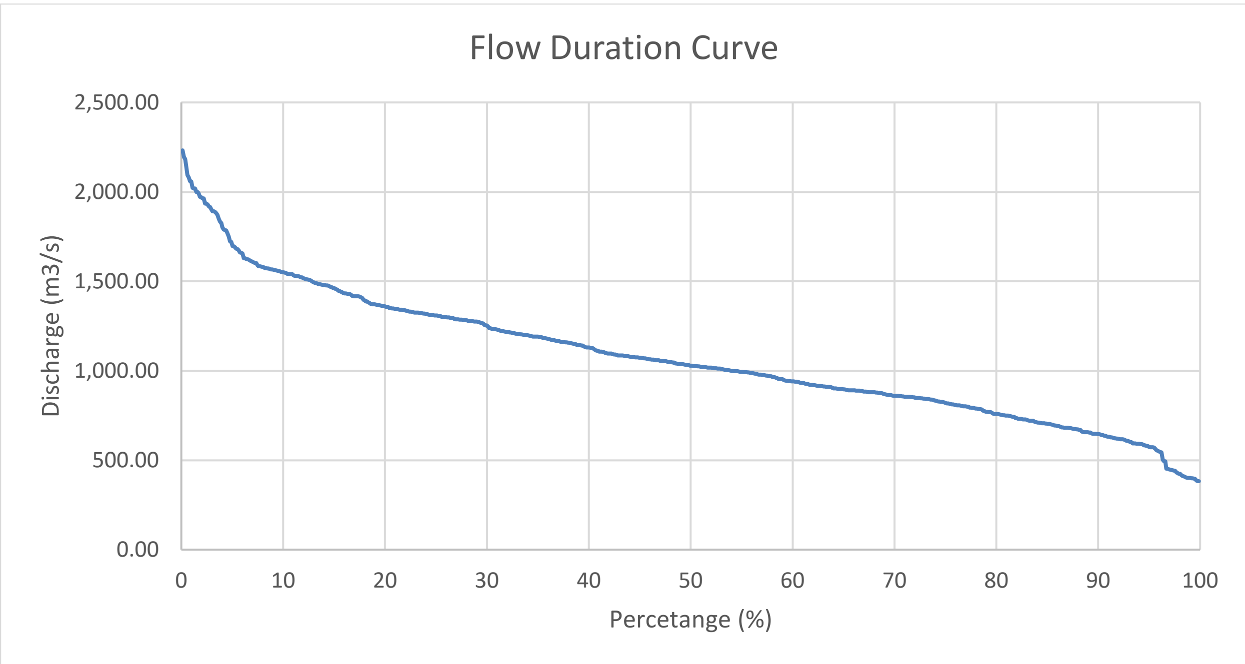


Figure 125: Flow Duration Curve for Stretch 8

The minimum flow requirement for the 298m^3/s for the baseline scenario and 210m^3/s for the dredging one. The percentage of the time when the minimum flow requirement for baseline situation is met is 100%, and this percentage for the dredging scenario is 100%.

Stretch 10 - Kyoga Nile

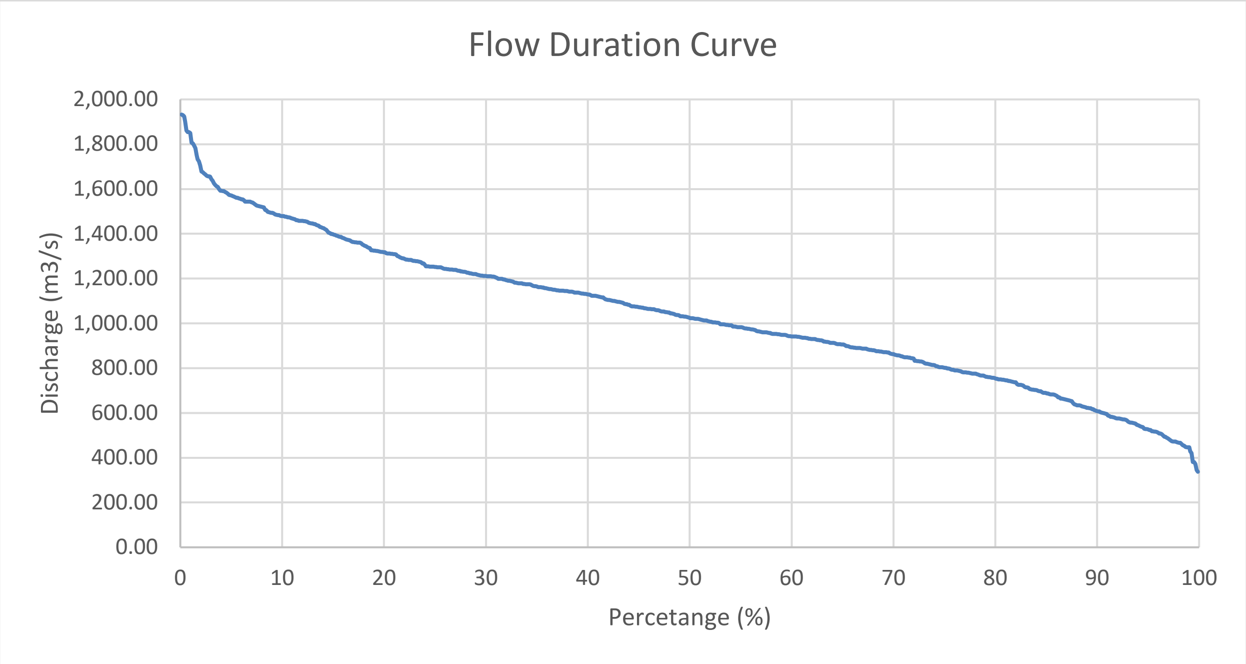


Figure 126: Flow Duration Curve for Stretch 10

The minimum flow requirement for the 510m^3/s for the baseline scenario and 495m^3/s for the dredging one. The percentage of the time when the minimum flow requirement for baseline situation is met is 96%, and this percentage for the dredging scenario is 96.5%.

Stretch 12 - Victoria Nile

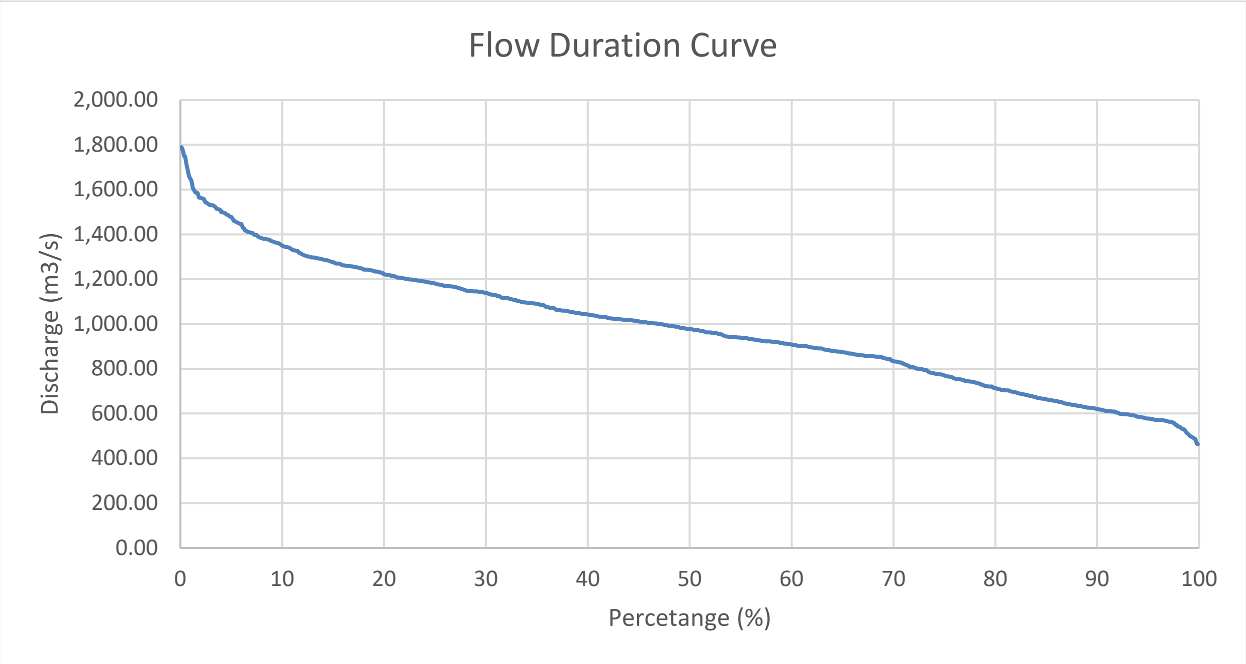


Figure 127: Flow Duration Curve for Stretch 12

Probabilistic Summary of Reliabilities of Navigability

The minimum flow requirement for the 210m³/s for the baseline scenario and the same 210m³/s for the dredging one. The percentage of the time when the minimum flow requirement for both scenarios is the same, and this is 100%.

As noted, the probabilistic values are shown in the tables below for the two scenarios, baseline and dredging ones.

Table 77. Probabilistic results for the baseline scenario

Stretch	Required min water depth (m)	Required min flow (m3/s)	Percentage time when this is met
1 - Main Nile Egypt	3	1420	68
2 - Lake Nasser	-	-	-
3 - Main Nile Sudan	2	920	92
4 - Blue Nile Sudan	2	600	40
5 - White Nile	2	210	100
6 - Sobat	2	195	63
7 - Bahr el Jebel	2	210	100
8 - Albert Nile	2	298	100
9 - Lake Albert	-	-	-
10 - Kyoga Nile	2	510	96
11 - Lake Kyoga	-	-	-
12 - Victoria Nile	2	210	100
13 - Lake Victoria	-	-	-

Table 78. Probabilistic results for the dredging scenario

Stretch	Required min water depth (m)	Required min flow (m3/s)	Percentage time when this is met
1 - Main Nile Egypt	3	1300	79
2 - Lake Nasser	-	-	-
3 - Main Nile Sudan	2	620	99
4 - Blue Nile Sudan	2	500	48
5 - White Nile	2	200	100
6 - Sobat	2	100	81
7 - Bahr el Jebel	2	200	100
8 - Albert Nile	2	210	100
9 - Lake Albert	-	-	-
10 - Kyoga Nile	2	495	97
11 - Lake Kyoga	-	-	-

Stretch	Required min water depth (m)	Required min flow (m3/s)	Percentage time when this is met
12 - Victoria Nile	2	**210**	100
13 - Lake Victoria	-	-	-

Synopsis Table

		Baseline	NBI medium	NBI ambitious	VICMED 1	VICMED 2	VICMED 3	VICMED 4		
Stretch 1	Main Nile in Egypt	Navigable	Navigable	Navigable	Navigable	Navigable	Navigable	Navigable		
Stretch 2	Lake Nasser/Lake Nubia	Navigable	Navigable	Navigable	Navigable	Navigable	Navigable	Navigable		
Stretch 3	Main Nile in Sudan	Partly navigable	Partly navigable	Navigable	Navigable	Partly navigable	Partly navigable	Navigable		
Stretch 4	Blue Nile	Partly navigable	Navigable	Navigable	Partly navigable	Partly navigable	Partly navigable	Partly navigable		
Stretch 5	White Nile	Partly navigable	Navigable	Navigable	Navigable	Navigable	Navigable	Navigable		
Stretch 6	Sobat	Partly navigable	Partly navigable	Navigable	Partly navigable	Partly navigable	Partly navigable	Partly navigable		
Stretch 7	Bahr el Jebel d/s of Juba	Partly navigable	Navigable	Navigable	Navigable	Navigable	Navigable	Navigable		
Stretch 8	Bahr el Jebel u/s of Juba, Albert Nile	Not	Not	Not	Navigable	Navigable	Not	Navigable		
Stretch 9	Lake Albert	Navigable	Navigable	Navigable	Navigable	Navigable	Navigable	Navigable		
Stretch 10	Kyoga Nile	Not	Not	Not	Navigable	Navigable	Not	Navigable		
Stretch 11	Lake Kyoga	Navigable	Navigable	Navigable	Navigable	Not	Not	Navigable		
Stretch 12	Victoria Nile	Not	Not	Not	Navigable	Not	Not	Navigable		
Stretch 13	Lake Victoria	Navigable	Navigable	Navigable	Navigable	Navigable	Navigable	Navigable		

The overview shows the different assumptions in the NBI development scenarios as well as the VICMED development alternatives. NBI scenarios focus on the easier to accomplish navigation development in the lower Nile reaches (downstream of Juba), while considering intermodal transport options for the upstream stretches. Further, the Sobat and lower Blue Nile are considered in the NBI scenarios, while VICMED does not consider these. The VICMED alternatives generally explore more investment intensive development options in various combinations with intermodal transport and additional development options in the Equatorial Lakes region.

Polyline Shapefiles of Main Nile Stretches

Polyline shapefiles for the Nile stretches described in this paper are provided as separate files. The polylines represent the thirteen stretches utilized in this study as follows:

Stretch 1	Main Nile in Egypt
Stretch 2	Lake Nasser/Lake Nubia
Stretch 3	Main Nile in Sudan
Stretch 4	Blue Nile
Stretch 5	White Nile
Stretch 6	Sobat
Stretch 7	Bahr el Jebel d/s of Juba
Stretch 8	Bahr el Jebel u/s of Juba, Albert Nile
Stretch 9	Lake Albert
Stretch 10	Kyoga Nile
Stretch 11	Lake Kyoga
Stretch 12	Victoria Nile
Stretch 13	Lake Victoria

Selection of the stretches was based on similar conditions with regards to hydraulic and navigation aspects and agreed during the project inception phase.

HEC-RAS Model Geometry File

A model geometry files including cross sectional profiles and hydraulic assumptions are provided as separate files. The geometry files consider measured as well as estimated cross sectional profiles for the various stretches depending on actual data availability. In addition, a set of improved trapezoidal cross sections has been developed to allow for a dredged scenario, where the riverbed has been reshaped to optimized waterdepth-flow relation and as such to allow navigation with less flow in the river. Details are provided in the Task 2 methodology section.

Scenario Information Overview Tables

STRETCH NO	STRETCH NAME	GIS POLYLINE ID	BASELINE - C/S PROFILE ID	DREDGED - C/S PROFILE ID
1	Main Nile in Egypt	1	see tablet CROSSECTIONS	see tablet CROSSECTIONS
2	Lake Nasser/Lake Nubia	2	see tablet CROSSECTIONS	see tablet CROSSECTIONS
3	Main Nile in Sudan	3	see tablet CROSSECTIONS	see tablet CROSSECTIONS
4	Blue Nile	4	see tablet CROSSECTIONS	see tablet CROSSECTIONS
5	White Nile	5	see tablet CROSSECTIONS	see tablet CROSSECTIONS
6	Sobat	6	see tablet CROSSECTIONS	see tablet CROSSECTIONS
7	Bahr el Jebel d/s of Juba	7	see tablet CROSSECTIONS	see tablet CROSSECTIONS
8	Bahr el Jebel u/s of Juba, Albert Nile	8	see tablet CROSSECTIONS	see tablet CROSSECTIONS
9	Lake Albert	9	see tablet CROSSECTIONS	see tablet CROSSECTIONS
10	Kyoga Nile	10	see tablet CROSSECTIONS	see tablet CROSSECTIONS
11	Lake Kyoga	11	see tablet CROSSECTIONS	see tablet CROSSECTIONS
12	Victoria Nile	12	see tablet CROSSECTIONS	see tablet CROSSECTIONS
13	Lake Victoria	13	see tablet CROSSECTIONS	see tablet CROSSECTIONS

Medium scenario description

STRETCH NO	STRETCH NAME	POLYLINE ID	MULTI MODAL	TARGET FLEET TYPE	PORT WORKS	CHANNEL WORKS	LOCKS WORKS	CANAL WORKS	DAM OPERATION	SCNEARIO CHANNEL PARAMTERS
1	Main Nile in Egypt	1	in place	draft max 2.5m (design water depth 3m)	ports are in place	n/a	none	none	n/a	n/a
2	Lake Nasser/Lake Nubia	2	need for upgrade	draft max 1.5m (design water depth 2m)	ports are in place	n/a	none	none	n/a	n/a
3	Main Nile in Sudan	3	need for upgrade	draft max 1.5m (design water depth 2m)	need for upgrade	n/a	none	none	GERD operated to promote year round sufficient flows in Main Nile	n/a
4	Blue Nile	4	need for upgrade	draft max 1.5m (design water depth 2m)	need for upgrade	n/a	none	none	GERD operated to promote year round more balanced flows in Blue Nile	n/a
5	White Nile	5	need for upgrade	draft max 1.5m (design water depth 2m)	need for upgrade	n/a	rehabilitation of Jebel Aulia Locks	none	n/a	n/a
6	Sobat	6	need for upgrade	draft max 1.5m (design water depth 2m)	need for upgrade	partly dredged	none	none	n/a	n/a
7	Bahr el Jebel d/s of Juba	7	need for upgrade	draft max 1.5m (design water depth 2m)	need for upgrade	partly dredged	none	Jonglei Canal may be assessed as a development option	n/a	Jonglei Canal assumption as per JIT report with trapezoidal shape, 30m bottom width, and 4m water depth*
8	Bahr el Jebel u/s of Juba, Albert Nile	8	need for upgrade	draft max 1.5m (design water depth 2m)	n/a	n/a	none (considered too expensive)	none	n/a	n/a

STRETCH NO	STRETCH NAME	POLYLINE ID	MULTI MODAL	TARGET FLEET TYPE	PORT WORKS	CHANNEL WORKS	LOCKS WORKS	CANAL WORKS	DAM OPERATION	SCNEARIO CHANNEL PARAMTERS
9	Lake Albert	9	need for upgrade	draft max 1.5m (design water depth 2m)	need for upgrade	n/a	none	none	n/a	n/a
10	Kyoga Nile	10	need for upgrade	draft max 1.5m (design water depth 2m)	n/a	n/a	none (considered too expensive)	none	n/a	n/a
11	Lake Kyoga	11	need for upgrade	draft max 1.5m (design water depth 2m)	need for upgrade	n/a	none	none	n/a	n/a
12	Victoria Nile	12	need for upgrade	draft max 1.5m (design water depth 2m)	n/a	n/a	none (considered too expensive)	none	n/a	n/a
13	Lake Victoria	13	need for upgrade	draft max 1.5m (design water depth 2m)	need for upgrade	n/a	none	none	n/a	n/a

* Note that a head regulator and lock is foreseen at the upstream end of Jonglei Canal

Ambitious scenario description

STRETCH NO	STRETCH NAME	GIS POLYLINE ID	MULTI MODAL	TARGET FLEET TYPE	PORT WORKS	CHANNEL WORKS	LOCKS WORKS	CANAL WORKS	DAM OPERATION	SCNEARIO CHANNEL PARAMTERS
1	Main Nile in Egypt	1	in place	draft max 2.5m (design water depth 3m)	ports are in place	n/a	Locks for Aswan Low Dam (upgrade) and Aswan High Dam	none	n/a	n/a
2	Lake Nasser/Lake Nubia	2	need for upgrade	draft max 1.5m (design water depth 2m)	ports are in place	n/a	none	none	n/a	n/a
3	Main Nile in Sudan	3	need for upgrade	draft max 1.5m (design water depth 2m)	need for upgrade	partly dredged	locks for Merowe Dam and potentially cataracts	none	GERD operated to promote year round sufficient flows in Main Nile	n/a
4	Blue Nile	4	need for upgrade	draft max 1.5m (design water depth 2m)	need for upgrade	n/a	locks for Sennar Dam, Roseires Dam, and GERD	none	GERD operated to promote year round more balanced flows in Blue Nile	n/a
5	White Nile	5	need for upgrade	draft max 1.5m (design water depth 2m)	need for upgrade	trapezoidal dredging	rehabilitation of Jebel Aulia Locks	none	n/a	n/a
6	Sobat	6	need for upgrade	draft max 1.5m (design water depth 2m)	need for upgrade	trapezoidal dredging	none	none	n/a	n/a
7	Bahr el Jebel d/s of Juba	7	need for upgrade	draft max 1.5m (design water depth 2m)	need for upgrade	trapezoidal dredging	none	Jonglei Canal may be assessed as a development option	n/a	Jonglei Canal assumption as per JIT report with trapezoidal shape, 30m bottom width,

STRETCH NO	STRETCH NAME	GIS POLYLINE ID	MULTI MODAL	TARGET FLEET TYPE	PORT WORKS	CHANNEL WORKS	LOCKS WORKS	CANAL WORKS	DAM OPERATION	SCNEARIO CHANNEL PARAMTERS
										and 4m water depth*
8	Bahr el Jebel u/s of Juba, Albert Nile	8	need for upgrade	draft max 1.5m (design water depth 2m)	n/a	n/a	none (considered too expensive)	none	n/a	n/a
9	Lake Albert	9	need for upgrade	draft max 1.5m (design water depth 2m)	need for upgrade	n/a	none	none	n/a	n/a
10	Kyoga Nile	10	need for upgrade	draft max 1.5m (design water depth 2m)	n/a	n/a	none (considered too expensive)	none	n/a	n/a
11	Lake Kyoga	11	need for upgrade	draft max 1.5m (design water depth 2m)	need for upgrade	n/a	none	none	n/a	n/a
12	Victoria Nile	12	need for upgrade	draft max 1.5m (design water depth 2m)	n/a	n/a	none (considered too expensive)	none	n/a	n/a
13	Lake Victoria	13	need for upgrade	draft max 1.5m (design water depth 2m)	need for upgrade	n/a	none	none	n/a	n/a

* Note that a head regulator and lock is foreseen at the upstream end of Jonglei Canal

Cross section overview

Stretch 1 - Main Nile in Egypt		Stretch 3 - Main Nile in Sudan		Stretch 4 - Blue Nile		Stretch 5 - White Nile		Stretch 6 - Sobat River		Stretch 7 - Bahr el Jebel d/s of Juba		Stretch 8 - Bahr el Jebel u/s of Juba, Albert Nile		Stretch 10 - Kyoga Nile		Stretch 12 - Victoria Nile	
HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station
1	2023894	Reach 10	2318487	7	26992	JubaRenk	497770	Reach 8	956920	JubaRenk	1437070	Reach 2	1007754	Reach 1	697037	2	4859
1	1933366	Reach 10	2284647	7	20512	JubaRenk	490570	Reach 8	924379	JubaRenk	1434771	Reach 2	957144	Reach 1	664747	2	3725
1	1758787	Reach 10	2238881	7	14032	JubaRenk	483571	Reach 8	887102	JubaRenk	1430871	Reach 2	928484	Reach 1	646989	2	2591
1	1542158	Reach 10	2147183	7	7552	JubaRenk	476570	Reach 8	834497	JubaRenk	1428370	Reach 2	874732	Reach 1	573652	2	1457
1	1484094	Reach 10	2070100	7	1072	JubaRenk	467471	Reach 8	809683	JubaRenk	1423771	Reach 2	835642	Reach 1	529914	2	323
1	1392741	Reach 10	1953777			JubaRenk	448270	Reach 8	778807	JubaRenk	1420971	Reach 2	782233	Reach 1	468769		
1	1151216	Reach 10	1887445			JubaRenk	439170	Reach 8	726345	JubaRenk	1416870	Reach 2	724566	Reach 1	348214		
1	1069316	Reach 10	1857652			JubaRenk	429870	Reach 8	702423	JubaRenk	1411870	Reach 2	647657	Reach 1	321509		
1	940584	Reach 10	1809413			JubaRenk	420570	Reach 8	675522	JubaRenk	1407171	Reach 2	588168	Reach 1	286642		
1	680799	Reach 10	1618193			JubaRenk	413470	Reach 8	633177	JubaRenk	1402670	Reach 2	539887	Reach 1	207836		
1	605078	Reach 10	1452764			JubaRenk	406470			JubaRenk	1397970	Reach 2	507307	Reach 1	163035		
1	529262	Reach 10	1323750			JubaRenk	403670			JubaRenk	1393470	Reach 2	451595	Reach 1	110150		

Stretch 1 - Main Nile in Egypt		Stretch 3 - Main Nile in Sudan		Stretch 4 - Blue Nile		Stretch 5 - White Nile		Stretch 6 - Sobat River		Stretch 7 - Bahr el Jebel d/s of Juba		Stretch 8 - Bahr el Jebel u/s of Juba, Albert Nile		Stretch 10 - Kyoga Nile		Stretch 12 - Victoria Nile	
HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station
1	396805	Reach 10	1205275			JubaRenk	394470			JubaRenk	1388871	Reach 2	386952	Reach 1	51721		
1	188327	Reach 10	1069605			JubaRenk	383070			JubaRenk	1384170	Reach 2	313441	Reach 1	2884		
1	126735	Reach 10	1022550			JubaRenk	371471			JubaRenk	1379570	Reach 2	278188				
1	48006	Reach 10	969478			JubaRenk	359770			JubaRenk	1375070	Reach 2	233073				
1	2831	Reach 10	924427			JubaRenk	350470			JubaRenk	1370469	Reach 2	203133				
		Reach 10	704014			JubaRenk	341270			JubaRenk	1365769	Reach 2	157058				
		Reach 10	593021			JubaRenk	332070			JubaRenk	1361170	Reach 2	107784				
		Reach 10	553173			JubaRenk	323070			JubaRenk	1356470	Reach 2	62463				
		Reach 10	492105			JubaRenk	313570			JubaRenk	1351970	Reach 2	36447				
		Reach 10	408596			JubaRenk	304370			JubaRenk	1347270	Reach 2	4172				
		Reach 10	266852			JubaRenk	295070			JubaRenk	1342870						
		Reach 10	152120			JubaRenk	285970			JubaRenk	1338170						
		Reach 10	87708			JubaRenk	276770			JubaRenk	1333571						

Stretch 1 - Main Nile in Egypt		Stretch 3 - Main Nile in Sudan		Stretch 4 - Blue Nile		Stretch 5 - White Nile		Stretch 6 - Sobat River		Stretch 7 - Bahr el Jebel d/s of Juba		Stretch 8 - Bahr el Jebel u/s of Juba, Albert Nile		Stretch 10 - Kyoga Nile		Stretch 12 - Victoria Nile	
HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station
		Reach 10	14264			JubaRenk	267470			JubaRenk	1328871						
						JubaRenk	258270			JubaRenk	1324271						
						JubaRenk	249070			JubaRenk	1319670						
						JubaRenk	239870			JubaRenk	1314970						
						JubaRenk	230671			JubaRenk	1310570						
						JubaRenk	221471			JubaRenk	1305971						
						JubaRenk	212270			JubaRenk	1301270						
						JubaRenk	203070			JubaRenk	1296870						
						JubaRenk	193871			JubaRenk	1292170						
						JubaRenk	184671			JubaRenk	1287570						
						JubaRenk	175471			JubaRenk	1282970						
						JubaRenk	166271			JubaRenk	1278471						
						JubaRenk	156970			JubaRenk	1273770						
						JubaRenk	147870			JubaRenk	1269170						
						JubaRenk	138571			JubaRenk	1264570						
						JubaRenk	129270			JubaRenk	1259870						
						JubaRenk	120070			JubaRenk	1255370						
						JubaRenk	110570			JubaRenk	1250670						
						JubaRenk	101271			JubaRenk	1246070						
						JubaRenk	94170			JubaRenk	1241371						
						JubaRenk	84671			JubaRenk	1234470						
						JubaRenk	75469			JubaRenk	1227970						
						JubaRenk	66470			JubaRenk	1220970						

Stretch 1 - Main Nile in Egypt		Stretch 3 - Main Nile in Sudan		Stretch 4 - Blue Nile		Stretch 5 - White Nile		Stretch 6 - Sobat River		Stretch 7 - Bahr el Jebel d/s of Juba		Stretch 8 - Bahr el Jebel u/s of Juba, Albert Nile		Stretch 10 - Kyoga Nile		Stretch 12 - Victoria Nile	
HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station
						JubaRenk	56370			JubaRenk	1214070						
						JubaRenk	47070			JubaRenk	1209270						
						JubaRenk	37870			JubaRenk	1202870						
						JubaRenk	28570			JubaRenk	1195670						
						JubaRenk	18971			JubaRenk	1188671						
						JubaRenk	9670			JubaRenk	1181770						
						JubaRenk	0			JubaRenk	1174971						
										JubaRenk	1167971						
										JubaRenk	1161070						
										JubaRenk	1154070						
										JubaRenk	1147471						
										JubaRenk	1140370						
										JubaRenk	1133471						
										JubaRenk	1126670						
										JubaRenk	1119970						
										JubaRenk	1113271						
										JubaRenk	1106170						
										JubaRenk	1099270						
										JubaRenk	1092170						
										JubaRenk	1085270						
										JubaRenk	1078370						
										JubaRenk	1071370						
										JubaRenk	1064470						
										JubaRenk	1055171						

Stretch 1 - Main Nile in Egypt		Stretch 3 - Main Nile in Sudan		Stretch 4 - Blue Nile		Stretch 5 - White Nile		Stretch 6 - Sobat River		Stretch 7 - Bahr el Jebel d/s of Juba		Stretch 8 - Bahr el Jebel u/s of Juba, Albert Nile		Stretch 10 - Kyoga Nile		Stretch 12 - Victoria Nile	
HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station
										JubaRenk	1048271						
										JubaRenk	1041470						
										JubaRenk	1034770						
										JubaRenk	1027670						
										JubaRenk	1020471						
										JubaRenk	1013670						
										JubaRenk	1006770						
										JubaRenk	999970						
										JubaRenk	990571						
										JubaRenk	981370						
										JubaRenk	974470						
										JubaRenk	967471						
										JubaRenk	960571						
										JubaRenk	953671						
										JubaRenk	946670						
										JubaRenk	939870						
										JubaRenk	932871						
										JubaRenk	926371						
										JubaRenk	919070						
										JubaRenk	912271						
										JubaRenk	905371						
										JubaRenk	898670						
										JubaRenk	891570						
										JubaRenk	884770						

Stretch 1 - Main Nile in Egypt		**Stretch 3 - Main Nile in Sudan**		**Stretch 4 - Blue Nile**		**Stretch 5 - White Nile**		**Stretch 6 - Sobat River**		**Stretch 7 - Bahr el Jebel d/s of Juba**		**Stretch 8 - Bahr el Jebel u/s of Juba, Albert Nile**		**Stretch 10 - Kyoga Nile**		**Stretch 12 - Victoria Nile**	
HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station
										JubaRenk	877770						
										JubaRenk	870970						
										JubaRenk	864070						
										JubaRenk	857170						
										JubaRenk	850071						
										JubaRenk	843371						
										JubaRenk	829470						
										JubaRenk	822371						
										JubaRenk	814471						
										JubaRenk	805169						
										JubaRenk	798271						
										JubaRenk	788670						
										JubaRenk	779170						
										JubaRenk	770471						
										JubaRenk	761070						
										JubaRenk	751870						
										JubaRenk	744970						
										JubaRenk	738070						
										JubaRenk	728970						
										JubaRenk	723670						
										JubaRenk	712870						
										JubaRenk	703670						
										JubaRenk	694570						
										JubaRenk	685270						

Stretch 1 - Main Nile in Egypt		**Stretch 3 - Main Nile in Sudan**		**Stretch 4 - Blue Nile**		**Stretch 5 - White Nile**		**Stretch 6 - Sobat River**		**Stretch 7 - Bahr el Jebel d/s of Juba**		**Stretch 8 - Bahr el Jebel u/s of Juba, Albert Nile**		**Stretch 10 - Kyoga Nile**		**Stretch 12 - Victoria Nile**	
HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station	HEC-RAS Reach No.	River Station
										JubaRenk	675969						
										JubaRenk	666871						
										JubaRenk	657670						
										JubaRenk	648470						
										JubaRenk	639270						
										JubaRenk	630070						
										JubaRenk	620770						
										JubaRenk	611470						
										JubaRenk	602571						
										JubaRenk	593070						
										JubaRenk	581470						
										JubaRenk	572270						
										JubaRenk	563170						
										JubaRenk	553970						
										JubaRenk	544771						
										JubaRenk	535570						
										JubaRenk	526370						
										JubaRenk	517070						
										JubaRenk	506670						

* Note: Cross sections are in the same location for both the baseline- as well as the trapezoidal dredged conditions

ONE RIVER

ONE PEOPLE

ONE VISION

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